

CS420: Operating Systems

OS Architecture

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Operating System Structure

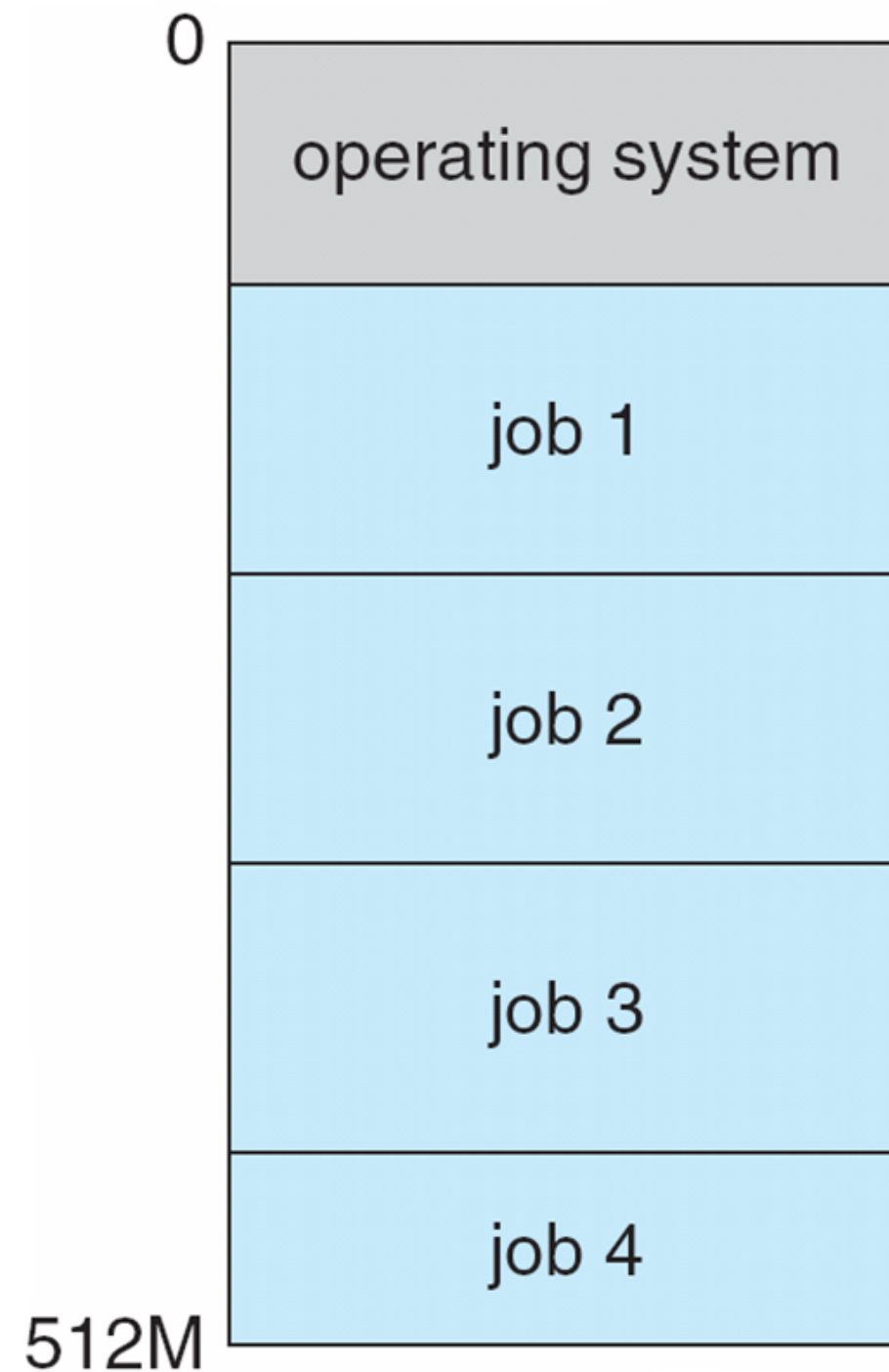
- **Multiprogramming needed for efficiency**

- Single user cannot keep CPU and I/O devices busy at all times
- Multiprogramming organizes jobs (code and data) so CPU always has one to execute
- A subset of total jobs in system is kept in memory
- One job selected and run via job scheduling
- When it has to wait (for I/O for example), OS switches to another job

