

Module 4: Processes

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

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Process Concept

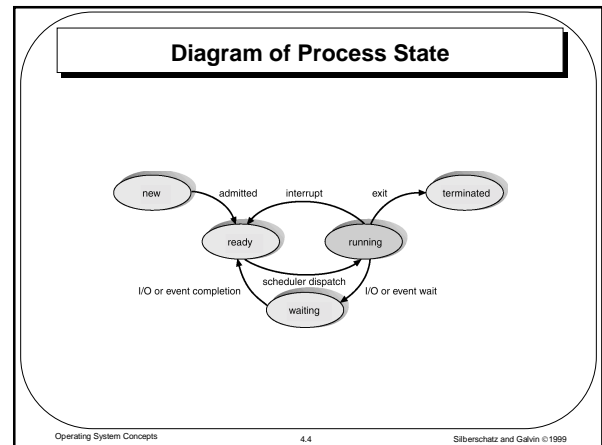
- An operating system executes a variety of programs:
 - Batch system – jobs
 - Time-shared systems – user programs or tasks
- Textbook uses the terms *job* and *process* almost interchangeably (and I like to use the term *task*).
- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes:
 - program counter
 - stack
 - data section

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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 process.
 - terminated: The process has finished execution.

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Process Control Block (PCB)

Information associated with each process.

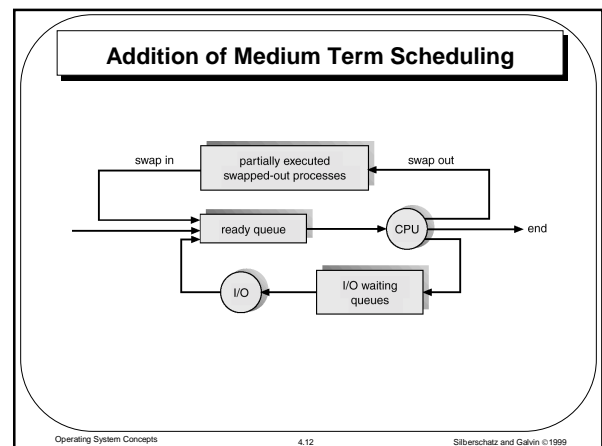
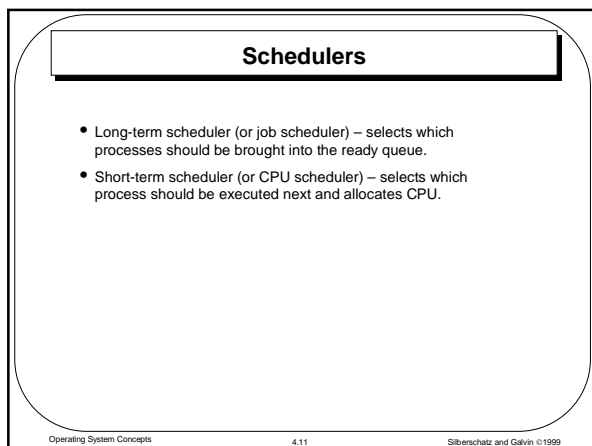
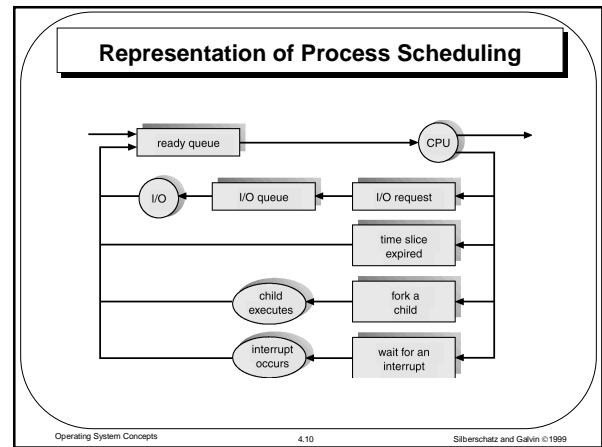
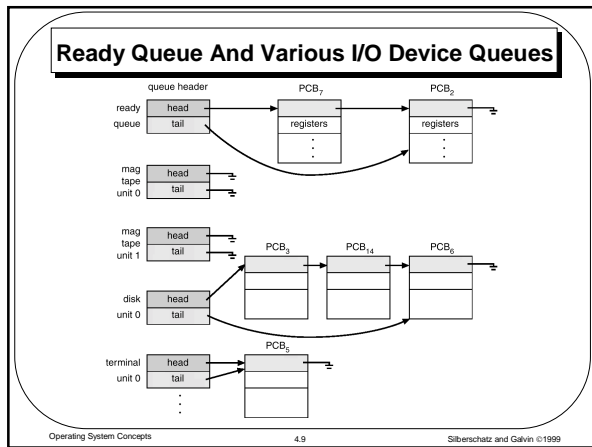
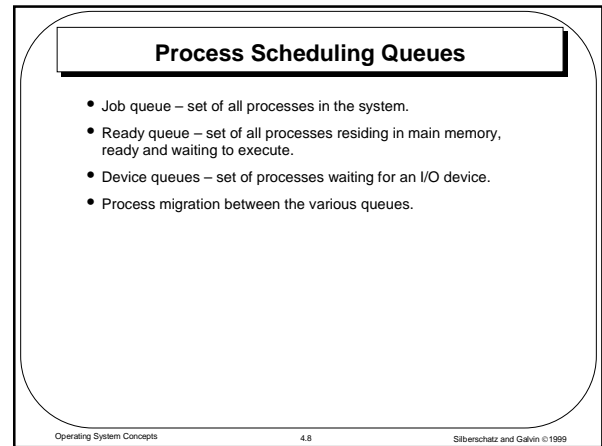
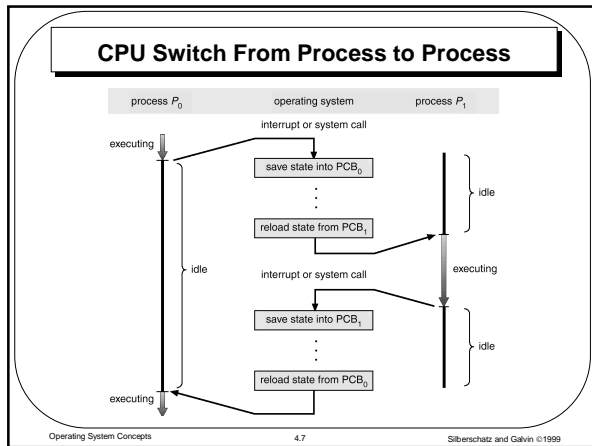
- Process ID
- Process state
- Program counter
- CPU registers
- CPU scheduling information
- Memory-management information
- Accounting information
- I/O status information

