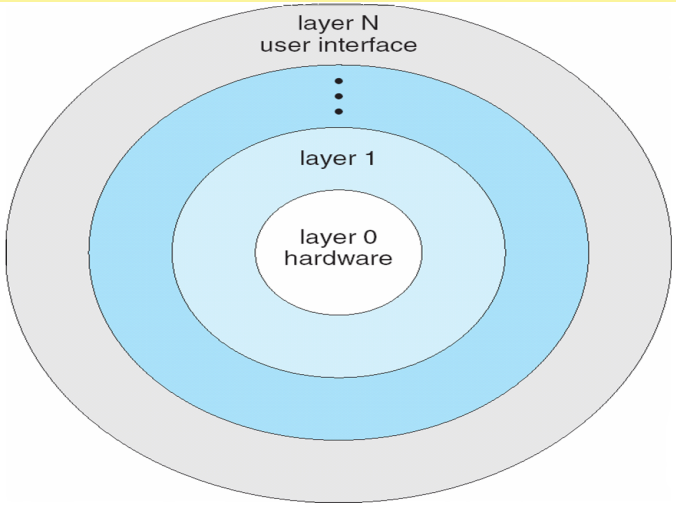
Layered Approach

- A system can be made modular in many ways. One method is the **layered approach**, in which the operating system is broken into a number of layers (levels). The bottom layer (layer 0) is the hardware; the highest (layer N) is the user interface.



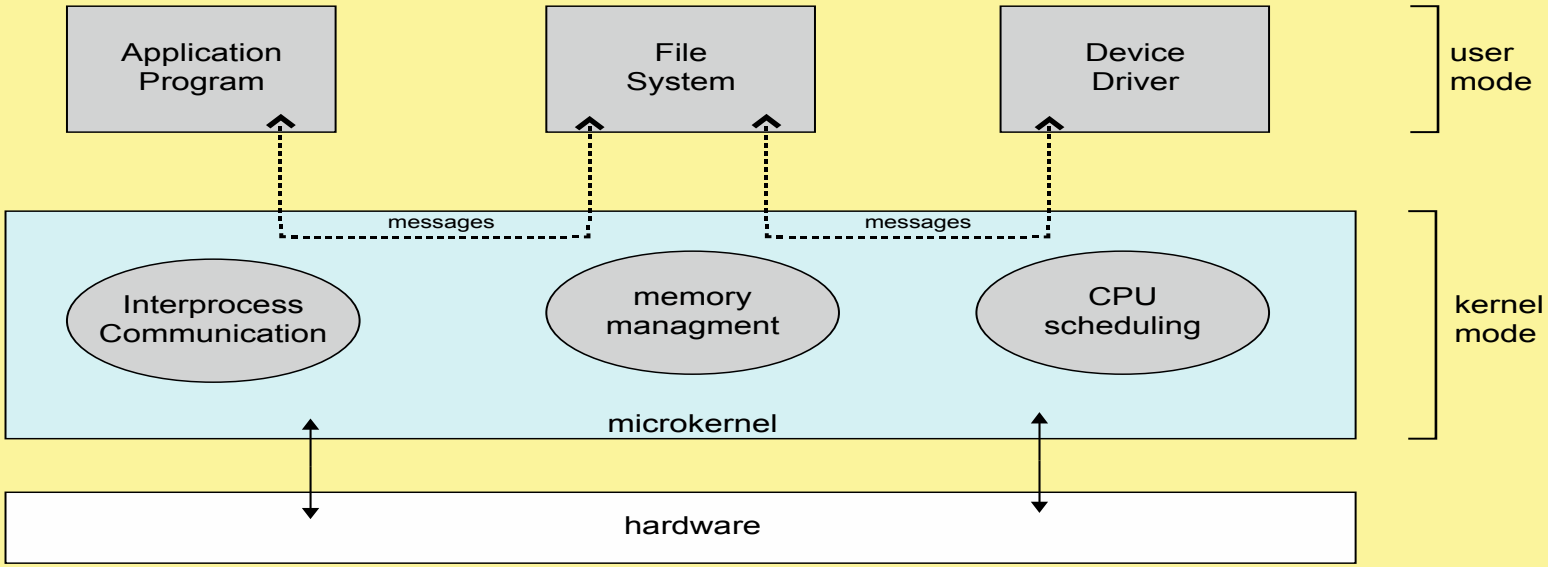
Layered Approach (Cont.)

- A typical operating-system layer -- say, layer M -- consists of data structures and a set of routines that can be invoked by higher-level layers. Layer M in turn, can invoke operations on lower-level layers.
- Each layer is implemented only with operations provided by lower-level layers. A layer does not need to know how these operations are implemented; it needs to know only what these operations do.
- Advantage: Simplicity of construction and debugging. The layers are selected so that each uses functions (operations) and services of only lower-level layers.
- Simplifies debugging and system verification. The first layer can be debugged without any concern for the rest of the system. Once the first layer is debugged, its correct functioning can be assumed while the second layer is debugged, and so on.


