ICS 212: Operating Systems

Lecture 1

Instructor:

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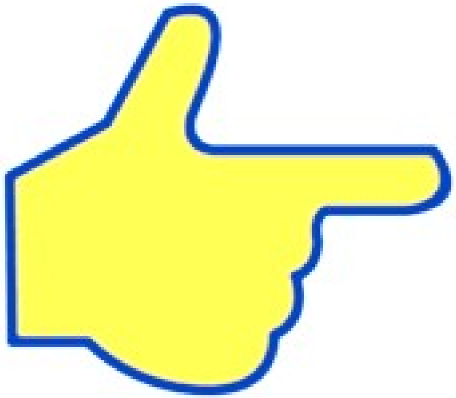
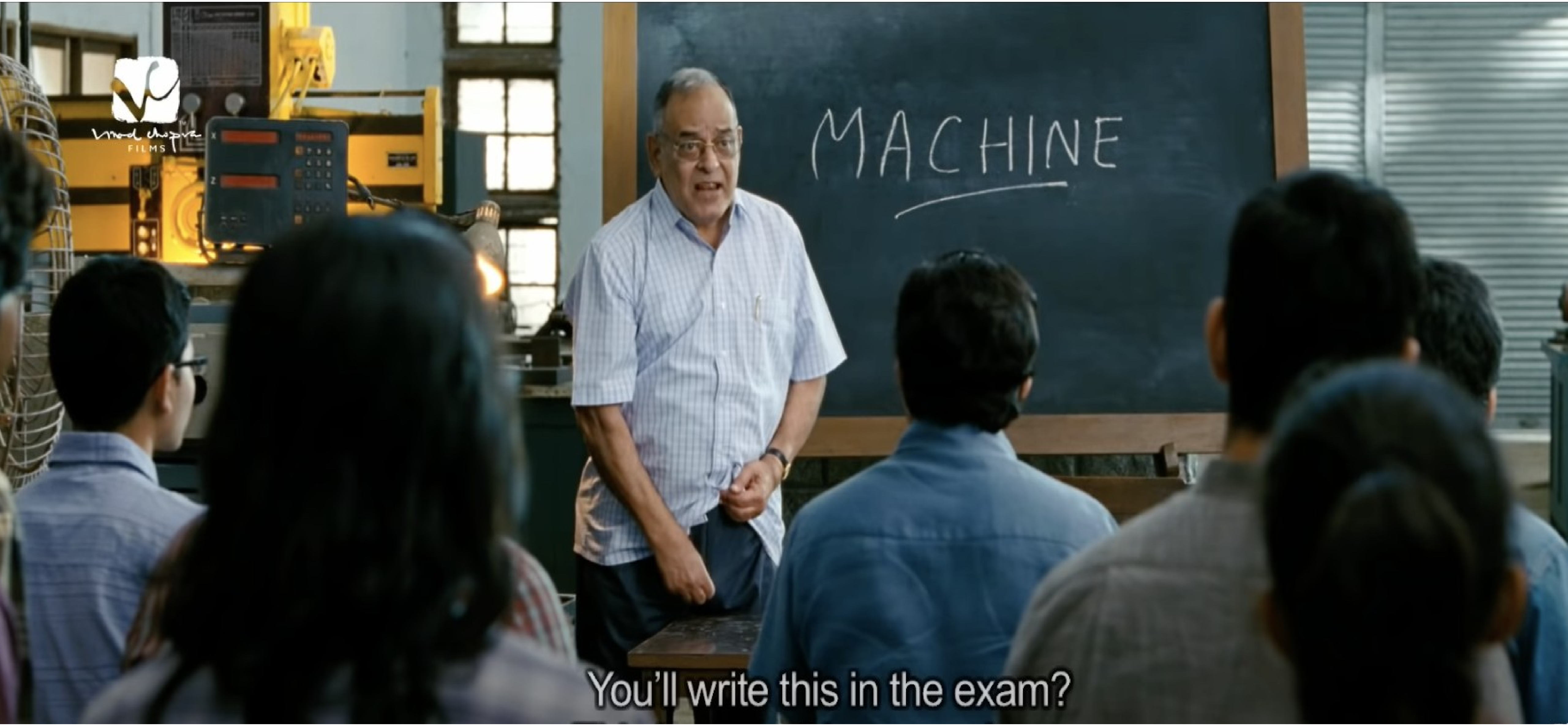
Books and reading materials

- **William Stallings**, *Operating systems: Internals & design principles, Pearson, Seventh edition, 2014.*
- **Silberschatz, Galvin, Gagne**, *Operating System Concepts, Wiley, Ninth Edition, 2016.*
- Other online resources and papers.

Let’s define OS..




MACHINE
You'll write this in the exam?

From the treatise

- Stallings: "An **Operating System** is a program that controls the execution of application programs and acts as an interface between the applications and the computer hardware."

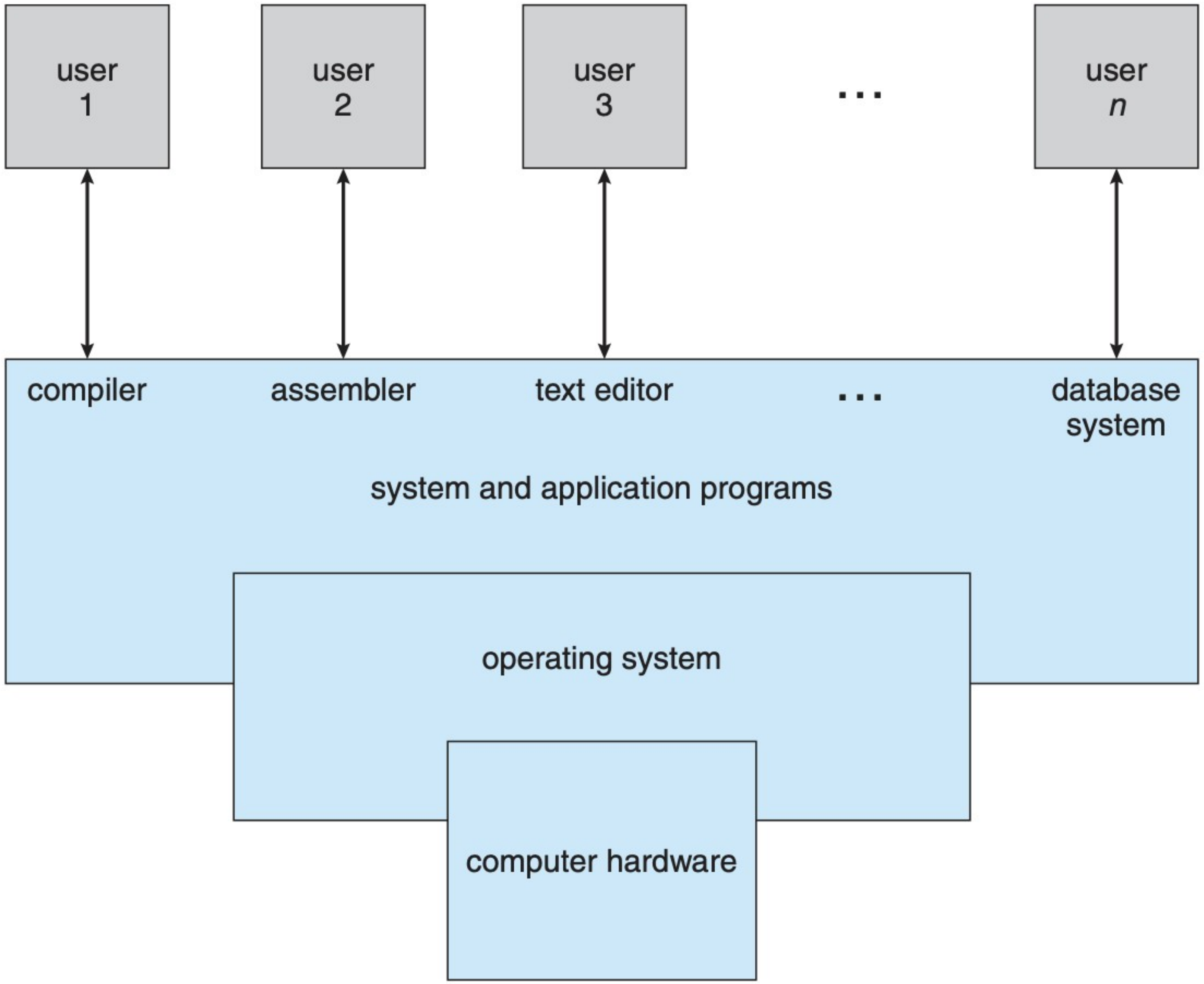
- Galvin: "An **operating system** is a program that manages a computer's hardware. It also provides a basis for application programs and acts as an intermediary between the computer user and the computer hardware."

- **Objectives**: *convenience*, *efficiency*, *evolving*

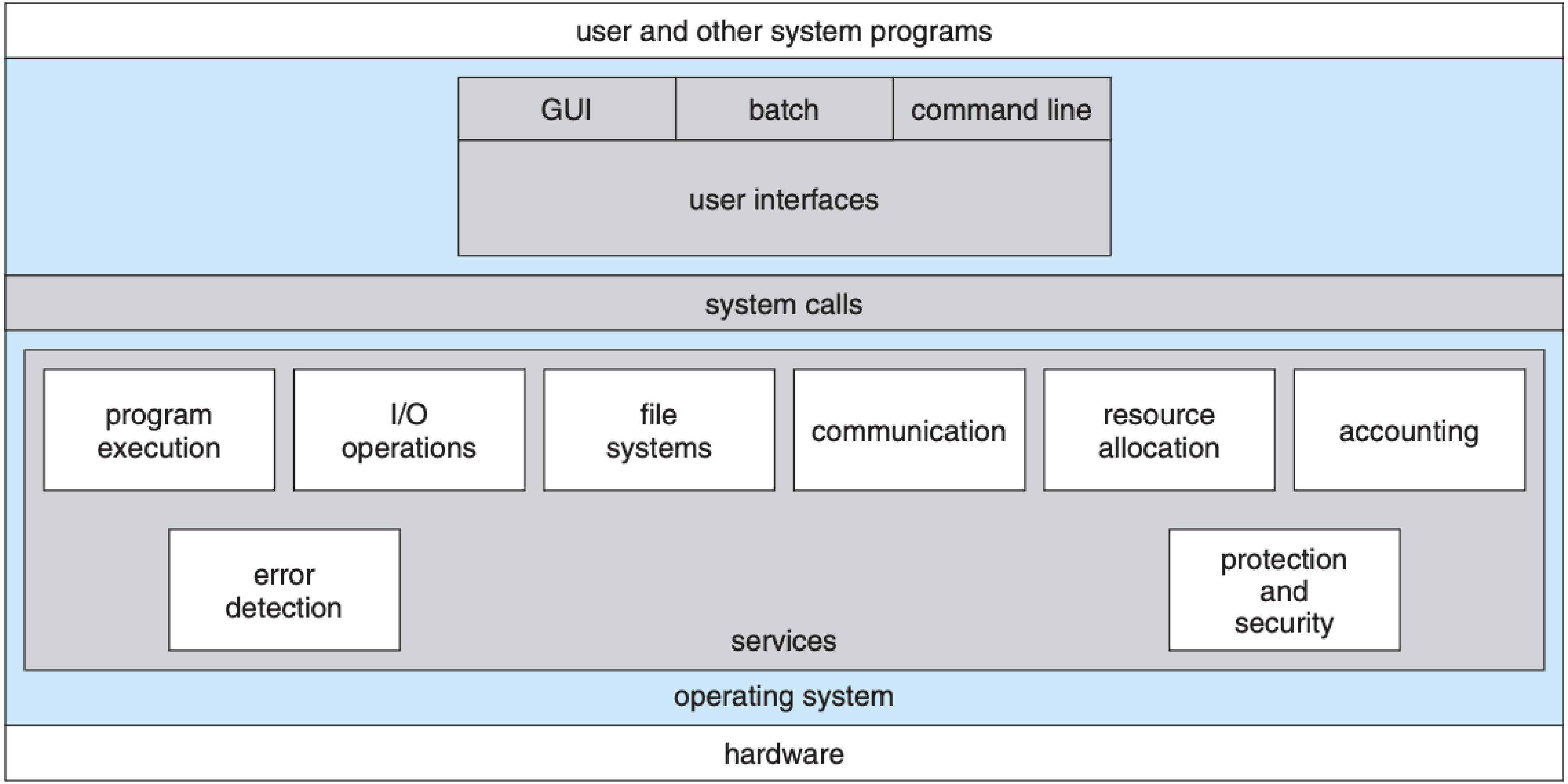
OS as per functionality

- Provides *interface* between hardware and software
- A *resource manager* that allows programs/users to share the hardware resources
- A *controller* that controls execution of programs to prevent errors and improper use of the computer
- Creates a virtual machine that is easier to program than the raw hardware
- Overall services by OS: *program development and execution*, *device control and access*, *error control*, *accounting*, *API*, etc.

Abstract View



OS services



user and other system programs
GUI
batch
command line
user interfaces
system calls
program execution
I/O operations
file systems
communication
resource allocation
accounting
error detection
protection and security
services
operating system
hardware

Over the years..

