Chapter 3:
Process Concept

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Today's Agenda

- Process Concept
- Process Scheduling
- Operations on Processes
- Interprocess Communication
- Examples of IPC Systems

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Objectives

- To introduce the notion of a process -- a program in execution, which forms the basis of all computation
- To describe the various features of processes, including scheduling, creation and termination, and communication
- To explore interprocess communication using shared memory and message passing

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Process Concept

- An operating system executes a variety of programs:
  - Batch system – **jobs**
  - Time-shared systems – **user programs** or **tasks**
- Textbook uses the terms ***job*** and ***process*** almost interchangeably
- **Process** – a program in execution; process execution must progress in sequential fashion
- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables
  - **Heap** containing memory dynamically allocated during run time

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Process Concept (Cont.)

- Program is ***passive*** entity stored on disk (**executable file**), process is ***active***
  - Program becomes process when executable file loaded into memory
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes
  - Consider multiple users executing the same program

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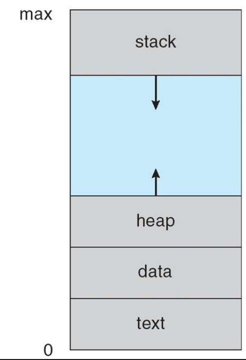
Process in Memory



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Process State

- As a process executes, it changes **state**
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned to a processor
  - **terminated**: The process has finished execution

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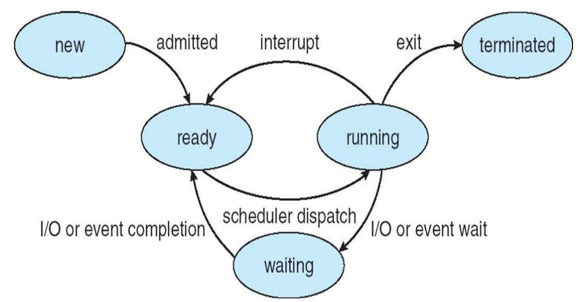
Five State Process Model



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Process State Transition

- New → Ready: OS ready to schedule the new process.
- Ready → Running: OS Scheduler selects one of the processes in the ready queue to run.
- Running → Exit: Process notifies OS to exit or abort.
- Running → Ready: Processes has reached its quantum and OS uses scheduling algorithm to find the next process in Ready state. Process can also release the processor.
- Running → Blocked: Process issues a request and must wait for the event.
- Blocked → Ready: Event for which the process is waiting has occurred.
- Ready → Exit: Parent process terminates a child process. Parent process terminates and all child processes also terminates.

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Seven State Model

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Suspended state and swapping

- **Suspended** : Another process has explicitly told this process to sleep. It will be awakened when a process explicitly awakens it.
- So far, all the processes had to be (at least partly) in main memory
- The OS may need to suspend some processes, i.e: to swap them out to disk. We add 2 new states:
- **Blocked Suspend**: blocked processes which have been swapped out to disk
- **Ready Suspend**: ready processes which have been swapped out to disk

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Suspended Processes

- Processor is faster than I/O so all processes could be waiting for I/O
  - Swap these processes to disk to free up more memory and use processor on more processes
- Blocked state becomes ***suspend*** state when swapped to disk
- Two new states
  - Blocked/Suspend
  - Ready/Suspend

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New state transitions (mid-term scheduling)

- Blocked --> Blocked Suspend
  - When all processes are blocked, the OS will make room to bring a ready process in memory
- Blocked Suspend --> Ready Suspend
  - When the event for which it has been waiting occurs (state info is available to OS)
- Ready Suspend --> Ready
  - when no more ready process in main memory or process has higher priority than other Ready processes.
- Ready--> Ready Suspend (unlikely)
  - OS needs to free up Main Memory for current process or next scheduled process.

