Operating Systems
(1DT020 & 1TT802)

Lecture 3
Processes, threads, process dispatching (cont'd)

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http://www.it.uu.se/edu/course/homepage/os/vt08

Goals for Today

- **Finish goals of last lecture**
  - **How do we provide multiprogramming?**
  - **What are Processes?**
  - **How are they related to Threads and Address Spaces?**

Note: Some slides and/or pictures in the following are adapted from slides ©2005 Silberschatz, Galvin, and Gagne, others from Kubiatowicz - CS162 ©UCB Fall 2007 (University of California at Berkeley)

Concurrency

- **Stream ("thread") of execution**
  - Independent Fetch/Decode/Execute loop
  - Operating in some Address space
- **Uniprogramming: *one thread at a time***
  - MS/DOS, early Macintosh, batch processing
  - Easier for operating system builder
  - Get rid concurrency by defining it away
  - Does this make sense for personal computers?
- **Multiprogramming: *more than one thread at a time***
  - Multics, UNIX/Linux, OS/2, Windows NT/2000/XP, Mac OS X
  - Often called "multitasking", but multitasking has other meanings (talk about this later)

The Basic Problem of Concurrency

- The basic problem of concurrency involves resources:
  - Hardware: single CPU, single DRAM, single I/O devices
  - Multiprogramming API: users think they have exclusive access to machine
- OS Has to coordinate all activity
  - Multiple users, I/O interrupts, …
  - How can it keep all these things straight?
- Basic Idea: Use Virtual Machine abstraction
  - Decompose hard problem into simpler ones
  - Abstract the notion of an executing program
  - Then, worry about multiplexing these abstract machines
- Dijkstra did this for the “THE system”
  - Few thousand lines vs 1 million lines in OS 360 (1K bugs)

Single-Threaded Example

- **Imagine the following C program:**

```
main() {
    ComputePI("pi.txt");
    PrintClassList("clist.text");
}
```

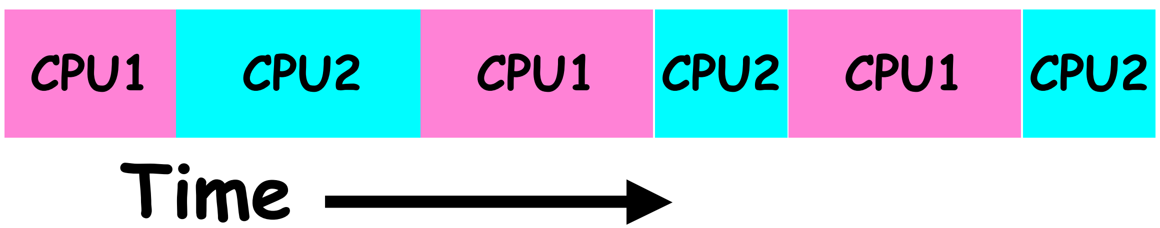
- **What is the behavior here?**
  - **Program would never print out class list**
  - **Why? ComputePI would never finish**

Use of Threads

- **Version of program with Threads:**

```
main() {
    CreateThread(ComputePI("pi.txt"));
    CreateThread(PrintClassList("clist.text"));
}
```

- **What does "CreateThread" do?**
  - Start independent thread running given procedure
- **What is the behavior here?**
  - Now, you would actually see the class list
  - This *should* behave as if there are two separate CPUs



Traditional UNIX Process

- **Process: *Operating system abstraction to represent what is needed to run a single program***
  - **Often called a "Heavy Weight Process"**
  - **Formally: a single, sequential stream of execution in its *own* address space**
- **Two parts:**
  - **Sequential Program Execution Stream**
    - » **Code executed as a *single, sequential* stream of execution**
    - » **Includes State of CPU registers**
  - **Protected Resources:**
    - » **Main Memory State (contents of Address Space)**
    - » **I/O state (i.e. file descriptors)**
- **Important: There is no concurrency in a heavyweight process**

