COS 318: Operating Systems

Non-Preemptive and Preemptive Threads

(http://www.cs.princeton.edu/courses/cos318/)

Quick recap on threads

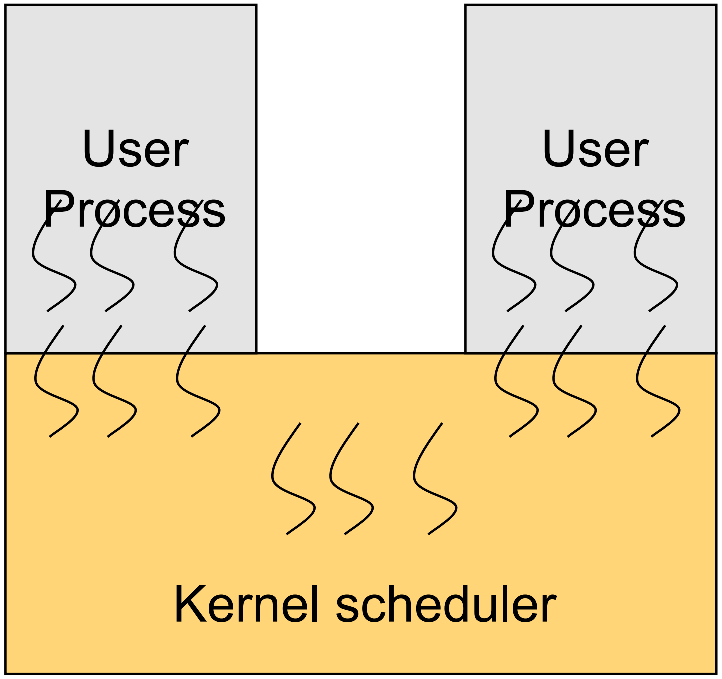
- Why are threads needed/useful?
- What about protection between threads since they share an address space?
- What happens when a process forks a child? How many threads should be created?
- What if some of the parent's threads are blocked?

Today’s Topics

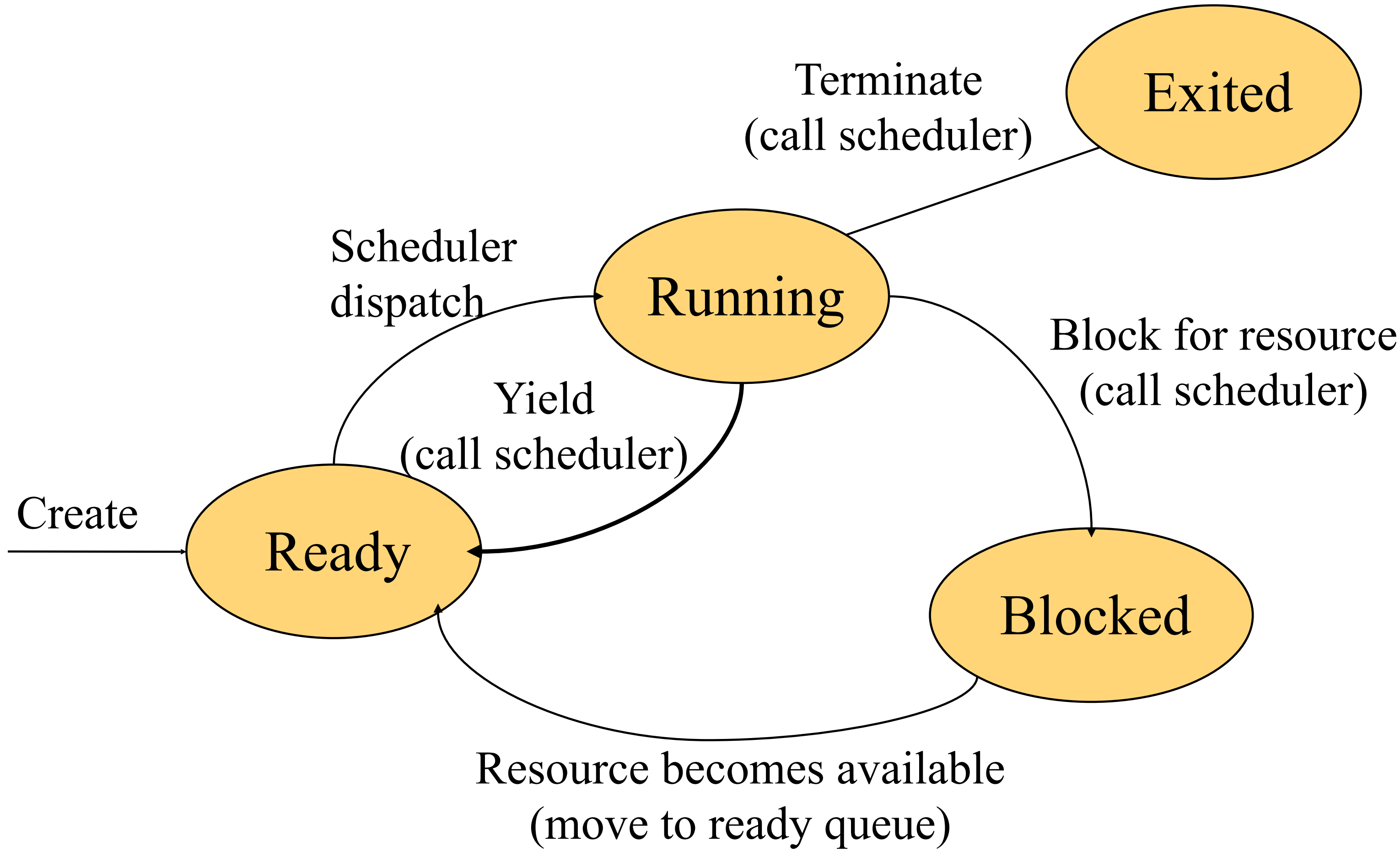
- Non-preemptive threads
- Preemptive threads
- Kernel vs. user threads
- “Too much milk” problem

