CMSC 611: Advanced Computer Architecture

Branch Prediction

Some material adapted from Mohamed Younis, UMBC CMSC 611 Spr 2003 course slides

Correlating Predictors

```
If (aa == 2)
        aa = 0;
If (bb == 2)
        bb = 0;
If (aa != bb) {
```

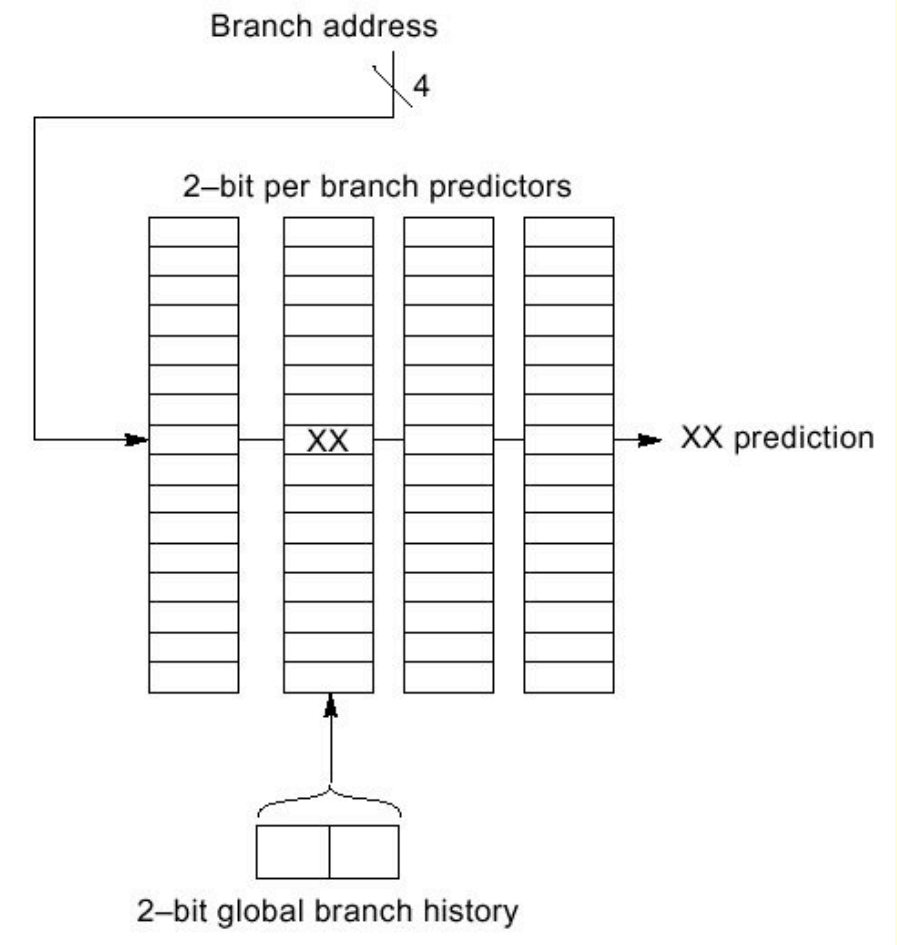
```
      DSUBUI   R3, R1, #2
      BNEZ     R3, L1          ; branch b1 (aa!=2)
      ANDI     R1, R1, #0      ; aa=0
L1:   SUBUI    R3, R2, #2
      BNEZ     R3, L2          ; branch b2 (bb!=2)
      ANDI     R2, R2, #0      ; bb=0
L2:   SUBU     R3, R1, R2      ; R3=aa-bb
      BEQZ     R3, L3          ; branch b3 (aa==bb)
```

- The behavior of branch b3 is correlated with the behavior of b1 and b2
- Clearly of both branches b1 and b2 are untaken, then b3 will be taken
- A predictor that uses only the behavior of a single branch to predict the outcome of that branch can never capture this behavior
- Branch predictors that use the behavior of other branches to make a prediction are called correlating or two-level predictors

Hypothesis: recent branches are correlated; that is, behavior of recently executed branches affects prediction of current branch