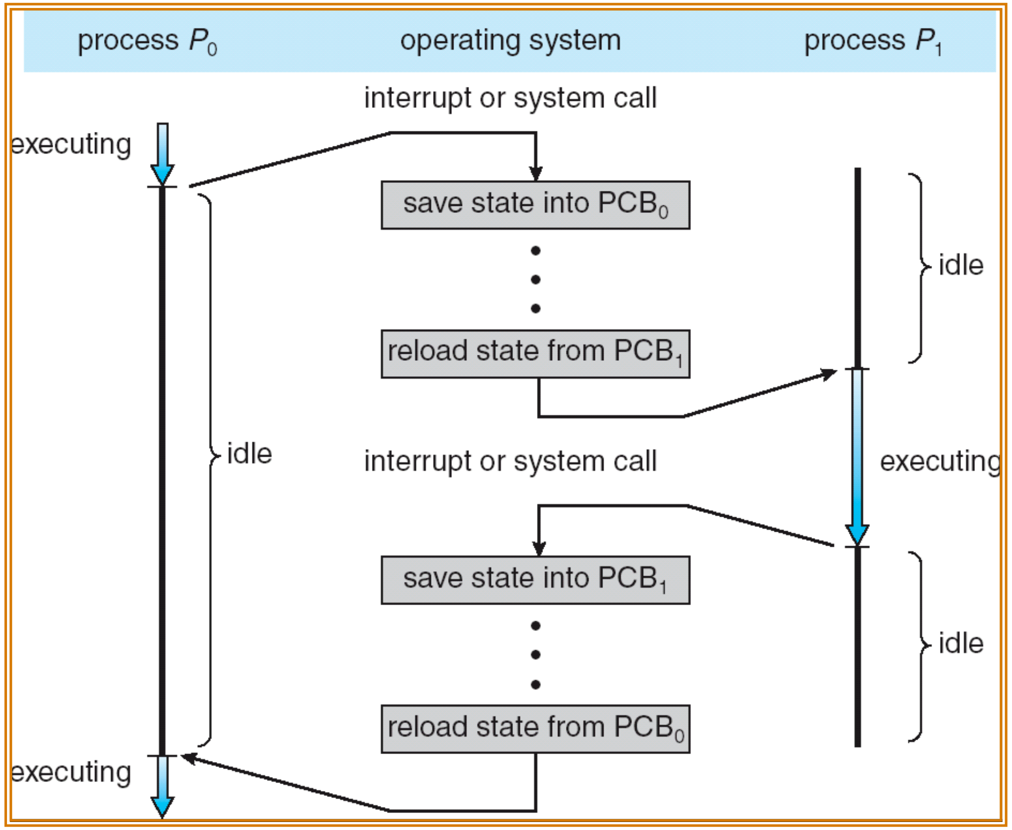
How do we multiplex processes?

- **The current state of process held in a process control block (PCB):**
  - This is a "snapshot" of the execution and protection environment
  - Only one PCB active at a time
- **Give out CPU time to different processes (CPU Scheduling or Process dispatching):**
  - Only one process "running" at a time
  - Give more time to important processes
- **Give pieces of resources to different processes (Protection):**
  - Controlled access to non-CPU resources
  - Sample mechanisms:
    - » Memory Mapping: Give each process their own address space
    - » Kernel/User duality: Arbitrary multiplexing of I/O through system calls

pointers	process state
process id	
program counter	
other registers	
memory limits	
list of open files	
⋮	

