Processes

Unit-II

Lecture -1

Session 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
- To describe communication in client-server systems

Session Outcomes

At the end of this session, participants will be able to

- Discuss process states, operations and interprocess communication

Agenda

1. Process Concept
2. Interprocess Communication

Presentation Outline

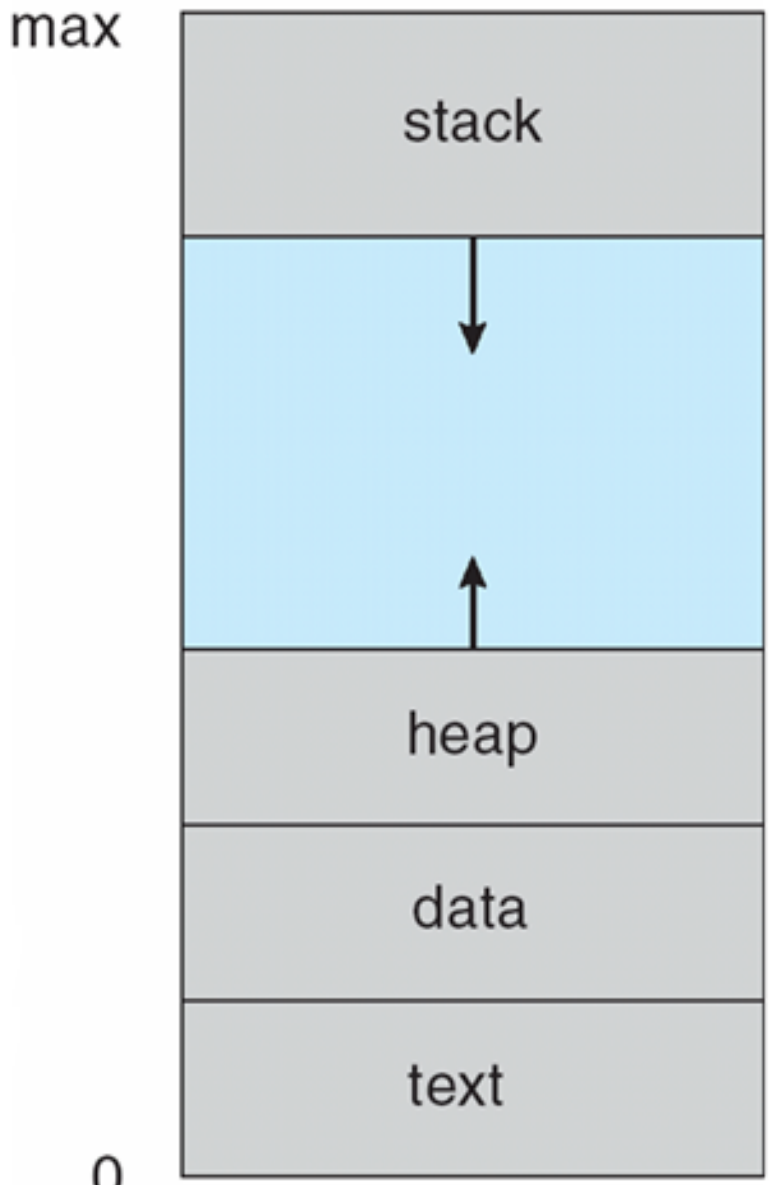
Process Concept

- An operating system executes a variety of programs:
  Batch system jobs
  Time-shared systems user programs or tasks
- 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

