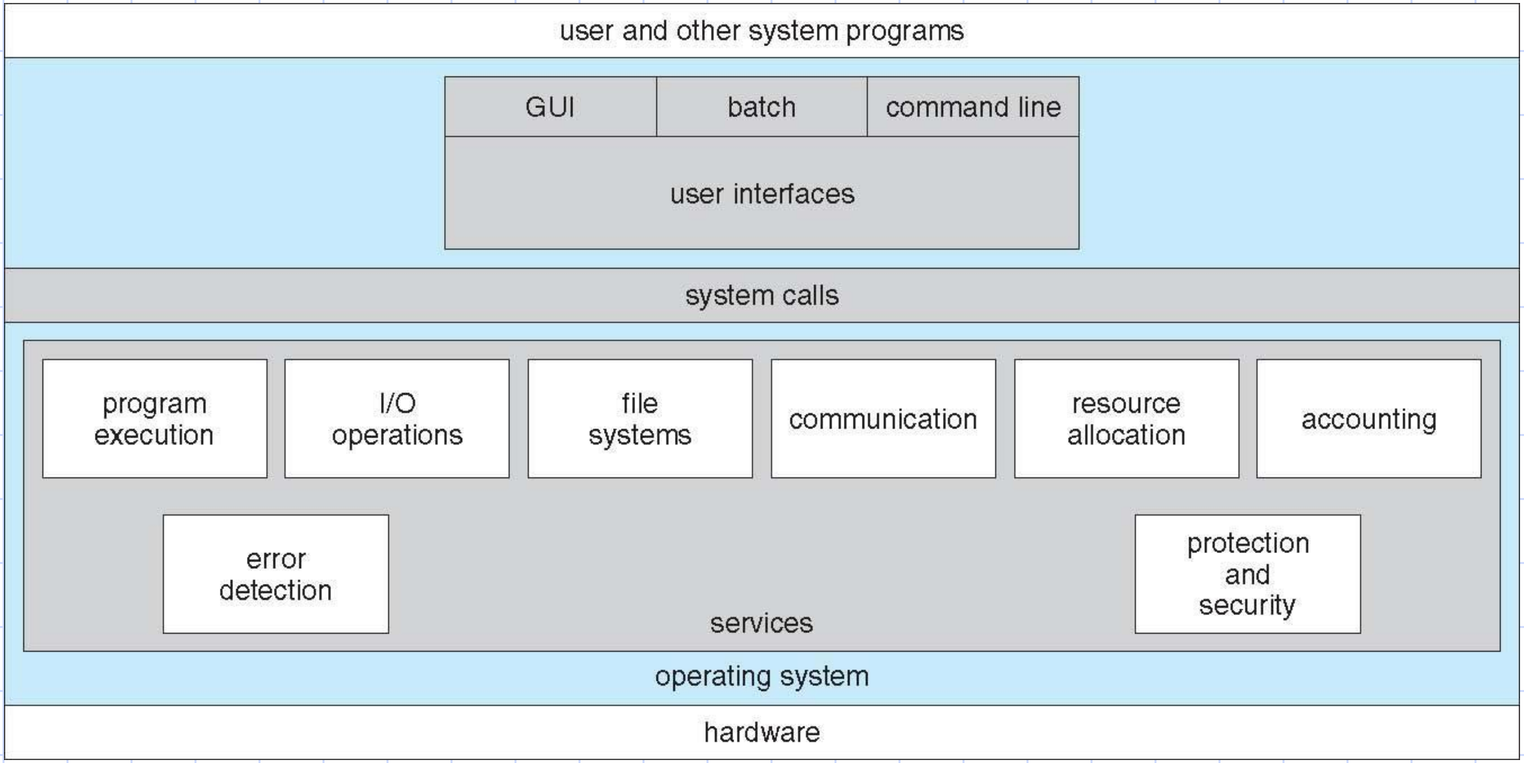
# The Process Model

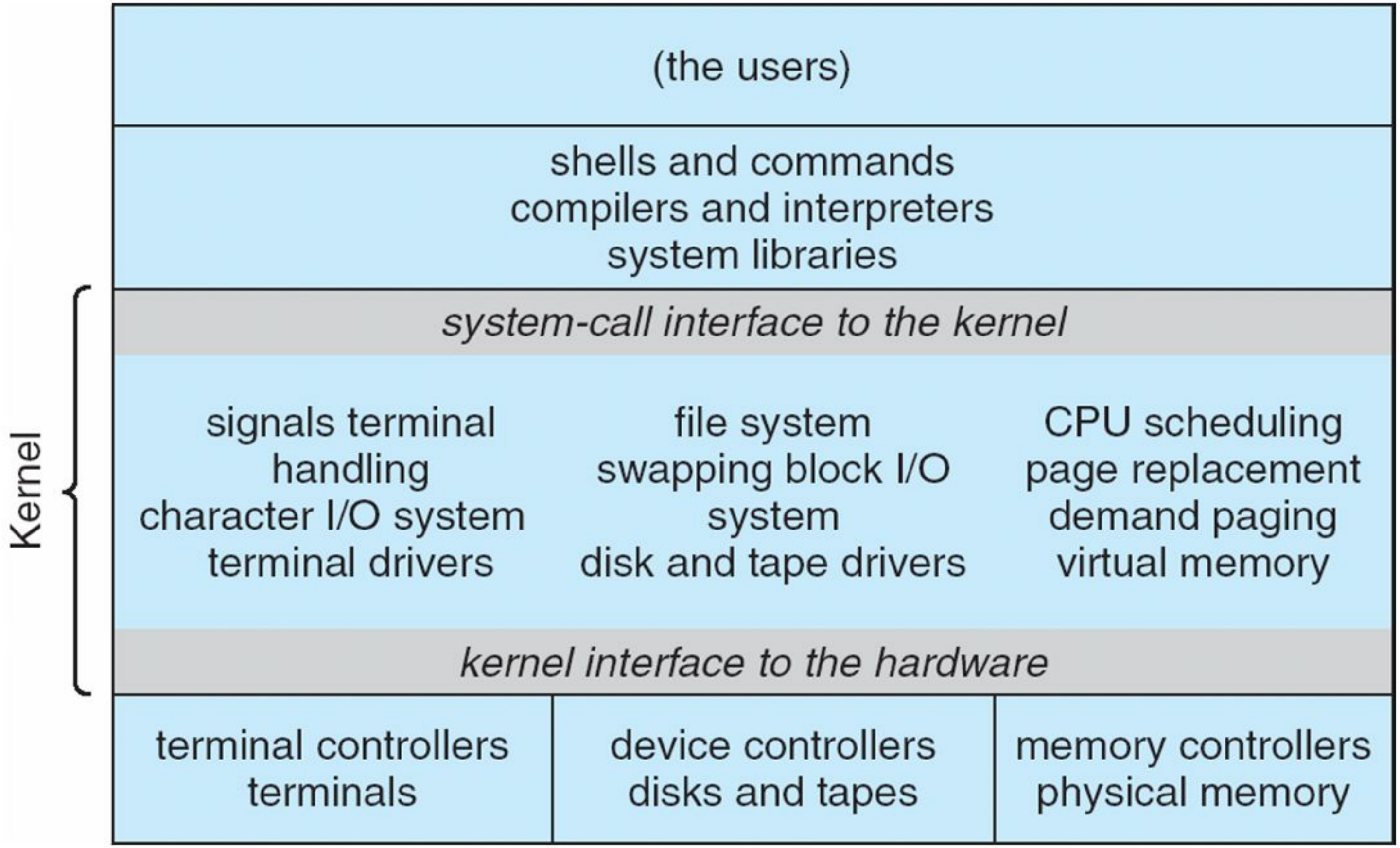
# Topics

- Review system call
- Introduce the process model
  - 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 describe communication in client-server systems

