CSE 451: Operating Systems Winter 2009

Module 12 Secondary Storage

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Secondary storage

- Secondary storage typically:
  - is anything that is outside of “primary memory”
  - does not permit direct execution of instructions or data retrieval via machine load/store instructions
- Characteristics:
  - it’s large: 50-1000GB (or more!)
  - it’s cheap: $0.25/GB … er… $0.10/Gb
  - it’s persistent: data survives power loss
  - it’s slow: milliseconds to access
    - why is this slow?
  - it *does* fail, if rarely
    - Big failures (disk dies)
    - Little failures (read/write errors, one byte in 10^13)

Another trip down memory lane …

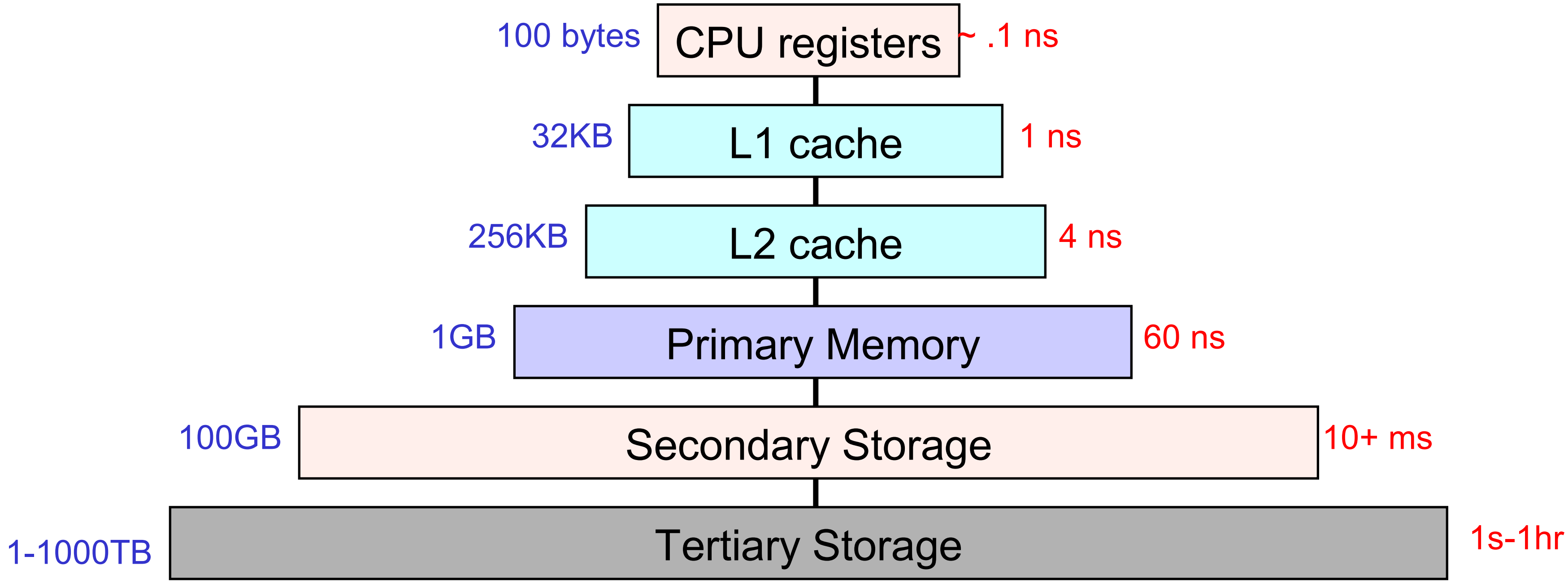
IBM 2314
About the size of
6 refrigerators
8 x 29MB (M!)
Required similar sized
air conditioning

Disk trends

- Disk capacity, 1975-1989
  - doubled every 3+ years
  - 25% improvement each year
  - factor of 10 every decade
  - Still exponential, but far less rapid than processor performance
- Disk capacity since 1990
  - doubling every 12 months
  - 100% improvement each year
  - factor of 1000 every decade
  - Capacity growth10x as fast as processor performance!
- Speed has NOT grown similarly

