

CS M151B Final , Junhang Wang (50494113)

$$ET = IC \cdot \frac{CPI}{\uparrow} \cdot CT$$

2



cost of mis-prediction: 2

R 50%

LW 25%

SW 10%

REQ / BNE 15%

25%

LW

DEP

20%

LW

DEP

10%

LW

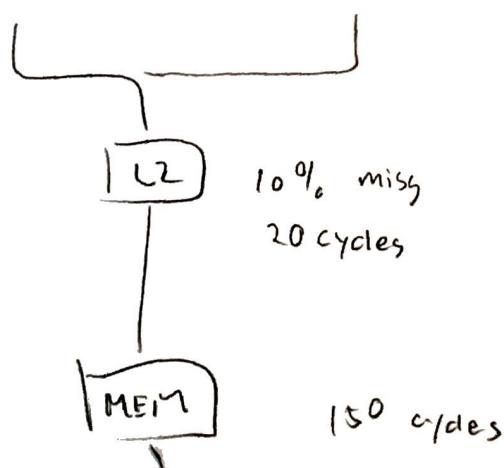
DEP

I \$

D \$

25% miss

30%



Branch resolves in EX

Branch predictor 20% miss

2

20

$$TCPJ = BCPJ + MCPI$$

$$BCPI = 1 + (\text{control hazard rate}) (\text{control hazard penalty})$$

$$+ (\text{data hazard rate}) (\text{data hazard penalty})$$

$$= 1 + 0.15 \cdot 0.2 \cdot 2 + 0.25 \cdot 0.25 \cdot 1$$

$$= 1.1225$$

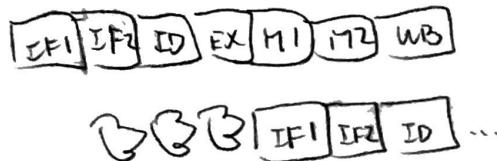
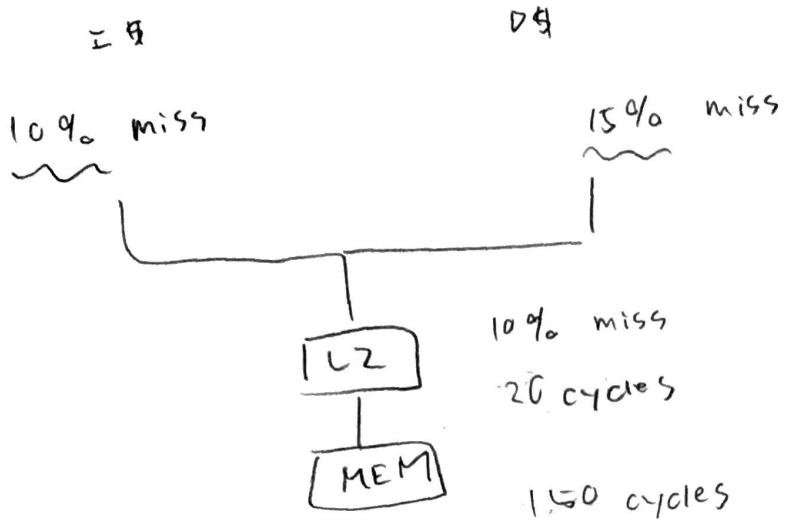
$$MCPI = I\$M + D\$M$$

$$= 1 \cdot 0.25 (20 + 0.1 \cdot 150) + 0.25 \cdot 0.3 (20 + 0.1 \cdot 150)$$

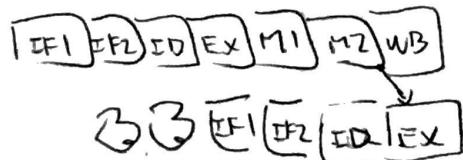
$$= 11.375$$

$$TCPJ = 1.1225 + 11.375$$

$$= 12.4975$$



cost of misprediction : 3



cost of data hazard followed by dep : 2

cost of data hazard followed by ind. dep : 1

cost of data hazard followed by ind. ind - dep : 0

$$TCP_I = BCPI + MCPI$$

$$BCPI = 1 + (\text{control hazard rate}) (\text{control hazard penalty})$$

$$+ (\text{data hazard rate}) (\text{data hazard penalty})$$

$$= 1 + 0.15 \cdot 0.2 \cdot 3 + 0.25 \cdot 0.25 \cdot 2 + 0.25 \cdot 0.2 \cdot 1$$

$$= 1.265$$

$$MCPI = 1 M + 0 M$$

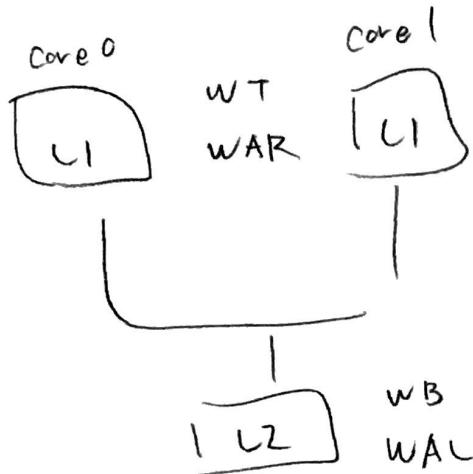
$$= 1 \cdot 0.1 \cdot (20 + 0.1 \cdot 150) + 0.25 \cdot 0.15 (20 + 0.1 \cdot 150)$$

