BUCKNELL UNIVERSITY
Computer Science

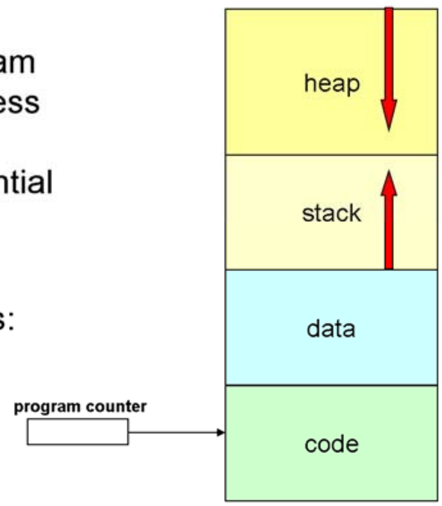
CSCI 315 Operating Systems Design

Processes

<u>Notice:</u> The slides for this lecture have been largely based on those accompanying an earlier edition of the textbook *Operating Systems Concepts with Java*, by Silberschatz, Galvin, and Gagne. Many, if not all, the illustrations contained in this presentation come from this source.

Process Concept

- Process – a program in execution; process execution must progress in sequential fashion.
- A process includes:
  - program counter,
  - stack,
  - data section.



Process Control Block (PCB)

OS bookkeeping information associated with each process:

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

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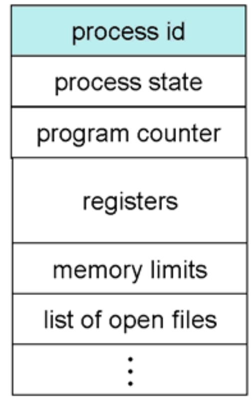
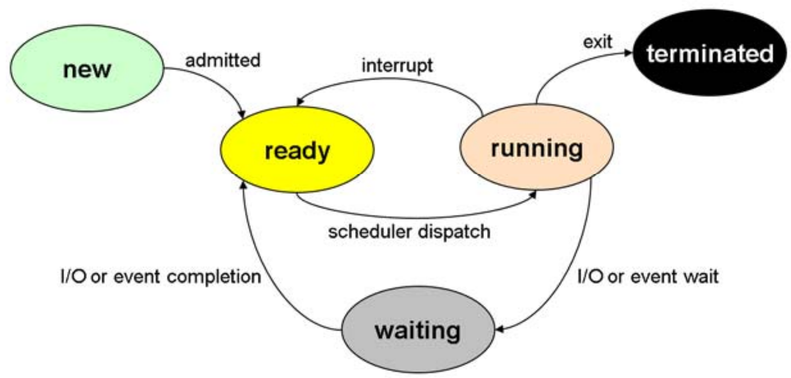


Process State Transition Diagram

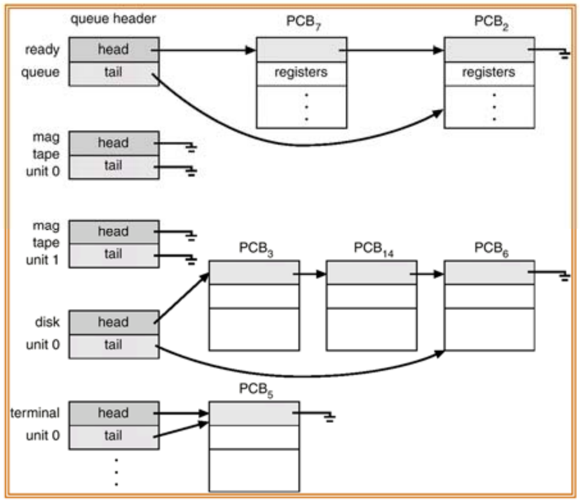


Process Scheduling Queues

- ***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 between the various queues.

Processes and OS 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

- 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; 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 create children processes, which, in turn can 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 may wait until children terminate.

Process Creation (Cont.)

- Address space:
  - Child has duplicate of parent's address space, or
  - Child can have a program loaded onto it.

- UNIX examples:
  - **fork** system call creates new process and returns with a pid (0 in child, > 0 in the parent),
  - **exec** system call can be 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 terminate 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**) if:
  - 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*

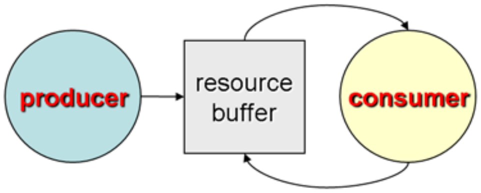
Cooperating Processes

- An ***independent*** process **cannot** affect or be affected by the execution of another process.
- A ***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

A paradigm for cooperating processes in which a ***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)

```
public interface Buffer
{
    // producers call this method
    public abstract void insert(Object
    item);

    // consumers call this method
    public abstract Object remove();
}
```

```
import java.util.*;
public class BoundedBuffer implements Buffer
{
    private static final int BUFFER SIZE = 5;
    private int count; // number of items in the buffer
    private int in; // points to the next free position
    private int out; // points to the next full position
    private Object[] buffer;
    public BoundedBuffer()  {
        // buffer is initially empty
        count = 0;
        in = 0;
        out = 0;
        buffer = new Object[BUFFER SIZE];
    }
    // producers calls this method
    public void insert(Object item) { // Slide 17 }
    // consumers calls this method
    public Object remove() { // Slide 18 }
}
```

Bounded-Buffer

(shared-memory solution)

```
public void insert(Object item) {
    while (count == BUFFER SIZE); // do nothing -- no free buffers
    // add an item to the buffer
    ++count;
    buffer[in] = item;
    in = (in + 1) % BUFFER SIZE;
}
```

Bounded-Buffer

(shared-memory solution)

```
public Object remove() {
    Object item;
    while (count == 0); // do nothing -- nothing to consume
    // remove an item from the buffer
    --count;
    item = buffer[out];
    out = (out + 1) % BUFFER SIZE;
    return item;
}
```

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 bi-directional?

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

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

Indirect Communication

- 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.

Indirect Communication

- 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.

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.
  - **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.
  - **Non-blocking** receive has the receiver receive a valid message or null.

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.