Operating Systems I

Unit 4 – Processes

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Module 4: Processes

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

Process Concept

- An operating system executes a variety of programs:
  - Batch system – jobs
  - Time-shared systems – user programs or tasks
- The terms *job* and *process* are used almost interchangeably.
- **Process: "a program in execution"**
  - **process execution must progress in sequential fashion**.
- A process includes:
  - program counter
  - stack
  - data section

Major Requirements of an Operating System

- Interleave the execution of several processes to **maximize processor utilization** while providing **reasonable response time**
- Allocate resources to processes
- Support interprocess communication and user creation of processes

Process Creation

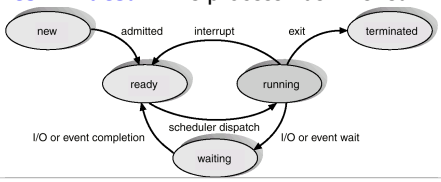
- Submission of a batch job
- User clicks on an application or file
- Create to provide a service such as printing
- Spawned by an existing process

Process Termination

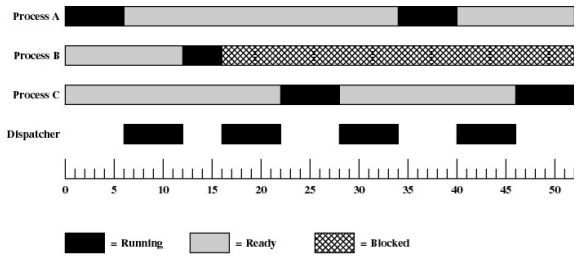
- Batch job issues Halt instruction
- User logs off
- Process executes a service request to terminate
- Parent terminates so child processes terminate
- Operating system intervention
  - E.g. when deadlock occurs
- Error and fault conditions
  - E.g. memory unavailable, protection error, arithmetic error, I/O failure, invalid instruction

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



Multiple Processes



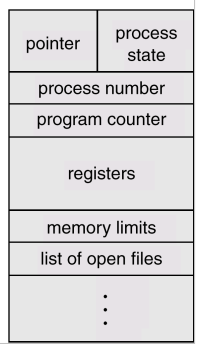
Scheduler

- Program that moves the processor from one process to another
- Prevents a single process from monopolizing processor time.
  - Every process should be able to use the processor for a **fair amount of time**

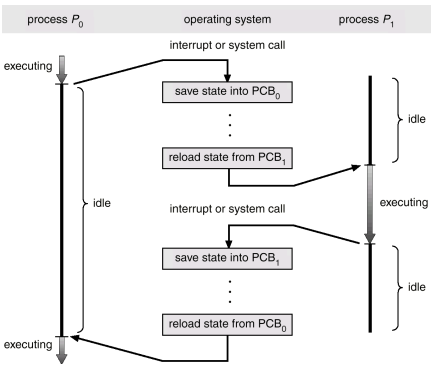
Process Control Block (PCB)

Information associated with each process.

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



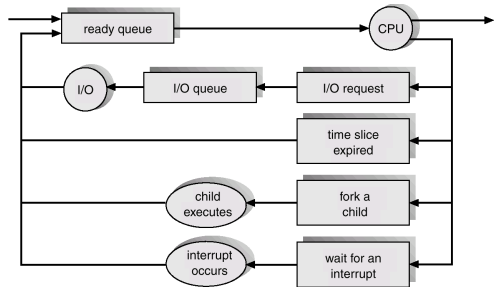
CPU Switch From Process to Process



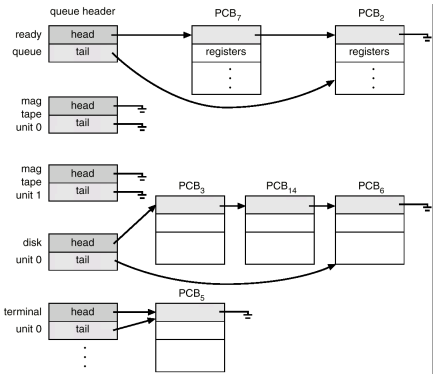
Process Scheduling Queues

- 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.