Revisit Monolithic OS Structure

- Kernel has its address space shared with all processes
- Kernel consists of
  - Boot loader
  - BIOS
  - Key drivers
  - Threads
  - Scheduler
- Scheduler
  - Use a ready queue to hold all ready threads
  - Schedule in the same address space (thread context switch)
  - Schedule in a new address space (process context switch)



Non-Preemptive Scheduling



Scheduler

- A non-preemptive scheduler invoked by calling
  - block()
  - yield()

- The simplest form

  Scheduler:

  save current process/thread state

  choose next process/thread to run

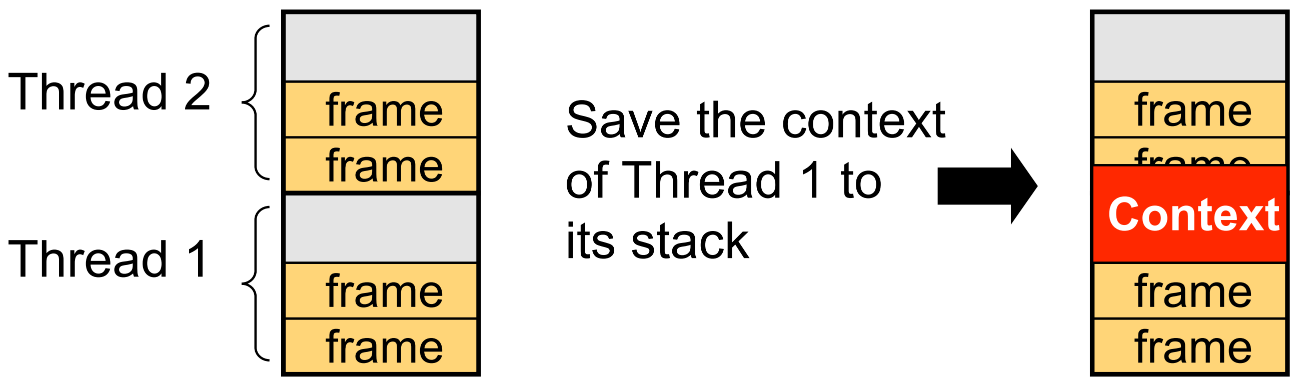
  dispatch (load PCB/TCB from table and jump to it)

More on Scheduler

- Should the scheduler use a special stack?
- Should the scheduler simply be a kernel thread?

