Seminar 1

Memory Hierarchy

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Problem 1

A set-associative cache consists of 64 lines, divided into four-line sets. Main memory contains 4K blocks of 128 bytes each. Show the format of the main memory addresses.

Problem 2

A two-way set-associative cache has lines of 16 bytes and a total size of 8 Kbytes. The 64-Mbyte main memory is byte addressable. Show the format of main memory addresses.

Problem 3

Consider a machine with a byte addressable main memory of 2^{16} bytes and block size of 8 bytes. Assume that a direct mapped cache consisting of 32 lines is used.

a. How is a 16-bit memory address divided into tag, line number, and byte number?

b. Into what line would bytes with each of the following addresses be stored?

   0001 0001 0001 1011

   1100 0011 0011 0100

   1101 0000 0001 1101

   1010 1010 1010 1010

c. Suppose the byte with address 0001 1010 0001 1010 is stored in the cache. What are the addresses of the other bytes stored along with it?

d. How many total bytes can be stored in the cache?

e. Why is the tag also stored in the cache?

Problem 4

Consider the following code:

```
for (i=0; i < 20; i++)
    for (j = 0; j < 10; j++)
        a[i] = a[i]*(j+1);
```

a. Give one example of the spacial locality in the code.
b. Give one example of the temporal locality in the code.

Problem 5

Consider an L1 cache with an access time of 1 ns and a hit ratio of H = 0.95. Suppose that we can change the cache design (size of the cache, cache organization) such that we increase H to 0.97, but increase the cache access time to 1.5 ns. What conditions must be met for this change to result in improved performance?

Problem 6

A Computer has a cache, main memory, and a disk used for virtual memory. If a referenced word is in the cache, 20ns are required to access it. If it is in main memory but not in the cache, 60 ns are needed to load it into the cache, and then the reference is started again. If the word is not in main memory, 12 ms are required to fetch the word from disk, followed by 60 ns to copy it to the cache, and then the reference is started again. The cache hit ratio is 0.9 and the main memory hit ratio is 0.6. What is the average time in nanoseconds required to access a referenced word on this system?