

CENG3420 Homework 3

Spring 2021

Solutions

Q1 (20%)

How many total bits are required for a direct-mapped cache with 16 KiB of data and 4-word blocks, assuming a 32-bit address?

Answer:

- In a 32-bit address CPU, 16 KiB is 4096 words.
- With a block size of 4 words, there are 1024 blocks.
- Each block has 4×32 or 128 bits of data plus a tag, which is $(32 - 10 - 2 - 2) = 18$ bits, plus a valid bit.
- Thus, the total cache size is $2^{10} \times (4 \times 32 + (32 - 10 - 2 - 2) + 1) = 2^{10} \times 147$ bits.
- For this cache, the total number of bits in the cache is about 1.15 times as many as needed just for the storage of the data.

Q2 (15%)

IBM mainframe hardware and VMM took three steps to improve the performance of virtual machines, do you know these steps?

Answer:

1. Reduce the cost of processor virtualization.
2. Reduce interrupt overhead cost due to the virtualization.
3. Reduce interrupt cost by steering interrupts to the proper VM without invoking VMM.

Q3 (10%) A machine has a base CPI of 2 clock cycles. Measurements obtained show that the instruction miss rate is 12% and the data miss rate is 6%, and that on average, 30% of all instructions contain one data reference. The miss penalty for the cache is 10 cycles. What is the total CPI?

Answer:

$$\begin{aligned} \text{Effective CPI} &= 2.0 + \text{instruction miss cycles} + \text{data miss cycles} \\ &= 2.0 + 0.12 \times 10 + 0.30 \times 0.06 \times 10 \\ &= 2.0 + 1.2 + 0.18 \\ &= 3.38 \end{aligned} \tag{1}$$

Q4 (15%)

1. What's the concept of *Page Faults*?

2. What are the reasons or characteristics of Page fault exceptions for data accesses are difficult to implement properly in a processor?

Answer:

1. If the valid bit for a virtual page is off, a page fault occurs. The operating system must be given control. This transfer is done with the exception mechanism, Once the operating system gets control, it must find the page in the next level of the hierarchy (usually flash memory or magnetic disk) and decide where to place the requested page in main memory.
2. (a) They occur in the middle of instructions, unlike instruction page faults.
(b) The instruction cannot be completed before handling the exception.
(c) After handling the exception, the instruction must be restarted as if nothing had occurred.

Q5 (15%)

A machine has a 32-bit virtual address space and a 16KB page size. It has 1GB of physical memory. How many pages does a process have?

Answer:

1.
$$\begin{aligned} \text{Pages per process} &= 2^{32} \text{bytes} \times (1 \text{page} / 16 \times 2^{10} \text{bytes}) \\ &= 2^{32} / 2^{14} \\ &= 2^{18} = 256\text{K pages} \end{aligned} \quad (2)$$