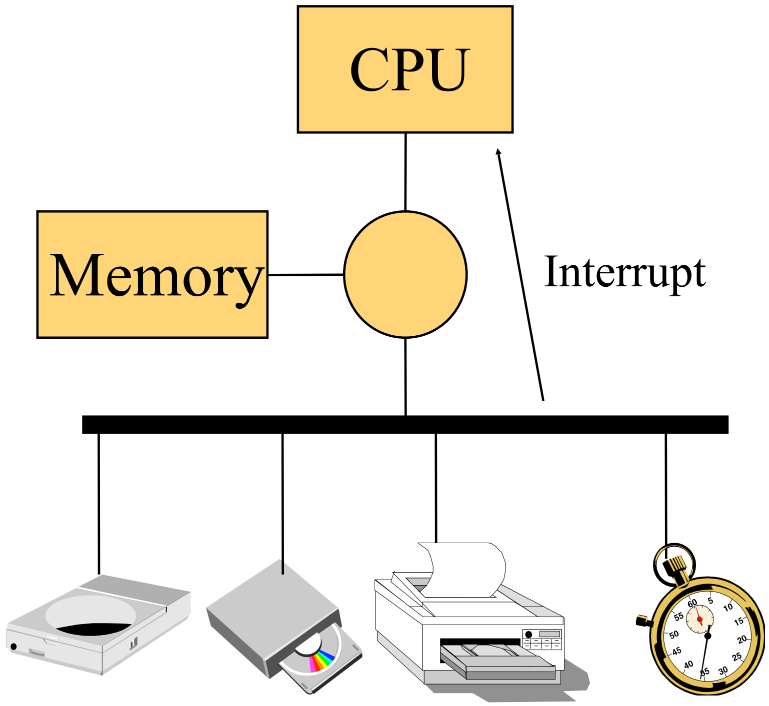
Where and How to Save Thread Context?

- Save the context on the thread's stack
  - Many processors have a special instruction to do it efficiently
  - But, need to deal with the overflow problem
- Check before saving
  - Make sure that the stack has no overflow problem
  - Copy it to the TCB residing in the kernel heap
  - Not so efficient, but no overflow problems

