Contents

Chapter 3
Process Concept

Processes

- Objective:
  - Process Concept & Definitions
- Process Classification:
  - Operating system processes executing system code
  - User processes executing system code
  - User processes executing user code

Processes

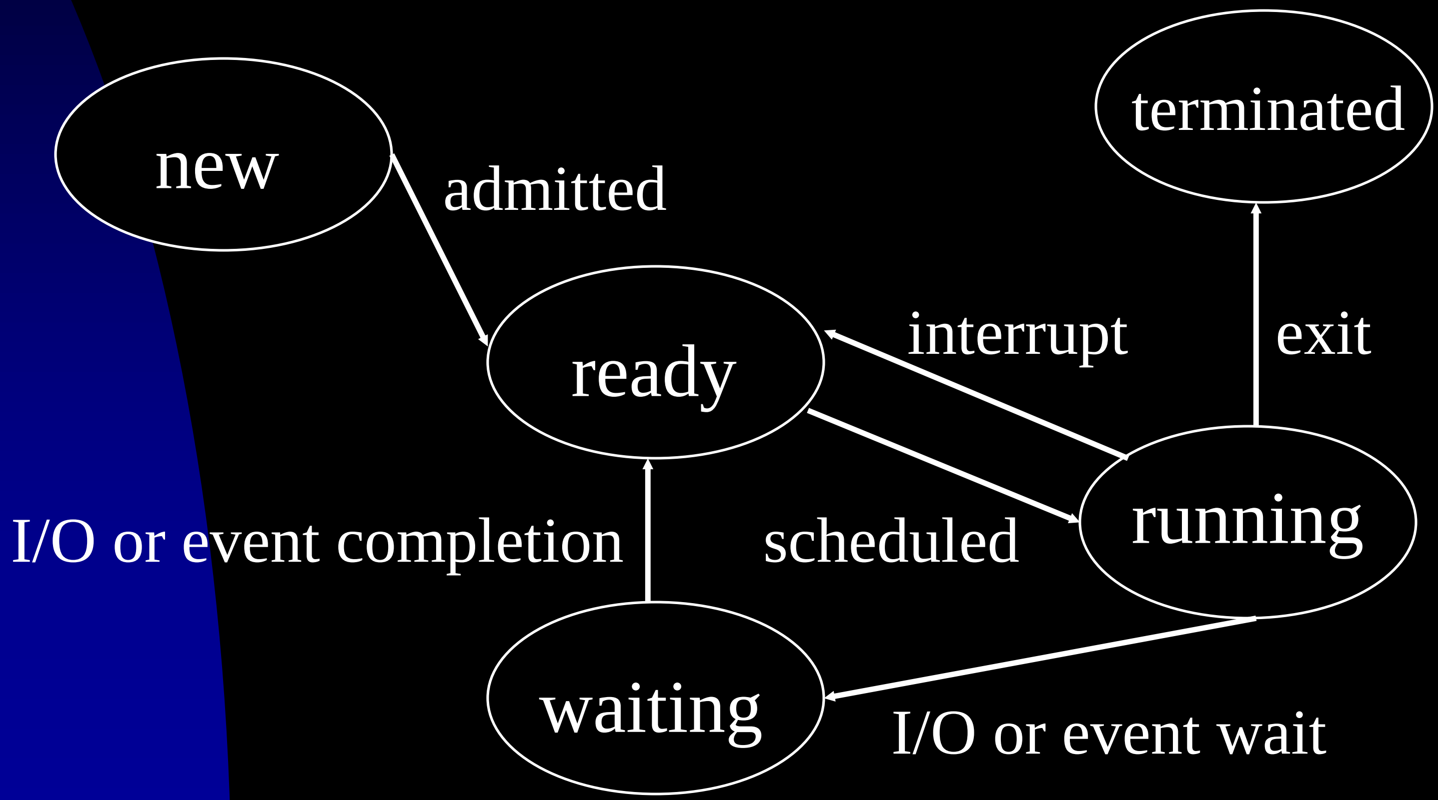
- Example: Special Processes in Unix
  - PID 0 – *Swapper* (i.e., the scheduler)
    - Kernel process
    - No program on disks correspond to this process
  - PID 1 – *init* responsible for bringing up a Unix system after the kernel has been bootstrapped. (/etc/rc* & init or /sbin/rc* & init)
    - User process with superuser privileges
  - PID 2 - pagedaemon responsible for paging
    - Kernel process

Processes

- Process
  - A Basic Unit of Work from the Viewpoint of OS
  - Types:
    - Sequential processes: an activity resulted from the execution of a program by a processor
    - Multi-thread processes
  - An Active Entity
    - Program Code – A Passive Entity
    - Stack and Data Segments
  - The Current Activity context
    - PC, Registers, Contents in the Stack and Data Segments