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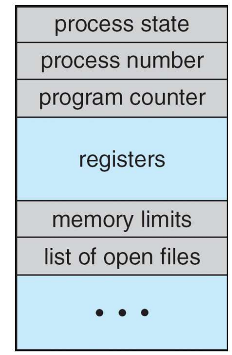
Process Control Block (PCB)

Information associated with each process

(also called **task control block**)

- Process state – running, waiting, etc
- Program counter – location of instruction to next execute
- CPU registers – contents of all process-centric registers
- CPU scheduling information- priorities, scheduling queue pointers
- Memory-management information – memory allocated to the process
- Accounting information – CPU used, clock time elapsed since start, time limits
- I/O status information – I/O devices allocated to process, list of open files



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Context Switch

- 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
  - The more complex the OS and the PCB ➔ the longer the context switch
- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU ➔ multiple contexts loaded at once

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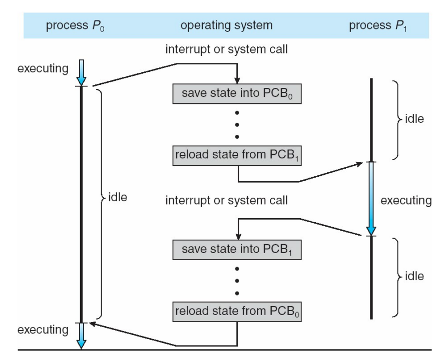
CPU Switch From Process to Process



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Process Scheduling

- Maximize CPU use, quickly switch processes onto CPU for time sharing
- **Process scheduler** selects among available processes for next execution on CPU
- Maintains **scheduling queues** of processes
  - **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

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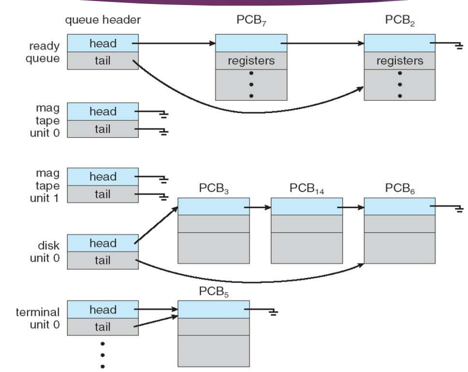
Ready Queue And Various I/O Device Queues



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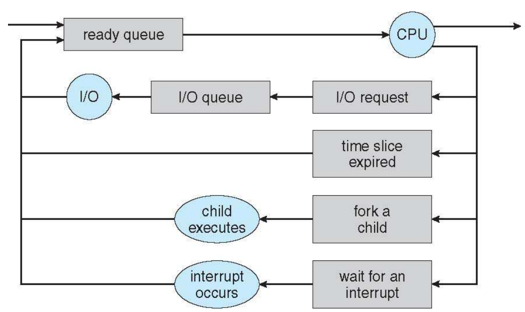
Representation of Process Scheduling

- **Queueing diagram** represents queues, resources, flows



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Schedulers

- **Short-term scheduler** (or **CPU scheduler**) – selects which process should be executed next and allocates CPU
  - Sometimes the only scheduler in a system
  - Short-term scheduler is invoked frequently (milliseconds) ⇒ (must be fast)
- **Long-term scheduler** (or **job scheduler**) – selects which processes should be brought into the ready queue
  - Long-term scheduler is invoked infrequently (seconds, minutes) ⇒ (may be slow)
  - The long-term scheduler controls the **degree of multiprogramming**
- 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
- Long-term scheduler strives for good ***process mix***

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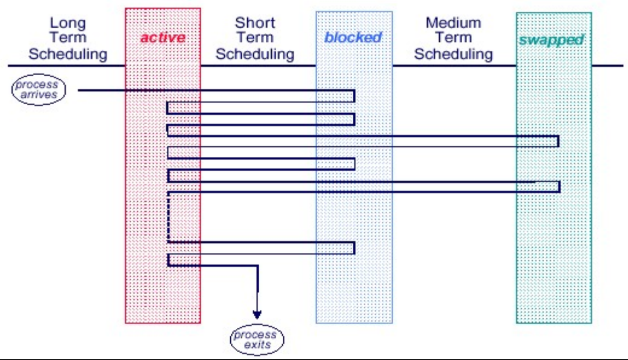
Life cycle of a typical process



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Dispatcher (short-term scheduler)

- Swaps processes out to secondary storage.
- It prevents a single process from monopolizing processor time.
- It decides who goes next according to a scheduling algorithm. (chapter 6)
- The CPU will always execute instructions from the dispatcher while switching from process A to process B.

