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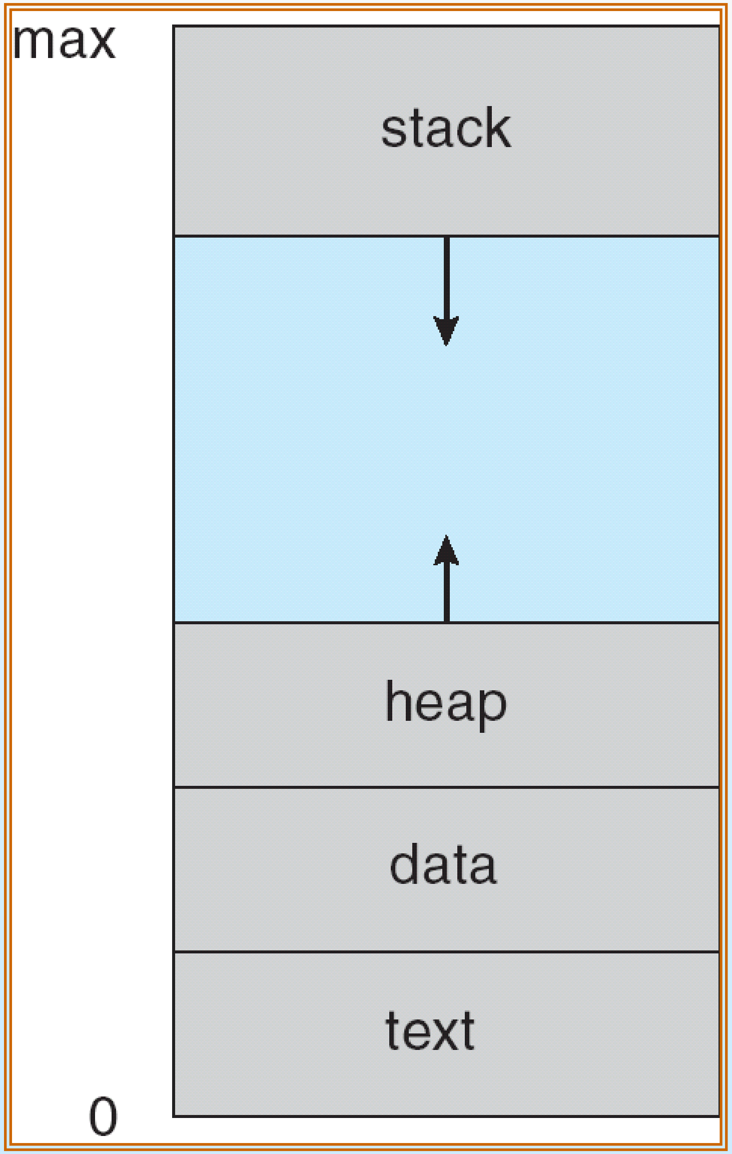
Chapter 3: Processes

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

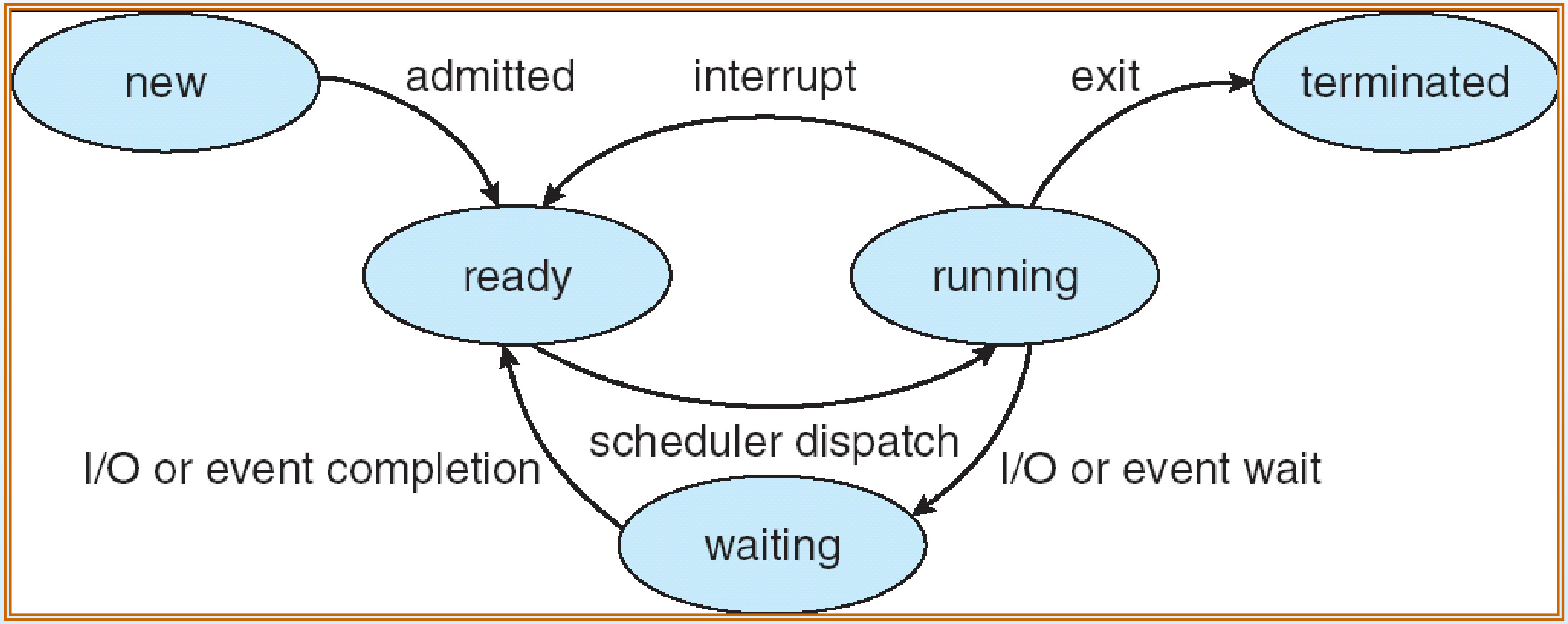
Process in Memory



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 process
  - **terminated**: The process has finished execution