Processes

- Process State

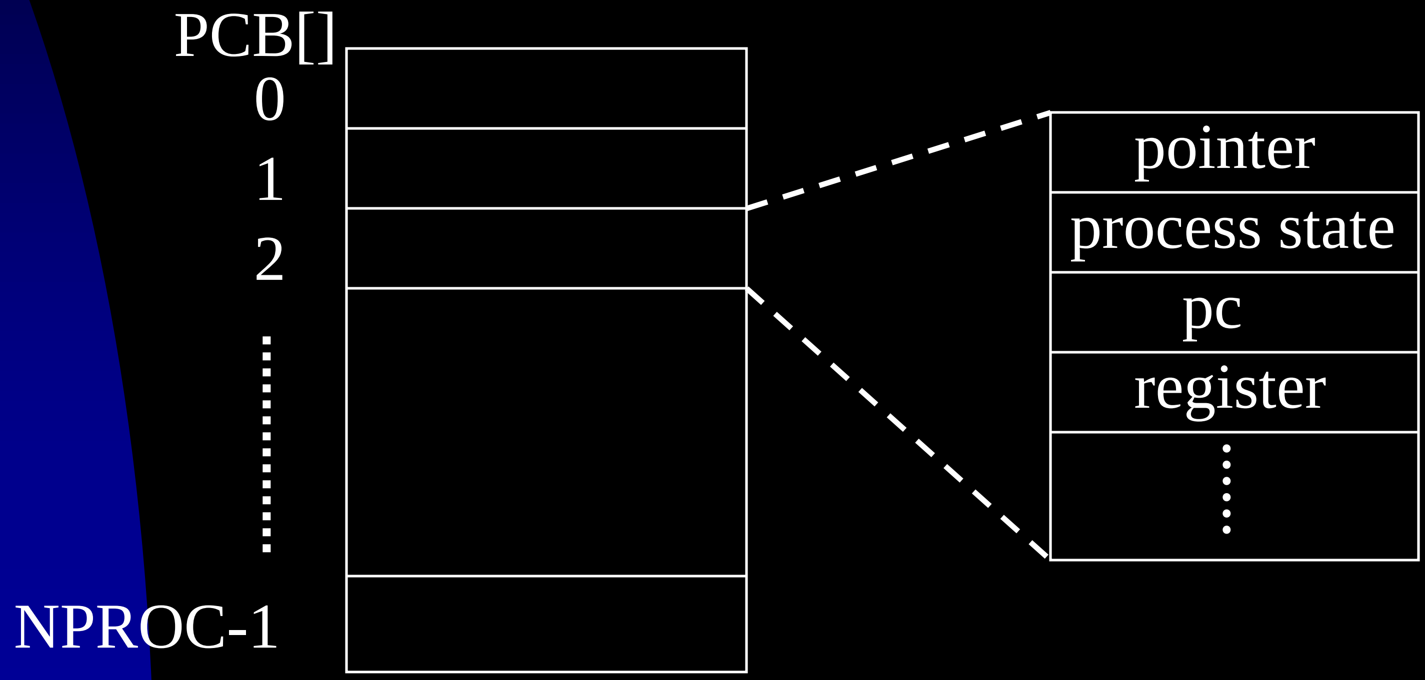


Processes

- Process Control Block (PCB)
  - Process State
  - Program Counter
  - CPU Registers
  - CPU Scheduling Information
  - Memory Management Information
  - Accounting Information
  - I/O Status Information

Processes

- PCB: The repository for any information that may vary from process to process

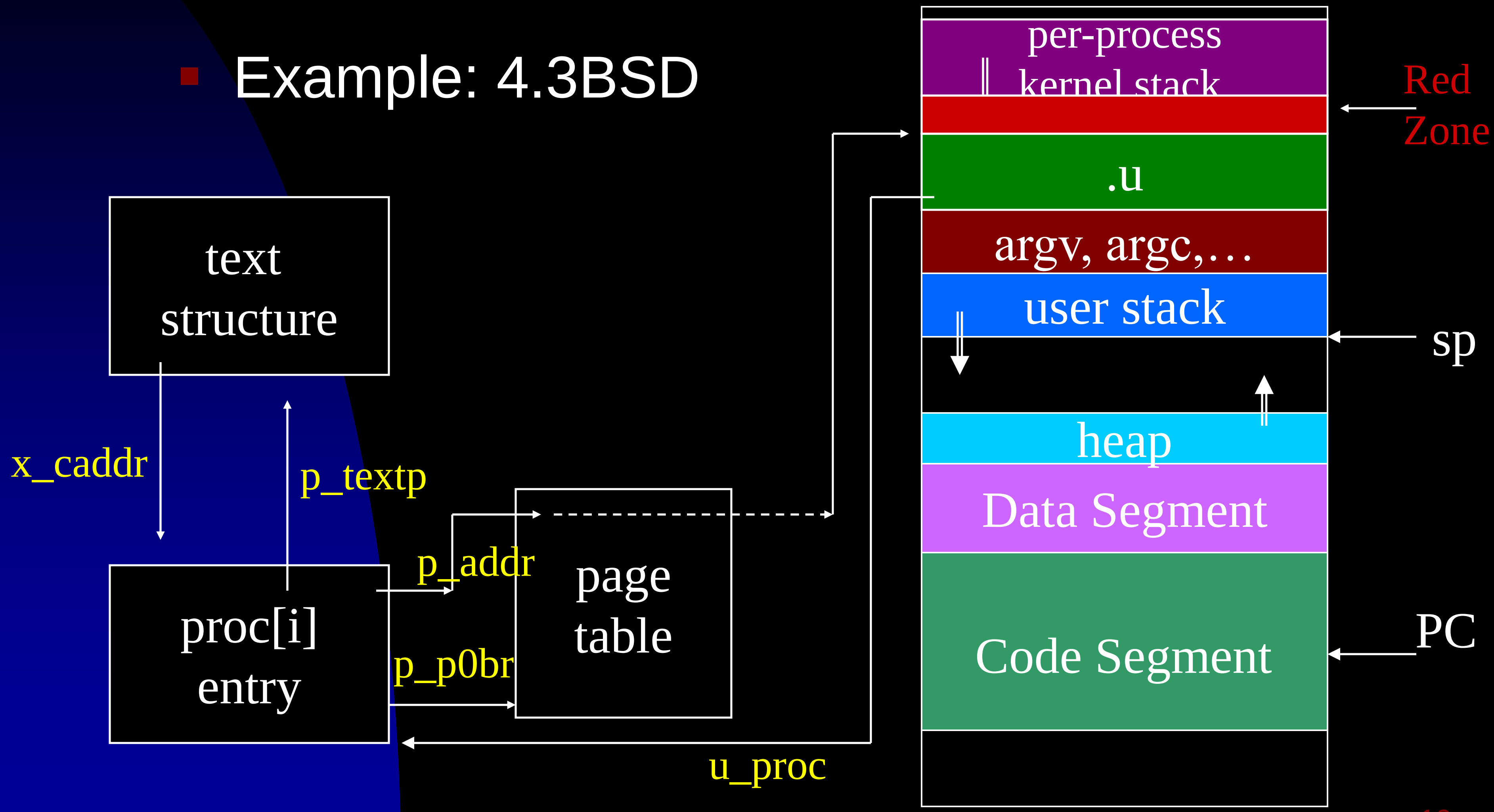


Processes

- Process Control Block (PCB) – An Unix Example
  - proc[i] 不論 run 或 wait 都要知道
    - Everything the system must know even when the process is swapped out.
      - pid, priority, state, timer counters, etc.
  - .u
    - Things the system should know when a process is running
      - signal disposition, statistics accounting, files[], etc.