Process Concept

- 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

Process in Memory

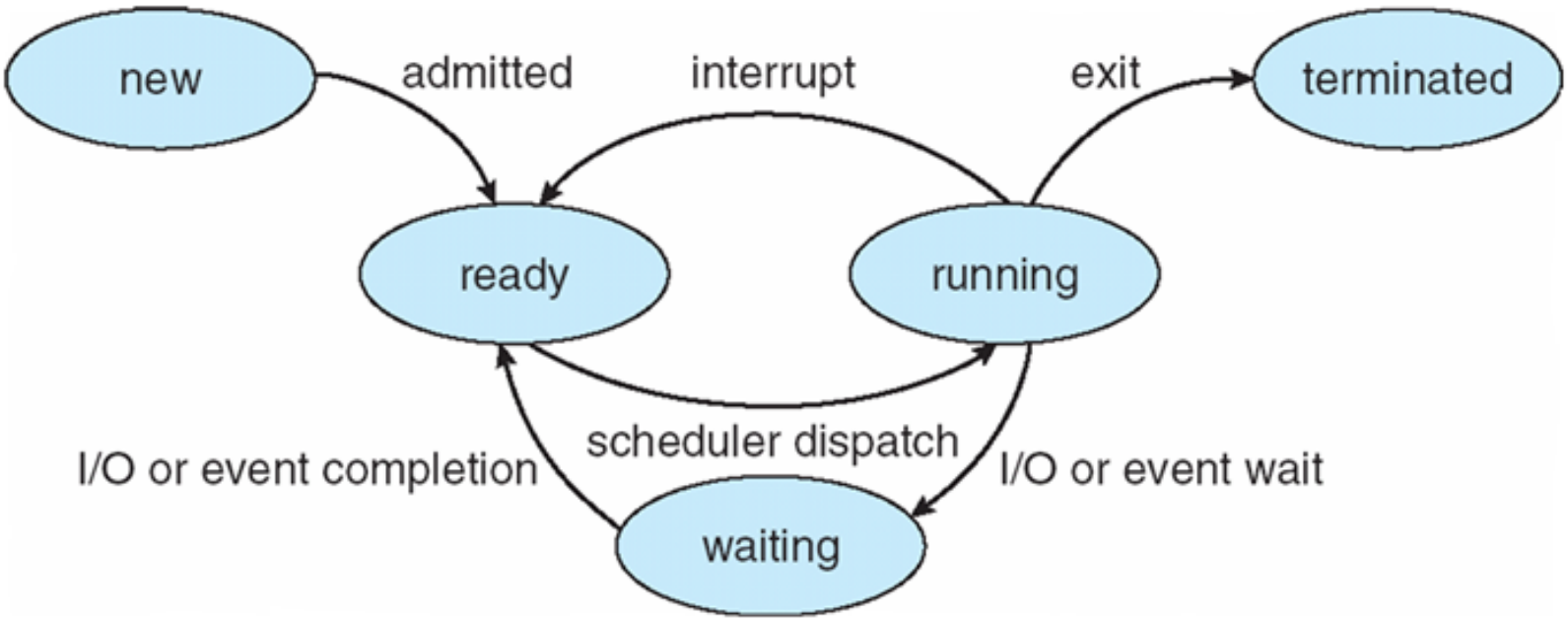


Process State

As a process executes, it changes state

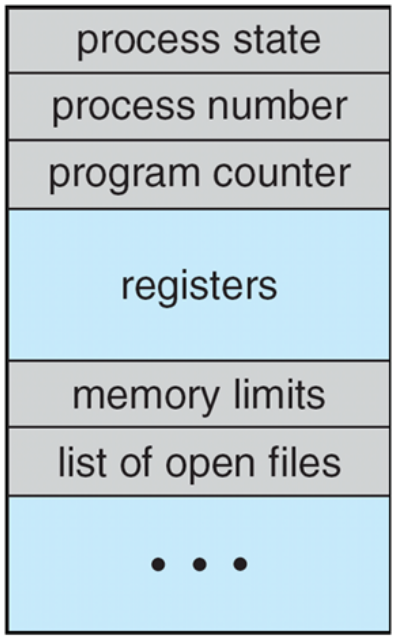
- **new**: The process is being created
- **running**: Instructions are being executed
- **waiting**: The process is waiting for some event to occur
- **ready**: The process is waiting to be assigned to a processor
- **terminated**: The process has finished execution

Process States

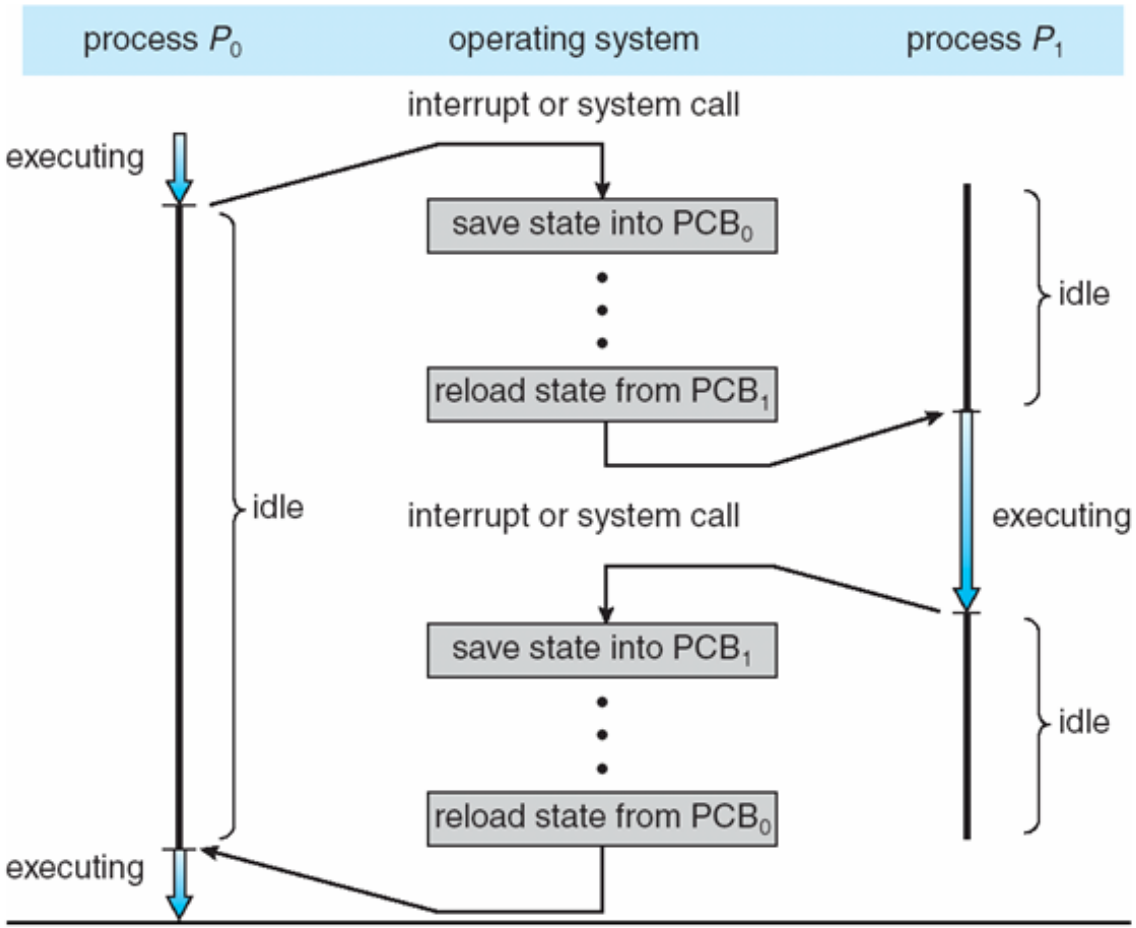


Process Control Block (PCB)

- Information associated with each process
- **Process state**, **Program counter**
- **CPU registers** contents of all process-centric registers
- **CPU scheduling information**- priorities, scheduling queue pointers
- **Memory-management** information
- **Accounting** information CPU used, clock time elapsed since start, time



