Computer Hardware Review (Memory Hierarchy)

Chapter 1.4

Learning Outcomes

- Understand the concepts of memory hierarchy and caching, and how they affect performance.

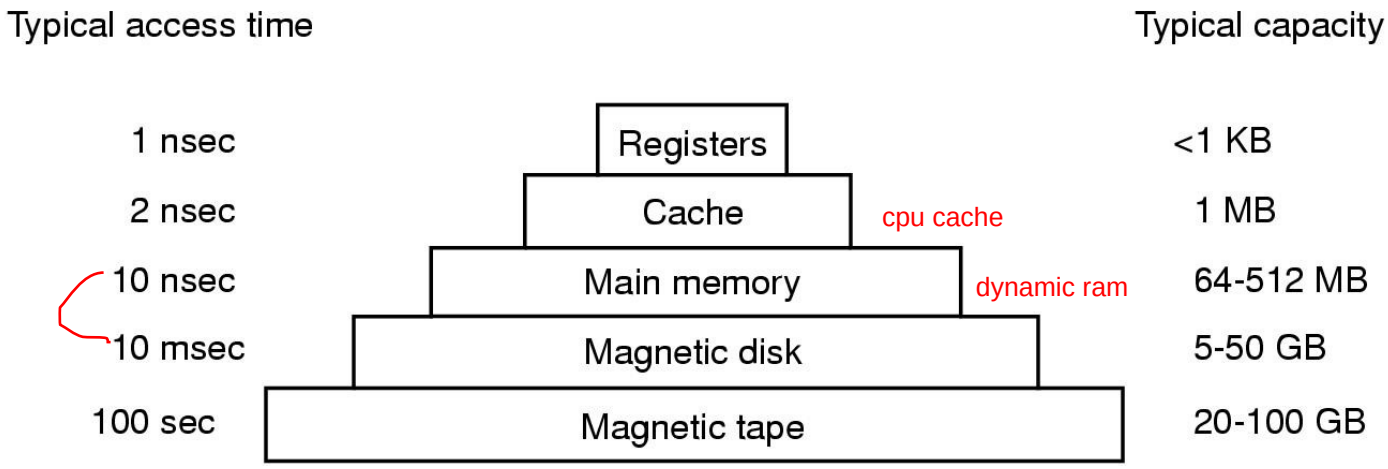
Operating Systems

- Exploit the hardware available
- Provide a set of high-level services that represent or are implemented by the hardware.
- Manages the hardware reliably and efficiently
- *Understanding operating systems requires a basic understanding of the underlying hardware*

Memory Hierarchy

- Going down the hierarchy
  - Decreasing cost per bit
  - Increasing capacity
  - Increasing access time
- Decreasing frequency of access to the memory by the processor
  - Hopefully
  - Principle of locality!!!!!

    data you used now is likely to be used in the future



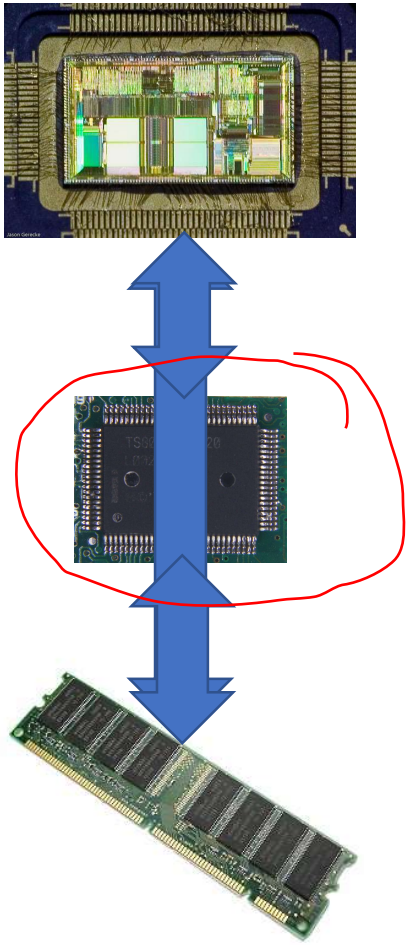
Caching as a general technique

- Given two-levels of data storage: small and fast, versus large and slow,
- Can speed access to slower storage by using intermediate-speed storage as a cache.

the data that's recently used in large and slow is cached in small and fast, hoping that they will be used in the near future

A hardware approach to improving system performance?

