CSC 4103 - Operating Systems
Spring 2008

Lecture - IV

Threads

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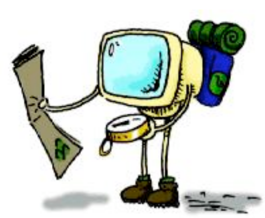
Roadmap

- Processes
  - Interprocess Communication
- Threads
  - Threads vs Processes
  - Multi-threading Models
  - Threading Issues



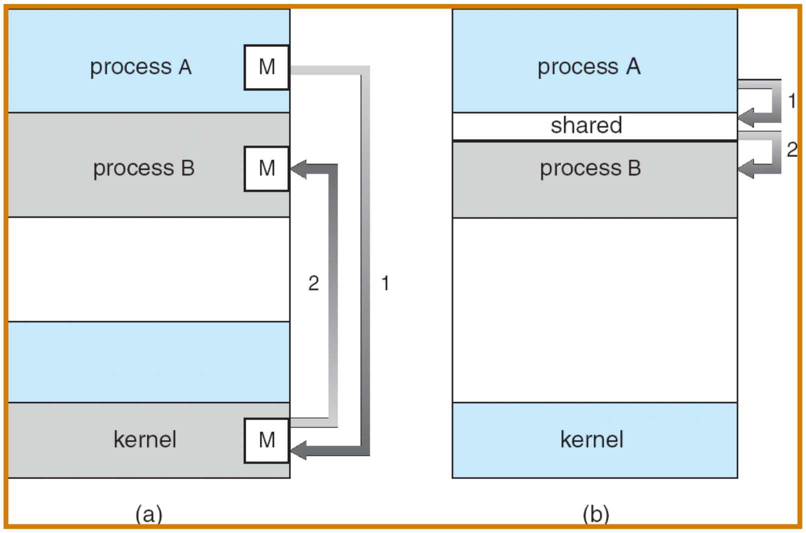
Cooperating Processes

- **Independent** process cannot affect or be affected by the execution of another process
- **Cooperating** process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Interprocess Communication (IPC)

- Mechanism for processes to communicate and to synchronize their actions
- Shared Memory: by using the same address space and shared variables
- Message Passing: processes communicate with each other without resorting to shared variables

Communications Models



a) Message Passing b) Shared Memory

Message Passing

- Message Passing facility 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
- Two types of Message Passing
  - direct communication
  - indirect communication

Message Passing – direct communication

- Processes must name each other explicitly:
  - **send** (*P, message*) – send a message to process P
  - **receive**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional
- Symmetrical vs Asymmetrical direct communication
  - **send** (*P, message*) – send a message to process P
  - **receive**(id, *message*) – receive a message from any process
- Disadvantage of both: limited modularity, hardcoded

Message Passing - indirect communication

- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Primitives are defined as:

  send(*A, message*) – send a message to mailbox A

  receive(*A, message*) – receive a message from mailbox A

Indirect Communication *(cont.)*

- Operations
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links
  - Link may be unidirectional or bi-directional

Indirect Communication *(cont.)*

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A
  - P_1, sends; P_2 and P_3 receive
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes
  - Allow only one process at a time to execute a receive operation
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** has the sender block until the message is received
  - **Blocking receive** has the receiver block until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking** send has the sender send the message and continue
  - **Non-blocking** receive has the receiver receive a valid message or null

