CMPUT 229 - Quiz # 5 - Fall 2010

Name:

Question 1 (100 points): The base CPI of a processor is 1.0. This base CPI is the average number of clocks per instruction when every memory reference results in a hit in L1. The clock rate of the processor is 4 GHz. An access to main memory requires 80 ns to complete. The processor has a split L1 cache. Accesses that hit either L1 cache are completed in 250 ps (1 $ps = 10^{-12}s$). The miss ratio of the L1 instruction cache is 2% and the miss ratio of the L1 data cache is 4%. In the program under analysis 25% of the instructions are load or store. The processor also has an L2 cache. The hit time for the L2 cache is 4 ns and the local miss rate for L2 is 20%. Remember that the *local miss rate* for a cache C is the proportion of the references that reach C and are not serviced by a data in C.

What is the Average Memory Access Time (AMAT), expressed both in terms of number of cycles and time, for this program in this architecture?

We will reduce all the penalties and access times to the number of cycles that they take.

$$\begin{aligned}
\text{ClockCycle} &= \frac{1}{4\ GHz} = \frac{1}{4 \times 10^9} = 0.25 \times 10^{-}9 = 0.25\ ns = 250\ ps \\
L1_{\text{hit time}} &= 1 \text{ cycle} \\
L2_{\text{hit time}} &= \frac{4\ ns}{0.25\ ns} = 16 \text{ cycles} \\
\text{Memory}_{\text{access time}} &= \frac{80ns}{0.25ns} = 320 \text{ cycles}
\end{aligned}$$

Now we need to write the AMAT equation for this program running in this architecture.

$$\begin{aligned}
AMAT &= L1_{\text{hit time}} + LI1_{\text{miss rate}} \times L1_{\text{miss penalty}} + \text{Data Instr Rate} \times LD1_{\text{miss rate}} \times L1_{\text{miss penalty}} \\
L1_{\text{miss penalty}} &= L2_{\text{hit time}} + L2_{\text{miss rate}} \times \text{Memory}_{\text{access time}} \\
L1_{\text{miss penalty}} &= 16 \text{ cycles} + 0.2 \times 320 \text{ cycles} = 80 \text{ cycles} \\
AMAT &= 1 + 0.02 \times 80 + 0.25 \times 0.04 \times 80 \\
AMAT &= 1 + 1.60 + 0.80 = 3.4 \text{ cycles} \\
&= 3.4 \times 0.25\ ns = 0.85\ ns = 850\ ps
\end{aligned}$$

The solution above converted all the penalties to cycles. Most students worked their solutions in terms of time. Below is the solution when you compute in terms of time.

$$
\begin{aligned}
AMAT &= L1_{\text{hit time}} + LI1_{\text{miss rate}} \times (L2_{\text{hit time}} + L2_{\text{miss rate}} \times \text{Memory}_{\text{access time}}) \\
&\quad + \text{Data Instr Rate} \times LD1_{\text{miss rate}} \times (L2_{\text{hit time}} + L2_{\text{miss rate}} \times \text{Memory}_{\text{access time}}) \\
&= L1_{\text{hit time}} + LI1_{\text{miss rate}} \times L2_{\text{hit time}} + LI1_{\text{miss rate}} \times L2_{\text{miss rate}} \times \text{Memory}_{\text{access time}} \\
&\quad + \text{Data Instr Rate} \times LD1_{\text{miss rate}} \times L2_{\text{hit time}} \\
&\quad + \text{Data Instr Rate} \times LD1_{\text{miss rate}} \times L2_{\text{miss rate}} \times \text{Memory}_{\text{access time}} \\
AMAT &= 0.25\ ns + 0.02 \times 4\ ns + 0.02 \times 0.2 \times 80\ ns \\
&\quad + 0.25 \times 0.04 \times 4\ ns + 0.25 \times 0.04\ ns \times 0.2 \times 80\ ns \\
AMAT &= 0.25\ ns + 0.08\ ns + 0.32\ ns + 0.04\ ns + 0.16\ ns \\
AMAT &= 0.850\ ns
\end{aligned}
$$