- Single user computers:
  - One user at a time using the console
  - One function at a time for the computer
- Batch processing:
  - Executes multiple jobs in batches
  - Jobs are submitted on cards or tapes, which are in turn batched sequentially
- Multiprogrammed Batch Systems:
  - Overlap I/O jobs and computing jobs
  - CPU can execute another job while waiting for another job
- Multiprogramming:
  - Several programs can run simultaneously
  - OS manages interactions

Thank You!

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Lecture 2

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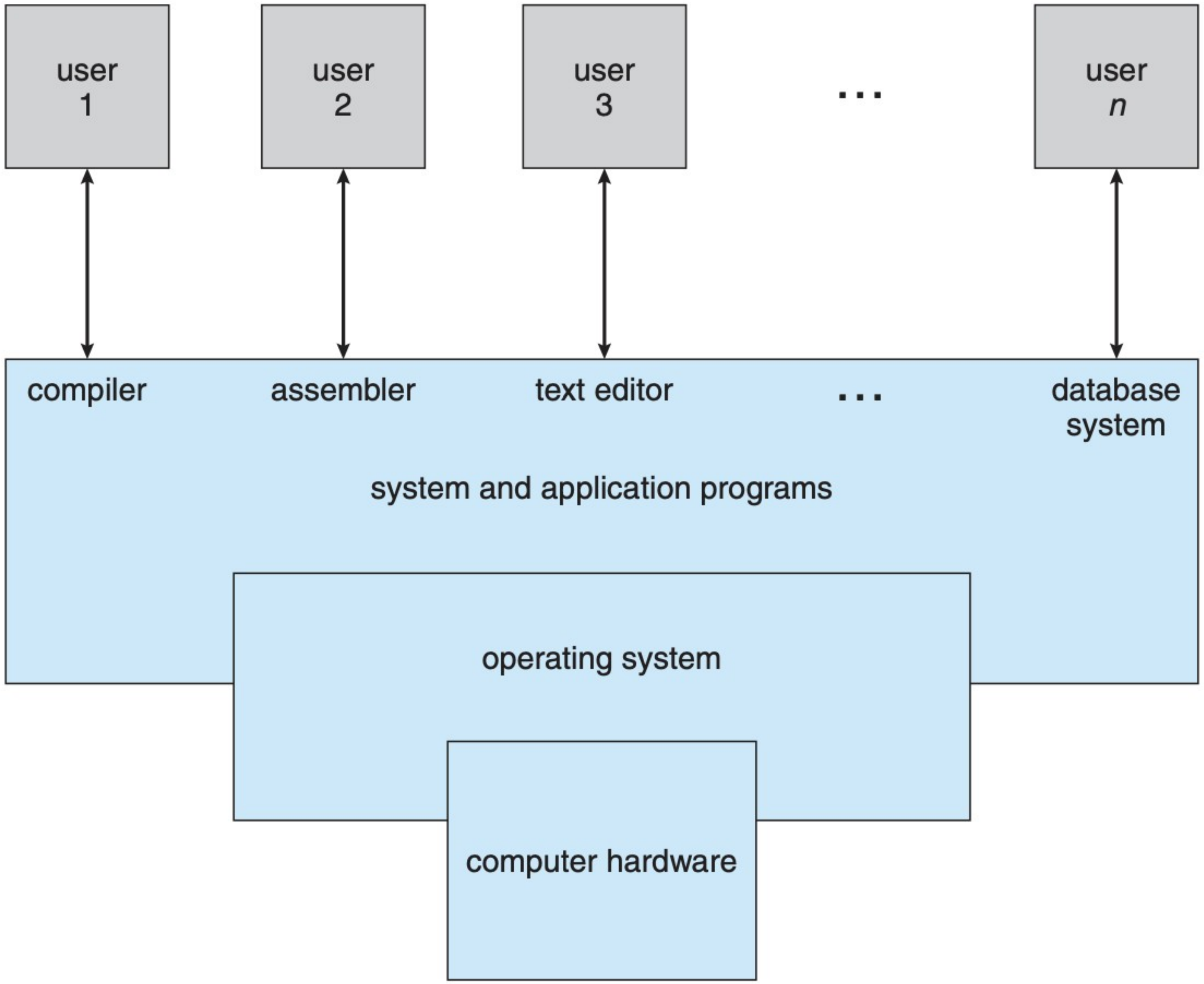
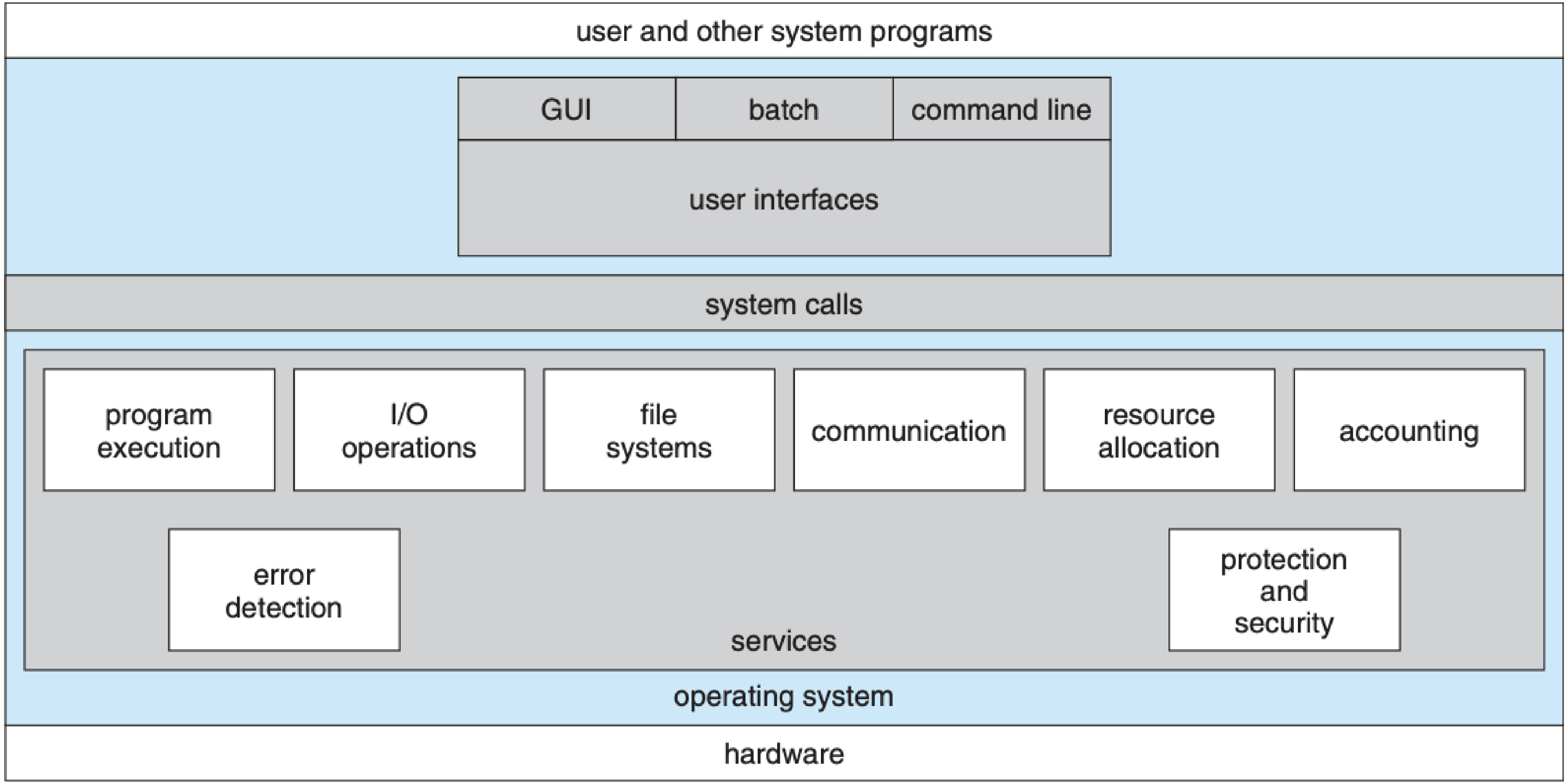
Abstract View



OS services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OS Timeline

Timeline of Operating Systems

1956 – GM-NAA I/O, produced by General Motors for its IBM 704

1977 – Apple][released

1981 – MS-DOS is released by Microsoft

1991 – Linux is released by Linus Torvalds

1995 – Windows 95 is released

2008 – Android is released (based on a Linux kernel)

2011 – OpenShift released by Red Hat

1960s – IBM develops a series of OSs for its 360 series. Multics is developed and abandoned but UNIX is developed as a consequence.

1970s – Unix becomes popular in academic circles and spawns many versions

1980s – The home computer revolution

1990s – Windows dominates the laptop and desktop market

2000s – Unix and then Linux dominate the Supercomputer Market

2010s – Smart phones become ubiquitous after the iPhone release in 2007

Computer System Organization

Architectural features

OS service	Hardware support
Interrupts	Interrupt vectors
Protection	Kernel/user mode, protected instructions, base/limit registers
System calls	Trap instructions, Trap vectors
I/O	Interrupts and memory mapping
Virtual memory	Translation lookaside buffers

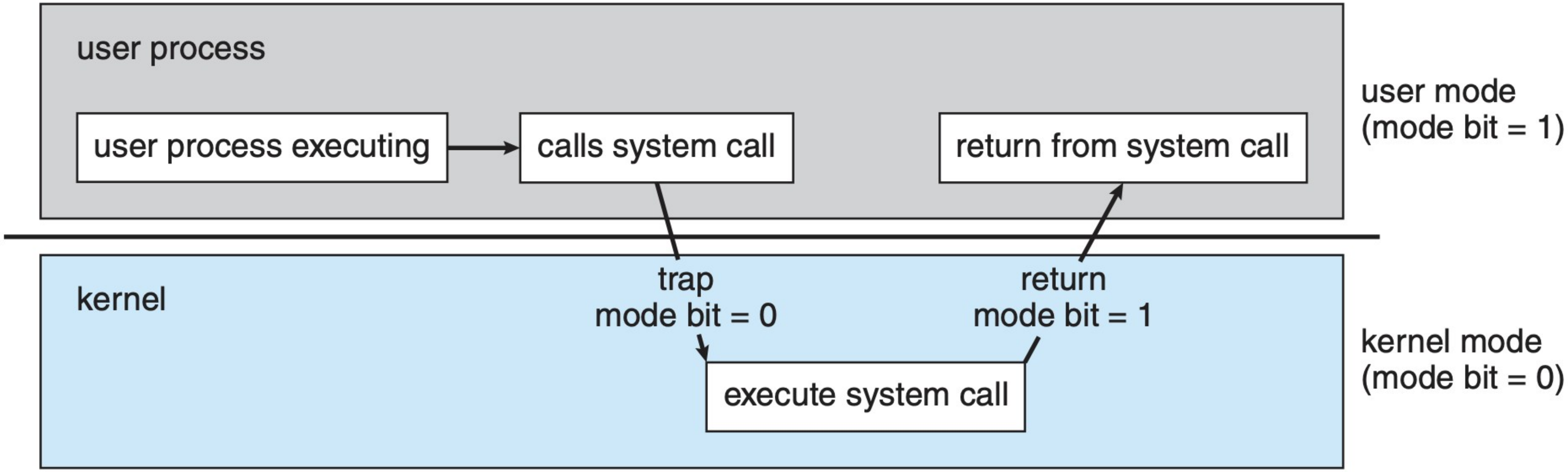
Functionalities of Interrupts

- **An operating system is interrupt driven**
- **Interrupt transfers control to the interrupt service routine generally, through the interrupt vector, which contains the addresses of all the service routines**
- **Interrupt architecture must save the address of the interrupted instruction**
- **Incoming interrupts are disabled while another interrupt is being processed to prevent a lost interrupt**

Protection

Crossing the boundaries

- **System calls: OS procedures that execute privileged instructions**



- **A *trap* is a software-generated interrupt caused either by an error or a user request**

System calls for UNIX

System Call	Description
access()	This checks if a calling process has access to the required file
chdir()	The chdir command changes the current directory of the system
chmod()	The mode of a file can be changed using this command
chown()	This changes the ownership of a particular file
kill()	This system call sends kill signal to one or more processes
link()	A new file name is linked to an existing file using link system call.
open()	This opens a file for the reading or writing process
pause()	The pause call suspends a file until a particular signal occurs.
stime()	This system call sets the correct time.
times()	Gets the parent and child process times
alarm()	The alarm system call sets the alarm clock of a process
fork()	A new process is created using this command
chroot()	This changes the root directory of a file.
exit()	The exit system call is used to exit a process.

