**2019 Computer Architecture Problem Set #1**

**1. We have two processors of which specification is as follows:**

|  |  |  |
| --- | --- | --- |
|  | **Processor A** | **Processor B** |
| **Clock frequency** | **2GHz** | **3GHz** |
| **CPI when running workload C** | **1.0** | **2.0** |
| **CPI when running workload D** | **2.0** | **2.5** |

Execution time = number of instructions \* CPI \* clock cycle time

**A. Assuming that the number of the instructions executed for workload C and D are 1000 and 2000, respectively, calculate the execution time of processor A and processor B when running workload C and D.**

Sol)

The execution time of processor A)

Execution time = (1.0\*1000 + 2.0\*2000) \* 1/(2\*109) = 2.5 \* 10-6

The execution time of processor B)

Execution time = (2.0\*1000 + 2.5\*2000) \* 1/(3\*109) = 2.333 \* 10-6.

**B. Assuming that a user uses workload C and D for 80% and 20% of the usage ratio, respectively, which processor is better choice for the user? And why (please quantitatively compare)?**

Sol)

Execution time of Processor A = (1000\*1\*0.8 + 2000\*2\*0.2) \* 1/(2\*109) = 0.8 \* 10-6 = 0.8 µs

Execution time of Processor B = (1000\*2\*0.8 + 2000\*2.5\*0.2) \* 1/(3\*109) = 0.866 \* 10-6 = 0.86 µs

Processor A is a better choice.

**2. What is potential problem when using MIPS (Million Instructions Per Second) instead of execution time as a performance metric? Please describe it with an example.**

Sol)

Please refer to the slides for Chapter 1 pp. 24~26.

**3. Assume for arithmetic, load/store, and branch instructions, a processor has CPIs of 1, 12, and 5, respectively. Also assume that on a single processor a program requires the execution of 2.56×109arithmetic instructions, 1.28×109 load/store instructions, and 256million branch instructions. Assume that each processor has a 2 GHz clock frequency. Assume that, as the program is parallelized to run over multiple cores, the number of arithmetic and load/store instructions per processor is divided by 0.7 × p (where p is the number of processors) but the number of branch instructions per processor remains the same.**

**A. Find the total execution time for this program on 1, 2, 4, and 8 processors, and show the relative speedup of the2, 4, and 8 processors result relative to the single processor result.**

Sol)

1 processor)

Total execution time = (1\*2.56\*109 + 12\*1.28\*109 + 5\*256\*106) \* 1/(2\*109) = 9.6

2 processors)

Total execution time = (1\*2.56\*109/1.4 + 12\*1.28\*109/1.4 + 5\*256\*106) \* 1/(2\*109) = 7.04

4 processors)

Total execution time = (1\*2.56\*109/2.8 + 12\*1.28\*109/2.8 + 5\*256\*106) \* 1/(2\*109) = 3.84

8 processors)

Total execution time = (1\*2.56\*109/5.6 + 12\*1.28\*109/5.6 + 5\*256\*106) \* 1/(2\*109) = 2.24

1 processor → 2 processors: 1.36**×** speedup

1 processor → 4 processors: 2.5**×** speedup

1 processor → 8 processors: 4.29**×** speedup

There is limitation of speedup even though the number of processor is increased.

**B. If the CPI of the arithmetic instructions was doubled, what would the impact be on the execution time of the program on 1, 2, 4, or 8 processors?**

Sol)

1 processor)

Total execution time = (2\*2.56\*109 + 12\*1.28\*109 + 5\*256\*106) \* 1/(2\*109) = 10.88

2 processors)

Total execution time = (2\*2.56\*109/1.4 + 12\*1.28\*109/1.4 + 5\*256\*106) \* 1/(2\*109) = 7.96

4 processors)

Total execution time = (2\*2.56\*109/2.8 + 12\*1.28\*109/2.8 + 5\*256\*106) \* 1/(2\*109) = 4.30

8 processors)

Total execution time = (2\*2.56\*109/5.6 + 12\*1.28\*109/5.6 + 5\*256\*106) \* 1/(2\*109) = 2.47

**C. To what should the CPI of load/store instructions be reduced in order for a single processor to match the performance of four processors using the original CPI values?**

Sol)

(1\*2.56\*109/2.8 + 12\*1.28\*109/2.8 + 5\*256\*106) \* 1/(2\*109) = (1\*2.56\*109 + X\*1.28\*109 + 5\*256\*106) \* 1/(2\*109)

X = 3. CPI of the load/store instruction should be 3.

**4. Assume a program requires the execution of 50 × 106 FP instructions, 110 × 106 INT instructions, 80 × 106 Load/Store instructions, and 16 × 106 branch instructions. The CPI for each type of instruction is 1, 1, 4, and 2, respectively. Assume that the processor has a 2 GHz clock rate.**

**A. By how much must we improve the CPI of FP instructions if we want the program to run two times faster?**

Sol)

The execution time of a program

= (50\*1\*106 + 110\*1\*106 + 80\*4\*106 + 16\*2\*106) / (2\*109) = 256\*10-3.

It is impossible to make the execution time of the program from 256(ms) to 128(ms) when only the CPI of FP instruction is reduced. Even though the CPI of FP instruction is 0, the execution time of a program is 231\*10-3, still much higher than 128\*10-3.

**B. By how much must we improve the CPI of Load/Store instructions if we want the program to run two times faster?**

Sol)

If the CPI of Load/Store instruction is 0.8, the execution time of the program will be an half.

= (50\*1\*106 + 110\*1\*106 + 80\***0.8**\*106 + 16\*2\*106) / (2\*109) = 128\*10-3

**C. By how much is the execution time of the program improved if the CPI of INT and FP instructions is reduced by 40% and the CPI of Load/Store and Branch is reduced by 30%?**

Sol)

CPI of INT and FP will be 0.6 after reducing by 40%.

CPI of Load/Sore and Branch will be 2.8 and 1.4 respectively after reduction of the CPI by 30%.

The execution time of improved program

= (50\*0.6\*106 + 110\*0.6\*106 + 80\*2.8\*106 + 16\*1.4\*106) / (2\*109) = 171.2\*10-3.

49.5% performance improvement after reduction the CPI of instructions.

**5. We have a system and need to improve it. There are three parts(A, B, and C)in the system. We can only improve one part due to the human resource constraints. We can improve the system performance as follows:**

|  |  |  |
| --- | --- | --- |
|  | **How much each part affects system performance** | **Possible improvement** |
| **A** | **30%** | **2X** |
| **B** | **50%** | **1.5X** |
| **C** | **20%** | **4X** |

**If you are a system designer, which part will you improve? And why?**

Sol)

Considering the total length of the execution time as 10, the length of A, B, and C parts will be 3, 5, and 2, respectively.

If we improve A part, the length of A part will be 1.5.

And total length of the improved system will be 1.5+5+2 = 8.5.

If we improve B part, the length of B part will be 3.3.

And total length of the improved system will be 3+3.3+2 = 8.3.

If we improve C part, the length of C part will be 0.5.

And total length of the improved system will be 3+5+0.5 = 8.5.

Improving the B part is most beneficial.