Microkernel System Structure

- Moves as much from the kernel into user space
- **Mach** example of **microkernel**
  - Mac OS X kernel (**Darwin**) partly based on Mach
- Communication takes place between user modules using **message passing**
- Benefits:
  - Easier to extend a microkernel
  - Easier to port the operating system to new architectures
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication


Microkernel System Structure



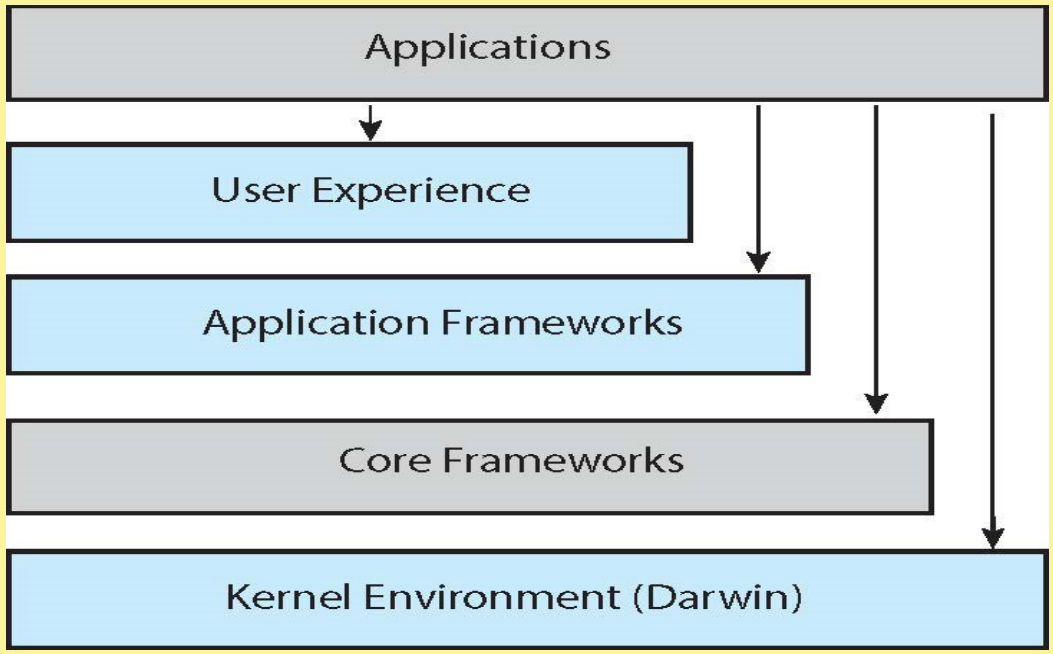
Modules

- Many modern operating systems implement **loadable kernel modules**
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
- Overall, similar to layers but with more flexible
  - Linux, Solaris, etc


Hybrid Systems

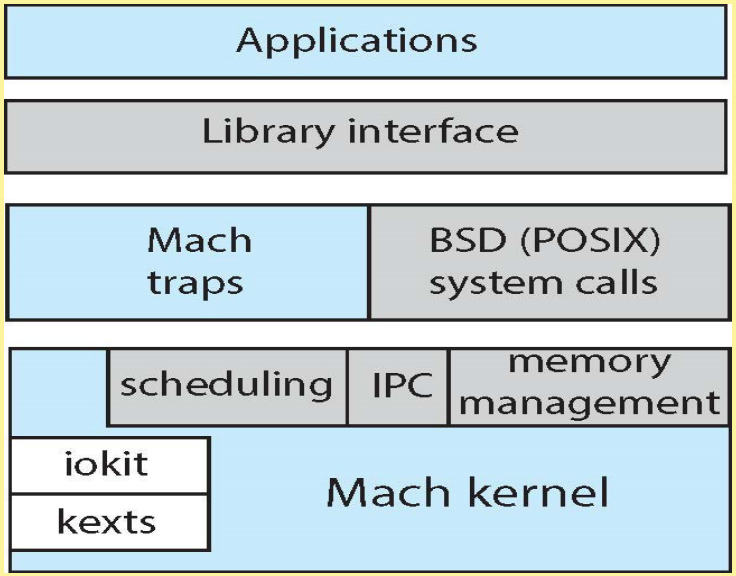
- In practice, very few operating systems adopt a single, strictly defined structure.
- Instead, they combine different structures, resulting in hybrid systems that address performance, security, and usability issues.
  - For example, Linux is monolithic, because having the operating system in a single address space provides very efficient performance. However, Linux are also modular, so that new functionality can be dynamically added to the kernel.


