

1 User Mode

- Is restricted
- Executing code has no ability to *directly* access hardware or reference memory ^[1]
- Crashes are always recoverable ^[1]
- Is where most of the code on our computer / applications are executed ^[3]

2 Kernel Mode

- Is privileged (non-restricted)
- Executing code has complete and unrestricted access to the underlying hardware ^[3]
- Is generally reserved for the lowest-level, most trusted functions of the operating system ^[1]
- Is fatal to crash; it will halt the entire PC (i.e the blue screen of death) ^[3]

3 Interrupt

- is caused by hardware (e.g. keyboard, mouse etc.) or software (page fault, protection violation, system call, etc.)
- Tells the CPU to stop its current activities and execute the appropriate part of the operating system (**Interrupt Handler**). ^[2]
- Has three different types ^[2]

1) Hardware Interrupts

- Are generated by hardware devices to signal that they need some attention from the OS.
- May be due to receiving some data

Examples

- * Keystrokes on the keyboard
- * Receiving data on the ethernet card
- May be due to completing a task which the operating system previously requested

Examples

Transferring data between the hard drive and memory

2) Software Interrupts

- Are generated by programs when a system call is requested

3) Traps

- Are generated by the CPU itself
- Indicate that some error or condition occurred for which assistance from the operating system is needed

4 Content Switch

- Is switching from running a user level process to the OS kernel and often to other user processes before the current process is resumed
- Happens during a timer interrupt or system call
- Saves the following states for a process during a context switch
 - Stack Pointer
 - Program Counter
 - User Registers
 - Kernel State
- May hinder performance

5 System Call

- Is the programmatic way in which a computer program requests a privileged service from the kernel of the operating system
- i.e. Reading from disk
- Is strictly a subset of software interrupts
- Steps
 - 1) Setup **trap tables** on boot
 - 2) Execute system call
 - 3) Save *Program Counter, CPU registers, kernel stack* (so process can resume after **return-from-trap** or **context switch**)
 - 4) Switch from **user mode** to **kernel mode**

- 5) Perform privileged operations
- 6) Finish and execute **return-from-trap** instruction
- 7) Return from **kernel mode** to **user mode** and resume user program

Example

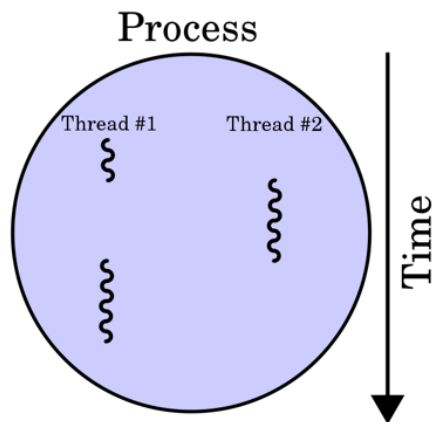
- `yield()`
 - Is a system call
 - Causes the calling thread to relinquish the CPU
 - Places the current thread at the end of the run queue
 - Schedules another thread to run

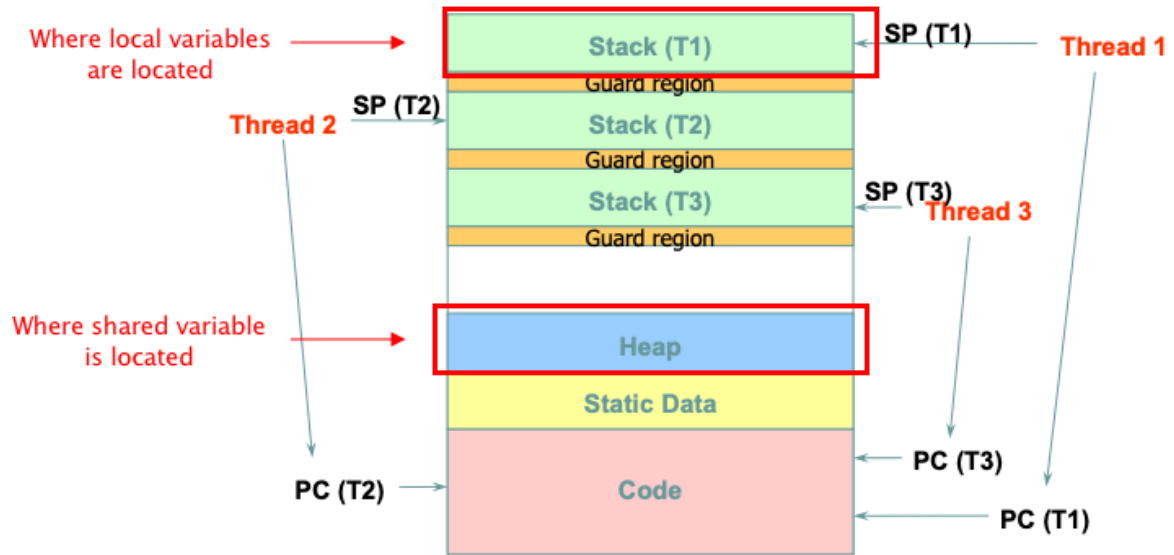
6 Critical Section

- Is a piece of code that accesses a *shared* resource, usually a variable or data structure