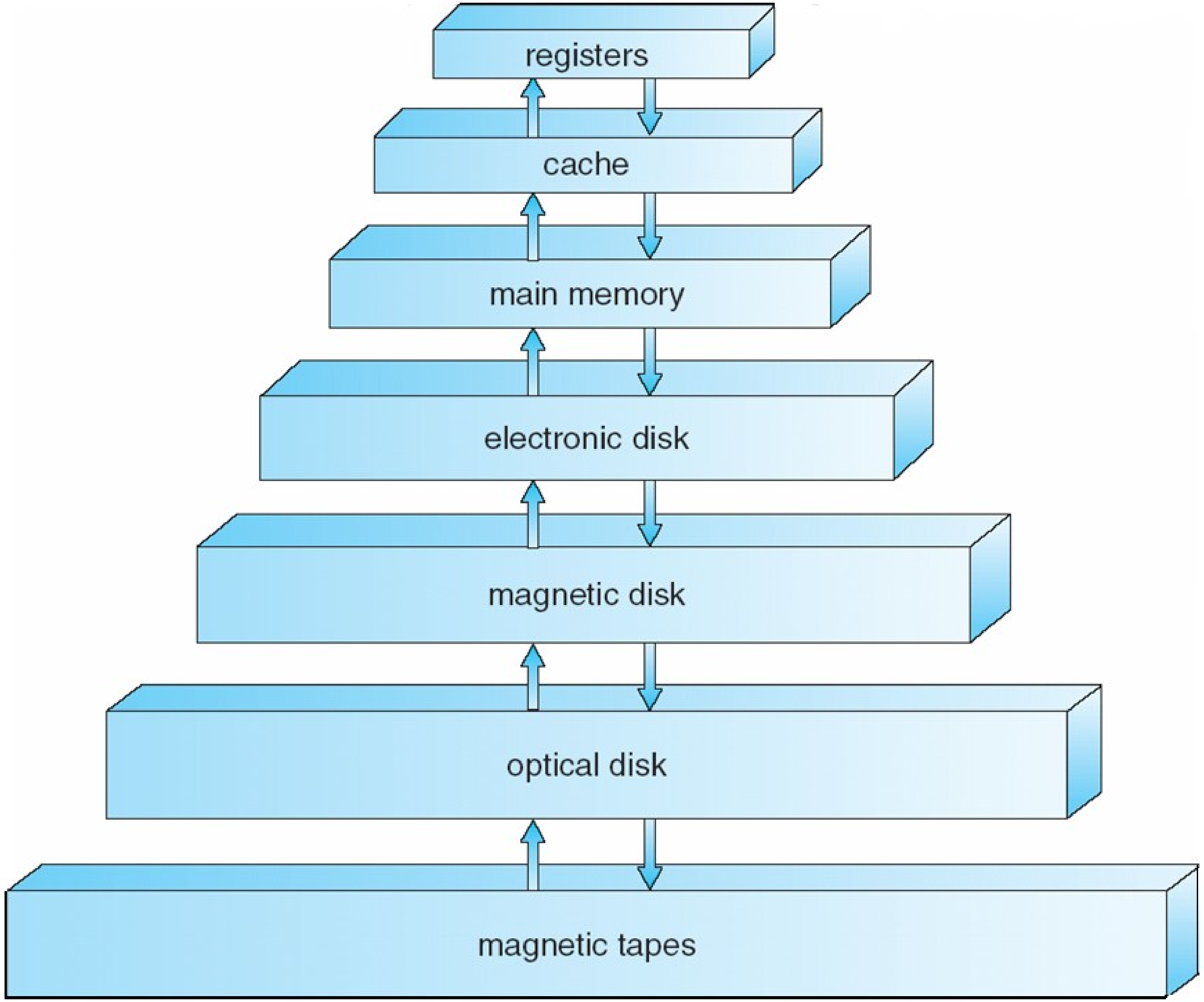
Memory protection

- Architecture must provide support for the OS to:
  - Protect user programs from each other
  - Protect OS from the user programs
- Solution: Based register, Limit register

Memory Structure

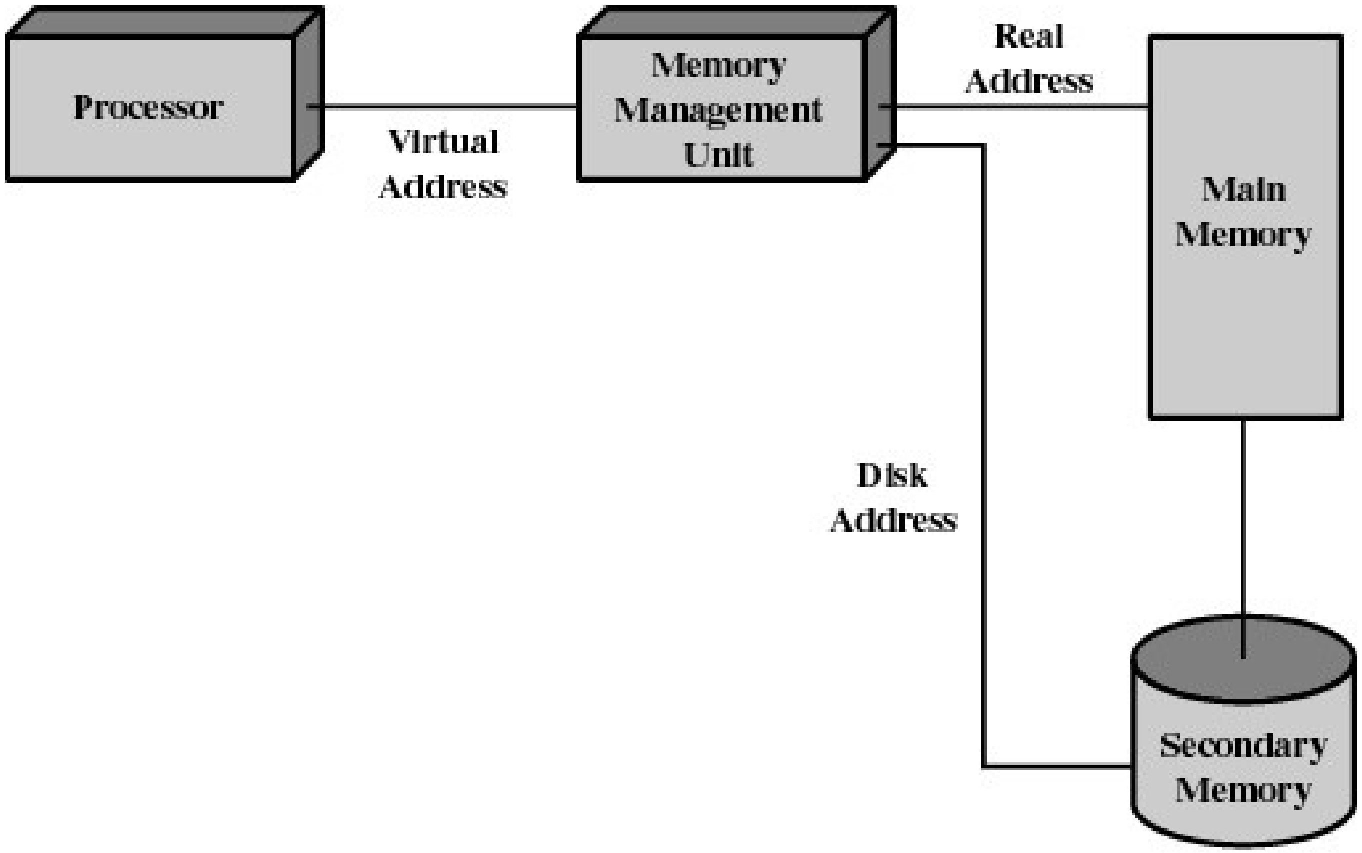
- **Main memory – only large storage media that the CPU can access directly**
- **Secondary storage – extension of main memory that provides large nonvolatile storage capacity**
- **Magnetic disks – rigid metal or glass platters covered with magnetic recording material**
  - **Disk surface is logically divided into tracks, which are subdivided into sectors**
  - **The disk controller determines the logical interaction between the device and the computer**

Storage-Device Hierarchy



Virtual memory

- Allows users to ***run programs without loading it completely***.
- OS ***keeps track of the individual parts*** of the programs
- **Translation lookaside buffers**



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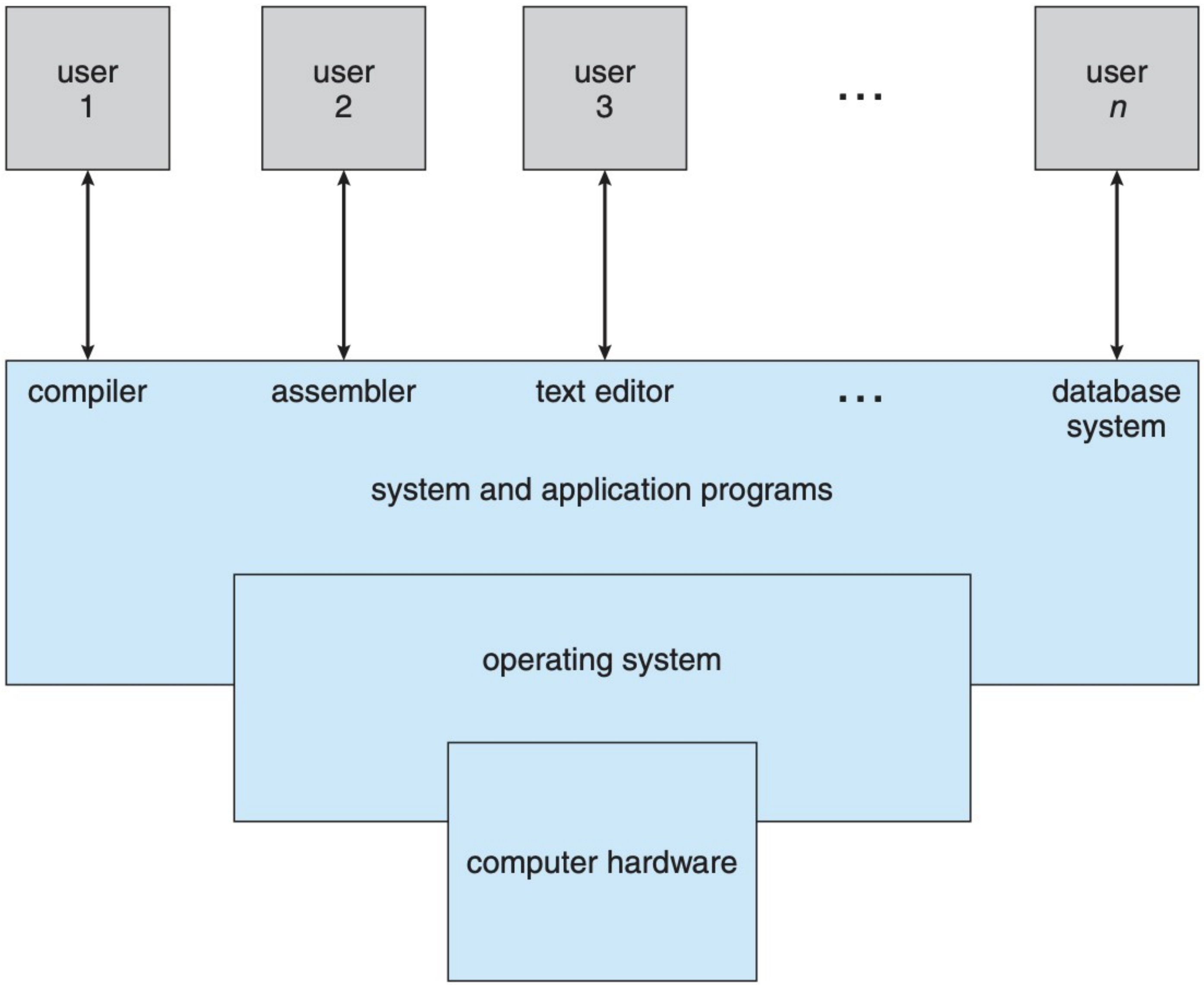
Abstract View of OS



Computer System

Registers

- **Dedicated name for one word of memory in the CPU**
- ***General purpose*** **registers**
- ***Special purpose*** **registers**

I/O Operation

- **I/O devices and the CPU can execute concurrently**
- **Each *device controller* is in-charge of a particular device type**
- **Each device controller has a local buffer**
- **CPU moves data from/to main memory to/from local buffers**
- **I/O is from the device to local buffer of controller**
- **I/O techniques: *programmed I/O*, *Interrupt-driven I/O*, *direct memory access (DMA)***

Main OS Concepts

- ***Process*** **Management**
- ***Memory*** **Management**
- **Information protection and security**
- ***Scheduling*** **and resource management**
- **System structure**