Architecture of Mac OS X and iOS



Darwin

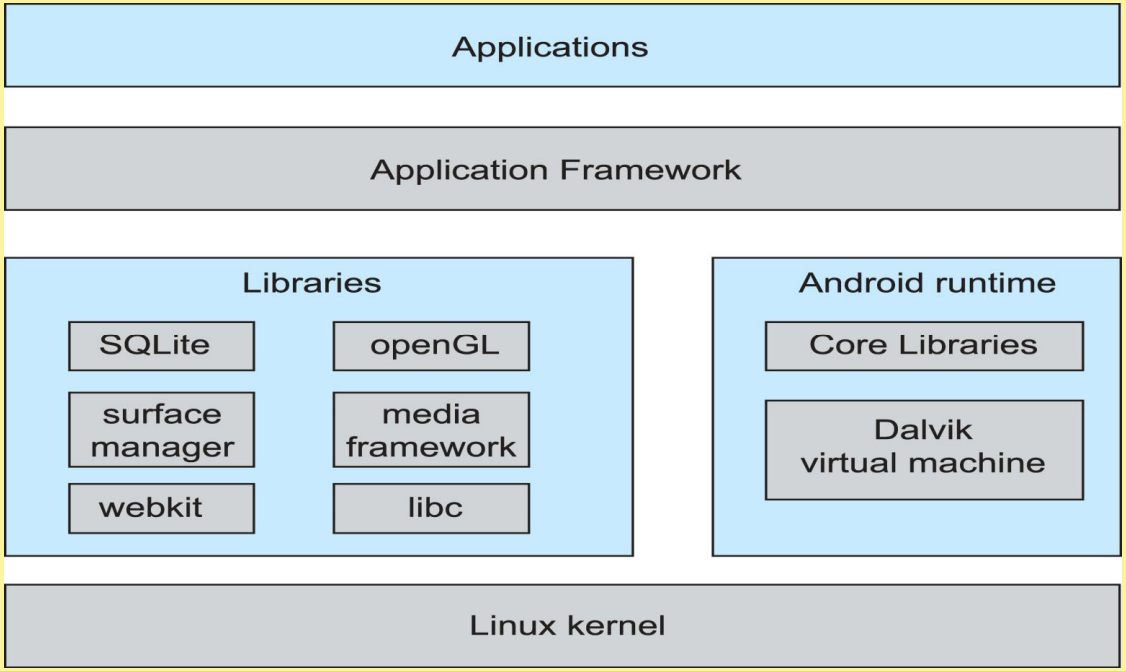
- Darwin uses a hybrid structure, and is shown Darwin is a layered system which consists primarily of the Mach microkernel and the BSD UNIX kernel.



Android

- Developed by Open Handset Alliance (mostly Google)
  - Open Source
- Similar stack to iOS
- Based on Linux kernel but modified
  - Provides process, memory, device-driver management
  - Adds power management
- Runtime environment includes core set of libraries and Dalvik virtual machine
  - Apps developed in Java plus Android API
    - Java class files compiled to Java bytecode then translated to executable than runs in Dalvik VM
- Libraries include frameworks for web browser (webkit), database (SQLite), multimedia, smaller libc


Android Architecture



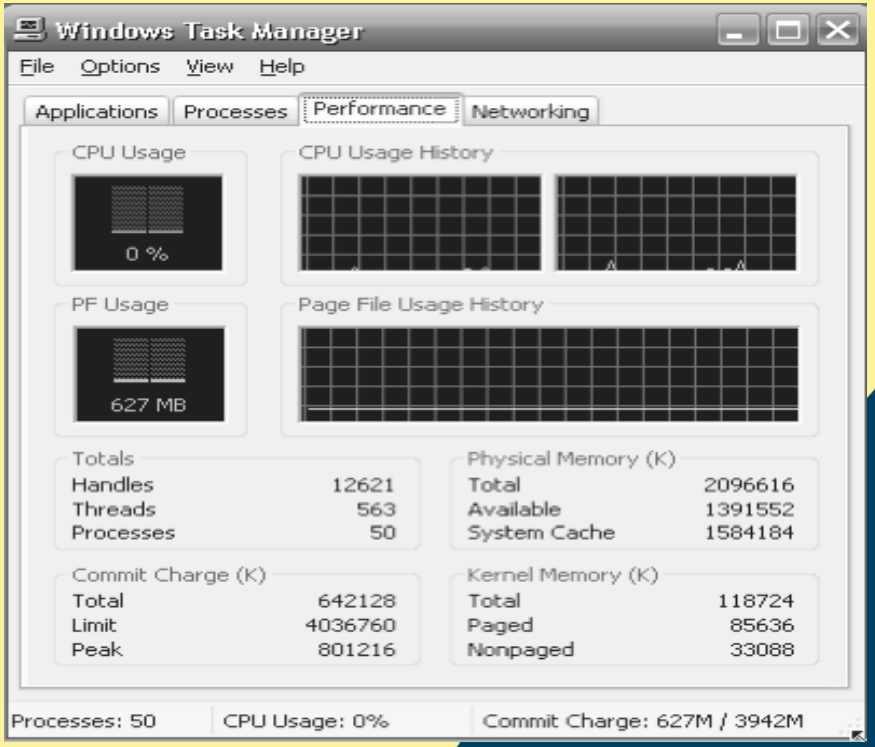
Operating-System Debugging

- **Debugging** is finding and fixing errors, or **bugs**
- OS generate **log files** containing error information
- Failure of an application can generate **core dump** file capturing memory of the process
- Operating system failure can generate **crash dump** file containing kernel memory
- Beyond crashes, performance tuning can optimize system performance
  - Sometimes using ***trace listings*** of activities, recorded for analysis
  - **Profiling** is periodic sampling of instruction pointer to look for statistical trends

Kernighan's Law: Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it."