Diagram of Process State

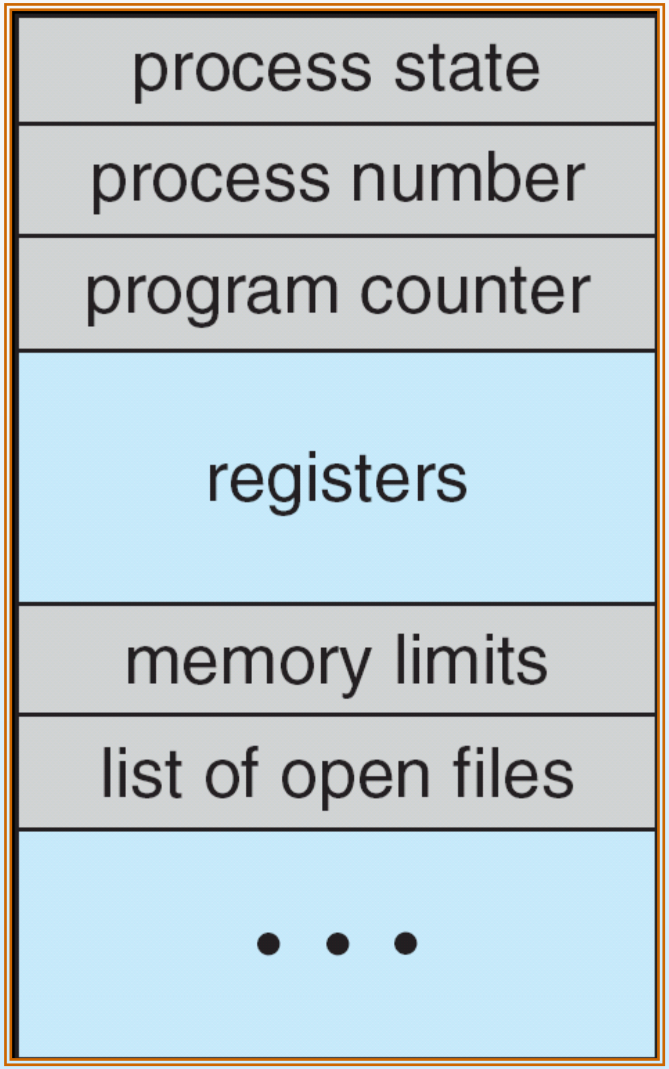


Process Control Block (PCB)

Information associated with each process

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

Process Control Block (PCB)



process state

process number

program counter

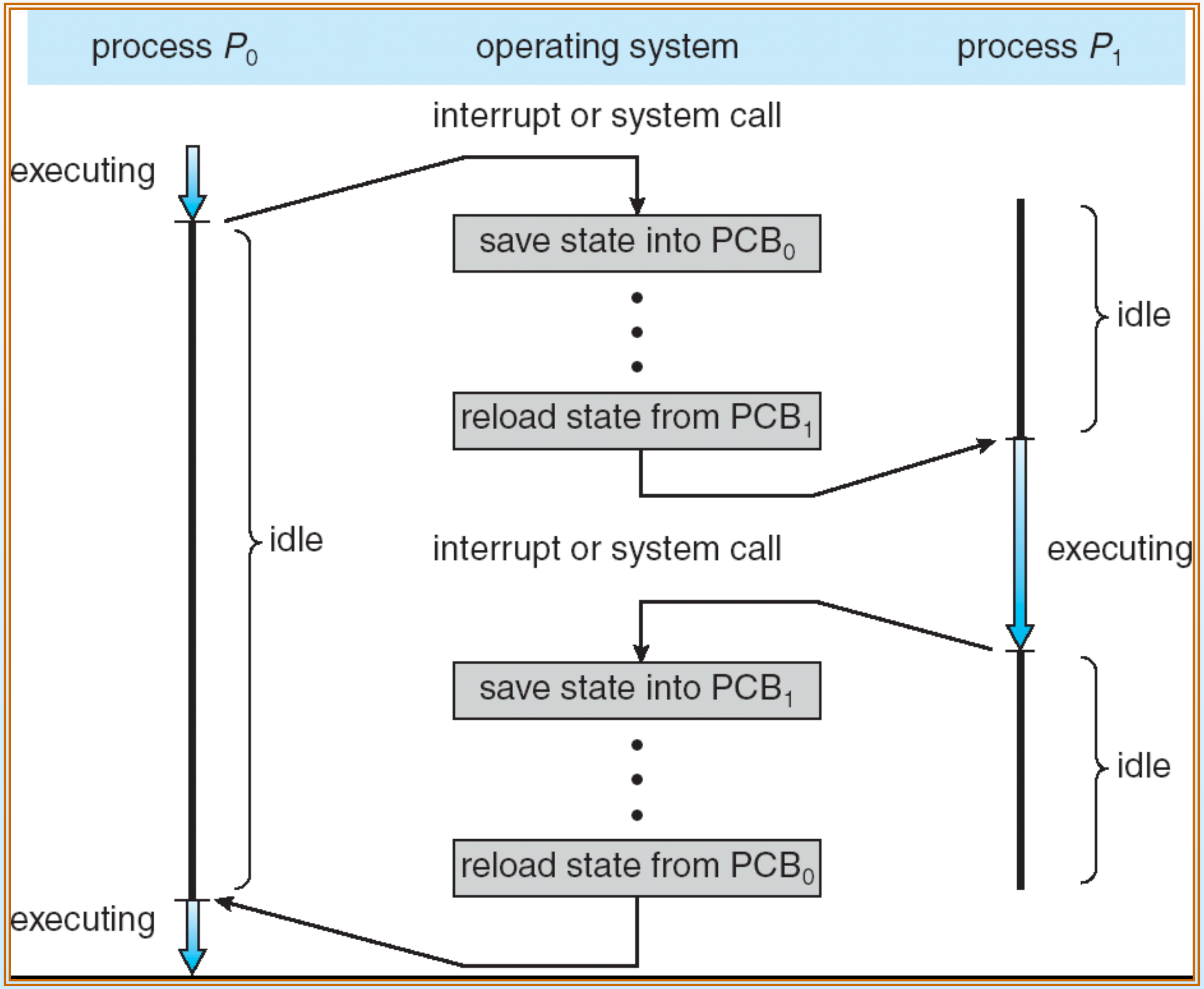
registers

memory limits

list of open files

• • •

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
- Processes migrate among the various queues