# A View of Operating System Services



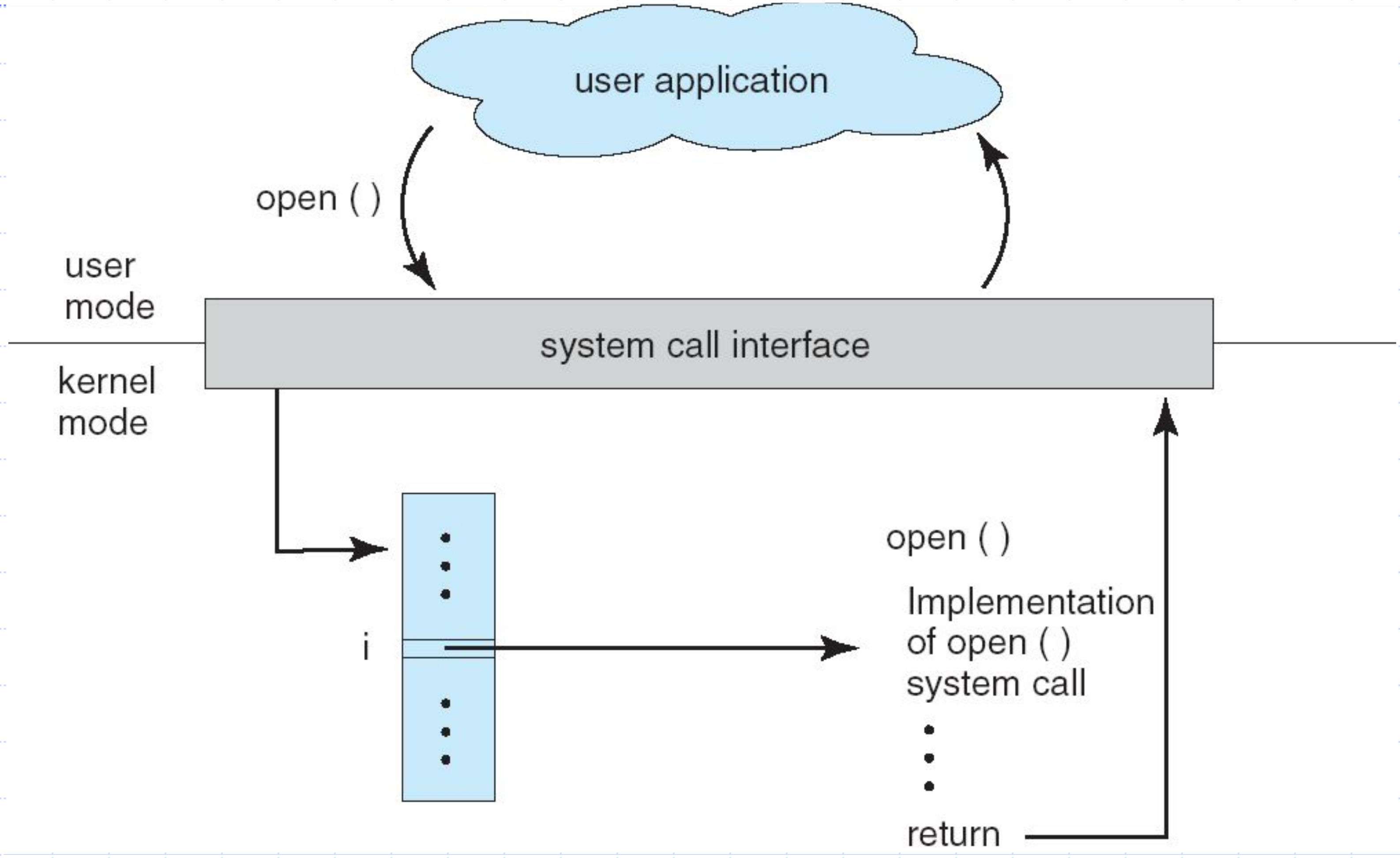
# Traditional UNIX System Structure



# System Call Implementation

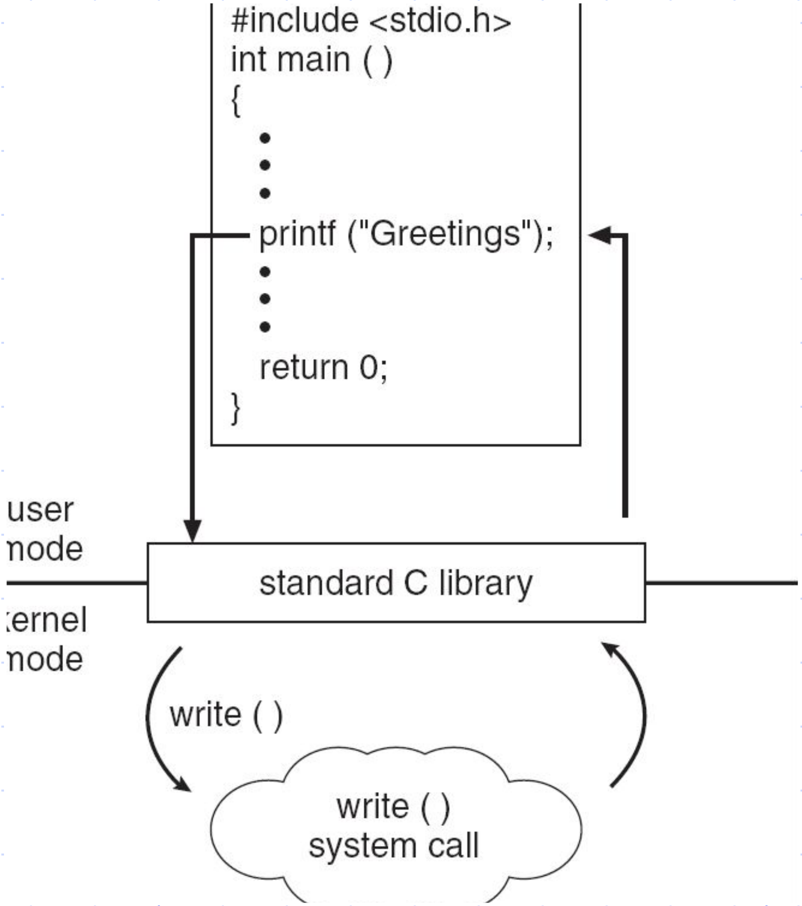
- Typically, a number associated with each system call
  - System-call interface maintains a table indexed according to these numbers
- The system call interface invokes intended system call in OS kernel and returns status of the system call and any return values
- The caller need know nothing about how the system call is implemented
  - Just needs to obey API and understand what OS will do as a result call
  - Most details of  OS interface hidden from programmer by API
    - Managed by run-time support library (set of functions built into libraries included with compiler)