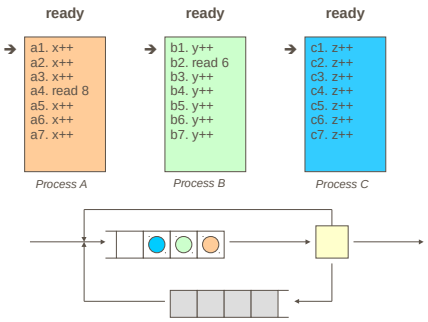
Representation of Process Scheduling



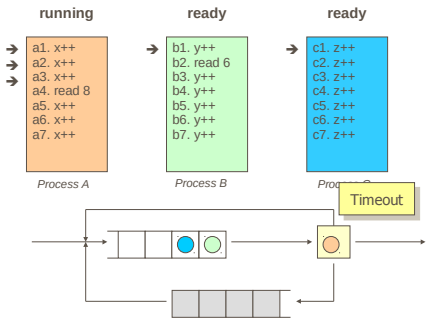
Ready Queue And Various I/O Device Queues



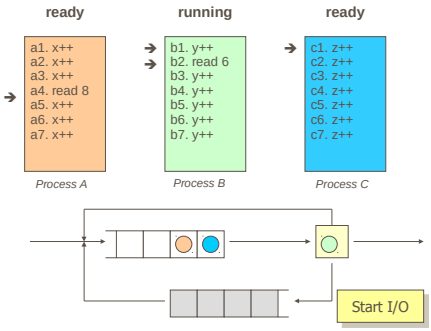
How process state changes (1/8)



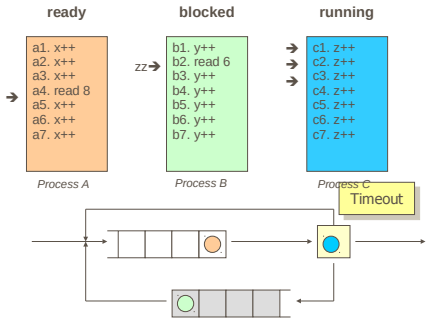
How process state changes (2/8)



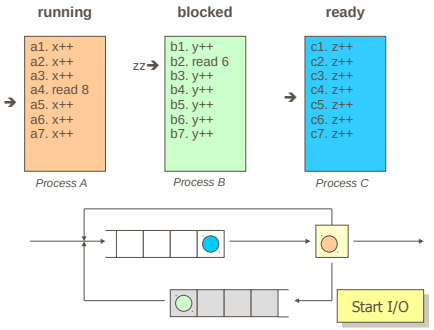
How process state changes (3/8)



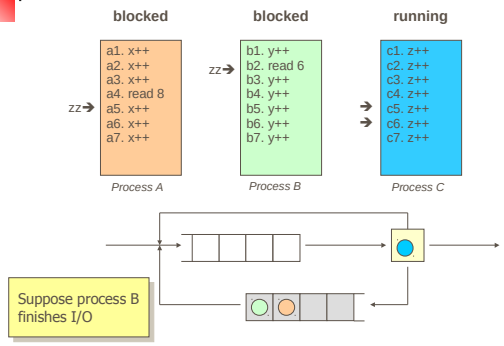
How process state changes (4/8)



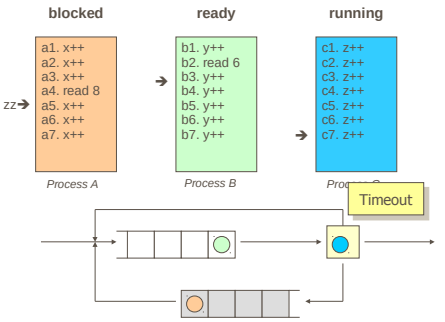
How process state changes (5/8)



