Preview

- Interprocess Communication
  - With Shared Memory
  - With Message Passing
    - Direct Communication
    - Indirect Communication
- Threads
  - Overview of Threads
  - Benefit of Threads
  - Multicore Programming with Threads

Interprocess Communication

- Processes executing concurrently in the operating system may be either independent processes or cooperating processes.
- Cooperating processes require an interprocess communication (IPC) mechanism that will allow them to exchange data.
- Reasons for providing an environment that allows process cooperation:
  - Information Sharing- several processes or threads can share information
  - Computation Speed up – jobs are divided and several process or threads run on different part of job on different CPU core. Eventually create final result
  - Modularity – construct the system in a modular fashion, dividing the system functions into separate processes or threads

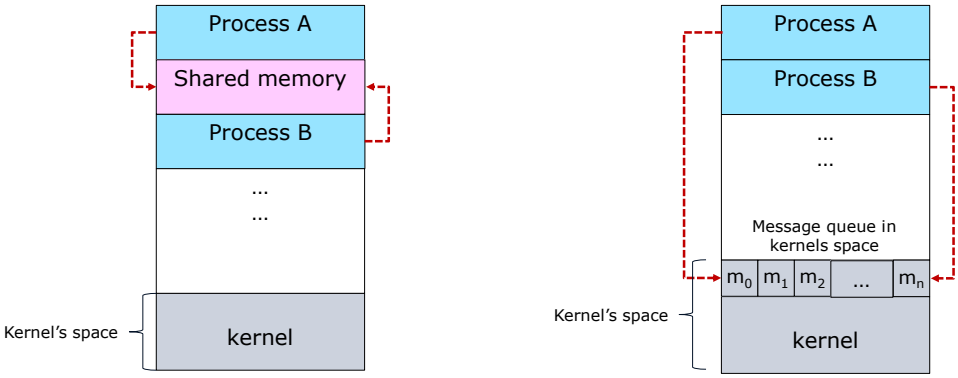
Interprocess Communication

- There are two fundamental models of interprocess communication:
  - Shared Memory- a region of memory is shared by processes with read /write operations. It is useful for exchanging smaller amount of data since no conflicts need be avoided.
  - Message Passing - communication takes place by means of messages exchanged between the cooperating processes (Message Queue). It is also easier to implement in a distributed system than shared memory.

Interprocess Communication

- Shared memory can be faster than message passing, since message-passing systems are typically implemented using system calls.
- In shared-memory systems, system calls are required only to establish shared memory regions. Once shared memory is established, all accesses are treated as routine memory accesses, without kernel's assistance.

Interprocess Communication



Shared memory Message Passing

Communication Model

Interprocess Communication
(Shared Memory)

- A process can create a shared-memory segment in RAM for interprocess communication. Other processes that wish to communicate using this shared-memory segment must attach it to their address space.
- Normally, the OS prevent one process from accessing another process's memory but OS remove this restriction for shared-memory. Then, several process can exchange information by reading and writing data in the shared areas.
- The form of the data and the location are determined by these processes and are not under the operating system's control.
- The processes are also responsible for mutual exclusion for writing.

Interprocess Communication
(Shared Memory)

producer consumer problem with shared memory

- To allow producer and consumer processes to run concurrently, we must have available a buffer of items that can be filled by the producer and emptied by the consumer.
- This buffer will reside in a region of memory that is shared by the producer and consumer processes. A producer can produce one item while the consumer is consuming another item.
- The producer and consumer must be synchronized, so that the consumer does not try to consume an item that has not yet been produced

Interprocess Communication
(Message-Passing)

- OS provide the means for interprocess communication via a message-passing facility (message queue, socket).
- Message passing provides a mechanism to allow processes to communicate and to synchronize their actions without sharing the same address space. It is particularly useful in a distributed environment, where the communicating processes may reside on different computers connected by a network.
- Two operation are provided as library or system calls.
  - Send(message)
  - Receive(message)
- To communicate between processes, a communication link must exist between them. This link can be implemented in various ways based on mean (message queue, socket, …)

Interprocess Communication
(Message-Passing)

- Logical Methods for implementing a link and send()/ receive operations.
  - Direct or indirect communication
  - Synchronous or asynchronous communication
  - Automatic or explicit buffering
- Under direct communication, each processes must know end point address for sending or receiving message between.
- Under indirect communication, the messages are sent to and received from mailboxes, or ports.

Interprocess Communication
(Message-Passing: Direct Communication)

- Under direct communication, each processes must know end point address for sending or receiving message between.
  - send (P, message) – send a message to process with end point address P.
  - Receive(Q, message) – receive a message from process with end point address Q.
- A communication link properties in direct communication
  - A link is established between every pair of processes to communicate. (each process in pair knows each identity (by ex. IP + port number).
  - A link is associated with exactly two processes.
  - There is one link between each pair of process

Interprocess Communication
(Message-Passing: Direct Communication)

- Direct communication method exhibits
  - symmetry in addressing since both processes know end point address each other.
    - send (P, message) – send a message to process with end point address P.
    - Receive(Q, message) – receive a message from process with end point address Q
  - Asymmetry in addressing since only one processes know end point address.
    - send (P, message) – send a message to process with end point address P.
    - receive(id, message) – receive a message from any process.