CPU Switch From Process to Process



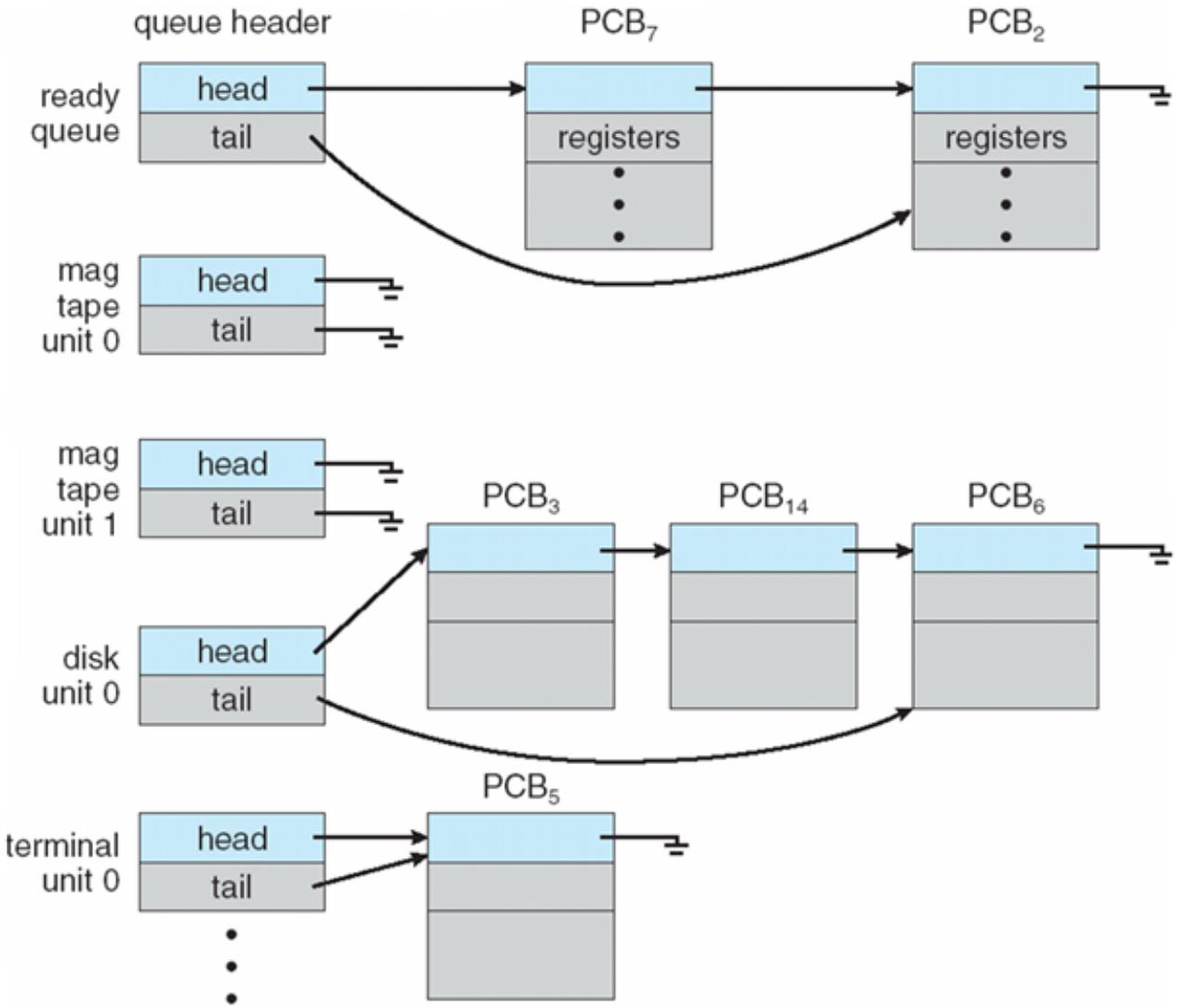
Threads

- So far, process has a single thread of execution
- Consider having multiple program counters per process
- Multiple locations can execute at once
- Multiple threads of control : threads
- Must then have storage for thread details, multiple program counters in PCB

Process Scheduling

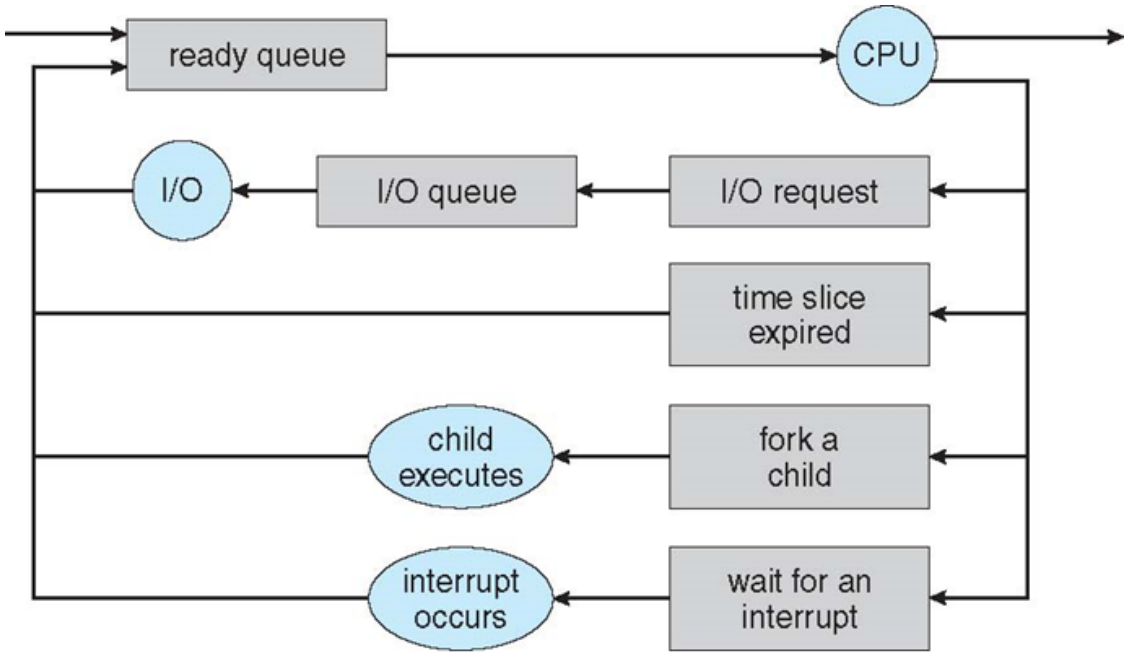
- Maximize CPU use, quickly switch processes onto CPU for time sharing
- Process scheduler selects among available processes for next execution on CPU
- Maintains scheduling queues of processes
  - **Job queue** set of all processes in the system
  - **Ready queue** set of all processes residing in main memory, ready and waiting to execute
  - **Device queues** set of processes waiting for an I/O device
  - Processes migrate among the various queues