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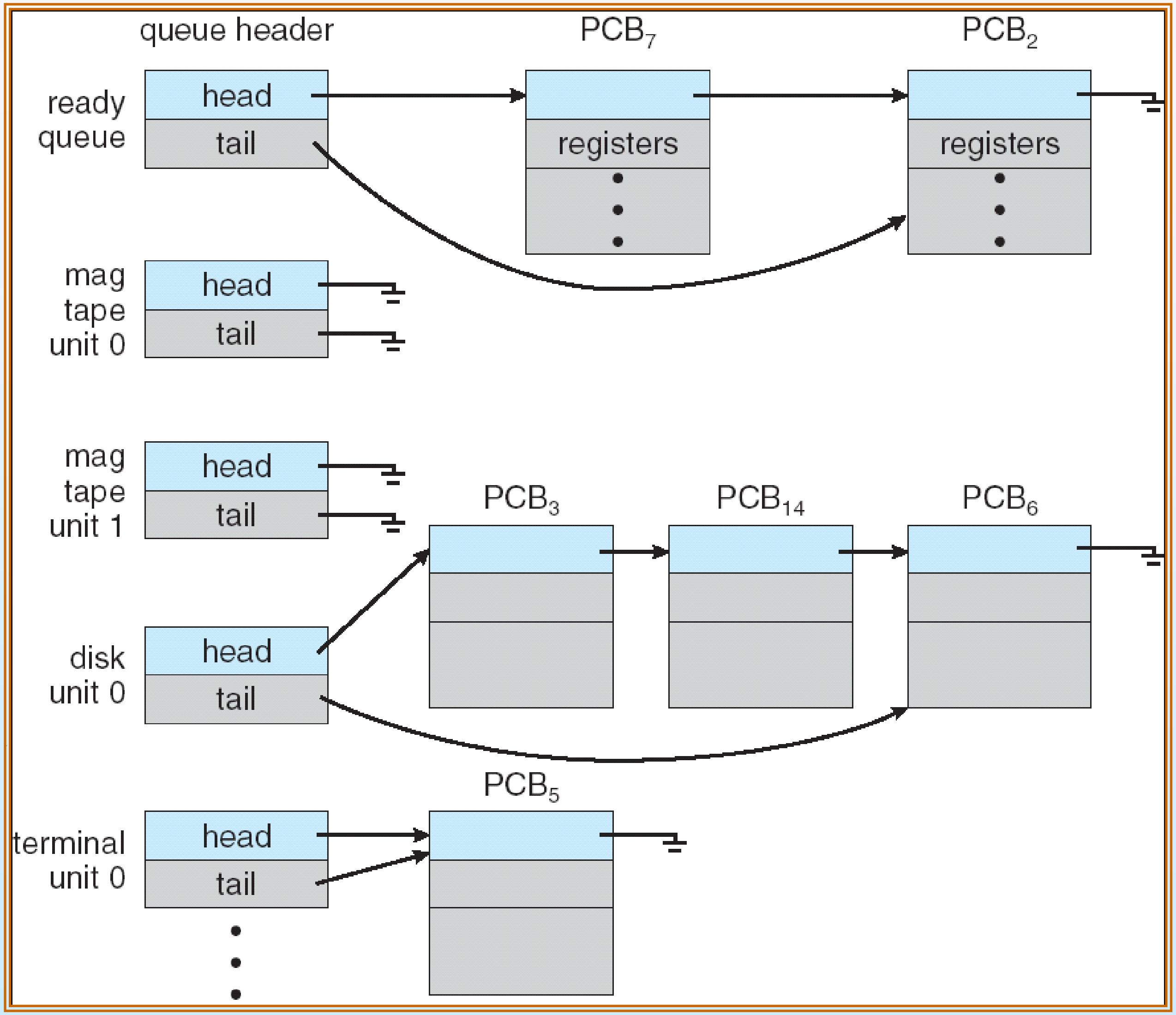
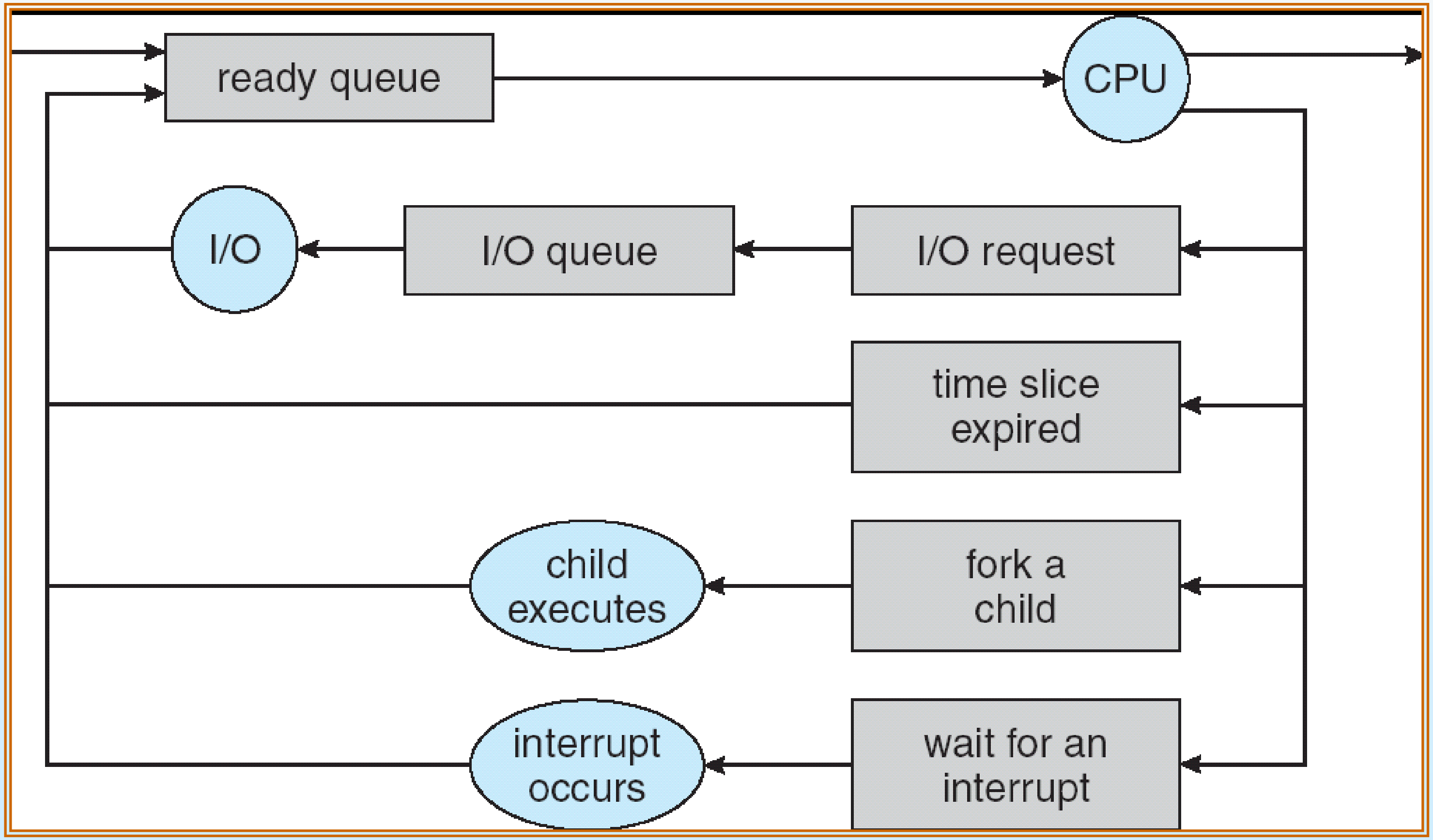
Ready Queue And Various I/O Device Queues