Operating System Structure

- **Timesharing (multitasking) is logical extension in which CPU switches jobs so frequently that users can interact with each job while it is running, creating interactive computing**
 - Response time should be < 1 second
 - Each user has at least one program executing in memory (a process)
 - If several jobs ready to run at the same time CPU scheduling is required
 - If processes don't fit in memory, swapping moves them in and out to run
 - Virtual memory allows execution of processes not completely in memory

Memory Layout for Multiprogrammed System

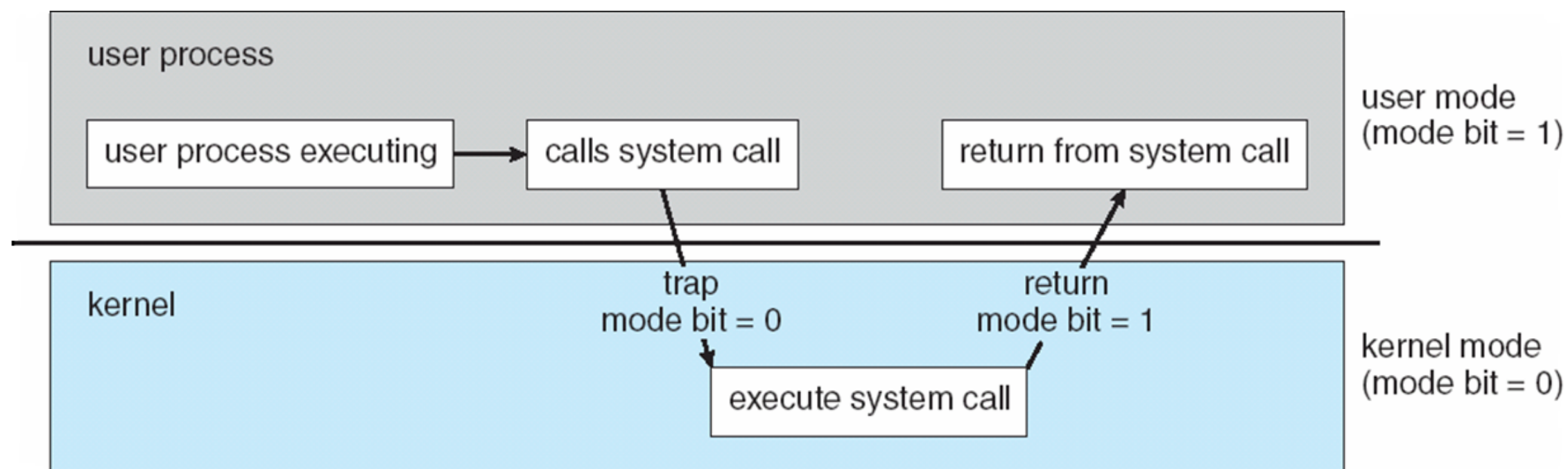


Operating-System Operations

- **Interrupt driven by hardware**
- **Software error or request creates exception or trap**
 - Division by zero, request for operating system service
- **Other process problems include infinite loop, processes modifying each other or the operating system**
- **Dual-mode operation allows OS to protect itself and other system components**
 - User mode and kernel mode
 - Mode bit provided by hardware
 - Provides ability to distinguish when system is running user code or kernel code
 - Some instructions designated as privileged, only executable in kernel mode
 - System call changes mode to kernel, return from call resets it to user

Transition from User to Kernel Mode

- **Timer to prevent infinite loop / process hogging resources**
 - Set interrupt after specific period
 - Operating system decrements counter
 - When counter zero generate an interrupt
 - Set up before scheduling process to regain control or terminate program that exceeds allotted time



Process Management

- **A process is a program in execution. It is a unit of work within the system. Program is a passive entity, process is an active entity.**
- **Process needs resources to accomplish its task**
 - CPU, memory, I/O, files
 - Initialization data
- **Process termination requires reclaim of any reusable resources**

Process Management (Cont.)