CPU Registers
Fast

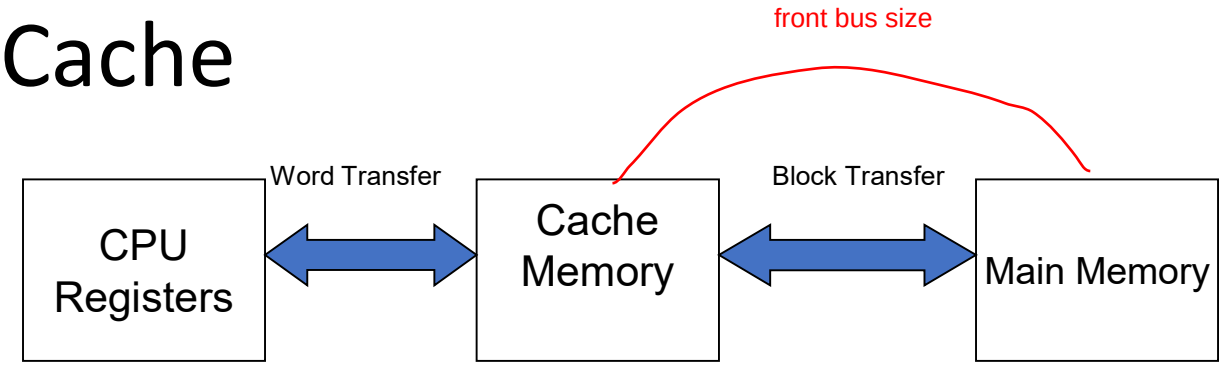


Cache Memory (SRAM)
Fast

Main Memory (DRAM)
Slow

random access from malloc of large memory is slower

CPU Cache

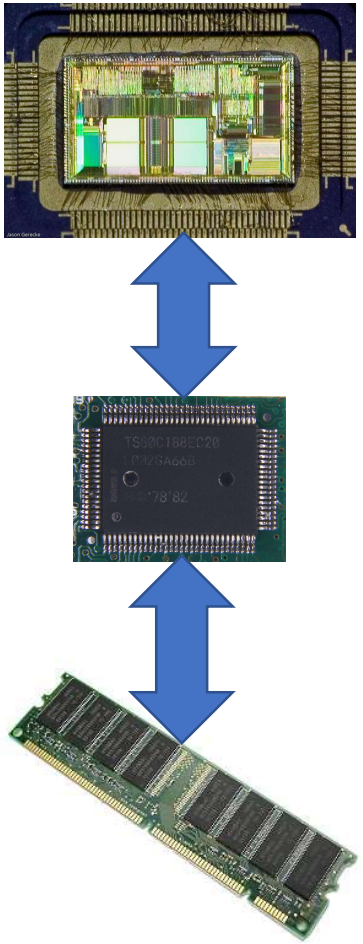


- CPU cache is fast memory placed between the CPU and main memory
  - 1 to a few cycles access time compared to RAM access time of tens – hundreds of cycles
- Holds recently used data or instructions to save memory accesses.
- Matches slow RAM access time to CPU speed if high hit rate
- Is hardware maintained and (mostly) transparent to software
- Sizes range from few kB to tens of MB.
- Usually a hierarchy of caches (2–5 levels), on- and off-chip.

hierarchy of caches, 2 is fastest, 5 is slowest

Performance

- What is the effective access time of memory subsystem?
- Answer: It depends on the hit rate in the first level.



