Correlating Branch Predictors

```
                        DSUBUI   R3, R1, #2
B1   if (aa==2)         BNEZ     R3, L1      ; b1  (aa!=2)
       aa=0;            DADD     R1, R0, R0  ; aa=0
                 L1:    DSUBUI   R3, R1, #2
B2   if (bb==2)         BNEZ     R3, L2      ; b2  (bb!=2)
       bb=0;            DADD     R2, R0, R0  ; bb==0
B3   if (aa!==bb){ L2:  DSUBUI   R3, R1, R2  ; R3=aa-bb
                        BEQZ     R3, L3      ; b3  (aa==bb)
```

If the condition is true → (B1,B2) branch NOT TAKEN
If the condition is true → B3 NOT taken
If B1 and B2 both NOT TAKEN B3 → TAKEN
There is a correlation between B3 and both B1 and B2

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Correlating Branch Predictors

- Correlating predictors (two-level predictors) use the behavior of other branches to make prediction.
- Simplest (1-bit) has 2 predictions, one if the last branch is take, the second is when the last branch is not taken
- The prediction is on the form NT/T

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Example

```
B1   if (d==0)         BNEZ     R1, L1     ; d == 0 ?
       d=1;            DADD     R1, R0, #1 ; YES d==1
B2   if (d==1)  L1:    DADD     R3, R1, #-1
       {               BNEZ     R3, L2     ; b2  (bb!=2)
                L2:
```

If b1 not taken, b2 is taken for sure

Initial d	d==0?	B1	d befoe b2	d==1	b2
0	Y	NO	1	Y	NO
1	N	Taken	1	Y	NO
2	N	Taken	2	N	Taken

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Example

Initial d	d==0?	B1	d befoe b2	d==1	B2
0	Y	NO	1	Y	NO
1	N	Taken	1	Y	NO
2	N	Taken	2	N	Taken

d	B1 Pred	B1 action	newB1 pred	B2 pred	B2 action	new B2 pred
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

Miss on every prediction

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Example

Initial d	d==0?	B1	d befoe b2	d==1	b2
0	Y	NO	1	Y	NO
1	N	Taken	1	Y	NO
2	N	Taken	2	N	Taken

d	b1 Pred	b1 action	newb1 pred	b2 pred	b2 action	new b2 pred
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

Misprediction on first try only

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Global Predictor

- Take for example 10 bits of the branch PC
- Take 4 bits of global branch history
- Access 2^{14} entry table
- Or, you could take the 14 bits of PC XORED with 14 bits of branch history (hashing) to access the same table
- Or any combination

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(2,2) Correlating Predictors

(2,2) predictor

– Behavior of recent branches selects between four predictions of next branch, updating just that prediction

Branch address

4

2-bits per branch predictor

Prediction

0   1

2-bit global branch history

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Correlating Predictors

- The 1-bit predictor is called (1,1) predictor.
- It uses one bit for history (last branch), to choose among two (2^1) 1-bit branch predictors.
- In general a predictor could me *(m,n)* predictor.
- It uses the last *m* branch to choose among 2^m branch predictors each is *n*-bit predictor.

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Local Predictor

- The recent history of the branch predicts the next one

Branch PC

n bits

??

110100101001

110100101001

01

2^m K entries each is a 2-bit predictor

2^n entries

m bits local history

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Comparison

1024 entries(2,2)

Unlimited 2-bit

4K 2-bit

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Tournament Predictor

- Tournament predictor:
  - Combine correlating predictor with local predictor
  - A selector is sued to decide which one of these to use
- The selector could be similar to a 2-bit predictor
  - A saturating 2-bit binary counter with 2 outcomes P1/P2

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Branch Prediction Performance

Branch Prediction

Branch predictor performance

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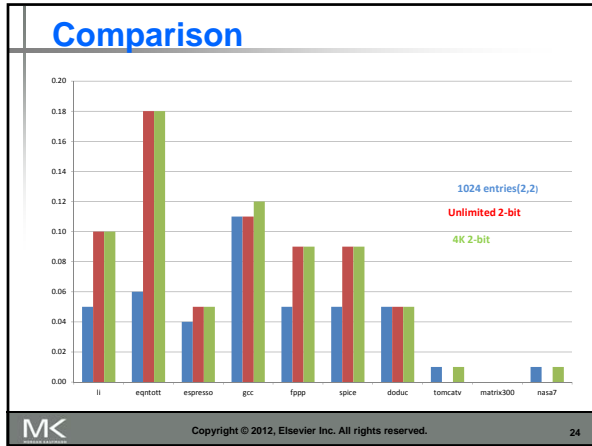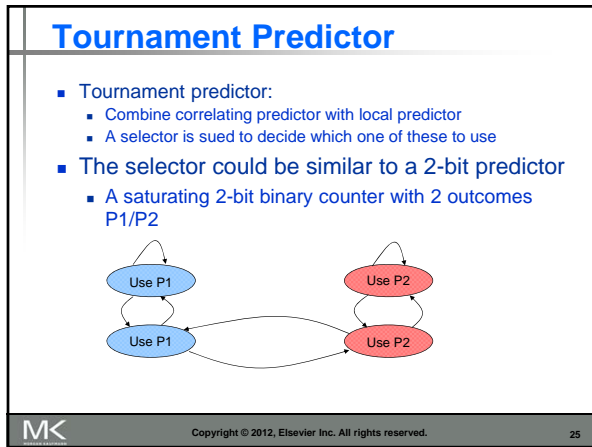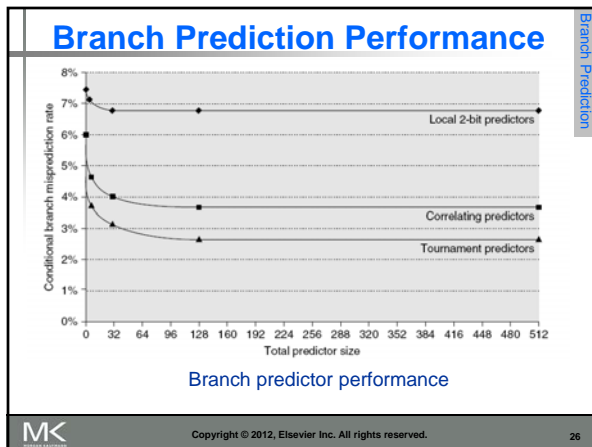
Alpha 21264 Branch Predictor

- Tournament predictor using, 4K 2-bit counters indexed by local branch address.

- Global predictor
  - 4K entries index by history of last 12 branches (2^{12} = 4K)
  - Each entry is a standard 2-bit predictor

- Local predictor
  - Local history table: 1024 10-bit entries recording last 10 branches, index by branch address
  - The pattern of the last 10 occurrences of that **particular** branch used to index table of 1K entries with 3-bit saturating counters

Branch Target Buffer

- Prediction tells us if the branch is taken or not.
- If taken, to where? Target address
- Branch target buffer tells us where (based on the PC, or parts of the PC).

Branch Prediction

gshare   tournament

Branch Prediction Performance

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Branch Prediction Performance

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