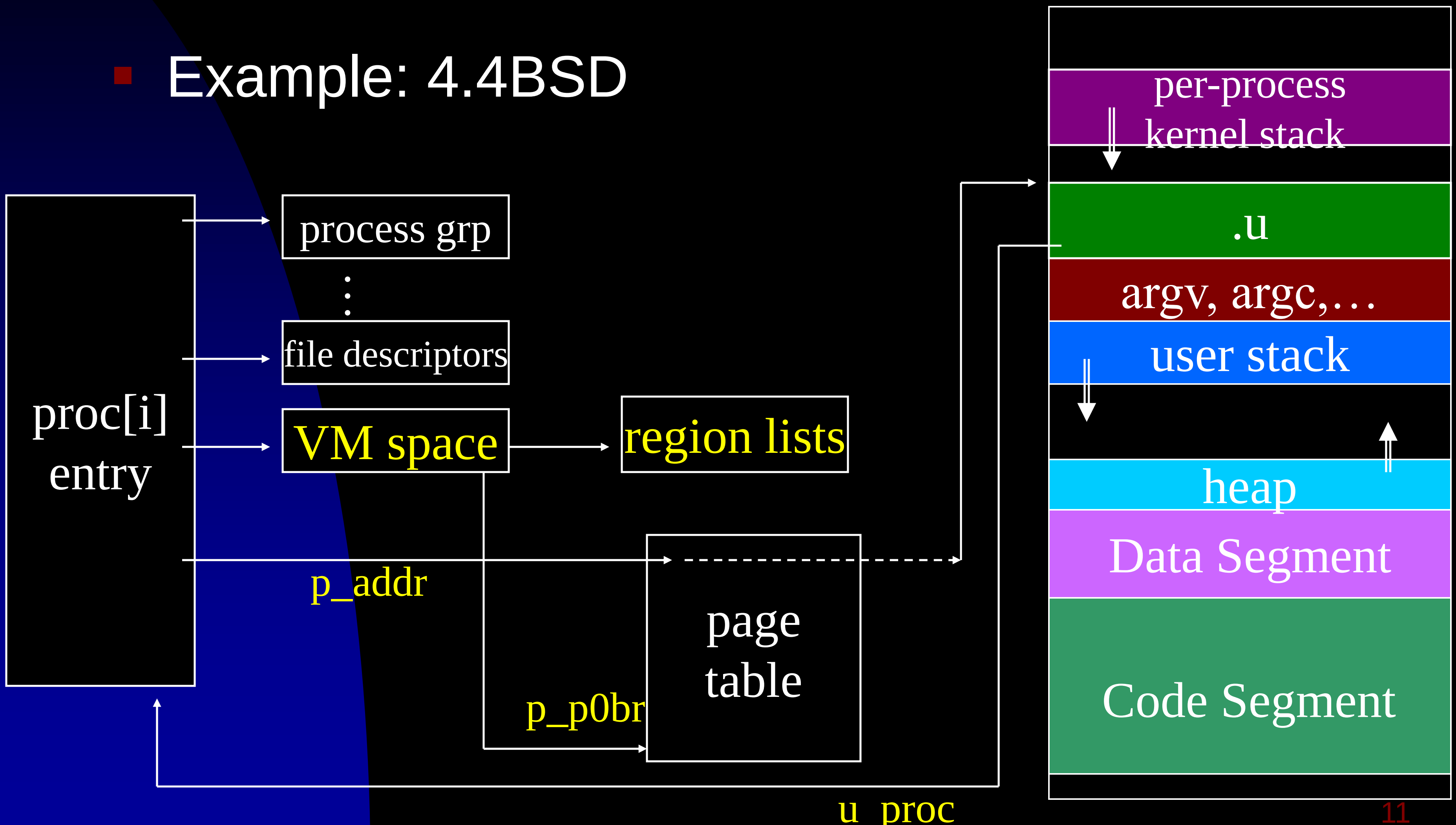
Processes

- Example: 4.3BSD



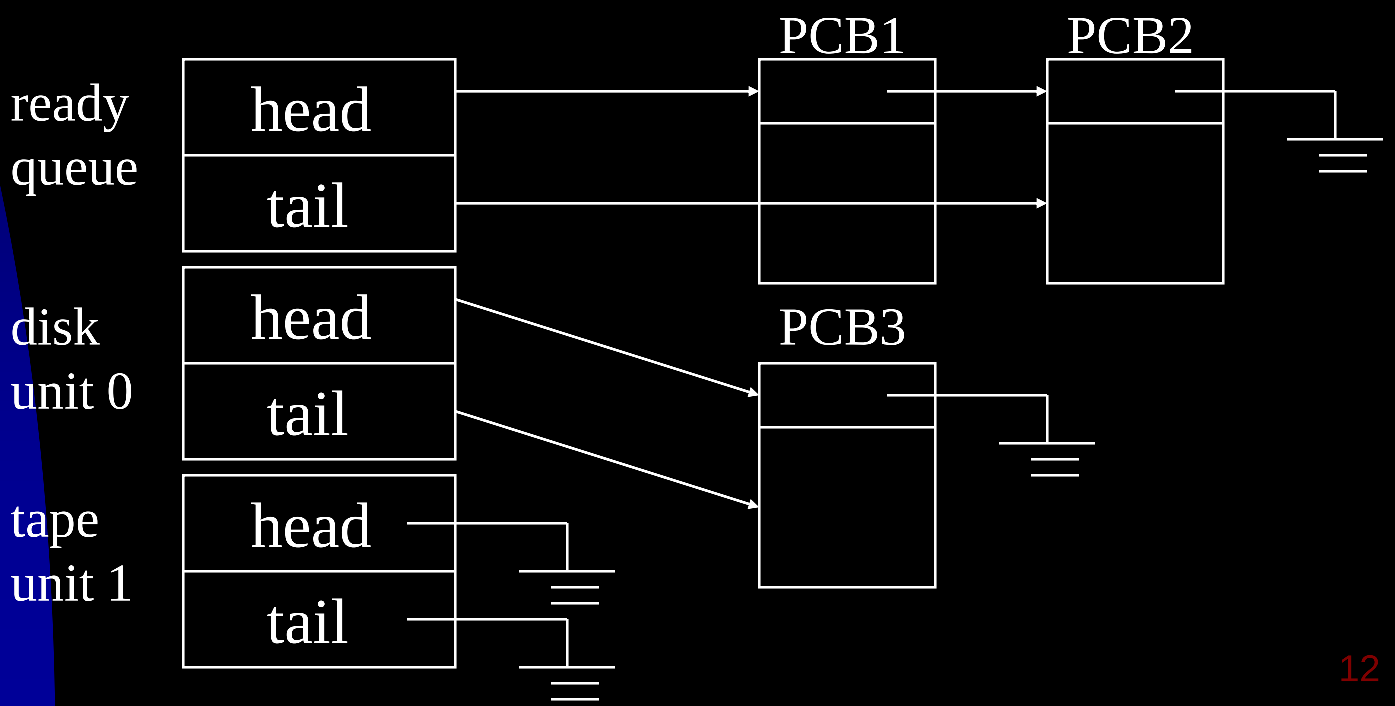
Processes

- Example: 4.4BSD

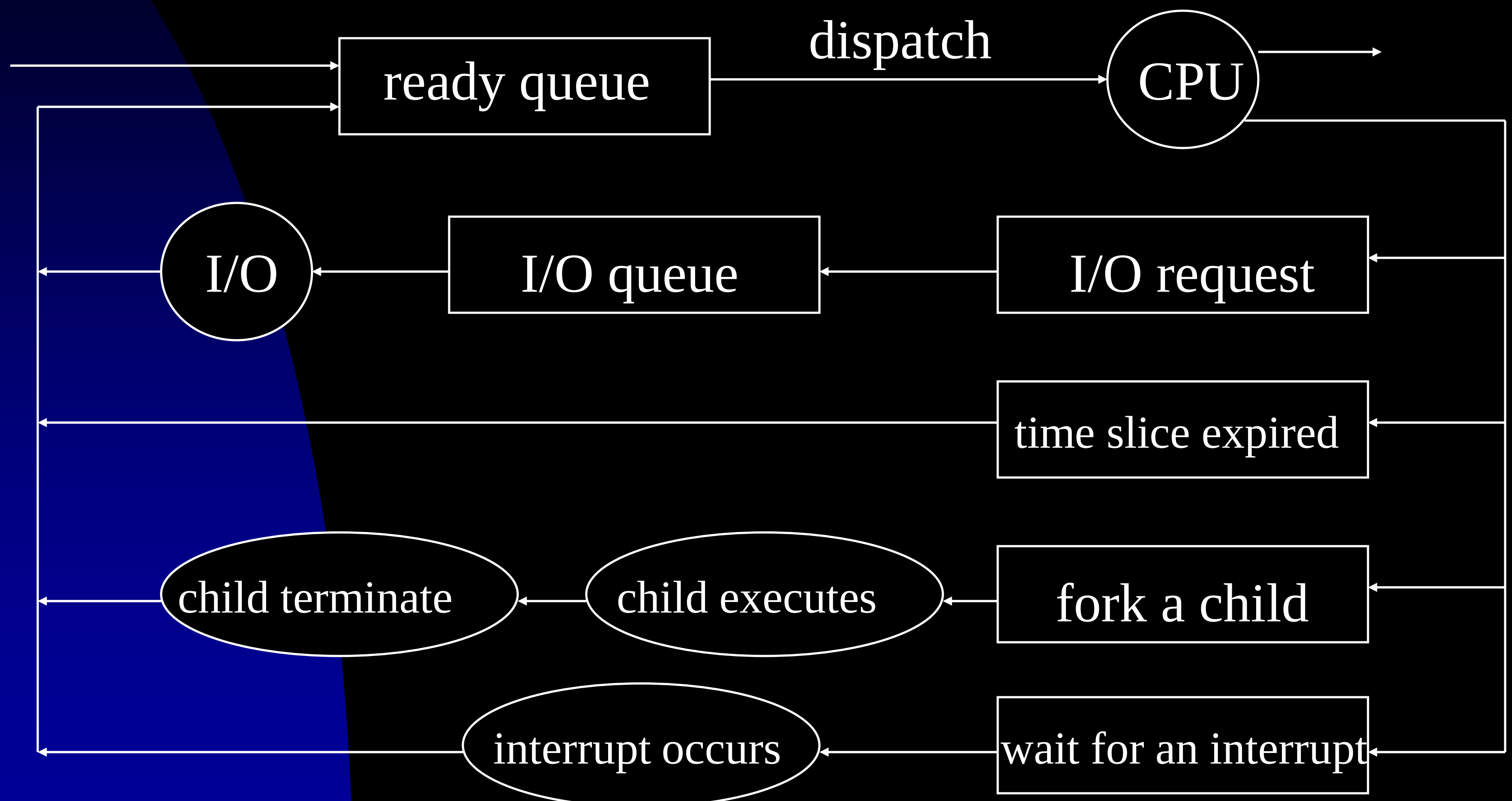


Process Scheduling

- The goal of multiprogramming
  - Maximize CPU/resource utilization!
- The goal of time sharing
  - Allow each user to interact with his/her program!



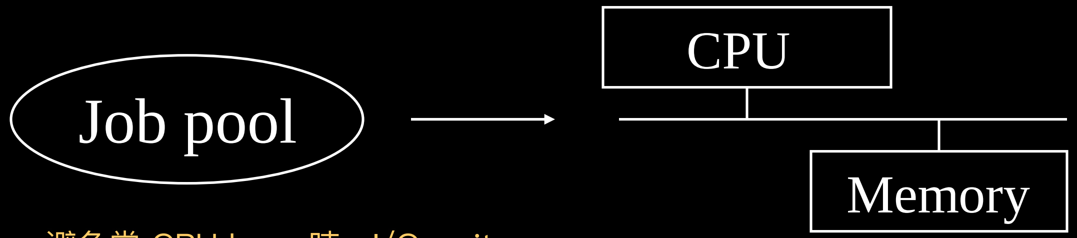
Process Scheduling – A Queueing Diagram



Process Scheduling – Schedulers

在個人電腦可能不存在系統裡

- Long-Term (/Job) Scheduler



避免當 CPU busy 時，I/O wait

- Goal: Select a good mix of I/O-bound and CPU-bound process

eg. 科學計算：MATLAB

eg. PowerPoint

- Remarks：
  1. Control the degree of multiprogramming
  2. Can take more time in selecting processes because of a longer interval between executions
  3. May not exist physically

Process Scheduling – Schedulers

- Short-Term (/CPU) Scheduler