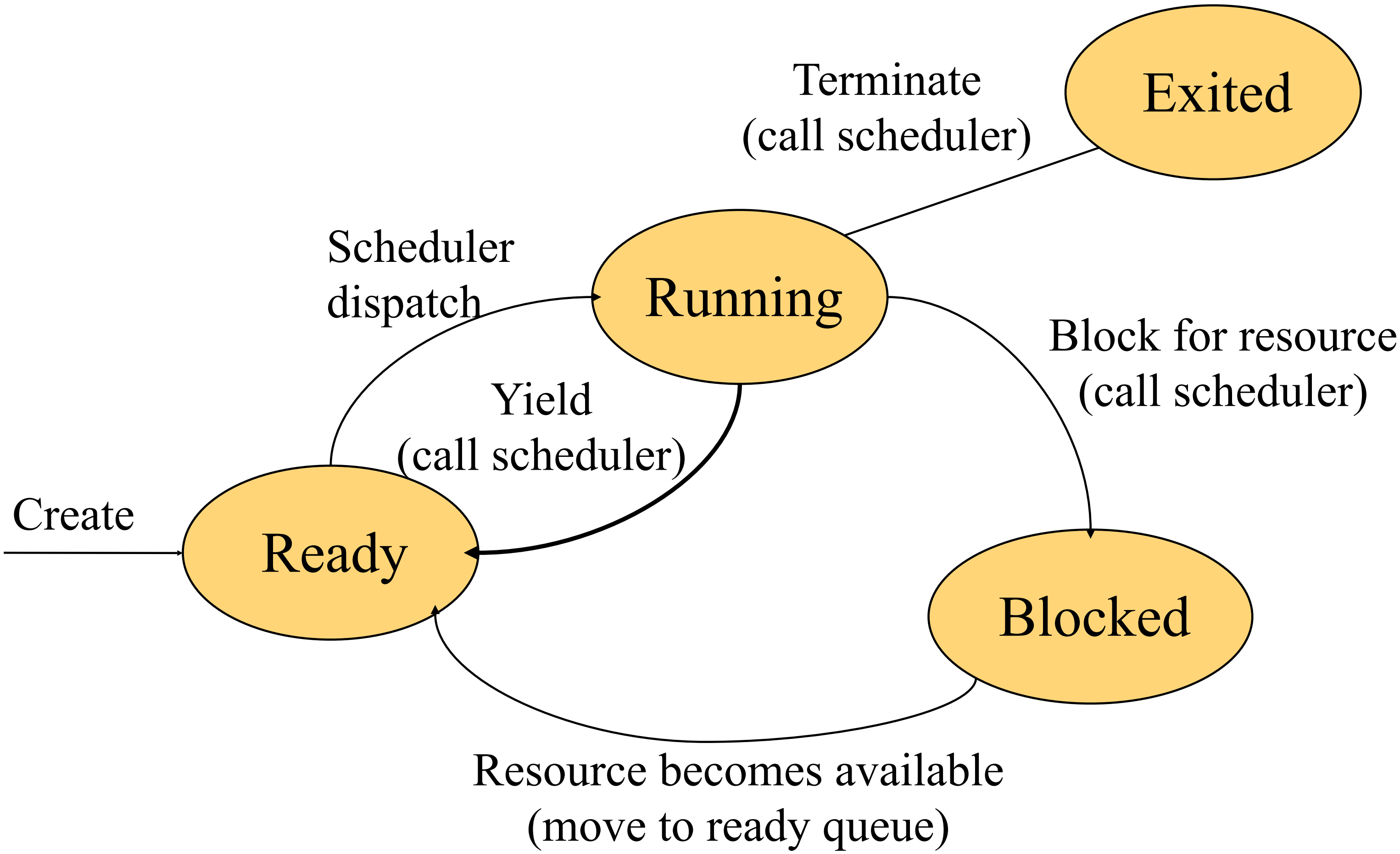


Preemption by I/O and Timer Interrupts

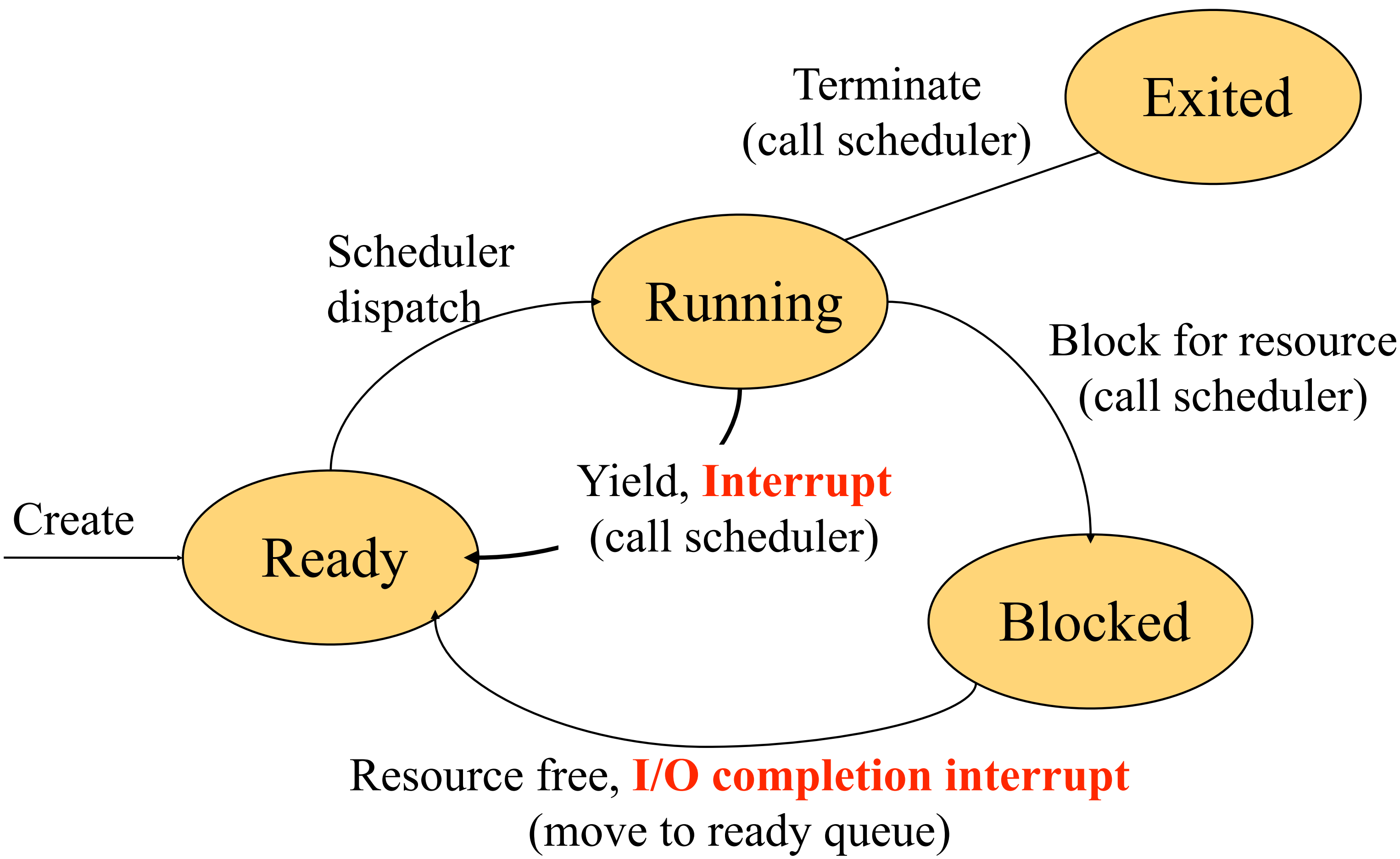
- Why
  - Timer interrupt to help CPU management
  - Asynchronous I/O to overlap with computation
- Interrupts
  - Between instructions
  - Within an instruction except atomic ones
- Manipulate interrupts
  - Disable (mask) interrupts
  - Enable interrupts
  - Non-Masking Interrupts



