Computer Architecture HW1

Author Sin-Han Yang
Student ID B08202029

1 Question 1

a The definition of MIPS is:

$$\text{MIPS} = \frac{\text{Clock rate}}{\text{CPI} \cdot 10^6} \tag{1}$$

So MIPS of P1 is:

$$\text{MIPS}_{P1} = \frac{2.7 \cdot 10^9}{1.5 \cdot 10^6} = 1800 \tag{2}$$

, MIPS of P2 is:

$$\text{MIPS}_{P2} = \frac{3 \cdot 10^9}{2 \cdot 10^6} = 1500 \tag{3}$$

, and MIPS of P3 is:

$$\text{MIPS}_{P3} = \frac{4 \cdot 10^9}{2.5 \cdot 10^6} = 1600 \tag{4}$$

b The number of instructions (NoI) can be derived from:

$$\text{NoI} = \frac{\text{Clock rate} \cdot \text{Execution Time}}{\text{CPI}} \tag{5}$$

The number of cycles (NoC) can be derived from:

$$\text{NoC} = \text{Clock rate} \cdot \text{Execution Time} \tag{6}$$

Therefore, the NoI of P1 is:

$$\text{NoI}_{P1} = \frac{2.7 * 10^9 \cdot 8}{1.5} = 1.44 * 10^{10} \tag{7}$$

and the NoC of P1 is:

$$\text{NoC}_{P1} = 2.7 * 10^9 \cdot 8 = 2.16 * 10^{10} \tag{8}$$

Therefore, the NoI of P2 is:

$$\text{NoI}_{P2} = \frac{3 * 10^9 \cdot 8}{2} = 1.2 * 10^{10} \tag{9}$$

and the NoC of P2 is:

$$\text{NoC}_{P2} = 3 * 10^9 \cdot 8 = 2.4 * 10^{10} \tag{10}$$

Therefore, the NoI of P3 is:

$$\text{NoI}_{P3} = \frac{4 * 10^9 \cdot 8}{2.5} = 1.28 * 10^{10} \tag{11}$$

and the NoC of P3 is:

$$\text{NoC}_{P3} = 4 * 10^9 \cdot 8 = 3.2 * 10^{10} \tag{12}$$

c Since NoI is fixed, from Eq. (5) we can see that:

$$\text{change of Clock rate} = \frac{\text{change of CPI}}{\text{change of Execution Time}} = \frac{1.35}{0.6} = 2.25 \tag{13}$$

Therefore, the clock rate of P1,P2 and P3 would be 6.075 GHz, 6.75 GHz and 9 GHz respectively.

2 Question 2

2.1 a

If p=1, The clock cycles would be:

$$\text{Clock cycles} = \sum_{i=1}^{3} \text{CPI} \cdot \text{Number of Instructions} = 2 * 2.6 * 10^9 + 11 * 1.3 * 10^9 + 7 * 3.9 * 10^9 = 4.68 * 10^{10} \quad (14)$$

If $p \geq 2$, the clock cycles would be:

$$\text{Clock cycles} == \frac{2 * 2.6 * 10^9 + 11 * 1.3 * 10^9}{0.65 * p} + 7 * 3.9 * 10^9 \quad (15)$$

Therefore, the clock cycles of this program with 2, 4 and 8 processors are $4.23 * 10^{10}$, $3.48 * 10^{10}$, and $3.105 * 10^{10}$ respectively. According to Eq. (6), the execution time is number of cycles being divided by Clock rate. Therefore, the execution time of p=1, p=2, p=4 and p=8 are 19.5, 17.625, 14.5 and 12.9375 seconds respectively. Therefore, the relative speedup with 2, 4 and 8 processors are $\frac{4.68}{4.23} \approx 1.10$, $\frac{4.68}{3.48} \approx 1.34$, and $\frac{4.68}{3.105} \approx 1.50$ respectively.

2.2 b

If p=1, according to Eq. (14) The clock cycles would be:

$$\text{Clock cycles} = \sum_{i=1}^{3} \text{CPI} \cdot \text{Number of Instructions} = 2 * 1.3 * 10^9 + 11 * 2.6 * 10^9 + 7 * 3.9 * 10^9 = 5.85 * 10^{10} \quad (16)$$

If $p \geq 2$, according to Eq. (15) the clock cycles would be:

$$\text{Clock cycles} == \frac{2 * 1.3 * 10^9 + 11 * 2.6 * 10^9}{0.65 * p} + 7 * 3.9 * 10^9 \quad (17)$$

Follow 2.1's steps, the execution time of execution time of p=1, p=2, p=4 and p=8 are 24.375, 21.375, 16.37 and 13.875 seconds respectively.

2.3 c

If the clock rate of of p=1 and p=2 are the same, then the performance will be the same. Let the reduced CPI to be x. Since the branch instructions are unaffected by the number of processors, the comparison between Eq. (14) and Eq. (15) is:

$$2 * 2.6 * 10^9 + 1.3x * 10^9 = frac2 * 2.6 * 10^9 + 11 * 1.3 * 10^9 0.65 * 2 \quad (18)$$

The solution is $x = \frac{9.8}{1.3}$. Therefore, the CPI of load/store instructions should be reduced by $\frac{11 - \frac{9.8}{1.3}}{11} \approx= 31.4\%$.

3 Question 3

3.1 a

According to Eq. (5), the CPI is:

$$CPI = \frac{\text{Clock rate} \cdot \text{Execution time}}{\text{NoI}} = \frac{2.2 * 10^9 * 772}{2.123 * 10^12} = 0.8 \quad (19)$$

3.2 b

$$\text{SPECratio} = \frac{\text{Execution time}_{reference}}{\text{Execution time}_P} = 12.5 \quad (20)$$

3.3 c

According to Eq. (19), if CPI is fixed, then execution time should increase 15% as well. Therefore, the increase time is $772 * 0.15 = 115.8$ seconds.

4 Question 4

4.1 a

Given n classes, The global CPI is defined as follows:

$$\text{CPI} = \sum_{i}^{n}(\text{CPI}_i \cdot \frac{\text{Instruction Count}_i}{\text{Instruction Count}}) \tag{21}$$

Therefore, the global CPI for P1 is:

$$\text{CPI}_{P1} = 1 * 0.2 + 2 * 0.25 + 3 * 0.45 + 2 * 0.1 = 2.25 \tag{22}$$

and global CPI for P2 is:

$$\text{CPI}_{P2} = 1.5 * 0.2 + 3 * 0.25 + 2 * 0.45 + 2 * 0.1 = 2.15 \tag{23}$$

4.2 b

According to Eq. (5), the execution time is:

$$\text{Execution time} = \frac{\text{NoI} \cdot \text{CPI}}{\text{Clock rate}} \tag{24}$$

Since NoI is fixed, the time for P1 is proportional to $\frac{2.25}{2.4} = 0.9375$, and the time for P1 is proportional to $\frac{2.15}{2.2} \approx 0.9772$. Therefore, P1 is faster.