  - Goal：Efficiently allocate the CPU to one of the ready processes according to some criteria.
- Mid-Term Scheduler PID 2
  - Swap processes in and out memory to control the degree of multiprogramming

當發現有些 process 進來佔用 CPU 時，導致整個 OS 效能不彰
–> 將他 swap out

Process Scheduling – Context Switches

一個 process 目前的 state: program counter, register… 希望 pure 越小越好

最常需要置換的東西存在 CPU 和 MMU 裡面

- Context Switch ~ Pure Overheads
  - Save the state of the old process and load the state of the newly scheduled process.
    - The context of a process is usually reflected in PCB and others, e.g., .u in Unix.

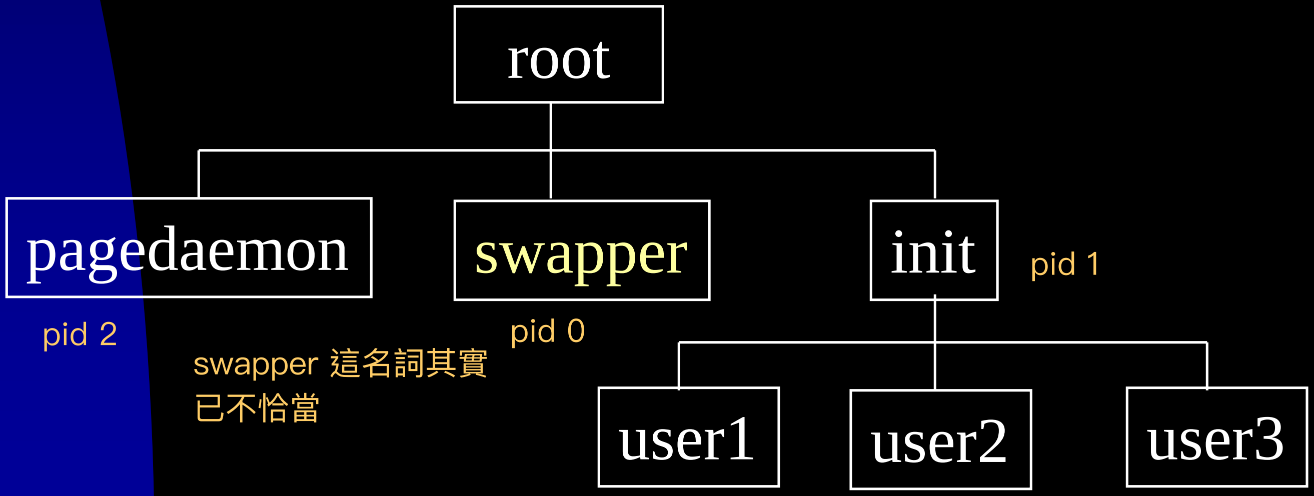
      Process Control Block
- Issues：
  - The cost depends on hardware support

    luxury approach
    - e.g. processes with multiple register sets or computers with advanced memory management.
  - Threads, i.e., light-weight process (LWP), are introduced to break this bottleneck！