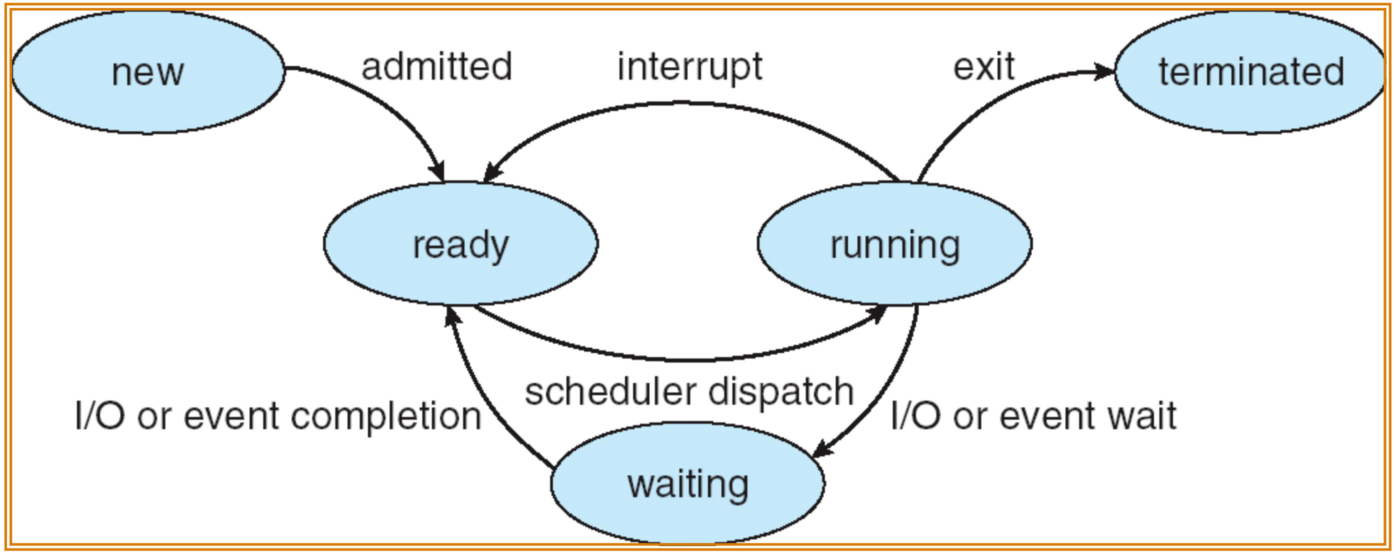
Process Control Block

CPU Switch From Process to Process



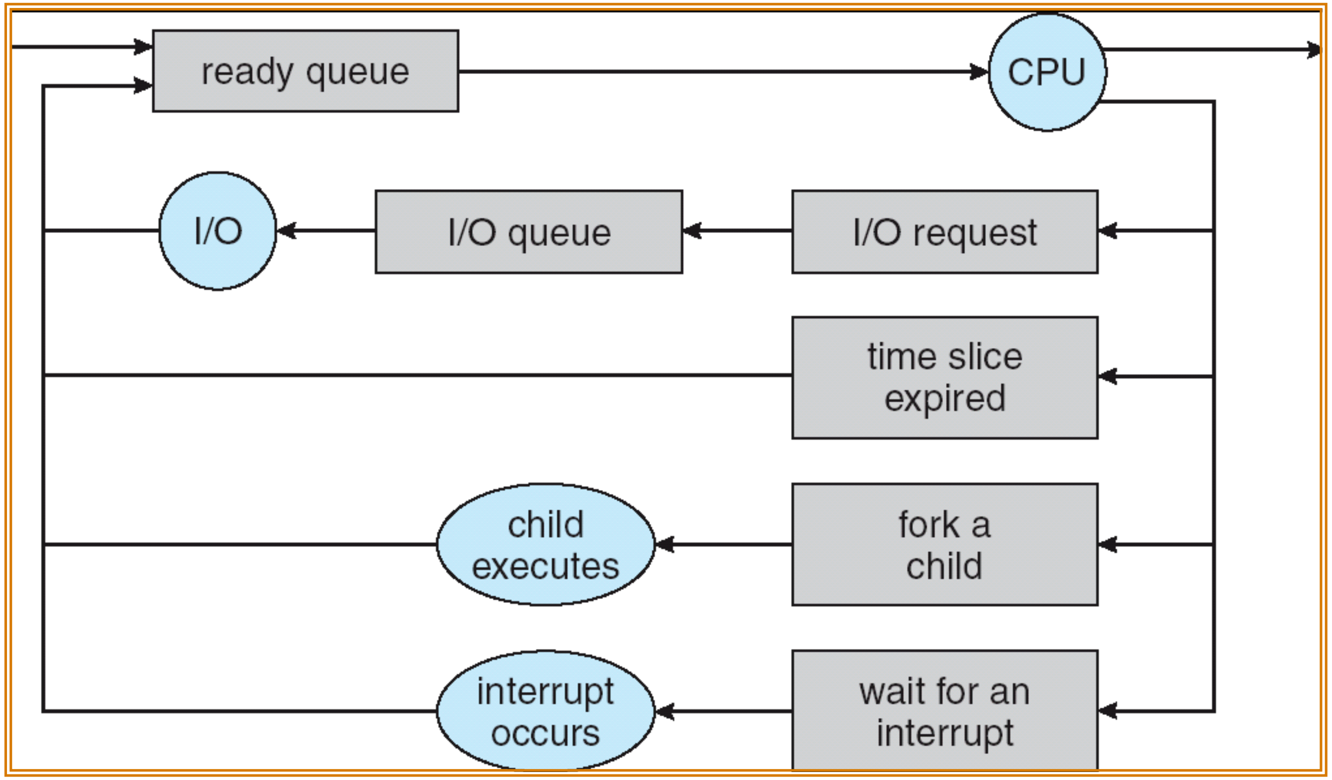
- **This is also called a "context switch"**
- **How long does it take to switch from one process to another ?**
- **Code executed in kernel above is overhead**
  - **Overhead sets minimum practical switching time**
  - **Less overhead with SMT/hyperthreading, but… contention for resources instead**

