God bless All

PPT3

Threads, SMP and Microkernels

Processes and Threads

- Processes have two characteristics
    - Resource ownership
        - Process includes a virtual address space to hold the process image
    - Scheduling/execution
        - Follows an execution path that may be interleaved with other processes.
- These two characteristics are treated independently by the operating system
- The dispatching unit is referred to as a thread or lightweight process.
- The entity that owns a resource is referred to as a process or a task.
- One process / task can have one or more threads.

Multithreading

- The ability of an OS to support multiple concurrent paths of execution within a single process.

Multithreading

- The ability of an OS to support multiple, concurrent paths of execution within a single process.

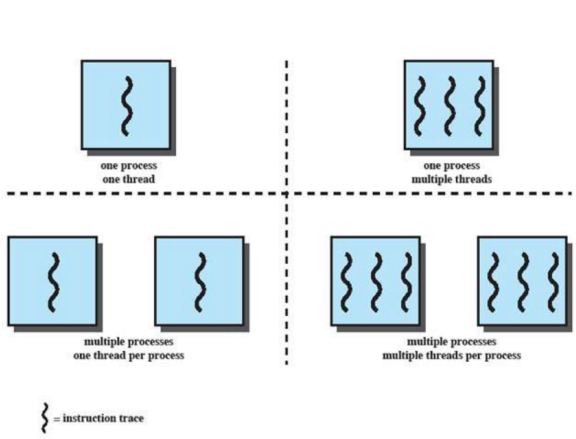


Figure 4.1 Threads and Processes [ANDE97]

- Java Run Time Environment is a single process with multiple threads.
- Multiple process and threads are found in Windows, Solaris and many modern versions of UNIX.

Single Thread Approaches

- MS-DOS supports a single user process and a single thread.
- Some UNIX, support multiple user processes but only support one thread per process

Processes

- A virtual space which holds the process images

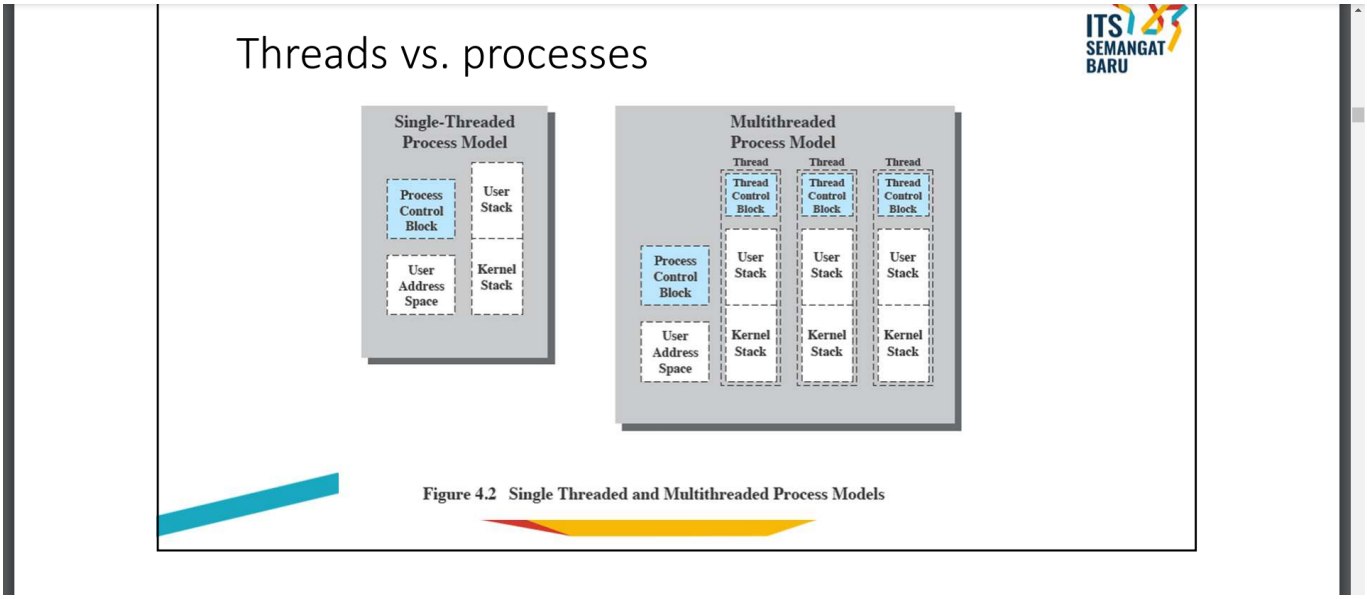
- Protected access to
    - Processors
    - Other processes
    - Files
    - I/O resources