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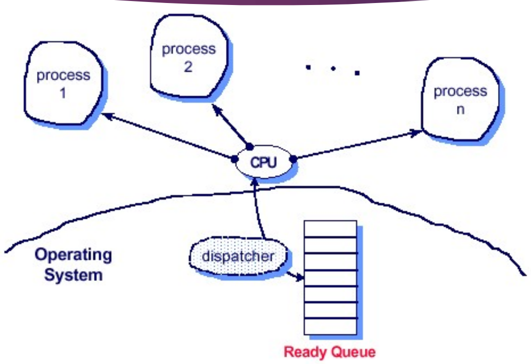
Dispatcher at Work



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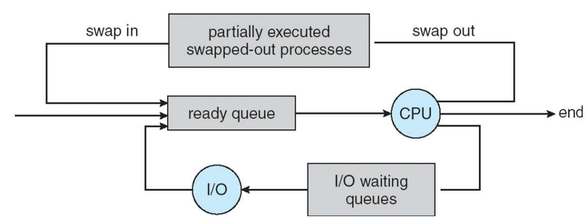
Addition of Medium Term Scheduling

- **Medium-term scheduler** can be added if degree of multiple programming needs to decrease
  - Remove process from memory, store on disk, bring back in from disk to continue execution: **swapping**



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Operations on Processes

- System must provide mechanisms for:
  - process creation,
  - process termination,
  - and so on as detailed next

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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 options
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate

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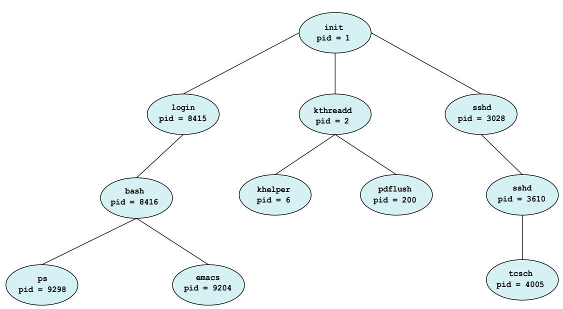
A Tree of Processes in Linux



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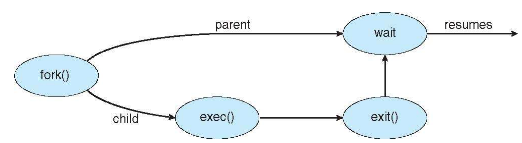
Process Creation (Cont.)

- 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



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Process Termination

- Process executes last statement and then asks the operating system to delete it using the `exit()` system call.
  - Returns status data from child to parent (via `wait()`)
  - Process' resources are deallocated by operating system
- Parent may terminate the execution of children processes using the `abort()` system call. Some reasons for doing so:
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - The parent is exiting and the operating systems does not allow a child to continue if its parent terminates

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Process Termination

- Some operating systems do not allow child to exists if its parent has terminated. If a process terminates, then all its children must also be terminated.
  - **cascading termination.** All children, grandchildren, etc. are terminated.
  - The termination is initiated by the operating system.
- The parent process may wait for termination of a child process by using the `wait()` system call. The call returns status information and the pid of the terminated process

```
pid = wait(&status);
```

- If no parent waiting (did not invoke `wait()`) process is a **zombie**
- If parent terminated without invoking `wait`, process is an **orphan**

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Interprocess Communication

- **Independent** process cannot affect or be affected by the execution of another process
- **Cooperating** process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - ***Information sharing*** (ex.: shared file)
  - ***Computation speedup*** (break up process into sub tasks to run faster and can be achieved only if the computer has multiple processing elements – CPUs or I/O channels)
  - ***Modularity*** (dividing system functions into separate processes or threads)
  - ***Convenience*** (individual user may work on many tasks at the same time could be editing, printing, and compiling in parallel)

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Interprocess Communication

- Mechanism for processes to communicate and to synchronize their actions
- Two models of IPC:

1) shared memory

cooperating processes exchange information by reading and writing data to a shared region of memory.

* allows maximum speed and convenience of communication.
* faster than message passing (system calls only to establish the region. All accesses are routine memory accesses, no assistance from the kernel).

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Contd…

2) message passing

messages are exchanged between the cooperating processes

→useful for exchanging smaller amounts of data.

→easier to implement than is shared memory for intercomputer communications.

→implemented using system calls (more time, kernel intervention).