Process Management

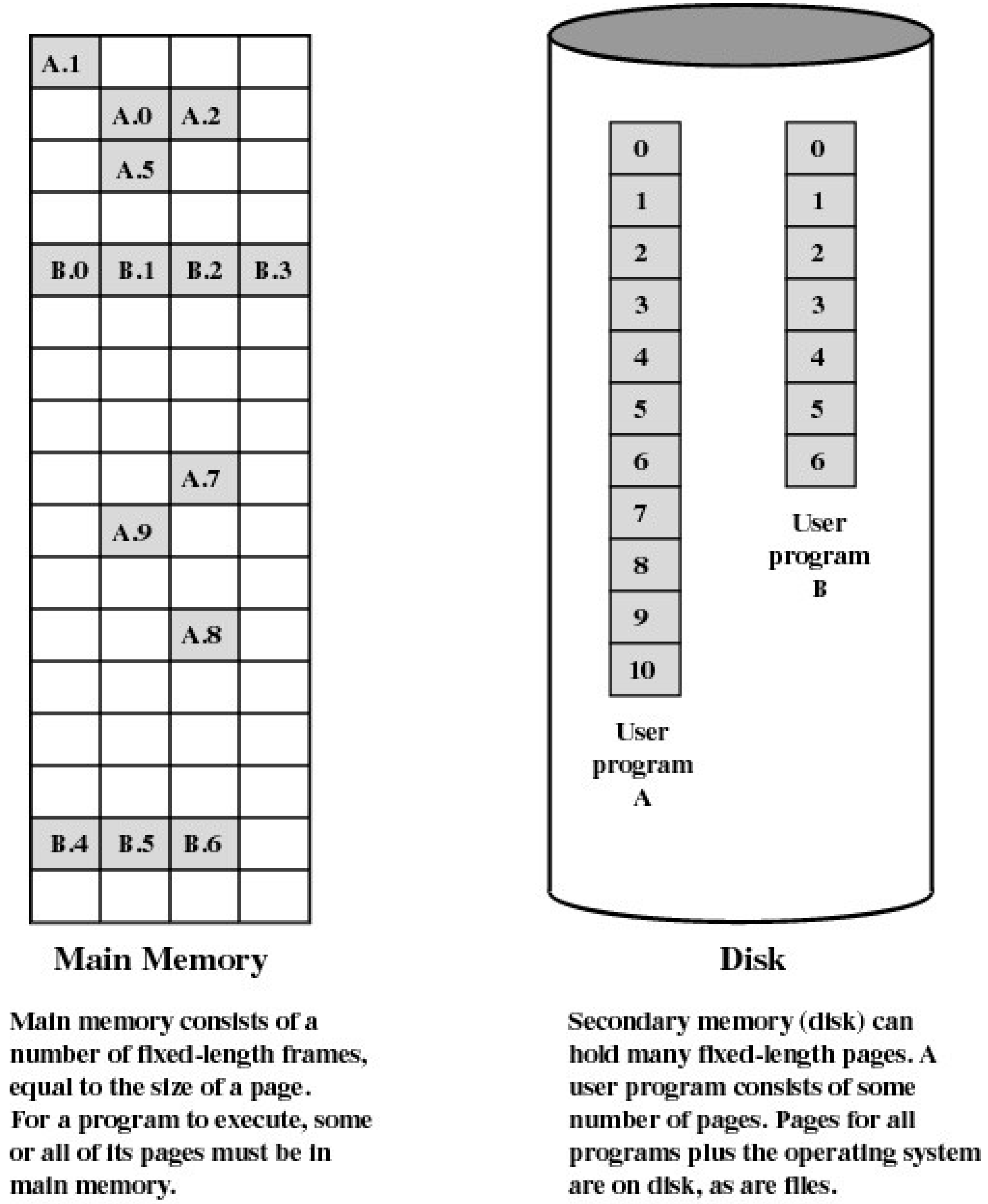
- **Process: a *program in execution***
- **An instance of a program running on a computer**
- **The entity that can be assigned to and executed on a processor**
- **A unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources**

Memory Management

- **Process isolation**
- **Automatic allocation and management**
- **Support for modular programming**
- **Protection and access control**
- **Long-term storage**

Paging

- Allows process to be comprised of a number of fixed-size blocks, called pages
- *Virtual address* is a page number and an offset within the page
- Each page may be located any where in main memory
- Real address or physical address in



Information Protection and Security

- *Access control*
  - Regulate user access to the system
- *Information flow control*
  - Regulate flow of data within the system and its delivery to users
- *Certification*
  - Proving that access and flow control perform according to specifications

Scheduling and Resource Management

- ***Fairness***
  - **Give equal and fair access to all processes**
- ***Differential responsiveness***
  - **Discriminate between different classes of jobs/users**
- ***Efficiency***
  - **Maximize throughput, minimize response time, and accommodate as many uses as possible**

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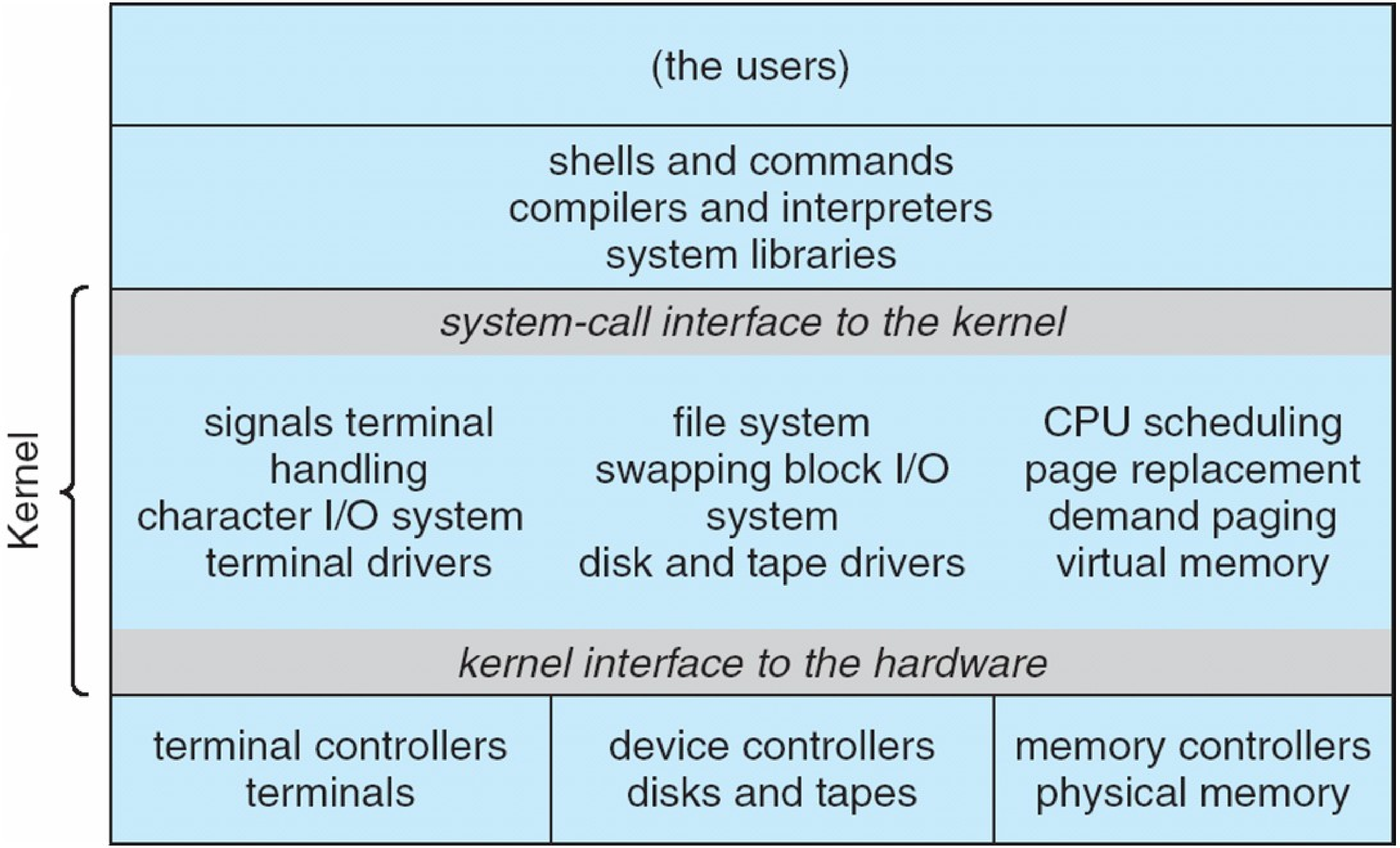
OS Structure

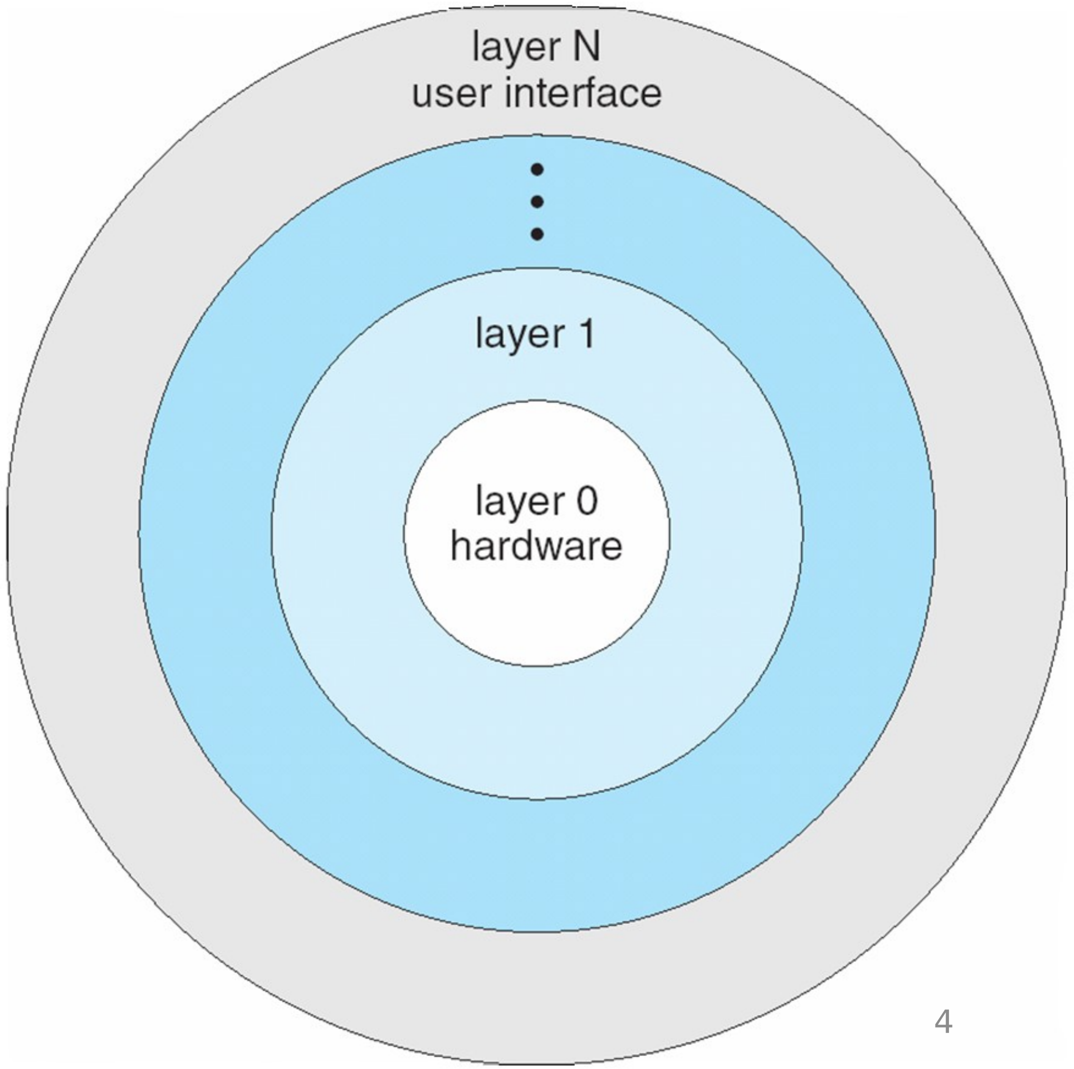
- **Kernel mode: user programs access via *system calls***
- **Architectures:**
  - ***Monolithic kernel***
  - ***Layered architecture***
  - ***Microkernel***
  - ***Modular approach***