One or More Threads in Process

- Each thread has - An execution state (running, ready, etc.) - Saved thread context when not running
    - An execution stack
    - Some per-thread static storage for local variables
    - Access to the memory and resources of its process (all threads of a process share this)

> One way to view a thread is as an independent program counter operating *within* a process

Threads vs processes



Benefits of Threads

- Takes less time to create a new thread than a process
- Less time to terminate a thread than a process
- Switching between two threads takes less times than switching processes
- Threads can communicate with each other
    - Without invoking the kernel

Thread use in a Single-User system

- Foreground and background work
- Asynchronous processing
- Speed of execution
- Modular program structure

Threads

- Several actions that affect all of the threads in a process
  - The OS must manage these at the process level.
- Examples:
  - Suspending a process involves suspending all threads of the process
  - Termination of a process, terminates all threads within the process

Activites similar to processes

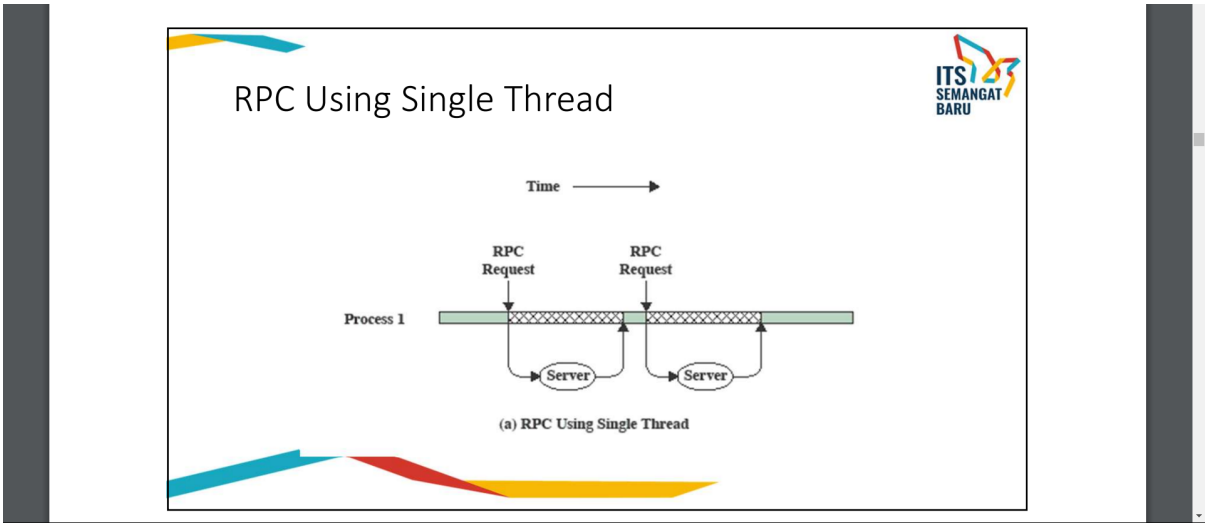
- Threads have execution states and may synchronize with one another.
  - Similar to processes
- We look at these two aspects of thread functionality in turn.
  - States
  - Synchronisation