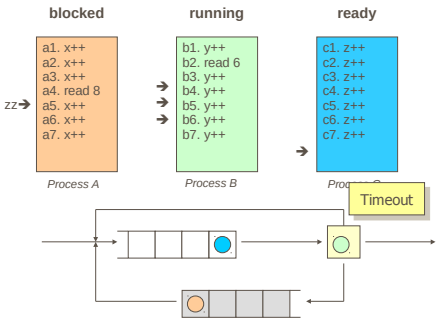
How process state changes (6/8)



How process state changes (7/8)



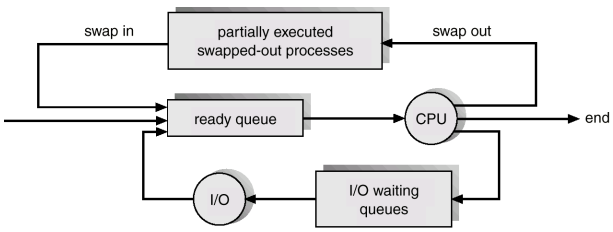
How process state changes (8/8)



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.

Addition of Medium Term Scheduling



Schedulers (Cont.)

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

Reasons for Process Suspension

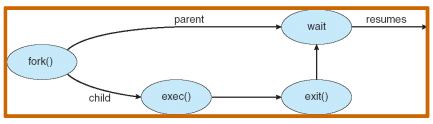
Swapping	The operating system needs to release sufficient main memory to bring in a process that is ready to execute.
Other OS reason	The operating system may suspend a background or utility process or a process that is suspected of causing a problem.
Interactive user request	A user may wish to suspend execution of a program for purposes of debugging or in connection with the use of a resource.
Timing	A process may be executed periodically (e.g., an accounting or system monitoring process) and may be suspended while waiting for the next time interval.
Parent process request	A parent process may wish to suspend execution of a descendent to examine or modify the suspended process, or to coordinate the activity of various descendents.

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.)

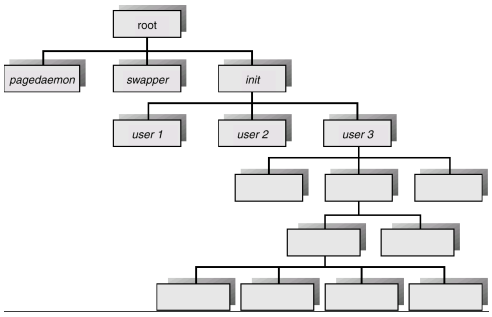
- Address space
  - Child duplicate of parent.
  - Child has a program loaded into it.
- UNIX examples
  - **fork** system call creates new process
  - **execve** system call used after a **fork** to replace the process' memory space with a new program.



Process Creation Example

```
int main()
{
Pid_t  pid;
    /* fork another process */
    pid = fork();
    if (pid < 0) { /* error occurred */
        fprintf(stderr, "Fork Failed");
        exit(-1);
    }
    else if (pid == 0) { /* child process */
        execlp("/bin/ls", "ls", NULL);
    }
    else { /* parent process */
        /* parent will wait for the child to complete */
        wait (NULL);
        printf ("Child Complete");
        exit(0);
    }
}
```

A Tree of Processes On A Typical UNIX System



Unix Process States

User Running	Executing in user mode.
Kernel Running	Executing in kernel mode.
Ready to Run, in Memory	Ready to run as soon as the kernel schedules it.
Asleep in Memory	Unable to execute until an event occurs; process is in main memory (a blocked state).
Ready to Run, Swapped	Process is ready to run, but the swapper must swap the process into main memory before the kernel can schedule it to execute.
Sleeping, Swapped	The process is awaiting an event and has been swapped to secondary storage (a blocked state).
Preempted	Process is returning from kernel to user mode, but the kernel preempts it and does a process switch to schedule another process.
Created	Process is newly created and not yet ready to run.
Zombie	Process no longer exists, but it leaves a record for its parent process to collect.