$$= 4.8125$$

$$TCP_I = 1.265 + 4.8125$$

$$= 6.0775$$

3

Core 1

$sw \$21, 8(\$+0)$
 \downarrow
 $0x504$



(word at $0x50C$) = $0x77777777$

L1 miss

L2 hit

L2

1	1	0x508	0x DE	A D	B E	E F	D E	F E	C 8	0x50F

↓

77 77 77 77

Core 0 L1 Detects change

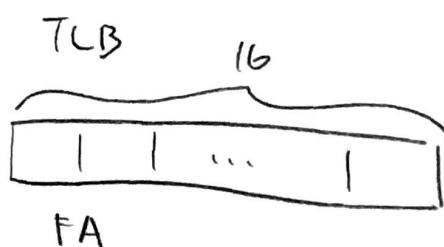
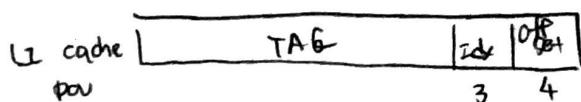
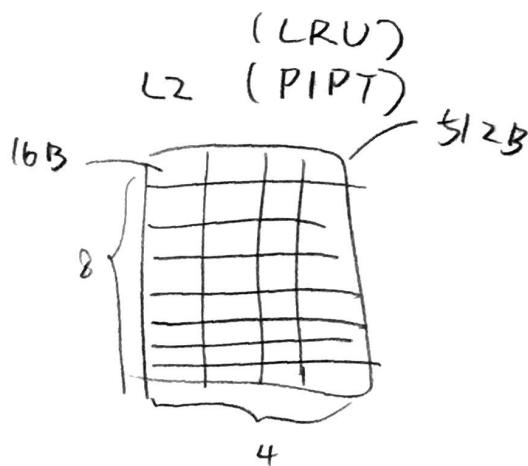
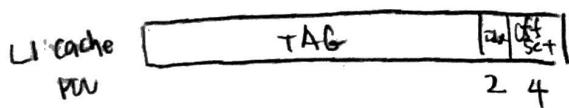
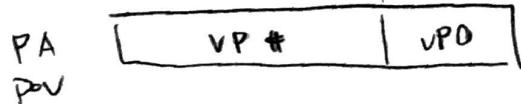
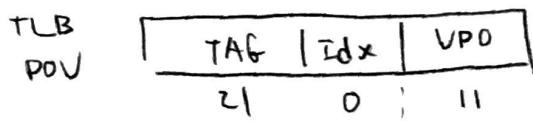
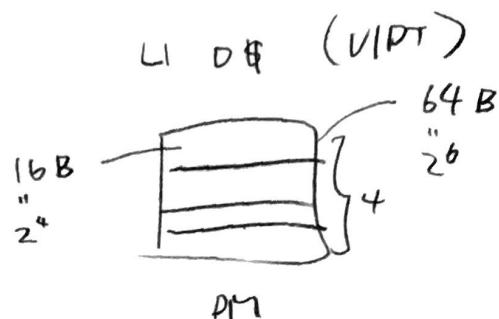
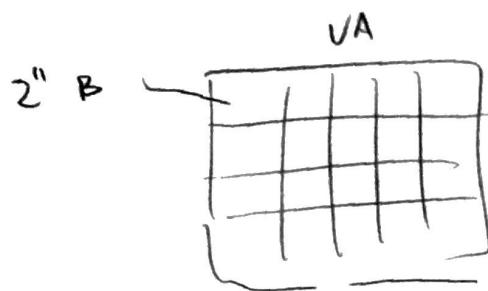
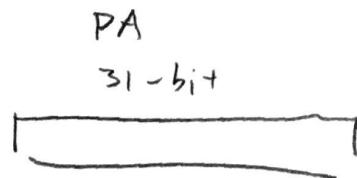
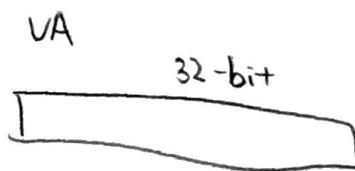
0x508 0x DE A D B E E F D E F E C 8 ED

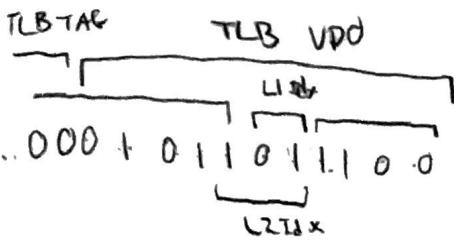
Assume write-invalidate protocol

4

problem
too many live variables

5





2 ...000101000000

3 ...0111010011000

4 ...000101001000

5 ...000001001100

6 ...0101010010000

7 ...0001010101100

8 ...0001010010000

9 ...0111010011000

10 ...0001010011000

11 ...0000010011000

12 ...0101010010000

L1

	U	D#	TAG
	Idx		
1	01	...	0001011
2	01	...	0001010
3	01	...	0111010
4	01	...	0001010
5	01	...	0000010
6	01	...	0101010
7	01	...	0001011
8	01	...	0001010
9	01	...	0111010
10	01	...	0001010
11	01	...	0000010
12	01	...	0101010

