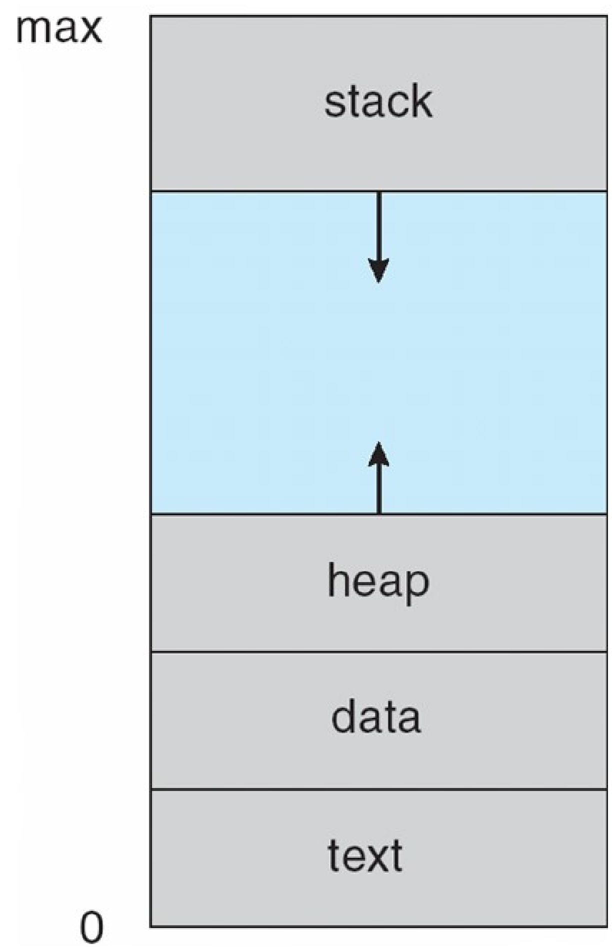
Final Review

2^{nd} Half

- Memory management
- Disk management
- Network and Security
- Virtual machine

Virtual Memory (VM)

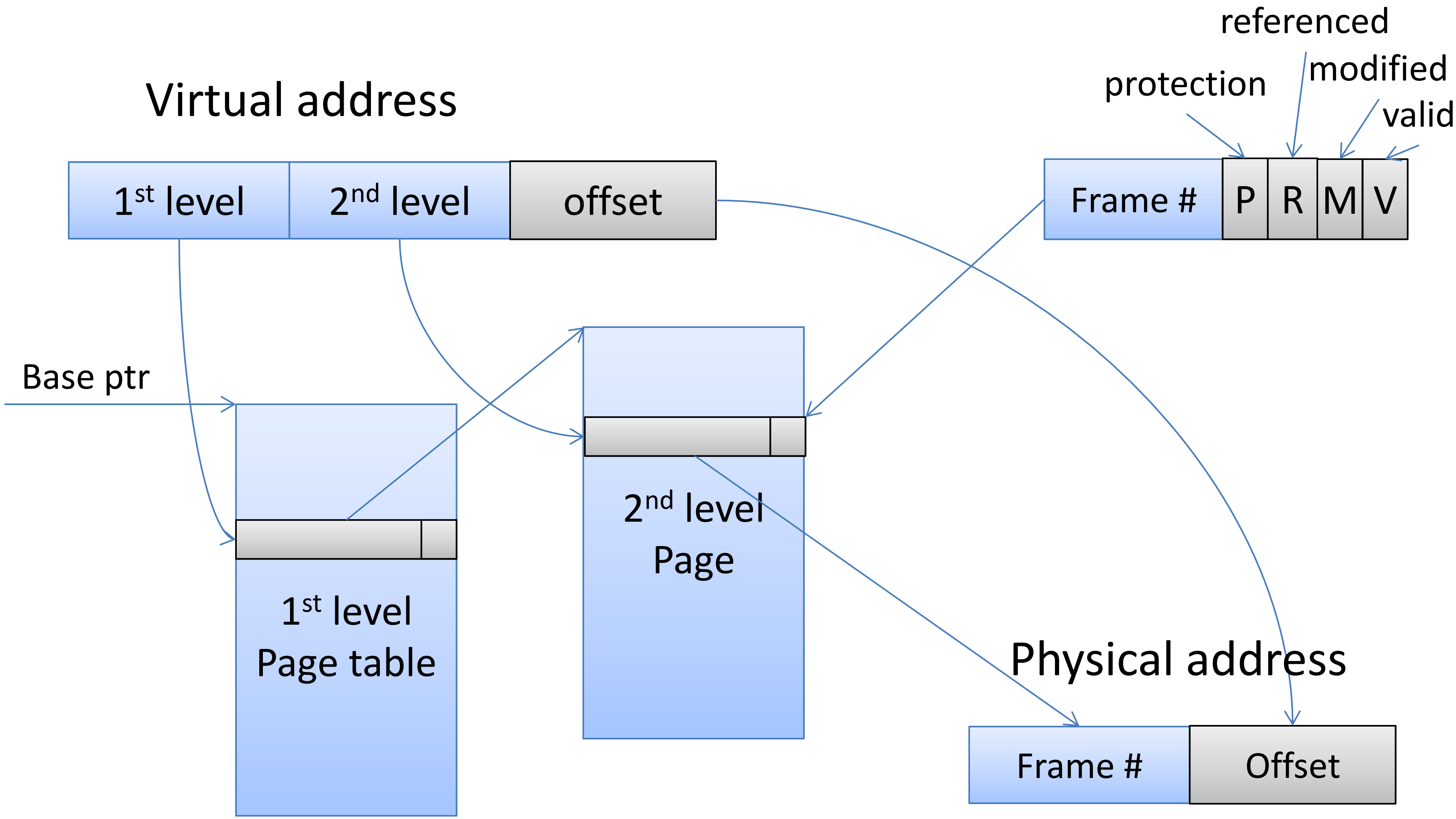
- Abstraction
  - 4GB (32bit) linear address space for each process
- Reality
  - 1GB of actual physical memory shared with 20 other processes



