ELEMENTS OF COMPUTER SYSTEMS

ASSIGNMENT - I

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1.6. GIVEN DATA:

	A	B	C	D	CLOCK RATE
P1	1	2	3	3	$CR_{P1} = 2.5 GHz$
P2	2	2	2	2	$CR_{P2} = 3 GHz$
IC	0.1×10^6	0.2×10^6	0.5×10^6	0.2×10^6	

SOLUTION:

$$\text{Execution Time}_{P1} = \frac{IC \times CPI_{P1}}{CR_{P1}} = \frac{[(1\times0.1)+(2\times0.2)+(3\times0.5)+(3\times0.2)] \times 10^6}{2.5\times10^9}$$

$$ET_{P1} = 1.04 \times 10^{-3}\, s$$

$$\text{Execution Time}_{P2} = \frac{IC \times CPI_{P2}}{CR_{P2}} = \frac{[(2\times0.1)+(2\times0.2)+(2\times0.5)+(2\times0.2)]\times10^6}{3\times10^9}$$

$$ET_{P2} = 0.67 \times 10^{-3}\, s$$

Execution time for P1 is greater than that of P2.

Hence, implementation with P2 is faster.

1. $$\text{Global } CPI_{P1} = \frac{1+2+3+3}{4} = 2.25$$

$$\text{Global } CPI_{P2} = \frac{2+2+2+2}{4} = 2$$

2. $$\text{Clock cycles, } CC_i = \sum_{i=1}^{n} [CPI_i \times IC_i]$$

$$CC_1 = (1 \times 0.1 \times 10^6) + (2 \times 0.2 \times 10^6) + (3 \times 0.5 \times 10^6) + (3 \times 0.2 \times 10^6)$$

$$CC_1 = 2.6 \times 10^6$$

$$CC_2 = (2 \times 0.1 \times 10^6) + (2 \times 0.2 \times 10^6) + (2 \times 0.5 \times 10^6) + (2 \times 0.2 \times 10^6)$$

$$CC_2 = 2 \times 10^6$$

1.9. <u>GIVEN DATA</u>:

	arithmetic	load/store	branch
~~for one processor~~, CPI	1	12	5
for one processor, $IC_{(1)}$	2.56×10^9	1.28×10^9	0.256×10^9
for two processors, $IC_{(2)}$	1.828×10^9	0.914×10^9	0.256×10^9
for four processors, $IC_{(4)}$	0.914×10^9	0.457×10^9	0.256×10^9
for eight processors, $IC_{(8)}$	0.457×10^9	0.228×10^9	0.256×10^9

Clock frequency = 2 GHz

Solution:

Execution Time, for 1 processor $ET_{(1)} = \frac{IC_{(1)} \times CPI_{(1)}}{CR} = 9.6\ s$

Execution Time for 2 processors, $ET_{(2)} = \frac{IC_{(2)} \times CPI_{(2)}}{CR} = 7.038\ s$

Execution Time for 4 processors, $ET_{(4)} = \frac{IC_{(4)} \times CPI_{(4)}}{CR} = 3.839\ s$

Execution Time for 8 processors, $ET_{(8)} = \frac{IC_{(8)} \times CPI_{(8)}}{CR} = 2.237\ s$

Relative speed up, $S_1 = \frac{ET_2}{ET_1} = \frac{7.038}{9.6} = 0.733$

$S_2 = \frac{ET_4}{ET_2} = \frac{3.839}{7.038} = 0.545$

$S_3 = \frac{ET_8}{ET_4} = \frac{2.237}{3.839} = 0.583$

2. Given:

CPI of arithmetic instruction is doubled.

	arithmetic	load/store	branch
⇒ CPI	2	12	5

Solution:

for one processor, $ET_{(1)} = \frac{IC_{(1)} \times CPI_{(1)}}{CR} = 10.88\ s$

for two processors, $ET_{(2)} = 7.952\ s$

for four processors, $ET_{(4)} = 4.296\ s$

for eight processors, $ET_{(8)} = 2.465\ s$

3. Question: To what should the CPI of load/store be reduced for single processor to match performance of four processor.