只要把 proc1 的東西 load 出去，再把 proc2 load 進來，MMU 就不用管了

Operations on Processes

- Process Creation & Termination
  - Restrictions on resource usage
  - Passing of Information
  - Concurrent execution



Operations on Processes

- Process Duplication
  - A copy of parent address space + context is made for child, except the returned value from fork()：
    - Child returns with a value 0
    - Parent returns with process id of child
  - No shared data structures between parent and child – Communicate via shared files, pipes, etc.
  - Use execve() to load a new program
  - fork() vs vfork() (Unix)

Operations on Processes

- A Unix Example:

```
…
 if ( pid = fork() ) == 0) {
    /* child process */
     execlp("/bin/ls", "ls", NULL);
  } else if (pid < 0) {
    fprintf(stderr, "Fork Failed");
    exit(-1);
  } else {
    /* parent process */
    wait(NULL);
   }
```

Operations on Processes

- A Win32 API Example:

```
STARTUPINFO si;  // properties, e.g., window size, handles to infile
PROCESS.INFORMATION pi; // a handle and ID's to the newly
   …                                    //      created process & its threads
 if (!CreateProcess(NULL, //use command line
    "c:\\WINDOWS\\system32\\mspaint.exe", // command line
    NULL, // don't inherit process handle
    NULL, // don't inherit thread handle
    FALSE, // disable handle inheritance
    0, // no creation flags
    NULL, // use parent's environment block
    NULL, // use parent's existing directory
   &si, &pi)) {
     fprintf(stderr, "Create Process Failed");
     return -1;
   }
 WaitForSingleObject(pi.hProcess, INFINITE);
   …
}
```

Operations on Processes

- Termination of Child Processes
  - Reasons:
    - Resource usages, needs, etc.
  - Restrictions:
    - Parent-child, superusers, etc.
  - Waiting of child processes
    - Zombie processes and orphans
  - Kill, exit, wait, abort, signal, etc.
- Cascading Termination

Interprocess Communication

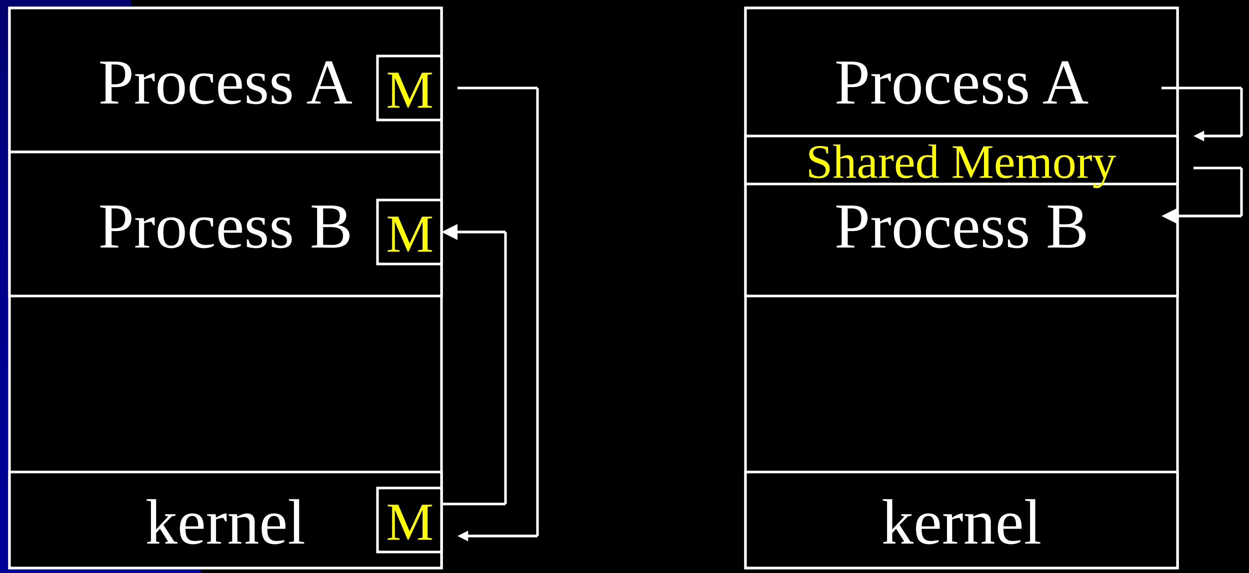
- Cooperating processes can affect or be affected by the other processes
  - Independent Processes
- Reasons:
  - Information Sharing, e.g., files
  - Computation Speedup, e.g., parallelism.
  - Modularity, e.g., functionality dividing
  - Convenience, e.g., multiple work

Interprocess Communication

- Why Inter-Process Communication (IPC)?
  - Exchanging of Data and Control Information!
- Why Process Synchronization?
  - Protect critical sections!
  - Ensure the order of executions!

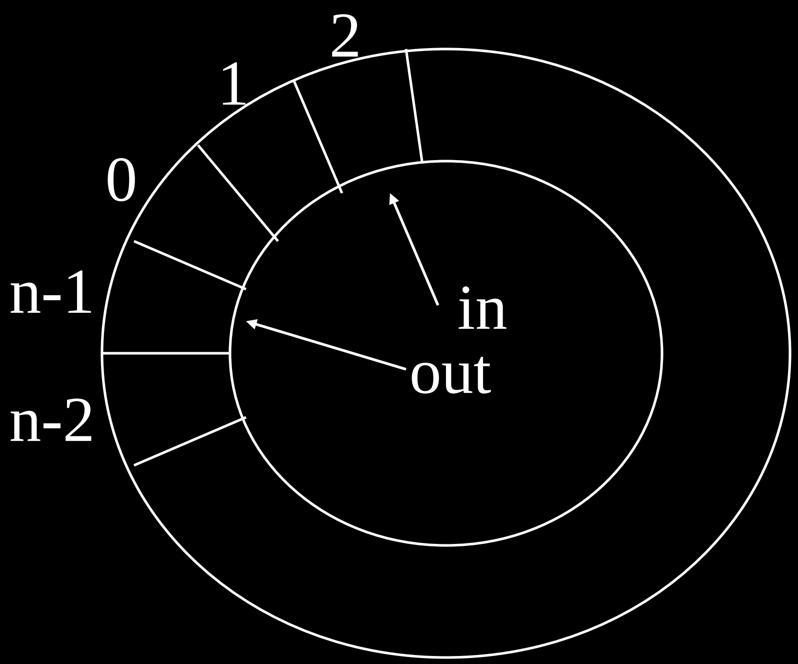
Interprocess Communication

- Shared Memory
  - Max Speed & Comm Convenience
- Message Passing
  - No Access Conflict & Easy Implementation