Performance Tuning

- Improve performance by removing bottlenecks
- OS must provide means of computing and displaying measures of system behavior
- For example, “top” program or Windows Task Manager



Operating System Generation

- Operating systems are designed to run on any of a class of machines; the system must be configured for each specific computer site
- **SYSGEN** program obtains information concerning the specific configuration of the hardware system
  - Used to build system-specific compiled kernel or system-tuned
  - Can general more efficient code than one general kernel


System Boot

- When power initialized on system, execution starts at a fixed memory location
  - Firmware ROM used to hold initial boot code
- Operating system must be made available to hardware so hardware can start it
  - Small piece of code – **bootstrap loader**, stored in **ROM** or **EEPROM** locates the kernel, loads it into memory, and starts it
  - Sometimes two-step process where **boot block** at fixed location loaded by ROM code, which loads bootstrap loader from disk
- Common bootstrap loader, **GRUB**, allows selection of kernel from multiple disks, versions, kernel options
- Kernel loads and system is then **running**


Conclusion

Conclusion:

- OS provides a set of services
- At lowest level system calls are present
- Once the system services are defined, the structure of the OS can be developed
- Since OS is very large, modularity is very important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Thank you

Operating System Fundamentals

Santanu Chattopadhyay
Electronics and Electrical Communication Engg.

Processes

Concepts Covered:

- Process Concept
- Process Scheduling
- Operations on Processes
- Inter-process Communication (IPC)
- Examples of IPC Systems
- Communication in Client-Server Systems

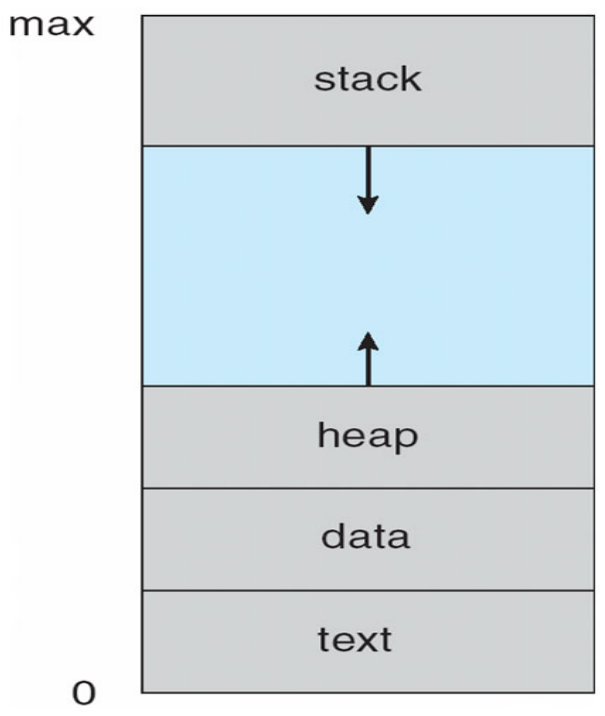
Process Concept

- **Process** – a program in execution; process execution must progress in sequential fashion
- 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 Structure

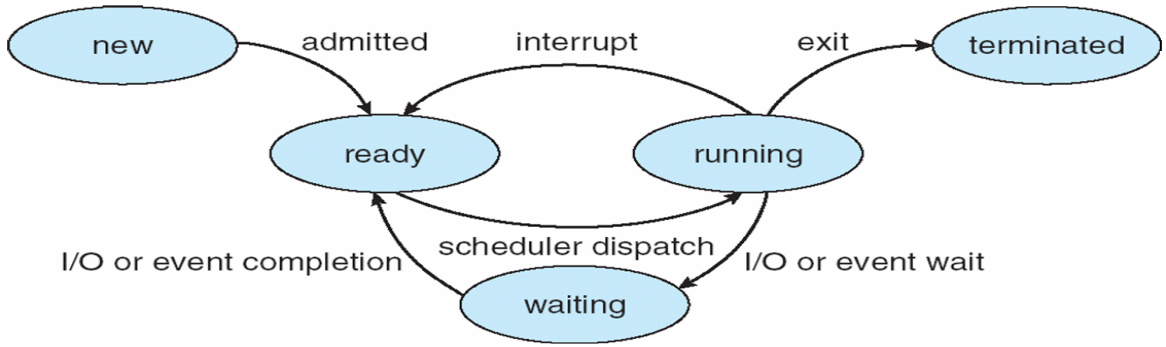
- A process is more than the program code, which is sometimes known as the **text** section.
- It also includes the current activity:
  - The value of the **program counter**
  - The contents of the **processor's registers**.
- It also includes the process **stack**, which contains temporary data (such as function parameters, return addresses, and local variables)
- It also includes the **data section**, which contains global variables.
- It may also include a **heap**, which is memory that is dynamically allocated during process run time.