Diagram of Process State



- **As a process executes, it changes *state***
  - new: **The process is being created**
  - ready: **The process is waiting to run**
  - running: **Instructions are being executed**
  - waiting: **Process waiting for some event to occur**
  - terminated: **The process has finished execution**

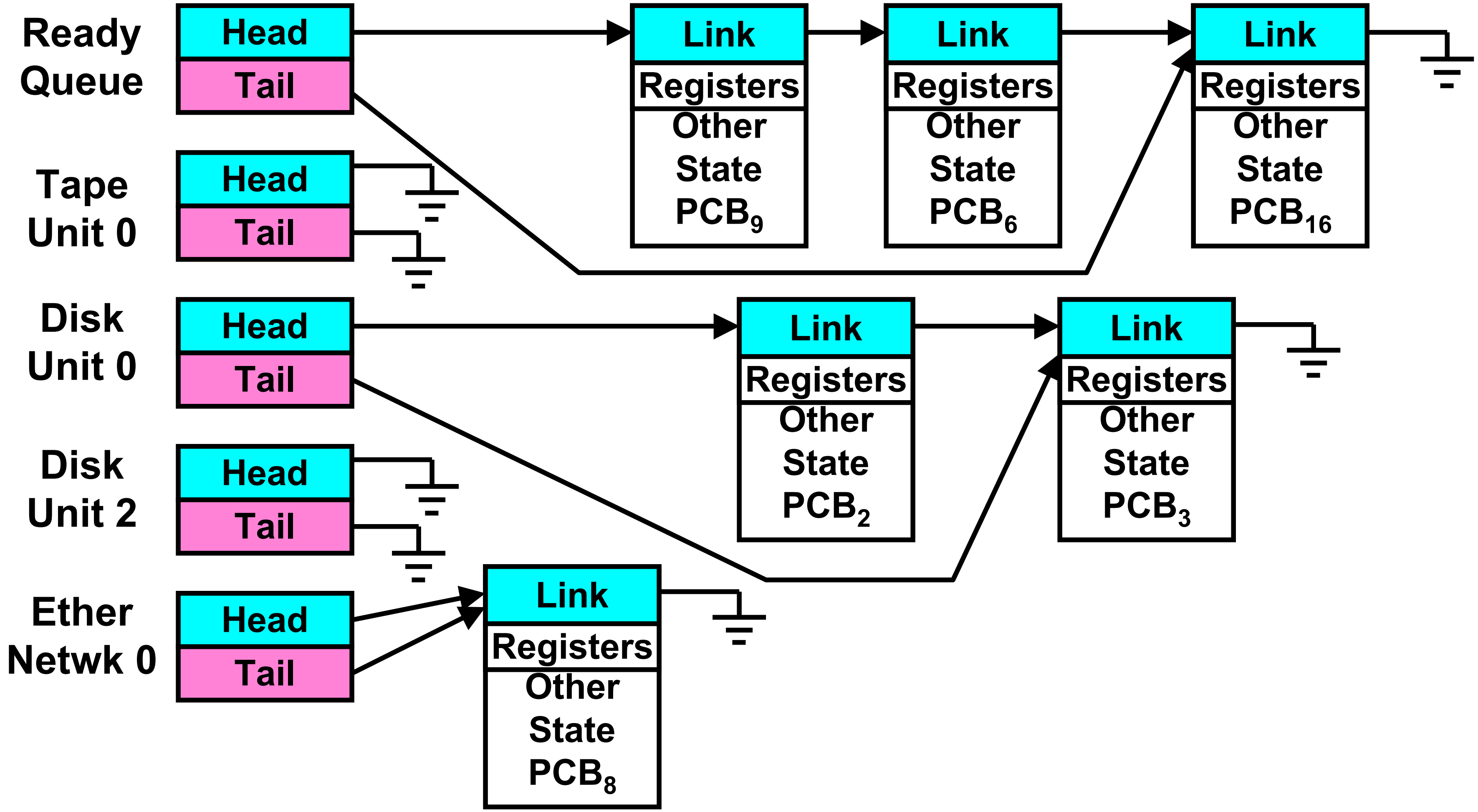
Process Scheduling



- **PCBs move from queue to queue as they change state**