Ready Queue And Various I/O Device Queues



Representation of Process Scheduling

Queueing diagram represents queues, resources, flows

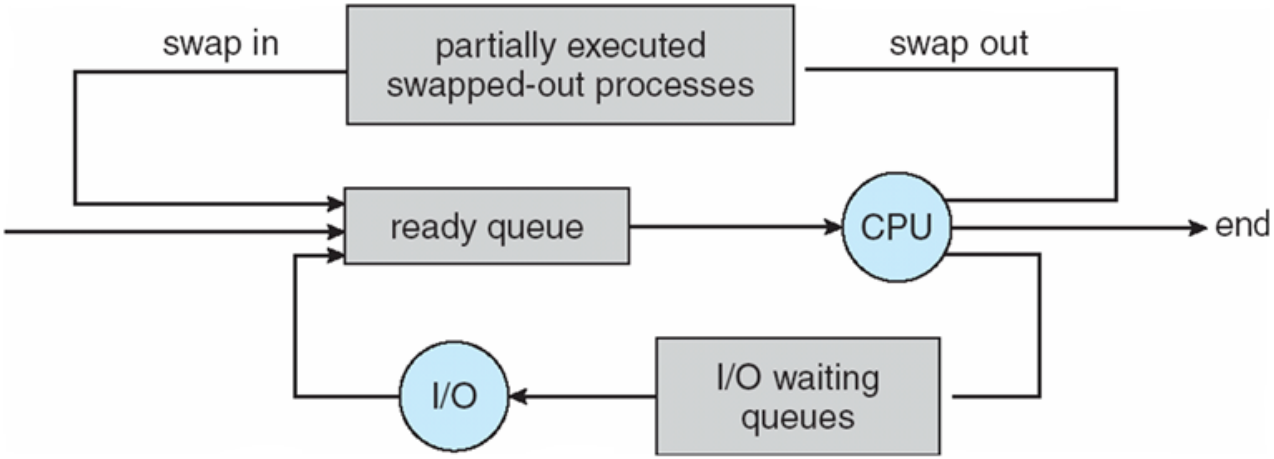


Schedulers

- **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

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**



Multitasking in Mobile Systems

- Some mobile systems (e.g., early version of iOS) allow only one process to run, others suspended
- Due to screen size, user interface limits iOS provides for a Single foreground process- controlled via user interface
- Multiple background processes in memory, running, but not on the display, and with limits
- Android runs foreground and background, with fewer limits
- Background process uses a service to perform tasks
- Service can keep running even if background process is suspended
- Service has no user interface, small memory use

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

Operations on Processes

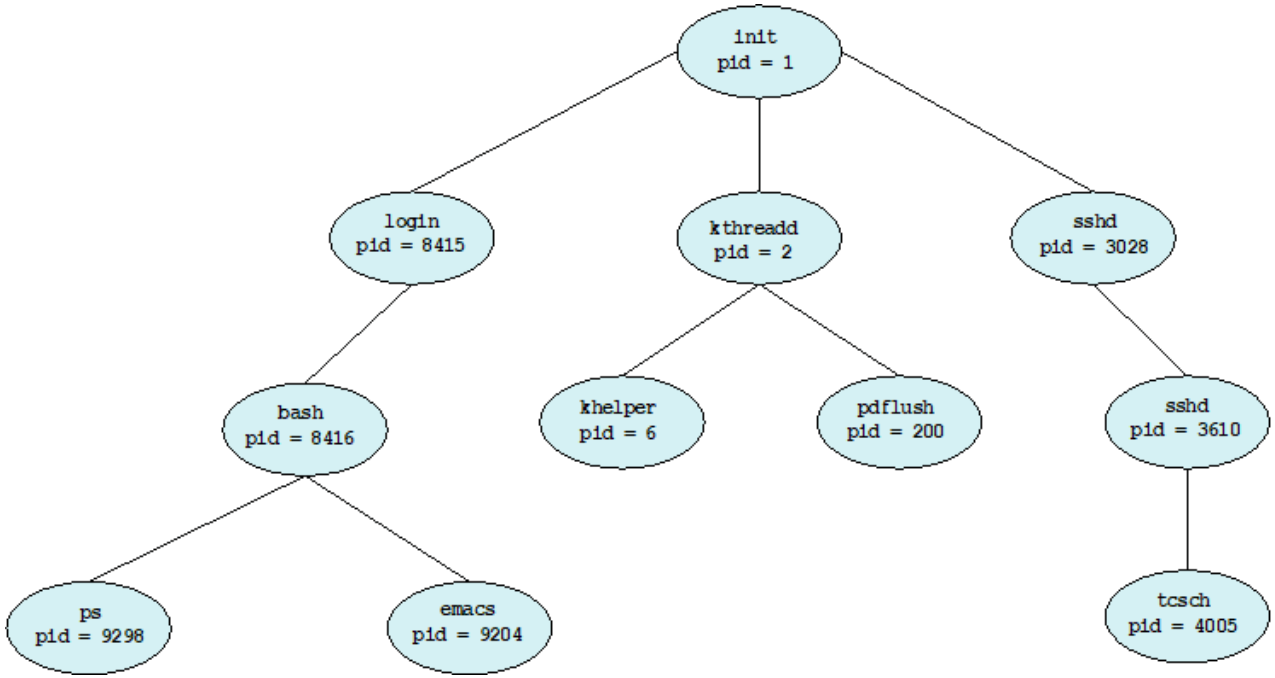
System must provide mechanisms for:

- process creation,
- process termination,
- and so on as detailed next

Process Creation

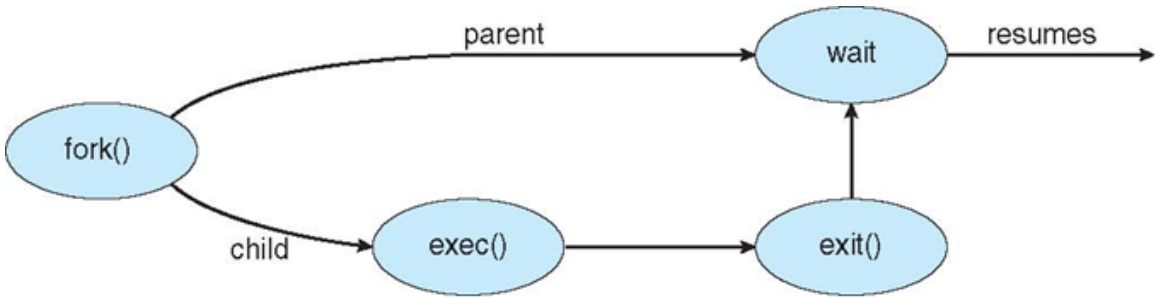
- Parent process create children processes, which, in turn create other processes, forming a tree of processes
- Generally, process identified and managed via a process identifier (pid)
- Resource sharing options
  - Parent and children share all resources
  - Children share subset of parents resources
  - Parent and child share no resources
- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate

A Tree of Processes in Linux



Process Creation

- 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



C Program Forking Separate Process


```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>

int main()
{
pid_t pid;

    /* fork a child process */
    pid = fork();

    if (pid < 0) { /* error occurred */
       fprintf(stderr, "Fork Failed");
       return 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");
    }

    return 0;
}
```

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

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**

Multiprocess Architecture Chrome Browser

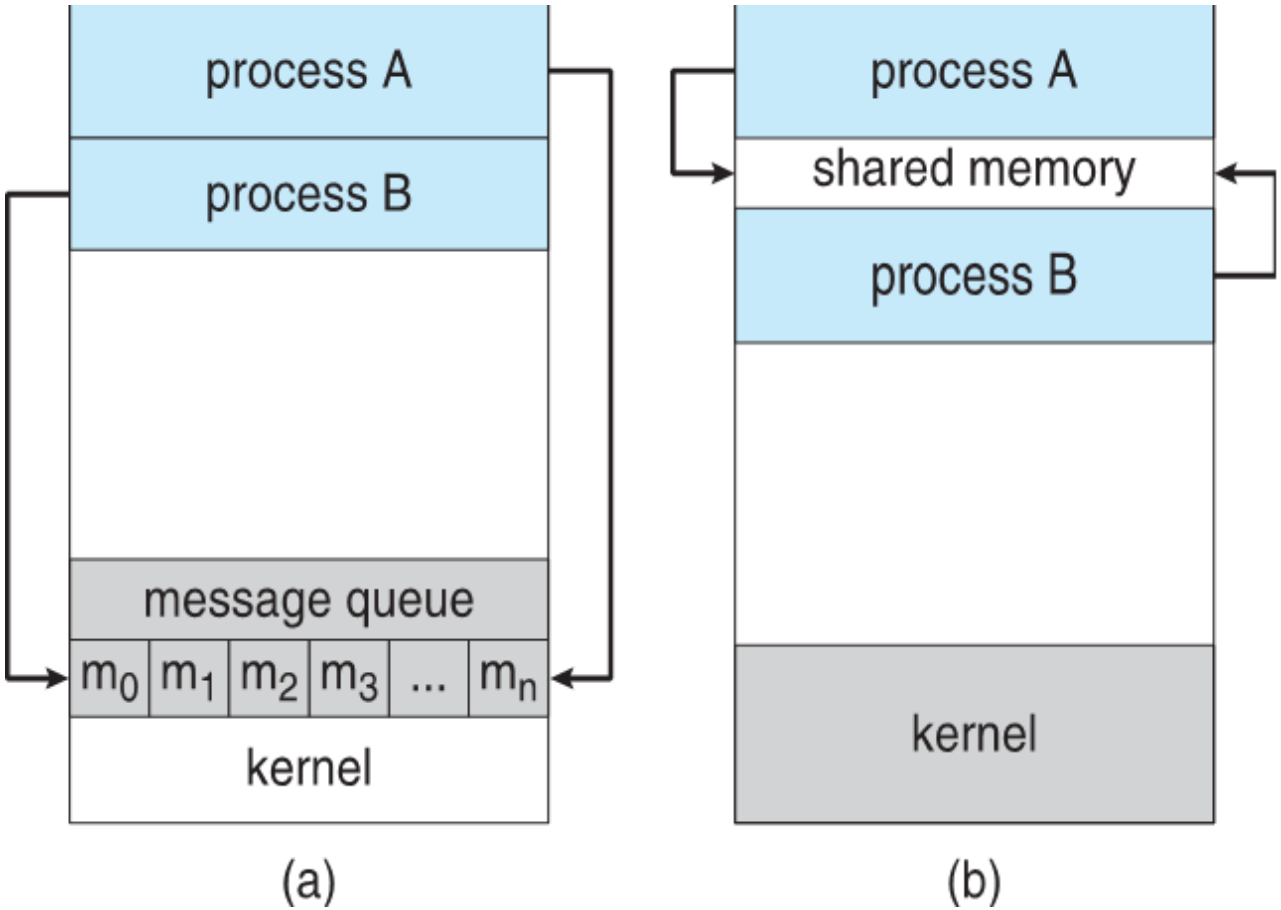
- Many web browsers ran as single process (some still do)
- If one web site causes trouble, entire browser can hang or crash
- Google Chrome Browser is multiprocess with 3 different types of processes:
- **Browser** process manages user interface, disk and network I/O
- process renders web pages, deals with HTML, Javascript. A new renderer created for each website opened
- Plug-in process for each type of plug-in

Presentation Outline

Interprocess Communication

- Processes within a system may be independent or cooperating
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication (IPC)**
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Communications Models



(a) Message passing. (b) shared memory.

