CSE 451: Operating Systems

Section 10

Project 3 wrap-up, final exam review

Final exam review

- Goal of this section: key concepts you should understand
  - Not just a summary of lectures
  - Slides coverage and final exam topics are not bijective
- Goal of CSE 451: tools for life
- Goal of your life: ???

Thread management

- Queues
  - Why do thread libraries make use of queues?
- Synchronization
  - What are the mechanisms for protecting critical sections, how do they work, and when should one be used over another?
- Preemption
  - What is preemption and how does the process of one thread preempting another work?

Memory management

- Purposes:
  - Resource partitioning / sharing
  - Isolation
  - Usability
- Paging
- Segmentation

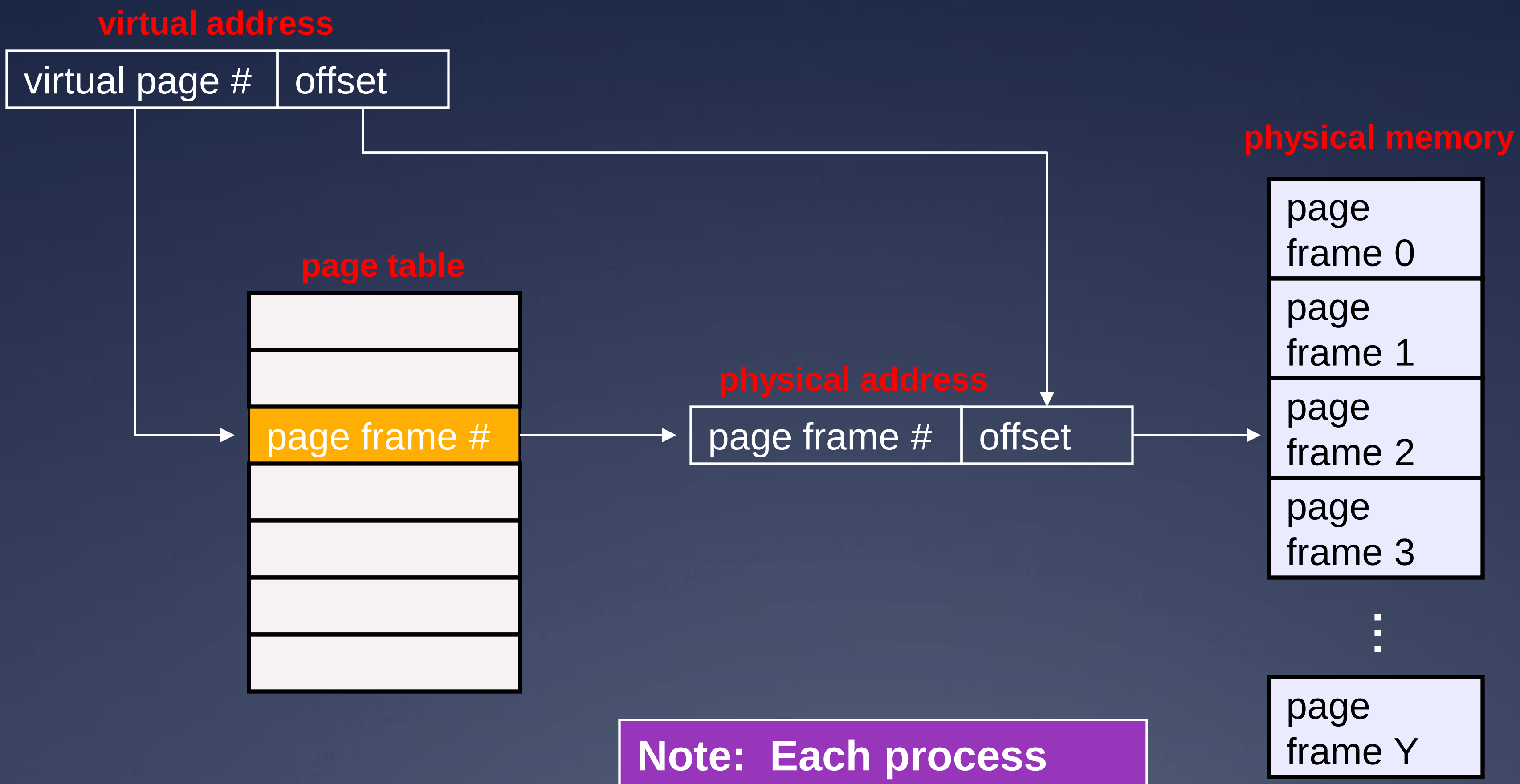
Virtual memory

- What happens on a virtual memory access?