To find CPI of load/store, $\text{performance}_{(\text{one processor})} = \text{performance}_{(\text{four processor})}$

$\text{performance} = \frac{1}{\text{execution time}} \Rightarrow ET_{(\text{oneprocessor})} = ET_{(\text{four processor})}$

$ET_{(4)} = 3.839\ s$

~~ET~~ Assuming CPI

$$\frac{(1 \times 2.56 \times 10^9) + (x \times 1.28 \times 10^9) + (5 \times 0.256 \times 10^9)}{2 \times 10^9} = 3.839$$

$$\frac{(2.56 + 1.28x + 1.28) \times 10^9}{2 \times 10^9} = 3.839$$

$x = 2.998 \Rightarrow CPI_{load/store} = 3$

1.11. $IC = 2.389 \times 10^{12}$; $ET = 750s$; Reference Time = 9650 s

1. $CPI = \frac{ET}{IC \times CT} \Rightarrow CPI = \frac{750}{2.389 \times 10^{12} \times 0.333 \times 10^{-9}}$

$CPI \simeq 0.942$

2. Find SPEC ratio.

$\text{SPEC ratio} = \frac{\text{reference time}}{\text{execution time}} = 12.87$

3. $CR = 1/CC = 1/0.333 \times 10^{-9} = 3\ GHz$

$\text{Execution Time} = \frac{IC \times CPI}{CR} = \frac{2.389 \times 10^{12} \times 0.942}{3 \times 10^9} = 0.750 \times 10^{-3}$

~~ET = 0.750 s~~ ET = 750 s

after 10% increase in IC, $ET_{new} = \frac{2.6279 \times 10^{12} \times 0.942}{3 \times 10^9}$

$ET_{new} = 0.825 \times 10^3$

$ET_{new} = 825$ s

Increase in CPU time = $ET_{new} - ET = 825 - 750$

= 75 s

4. ET = 750 s

after 10% increase in IC & 5% increase in CPI,

$ET_{new} = \frac{2.6279 \times 10^{12} \times 0.989}{3 \times 10^9} = 866$ s

Increase in CPU time = $ET - ET_{new} = 866 - 750$

= 116 s

5. $\text{SPEC ratio}_{new} = \frac{\text{reference time}}{\text{execution time}} = \frac{9650}{116} = 11.143$

change in SPEC ratio = $\text{SPECratio} - \text{SPEC ratio}_{new}$

= 12.87 − 11.143

= 1.727

6. $CR = 4 \times 10^9$ Hz; $IC_{new} = 2.03065 \times 10^{12}$; $ET_{new} = 700$;

$SPEC_{new} = 13.7$; $CC = ET \times CR = 700 \times 4 \times 10^9 = 2800$ GHz

$CPI_{new} = \frac{CC}{IC} = \frac{2800}{2.03065 \times 10^{12}} = 1.379$

7. $CR = 4 \times 10^9$ Hz ; $CC = 700 \times 4 \times 10^9 = 2800$ Hz

$IC = 2.389 \times 10^9$

$$CPI_{new} = \frac{2800 \times 10^9}{2.389 \times 10^{12}} = 1.172$$

$CPI_{new} = 1.172$; $CPI_{old} = 0.942$

$CR_{new} = 4$ GHz ; $CR_{old} = 3$ GHz

Hence, the increase is similar.

8. $$CPU_{old} = \frac{IC_{old} \times CPI_{old}}{CR_{old}} = \frac{2.389 \times 10^{12} \times 0.942}{3 \times 10^9} = 0.750 \times 10^3$$

$CPU_{old} = 757$ s

$$CPU_{new} = \frac{IC_{new} \times CPI_{new}}{CR_{new}} = \frac{2.389 \times 10^{12} \times 1.172}{4 \times 10^9} = 0.699 \times 10^3$$