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
- Solution is correct, but can only use BUFFER_SIZE-1 elements

```
#define BUFFER_SIZE 10
typedef struct {
. . .
} item;

item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

Bounded-Buffer Producer


```
        item next_produced;
        while (true) {
/* produce an item in next produced */
        while(((in + 1)% BUFFER_SIZE)==out);
         /* do nothing */
        buffer[in] = next_produced;
        in = (in + 1) % BUFFER_SIZE;
        }
```

Bounded-Buffer Consumer


```
item next_consumed;
while (true)
 {
     while (in == out);
      /* do nothing*/
     next_consumed = buffer[out];
     out = (out+1) % BUFFER_SIZE;
 /* consume the item in next consumed */
}
```

Interprocess Communication Shared Memory

- An area of memory shared among the processes that wish to communicate
- The communication is under the control of the users processes not the operating system.
- Major issue is to provide mechanism that will allow the user processes to synchronize their actions when they access shared memory.

Interprocess Communication Message Passing

- 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)*
  - *receive(message)*
- The message size is either fixed or variable

Message Passing

- If processes P and Q wish to communicate, they need to:
  - **Establish** a communication link between them
  - **Exchange messages** via send/receive
- Implementation issues:
  - 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?

Message Passing

Implementation of communication link

- Physical:
  - Shared memory
  - Hardware bus
  - Network
- Logical:
  - Direct or indirect
  - Synchronous or asynchronous
  - Automatic or explicit buffering

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 (port)
  - 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
  - P1, P2, and P3 share mailbox A
  - P1, sends; P2 and P3 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** – the sender is blocked until the message is received
  - **Blocking receive** – the receiver is blocked until a message is available
- Non-blocking is considered asynchronous
  - **Non-blocking send** – the sender sends the message and continue
  - **Non-blocking receive** – the receiver receives:
    A valid message, or
    Null message
- Different combinations possible
  If both send and receive are blocking, we have a rendezvous

Synchronization

- Producer-consumer becomes trivial

```
        message next_produced;
        while (true)
        {
/*produce an item in next produced*/
         send(next_produced);
        }
        message next_consumed;
        while (true) {
        receive(next_consumed);
/*consume the item in next consumed*/