- **Single-threaded process has one program counter specifying location of next instruction to execute**
 - Process executes instructions sequentially, one at a time, until completion
- **Multi-threaded process has one program counter per thread**
- **Typically system has many processes, some user, some operating system running concurrently on one or more CPUs**
 - Concurrency by multiplexing the CPUs among the processes / threads

Process Management Activities

- **The operating system is responsible for the following activities in connection with process management:**
 - Creating and deleting both user and system processes
 - Suspending and resuming processes
 - Providing mechanisms for process synchronization
 - Providing mechanisms for process communication
 - Providing mechanisms for deadlock handling

Memory Management

- **All data in memory before and after processing**
- **All instructions in memory in order to execute**
- **Memory management determines what is in memory when**
 - Optimizing CPU utilization and computer response to users
- **Memory management activities**
 - Keeping track of which parts of memory are currently being used and by whom
 - Deciding which processes (or parts thereof) and data to move into and out of memory
 - Allocating and deallocating memory space as needed

Storage Management

- **OS provides uniform, logical view of information storage**
 - Abstracts physical properties to logical storage unit - file
 - Each medium is controlled by device (i.e., disk drive, tape drive)
 - Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)

Storage Management

- **File-System management**

- Files usually organized into directories
- Access control on most systems to determine who can access what
- OS activities include
 - Creating and deleting files and directories
 - Primitives to manipulate files and directories
 - Mapping files onto secondary storage
 - Backup files onto stable (non-volatile) storage media

Mass-Storage Management

- **Usually disks used to store data that does not fit in main memory or data that must be kept for a “long” period of time**
- **Entire speed of computer operation hinges on disk subsystem and its algorithms**
- **OS activities**
 - Free-space management
 - Storage allocation
 - Disk scheduling
- **Some storage need not be fast**
 - Tertiary storage includes optical storage, magnetic tape
 - Still must be managed – by OS or applications
 - Varies between WORM (write-once, read-many-times) and RW (read-write)

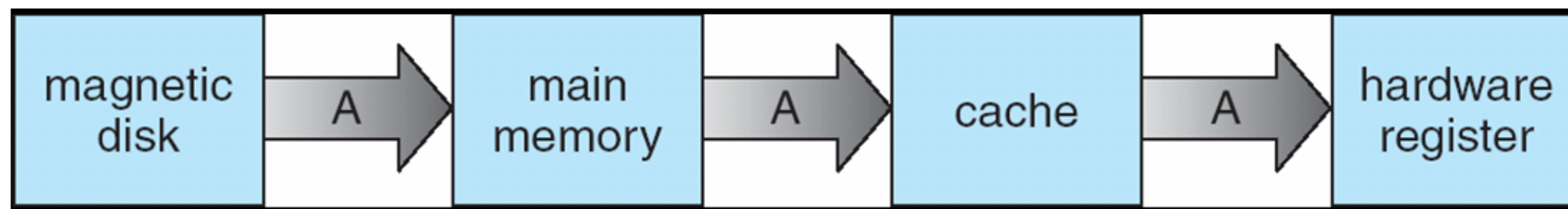
Performance of Various Levels of Storage

- **Movement between levels of storage hierarchy can be explicit or implicit**

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Migration of Integer A from Disk to Register

- **Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy**



- **Multiprocessor environment must provide cache coherency in hardware such that all CPUs have the most recent value in their cache**
- **Distributed environment situation even more complex**
 - Several copies of a datum can exist

I/O Subsystem

- **One purpose of OS is to hide peculiarities of hardware devices from the user**
- **I/O subsystem responsible for**
 - Memory management of I/O including buffering (storing data temporarily while it is being transferred), caching (storing parts of data in faster storage for performance), spooling (the overlapping of output of one job with input of other jobs)
 - General device-driver interface
 - Drivers for specific hardware devices

Protection and Security

- **Protection – any mechanism for controlling access of processes or users to resources defined by the OS**
- **Security – defense of the system against internal and external attacks**
 - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- **Systems generally first distinguish among users, to determine who can do what**
 - User identities (user IDs, security IDs) include name and associated number, one per user
 - User ID then associated with all files, processes of that user to determine access control
 - Group identifier (group ID) allows set of users to be defined and controls managed, then also associated with each process, file
 - Privilege escalation allows user to change to effective ID with more rights

Distributed Computing

- **Collection of separate, possibly heterogeneous, systems networked together**
 - Network is a communications path
 - Local Area Network (LAN)
 - Wide Area Network (WAN)
 - Metropolitan Area Network (MAN)
- **Network Operating System provides features between systems across network**
 - Communication scheme allows systems to exchange messages
 - Illusion of a single system