Paging

- MMU (memory management unit)
  - Segmentation (base+limit),
  - Paging (page table)
  - TLB (translation lookaside buffer)
- Page table
  - Virtual addr → physical address translation table
- Other concepts to know
  - Fragmentation

Two Level Address Translation



Quiz: Address Translation

8 bits	8 bits	8 bits	
1^{st} level	2^{nd} level	offset	Virtual address format (24bits)

4 bits	3	1	
Frame #	Unused	V	Page table entry (8bit)

- What is the size of a single page?
  - 256 bytes
- What is the size of the virtual address space?
  - 2^24 = 16MB
- What is the size of the physical address space?
  - 2^12 = 4KB

Quiz: Address Translation

8 bits	8 bits	8 bits
1^{st} level	2^{nd} level	offset

Virtual address format (24bits)

4 bits	3	1
Frame #	Unused	V

Page table entry (8bit)

Vaddr: 0x0703FE
Paddr: 0x3FE

Vaddr: 0x072370
Paddr: ???

Vaddr: 0x082370
Paddr: ???

Page-table base address = 0x100

Addr	+0	+1	+2	+3	+4	+5	+6	+7	+8	+A	+B	+C	+D	+E	+F
0x000				31											
0x010															
0x020				41											
..															
0x100	00	01						01	00			01			
..															
0x200															

Quiz: Address Translation

8 bits	8 bits	8 bits
1st level	2nd level	offset

Virtual address format (24bits)

4 bits	3	1
Frame #	Unused	V

Page table entry (8bit)

Vaddr: 0x0703FE
Paddr: 0x3FE

Vaddr: 0x072370
Paddr: **0x470**

Vaddr: 0x082370
Paddr: **invalid**

Page-table base address = 0x100

Addr	+0	+1	+2	+3	+4	+5	+6	+7	+8	+A	+B	+C	+D	+E	+F
0x000				31											
0x010															
0x020				41											
..															
0x100	00	01						01	00			01			
..															
0x200															