Monolithic kernel



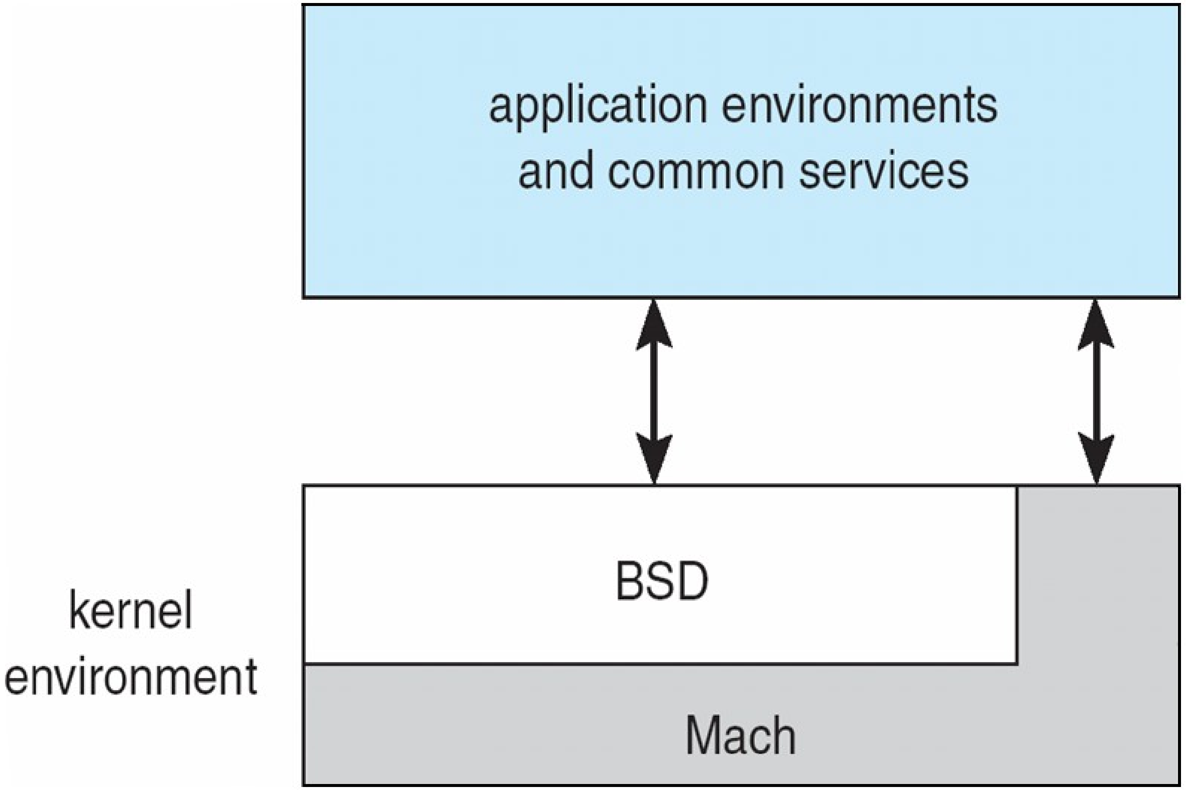
Layered architecture

- **Leyer uses Layer and provides services to Layer**



Microkernel

- **Moves as much from the kernel into “*user*” space**



Benefits:

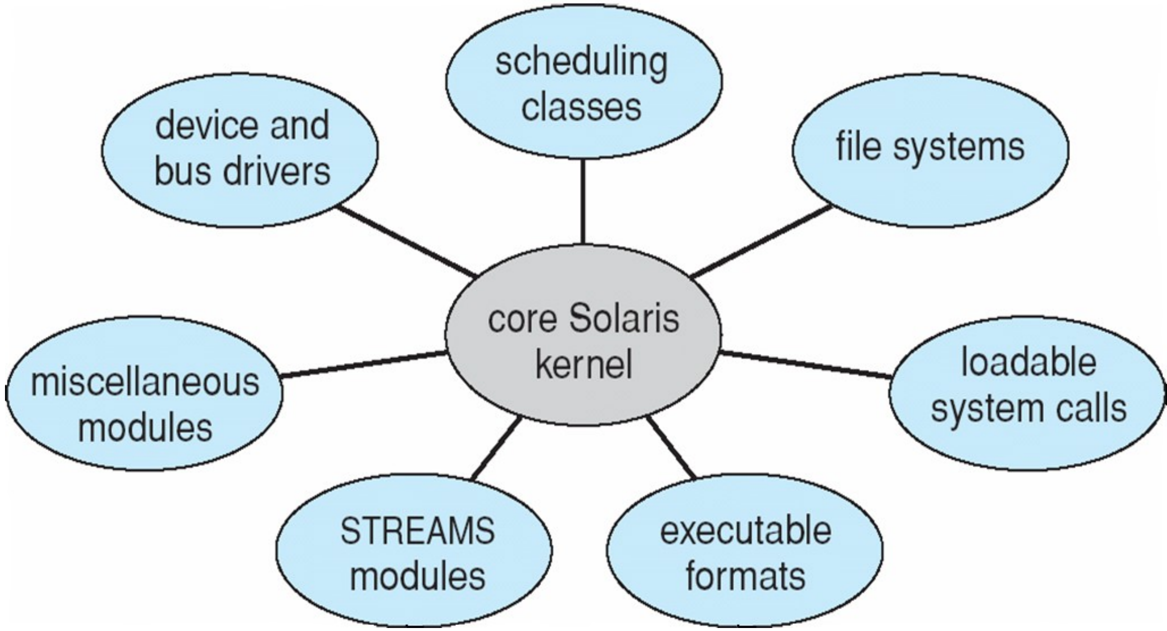
- **Easier to extend a microkernel**
- **Easier to port the operating system to new architectures**
- **More reliable (less code is running in kernel mode)**
- **More secure**

Disadvantage:

- **Performance overhead of user space to kernel space communication**

Modular approach

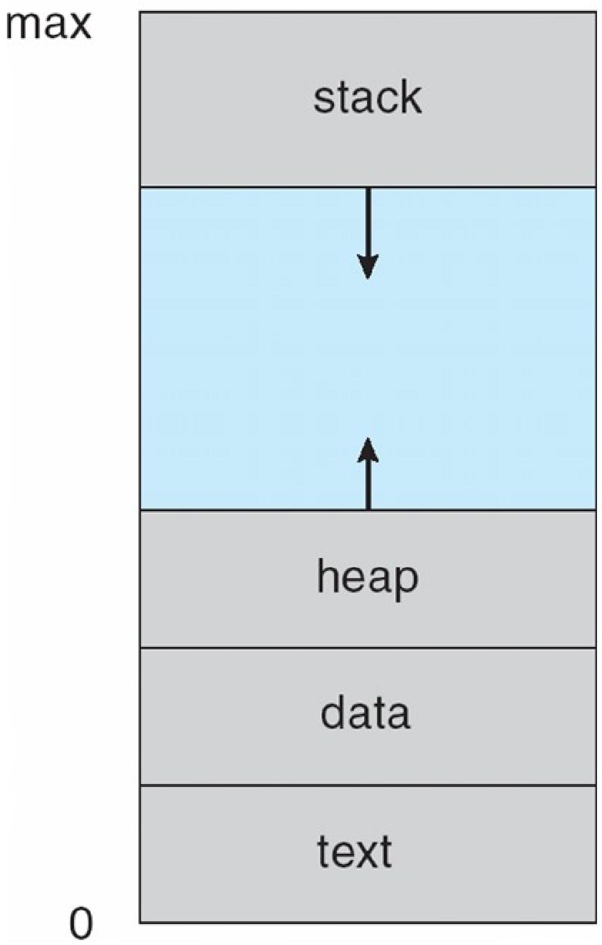
- **Most modern operating systems implement kernel modules**
  - **Uses object-oriented approach**
  - **Each core component is separate**
  - **Each talks to the others over known interfaces**
  - **Each is loadable as needed within the kernel**
- **Overall, similar to layers but with more flexible**



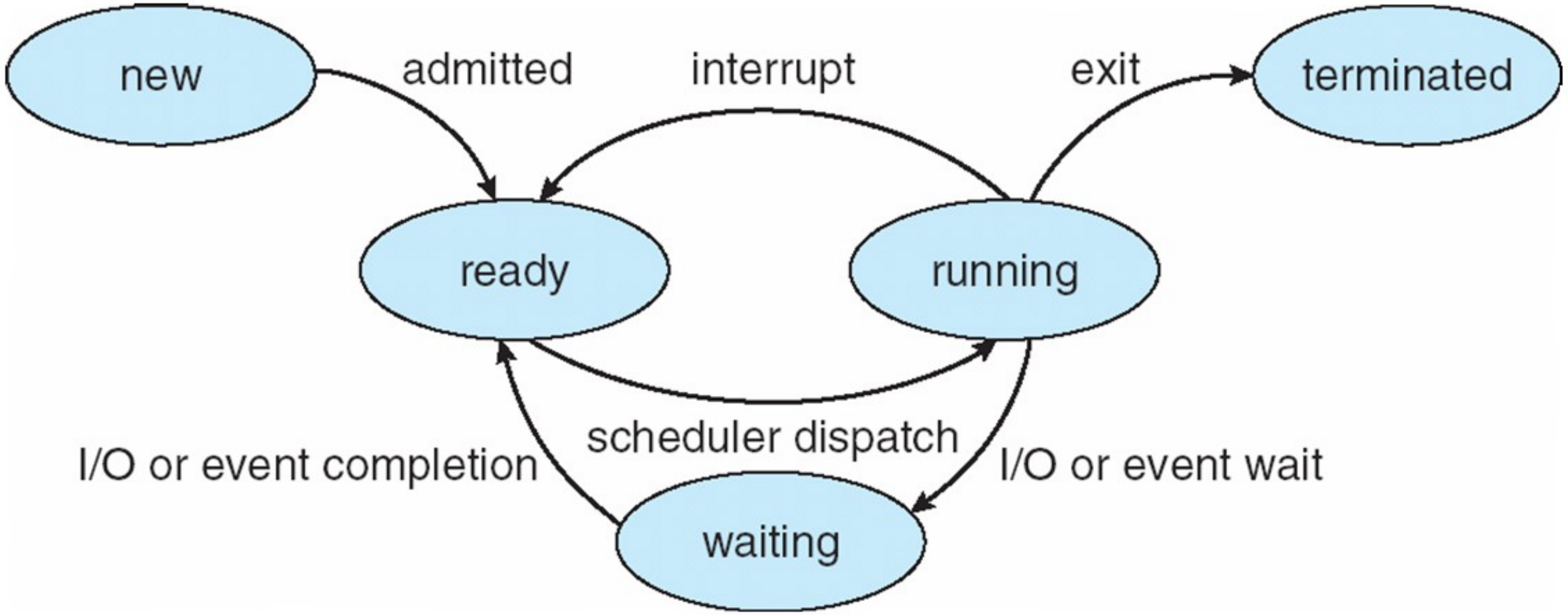
Processes

- **An operating system executes a variety of programs:**
  - **Batch system – jobs**
  - **Time-shared systems – user programs or tasks**
- **Process – *a program in execution***
- **Also called a *task***
- **Can be traced**
  - **List the sequence of instructions that execute**
- **A process includes:**
  - ***Program counter***
  - ***Stack pointer***
  - ***Data section***
  - ***etc.. (more on this soon)***

Process in Memory



Process state

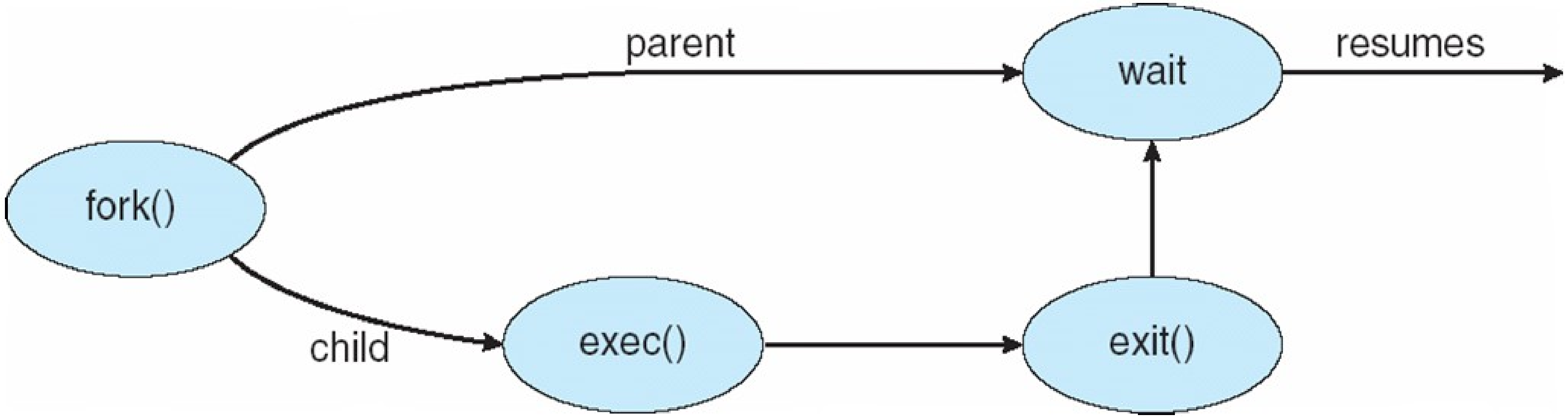


Process Creation

- ***Parent process create children processes***, **which, in turn create other processes, forming a tree of processes**
- **Generally, process identified and managed via a *process identifier (pid)***
- **Resource sharing**
  - **Parent and children share all resources**
  - **Children share subset of parent's resources**
  - **Parent and child share no resources**
- **Execution**
  - **Parent and children execute concurrently**
  - **Parent waits until children terminate**

Process Creation

- **Address space**
  - ***Child duplicate of parent***
  - **Child has a program loaded into it**
- **UNIX examples**
  - **fork system call creates new process**
  - **exec system call used after a fork to replace the process’ memory space with a new program**



Process Termination

- Process executes last statement and asks the operating system to delete it (exit)
  - Output data from child to parent (via wait)
  - Process’ resources are deallocated by operating system
- Parent may terminate execution of children processes (abort)
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - *If parent is exiting*
    - Some operating system do not allow child to continue if its parent terminates
      - All children terminated - cascading termination

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Last class

- **Process: a *program in execution***
- Process States: ***new, ready, executing, waiting, terminated***
- A process includes:
    - *program counter*
    - *stack*
    - *data section*