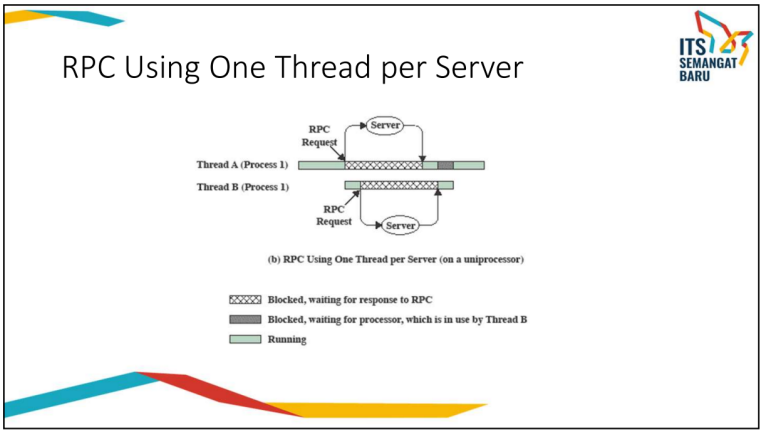
Thread Execution States

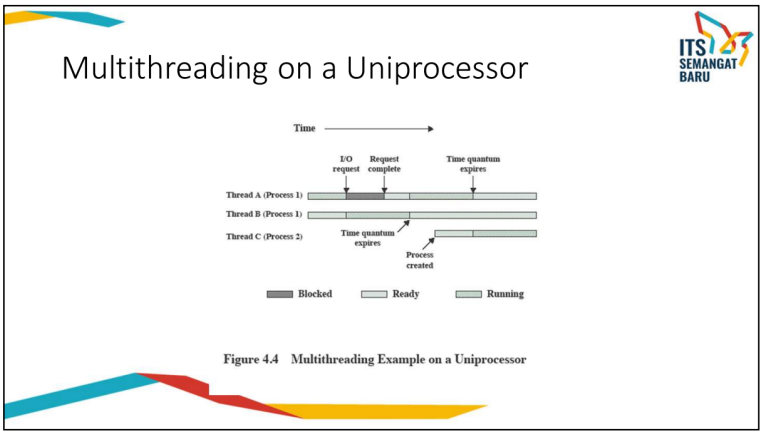
- States associated with a change in thread state
  - Spawn (another thread)
  - Block
    - Issue: will blocking a thread block other, or all threads
  - Unblock
  - Finish (thread)
    - Deallocate register context and stacks

Example: Remote Procedure Call

- Consider:
  - A program that performs two remote procedure calls (RPCs)
  - to two different hosts
  - to obtain a combined result.