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
- Diagram of Process State

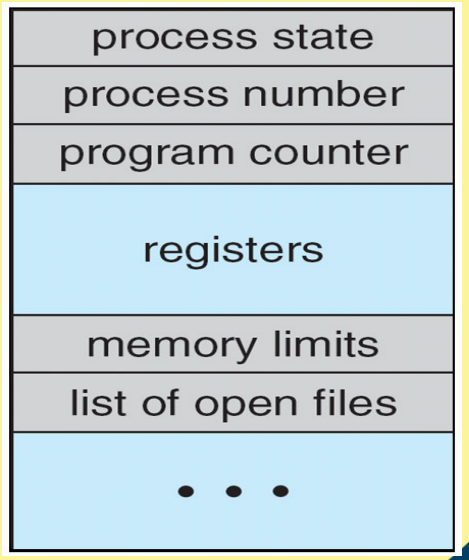


Process Control Block (PCB)

Information associated with each process

(also called **task control block**)

- Process state – running, waiting, etc
- Program counter – location of instruction to next execute
- CPU registers – contents of all process-centric registers
- CPU scheduling information- priorities, scheduling queue pointers
- Memory-management information – memory allocated to the process
- Accounting information – CPU used, clock time elapsed since start, time limits
- I/O status information – I/O devices allocated to process, list of open files



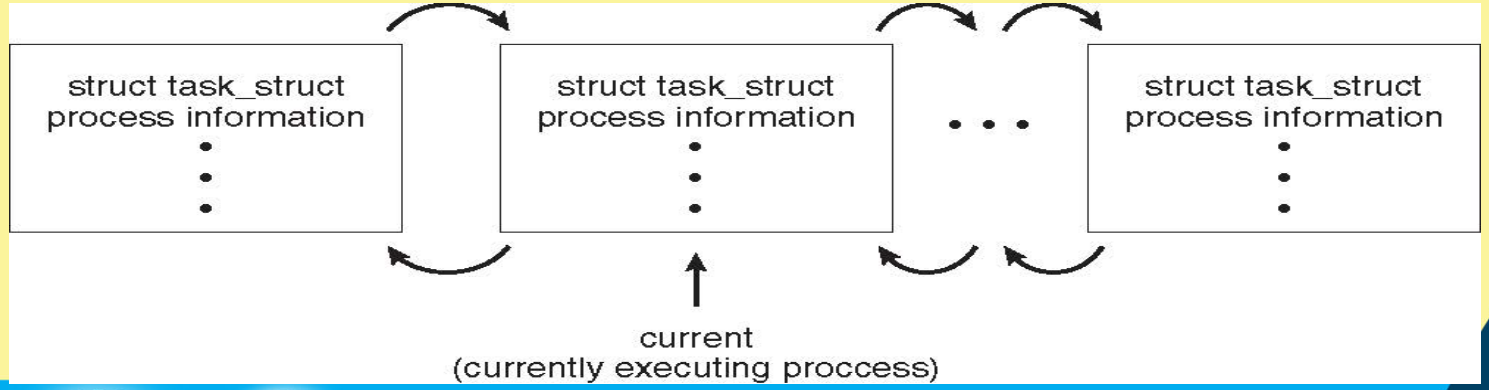
Threads

- 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**
- Need storage for thread details, multiple program counters in PCB
- Covered in the next chapter

Process Representation in Linux

Represented by the C structure `task_struct`

```
pid t_pid; /* process identifier */
long state; /* state of the process */
unsigned int time_slice /* scheduling information */
struct task_struct *parent; /* this process's parent */
struct list_head children; /* this process's children */
struct files_struct *files; /* list of open files */
struct mm_struct *mm; /* address space of this process */
```