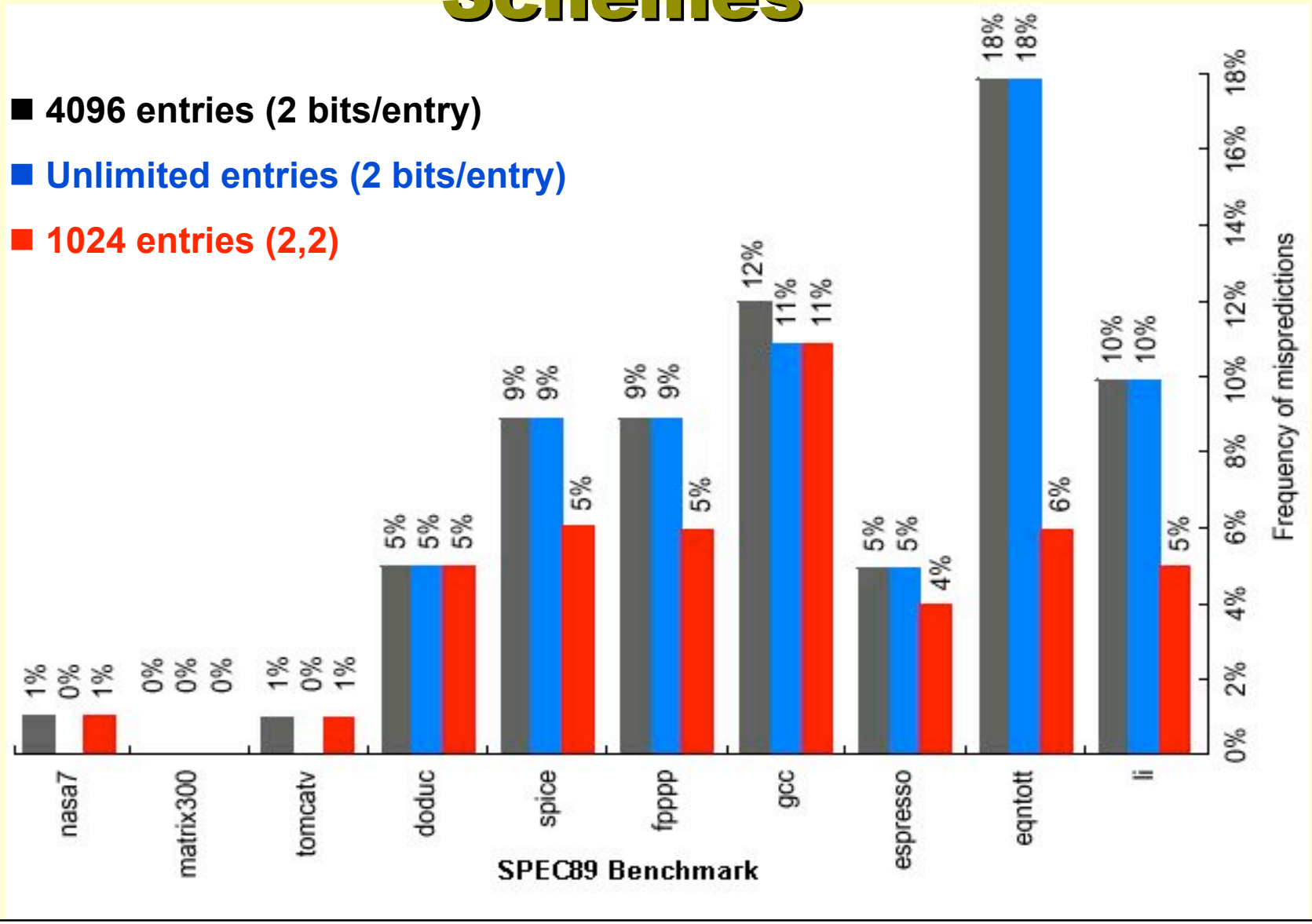
(2,2) Correlating Predictors

- Record m most recently executed branches as taken or not taken, and use that pattern to select the proper branch history table
- (m,n) predictor means record last m branches to select between 2m history tables each with n-bit counters
  - Old 2-bit branch history table is a (0,2) predictor
- In a (2,2) predictor, the behavior of recent branches selects between, four predictions of next branch, updating just that prediction



Total size = $2^m \times n \times$ # prediction entries selected by branch address