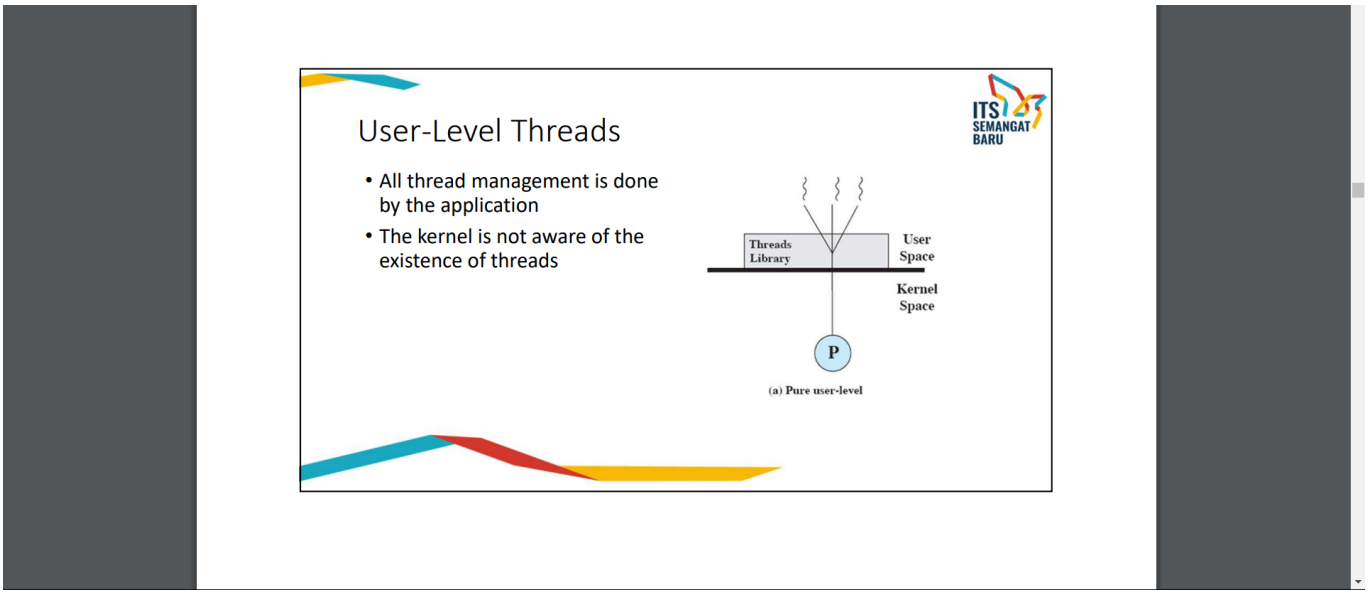




Categories of Thread Implementation

- User Level Thread (ULT)
  - thread that are managed entirely by user-level code
  - Not requiring any support from the operating system kernel.
- Kernel level Thread (KLT) also called:
  - kernel-supported threads
  - lightweight processes.

User level threads



Kernel-level threads

- Kernel maintains context information for the process and the threads
  - No thread management done by application
- Scheduling is done on a thread basis
- Windows is an example of this approach