Process Control Block

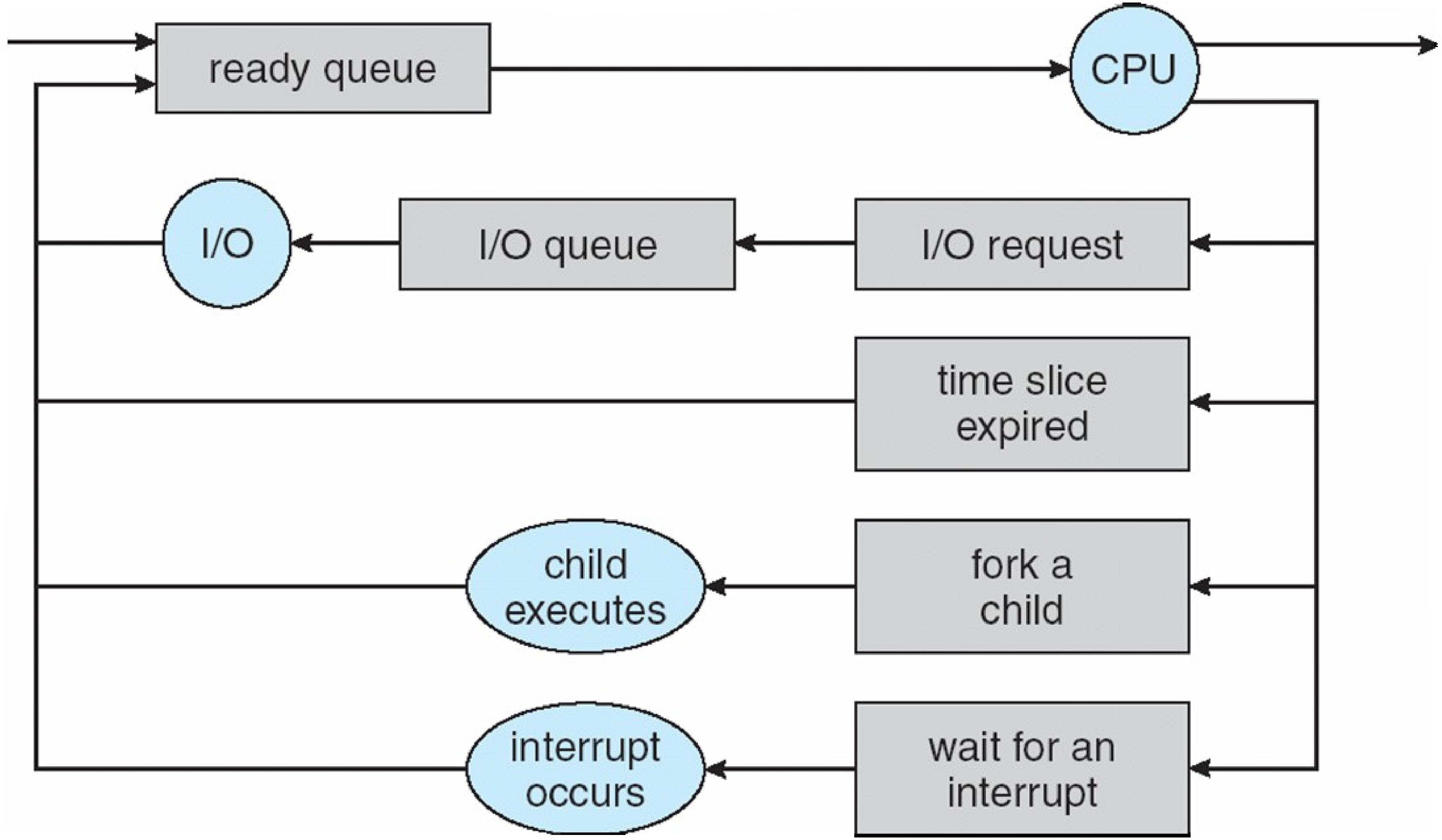
Information associated with each process

- *Process Identifier*
- *Process state*
- *Priority*
- *Program counter*
- *Memory pointers*
- *CPU scheduling information*
- *Accounting information*
- *I/O status information*

Process Scheduling Queues

- ***Job queue*** – set of all processes in the system
- ***Ready queue*** – set of all processes residing in main memory, ready and waiting to execute
- ***Device queues*** – set of processes waiting for an I/O device
- *Processes migrate among the various queues*

Representing Process Scheduling

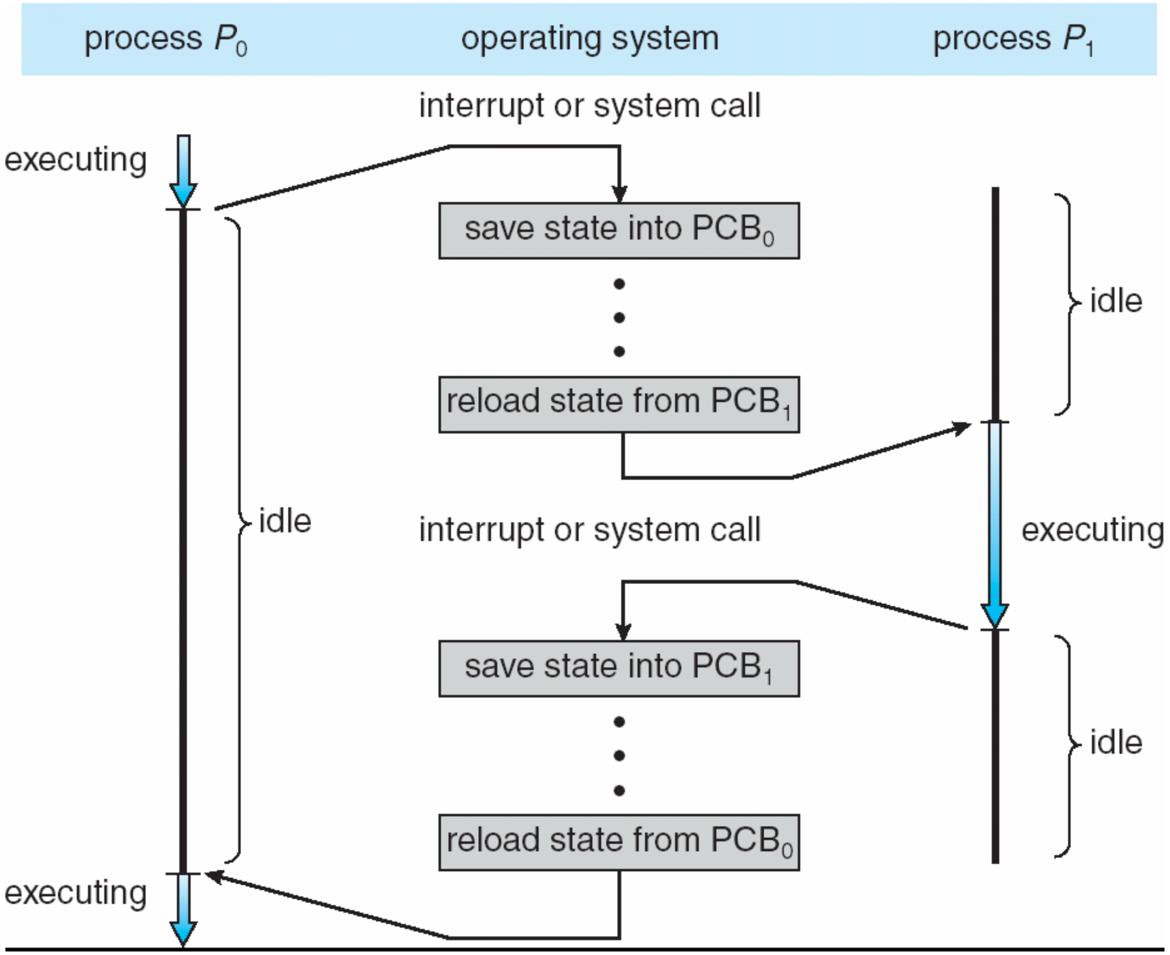


Process Schedulers

- ***Long-term scheduler*** (or job scheduler) – selects which processes should be brought into the ready queue
- ***Short-term scheduler*** (or CPU scheduler) – selects which process should be executed next and allocates CPU
- Processes can be described as either:
    - ***I/O-bound process*** – spends more time doing I/O than computations, many short CPU bursts
    - ***CPU-bound process*** – spends more time doing computations; few very long CPU bursts

Context Switching

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process via a context switch
- Context of a process represented in the PCB
- Context-switch time is overhead; the system does no useful work while switching
- Time dependent on hardware support


process P_0
operating system
process P_1
interrupt or system call
executing
save state into PCB_0
idle
reload state from PCB_1
idle
interrupt or system call
executing
save state into PCB_1
idle
reload state from PCB_0
executing

Independent and Cooperating Processes

- Processes within a system may be ***independent*** or ***cooperating***
- Independent processes don’t affect each other and don’t share.
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperation:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication** (**IPC**)
  - Message Passing
  - Shared memory

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Independent and Cooperating Processes

- **Processes within a system may be *independent* or *cooperating***
- **Independent processes don’t affect each other and don’t share.**
- **Cooperating process can affect or be affected by other processes, including sharing data**
- **Reasons for cooperation:**
  - **Information sharing**
  - **Computation speedup**
  - **Modularity**
  - **Convenience**
- **Cooperating processes need *interprocess communication (IPC)***
  - **Message Passing**
  - **Shared memory**

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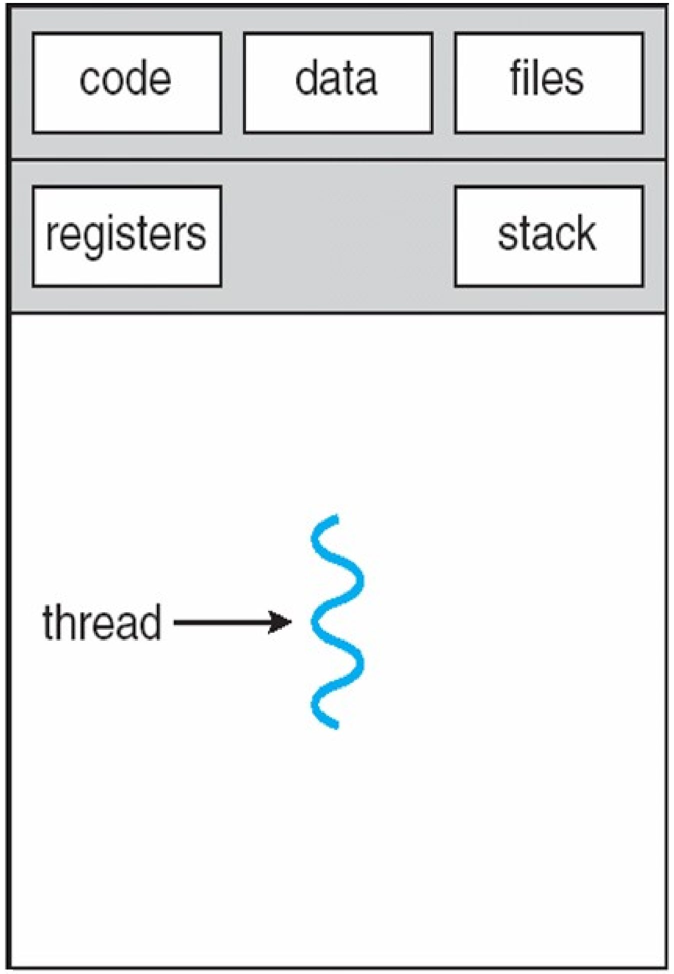
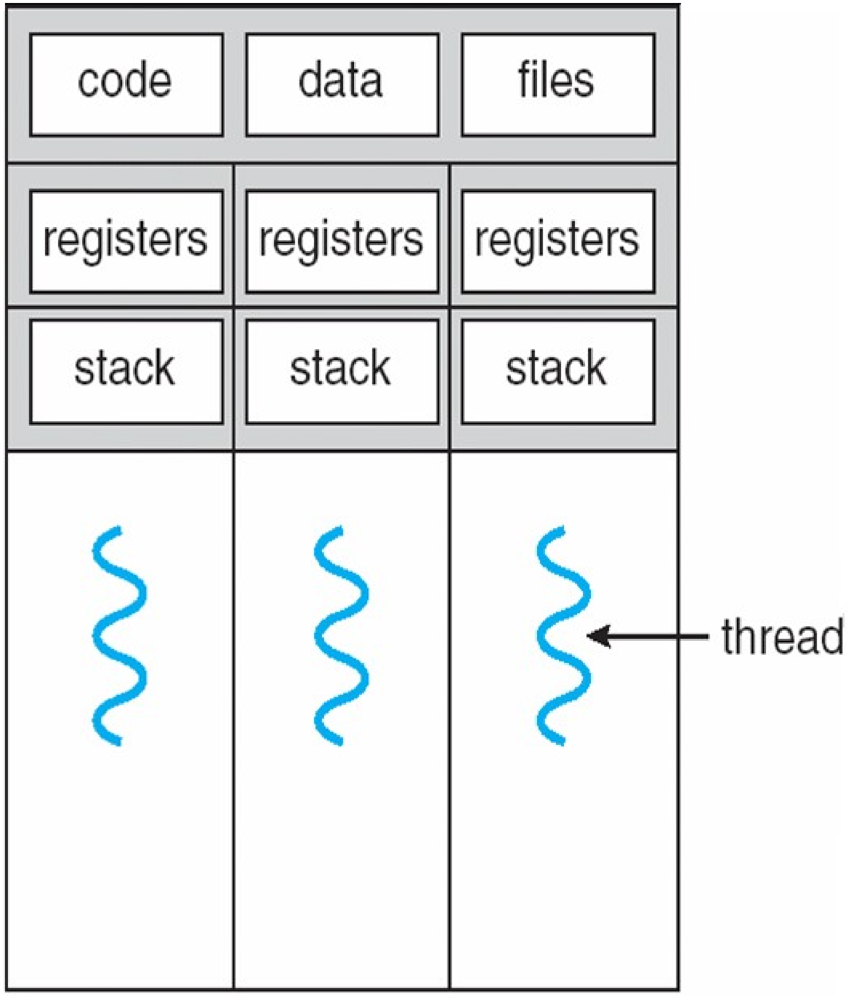
Threads

- A single sequential execution stream within a process.
- An ***independent unit of execution*** created ***within*** the context of a ***process***.
- ***Multithreading*** is a model of program execution that allows for *multiple threads to be created within a process*, executing independently but concurrently sharing process resources.