        }
```

Buffering

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

1. **Zero capacity**: no messages are queued on a link. Sender must wait for receiver
2. **Bounded capacity**: finite length of n messages. Sender must wait if link full
3. **Unbounded capacity**: infinite length
   sender never waits.

Examples of IPC Systems - Mach

Mach communication is message based

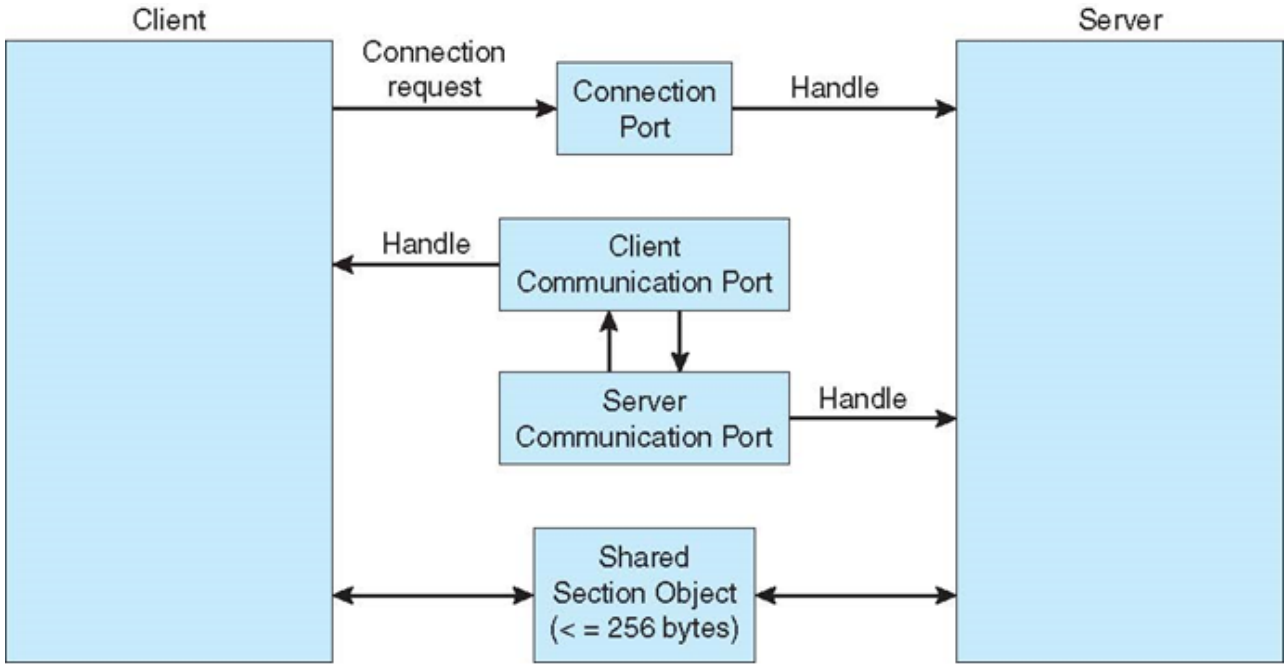
- Even system calls are messages
- Each task gets two mailboxes at creation- Kernel and Notify
- Only three system calls needed for message transfer msg_send(), msg_receive(), msg_rpc()
- Mailboxes needed for communication, created via port_allocate()
- Send and receive are flexible, for example four options if mailbox full:
  - Wait indefinitely
  - Wait at most n milliseconds
  - Return immediately
  - Temporarily cache a message

Examples of IPC Systems Windows

Message-passing centric via **advanced local procedure call (LPC)** facility

- Only works between processes on the same system
- Uses ports (like mailboxes) to establish and maintain communication channels
- Communication works as follows:
  - The client opens a handle to the subsystems **connection port** object.
  - The client sends a connection request.
  - The server creates two private **communication ports** and returns the handle to one of them to the client.
  - The client and server use the corresponding port handle to send messages or callbacks and to listen for replies

Local Procedure Calls in Windows



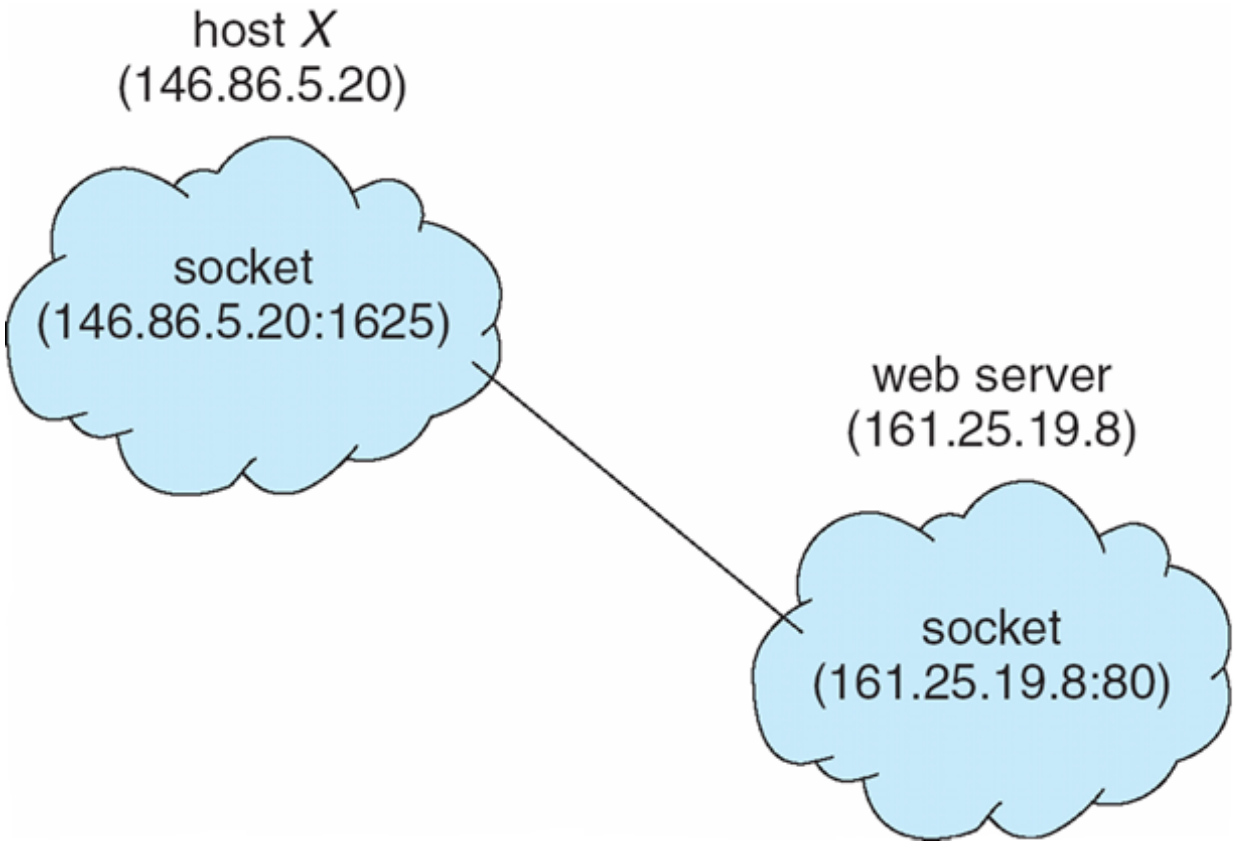
Communications in Client-Server Systems

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

Sockets

- A **socket** is defined as an endpoint for communication
- Concatenation of IP address and **port** - a number included at start of message packet to differentiate network services on a host
- The socket 161.25.19.8:1625 refers to port 1625 on host 161.25.19.8
- Communication consists between a pair of sockets
- All ports below 1024 are well known, used for standard services
- Special IP address 127.0.0.1 (**loopback**) to refer to system on which process is running

Socket Communication



Sockets in Java

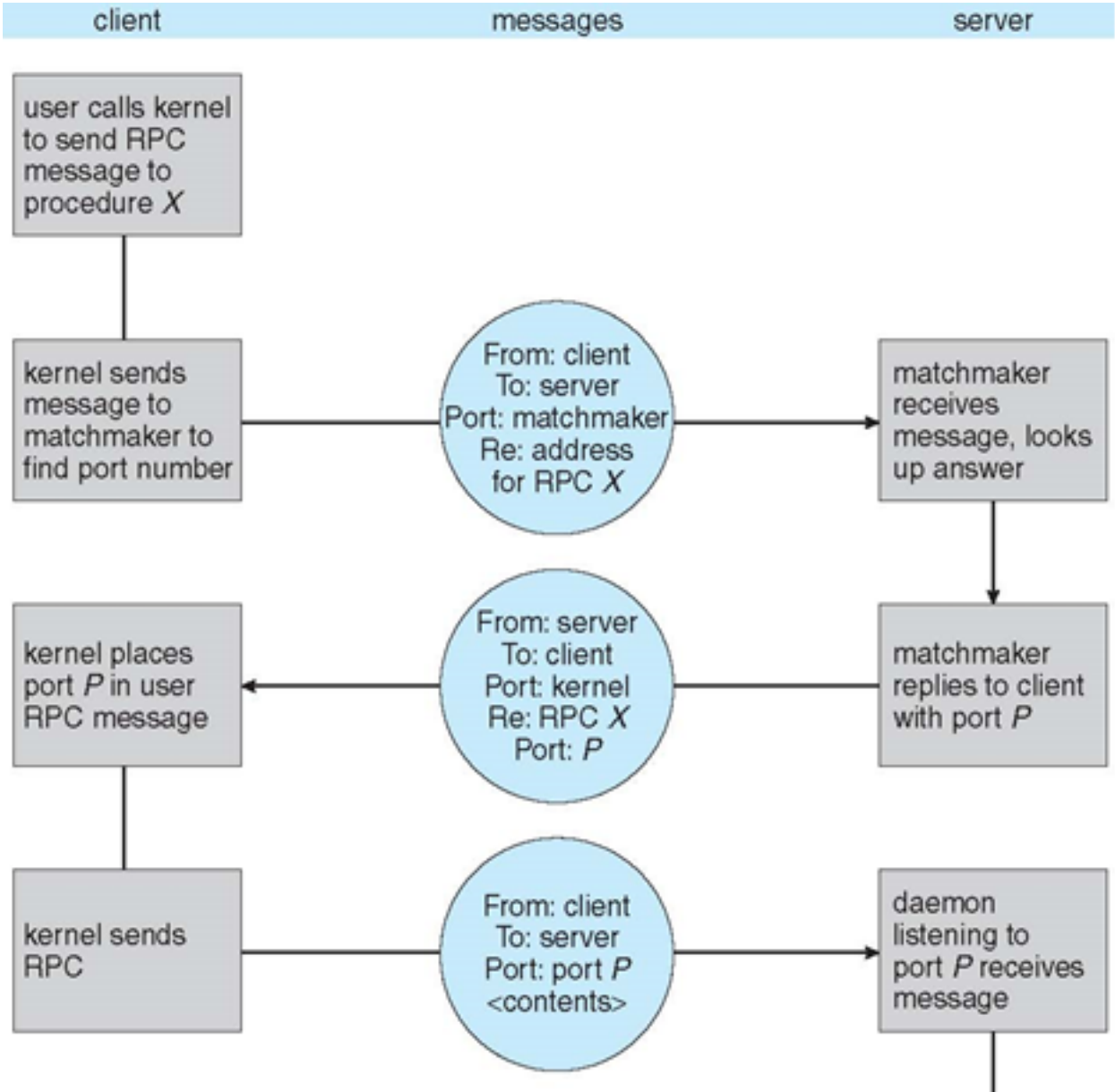
- Three types of sockets
- **Connection-oriented (TCP)**
- **Connectionless (UDP)**
- *MulticastSocket* class - data can be sent to multiple recipients

Remote Procedure Calls

- Remote procedure call (RPC) abstracts procedure calls between processes on networked systems
- Again uses ports for service differentiation
- **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 performs the procedure on the server
- On Windows, stub code compile from specification written in **Microsoft Interface Definition Language (MIDL)**

Remote Procedure Calls

- Data representation handled via **External Data Representation (XDL)** format to account for different architectures