# API – System Call – OS Relationship

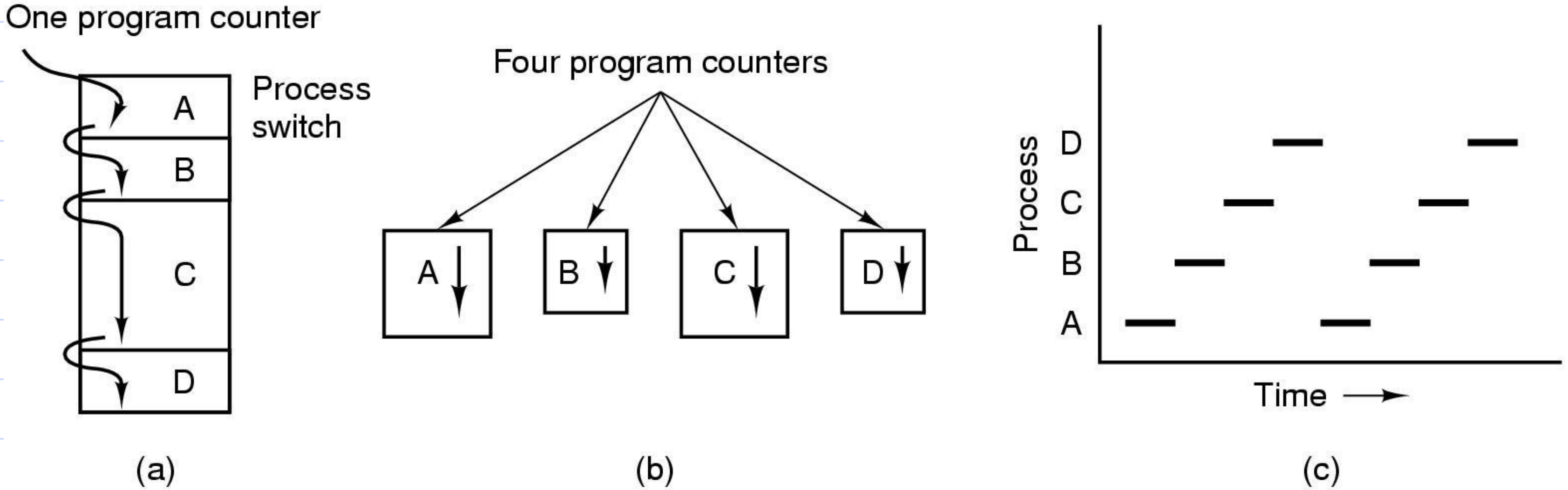


# Standard C Library Example

- C program invoking printf() library call, which calls write() system call



# Processes
## The Process Model

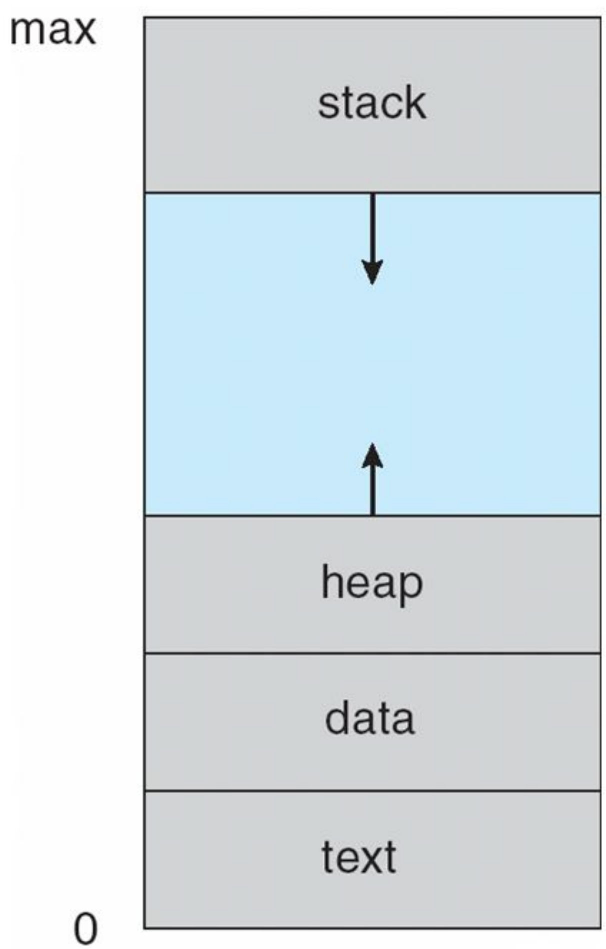



- Multiprogramming of four programs
- Conceptual model of 4 independent, sequential processes
- Only one program active at any instant

# What is a process?

- A process is simply a program in execution: an instance of a program execution.
- Unit of work individually schedulable by an operating system.
- A process includes:
  - program counter
  - stack
  - data section
- OS keeps track of all the active processes and allocates system resources to them according to policies devised to meet design performance objectives.
- To meet process requirements OS must maintain many data structures efficiently.
- The process abstraction is a fundamental OS means for management of concurrent program execution. Example: instances of process co-existing.

# Process in Memory



# Process creation

- Four common events that lead to a process creation are:

1) When a new batch-job is presented for execution.
2) When an interactive user logs in / system initialization.
3) When OS needs to perform an operation (usually IO) on behalf of a user process, concurrently with that process.
4) To exploit parallelism an user process can spawn a number of processes.

# Termination of a process

- Normal completion, time limit exceeded, memory unavailable
- Bounds violation, protection error, arithmetic error, invalid instruction
- IO failure, Operator intervention, parent termination, parent request, killed by another process
- A number of other conditions are possible.
- **Segmentation fault** : usually happens when you try write/read into/from a non-existent array/structure/object component. Or access a pointer to a dynamic data before creating it. (new etc.)
- **Bus error:** Related to function call and return. You have messed up the stack where the return address or parameters are stored.