Representation of Process Scheduling

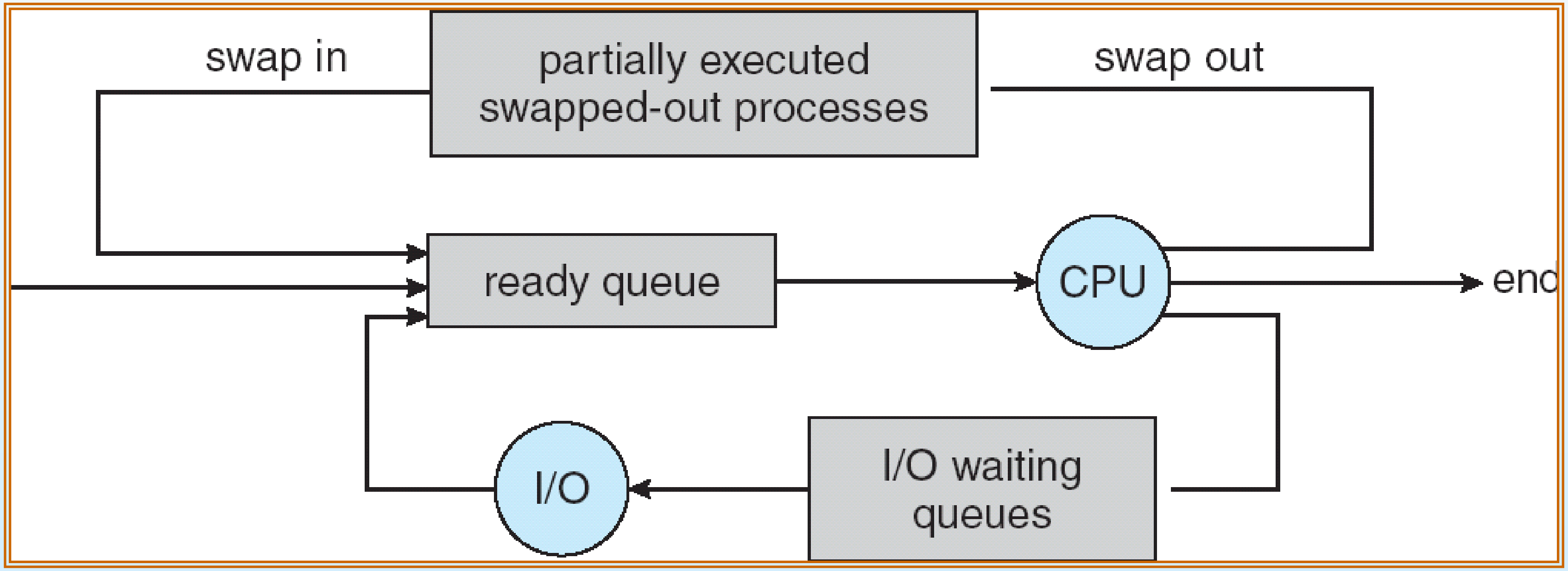


Schedulers

- **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 invoked very frequently (milliseconds) ⇒ (must be fast)
- Long-term scheduler invoked very infrequently (seconds, minutes) ⇒ (may be slow)
- Long-term scheduler controls *degree of multiprogramming*
- Mix of:
  - **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

- CPU switches to another process:
  - must save the state of the old process
  - load the saved state for the new process
- Context-switch time: **overhead**;
  - no useful work while switching
- Time dependent on hardware support

Process Creation

- Parent process create children processes, which, in turn create other processes (**tree** of processes)

- Resource sharing **POLICIES**
  - Parent/children **share all** resources
  - Children **share subset** of parent’s resources
  - Parent and child **share no** resources