Buffering

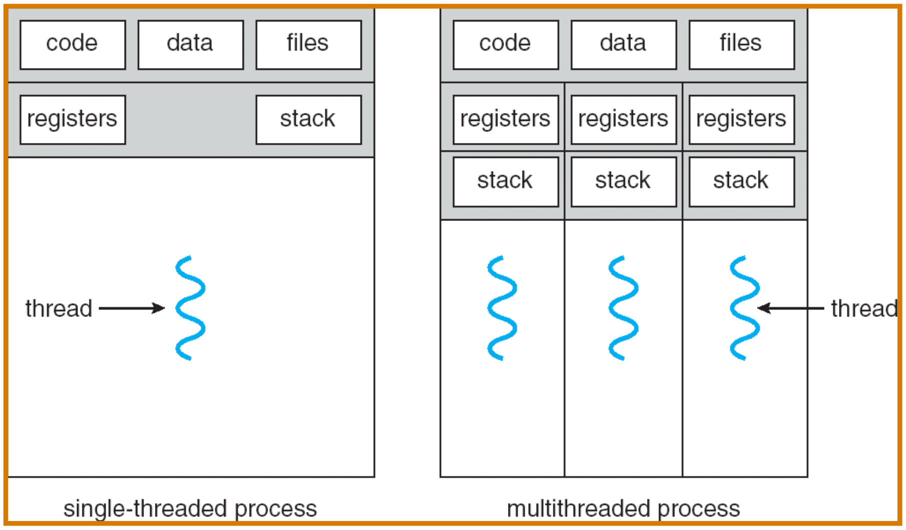
- Queue of messages attached to the link; implemented in one of three ways
  1. Zero capacity – 0 messages
     Sender must wait for receiver (rendezvous)
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full
  3. Unbounded capacity – infinite length
     Sender never waits

Threads

Motivation

- In certain cases, a single application may need to run several tasks at the same time
  - Create a new process for each task
    - Time consuming
  - Use a single process with multiple threads

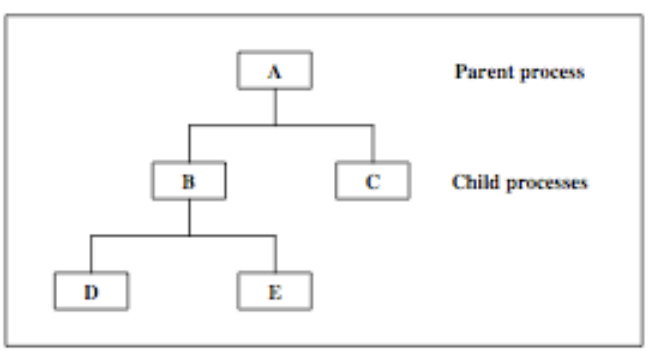
Single and Multithreaded Processes



Multi-process model

Process Spawning:

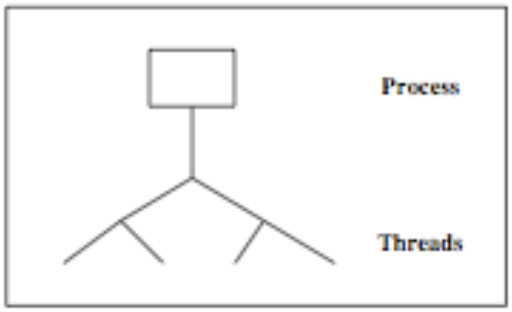
Process creation involves the following four main actions:
- **setting up the process control block,**
- **allocation of an address space and**
- **loading the program into the allocated address space and**
- **passing on the process control block to the scheduler**



Multi-thread model

Thread Spawning:

• **Threads are created *within and belonging to* processes**
• **All the threads created within one process share the resources of the process including the address space**
• **Scheduling is performed on a per-thread basis.**
• **The thread model is a *finer grain scheduling model* than the process model**
• **Threads have a similar *lifecycle* as the processes and will be managed mainly in the same way as processes are**



Threads vs Processes

- Heavyweight Process = Process
- Lightweight Process = Thread

Advantages (Thread vs. Process):
- Much quicker to create a thread than a process
- Much quicker to switch between threads than to switch between processes
- Threads share data easily