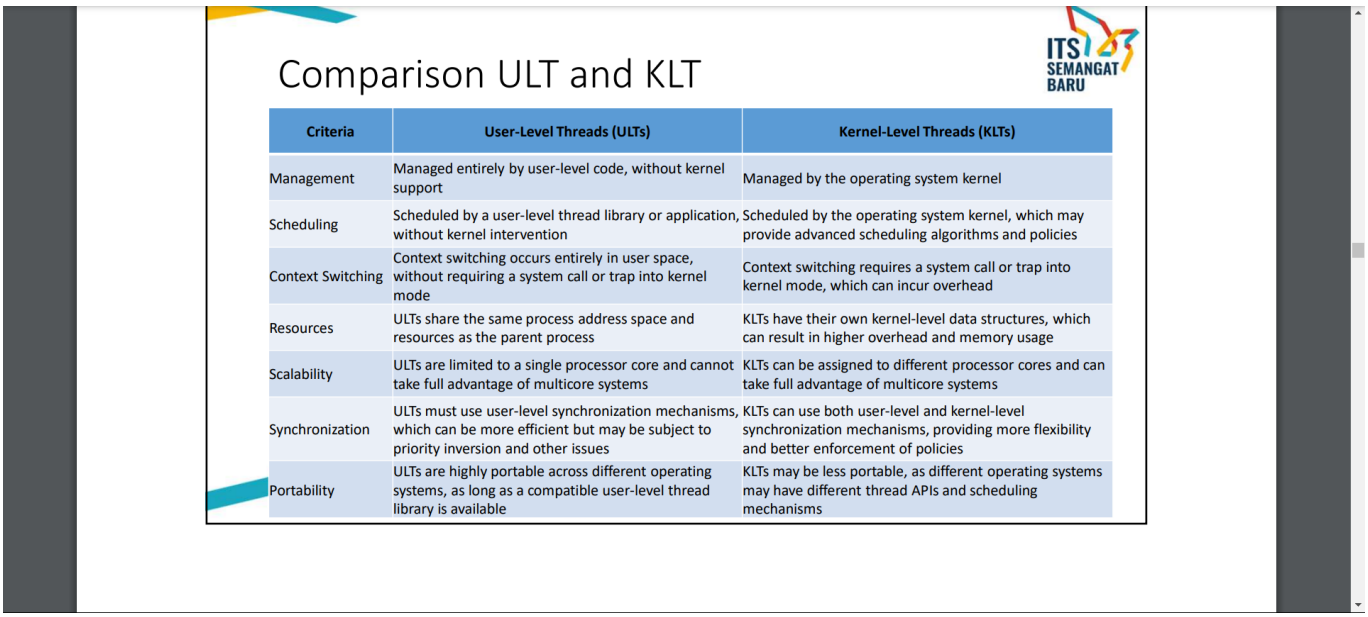
Advantages of KLT

- The kernel can simultaneously schedule multiple threads from the same process on multiple processors.
- If one thread in a process is blocked, the kernel can shedule another thread of the same process.
- Kernel routines themselves can be multithreaded

Disadvantages of KLT

- The transfer of control from one thread to another within the same process require a mode switch to the kernel.

Comparison ULT and KLT

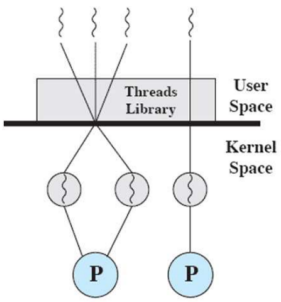


Criteria	User-Level Threads (ULTs)	Kernel-Level Threads (KLTs)
Management	Managed entirely by user-level code, without kernel support	Managed by the operating system kernel
Scheduling	Scheduled by a user-level thread library or application, without kernel intervention	Scheduled by the operating system kernel, which may provide advanced scheduling algorithms and policies
Context Switching	Context switching occurs entirely in user space, without requiring a system call or trap into kernel mode	Context switching requires a system call or trap into kernel mode, which can incur overhead
Resources	ULTs share the same process address space and resources as the parent process	KLTs have their own kernel-level data structures, which can result in higher overhead and memory usage
Scalability	ULTs are limited to a single processor core and cannot take full advantage of multicore systems	KLTs can be assigned to different processor cores and can take full advantage of multicore systems
Synchronization	ULTs must use user-level synchronization mechanisms, which can be more efficient but may be subject to priority inversion and other issues	KLTs can use both user-level and kernel-level synchronization mechanisms, providing more flexibility and better enforcement of policies
Portability	ULTs are highly portable across different operating systems, as long as a compatible user-level thread library is available	KLTs may be less portable, as different operating systems may have different thread APIs and scheduling mechanisms

Combined Approaches

Combined Approaches

- Thread creation done in the user space
- Bulk of scheduling and synchronization of threads by the application
- Example is Solaris



(c) Combined

Relationship between Thread and Processes

Relationship Between Thread and Processes

Table 4.2 Relationship Between Threads and Processes

Threads:Processes	Description	Example Systems
1:1	Each thread of execution is a unique process with its own address space and resources.	Traditional UNIX implementations
M:1	A process defines an address space and dynamic resource ownership. Multiple threads may be created and executed within that process.	Windows NT, Solaris, Linux, OS/2, OS/390, MACH
1:M	A thread may migrate from one process environment to another. This allows a thread to be easily moved among distinct systems.	Ra (Clouds), Emerald
M:N	Combines attributes of M:1 and 1:M cases.	TRIX

Symmetric Multiprocessing (SMP).