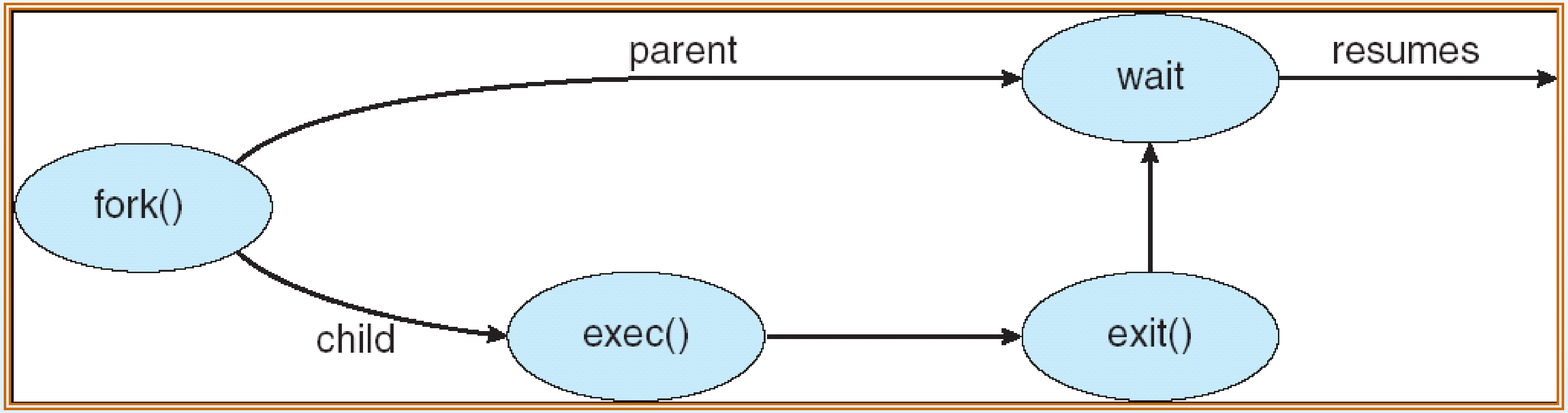
- Execution **POLICIES**
  - Parent and children execute **concurrently**
  - Parent **waits** until children terminate

Process Creation (Cont.)

- Address space **POLICIES**
  - Child **duplicate** of parent
  - Child has a **new program** loaded into it

- UNIX examples
  - **fork** system call creates new process
  - **exec** system call used (in general, after a **fork)** to replace process' memory space with a new program