Special-Purpose Systems

- **Real-time embedded systems most prevalent form of computers**
 - Vary considerably, special purpose, limited purpose OS, real-time OS
- **Multimedia systems**
 - Streams of data must be delivered according to time restrictions
- **Handheld systems**
 - Tablets, smart phones, limited CPU, memory, power
 - Reduced feature set OS, limited I/O

Computing Environments

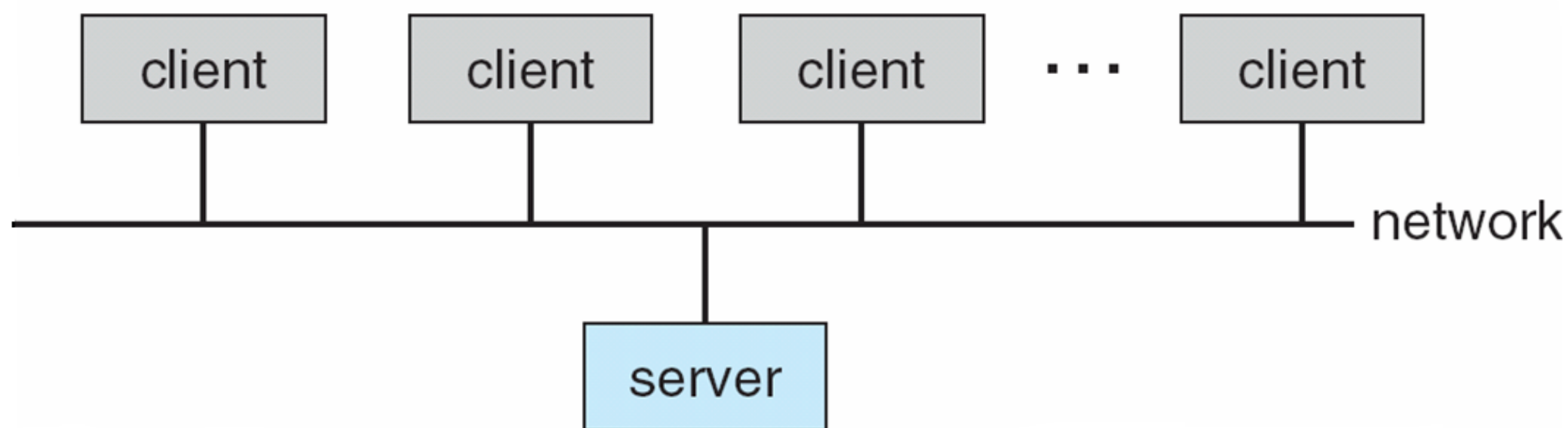
- **Traditional computer**

- Blurring over time
- Office environment
 - PCs connected to a network, terminals attached to mainframe or minicomputers providing batch and timesharing
 - Now portals allowing networked and remote systems access to same resources
- Home networks
 - Used to be single system, then modems
 - Now firewalled, networked

Computing Environments (Cont.)

- **Client-Server Computing**

- Dumb terminals supplanted by smart PCs
- Many systems now **servers**, responding to requests generated by **clients**
- **Compute-server** provides an interface to client to request services (i.e., database)
- **File-server** provides interface for clients to store and retrieve files



Peer-to-Peer Computing

- **Another model of distributed system**
- **P2P does not distinguish clients and servers**
 - Instead all nodes are considered peers
 - May each act as client, server or both
 - Node must join P2P network
 - Registers its service with central lookup service on network, or
 - Broadcast request for service and respond to requests for service via discovery protocol
 - Examples include Napster and Gnutella

Web-Based Computing

- **Web has become ubiquitous**
- **PCs most prevalent devices**
- **More devices becoming networked to allow web access**
- **New category of devices to manage web traffic among similar servers: load balancers**
- **Use of operating systems like Windows 95, client-side, have evolved into Linux and versions of Windows, which can be clients and servers**

Open-Source Operating Systems

- **Operating systems made available in source-code format rather than just binary closed-source**
- **Counter to the copy protection and Digital Rights Management (DRM) movement**
- **Started by Free Software Foundation (FSF), which has “copyleft” GNU Public License (GPL)**
- **Examples include GNU/Linux and BSD UNIX (including core of Mac OS X), and many more**