Module 4: Processes

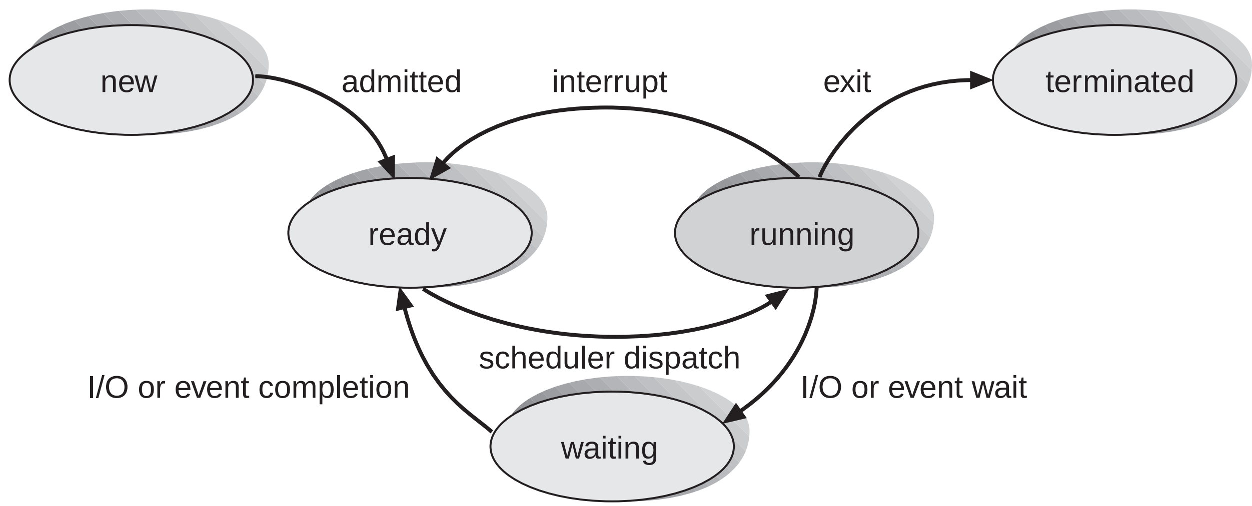
- Process Concept
- Process Scheduling
- Operation on Processes
- Cooperating Processes
- Threads
- Interprocess Communication

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 a sequential fashion.
- A process includes:
  - program counter
  - stack
  - data section

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.
- Diagram of process state:



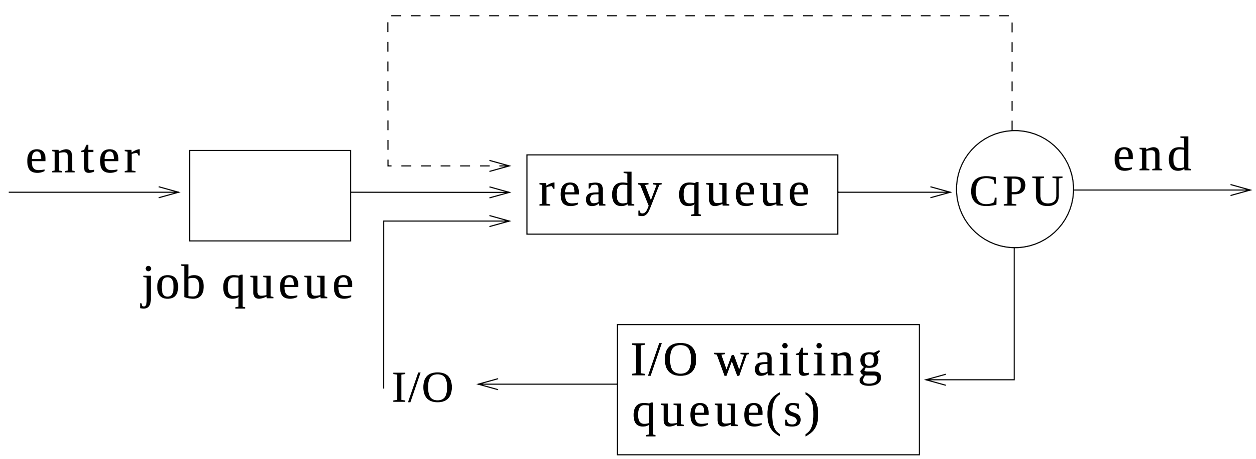
Process Control Block (PCB)

Information associated with each process.

- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information

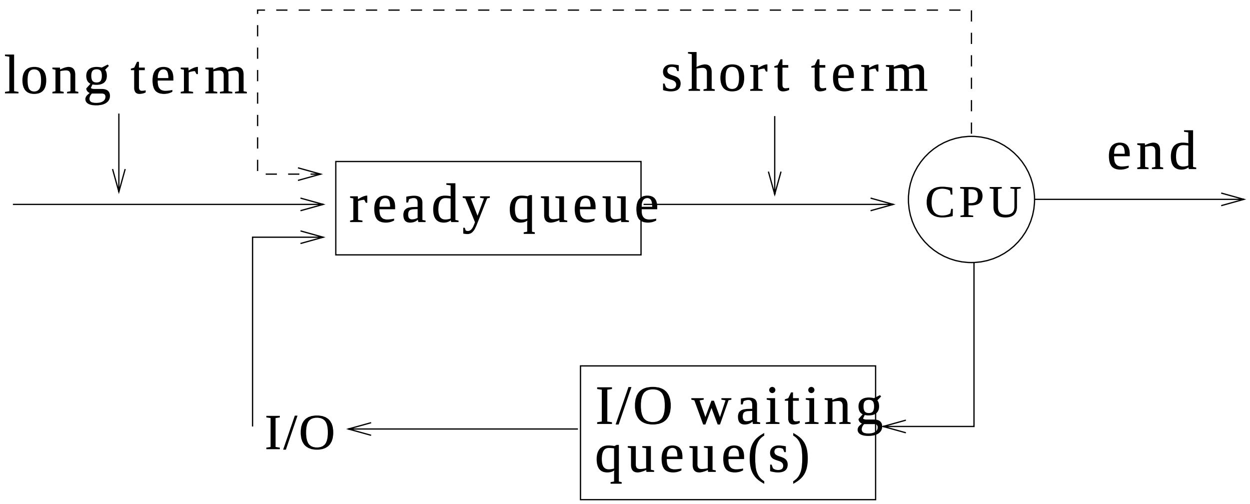
Process Scheduling Queues

- 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.
- Process migration between the various queues.



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.



Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) $\Rightarrow$ (must be fast).
- Long-term scheduler is invoked very infrequently (seconds, minutes) $\Rightarrow$ (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.

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.
- Context-switch time is overhead; the system does no useful work while switching.
- Time dependent on hardware support.

Process Creation

- Parent process creates children processes, which, in turn create other processes, forming a tree of processes.
- 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 (Cont.)

- Address space
  - Child duplicate of parent.
  - Child has a program loaded into it.
- UNIX examples
  - **fork** system call creates new process.
  - **execve** 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.
  - Parent is exiting.
    * Operating system does not allow child to continue if its parent terminates.
    * Cascading termination.

Cooperating Processes

- *Independent* process cannot affect or be affected by the execution of another process.
- *Cooperating* process can affect or be affected by the execution of another process.
- Advantages of process cooperation:
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Producer-Consumer Problem

- Paradigm for cooperating processes; *producer* process produces information that is consumed by a *consumer* process.
  - *unbounded-buffer* places no practical limit on the size of the buffer.
  - *bounded-buffer* assumes that there is a fixed buffer size.

Bounded-Buffer – Shared-Memory Solution

- Shared data

var *n;*
type *item* = ... ;
var *buffer*: **array** [0..$n-1$] **of** *item;*
in, out: 0..$n-1$;

- Producer process

repeat
...
produce an item in *nextp*
...
while *in*+1 **mod** *n* = *out* **do** *no-op;*
buffer[*in*] := *nextp;*
in := *in*+1 **mod** *n;*
until *false;*

Bounded-Buffer (Cont.)

- Consumer process

repeat
    while *in* = *out* **do** *no-op;*
    nextc := *buffer*[*out*];
    out := *out*+1 **mod** *n;*
        ...
    consume the item in *nextc*
        ...
until *false;*

- Solution is correct, but can only fill up $n - 1$ buffer.