# Process control

- Process creation in unix is by means of the system call fork().
- OS in response to a fork() call:
  - Allocate slot in the process table for new process.
  - Assigns unique pid to the new process..
  - Makes a copy of the process image, except for the shared memory.
  - both child and parent are executing the same code following fork()
  - Move child process to Ready queue.
  - **it returns pid of the child to the parent, and a zero value to the child**.

# Process control (contd.)

- All the above are done in the kernel mode in the process context. When the kernel completes these it does one of the following as a part of the dispatcher:
  - Stay in the parent process. Control returns to the user mode at the point of the fork call of the parent.
  - Transfer control to the child process. The child process begins executing at the same point in the code as the parent, at the return from the fork call.
  - Transfer control another process leaving both parent and child in the Ready state.

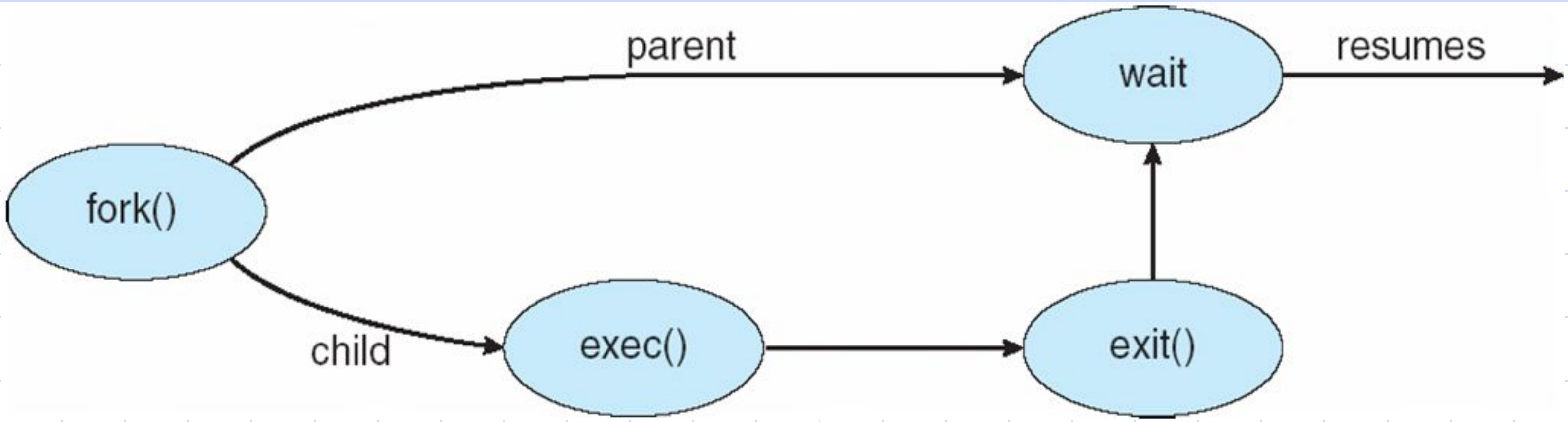
# Process Creation (contd.)

- **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
  - 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 (Contd.)

- 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

# Process Creation (contd.)



# C Program Forking Separate Process

```
int main() {
int retVal;
   /* fork another process */
   retVal = fork();
   if (retVal < 0) { /* error occurred */
    fprintf(stderr, "Fork Failed");
    exit(-1);
   }
   else if (retVal == 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);
   } }
```

# 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**

# fork and exec

- Child process may choose to execute some other program than the parent by using exec call.
- Exec overlays a new program on the existing process.
- Child will not return to the old program unless exec fails. This is an important point to remember.
- Why does fork need to clone?
- Why do we need to separate fork and exec?
- Why can't we have a single call that fork a new program?

# Example

```
if (( result = fork()) == 0 ) {
   // child code
  if (execv ("new program",..) < 0)
      perror ("execv failed ");
      exit(1);
}
else if (result < 0 ) perror ("fork"); ...}
/* parent code */
```