Effective Access Time

$$T_{eff} = H \times T_1 + (1 - H) \times T_2$$

$T_1 =$ access time of memory 1

$T_2 =$ access time of memory 2

$H =$ hit rate in memory 1

$T_{eff} =$ effective access time of system

Example

- Cache memory access time 1ns
- Main memory access time 10ns
- Hit rate of 95%

$$T_{eff} = 0.95 \times 10^{-9} +$$

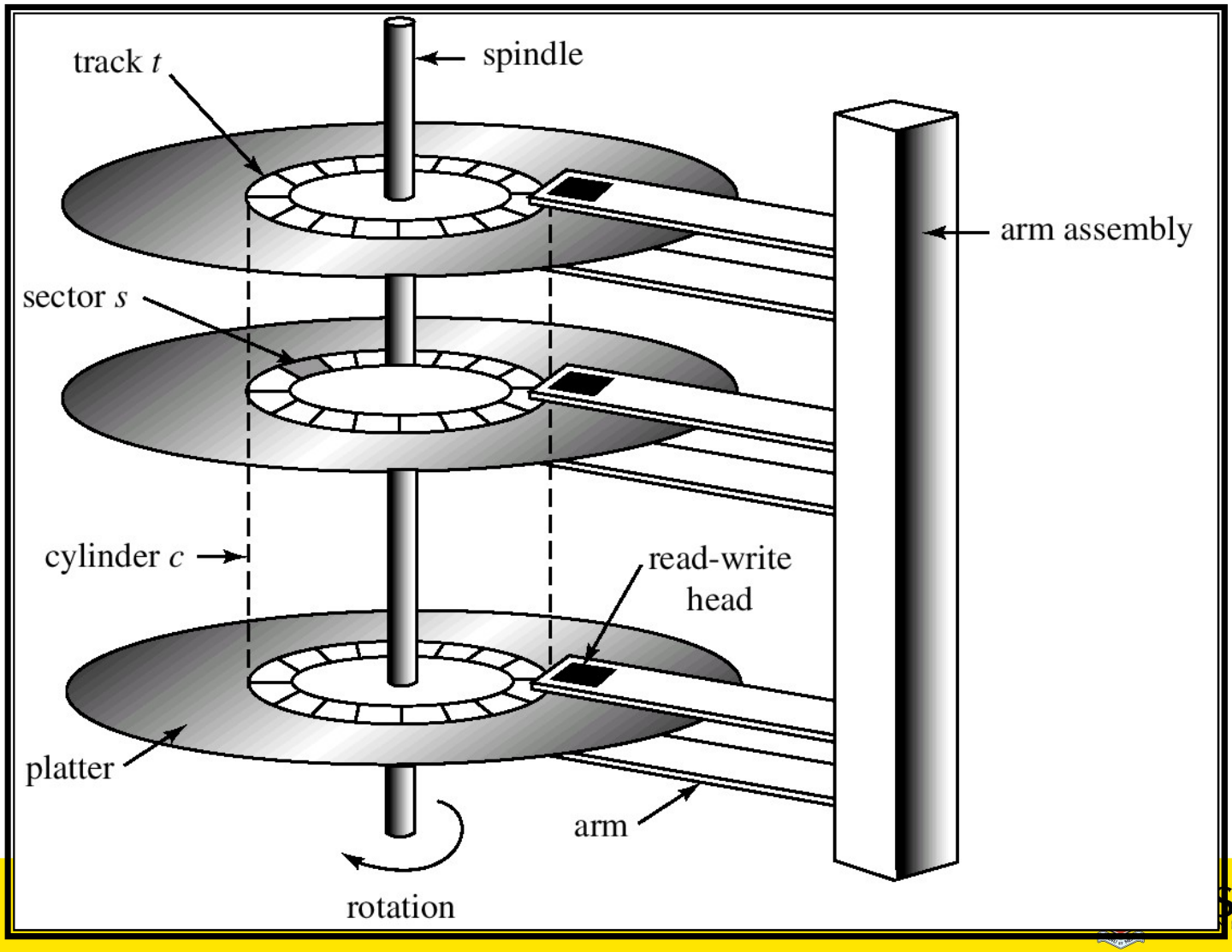
$$(1 - 0.95) \times (10^{-9} + 10 \times 10^{-9})$$