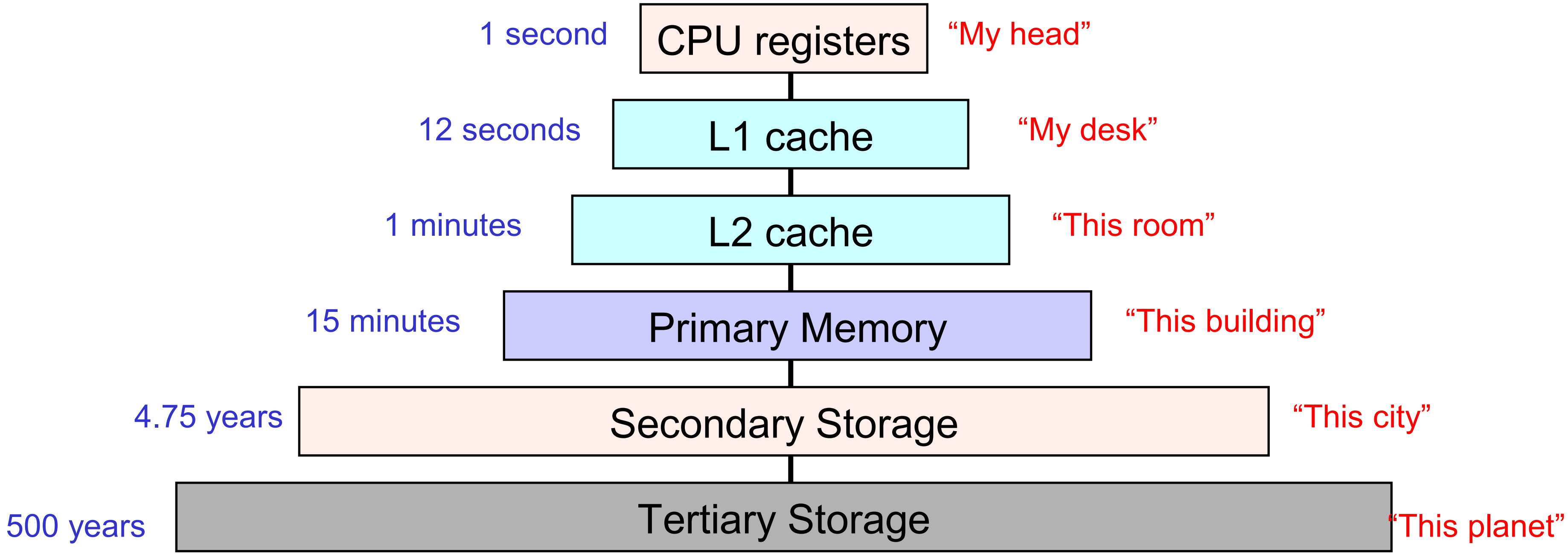
- Only a few years ago, we purchased disks by the megabyte (and it hurt!)
- Today, 1 GB (a billion bytes) costs $1 $0.50 $0.25 $0.10 from Dell (except you have to buy in increments of 40 80 250 500 GB)
  - => 1 TB costs $1K $500 $250 $100, 1 PB costs $1M $500K $250K $10000
- Technology is amazing
  - Flying 747 six inches above the ground at 600mph
  - Reading/writing a strip of postage stamps
  - 5-20 *molecules of gas separating platter from head*
- But…
  - Jet bumps down
  - Bits are so close that cosmic rays/quantum effects change them

Memory hierarchy



- Each level acts as a cache of lower levels

Memory hierarchy: distance analogy



Big Picture

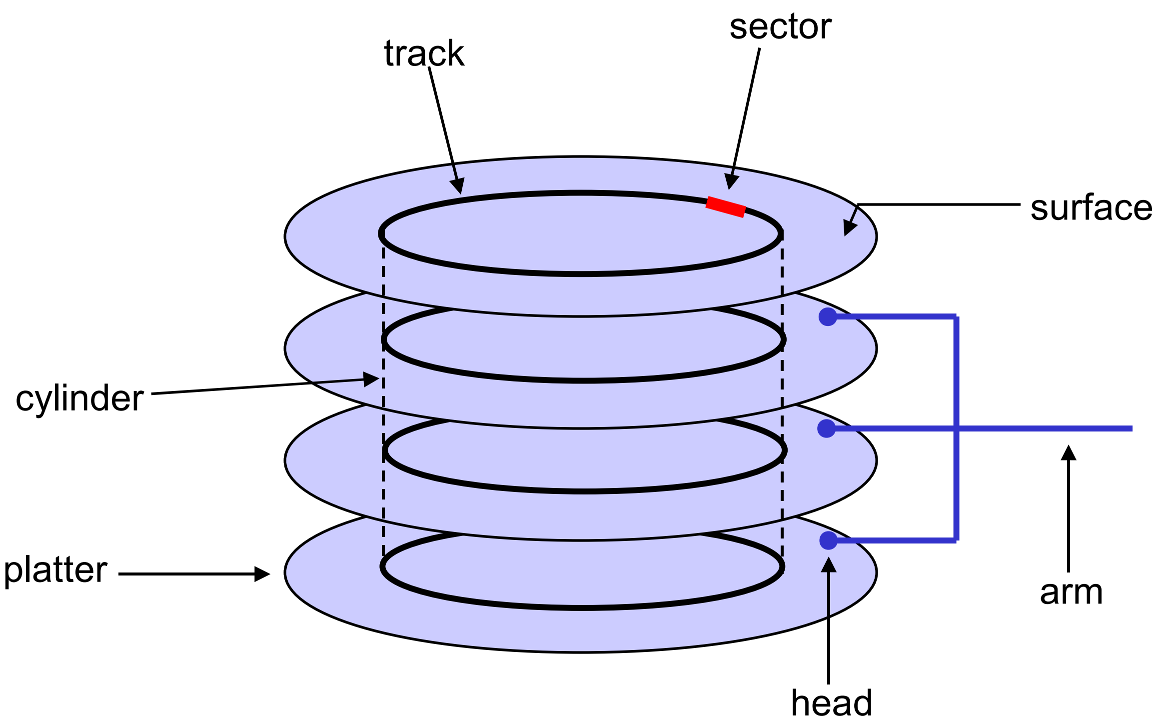
- OS provides abstractions to allow physical HW resources to be shared / protected
  - CPU sharing with threads (virtual CPU)
  - Memory sharing with virtual memory
  - Disk sharing with files