L2

	Idx	TAG
1	101	...000101
2	001	...0001011
3	001	...011101
5	001	...000000
6	001	...010101

TLB

	TAG
1	...00
2	...01

6

$$ET = \frac{IC}{\downarrow} \cdot \frac{CPI}{\overline{\quad}} \cdot \frac{CT}{\uparrow}$$

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Branch delay slots

LW / SW	ALU / Branch	
lw \$t0, 8(\$s0)		lw \$t0, 8(\$s0)
	addi \$s0, \$s0, 16	add \$t1, \$t1, \$s1
	add \$t0, \$t0, \$s1	lw \$t1, 0(\$t1)
lw \$t0, 0(\$t0)	bne \$s0, \$s2, HERE	add \$t9, \$t9, \$t1 addi \$s0, \$0, 32 bne \$s0, \$s2, HERE
	add \$t9, \$t9, \$t0	

LW / SW	ALU / Branch
lw \$t0, 8(\$s0)	addi \$s0, \$s0, 32
lw \$t1, 24(\$s0)	add \$t0, \$t0, \$s1
lw \$t0, 0(\$t0)	add \$t1, \$t1, \$s1
lw \$t1, 0(\$t1)	bne \$s0, \$s2, HERE
	add \$t9, \$t9, \$t0
	add \$t9, \$t9, \$t1

unroll Once

lw \$t0, 8(\$s0)

add \$t0, \$t0, \$s1

lw \$t0, 0(\$t0)

~~add \$t9, \$t9, \$t0~~

lw \$t1, 24(\$s0)

add \$t1, \$t1, \$s1

lw \$t1, 0(\$t1)

add \$t9, \$t9, \$t1

addi \$s0, \$0, 32

bne \$s0, \$s2, HERE

$$ET = \frac{IC}{\downarrow} \cdot \frac{CPI}{\text{same}} \cdot \frac{CT}{\text{same}}$$

9

W A R

~~WA~~ or WT



10			
HERE : ... 00000	lw \$t0, 0(\$t1)		(PC > 2) / 04
add			
lw			
sub			
beq		... THERE (T, NT, T)	0
lw			
add			
THERE : add			
bne : HERE		(T, T, NT)	0

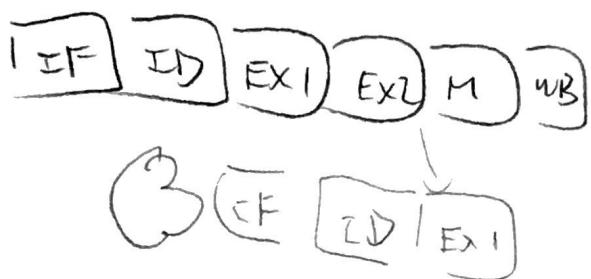
BP

00	00
01	01
10	01
11	01

Both branches map to the same entry

current state	prediction	actual branch	new state
01	NT	BEQ1 T	11
11	T	BNE1 T	11
11	T	BEQ2 NT	10
10	T	BNE2 T	11
11	T	BEQ3 T	11
11	T	BNE3 NT	10

11



12

A-4
A-3 X
A-2 WB
A-1 M
A EX2
A+1 EX1
A+2

16

↓ in control hazard

14

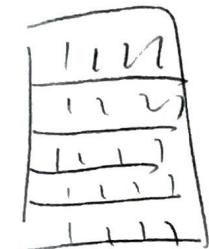
2 instructions per cycle

$$\begin{array}{r} 20 + 60 \\ \hline 40 \end{array}$$

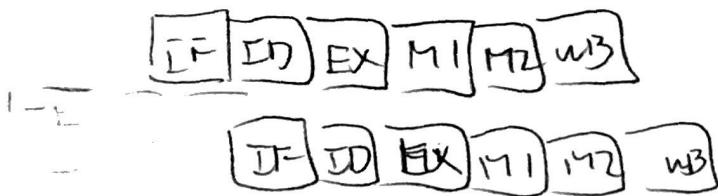
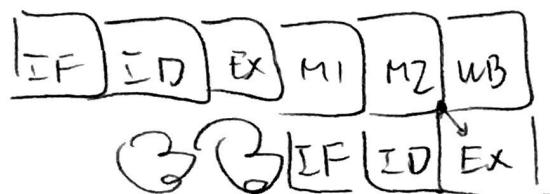
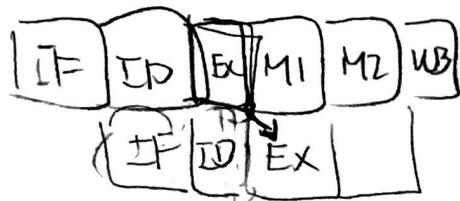
15.

L1

capacity miss



16



20