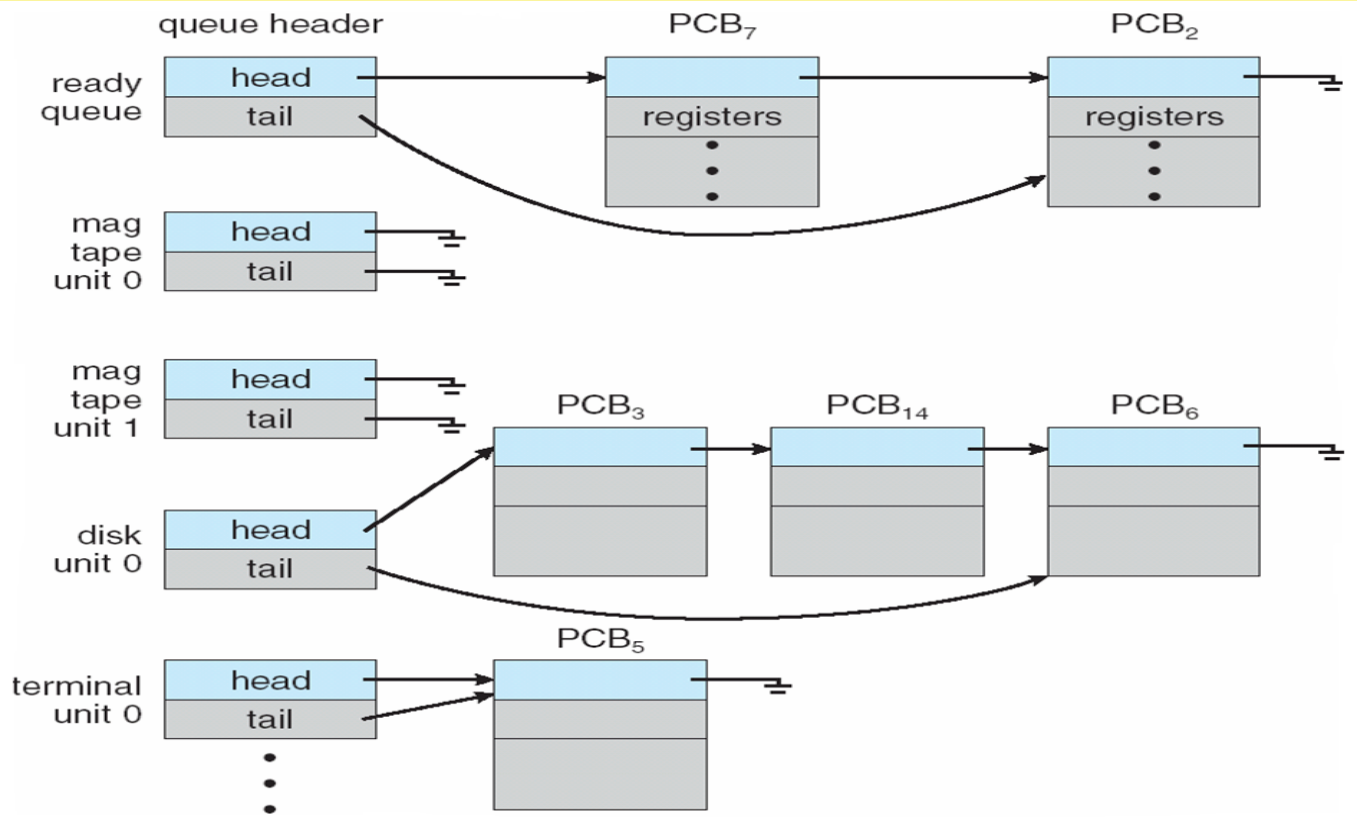
Process Scheduling

- Maximize CPU use
  - Quickly switch processes onto CPU for time sharing
- Process “gives” up then CPU under two conditions:
  - I/O request
  - After N units of time have elapsed (need a timer)
- Once a process gives up the CPU it is added to the “ready queue”
- **Process scheduler** selects among available processes in the ready queue for next execution on CPU