Threads

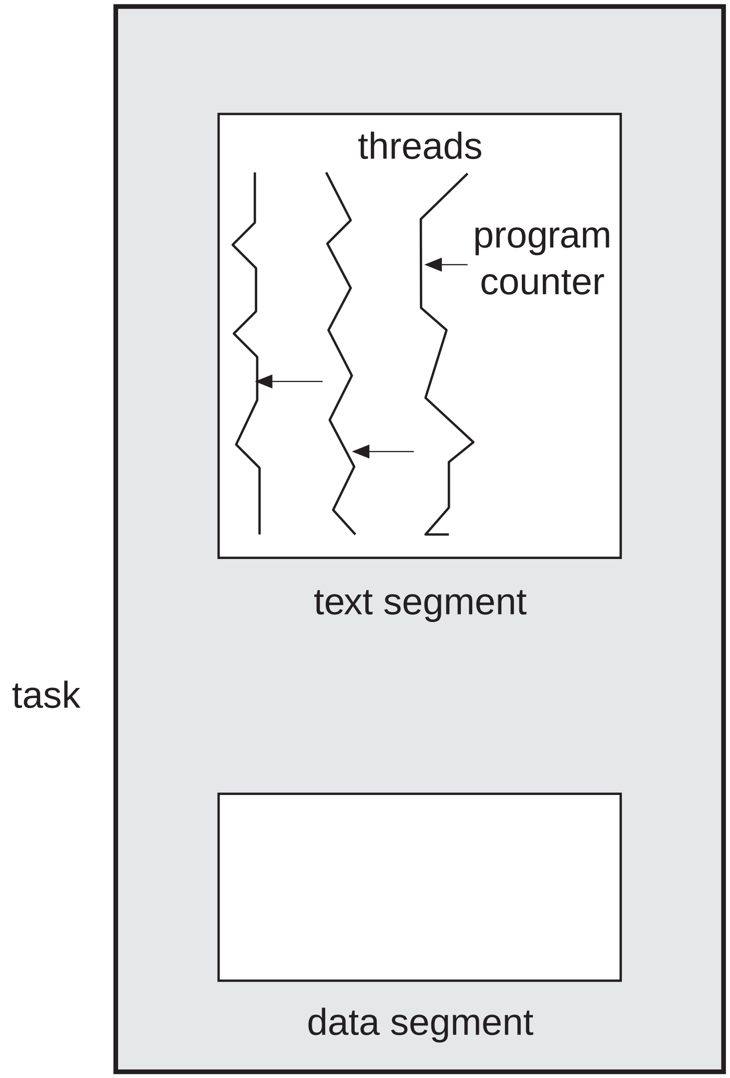
- A *thread* (or *lightweight process*) is a basic unit of CPU utilization; it consists of:
  - program counter
  - register set
  - stack space
- A thread shares with its peer threads its:
  - code section
  - data section
  - operating-system resources

  collectively known as a *task*.
- A traditional or *heavyweight* process is equal to a task with one thread.

Threads (Cont.)

- In a multiple threaded task, while one server thread is blocked and waiting, a second thread in the same task can run.
  - Cooperation of multiple threads in same job confers higher throughput and improved performance.
  - Applications that require sharing a common buffer (i.e., producer–consumer) benefit from thread utilization.
- Threads provide a mechanism that allows sequential processes to make blocking system calls while also achieving parallelism.
- Kernel-supported threads (Mach and OS/2).
- User-level threads; supported above the kernel, via a set of library calls at the user level (Project Andrew from CMU).
- Hybrid approach implements both user-level and kernel-supported threads (Solaris 2).