Process Creation

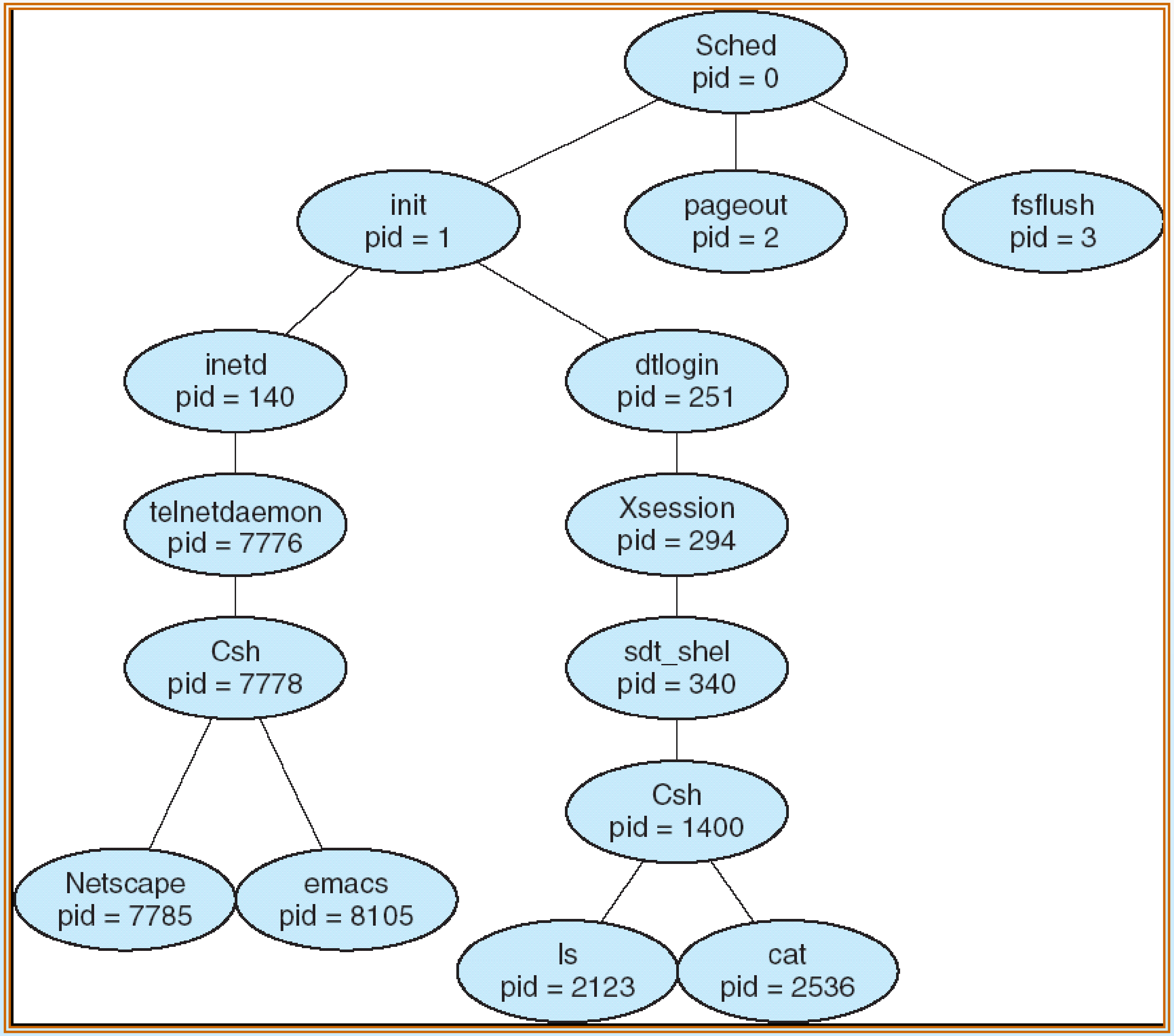


C Program Forking Separate Process

```
int main()  {
   Pid_t  pid;

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

A tree of processes on a typical Solaris



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
  - If parent is exiting
    - Some operating system do not allow child to continue if its parent terminates
      - All children terminated - *cascading termination*

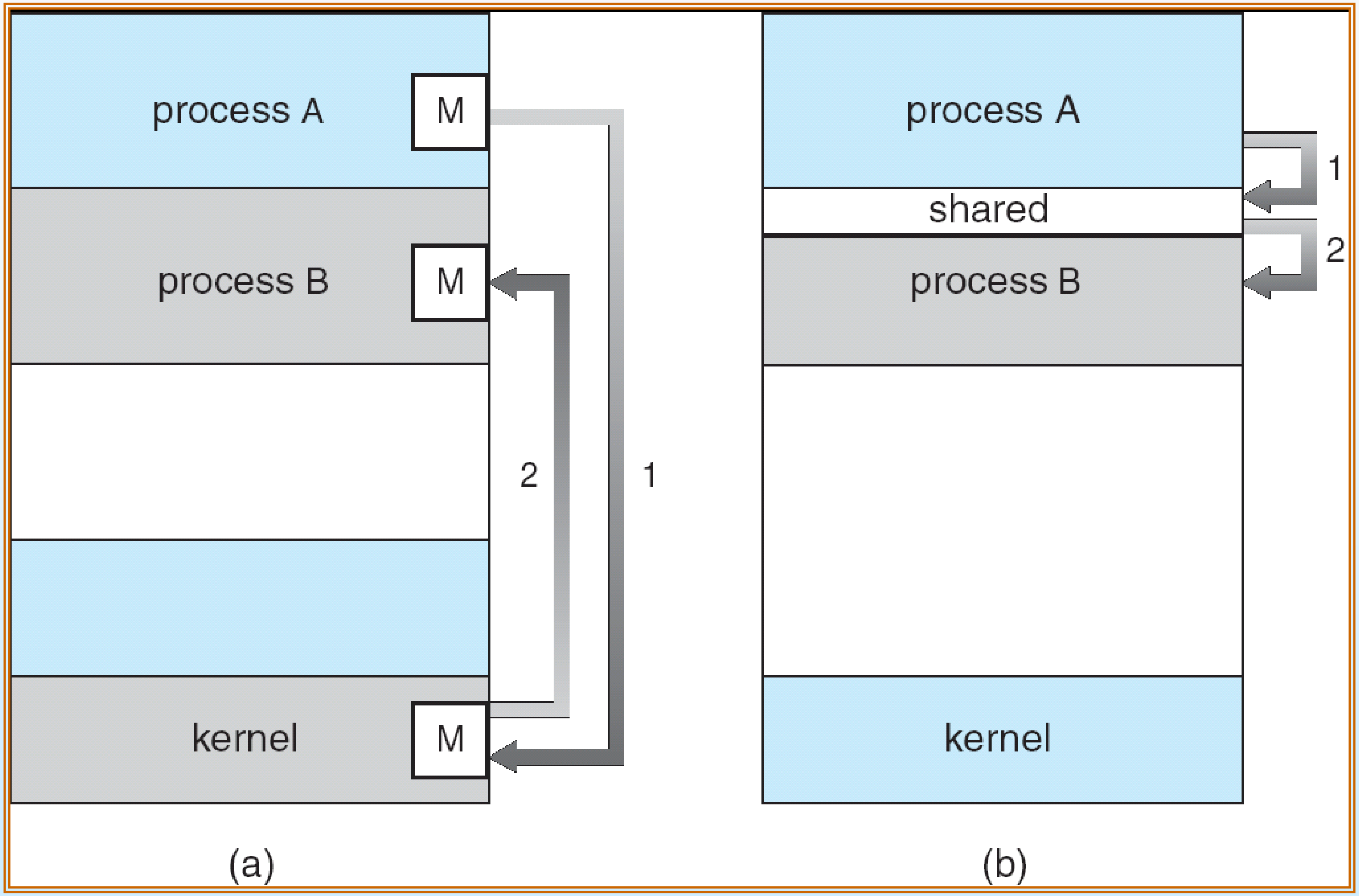
Interprocess Communication (IPC)

- Mechanism for processes to communicate and synchronize their actions
- Message passing – 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 for the fixed or variable?
- Is a link unidirectional or bi-directional?

Communications Models