Disks and the OS

- Disks are messy, messy devices
  - errors, bad blocks, missed seeks, etc.
- Job of OS is to hide this mess from higher-level software
  - low-level device drivers (initiate a disk read, etc.)
  - higher-level abstractions (files, databases, etc.)
- OS may provide different levels of disk access to different clients
  - physical disk block (head, cylinder, sector)
  - disk logical block (disk block #)
  - file logical (filename, block or record or byte #)

Physical disk structure

- Disk components
  - platters
  - surfaces
  - tracks
  - sectors
  - cylinders
  - arm
  - heads



Disk performance

- Performance depends on a number of steps
  - seek: moving the disk arm to the correct cylinder
    - depends on how fast disk arm can move
      - seek times aren't diminishing very quickly (why?)
  - rotation (latency): waiting for the sector to rotate under head
    - depends on rotation rate of disk
      - rates are increasing, but slowly (why?)
  - transfer: transferring data from surface into disk controller, and from there sending it back to host
    - depends on density of bytes on disk
      - increasing, relatively quickly
- When the OS uses the disk, it tries to minimize the cost of all of these steps
  - particularly seeks and rotation

Performance via disk layout

- OS may increase file block size in order to reduce seeking
- OS may seek to co-locate “related” items in order to reduce seeking
  - blocks of the same file
  - data and metadata for a file

Performance via caching, pre-fetching

- Keep data or metadata in memory to reduce physical disk access
  - problem?
- If file access is sequential, fetch blocks into memory before requested

Performance via disk scheduling

- Seeks are very expensive, so the OS attempts to schedule disk requests that are queued waiting for the disk
  - FCFS (do nothing)
    - reasonable when load is low
    - long waiting time for long request queues
  - SSTF (shortest seek time first)
    - minimize arm movement (seek time), maximize request rate
    - unfairly favors middle blocks
  - SCAN (elevator algorithm)
    - service requests in one direction until done, then reverse
    - skews wait times non-uniformly (why?)
  - C-SCAN
    - like scan, but only go in one direction (typewriter)
    - uniform wait times

Interacting with disks

- In the old days…
  - OS would have to specify cylinder #, sector #, surface #, transfer size
    - i.e., OS needs to know all of the disk parameters
- Modern disks are even more complicated
  - not all sectors are the same size, sectors are remapped, …
  - disk provides a higher-level interface, e.g., SCSI
    - exports data as a logical array of blocks [0 … N]
    - maps logical blocks to cylinder/surface/sector
    - OS only needs to name logical block #, disk maps this to cylinder/surface/sector
    - on-board cache
    - as a result, physical parameters are hidden from OS
      - both good and bad

Example disk characteristics

- IBM Ultrastar 36XP drive
  - form factor: 3.5”
  - capacity: 36.4 GB (150x those 6 fridges!)
  - rotation rate: 7,200 RPM (120 RPS)
  - platters: 10
  - surfaces: 20
  - sector size: 512-732 bytes (why?)
  - cylinders: 11,494
  - cache: 4MB
  - transfer rate: 17.9 MB/s (inner) – 28.9 MB/s (outer) (why?)
  - full seek: 14.5 ms
  - head switch: 0.3 ms