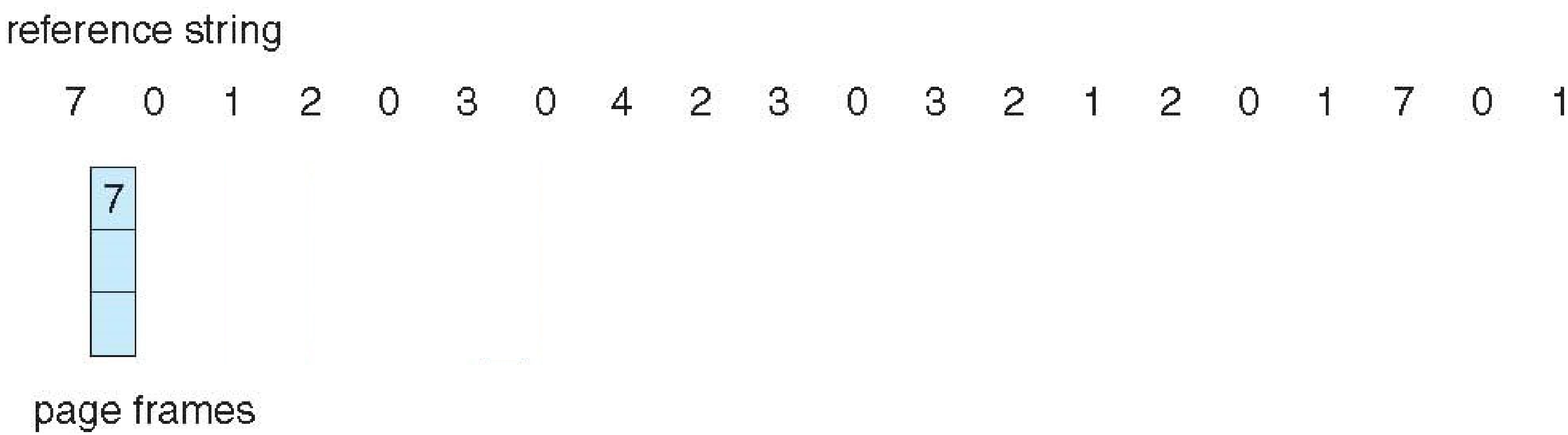
Demand Paging

- Key idea
  - no need to load all pages on memory.
- Page fault
  - Occurs when there’s no valid virt -> phys addr translation
  - Allocate a free frame [and load a page from the disk]
- Copy-on-write
  - Fork()/exec() semantic
- Other concepts to know
  - Page Table Entry (PTE) bits: valid/invald, …

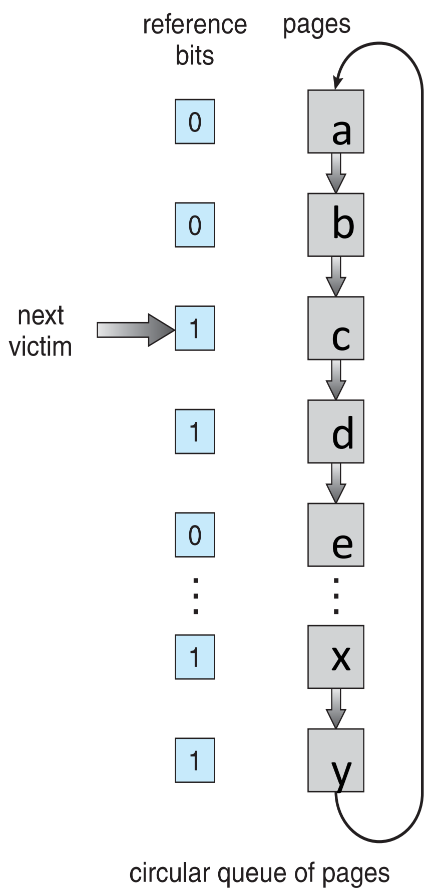
Page Replacement & Swapping

- Least Recently Used (LRU)
  - Approximation: clock algorithm, N-clock algorithm
  - When swapping occurs in the page fault handler?
- Other concepts to know
  - Thrashing
  - FIFO, MIN (optimal) replacement algorithms

Exercise: LRU Replacement



Second Chance Algorithm



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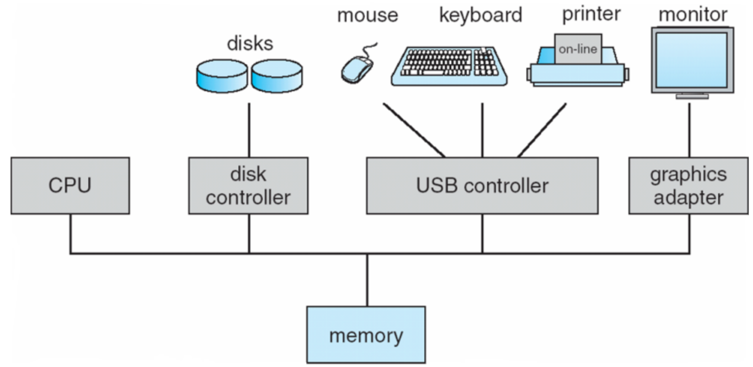
I/O Devices



- Block devices
  - E.g., disk, cd-rom, USB stick
  - High speed, block (sector) level accesses
- Character devices
  - E.g., keyboard, mouse, joystick
  - Low speed, character level accesses
- Network devices
  - E.g., ethernet, wifi, bluetooth
  - Socket interface