7 Thread

- Is a lightweight process that can be managed independently by a scheduler ^[4]
- Improves the application performance using parallelism. (e.g peach)





- A thread is bound to a single process
- A process can have multiple threads
- Has two types
 - **User-level Threads:**
 - * Are implemented by users and kernel is not aware of the existence of these threads
 - * Are represented by a program counter(PC), stack, registers and a small process control block
 - * Are small and much faster than kernel level threads
 - **Kernel-level Threads:**
 - * Are handled by the operating system directly
 - * Thread management is done by the kernel
 - * Are slower than user-level threads

8 Thread API

- `pthread_cond_wait`
 - Puts the calling thread to sleep (a blocked state)
 - Waits for some other thread to signal it

Example

```
pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER;
pthread_cond_t  cond = PTHREAD_COND_INITIALIZER;

pthread_mutex_lock(&lock);
while (ready == 0)
    pthread_cond_wait(&cond, &lock);
pthread_mutex_unlock(&lock);
```

Puts calling thread cond to sleep

- `pthread_cond_signal`
 - Is used to unblocks at least one of the threads that are blocked on the specified condition variable `cond`

Example

```
pthread_mutex_lock(&lock);
ready = 1;
pthread_cond_signal(&cond);
pthread_mutex_unlock(&lock);
```

Wakes a thread that's been put to sleep on cond variable

9 Process

- Is a program in execution
- Is named by it's process ID or PID
- Can be described by the following states at any point in time
 - Address Space
 - CPU Registers
 - Program Counter
 - Stack Pointer
 - I/O Information

(wait. this is PCB)

- Exists in one of many different **process states**, including
 1. Running
 2. Ready to Run
 3. Blocked
- Different events (Getting Scheduled, descheduled, or waiting for I/O) transitions one of these states to the other

10 Signals

- Provides a way to communicate with the process
- Can cause job to stop, continue, or terminate
- Can be delivered to an application
 - Stops the application from whatever its doing
 - Runs Signal handler (some code in application to handle the signal)
 - When finished, the process resumes previous behavior

11 Spinlock

- Is the simplest lock to build
- Uses a lock variable
 - 0 - (available/unlock/free)
 - 1 - (acquired/locked/held)
- Has two operations
 1. `acquire()`

```
boolean test_and_set(boolean *lock)
{
    boolean old = *lock;
    *lock = True;
    return old;
}

boolean lock;

void acquire(boolean *lock) {
    while (test_and_set(lock));
}
```

2. release()

```
void release(boolean *lock) {
    *lock = false;
}
```

- Allows a single thread to enter critical section at a time
- Spins using CPU cycles until the lock becomes available.
- May spin forever

12 Response Time

- **Formula** $T_{response} = T_{firstrun} - T_{arrival}$
- measures the interactive performance between users and the system

13 Turnaround Time

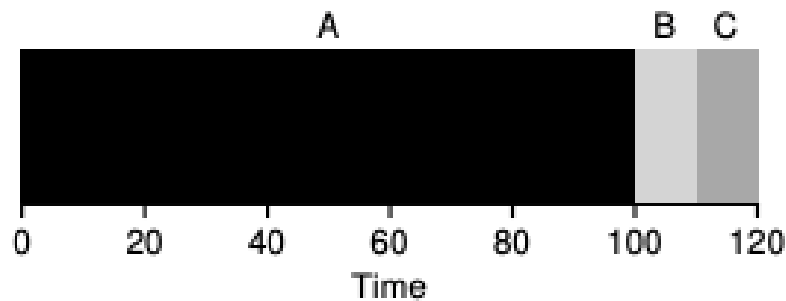
- **Formula** $T_{turnaround} = T_{completion} - T_{arrival}$
- measures the amount of time taken to complete a process

14 Starvation

- Is the problem that occurs when high priority processes keep executing and low priority processes get blocked for indefinite time ^[1]

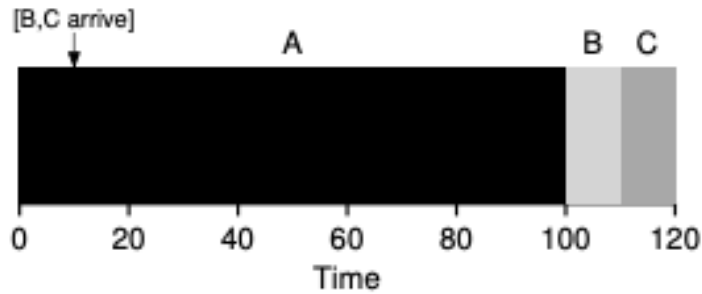
15 Convoy Effect

- Is the problem where number of relatively-short potential consumers of a resource get queued behind a heavy weight consumer