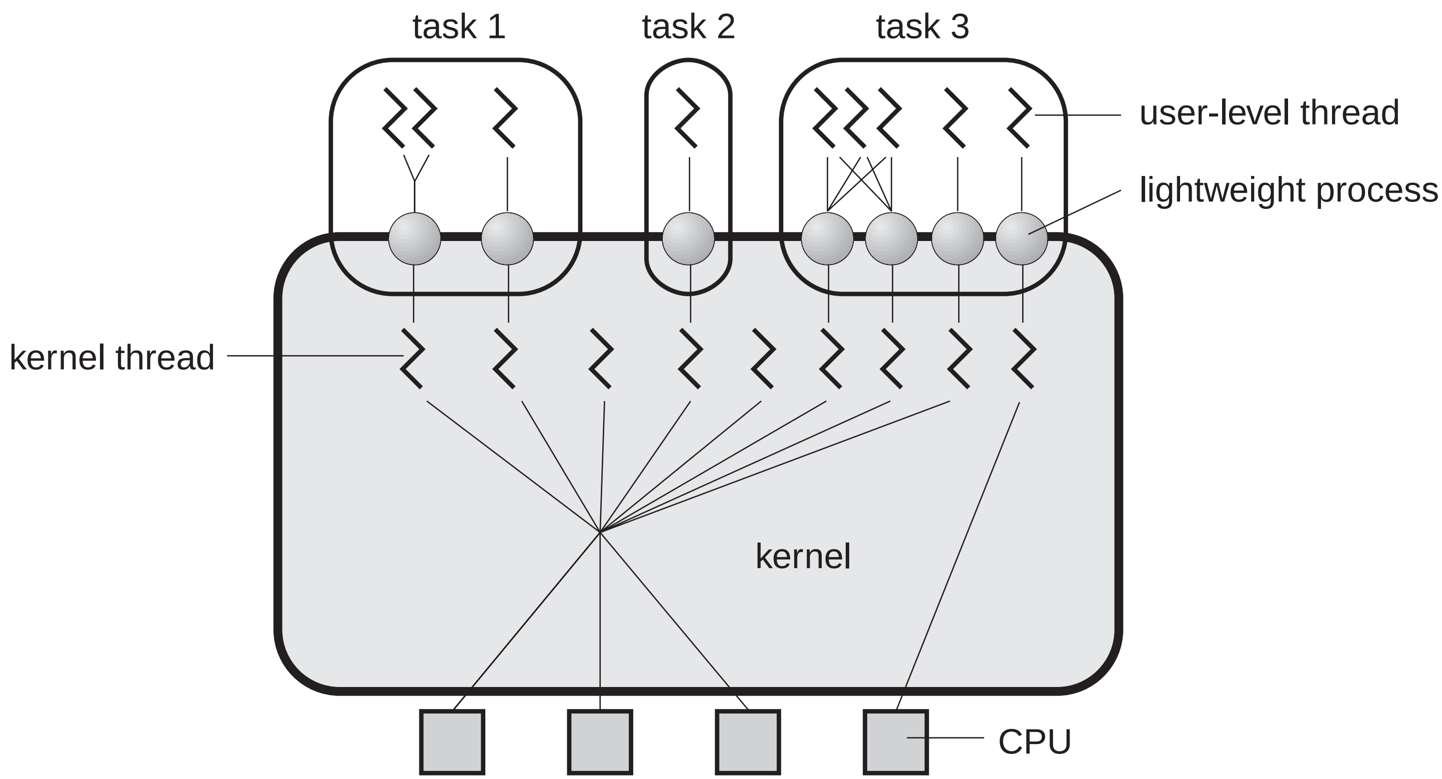
Threads (Cont.)



Thread Support in Solaris 2

- Solaris 2 is a version of UNIX with support for threads at the kernel and user levels, symmetric multiprocessing, and real-time scheduling.
- LWP – intermediate level between user-level threads and kernel-level threads.
- Resource needs of thread types:
  - Kernel thread: small data structure and a stack; thread switching does not require changing memory access information – relatively fast.
  - LWP: PCB with register data, accounting and memory information; switching between LWPs is relatively slow.
  - User-level thread: only needs stack and program counter; no kernel involvement means fast switching. Kernel only sees the LWPs that support user-level threads.

Threads in Solaris 2



Interprocess Communication (IPC)

- Mechanism for processes to communicate and to synchronize their actions.
- Message system – processes communicate with each other without resorting to shared variables.
- IPC facility provides two operations:
  - **send***(message)* – message size fixed or variable
  - **receive***(message)*
- If *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)

Implementation Questions

- How are links established?
- Can a link be associated with more than two processes?
- How many links can there be between every pair of communicating processes?
- What is the capacity of a link?
- Is the size of a message that the link can accommodate fixed or variable?
- Is a link unidirectional or bidirectional?

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
- Properties of communication link
  - Links are established automatically.
  - 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 bidirectional.

Indirect Communication

- Messages are directed and received from *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.
  - Link may be unidirectional or bidirectional.
- Operations
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox

Indirect Communication (Continued)

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A.
  - P_1 sends; P_2 and P_3 receive.
  - 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. Sender is notified who the receiver was.

Buffering

- Queue of messages attached to the link; implemented in one of three ways.

  1. Zero capacity – 0 messages
     Sender must wait for receiver (*rendezvous*).
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full.
  3. Unbounded capacity – infinite length
     Sender never waits.

Exception Conditions – Error Recovery

- Process terminates
- Lost messages
- Scrambled Messages