Single threading v Multi threading



single-threaded process



multithreaded process

Why threading?

- Responsiveness
- Resource Sharing
- Economy
- Scalability

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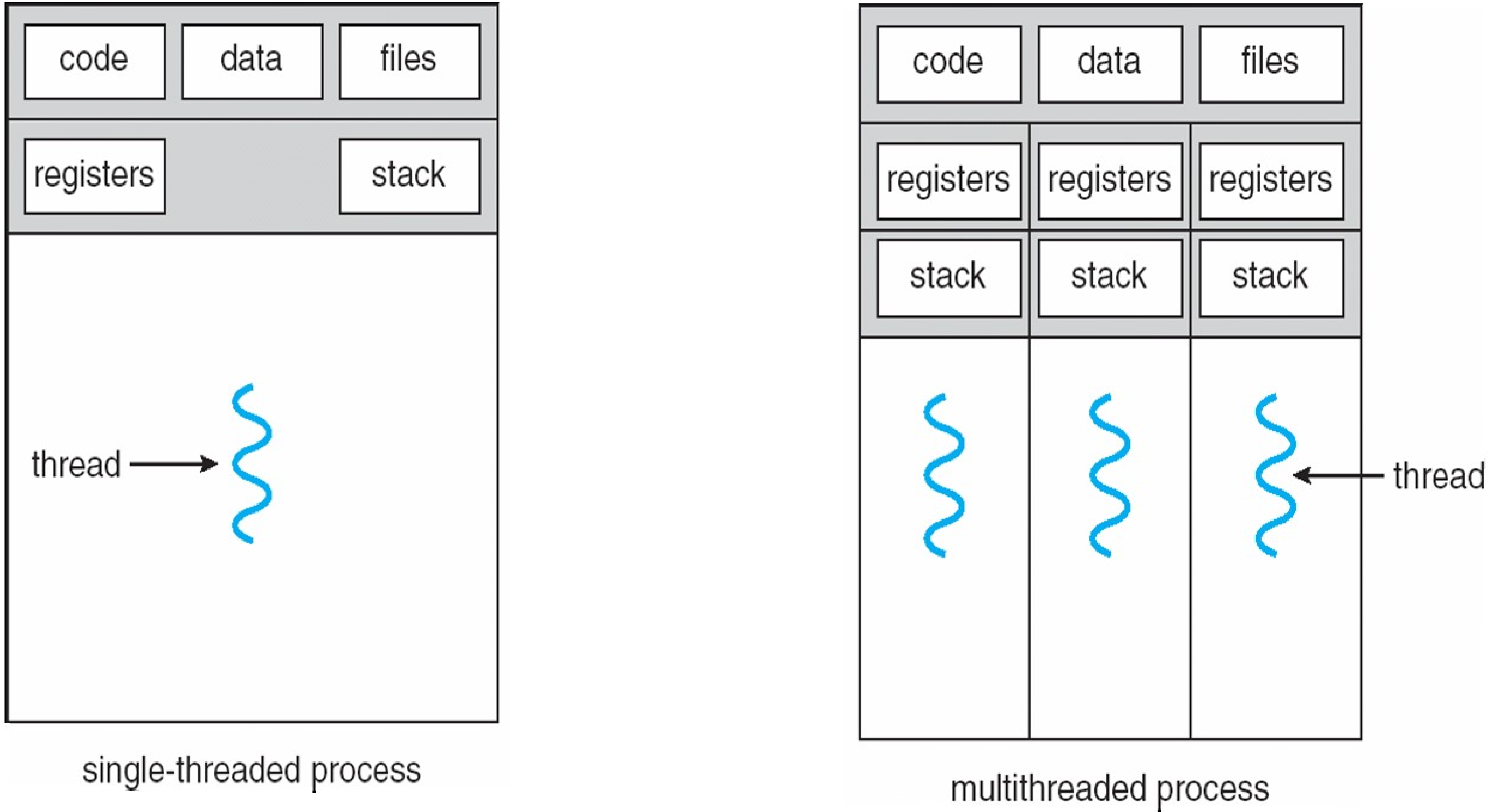
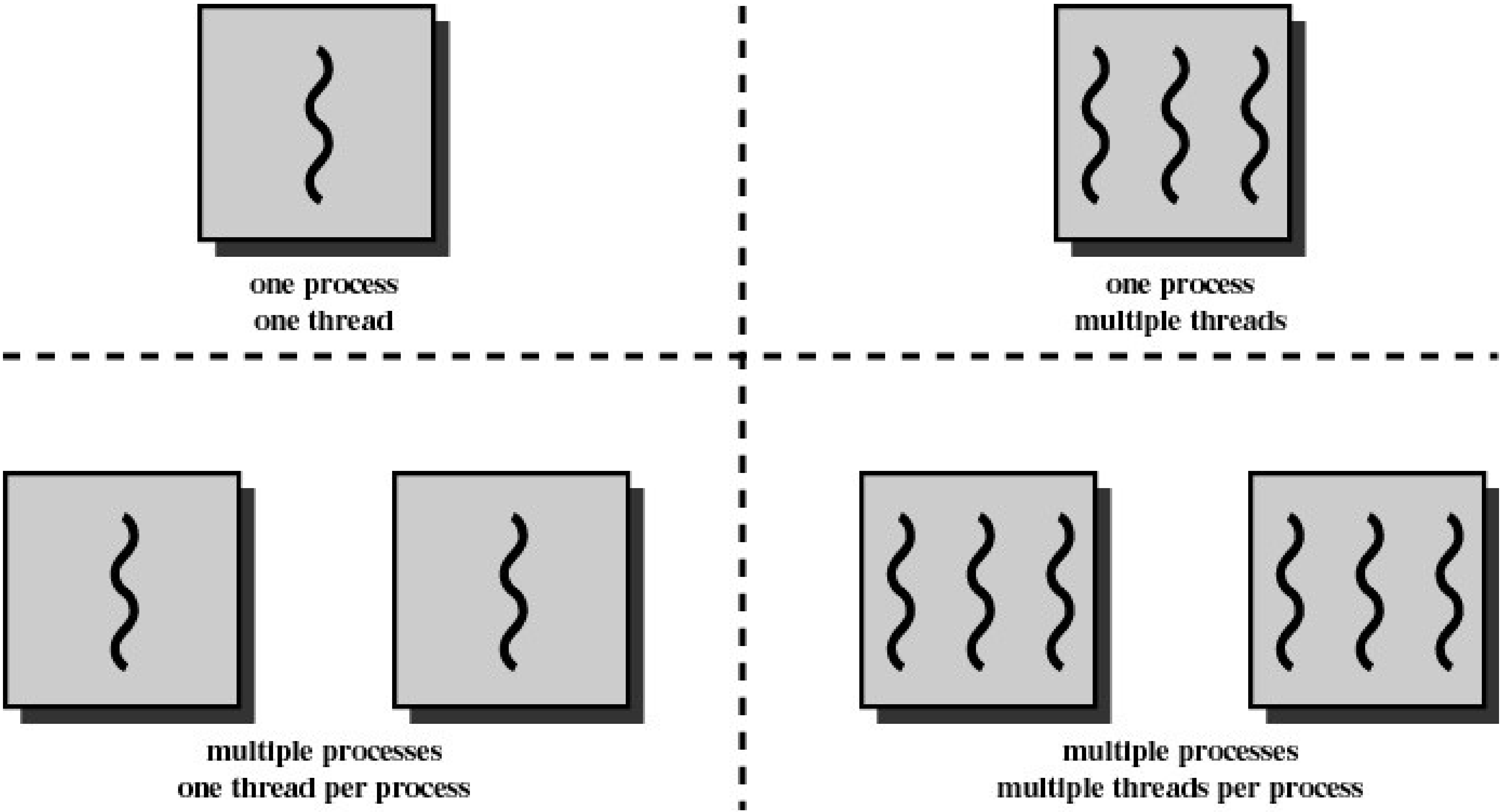
Processes and Threads




one process
one thread
one process
multiple threads
multiple processes
one thread per process
multiple processes
multiple threads per process

Types of threads

- User-level threads
  - *All thread management is done by the application*
  - The kernel is not aware of the existence of threads
- Advantages of user-level threads −
  - User-level threads are easier and faster to create than kernel-level threads.
  - They are more easily managed.
  - User-level threads can be run on any operating system.
  - There are no kernel mode privileges required for thread switching in user-level threads.

Types of threads

- **Kernel-level threads**
  - ***Managed by the kernel***
  - **Scheduling is done on a thread basis**
- **Advantages of kernel-level threads:**
  - **Multiple threads of the same process can be scheduled on different processors in kernel-level threads.**
  - **The kernel routines can also be multithreaded.**
  - **If a kernel-level thread is blocked, another thread of the same process can be scheduled by the kernel.**

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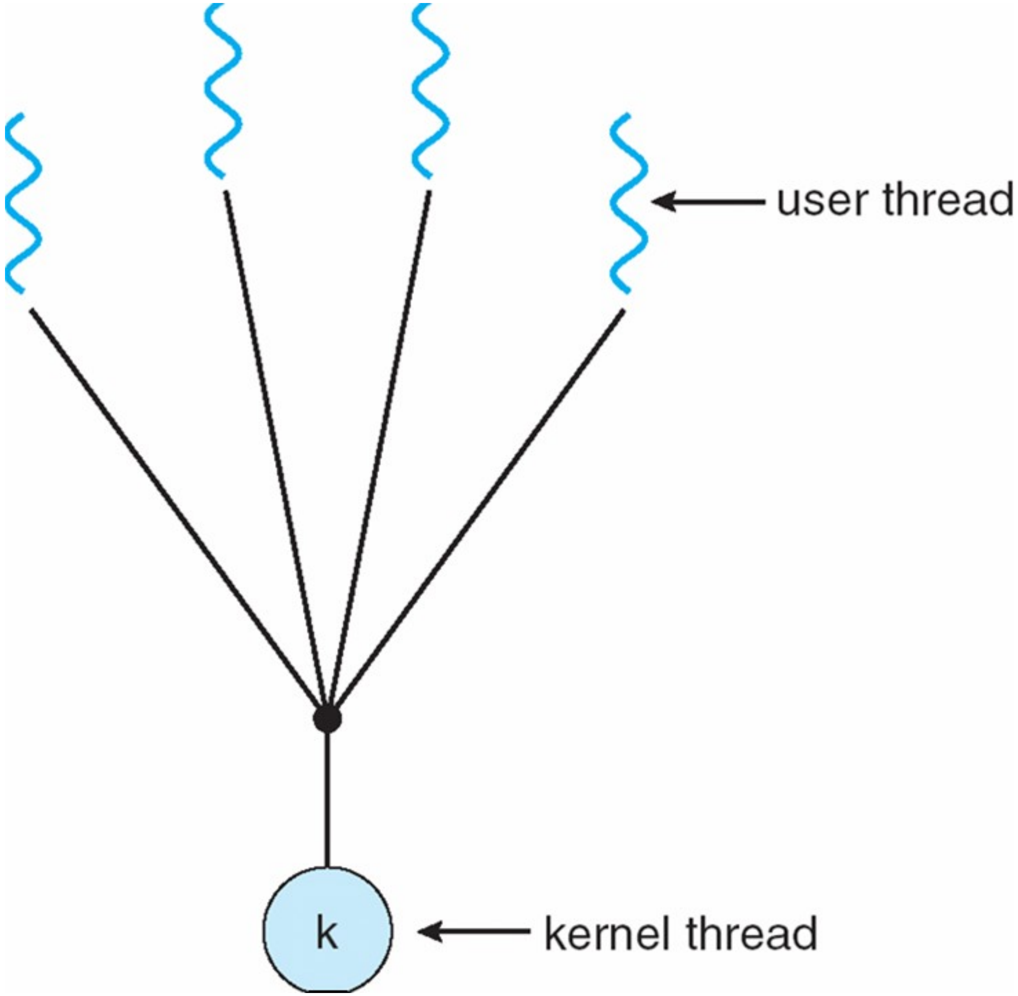
Types of threads