State Transition for Non-Preemptive Scheduling



State Transition for Preemptive Scheduling

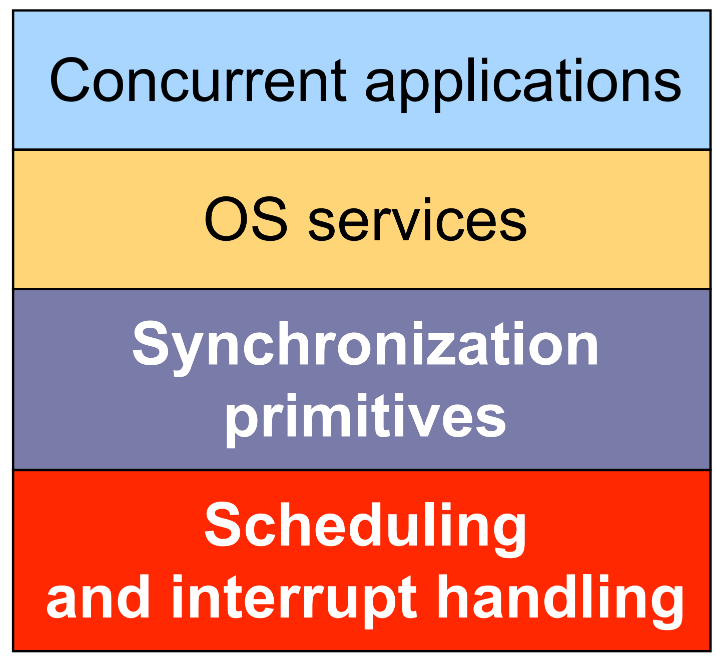


Interrupt Handling for Preemptive Scheduling

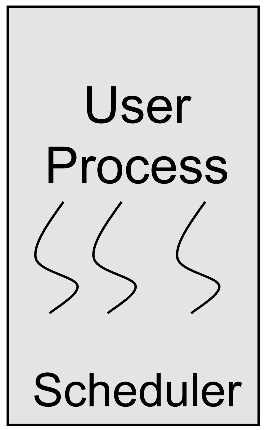
- Timer interrupt handler:
  - Save the current process / thread to its PCB / TCB
  - Call scheduler
- Other interrupt handler:
  - Save the current process / thread to its PCB / TCB
  - Do the I/O job
  - Call scheduler
- Issues
  - Disable/enable interrupts
  - Make sure that it works on multiprocessors

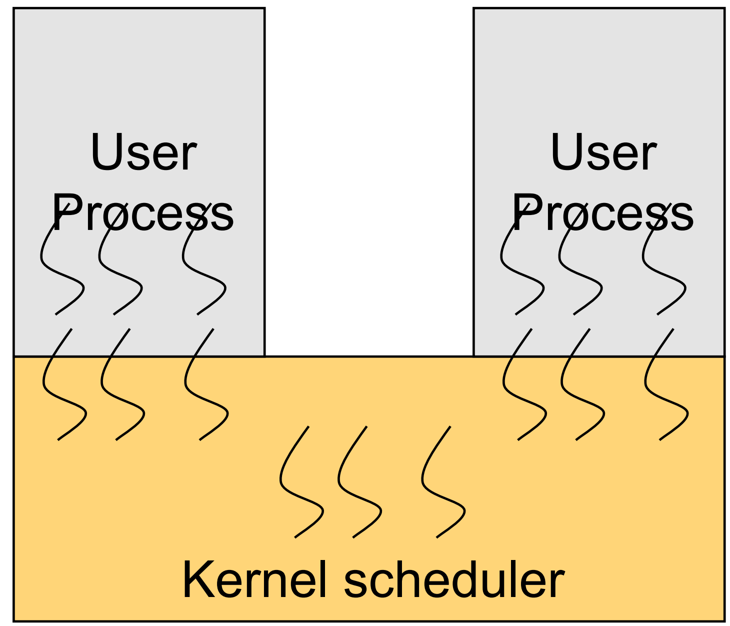
Dealing with Preemptive Scheduling

- Problem
  - Interrupts can happen anywhere
- An obvious approach
  - Worry about interrupts and preemptions all the time
- What we want
  - Worry less all the time
  - Low-level behavior encapsulated in “primitives”
  - Synchronization primitives worry about preemption
  - OS and applications use synchronization primitives