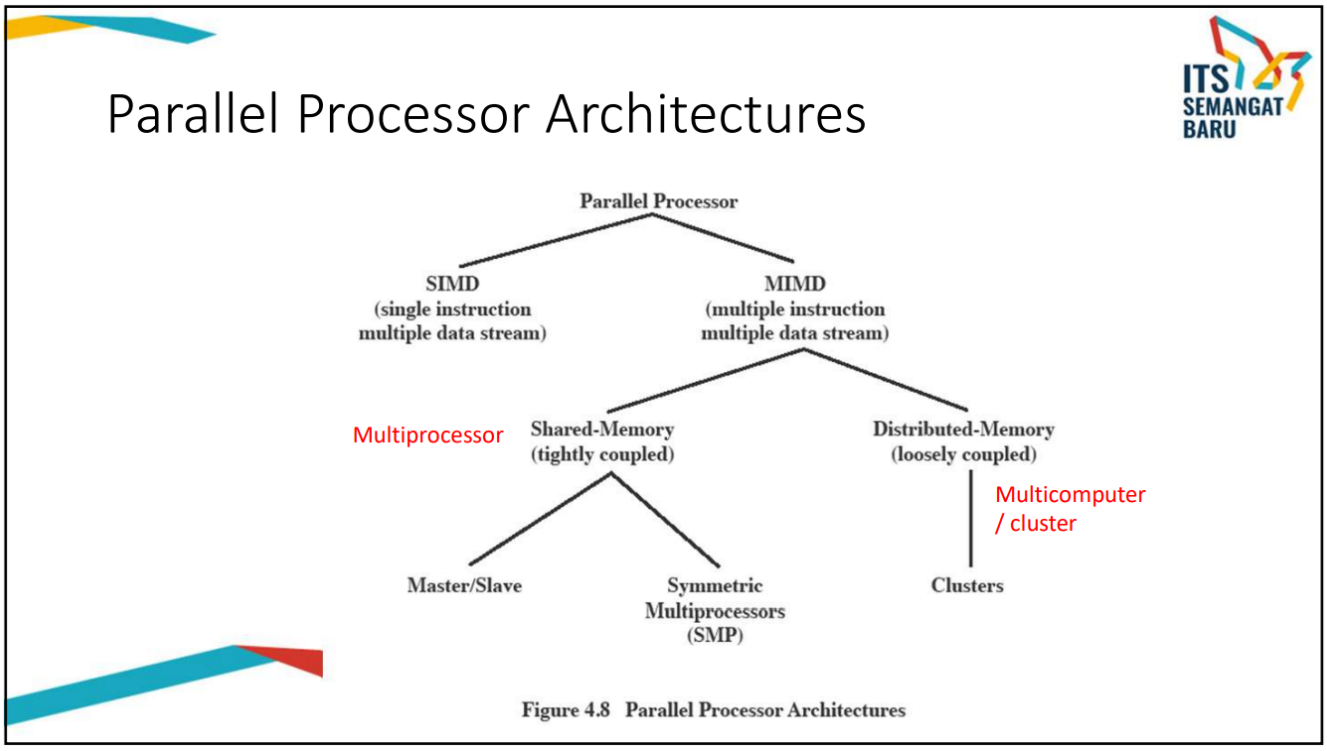
- Traditionally the computer has been viewed as a sequential machine.
  - A processor executes instructions one at a time in sequence
  - Each instruction is a sequence of operations
- Two popular approaches to providing parallelism
  - Symmetric Multi Processors (SMPs)
  - Clusters (ch 16)

Categories of Computer Systems

- Single Instruction Single Data (SISD) stream
  - Single processor executes a single instruction stream to operate on data stored in a single memory
- Single Instruction Multiple Data (SIMD) stream

    - Each instruction is executed on a different set of data by the different processors
- Multiple Instruction Single Data (MISD) stream
    - A sequence of data is transmitted to a set of processors, each of execute a different instruction sequence
- Multiple Instruction Multiple Data (MIMD)
    - A set of processors simultaneously execute different instruction sequences on different data sets