Interprocess Communication – Shared Memory

- A Consumer-Producer Example:
  - Bounded buffer or unbounded buffer
    - Supported by inter-process communication (IPC) or by hand coding



buffer[0…n-1]

Initially,

in=out=0；

Interprocess Communication – Shared Memory

Producer:

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

Synchonization

0, 1, … , BUFFER_SIZE – 1

Interprocess Communication – Shared Memory

Consumer:

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

Interprocess Communication – Message Passing

- Logical Implementation of Message Passing
  - Fixed/variable msg size, symmetric/asymmetric communication, direct/indirect communication, automatic/explicit buffering, send by copy or reference, etc.

Interprocess Communication – Message Passing

- Classification of Communication by Naming
  - Processes must have a way to refer to each other!
  - Types
    - Direct Communication
    - Indirect Communication

Interprocess Communication – Direct Communication

- Process must explicitly name the recipient or sender of a communication
  - Send(P, msg), Receive(Q, msg)
- Properties of a Link:
  a. Communication links are established automatically.
  b. Two processes per a link
  c. One link per pair of processes
  d. Bidirectional or unidirectional

Interprocess Communication – Direct Communication

- Issue in Addressing:
  - Symmetric or asymmetric addressing

    Send(P, msg), Receive(id, msg)

- Difficulty:
  - Process naming vs modularity

Interprocess Communication – Indirect Communication

- Two processes can communicate only if the process share a mailbox (or ports)

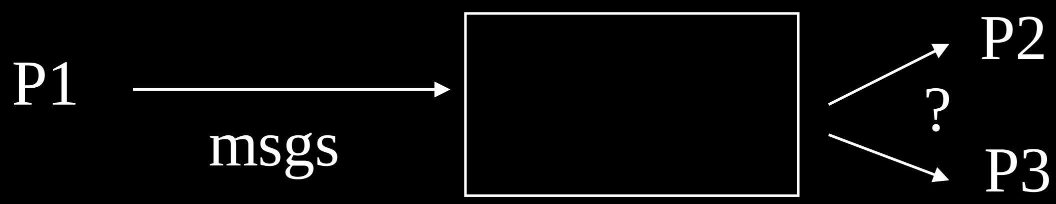
send(A, msg)=> A =>receive(A, msg)

- Properties:

1. A link is established between a pair of processes only if they share a mailbox.
2. *n* processes per link for *n* >= 1.
3. *n* links can exist for a pair of processes for *n* >=1.
4. Bidirectional or unidirectional

Interprocess Communication – Indirect Communication

- Issues:
  a. Who is the recipient of a message?



  b. Owners vs Users
     - Process → owner as the sole recipient?
     - OS → Let the creator be the owner?
       Privileges can be passed?
       Garbage collection is needed?

Interprocess Communication – Synchronization

- Blocking or Nonblocking (Synchronous versus Asynchronous)
  - Blocking send
  - Nonblocking send
  - Blocking receive
  - Nonblocking receive
- Rendezvous – blocking send & receive

Interprocess Communication – Buffering

- The Capacity of a Link = the # of messages could be held in the link.
  - Zero capacity(no buffering)
    - Msg transfer must be synchronized – rendezvous!
  - Bounded capacity
    - Sender can continue execution without waiting till the link is full
  - Unbounded capacity
    - Sender is never delayed!
- The last two items are for asynchronous communication and may need acknowledgement

Interprocess Communication – Buffering

- Special cases:
  a. Msgs may be lost if the receiver can not catch up with msg sending → synchronization
  b. Senders are blocked until the receivers have received msgs and replied by reply msgs

     → A Remote Procedure Call (RPC) framework

Interprocess Communication – Exception Conditions

- Process termination
  a. Sender Termination → Notify or terminate the receiver!
  b. Receiver Termination
     a. No capacity → sender is blocked.
     b. Buffering → messages are accumulated.

Interprocess Communication – Exception Conditions

- Ways to Recover Lost Messages (due to hardware or network failure):
  - OS detects & resends messages.
  - Sender detects & resends messages.
  - OS detects & notifies the sender to handle it.
- Issues:
  a. Detecting methods, such as the timeout!
  b. Distinguish multiple copies if retransmitting is possible
- Scrambled Messages:
  - Usually OS adds checksums, such as CRC, inside messages & resend them as necessary!

Example – POSIX

- Creation of a Shared Memory Object

  shm_fd = shm_open(name, O_CREAT | O_RDRW, 0666);
  - Implementation over memory-mapped files: name, RW, dir rights
- Size Config, Memory Map, Remove

  ftruncate(shm_fd, 4096);

  ptr = mmap(0, SIZE, PROT_WRITE, MAP_SHARED, shm_fd, 0);

  shm_unlink(name);
- Access
  - sprintf(ptr, “%s”, “Writing to shared mem”);

Example – Mach

- Mach – A message-based OS from the Carnegie Mellon University
  - When a task is created, two special mailboxes, called ports, are also created.
    - The *Kernel* mailbox is used by the kernel to communicate with the tasks
    - The *Notify* mailbox is used by the kernel sends notification of event occurrences.

Example - Mach

- Three system calls for message transfer:
  - msg_send:
    - Options when mailbox is full:
      a. Wait indefinitely
      b. Return immediately
      c. Wait at most for *n* ms
      d. Temporarily cache a message.
         a. A cached message per sending thread for a mailbox

* One task can either own or receive from a mailbox.

Example - Mach

- msg_receive
  - To receive from a mailbox or a set of mailboxes. Only one task can own & have a receiving privilege of it

    * options when mailbox is empty:

    a. Wait indefinitely

    b. Return immediately

    c. Wait at most for *n* ms
- msg_rpc
  - Remote Procedure Calls

Example - Mach

- port_allocate
  - create a mailbox (owner)
  - port_status ~ .e.g, # of msgs in a link
- All messages have the same priority and are served in a FIFO fashion for the same sender.
- Message Size
  - A fixed-length head + a variable-length data + two mailbox names
- Message copying: message copying → remapping of addressing space
- System calls are carried out by messages.