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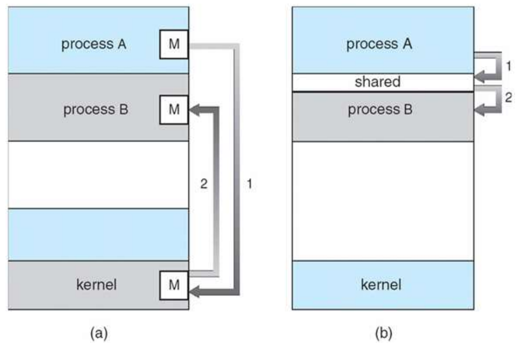
Communications Models



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1. Shared memory system

- IPC using shared memory requires communicating processes to establish region of shared memory.
- The region resides in the address space of the process creating the shared memory segment.
- Shared memory requires that two or more processes agree to remove the restriction.
- Exchange information by reading and writing data in the shared area.
- The processes are responsible for ensuring that they are not writing to the same location simultaneously.

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Example: Producer-Consumer Problem

- A common Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.
- Ex. The assembler produce object modules, which are consumed by the loader.
- Ex. Web server produces(provides) HTML files and images, which are consumed (read) by the web browser requesting the resource.
- One solution to the producer-consumer problem uses shared memory.
- To Allow the P and C processes to run concurrently, we must have a buffer that can be filled by the P and emptied by the C.
- This buffer reside in a region of memory that is shared by the P and C processes.

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Contd....

- *The P and C must be synchronized, so that the C does not try to consume an item that has not yet been produced.*
- *Two types of buffers:*
  - *unbounded-buffer* places no practical limit on the size of the buffer (the C may wait, the P can always produce new items)
  - *bounded-buffer* assumes that there is a fixed buffer size (the C must wait if buffer empty, the P must wait if the buffer is full).

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2. Message Passing

- Provides a Mechanism for processes to communicate and to synchronize their actions.
- Message system – processes communicate with each other without resorting to shared variables.
- IPC message-passing facility provides two operations:
  - **send**(*message*) – message size fixed or variable
  - **receive**(*message*)
- If processes *P* and Q wish to communicate, they need to:
  - establish a *communication link* between them
  - exchange messages via send/receive
- Implementation of communication link :
  - physical (e.g., shared memory, hardware bus)
  - logical (e.g., logical properties)

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Contd…

- Several methods for logically implementing a link, and the send()/receive() operations :
  - Direct or indirect communication.
  - Synchronous or asynchronous communication.
  - Automatic or explicit buffering.

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(i). Direct Communication

- Processes must name each other explicitly:
  - **send** (*P, message*) – send a message to process P
  - **receive**(*Q, message*) – receive a message from process Q
- The Properties of the communication link:
  - Links are established automatically between every pair of processes that want to communicate. The processes need to know only each other's identity to communicate.
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional

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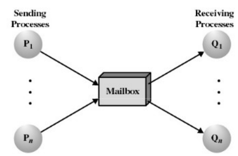
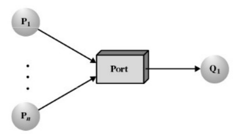
(ii). Indirect Communication

- Messages are directed and received from shared mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links, with each link corresponding to one mailbox.
  - Link may be unidirectional or bi-directional





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Contd…

- A mailbox may be owned either by a process (part of its address space) or by the OS.
- When a process that owns a mailbox terminates, the mailbox disappears.
- OS allows the process the operations:
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox
- Primitives are defined as:
- **send**(*A, message*) – send a message to mailbox A
- **receive**(*A, message*) – receive a message from mailbox A

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Contd…

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A.
  - P_1, sends a message to A; P_2 and P_3 receive from A.
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes
  - Allow only one process at a time to execute a receive operation
  - Allow the system to select arbitrarily the receiver (P_2 or P_3 not both) Sender is notified who the receiver was.

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(iii). Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** has the sender block until the message is received by the receiving process or by the mailbox.
  - **Blocking receive** has the receiver block until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** has the sender send the message and continue operation.
  - **Non-blocking receive** has the receiver receive either a valid message or null
- When Both send() and receive() are blocking, we have a
- **rendezvous** between the sender and the receiver.

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(iv). Buffering

- Messages exchanged by processes reside in a temporary queue.
- Queue of messages attached to the link; implemented in one of three ways
  1. Zero capacity – max length of 0 messages (cannot have any messages waiting in it).
- Sender must wait(blocked) for receiver (rendezvous)
  2. Bounded capacity – finite length of *n* messages Sender must wait (block) if link is full
  3. Unbounded capacity – infinite length Sender never waits.

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End of Chapter 3

Thank you

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