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Process Control Block (PCB)

pointer	process state
process number	
program counter	
registers	
memory limits	
list of open files	
⋮	

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Schedulers (Cont.)

- Short-term scheduler is invoked very frequently (milliseconds) => (must be fast).
- Long-term scheduler is invoked very 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.

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

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Process Creation

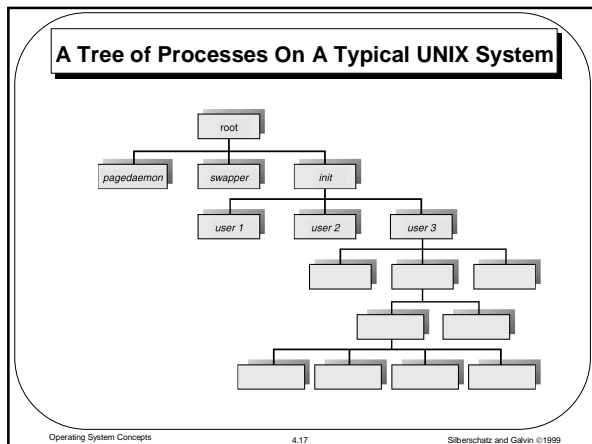
- Parent process creates children processes, which, in turn create other processes, forming a tree of processes.
- Resource sharing
 - Parent and children share all resources.
 - Children share subset of parent's resources.
 - Parent and child share no resources.
- Execution
 - Parent and children execute concurrently.
 - Parent waits until children terminate.

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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
 - `exec1()` 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 asks the operating system to decide 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.

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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

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Producer-Consumer Problem

- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.
 - Here, we have *one* producer and *one* consumer process
 - Concurrency causes coordination problems
 - ⊛ Consumers can't consume until Producers have produced
 - *unbounded-buffer* places no practical limit on the size of the buffer.
 - *bounded-buffer* assumes that there is a fixed buffer size.

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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;
```

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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.

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

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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).

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Multiple Threads within a Task

- Threads possess their own:
 - Registers
 - Program counter
 - Stack frame
 - Private data segment (local variables)
- Threads share:
 - The parent process's address space
 - ⊗ Code segment (read-only)
 - ⊗ Data segment (shared memory)

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Threads 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 need stack and program counter; no kernel involvement means fast switching. Kernel only sees the LWPs that support user-level threads.

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Kernel to User Thread Mappings

- One to Many
 - One kernel process "holds" many user threads
 - Also known as "green" threads
 - Simple for OS to manage
- One to One (Windows, OS/2)
 - One kernel thread for each user thread
 - Limits must be placed on the number of threads users can create
- Many to Many (Solaris)
 - Kernel thread "pools" exist, with the size set at system initialization
 - No limits placed arbitrarily on user threads

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Solaris 2 Threads

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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)

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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 bi-directional?

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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 bi-directional.

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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 bi-directional.
- Operations
 - create a new mailbox
 - send and receive messages through mailbox
 - destroy a mailbox

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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.

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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.

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Exception Conditions – Error Recovery

- Process terminates
- Lost messages
- Scrambled Messages

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