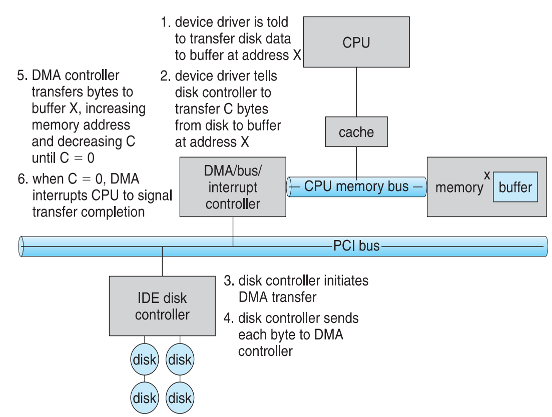
Disk

- Magnetic disk
  - Key characteristic: long seek time
- Solid state disk (SSD)
  - Key characteristic: zero seek time
- Performance metrics
  - Access latency, price/storage space

I/O Mechanisms

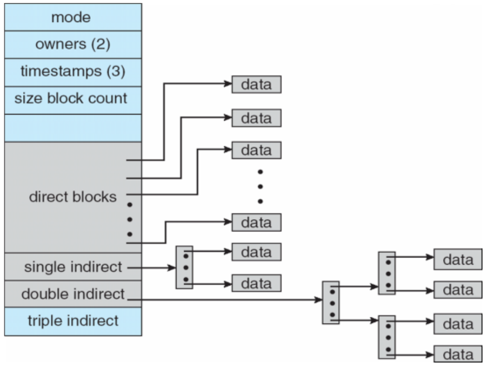
- Memory-mapped I/O vs. I/O instructions
  - MMIO: Address space → registers in the hardware
  - I/o instructions: *inb* or *outb* in x86

- Programmed I/O (PIO) vs. DMA
  - PIO: Reads/writes by CPU
  - DMA: DMA hw operation steps



Filesystem

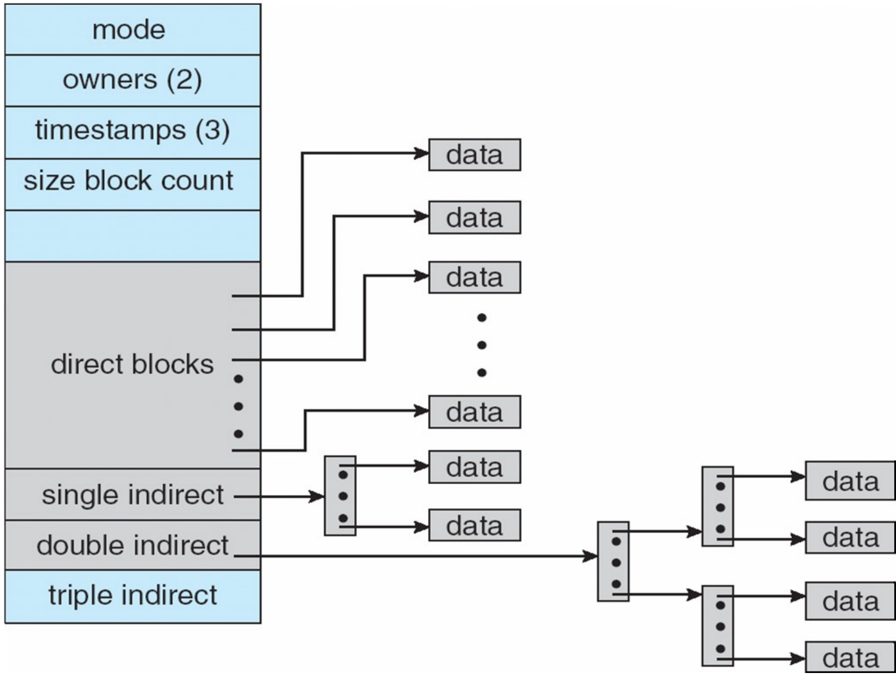
- Disk block allocation methods
  - Continuous allocation
  - **Linked allocation**
  - **Indexed allocation**



- Other concepts to know
  - Metadata, inode, directory
  - **Direct/single/double/triple indirect blocks**
    - How they differs. Why different levels?