  - **Decisions about which order to remove from queues are Scheduling decisions**
  - **Many algorithms possible**

Ready Queue And Various I/O Device Queues

- **Process not running ⇒ PCB is in some scheduler queue**
  - Separate queue for each device/signal/condition
  - Each queue can have a different scheduler policy



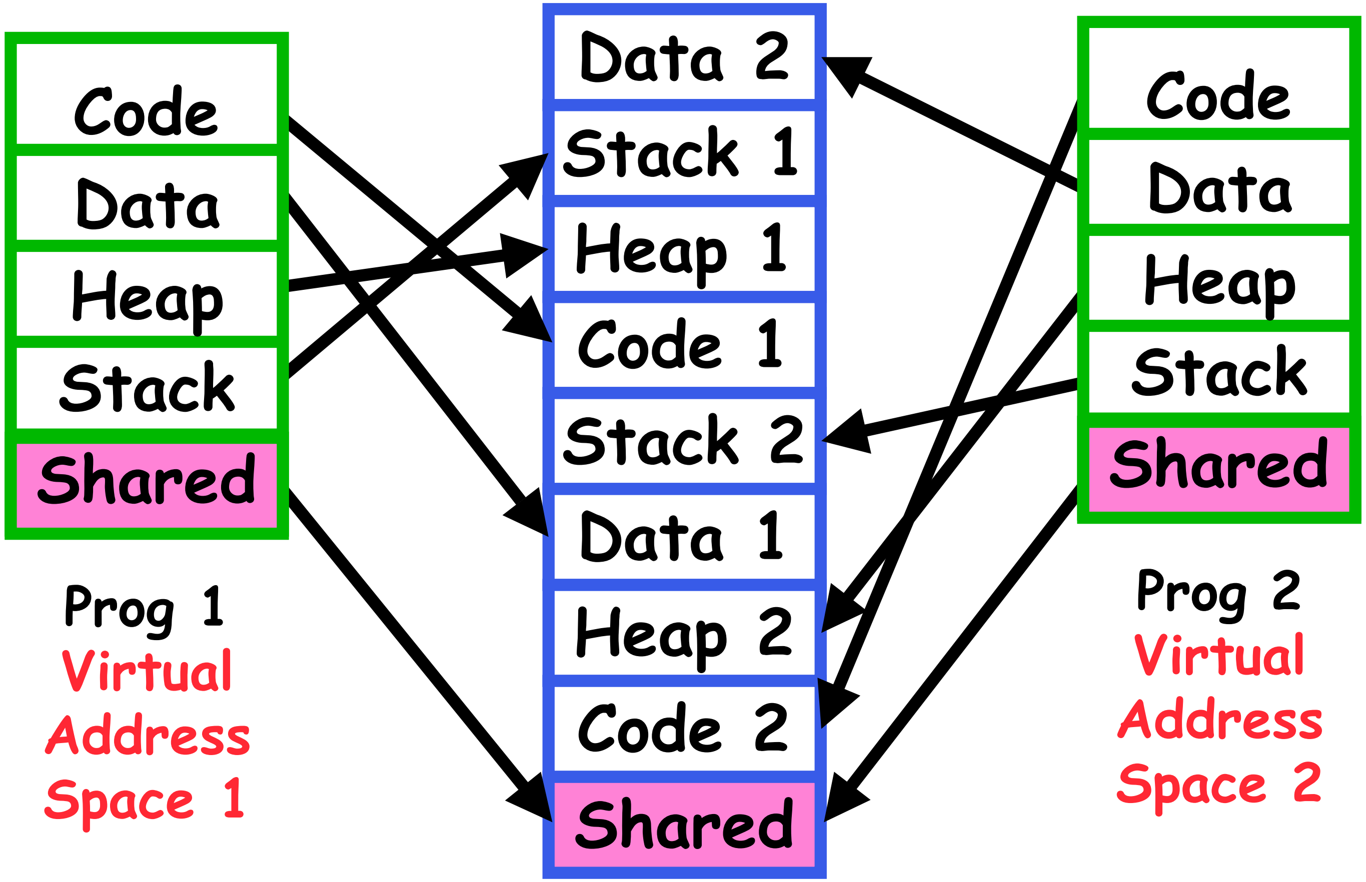
What does it take to create a process?

