HW#1 (CSC390-Spring 2016)

SOLUTION

Q1. Computer A has an overall CPI of 1.3 and can be run at a clock rate of 600MHz. Computer B has a CPI of 2.5 and can be run at a clock rate of 750 Mhz. We have a particular program we wish to run. When compiled for computer A, this program has exactly 100,000 instructions. How many instructions would the program need to have when compiled for Computer B, in order for the two computers to have exactly the same execution time for this program?

Sol:

$$(\text{CPUTime})_A = (\text{Instruction count})_A * (\text{CPI})_A * (\text{Clock cycle Time})_A$$
$$= (100{,}000)*(1.3)/(600*10^6) \text{ ns}$$
$$(\text{CPUTime})_B = (\text{Instruction count})_B * (\text{CPI})_B * (\text{Clock cycle Time})_B$$
$$= (I)_B*(2.5)/(750*10^6) \text{ ns}$$

Since $(\text{CPUTime})_A = (\text{CPUTime})_{B,}$

we have to solve for $(I)_B$ and get 65000

Answer the following questions (these questions are taken from your text books):

1.9 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 2.56E9 arithmetic instructions, 1.28E9 load/store instructions, and 256 million 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 x p (where p is the number of processors) but the number of branch instructions per processor remains the same.

1.9.1 [5] <§1.7> Find the total execution time for this program on 1, 2, 4, and 8 processors, and show the relative speedup of the 2, 4, and 8 processor result relative to the single processor result.

1.9.2 [10] <§§1.6, 1.8> 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?

1.9.3 [10] <§§1.6, 1.8> 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:

1.9.1

Given, Processor frequency, f=2GHz. Formula, Execution time = CPIxInstruction/f

Processor nos.	Arithmetic Instruction	CPI-Arith	Load/Store Instruction	CPI-L/S	Brunch Instruction	CPI-Branch	Total Cycles	Execution Time	Speed-Up
1	2.56E+09	1	1.29E+09	12	2.56E+08	5	1.93E+10	9.66E+00	1.00E+00
2	1828571429	1	921428571	12	2.56E+08	5	1.42E+10	7.08E+00	1.36E+00
4	914285714	1	460714286	12	2.56E+08	5	7.72E+09	3.86E+00	2.50E+00
8	457142857	1	230357143	12	2.56E+08	5	4.50E+09	2.25E+00	4.29E+00

1.9.2

Processor nos.	Arithmetic Instruction	CPI-Arith	Load/Store Instruction	CPI-L/S	Brunch Instruction	CPI-Branch	Total Cycles	Execution Time	Speed-Up
1	2.56E+09	2	1.29E+09	12	2.56E+08	5	2.19E+10	10.94	1.00E+00
2	1828571429	2	921428571	12	2.56E+08	5	1.60E+10	7.997143	1.37E+00
4	914285714	2	460714286	12	2.56E+08	5	8.64E+09	4.318571	2.53E+00
8	457142857	2	230357143	12	2.56E+08	5	4.96E+09	2.479286	4.41E+00

1.9.3

(2.56E9*1+1.29E9*(Desired_CPI_LS)+2.56E8*5)/f=3.86

So, the Desired CPI_LS = 3.00996678

1.11 The results of the SPEC CPU2006 bzip2 benchmark running on an AMD Barcelona has an instruction count of 2.389E12, an execution time of 750 s, and a reference time of 9650 s.

1.11.1 [5] <§§1.6, 1.9> Find the CPI if the clock cycle time is 0.333 ns.

1.11.2 [5] <§1.9> Find the SPECratio.

1.11.3 [5] <§§1.6, 1.9> Find the increase in CPU time if the number of instructions of the benchmark is increased by 10% without affecting the CPI.

1.11.4 [5] <§§1.6, 1.9> Find the increase in CPU time if the number of instructions of the benchmark is increased by 10% and the CPI is increased by 5%.

1.11.5 [5] <§§1.6, 1.9> Find the change in the SPECratio for this change.

1.11.6 [10] <§1.6> Suppose that we are developing a new version of the AMD Barcelona processor with a 4 GHz clock rate. We have added some additional instructions to the instruction set in such a way that the number of instructions has been reduced by 15%. The execution time is reduced to 700 s and the new SPECratio is 13.7. Find the new CPI.

1.11.7 [10] <§1.6> This CPI value is larger than obtained in 1.11.1 as the clock rate was increased from 3 GHz to 4 GHz. Determine whether the increase in the CPI is similar to that of the clock rate. If they are dissimilar, why?

1.11.8 [5] <§1.6> By how much has the CPU time been reduced?

1.11.9 [10] <§1.6> For a second benchmark, libquantum, assume an execution time of 960 s, CPI of 1.61, and clock rate of 3 GHz. If the execution time is reduced by an additional 10% without affecting to the CPI and with a clock rate of 4 GHz, determine the number of instructions.

1.11.10 [10] <§1.6> Determine the clock rate required to give a further 10% reduction in CPU time while maintaining the number of instructions and with the CPI unchanged.

1.11.11 [10] <§1.6> Determine the clock rate if the CPI is reduced by 15% and the CPU time by 20% while the number of instructions is unchanged.