Interprocess Communication
(Message-Passing: Indirect Communication)

- With indirect communication, the messages are sent to and received from mailboxes, or ports.
- Each mailbox has a unique identification. For example, POSIX message queues use an integer value to identify a mailbox.
- A process can communicate with another process via a number of different mailboxes, but two processes can communicate only if they have a shared mailbox.

Interprocess Communication
(Message-Passing: Indirect Communication)

- Operations
  - create (A) – create a mailbox (in POSIX with ftok(), msgget())
  - send(A, message)—Send a message to mailbox A. (in POSIX with msgsnd())
  - receive(A, message)—Receive a message from mailbox A.(in POSIX with msgrcv())
  - remove (A) – remove mailbox (in POSIX with msgctl())
- communication link properties in indirect communication
  - 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

Interprocess Communication
(Message-Passing: Indirect Communication)

- Since a mailbox can be shared by several processes, we need consider mailbox sharing.
  - Let's assume process P1, P2 and P3 share mailbox A
  - P1 send a message to the mailbox.
  - P2 and P3 try to receive message from the mailbox.
  - Who gets the message?
- Possible 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.

Interprocess Communication
(Message-Passing: Synchronization)

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** -- the sender is blocked until the message is received
  - **Blocking receive** -- the receiver is blocked until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** -- the sender sends the message and continue
  - **Non-blocking receive** -- the receiver receives:
    - A valid message, or
    - Null message
- Different combinations possible
  - If both send and receive are blocking, we have a **rendezvous**

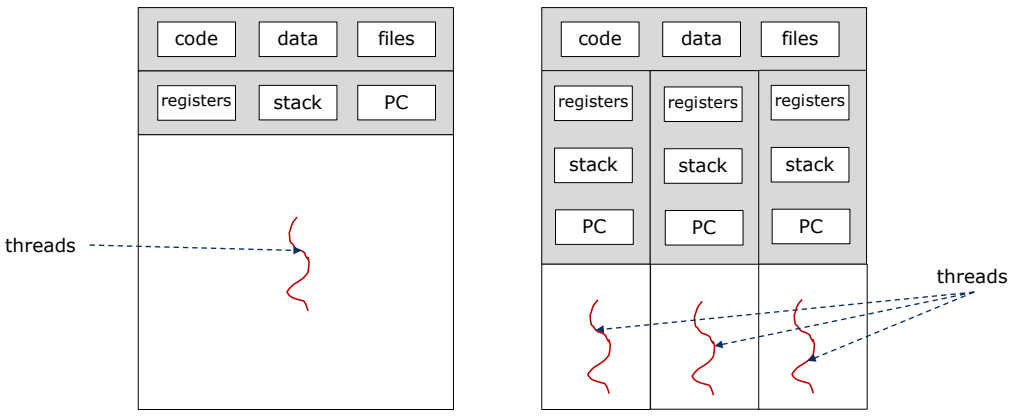
Interprocess Communication
(Message-Passing: Buffering)

- Queue of messages attached to the link.
- Implemented in one of three ways
  - Zero capacity – no messages are queued on a link.
    Sender must wait for receiver (rendezvous)
  - Bounded capacity – finite length of n messages
    Sender must wait if link full
  - Unbounded capacity – infinite length
    Sender never waits

Overview of Thread

- Most software run on modern computers or mobile devices are multithreaded. An application typically is implemented as a separate process with several threads of control.
- Each threads are run on different part of a process.
- Each thread consist of a thread ID, a program counter (PC), a register set, and a stack.
- It shares with other threads belonging to the same process its code section, data section, and other operating-system resources, such as open files and signals