- **Must construct new PCB**
  - **Inexpensive**
- **Must set up new translation map for address space**
  - **More expensive**
- **Copy data from parent process? (Unix `fork()`)**
  - **Semantics of Unix `fork()` are that the child process gets a complete copy of the parent memory and I/O state**
  - **Originally *very* expensive**
  - **Much less expensive with "copy on write"**
- **Copy I/O state (file handles, etc)**
  - **Medium expense**

Multiple Processes Collaborate on a Task

- (Relatively) High Context-Switch Overhead
- Separate address spaces isolates processes
- Need Inter-Process Communication mechanism (IPC):
  - Shared-Memory Mapping
    - » Accomplished by mapping addresses to common DRAM
    - » Read and Write through memory
  - Message Passing
    - » `send()` and `receive()` messages
    - » Works across network

Shared Memory Communication



- Communication occurs by "simply" reading/writing to shared address page
  - Really low overhead communication
  - Introduces complex synchronization problems

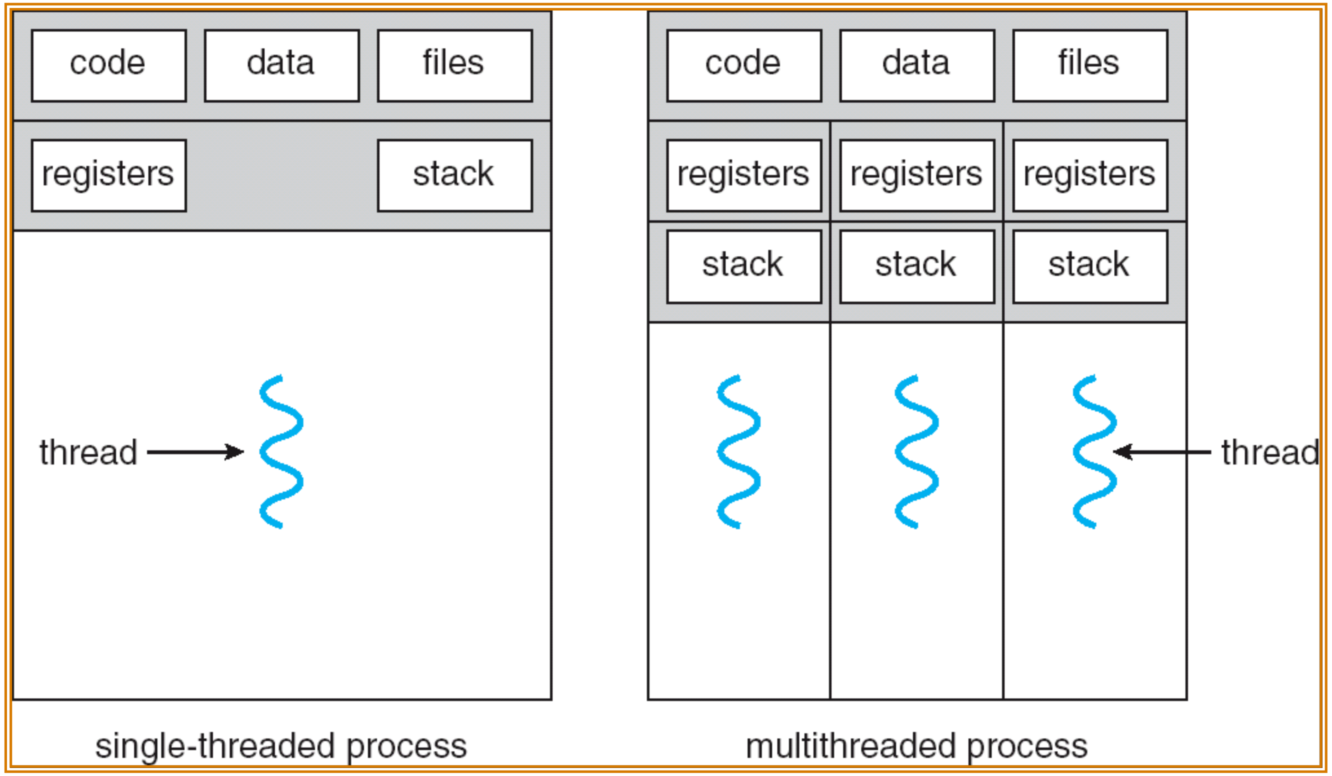
Message Passing Communication

- **Mechanism for processes to communicate and to synchronize their actions**
- **Message system – processes communicate with each other without resorting to shared variables**
- **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, system calls/traps)**
  - **logical (software)**

Modern "Lightweight" Process with Threads

- **Thread: *a sequential execution stream within process* (Sometimes called a "Lightweight process")**
  - **Process still contains a single Address Space**
  - **No protection between threads**
- **Multithreading: *a single program made up of a number of different concurrent activities***
  - **Sometimes called multitasking, as in Ada…**
- **Why separate the concept of a thread from that of a process?**
  - **Deal with the "thread" part of a process (concurrency) separate from the "address space" (Protection)**
- **Heavyweight Process ≡ Process with one thread**

Single and Multithreaded Processes



- **Threads encapsulate concurrency: "Active" component**
- **Address spaces encapsulate protection: "Passive" part**
  - **Keeps buggy program from trashing the system**
- **Why have multiple threads per address space?**

Examples of multithreaded programs

- **Embedded systems**