16 Scheduling policies

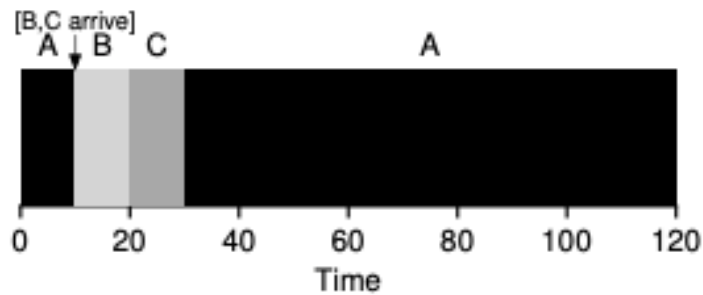
- Are algorithms for allocating CPU resources to concurrent tasks deployed on (i.e., allocated to) a processor (i.e., computing resource) or a shared pool of processors ^[5]
- Are sometimes called **Discipline**
- Covers the following algorithms in textbook
 - **First In First Out**
 - * Is the most basic scheduling algorithm
 - * Is vulnerable to **convoy effect**
 - * No **starvation** as long as every process eventually completes
 - **Shortest Job First**
 - * Improves average **turnaround time** given processes of uneven length
 - * Is a general scheduling principle useful in situation where turnaround time per process matters
 - * Is vulnerable to **convoy effect**



- * Is vulnerable to **starvation**
 - When only short-term jobs come in while a long term job is in queue

– Shortest Time-to-completion First

- * Addresses **convoy effect** in **Shortest Job First**
- * Determines which of the remaining+new jobs has least time left, and schedule accordingly at any time



- * Is vulnerable to **starvation**
 - When only short-term jobs come in while a long term job is in queue

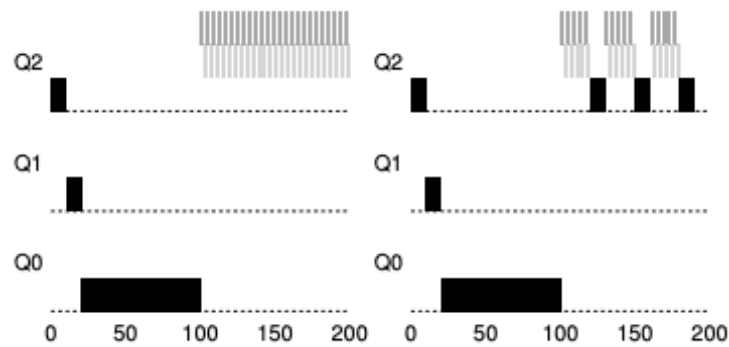
– Round Robin

- * Has good **response time** but terrible **turnaround time**
- * Runs job for a **time slice** or **quantum**
- * Each job gets equal share of CPU time
- * Is clock-driven ^[6]
- * Is starvation-free ^[7]
- * Must have the length of a time slice (**quantum**) as multiple of timer-interrupt period

```
void release(boolean *lock) {
    *lock = false;
}
```

– Multi-level Feedback Queue

- * Is the most well known approaches to scheduling
- * Optimizes **turnaround time**, and minimizes **response time**
- * Observes the execution of a job and prioritizes accordingly without prior knowledge
- * Rules
 - **Rule 1:** If $\text{Priority}(A) > \text{Priority}(B)$, A runs (B doesn't)
 - **Rule 2:** If $\text{Priority}(A) = \text{Priority}(B)$. A & B run in round-robin fashion using the time slice (quantum length) of the given queue
 - **Rule 3:** When a job enters the system, it is placed at the highest priority (the top most queue)
 - **Rule 4:** Once a job uses up its time allotment at a given level (regardless of how many times it has given up the CPU), its priority is reduced (it moves down on queue)
 - **Rule 5:** After some time period S, move all the jobs in the system to the topmost queue.



References

- 1) Coding Horror, Understanding User and Kernel Mode, [link](#)
- 2) Kansas State University, Basics of How Operating Systems Work, [link](#)
- 3) Kansas State University, Glossary, [link](#)
- 4) Tutorials Point, User-level threads and Kernel-level threads, [link](#)
- 5) Science Direct, Scheduling Policy, [link](#)
- 6) Guru 99: What is CPU Scheduling?, [link](#)
- 7) Wikipedia: Round-robin Scheduling, [link](#)