miss on the cache, you still have to access cache to miss

$$= 1.5 \times 10^{-9}$$

Moving-Head Disk Mechanism

mechanical disk is limited by the speed of rotation, movement of arm

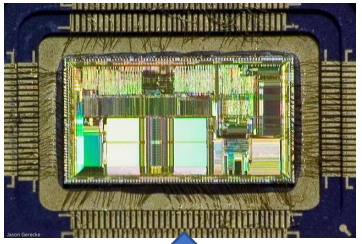


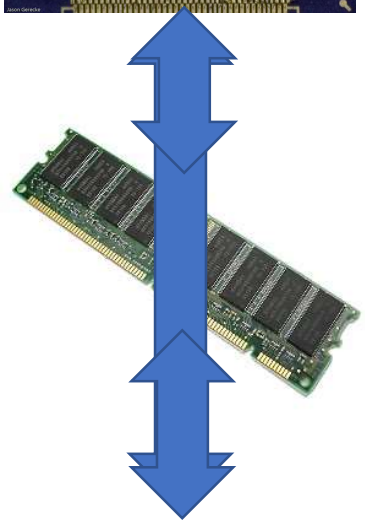
Example Disk Access Times

- Disk can read/write data relatively fast
  - 15,000 rpm drive - 80 MB/sec
  - 1 KB block is read in 12 microseconds
- Access time dominated by time to locate the head over data
  - Rotational latency
    - Half one rotation is 2 milliseconds
  - Seek time
    - Full inside to outside is 8 milliseconds
    - Track to track .5 milliseconds
- 2 milliseconds is 164KB in “lost bandwidth”

A OS approach to improving system performance?

CPU Registers
Fast





Main Memory (DRAM)
Fast

Hard disk
Slow…

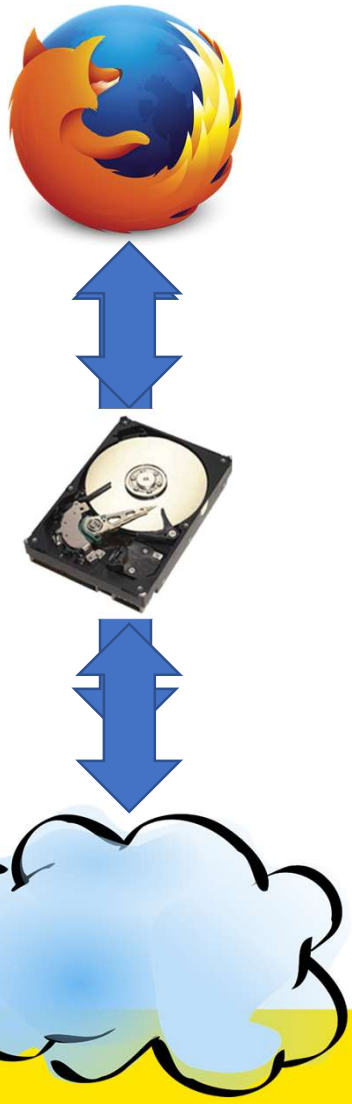
A Strategy: Avoid Waiting for Disk Access

- Keep a subset of the disk's data in main memory

⇒ OS uses main memory as a *cache* of disk contents

Application approach to improving system performance

Web browser
Fast



Hard disk
Fast

Internet
Slow…

A Strategy: Avoid Waiting for Internet Access

- Keep a subset of the Internet's data on disk

⇒ Application uses disk as a *cache* of the Internet