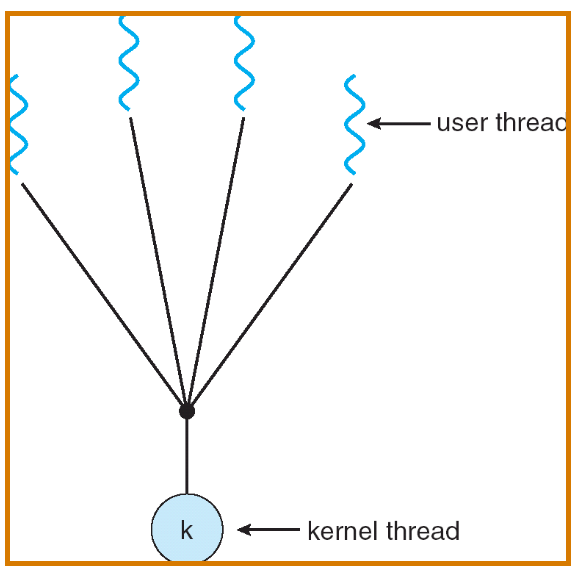
Disadvantages (Thread vs. Process):
- Processes are more flexible
  - They don't have to run on the same processor
- No security between threads: One thread can stomp on another thread's data
- For threads which are supported by user thread package instead of the kernel:
  - If one thread blocks, all threads in task block.

Different Multi-threading Models

- Many-to-One
- One-to-One
- Many-to-Many

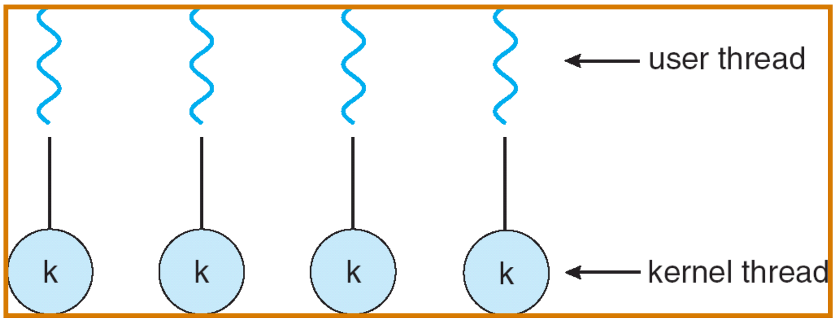
Many-to-One Model

- Several user-level threads mapped to single kernel thread
- Thread management in user space → efficient
- If a thread blocks, entire process blocks
- One thread can access the kernel at a time → limits parallelism
- Examples:
  - Solaris Green Threads
  - GNU Portable Threads



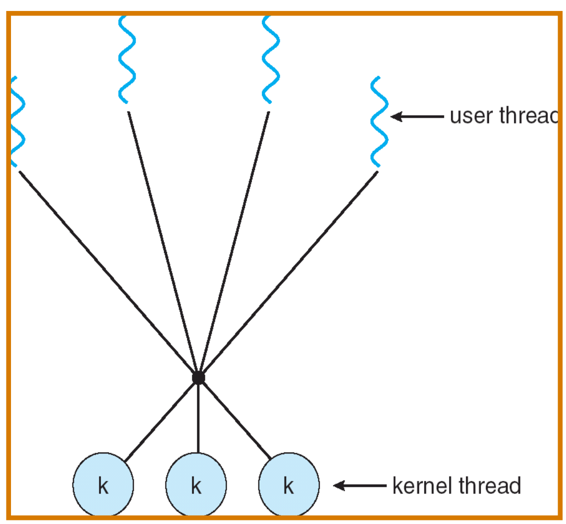
One-to-One Model

- Each user-level thread maps to a kernel thread
- A blocking thread does not block other threads
- Multiple threads can access kernel concurrently → increased parallelism
- Drawback: Creating a user level thread requires creating a kernel level thread → increased overhead and limited number of threads
- Examples: Windows NT/XP/2000, Linux, Solaris 9 and later