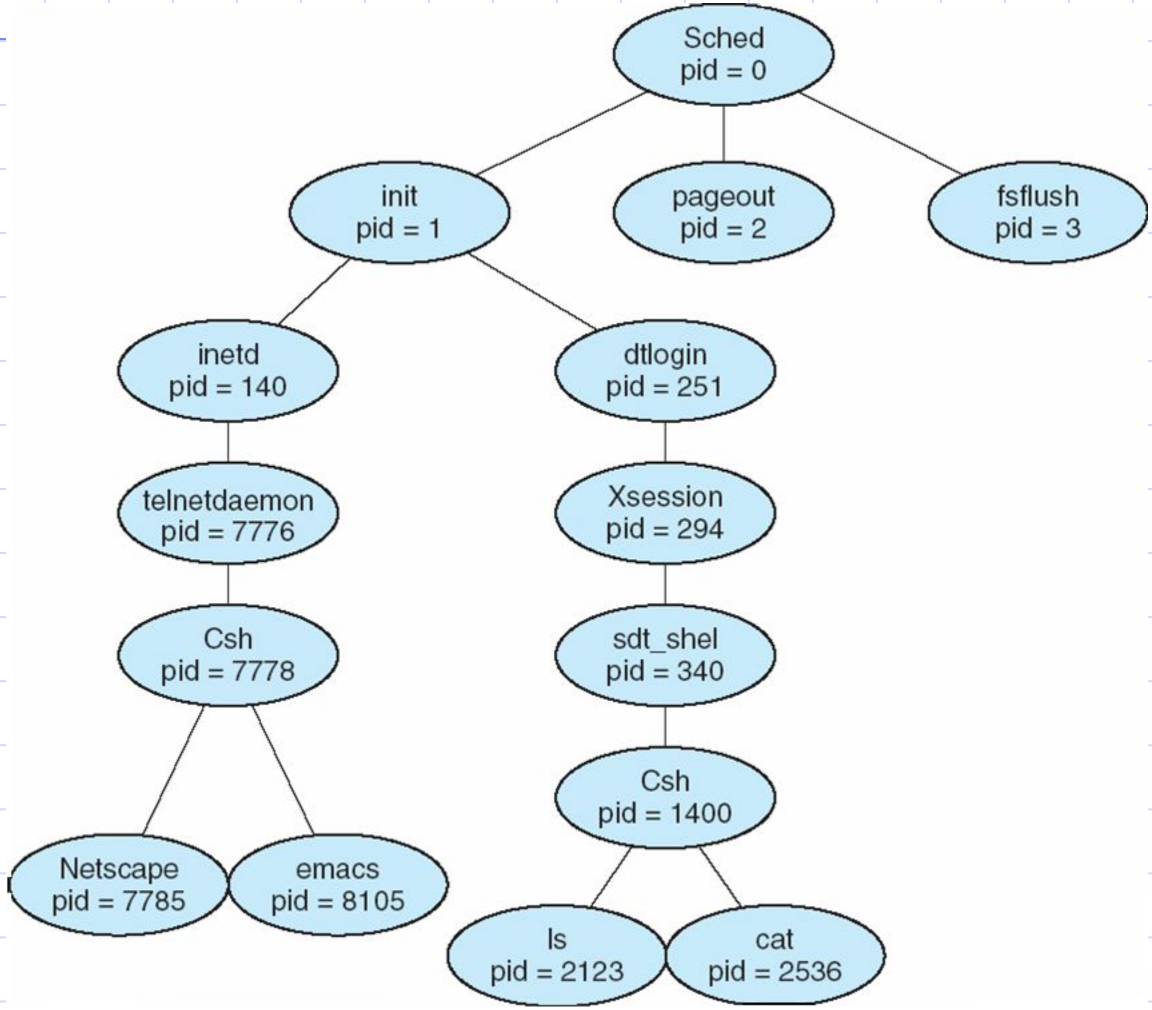
# Versions of exec

- Many versions of exec are offered by C library: exece, execve, execvp,execl, execle, execlp
- We will look at these and methods to synchronize among various processes (wait, signal, exit etc.).

# Process Hierarchies

- Parent creates a child process, child processes can create its own process
- Forms a hierarchy
  - UNIX calls this a "process group"
- Windows has no concept of process hierarchy
  - all processes are created equal