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 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/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

Client-Server Communication

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

Sockets

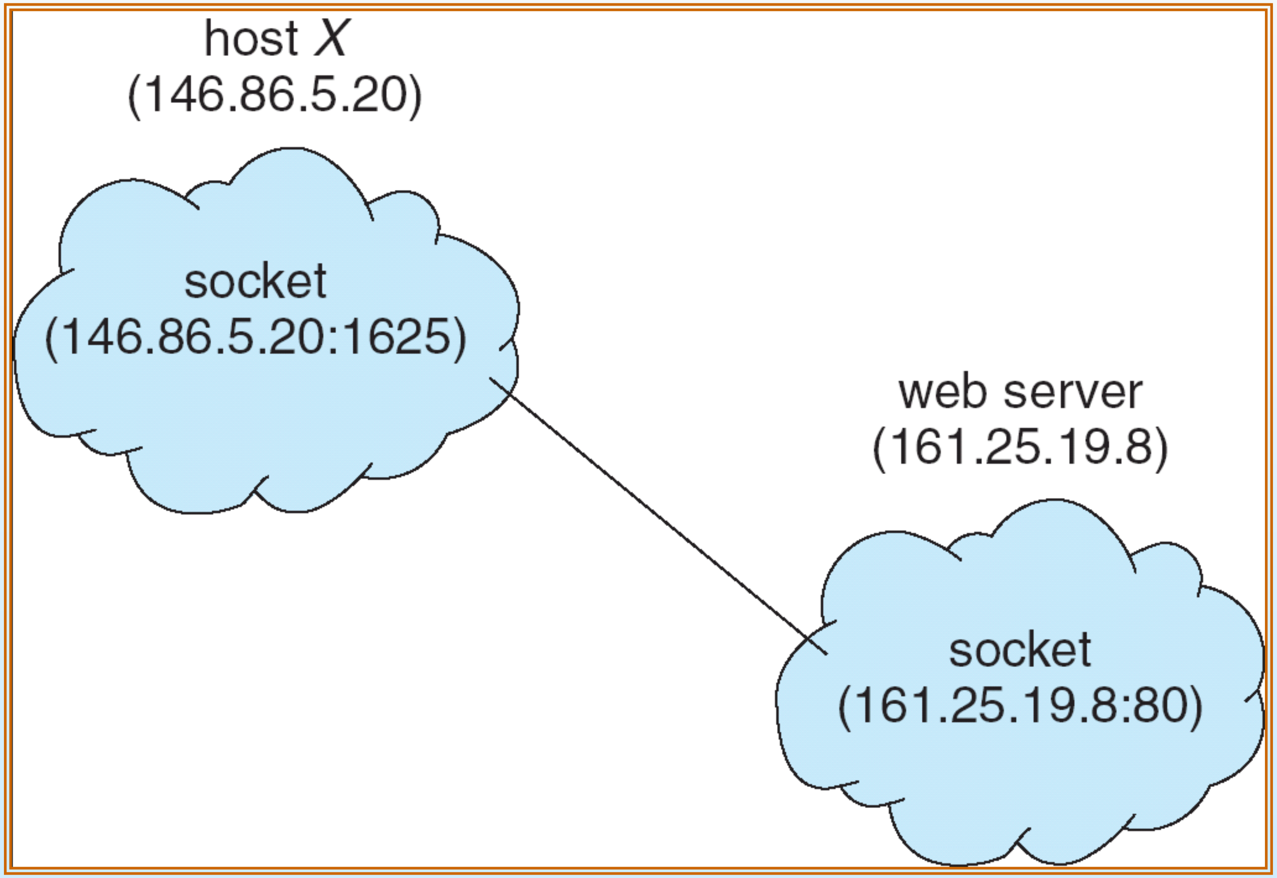
- A socket is defined as an *endpoint for communication*

- 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 (RPC)

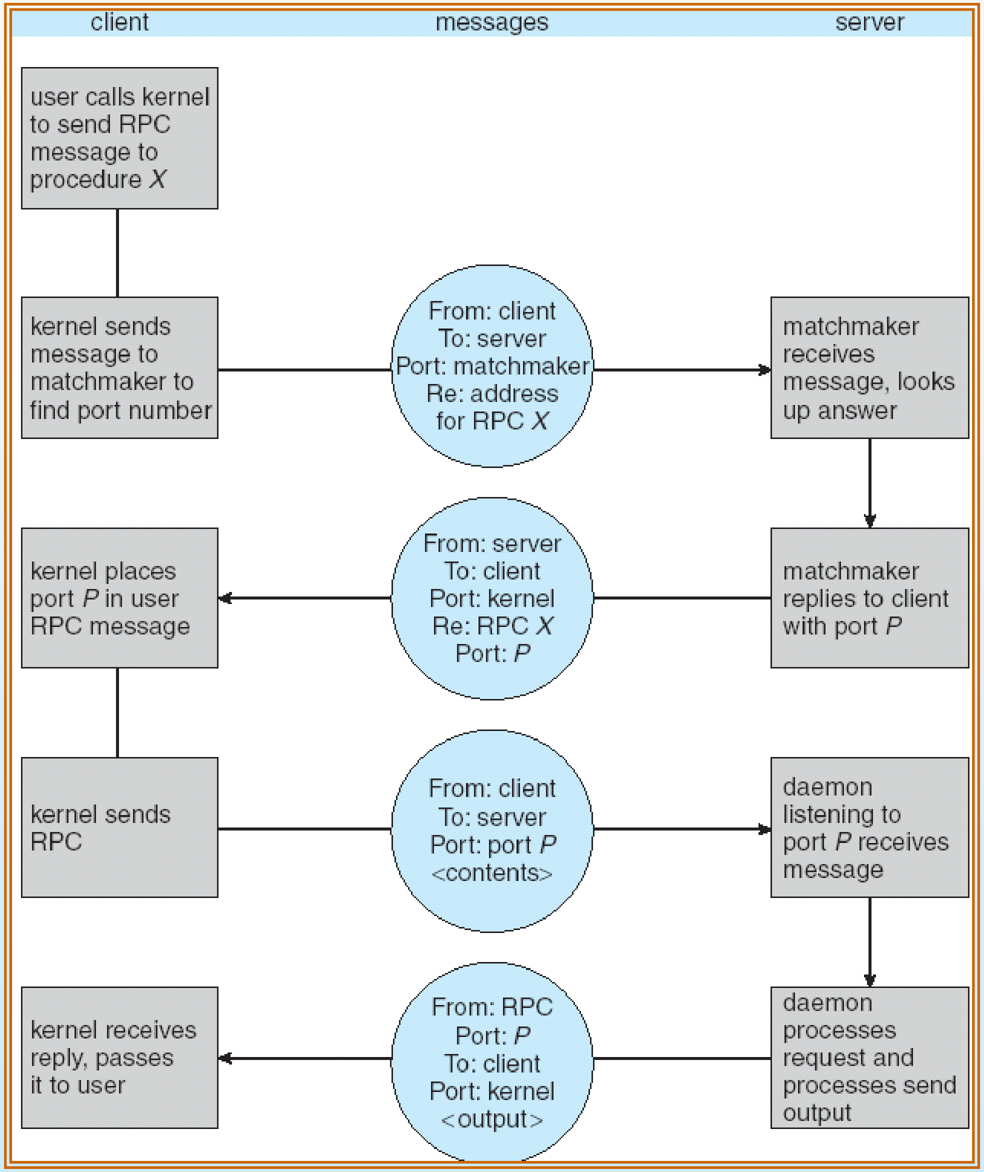
- RPC abstracts procedure calls between processes on networked systems.

- **Stubs** – client-side proxy for the actual procedure on the server.

- The client-side stub locates the server and *marshalls* the parameters.

- Server-side stub receives this message, unpacks the marshalled parameters, and performs the procedure on the server.

Execution of RPC



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