$CPU_{new} = 699$ s

difference in CPU time = $CPU_{old} - CPU_{new} = 750 - 699$

$= \cancel{58}$ 51 s

9. $ET = 960$ ns ; $CPI = 1.61$; $CR = 3$ GHz

when ET is reduced by 10%, $ET_{new} = 864$ ns

$CR_{new} = 4$ GHz

$$IC_{new} = \frac{ET_{new}}{CPI \times CT} \; ; \; CT_{new} = 1/CR_{new} = 0.25 \times 10^{-9} \text{ s}$$

$$IC_{new} = \frac{864 \times 10^{-9}}{1.61 \times 0.25 \times 10^{-9}} = 2146.58$$

10. $IC = 2.389 \times 10^{12}$; $CPI = 0.942$; $CR = 3GHz$

$$CPU_{time} = \frac{IC \times CPI}{CR} = \frac{2.389 \times 10^{12} \times 0.942}{3 \times 10^{9}}$$

$$CPU_{time} = 750\ s$$

after 10% reduction in $CPU_{time} \Rightarrow CPU_{new} = \cancel{750s}$ 675 s

$$CPU_{new} = \frac{IC \times CPI}{CR_{new}} \Rightarrow 675 = \frac{2.389 \times 10^{12} \times 0.942}{CR_{new}}$$

$$CR_{new} = 3.33\ GHz$$

11. $CPI = 0.942$; after 15% reduction, $CPI_{new} = 0.800$

$CPUtime = 750s$; after 20% reduction, $CPU_{new} = 600\ s$

$IC = 2.389 \times 10^{12}$

$$CR = \frac{IC \times CPI}{CPU} = \frac{2.389 \times 10^{12} \times 0.800}{600} = 3.185\ GHz$$

1.12. for processor P1, $CR_1 = 4GHz$; $CPI_1 = 0.9$; $IC_1 = 5 \times 10^{9}$

for processor P2, $CR_2 = 3GHz$; $CPI_2 = 0.75$; $IC_2 = 1.0 \times 10^{9}$

1. $$ET_{P1} = IC_1 \times CPI_1 \times \frac{1}{CR_1} = 5 \times 10^{9} \times 0.9 \times \frac{1}{4 \times 10^{9}} = 1.125\ s$$

$$ET_{P2} = IC_2 \times CPI_2 \times \frac{1}{CR_2} = 1 \times 10^{9} \times 0.75 \times \frac{1}{3 \times 10^{9}} = 0.25\ s$$

$$\text{Performance } P_1 = \frac{1}{1.125} = 0.888$$

$$\text{Performance } P_2 = \frac{1}{0.25} = 4$$

The fallacy is false in this case.

2. for processor P1, $IC_1 = 1\times10^9$, $CPI_{P1} = 0.9$

for processor P2, $CPI_{P2} = 0.75$,

~~Eth~~ by given data, $ET_1 = ET_2$

$$\Rightarrow ET_1 = \frac{IC_1 \times CPI_1}{CR} = 0.225$$

$$0.225 = \frac{x \times 0.75}{3\times10^9} \Rightarrow IC = 0.9\times10^9$$

3. $$MIPS = \frac{IC}{ET \times 10^6} = \frac{CR}{CPI \times 10^6}$$

$$\Rightarrow MIPS_{P1} = \frac{4\times10^9}{0.9\times10^6} = 4.45\times10^3$$

$$MIPS_{P2} = \frac{3\times10^9}{0.75\times10^6} = 4\times10^3$$

Hence, the fallacy is not true in this case.

4. $$MFLOPS_{P1} = \frac{0.4\times5\times10^9}{1.125\times10^6} = 1.77\times10^3$$

$$MFLOPS_{P2} = \frac{0.4\times10^9}{0.25\times10^6} = 1.6\times10^3$$

1.13. $ET_{total} = 250s$

$ET_{FP} = 70s$, $ET_{L/S} = 85s$, $ET_{BI} = 40s$; ~~E~~

1. $\Rightarrow E_{INT} = 55s$

new $ET_{FP} = 56s$; new $ET_{total} = 236s$

Time reduced = 14 s

2. $ET_{total} = 200s$; $E_{INTnew} = 44s$

It is reduced by 11 seconds.

3. The total time cannot be~~x~~ reduced by 20%. by reducing the branch instructions alone because even when the branch instruction is eliminated as whole, the total time does not lessen by 20%.