Accuracy of Different Schemes



Example

- Assume that d has values 0, 1, or 2 (alternating between 0, 2)
- Assume that the sequence will be executed repeatedly
- Ignore all other branches including those causing the sequence to repeat
- All branches are initially predicted to untaken state

```
if (d==0)
    d=1;
if (d==1)
```

```
        BNEZ     R1, L1        ; branch b1 (d!=0)
        DADDI    R1, R0, #1    ; d==0, sp d=1
L1:     DSUBUI   R3, R1, #1
        BNEZ     R3, L2        ; branch b2 (d!=1)
….
L2:
```

Example

With a single bit predictor

d=?	b1 prediction	b1 action	New b1 prediction	b2 prediction	b2 action	New b2 prediction
2	NT	T	T	NT	T	T
0	T	NT	NT	T	NT	NT
2	NT	T	T	NT	T	T
0	T	NT	NT	T	NT	NT

- *All branches are mispredicted*

```
if (d==0)
    d=1;
if (d==1)
```

```
      BNEZ     R1, L1      ; branch b1 (d!=0)
      DADDI    R1, R0, #1  ; d==0, sp d=1
L1:   DSUBUI   R3, R1, #1
      BNEZ     R3, L2      ; branch b2 (d!=1)
....
L2:
```

Example

With one bit predictor with one bit of correlation

d=?	b1 prediction	b1 action	New b1 prediction	b2 prediction	b2 action	New b2 prediction
2	NT/NT	T	T/NT	NT/NT	T	NT/T
0	T/NT	NT	T/NT	NT/T	NT	NT/T
2	T/NT	T	T/NT	NT/T	T	NT/T
0	T/NT	NT	T/NT	NT/T	NT	NT/T

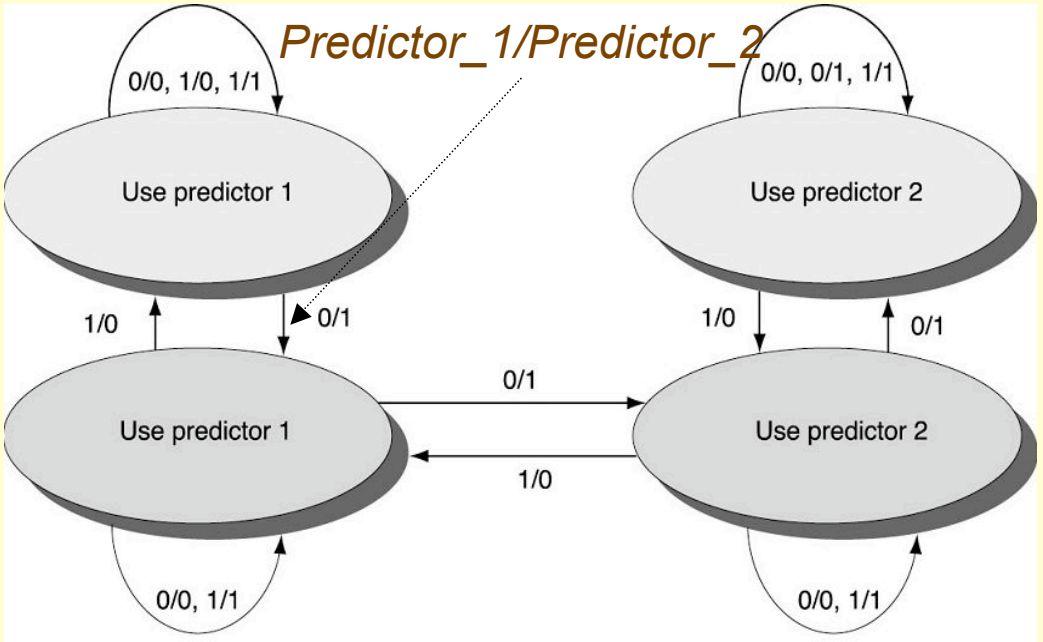
- *Except for first iteration, all branches are correctly predicted*

```
if (d==0)
    d=1;
if (d==1)
```