Virtual memory

- What happens on a virtual memory access?
  - Address translation: who performs it?
    - Page table lookup
    - Translation Lookaside Buffer (TLB)
  - Page fault?
    - Page replacement
    - Process/queue management
- How does all of this overhead pay off?
  - Locality! Both temporal (in time) and spatial (nearby).

Virtual memory



Note: Each process has its own page table!

Page replacement

- Algorithms:
  - Belady, FIFO, LRU, LRU clock / NRU, random, working set…
  - Local vs. global
- How/why are any of these better or worse than the others?
- What happens when paging goes wrong?
  - Thrashing, 10-year old computers running XP?

Advanced virtual memory

- What problem does a TLB address?
- What problem do two-level page tables address?
  - What’s the key concept?

Advanced virtual memory

- What problem does a TLB address?
  - Increases speed of virtual address translation
- What problem do two-level page tables address?
  - What's the key concept?
    - Indirection

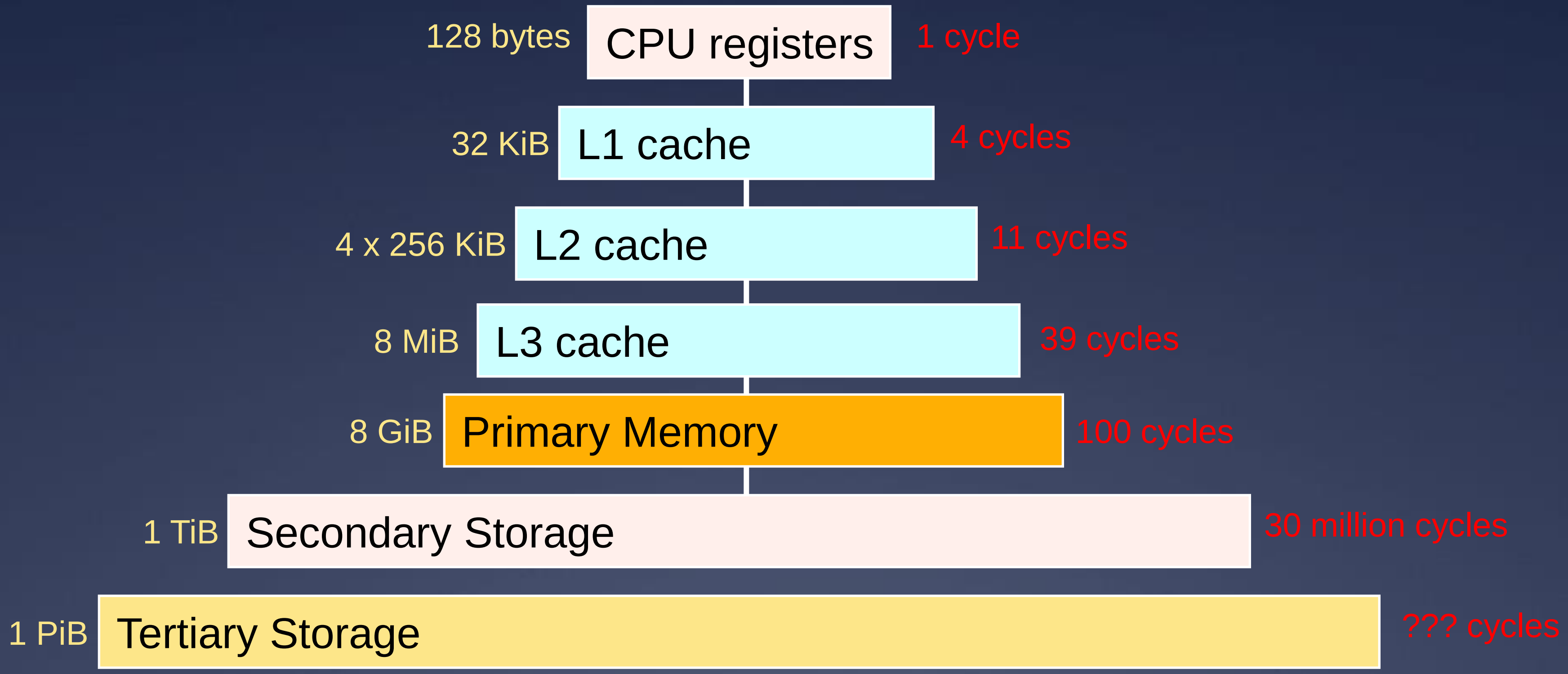
Secondary storage

- Memory forms a hierarchy
- Different levels of disk abstraction:
  - Sectors
  - Blocks
  - Files
- What factor most influences the ways that we interact with disks?

Secondary storage

- Memory forms a hierarchy
- Different levels of disk abstraction:
  - Sectors
  - Blocks
  - Files
- What factor most influences the ways that we interact with disks?
  - Latency

Memory hierarchy



128 bytes CPU registers 1 cycle

32 KiB L1 cache 4 cycles

4 x 256 KiB L2 cache 11 cycles

8 MiB L3 cache 39 cycles

8 GiB Primary Memory 100 cycles

1 TiB Secondary Storage 30 million cycles

1 PiB Tertiary Storage ??? cycles

- Each level acts as a cache of lower levels
  - (Stats more or less for Core i7 3770)

File systems

- What does a file system give you?
  - Useful abstraction for secondary storage
  - Organization of data
    - Hierarchy of directories and files
  - Sharing of data

File system internals

- Directories
- Directory entries
- Inodes
- Files:
  - One inode per file
  - Multiple directory entries (links) per file

Inode-based file system