Sol:

1.11.1 CPI = clock rate × CPU time/instr. count

clock rate = 1/cycle time = 3 GHz

CPI(bzip2) = $3 \times 10^9 \times 750/(2389 \times 10^9)$= 0.94

1.11.2 SPEC ratio = ref. time/execution time

SPEC ratio(bzip2) = 9650/750 = 12.86

1.11.3. CPU time = No. instr. × CPI/clock rate

If CPI and clock rate do not change, the CPU time increase is equal to the increase in the of number of instructions, that is 10%.

1.11.4 CPU time(before) = No. instr. × CPI/clock rate

CPU time(after) = 1.1 × No. instr. × 1.05 × CPI/clock rate

CPU time(after)/CPU time(before) = 1.1 × 1.05 =1.155. Thus, CPU time is increased by 15.5%.

1.11.5 SPECratio = reference time/CPU time

SPECratio(after)/SPECratio(before) = CPU time(before)/CPU time(after) = 1/1.1555 = 0.86. The SPECratio is decreased by 14%.

1.11.6 CPI = (CPU time × clock rate)/No. instr.

CPI = $700 \times 4 \times 10^9/(0.85 \times 2389 \times 10^9)$ = 1.37

1.11.7 Clock rate ratio = 4 GHz/3 GHz = 1.33

CPI @ 4 GHz = 1.37, CPI @ 3 GHz = 0.94, ratio = 1.45

They are different because, although the number of instructions has been reduced by 15%, the CPU time has been reduced by a lower percentage.

1.11.8 700/750 = 0.933. CPU time reduction: 6.7%

1.11.9 No. instr. = CPU time × clock rate/CPI

No. instr. = $960 \times 0.9 \times 4 \times 10^9/1.61 = 2146 \times 10^9$

1.11.10 Clock rate = No. instr. × CPI/CPU time.

Clock rate_{new} = No. instr. × CPI/0.9 × CPU time = 1/0.9 clock rate_{old} = 3.33 GHz

1.11.11 Clock rate = No. instr. × CPI/CPU time.

Clock $rate_{new}$ = No. instr. × 0.85× CPI/0.80 CPU time = 0.85/0.80, clock $rate_{old}$ = 3.18 GHz

1.14 Assume a program requires the execution of 50×10^6 FP instructions, 110×10^6 INT instructions, 80×10^6 L/S instructions, and 16×10^6 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.

1.14.1 [10] <§1.10> By how much must we improve the CPI of FP instructions if we want the program to run two times faster?

1.14.2 [10] <§1.10> By how much must we improve the CPI of L/S instructions if we want the program to run two times faster?

1.14.3 [5] <§1.10> 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 L/S and Branch is reduced by 30%?

Sol:

1.14.1 Clock cycles = CPI_{fp} × No. FP instr. + CPI_{int} × No. INT instr. + $CPI_{l/s}$ × No. L/S instr. + CPI_{branch} × No. branch instr.

T_{CPU} = clock cycles/clock rate = clock cycles/2×10^9

clock cycles = 512×10^6; T_{CPU} = 0.256 s

To have the number of clock cycles by improving the CPI of FP instructions:

$CPI_{improved\ fp}$ × No. FP instr. + CPI_{int} × No. INT instr. + $CPI_{l/s}$ × No. L/S instr. + CPI_{branch} × No. branch instr. = clock cycles/2

$CPI_{improved\ fp}$ = (clock cycles/2 − (CPI_{int} × No. INT instr. + $CPI_{l/s}$ × No. L/S instr. + CPI_{branch} × No. branch instr.)) / No. FP instr.

$CPI_{improved\ fp}$ = (256−462)/50 <0 ==> not possible

1.14.2 Using the clock cycle data from a.

To have the number of clock cycles improving the CPI of L/S instructions:

$CPI_{fp} \times$ No. FP instr. $+ CPI_{int} \times$ No. INT instr. $+ CPI_{improved\ l/s} \times$ No. L/S instr. $+ CPI_{branch} \times$ No. branch instr. $=$ clock cycles/2

$CPI_{improved\ l/s} =$ (clock cycles/2 $-$ ($CPI_{fp} \times$ No. FP instr. $+ CPI_{int} \times$ No. INT instr. $+ CPI_{branch} \times$ No. branch instr.)) / No. L/S instr.

$CPI_{improved\ l/s} = (256-198)/80 = 0.725$

1.14.3 Clock cycles $= CPI_{fp} \times$ No. FP instr. $+ CPI_{int} \times$ No. INT instr. $+ CPI_{l/s} \times$ No. L/S instr. $+ CPI_{branch} \times$ No. branch instr.

T_{CPU} = clock cycles/clock rate = clock cycles/2×10^9

$CPI_{int} = 0.6 \times 1 = 0.6$; $CPI_{fp} = 0.6 \times 1 = 0.6$; $CPI_{l/s} = 0.7 \times 4 = 2.8$; $CPI_{branch} = 0.7 \times 2 = 1.4$

T_{CPU} (before improv.) = 0.256 s; T_{CPU} (after improv.)= 0.171 s