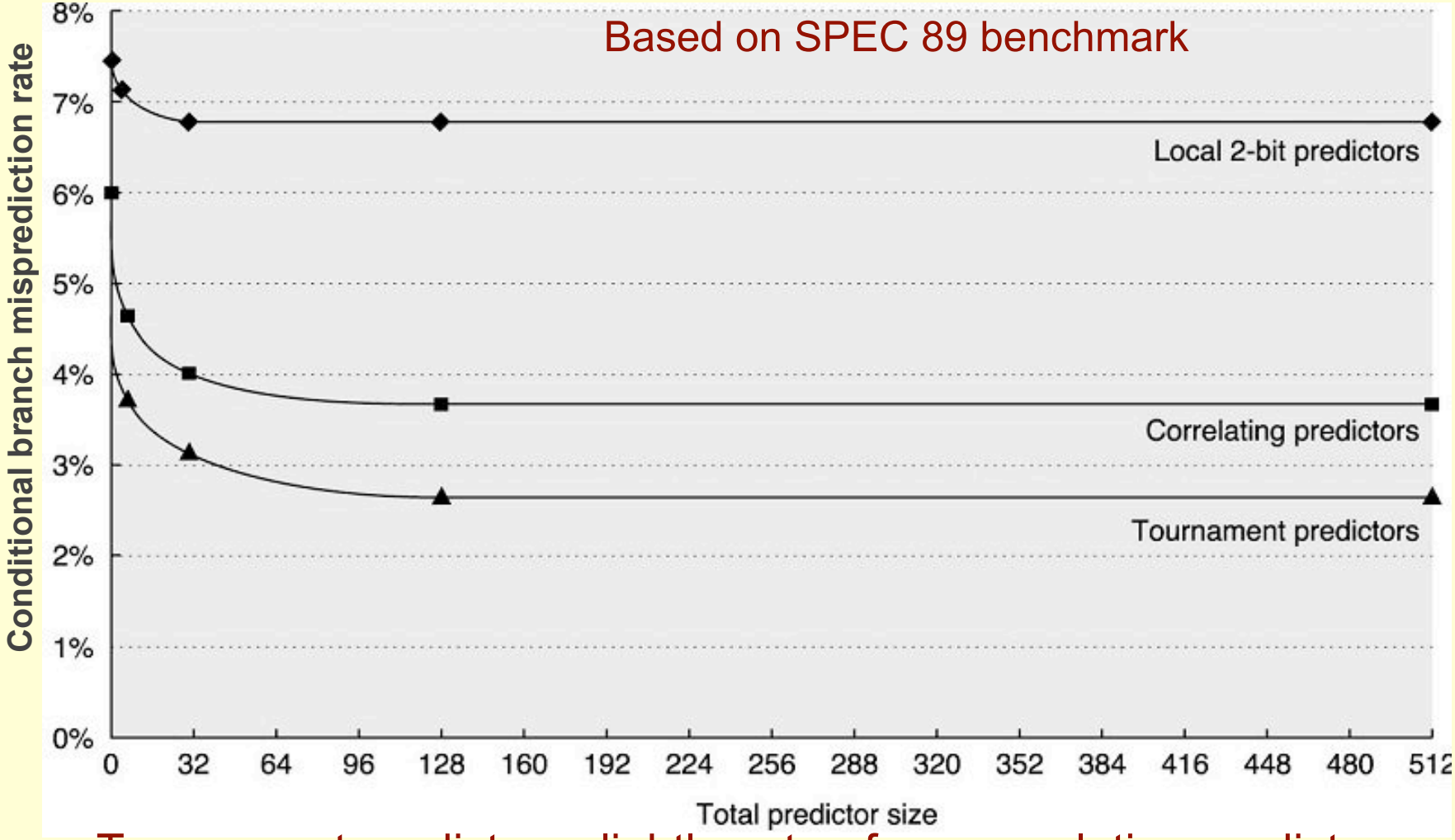
```
        BNEZ    R1, L1      ; branch b1 (d!=0)
        DADDI   R1, R0, #1  ; d==0, sp d=1
L1:     DSUBUI  R3, R1, #1
        BNEZ    R3, L2      ; branch b2 (d!=1)
....
L2:
```

Tournament Predictors

- Multilevel branch predictors use several levels of branch prediction tables together with an algorithm to choose among them
- Tournament selectors are the most popular form of multilevel branch predictors (e.g. DEC Alpha 21264)
- Tournament predictors combines both local and global predictor
- Selection between the two predictors are based on a selector (2-bit counter)
- Make a transition with two wrong prediction using the current table for which the correct prediction would have been possible using the other predictor



Performance of Tournament Predictors



Tournament predictors slightly outperform correlating predictors