Example – Windows

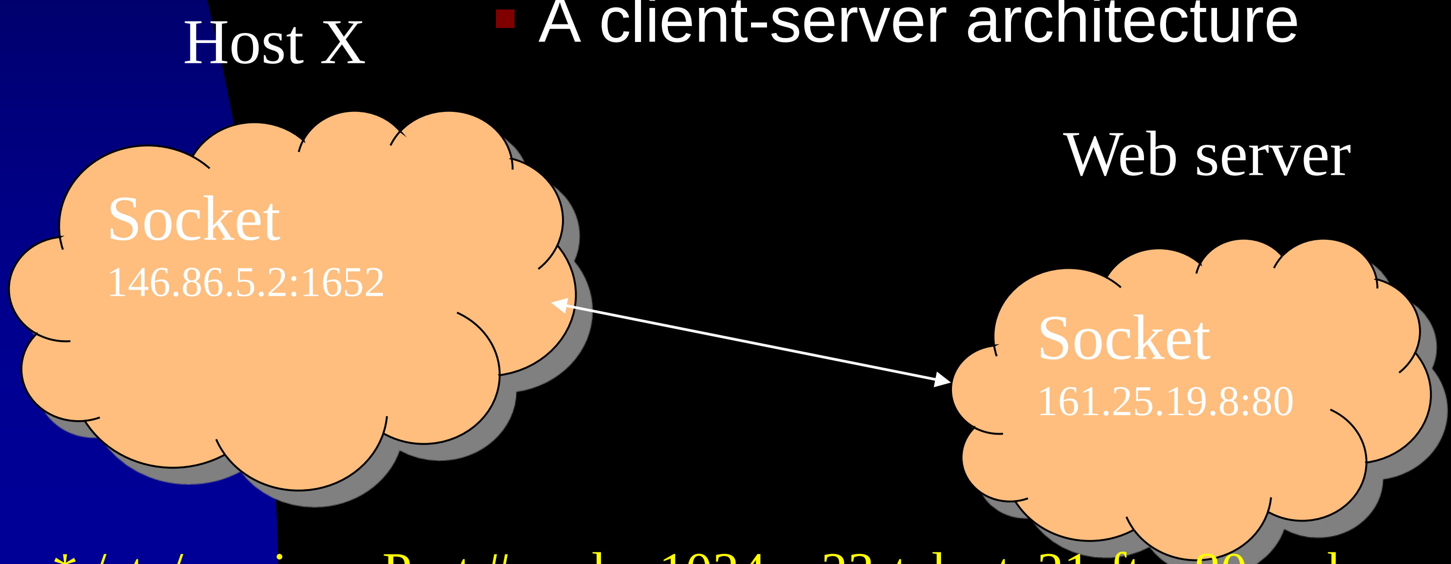
- Advanced Local Procedure Call (ALPC) – Message Passing on the Same Processor
  1. The client opens a handle to a subsystem’s *connection port* object.
  2. The client sends a connection request.
  3. The server creates a channel with two private *communication ports*, and returns the handle to one of them to the client.
  4. The client and server use the corresponding port handle to send messages or callbacks and to listen for replies.

Example – Windows

- Two Types of Message Passing Techniques
  - Small messages (<= 256 bytes)
    - Message copying
  - Large messages – section object or API
    - To avoid memory copy
      - Sending and receiving of the pointer and size information of the object
      - Call API to directly read and write to the address space of a client for data not fitting in a section object
- A callback mechanism
  - When a response could not be made immediately.

Communication in Client-Server Systems

- Socket
  - An endpoint for communication identified by an IP address concatenated with a port number
    - A client-server architecture



* /etc/services: Port # under 1024 ~ 23-telnet, 21-ftp, 80-web server, etc.

Communication in Client-Server Systems

- Three types of sockets in Java
  - Connection-oriented (TCP) – Socket class
  - Connectionless (UDP) – DatagramSocket class
  - MulticastSocket class – DatagramSocket subclass

Server

```
sock = new ServerSocket(5155);
…
client = sock.accept();
pout = new PrintWriter(client.getOutputStream(),
      true);
…
Pout.println(new java.util.Date().toString());
pout.close();
client.close();
```

Client

```
sock = new Socket("127.0.0.1",5155);
…
in = sock.getInputStream();
bin = new BufferReader(new
      InputStreamReader(in));
…
line = bin.readLine();
sock.close();
```