matchmaker replies to client with port *P*

From: server
To: client
Port: kernel
Re: RPC *X*
Port: *P*

kernel places port *P* in user RPC message

kernel sends RPC

From: client
To: server
Port: port *P*
<contents>

daemon listening to port *P* receives message

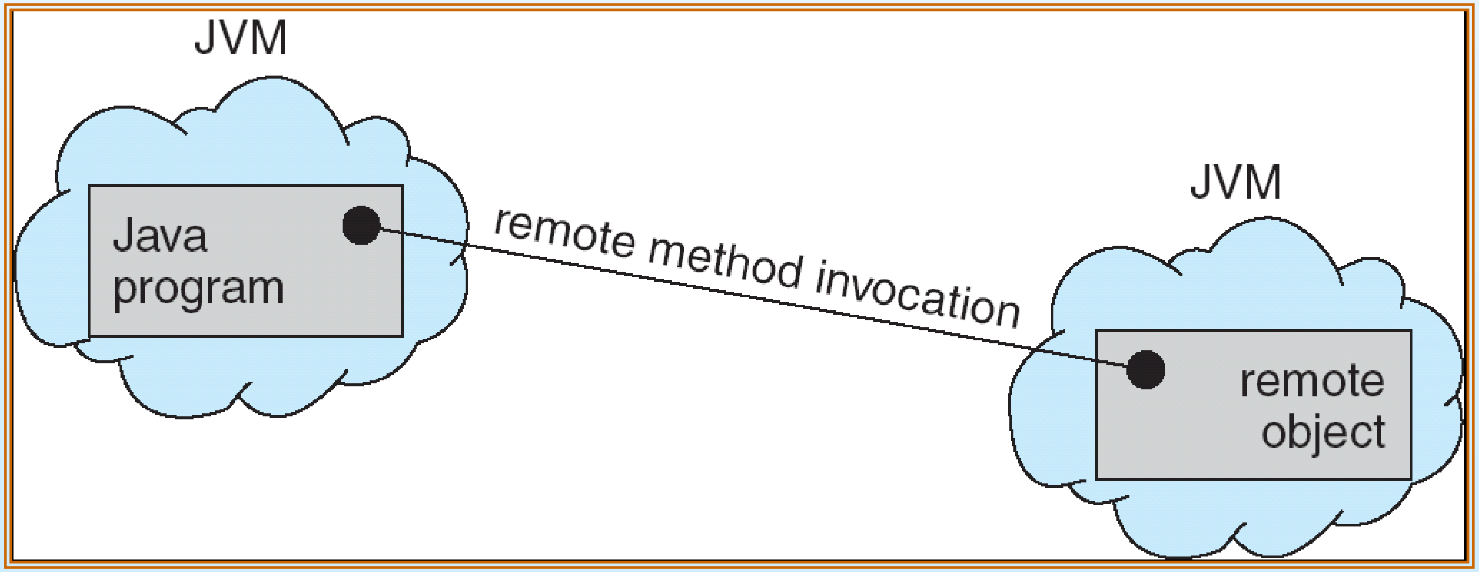
daemon processes request and processes send output

From: RPC
Port: *P*
To: client
Port: kernel
<output>

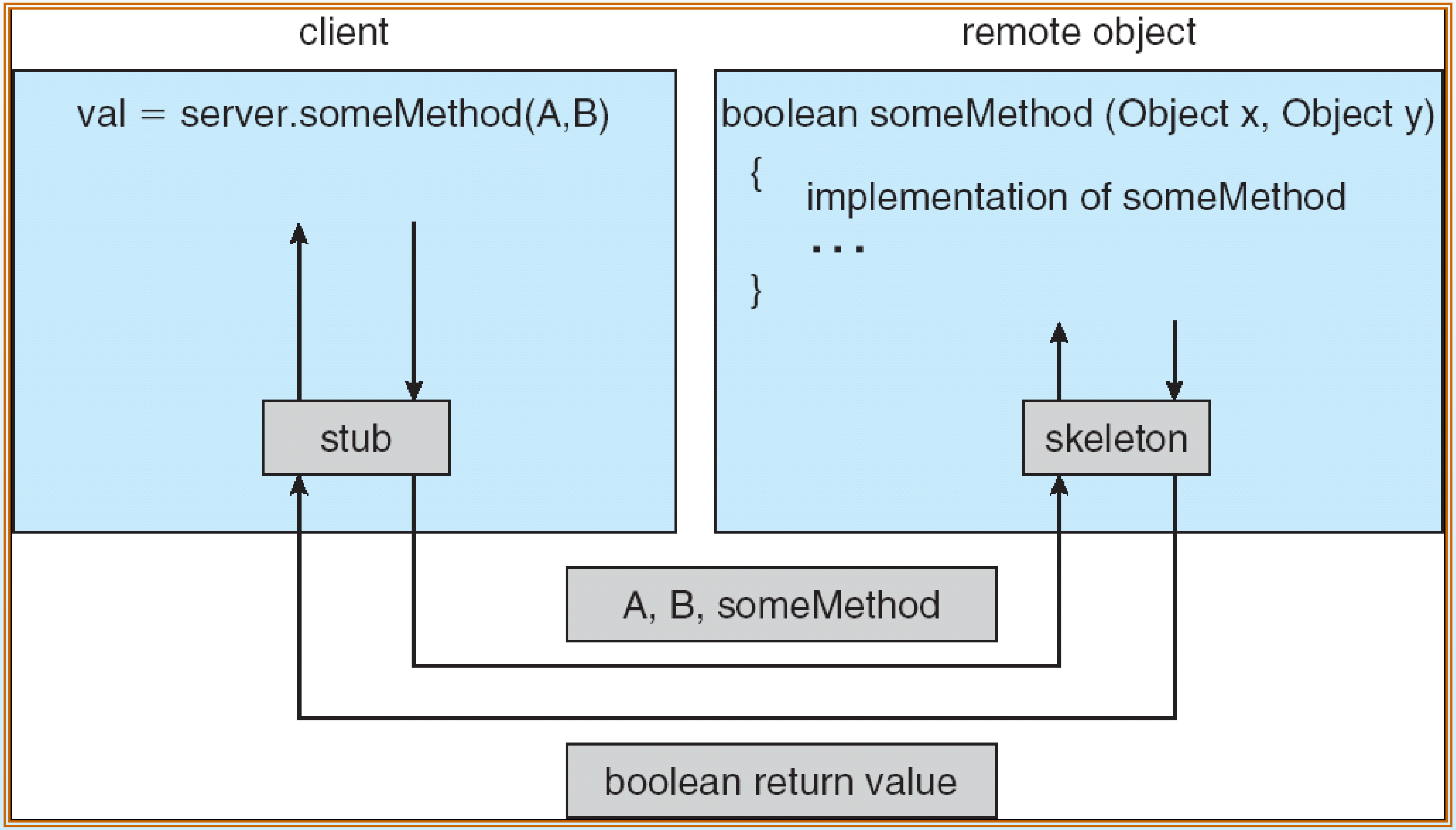
kernel receives reply, passes it to user

Remote Method Invocation (RMI)

- 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


client
remote object
val = server.someMethod(A,B)
boolean someMethod (Object x, Object y)
{
implementation of someMethod
. . .
}
stub
skeleton
A, B, someMethod
boolean return value

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End of Chapter 3