Overview of Thread



Single-threaded process

Multi-threaded process

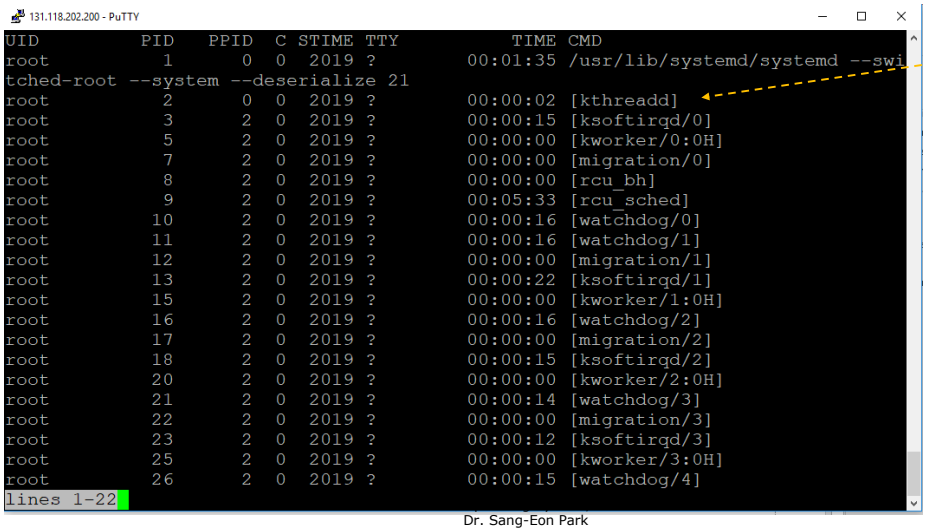
Overview of Thread

- Multi-threaded software example
  - Web browser: one thread display images or text, another thread retrieves data from the network.
  - A word processer: a thread for displaying grapics, a thread for responding to keyboard keystrokes, a thread performing spelling and grammar checking in the background.
  - A web server: for each client's request, server create a thread to take care one client request.

Overview of Thread

- Most operating system kernels are also typically multithreaded. As an example, during system boot time on Linux systems, several kernel threads are created. Each thread performs a specific task, such as managing devices, memory management, or interrupt handling.
- The command ps -ef can be used to display the kernel threads on a running Linux system.
- Examining the output of this command will show the kernel thread kthreadd (with pid = 2), which serves as the parent of all other kernel threads.

Overview of Thread



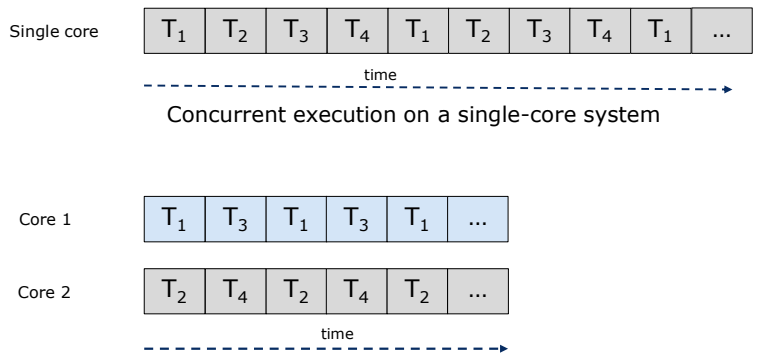
Benefits with Threads

- Resource sharing - threads share the memory and the resources of the process to which they belong by default. The benefit of sharing code and data is that it allows an application to have several different threads of activity within the same address space.
- Economy - Because threads share the resources of the process to which they belong, it is more economical to create and context-switch threads.
- Responsiveness - Application may allow a program to continue running even if part of program which is run by a thread is blocked.
- Scalability - The benefits of multithreading can be even greater in a multiprocessor architecture, where threads may be running in parallel on different processing cores.

Multicore Programming with Threads

- Multithreaded programming with multicore CPU provides a improved concurrency.
- Consider an application with four threads run on a system with a single core CPU.
- Since the single core in CPU can take care one thread at a time, need context switch between threads to support concurrency.
- Consider an application with four threads run on a system with two-core CPU. Some threads can run in parallel in this system.
  - A concurrent system supports more than one task by allowing all the tasks to make progress.
  - In contrast, a parallel system can perform more than one task simultaneously.

Multicore Programming with Threads



Multicore Programming with Threads

- OS and application developer's challenges with Multi-core or multiple CPU.
  - Designers of operating systems must write scheduling algorithms that use multiple processing cores to allow the parallel execution.
  - For application programmers, the challenge is to modify existing programs as well as design new programs that are multithreaded.

Multicore Programming with Threads

- Five areas present challenges in programming for multicore systems:
  1. Identifying tasks – examining applications to find areas that can be divided into separate concurrent tasks.
  2. Balance – applications are divided into multiple tasks with balanced working load
  3. Data Splitting -Just as applications are divided into separate tasks, the data accessed and manipulated by the tasks must be divided to run on separate cores.
  4. Data Dependency – If there are data dependency between tasks, programmer need consider synchronization for avoid race condition.
  5. Testing and debugging -Testing and debugging multi-threaded programs is more difficult than single threaded programs

Multicore Programming with Threads
(Types of Parallelism)

- Data parallelism focuses on distributing subsets of the same data across multiple computing cores and performing the same operation on each core.

  Ex) summation of array size 2N
  - A thread on $core_0$ (or CPU_0) sum the elements [0] .. [N-1]
  - A thread on $core_0$ (or CPU_0) sum the elements [N] .. [2N-1]
- Task parallelism involves distributing tasks (threads) across multiple computing cores. Each thread is performing a unique operation. Different threads may be operating on the same data, or they may be operating on different data

Multicore Programming with Threads
(Types of Parallelism)