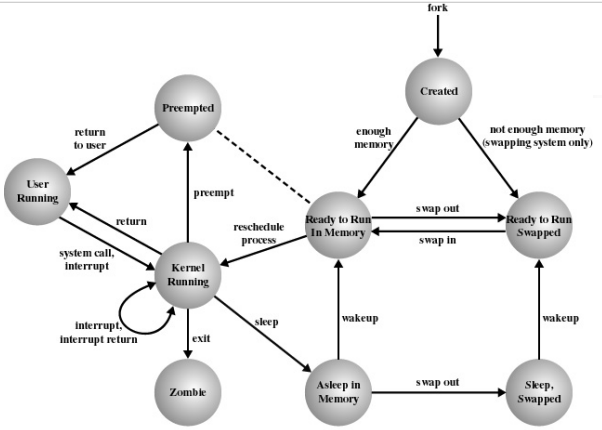


Figure 3.16 UNIX Process State Transition Diagram

Process Termination

- Normal completion
- Time limit exceeded
- Memory unavailable
- Bounds violation
- Protection error
  - example write to read-only file
- Arithmetic error
- Time overrun
  - process waited longer than a specified maximum for an event

Process Termination

- I/O failure
- Invalid instruction
  - happens when try to execute data
- Privileged instruction
- Data misuse
- Operating system intervention
  - such as when deadlock occurs
- Parent terminates so child processes terminate
- Parent request

IPC & Cooperative Processes

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.

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*)

Interprocess Communication (IPC)

- 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

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.

Synchronization

- Message passing may be either **blocking** or **non-blocking.**
- **Blocking** is considered **synchronous**
- **Non-blocking** is considered **asynchronous**
- **send** and **receive** primitives may be either blocking or non-blocking.

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

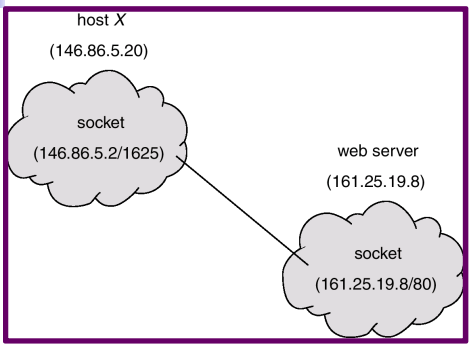
Client/Server Communication

- Sockets
- Remote Procedure Calls
- Remote Method Invocation (Java)

Sockets

- A socket is defined as an *endpoint for communication*.
- Concatenation of IP address and port
- The socket **161.25.19.8:1625** refers to port **1625** on host **161.25.19.8**
- Communication consists between a pair of sockets.

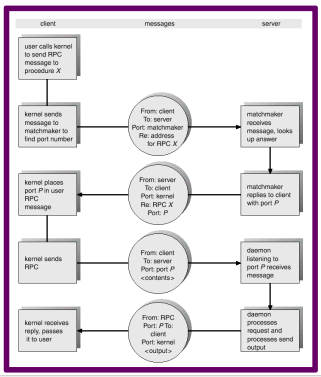
Socket Communication



Remote Procedure Calls

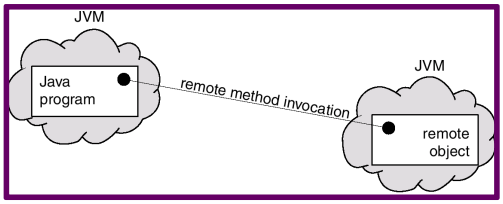
- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems.
- **Stubs** – client-side proxy for the actual procedure on the server.
- The client-side stub locates the server and *marshalls* the parameters.
- The server-side stub receives this message, unpacks the marshalled parameters, and peforms the procedure on the server.

Execution of RPC



Remote Method Invocation

- Remote Method Invocation (RMI) is a Java mechanism similar to RPCs.
- RMI allows a Java program on one machine to invoke a method on a remote object.



Marshalling Parameters