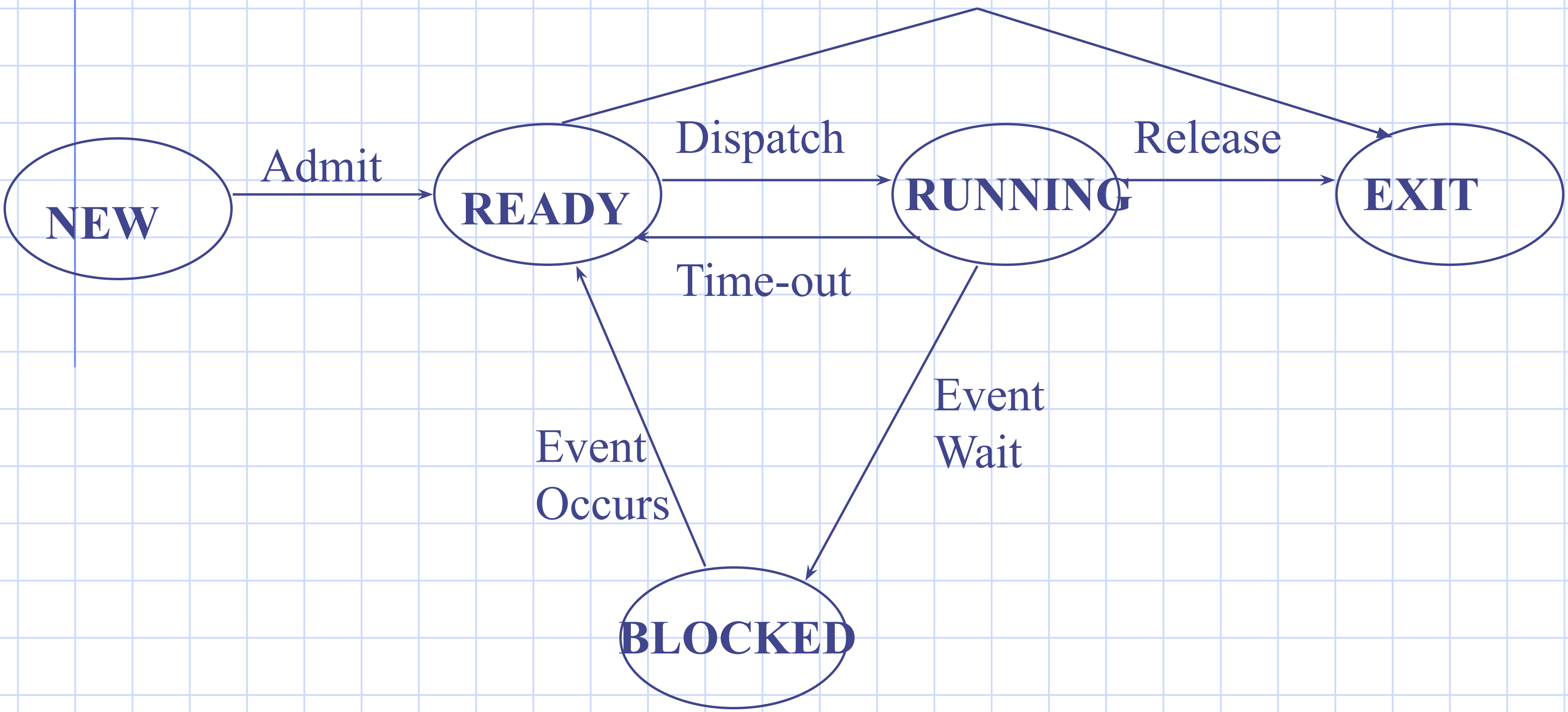
# A tree of processes on a typical Unix system



# A five-state process model

- Five states: New, Ready, Running, Blocked, Exit
- **New** : A process has been created but has not yet been admitted to the pool of executable processes.
- **Ready** : Processes that are prepared to run if given an opportunity. That is, they are not waiting on anything except the CPU availability.
- **Running**: The process that is currently being executed. (Assume single processor for simplicity.)
- **Blocked** : A process that cannot execute until a specified event such as an IO completion occurs.
- **Exit**: A process that has been released by OS either after normal termination or after abnormal termination (error).

# State Transition Diagram (1)




Think of the conditions under which state transitions may take place.

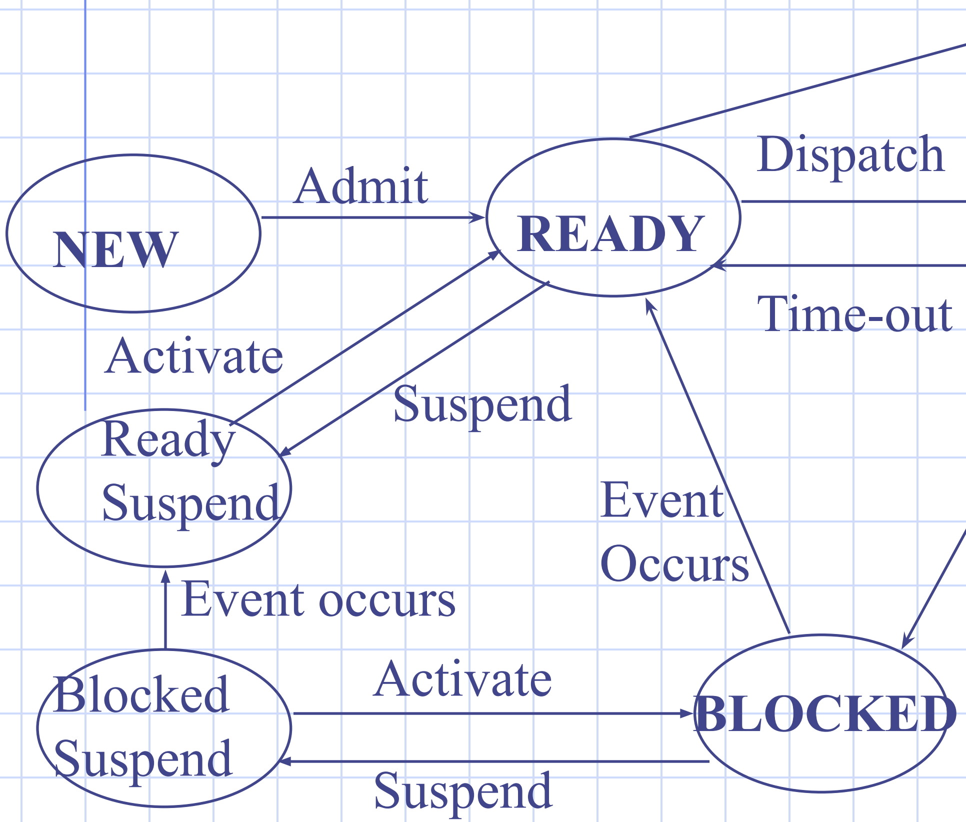
# Process suspension

- Many OS are built around (Ready, Running, Blocked) states. But there is one more state that may aid in the operation of an OS - **suspended** state.
- When none of the processes occupying the main memory is in a Ready state, OS swaps one of the blocked processes out onto to the Suspend queue.
- When a Suspended process is ready to run it moves into “Ready, Suspend” queue. Thus we have two more state: Blocked_Suspend, Ready_Suspend.

