

$$1) \text{ Speedup} = \frac{\text{CPI}_{\text{no BTB}}}{\text{CPI}_{\text{BTB}}} = \frac{\text{CPI}_{\text{base}} + \text{Stalls}_{\text{no BTB}}}{\text{CPI}_{\text{base}} + \text{Stalls}_{\text{BTB}}}$$

$$\text{Stalls}_{\text{no BTB}} = (15\%) * 2 = 0.15 * 2 = 0.30 \text{ per } \phi \text{ cycles/instruction}$$

\uparrow fraction of branch instructions \uparrow penalty per branch instruction

Processor-1

For $\text{Stalls}_{\text{BTB}}$, consider the following:

BTB result	BTB prediction	Frequency (per instr.)	Penalty (ϕ cycles)
Miss	N/A	$15\% * 10\% = 0.015$	4
Hit	Correct	$15\% * 90\% * 90\% = 0.1215$	0
Hit	Incorrect	$15\% * 90\% * 10\% = 0.0135$	3

$$\therefore \text{Stalls}_{\text{BTB}} = (0.015 * 4) + (0.1215 * 0) + (0.0135 * 3) = 0.06 + 0 + 0.0405 = 0.1005$$

\hookrightarrow for Processor-2

$$\therefore \text{Speedup} = \frac{1.0 + 0.30}{1.0 + 0.1005} = \frac{1.3}{1.1005} = \underline{\underline{1.18}}$$

6) (Processor-3) Has no BTB, no branch prediction.

Since Branch Outcome is resolved in EX stage, there is a 2 ϕ cycle penalty if branch is taken. Suppose the % of taken branches is $\alpha\%$. Then,

$$\text{Stalls}_{\text{Processor-3}} = \text{Branch Instructions} * 0.15 * (1 - \frac{\alpha}{100}) * 0 + 0.15 * \frac{\alpha}{100} * 2$$

\uparrow % of branch instructions \uparrow (no) penalty \uparrow penalty for every taken branch.

$$= 0.003\alpha$$

$$\therefore \text{Speedup} = \frac{\text{CPI}_{\text{Processor-1}}}{\text{CPI}_{\text{Processor-3}}} = \frac{1.0 + 0.30}{1.0 + 0.003\alpha}$$

e.g.

Suppose $\alpha = 60\%$

$$\therefore \text{Speedup}_{60\% \text{ taken branch}} = \frac{1.3}{1.0 + (0.003 * 60)} = \underline{\underline{1.10}}$$

Note:

Write (COB)

Cannot write
at 12 because
of COB contention
Also, no forwarding

a) Instr.

loop: ld x1, 0(x2)

resp. $\alpha x_1, \alpha x_2$

$$add; x_1, x_1, 1$$

$S \propto x_1, O(x_2)$

add: $x_2, x_2, 9$

 $x_4, x_3, x_2,$

e2 x4, Loop

[Faint handwritten notes at the bottom of the page]

Next Successor - 1)

ect Successor-2) /
x1, A(x2)

he unrolled to

ation on the

However, be

cycle.

of cycles

Here is a

70. 0/0/0/0

Successor

20/10/2019

2000

11/11/11

$$\text{total size} = (2^6 \times 14 + 2^{14} \times 3) \text{ bits} = 50048 \text{ bits} = \underline{\underline{6256 \text{ bytes}}}$$

18 19 20 21 22 23 24 25 26 27

M 2

 \downarrow \dot{E} M ω

100

F D X

F X

→ F D

1

10

10

1

10

2