- **Big-endian and little-endian**
- Remote communication has more failure scenarios than local
- Messages can be delivered **exactly once** rather than **at most once**
- OS typically provides a rendezvous (or **matchmaker**) service to connect client and server


client
messages
server
user calls kernel to send RPC message to procedure X
kernel sends message to matchmaker to find port number
From: client
To: server
Port: matchmaker
Re: address for RPC X
matchmaker receives message, looks up answer
kernel places port P in user RPC message
From: server
To: client
Port: kernel
Re: RPC X
Port: P
matchmaker replies to client with port P
kernel sends RPC
From: client
To: server
Port: port P
<contents>
daemon listening to port P receives message

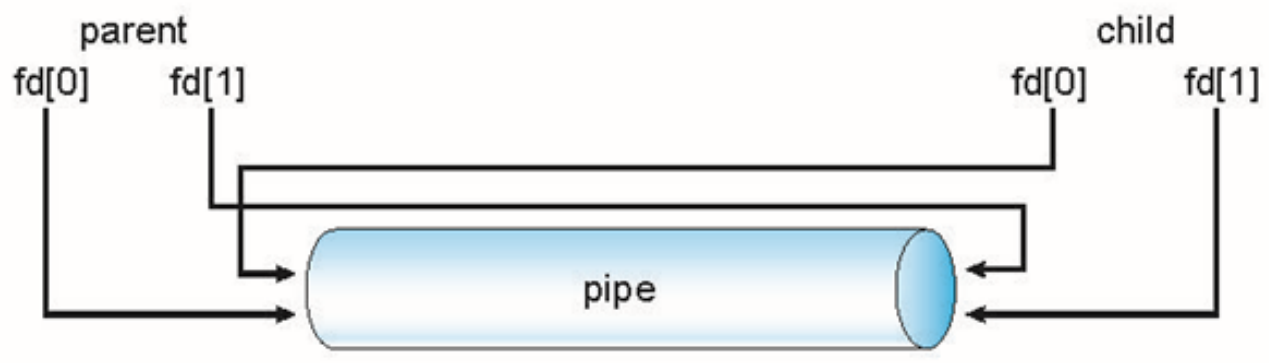
Pipes

Acts as a conduit allowing two processes to communicate
Issues:

- Is communication unidirectional or bidirectional?
- In the case of two-way communication, is it half or full-duplex?
- Must there exist a relationship (i.e., parent-child) between the communicating processes?
- Can the pipes be used over a network?
- Ordinary pipes cannot be accessed from outside the process that created it.
- Typically, a parent process creates a pipe and uses it to communicate with a child process that it created.
- Named pipes can be accessed without a parent-child relationship.

Ordinary Pipes

- Ordinary Pipes allow communication in standard producer-consumer style
- Producer writes to one end (the **write-end** of the pipe)
- Consumer reads from the other end (the **read-end** of the pipe)
- Ordinary pipes are therefore unidirectional
- Require parent-child relationship between communicating processes
- Windows calls these anonymous pipes



Named Pipes

- Named Pipes are more powerful than ordinary pipes
- Communication is bidirectional
- No parent-child relationship is necessary between the communicating processes
- Several processes can use the named pipe for communication
- Provided on both UNIX and Windows systems

Summary

- A process is a program in execution
- Each process may be in one of the following states: new, ready, running, waiting, or terminated.
- Each process is represented by a PCB
- Long-term scheduling, Short-term scheduling
- The processes may be either independent processes or cooperating processes
- Communication is achieved through two schemes: shared memory and message passing.
- Communication in clientserver systems may use sockets or remote procedure calls (RPCs).

Test your understanding

- Differences among short-term, medium-term, and longterm scheduling.
- When a process creates a new process using the *fork()* operation, which of the following states is shared between the parent process and the child process?
  a. Stack
  b. Heap
  c. Shared memory segments