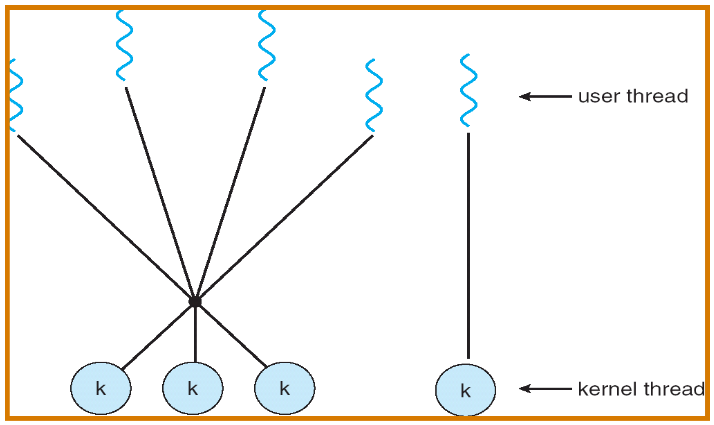
Many-to-Many Model

- Allows many user level threads to be mapped to a smaller number of kernel threads
- Allows the operating system to create a sufficient number of kernel threads
- Increased parallelism as well as efficiency
- Solaris prior to version 9
- Windows NT/2000 with the *ThreadFiber* package



Two-level Model

- Similar to M:M, except that it allows a user thread to be **bound** to kernel thread
- Examples: IRIX, HP-UX, Tru64 UNIX, Solaris 8 and earlier



Threading Issues

- Semantics of **fork()** and **exec()** system calls
- Thread cancellation
- Signal handling
- Thread pools
- Thread specific data

Semantics of fork() and exec()

- Semantics of **fork()** and **exec()** system calls change in a multithreaded program
  - Eg. if one thread in a multithreaded program calls fork()
    - Should the new process duplicate all threads?
    - Or should it be single-threaded?
  - Some UNIX systems implement two versions of fork()
  - If a thread executes exec() system call
    - Entire process will be replaced, including all threads

Thread Cancellation

- Terminating a thread before it has finished
  - If one thread finishes the searching a database, others may be terminated
  - If user presses a button on a web browser, web page can be stopped from loading further
- Two approaches to cancel the target thread
  - **Asynchronous cancellation** terminates the target thread immediately
  - **Deferred cancellation** allows the target thread to periodically check if it should be cancelled
    - More controlled and safe

Signal Handling

- Signals are used in UNIX systems to notify a process that a particular event has occurred
- All signals follow this pattern:
  1. Signal is generated by particular event
  2. Signal is delivered to a process
  3. Once delivered, a signal must be handled
- In multithreaded systems, there are 4 options:
  - Deliver the signal to the thread to which the signal applies
  - Deliver the signal to every thread in the process
  - Deliver the signal to certain threads in the process
  - Assign a specific thread to receive all signals for the

Thread Pools

- Threads come with some overhead as well
- Unlimited threads can exhaust system resources, such as CPU or memory
- Create a number of threads at process startup) and put them in a pool, where they await work
- When a server receives a request, it awakens a thread from this pool
- Advantages:
  - Usually faster to service a request with an existing thread than create a new thread
  - Allows the number of threads in the application(s) to be bound to the size of the pool
- Number of threads in the pool can be setup according to:
  - Number of CPUs, memory, expected number of concurrent requests

Thread Specific Data

- Threads belonging to the same process share the data of the process
- In some cases, each thread needs to have its own copy of data → thread specific
- Useful when you do not have control over the thread creation process (i.e., when using a thread pool)

Summary

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  - Threads vs Processes
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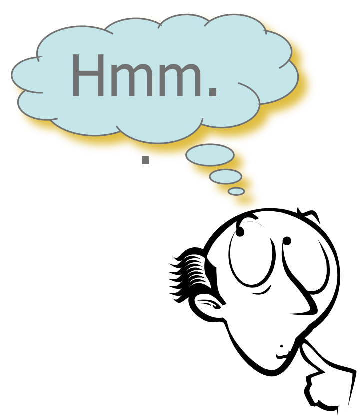

- Next Lecture: CPU Scheduling
- Reading Assignment: Chapter 4 from Silberschatz.
- HW 1 is due next Thursday before the class

Acknowledgements

- "Operating Systems Concepts" book and supplementary material by A. Silberschatz, P. Galvin and G. Gagne

- "Operating Systems: Internals and Design Principles" book and supplementary material by W. Stallings

- "Modern Operating Systems" book and supplementary material by A. Tanenbaum

- R. Doursat and M. Yuksel from UNR