Recap: Ext2

- Inode
  - 12 blocks are directly mapped, 1 indirect pointer. 1 double indirect pointer, 1 triple indirect pointer. 32bit pointer
- Maximum file size?
  - $min(((b/4)^3+(b/4)^2+b/4+12)*b,$ $(2^{32}-1)*512)$
  - 1K block size
    - 1K * (12 + 256 + 256^2 + 256^3) = 16GB
  - 2K block size
    - 2K * (12 + 512+ 512^2 + 512^3) = 256G
  - 4K block size
    - (2^32-1)*512 = 2TB
- Maximum disk size?
  - 2^{32} * block size



Name Resolution

- How many disk accesses to resolve “/usr/bin/top”?
  - Read “/” directory inode
  - Read first data block of “/” and search “usr”
  - Read “usr” directory inode
  - Read first data block of “usr” and search “bin”
  - Read “bin” directory inode
  - Read first block of “bin” and search “top”
  - Read “top” file inode
  - Total 7 disk reads!!!
    - This is the minimum. Why? Hint: imagine 10000 entries in each directory

Storage caches

- Directory cache
  - For faster name resolution
  - Steps to resolve a file name to inode
- Buffer cache
  - Frequently used disk blocks

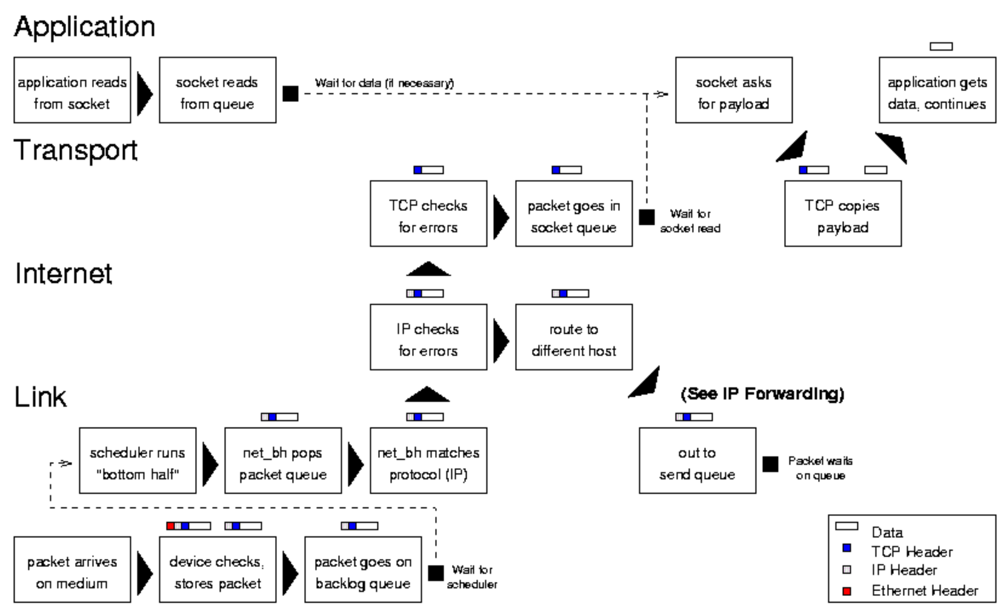
- Other concepts to know
  - Unified buffer and page cache
  - Journaling

Types of Journaling

- Full journaling
  - All data & metadata are written twice
- Metadata journaling
  - Only write metadata of a file to the journal

Network

- OSI 7 layers vs. TCP/IP 5 layers
- Steps for sending/receiving a packet



Security & Virtual Machine

- Buffer overflow bugs
  - Look at the example code

- Virtual machine monitor (VMM)

- Native VMM vs. hosted VMM

- Full virtualization vs. para virtualization

1^{st} Half

OS Structure

- User mode/ kernel mode
  - Memory protection, privileged instructions
- System call
  - Definition, examples, how it works?
- Other concepts to know
  - Monolithic kernel vs. Micro kernel

Process/Thread

- Address space layout
  - Code, data, heap, stack
- Process states
  - new, ready, running, waiting, terminated

- Other concepts to know
  - Process Control Block
  - Context switch
  - Zombie, Orphan
  - Communication overheads of processes vs. threads

Synchronization

- Spinlock
  - Semantics of test & set, compare & swap
  - Implementation using compare & swap
- Blocking synchronization primitives
  - Busy waiting vs. blocking
  - Mutex, semaphore, monitor
- Example problems
  - Bounded buffer, read/writer

Deadlock

- Deadlock conditions
  - mutual exclusion, no preemption, hold and wait, circular wait
- Deadlock prevention
- **Banker's algorithm**

- Other concepts to know
  - Starvation vs. deadlock

Scheduling

- Three main schedulers
  - FCFS, SJF/SRTF, RR
  - Gant chart examples

- Other concepts to know
  - Fair scheduling (CFS)
  - Fixed priority scheduling
  - Multi-level queue scheduling
  - Load balancing and multicore scheduling

Thank you!