- Sequence of steps when I run *echo "some text" > /home/jay/file.txt* ?
  - Open file:
    - Get inode for / -> get data block for /
    - Read directory entry for / -> get inode for /homes
    - Repeat… -> get data block for file.txt, check permissions
  - Write to file:
    - Modify data block(s) for file.txt in buffer cache
  - Close file:
    - Mark buffer as dirty, release to buffer cache
    - Kernel flushes dirty blocks back to disk at a later time

Other file systems

- What problem does each of these address?
  - BSD Unix fast file system (FFS):
    - Performance: smarter physical disk layout
  - Journaling file systems (JFS):
    - Reliability: transactions prevent inconsistencies after crash
  - Berkeley log-structured file system (LFS):
    - Performance: even smarter physical disk layout?

RAID

- Striping: read/write from multiple disks simultaneously
  - Improves performance
  - Hurts reliability
- Parity: store redundant information to allow data recovery after disk failures
  - Improves reliability
  - Hurts performance

Devices and Drivers

- How should the OS provide access to physical hardware to user processes?
  - Multiplexing
  - Mutual exclusion
- UNIX / Linux device driver model
- Virtual devices, and what they can do for you
  - FUSE

Networking

- Layering
- Encapsulation

RPC

- Benefits:
  - Low-level details taken care of for you
  - Natural interface
- Implementation issues:
  - Network failures / retries
  - Architecture differences
  - Performance

Distributed file systems

- Why do we want them?
  - Location independence
  - Large-scale data sharing
- Why are they hard?
  - Consistency
  - Replication
  - Performance
- Understand the target workloads

Distributed systems

- Scalability
  - Limited by sharing
    - How does this relate to multi-core CPUs?
  - Do more nodes equal more performance?
  - How do companies like Amazon, Facebook, Google, Microsoft, etc. parallelize workloads?

Virtual machine monitors

- VMM is an additional layer between OS and hardware
  - Can interpose on instruction execution, memory accesses, I/O requests, and network communication