User Threads vs. Kernel Threads





- Context switch at user-level without a system call (Java threads)
- Is it possible to do preemptive scheduling?
- What about I/O events?

- A user thread
  - Makes a system call (e.g. I/O)
  - Gets interrupted
- Context switch in the kernel

Summary of User vs. Kernel Threads

- User-level threads
  - User-level thread package implements thread context switches using codes like co-routines
  - Preemption done through signals
  - When a user-level thread is blocked on an I/O event, the whole process is blocked
- Kernel-threads
  - Kernel-level threads are scheduled by a kernel scheduler
  - A context switch of kernel-threads is more expensive than user threads due to crossing protection boundaries
- Hybrid
  - It is possible to have a hybrid scheduler, but it is complex

Interactions between User and Kernel Threads

- Two approaches
  - Each user thread has its own kernel stack
  - All threads of a process share the same kernel stack

	Private kernel stack	Shared kernel stack
Memory usage	More	Less
System services	Concurrent access	Serial access
Multiprocessor	Yes	Not within a process
Complexity	More	Less

"Too Much Milk" Problem

- Do not want to buy too much milk
- Any person can be distracted at any point

	Student A	Student B
15:00	Look at fridge: out of milk	
15:05	Leave for Wawa	
15:10	Arrive at Wawa	Look at fridge: out of milk
15:15	Buy milk	Leave for Wawa
15:20	Arrive home; put milk away	Arrive at Wawa
15:25		Buy milk
		Arrive home; put milk away Oh No!

Using A Note?

Thread A

```
if ( noMilk ) {
   if (noNote) {
      leave note;
      buy milk;
      remove
note;
   }
}
```

Thread B

```
if ( noMilk ) {
   if (noNote) {
      leave note;
      buy milk;
      remove
note;
   }
}
```

- Any issue with this approach?

Another Possible Solution?

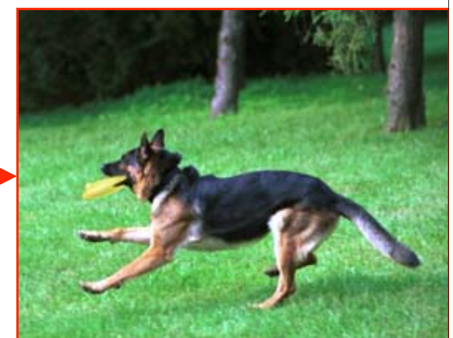
Thread A

```
leave noteA
if (noNoteB) {
   if (noMilk) {
      buy milk
   }
}
remove noteA
```

Didn't buy milk

Thread B

```
leave noteB
if (noNoteA)
   if (noMilk)
{
      buy milk
   }
}
remove noteB
```



Didn't buy milk

- Does this method work?

Yet Another Possible Solution?

Thread A

```
leave noteA
while (noteB)
  do nothing;
if (noMilk)
  buy milk;
remove noteA
```

Thread B

```
leave noteB
if (noNoteA) {
  if (noMilk) {
    buy milk
  }
}
remove noteB
```

- Would this fix the problem?

Remarks

- The last solution works, but
  - Life is too complicated
  - A's code is different from B's
  - Busy waiting is a waste
- Peterson's solution is also complex
- What we want is:

```
Acquire(lock);
if (noMilk)
  buy milk;
Release(lock);
```

Critical section

What Is A Good Solution

- Only one process/thread inside a critical section
- No assumption about CPU speeds
- A process/thread inside a critical section should not be blocked by any process outside the critical section
- No one waits forever

- Works for multiprocessors
- Same code for all processes/threads

Summary

- Non-preemptive threads issues
  - Scheduler
  - Where to save contexts
- Preemptive threads
  - Interrupts can happen anywhere!
- Kernel vs. user threads
  - Main difference is which scheduler to use
- Too much milk problem
  - What we want is mutual exclusion