- User-level threads
  - All thread management is done by the application
  - The kernel is not aware of the existence of threads
  - Implemented as a ***thread library*** which contains the code for thread creation, termination, scheduling and switching
- Kernel-level threads
  - Managed by the kernel
  - Scheduling is done on a thread basis

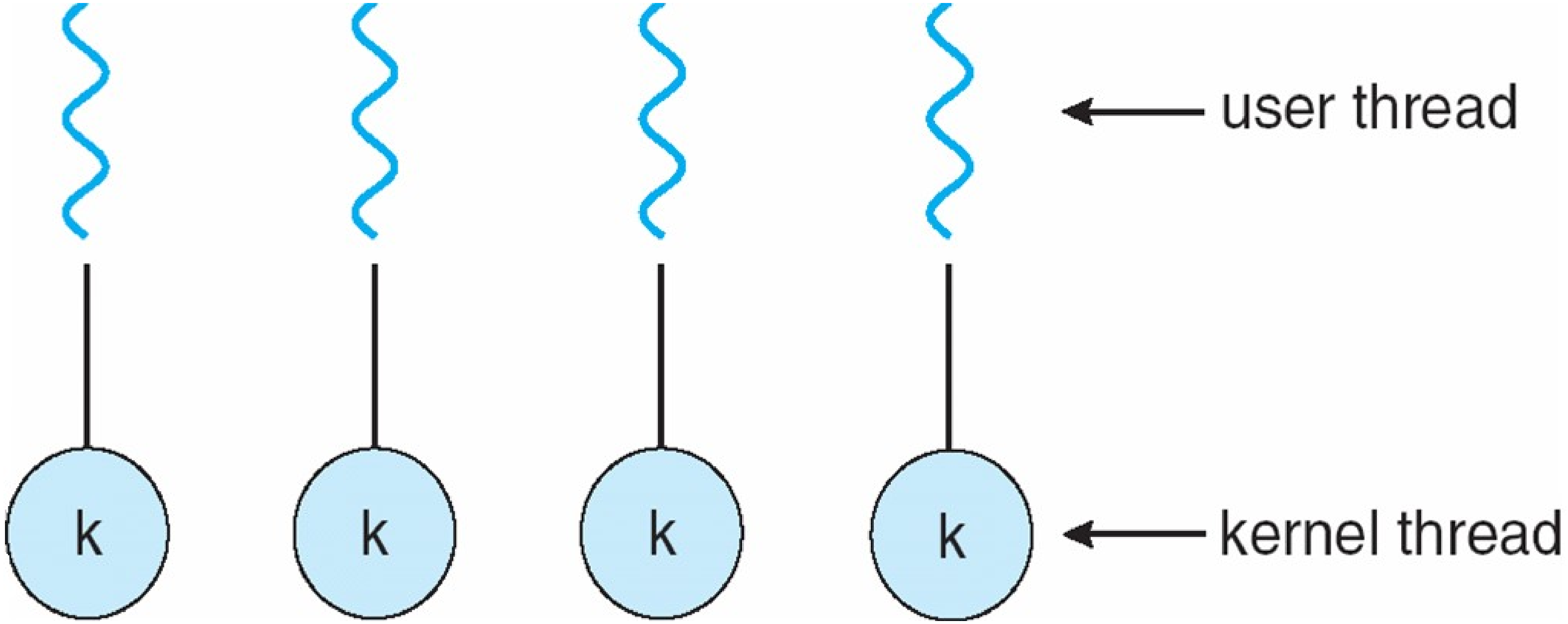
Many-to-one model



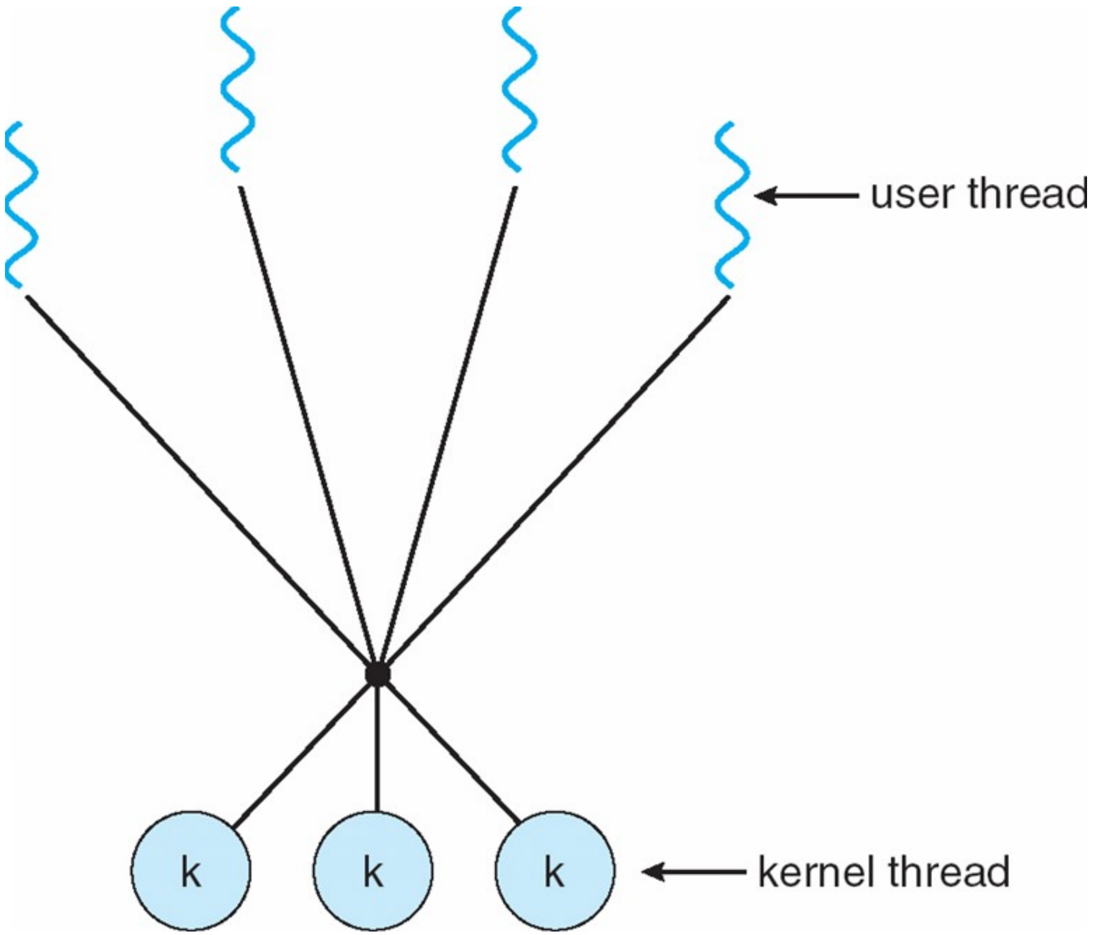
- Many user threads are mapped to one kernel thread
- The entire process will be ***blocked*** if a thread makes a blocking system call
- Multiple threads are unable to run in parallel

One-to-one model

- Each user thread is mapped to a kernel thread
- Multiple *threads can run in parallel* on multiprocessors
- Creating a user thread requires creating a corresponding kernel thread
- Implementational restriction

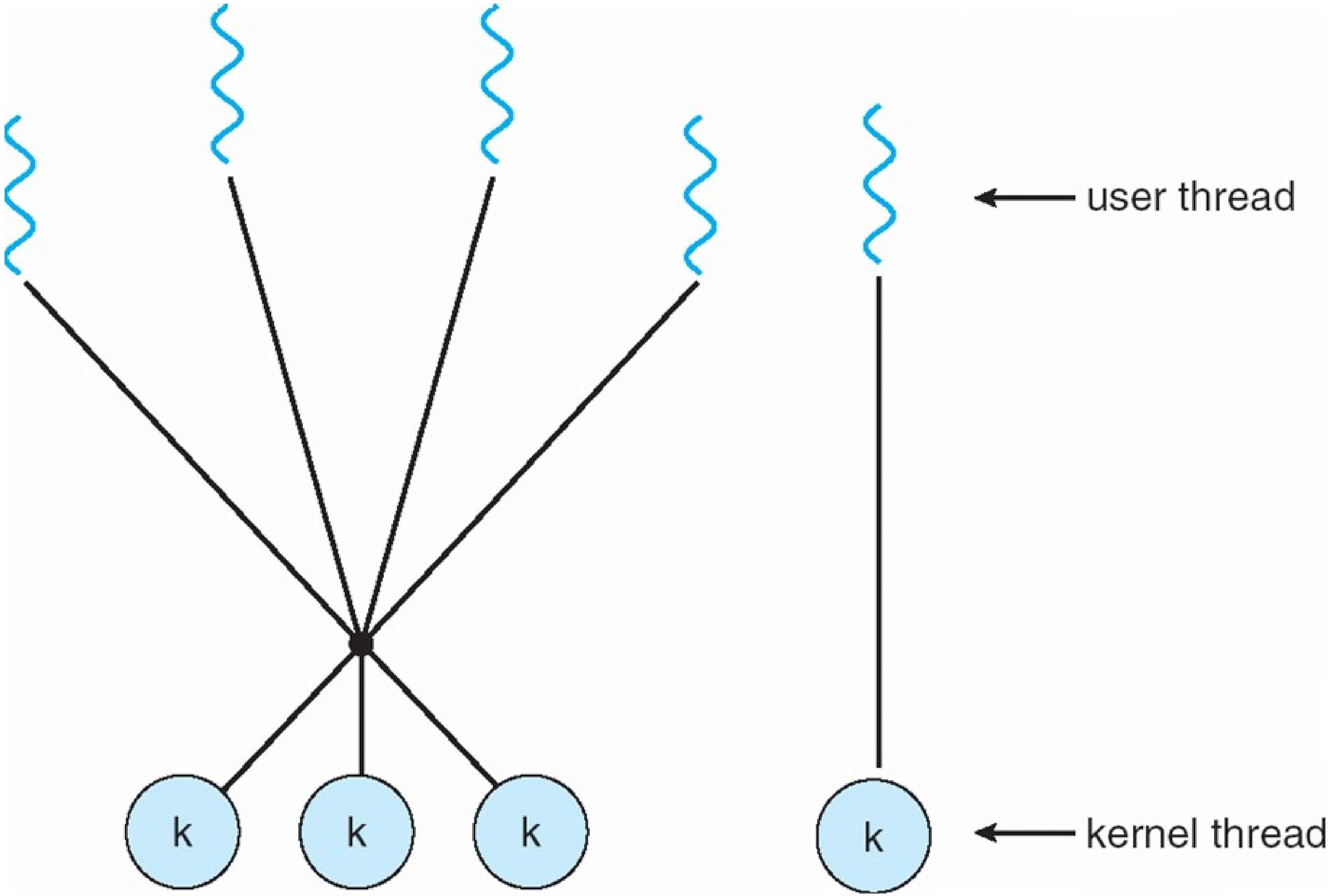


Many-to-many model



- Allows many user level threads to be mapped to some (equal or lesser) kernel threads
- Allows the *operating system to create a sufficient number of kernel threads*
- During a *blocking system call by one thread, kernel schedules another thread* for execution.

Two-level model



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Thread library

- Thread library provides programmers with APIs for creating and managing threads
- Two primary ways of implementing
  - Library entirely in user space
  - Kernel-level library supported by the OS

Common thread libraries

- POSIX threads:
  - A *POSIX* standard (IEEE 1003.1c) API
  - *Common in UNIX* based operating systems
  - Can be provided as *either a user level or a kernel level* library
- Win 32 threads
  - *For Windows* systems
  - *Only kernel* level library
- Java threads
  - Managed by the JVM
  - Typically implemented using the threads model provided by underlying OS as Java program

POSIX: Layers of Abstraction

- A ***Pthread*** is the POSIX specification for thread behaviour.
- A *kernel thread* is the entity actually created, scheduled and managed by the kernel as the context to execute a thread in a process
- *"The thread library may provide no more than a simple wrapper routine to a kernel system call to implement the POSIX specification; or it may provide full support for thread creation, scheduling and management, independently of the kernel."*

Pthread objects

Type	Description
pthread_t	Thread identifier
Pthread_attr_t	Thread attribute
Pthread_cond_t	Condition variable
Pthread_condattr_t	Condition variable attribute
Pthread_key_t	Access key for thread-specific data
Pthread_mutex_t	mutex
Pthread_mutexattr_t	Mutex attribute
Pthread_once_t	One time initialization
Pthread_rwlock_t	Read-write lock
Pthread_rwlockattr_t	Read-write lock attribute

Thread management functions in POSIX

Function	Description
Pthread_create	Create a thread
Pthread_cancel	Terminate another thread
Pthread_detach	Set thread to release resources
Pthread_equal	Test two thread IDs for equality
Pthread_exit	Exit a thread w/o exiting process
Pthread_kill	Send a signal to a thread
Pthread_join	Wait for a thread

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