  - Elevators, Planes, Medical systems, Wristwatches
  - Single Program, concurrent operations
- **Most modern OS kernels**
  - Internally concurrent because have to deal with concurrent requests by multiple users
  - But no protection needed within kernel
- **Database Servers**
  - Access to shared data by many concurrent users
  - Also background utility processing must be done

Examples of multithreaded programs (con't)

- Network Servers
  - Concurrent requests from network
  - Again, single program, multiple concurrent operations
  - File server, Web server, and airline reservation systems
- Parallel Programming (More than one physical CPU)
  - Split program into multiple threads for parallelism
  - This is called Multiprocessing
- Some multiprocessors are actually uniprogrammed:
  - Multiple threads in one address space but one program at a time

Thread State

- **State shared by all threads in process/addr space**
  - **Contents of memory (global variables, heap)**
  - **I/O state (file system, network connections, etc)**
- **State "private" to each thread**
  - **Kept in TCB ≡ Thread Control Block**
  - **CPU registers (including, program counter)**
  - **Execution stack – what is this?**

- **Execution Stack**
  - **Parameters, local variables, temporary storage**
  - **return PCs are kept while called procedures are executing**

Classification

# threads Per AS: / # of addr spaces:	One	Many
One	MS/DOS, early Macintosh	Traditional UNIX
Many	Embedded systems (Geoworks, VxWorks, JavaOS,etc) JavaOS, Pilot(PC)	Mach, OS/2, Linux Windows 9x??? Win NT to XP, Solaris, HP-UX, OS X

- Real operating systems have either
  - One or many address spaces
  - One or many threads per address space
- Windows 95/98/ME did not have real memory protection
  - Users could overwrite process tables/System DLLs

Summary

- **Processes have two parts**
  - Threads (Concurrency)
  - Address Spaces (Protection)
- **Concurrency accomplished by multiplexing CPU Time:**
  - Unloading current thread (PC, registers)
  - Loading new thread (PC, registers)
  - Such context switching may be voluntary (`yield()`, I/O operations) or involuntary (timer, other interrupts)
- **Protection accomplished by restricting access:**
  - Memory mapping isolates processes from each other
  - Dual-mode for isolating I/O, other resources