# Process suspension (contd.)

- Blocked_suspend : The process is in the secondary memory and awaiting an event.
- Ready_suspend : The process is in the secondary memory but is available for execution as soon as it is loaded into the main memory.
- State transition diagram on the next slide.
- Observe on what condition does a state transition take place? What are the possible state transitions?

# State Transition Diagram (2)




Think of the conditions under which state transitions may take place.

# Implementation of Processes

| Process management | Memory management | File management |
|---|---|---|
| Registers<br>Program counter<br>Program status word<br>Stack pointer<br>Process state<br>Priority<br>Scheduling parameters<br>Process ID<br>Parent process<br>Process group<br>Signals<br>Time when process started<br>CPU time used<br>Children's CPU time<br>Time of next alarm | Pointer to text segment<br>Pointer to data segment<br>Pointer to stack segment | Root directory<br>Working directory<br>File descriptors<br>User ID<br>Group ID |

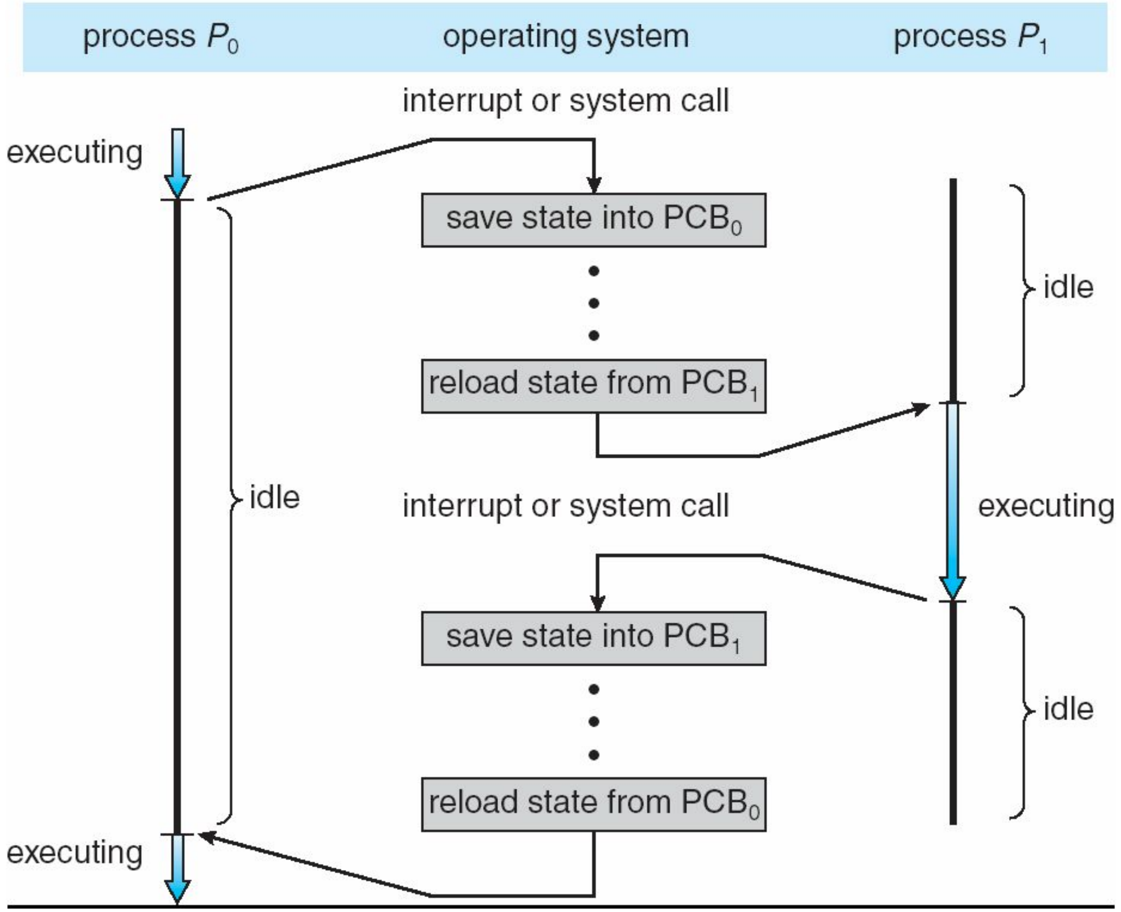
# Process Control Block (PCB)

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)

# CPU Switch From Process to Process



# 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
- Time dependent on hardware support

# Summary

- A process is a unit of work for the Operating System.
- Implementation of the process model deals with process description structures and process control methods.
- Process management is the of the operating system requiring a range of functionality from interrupt handling to IO management.
- All the concepts discussed will be illustrated in the project 1.