Scheduling Queues

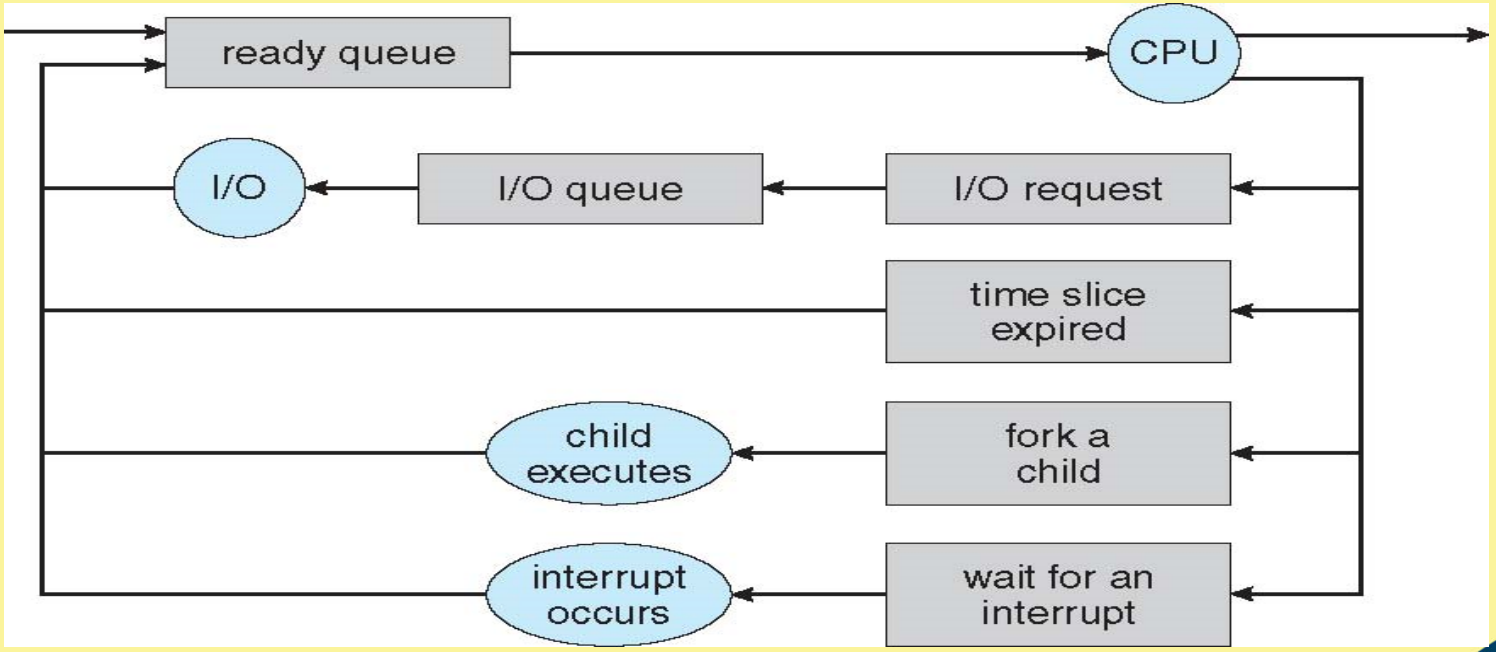
- OS Maintains **scheduling queues** of processes
  - **Job queue** – set of all processes in the system
  - **Ready queue** – set of all processes residing in main memory, ready and waiting to execute
  - **Device queues** – set of processes waiting for an I/O device
  - Processes migrate among the various queues


Ready Queue And Various I/O Device Queues

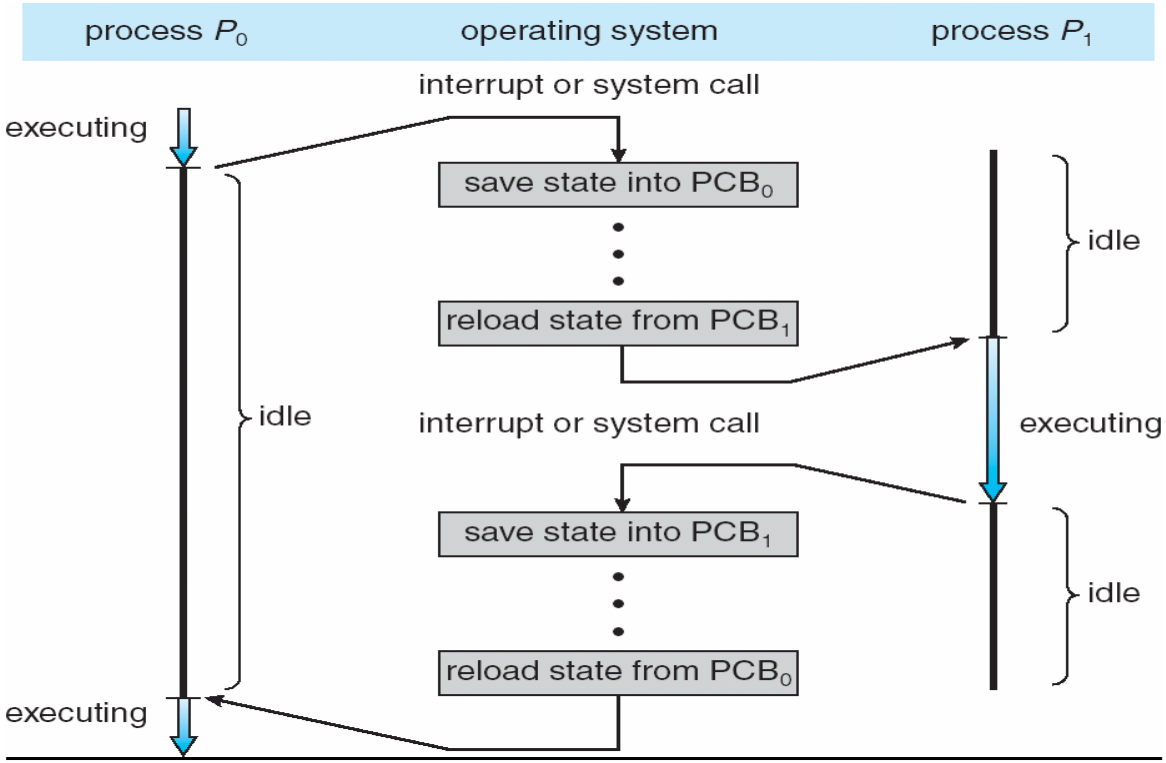


Representation of Process Scheduling

- **Queuing diagram** represents queues, resources, flows



CPU Switch From Process to Process



Schedulers

- **Short-term scheduler** (or **CPU scheduler**) – selects which process should be executed next and allocates a 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***