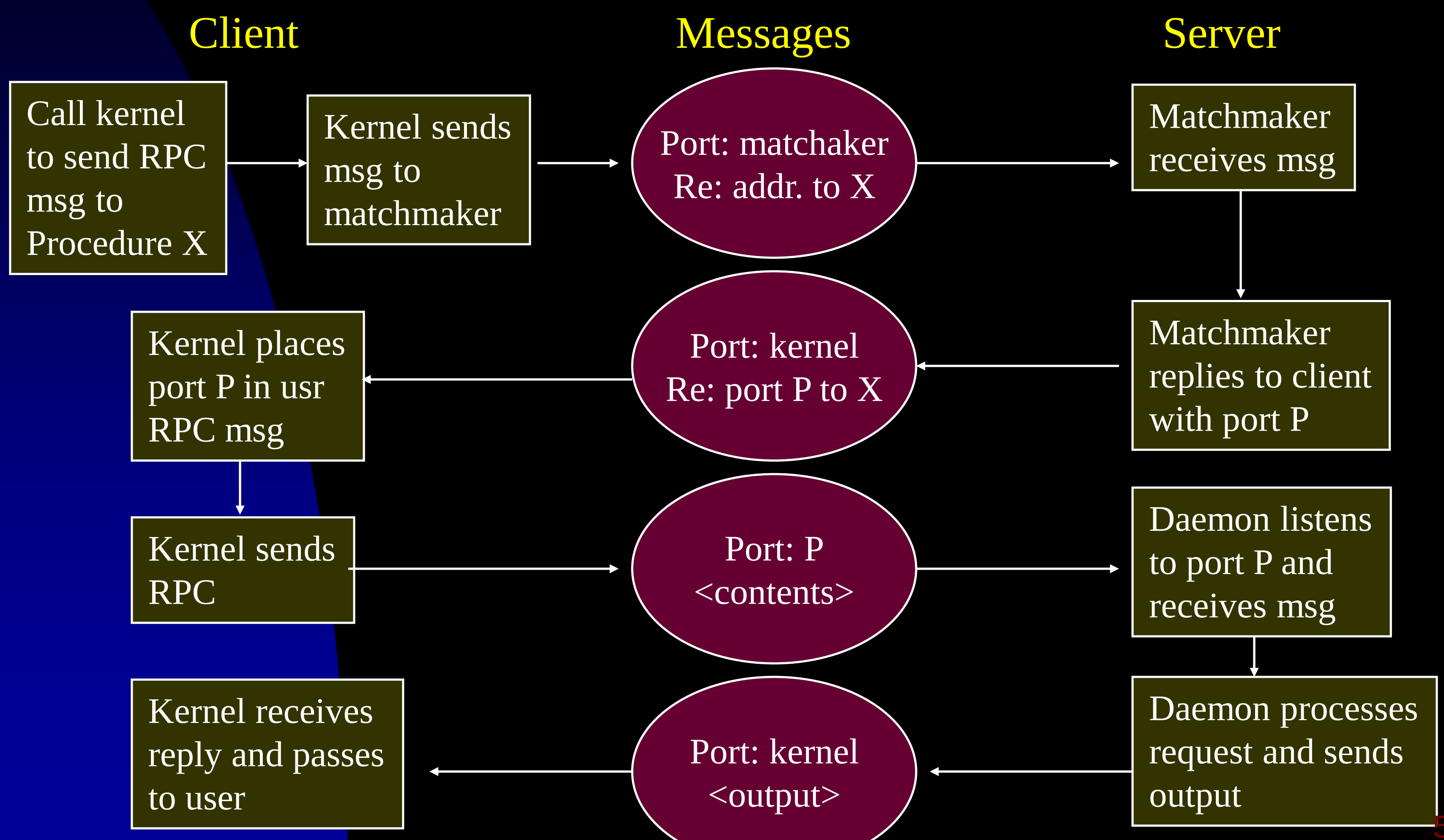
Communication in Client-Server Systems

- Remote Procedure Call (RPC)
  - A way to abstract the procedure-call mechanism for use between systems with network connection.
  - Needs:
    - Ports to listen from the RPC daemon site and to return results, identifiers of functions to call, parameters to pack, etc.
    - Stubs at the client site
      - One for each RPC
      - Locate the proper port and marshall parameters.

Communication in Client-Server Systems

- Needs (continued)
  - Stubs at the server site
    - Receive the message
    - Invoke the procedure and return the results.
- Issues for RPC
  - Data representation
    - External Data Representation (XDR)
      - Parameter marshalling
  - Semantics of a call
    - History of all messages processed
  - Binding of the client and server port
    - Matchmaker – a rendezvous mechanism

Communication in Client-Server Systems



Communication in Client-Server Systems

- An Example for RPC
  - A Distributed File System (DFS)
    - A set of RPC daemons and clients
    - DFS port on a server on which a file operation is to take place:
      - Disk operations: read, write, delete, status, etc – corresponding to usual system calls

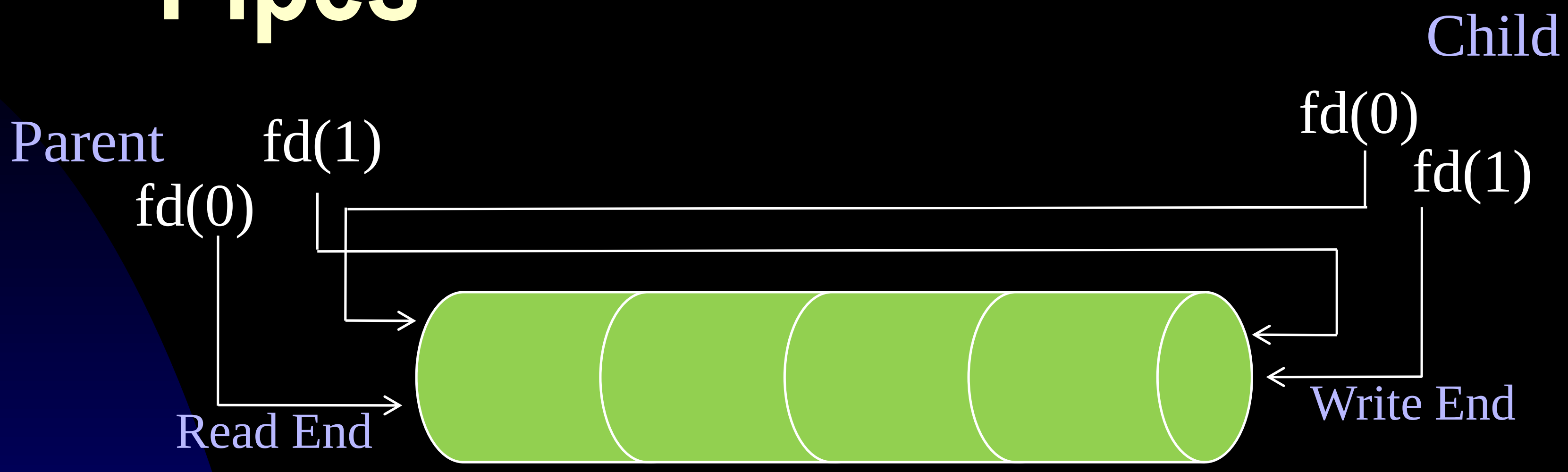
Communication in Client-Server Systems

- Remote Method Invocation (RMI)
  - Allow a thread to invoke a method on a remote object.
    - boolean val = Server.someMethod(A,B)
- Implementation
  - Stub – a proxy for the remote object
    - Parcel – a method name and its marshalled parameters, etc.
  - Skeleton – for the unmarshalling of parameters and invocation of the method and the sending of a parcel back

Communication in Client-Server Systems

- Parameter Passing
  - Local (or Nonremote) Objects
    - Pass-by-copy – an object serialization
  - Remote Objects – Reside on a different Java virtual machine (JVM)
    - The stub for that remote object is passed.
  - Implementation of the interface – *java.io.Serializable*

Pipes



- Implementation Issues
  - Unidirectional or Bidirectional?
  - Half or Full Duplex?
  - The Existence of a Relationship, e.g., Parent-Child?
  - Inter- or Intra-Machine?

Pipes – Ordinary Pipes

- Ordinary Pipes – The Read and Write Ends
  - A unidirectional pipe that is created by calling pipe(int fd[]) and usually followed by a fork() to allow Parent and Child to communicate with each other.
- Exampe: UNIX and Windows
  - Anonymous Pipe of Windows

```
int main(VOID) {
HANDLE ReadHandle, WriteHandle;
STARTINFO si;
PROCESS_INFORMATION pi;
…
SECURITY_ATTRIBUTES sa = {
  sizeof(SECURITY_ATTRIBUTES),
  NULL, TRUE);
if  (!CreatePipe(&ReadHandle,
      &WriteHandle, &sa, 0) {
 … }
…
CreateProcess(NULL, “child.exe”,
  NULL, NULL,
  TRUE, /* inherit handles */
   0, NULL, NULL, &si, &pi);
…}
```

Pipes – Named Pipes

- Motivation
  - Bidirectional Pipes
  - No requirement for a parent-child relationship
  - Multiple Readers and Writers
  - Existence After the Termination of Communicating Processes
- Example
  - FIFOS of UNIX – mkfifo(), open(), close(), read(), write(); Half Dulex; Byte-Oriented Transmissions
  - Pipes of Windows: CreateNamePipe(), ConnectNamePipe(); ReadFile(); Full Duplex, Byte/Message-Oriented Transmissions