Multitasking in Mobile Systems

- Some mobile systems (e.g., early version of iOS) allow only one process to run, others suspended
- Starting with iOS 4, it provides for a
  - Single **foreground** process – controlled via user interface
  - Multiple **background** processes – in memory, running, but not on the display, and with limits
  - Limits include single, short task, receiving notification of events, specific long-running tasks like audio playback
- 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

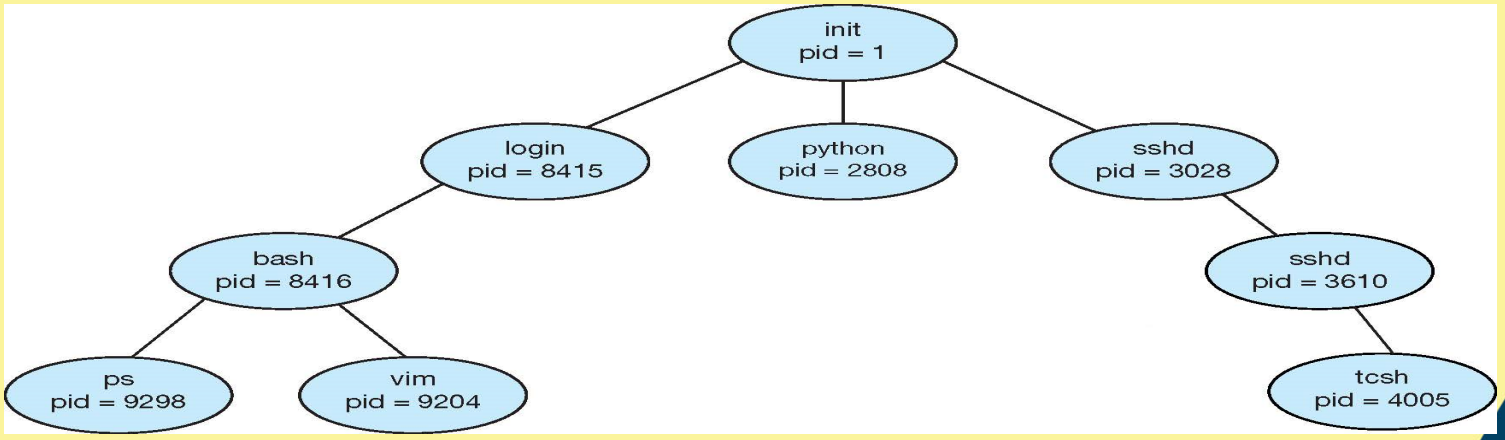
- When CPU switches to another process, the system must **save the state** of the old process and load the **saved state** for the new process via a **context switch**
- **Context** of a process represented in the PCB
- Context-switch time is pure overhead; the system does no useful work while switching
  - 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

- A **process** may create other processes.
- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes
- Generally, a process is identified and managed via a **process identifier** (**pid**)
- A Tree of Processes in UNIX

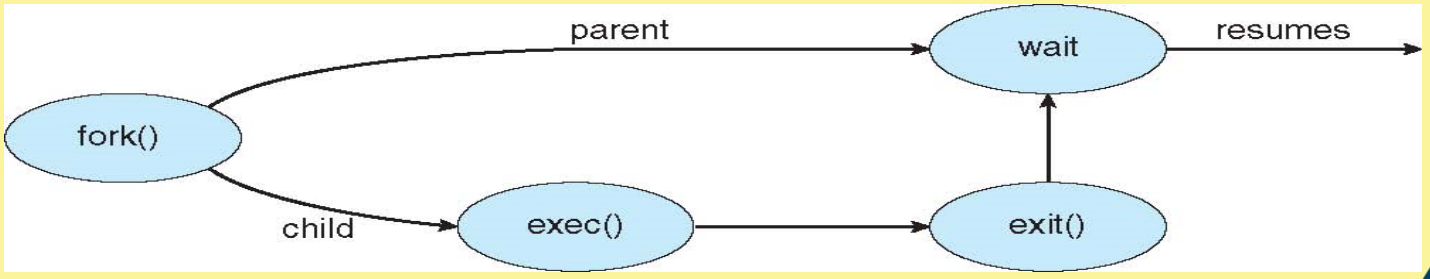


Process Creation (Cont.)

- Resource sharing among parents and children options
  - Parent and children share all resources
  - Children share subset of parent’s resources
  - Parent and child share no resources
- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate

Process Creation (Cont.)

- Address space
  - A child is a duplicate of the parent address space.
  - A child loads a program into the address space.
- UNIX examples
  - **`fork()`** system call creates new process
  - **`exec()`** system call used after a **`fork()`** replaces the process' memory space with a new program



C program to create a separate process in UNIX

```
int main()
{
pit.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;
}
```