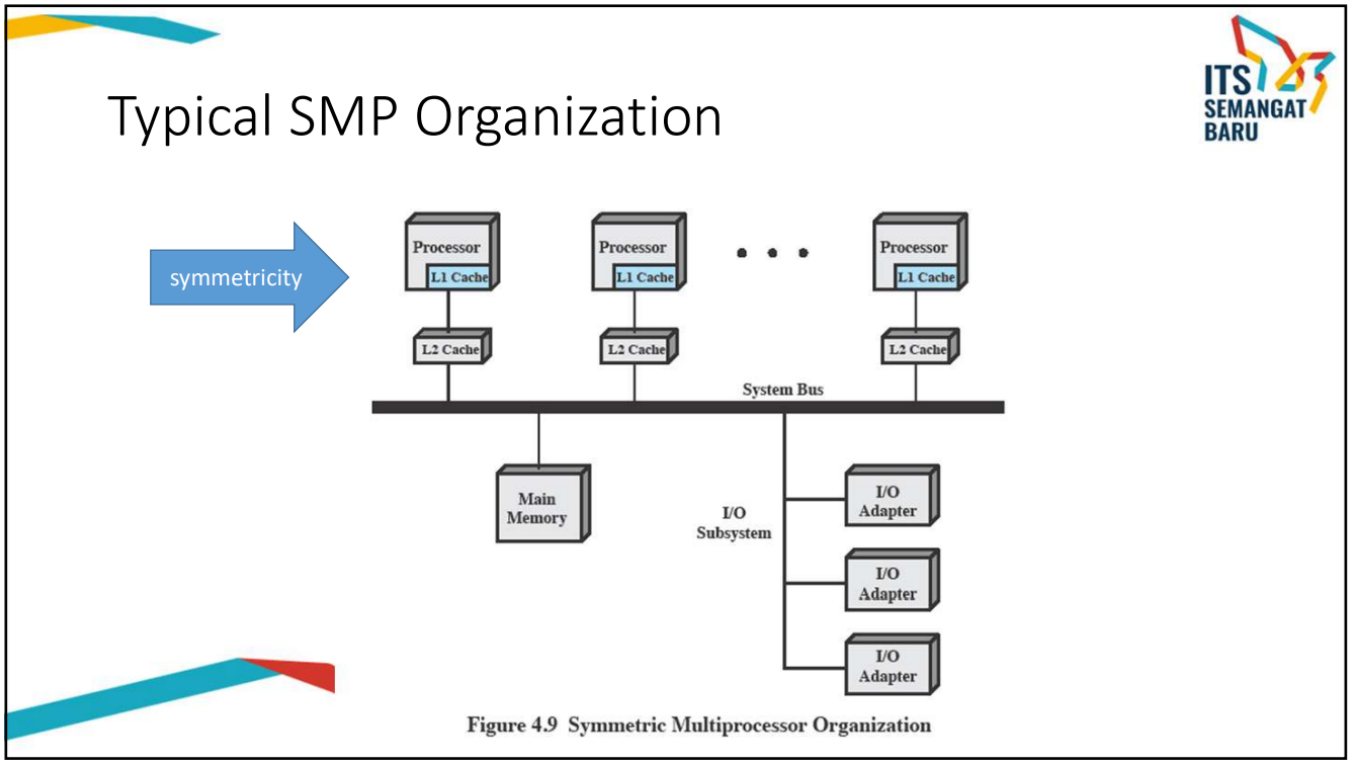
Parallel Processor Architecture



Symmetric Multiprocessing

- Kernel can execute on any processor
    - Allowing portions of the kernel to execute in parallel
- Typically, each processor does self-scheduling from the pool of available process or threads

Typical SMP Organization



Multiprocessor OS Design Considerations

- The key design issues include
  - Simultaneous concurrent processes or threads
  - Scheduling
  - Synchronization
  - Memory Management - Reliability and Fault Tolerance

Microkernel

- A microkernel is a small OS core that provides the foundation for modular extensions.
- Big question is how small must a kernel be to qualify as a microkernel
  - Must drivers be in user space?
- In theory, this approach provides a high degree of flexibility and modularity.

Kernel Architecture

Kernel Architecture

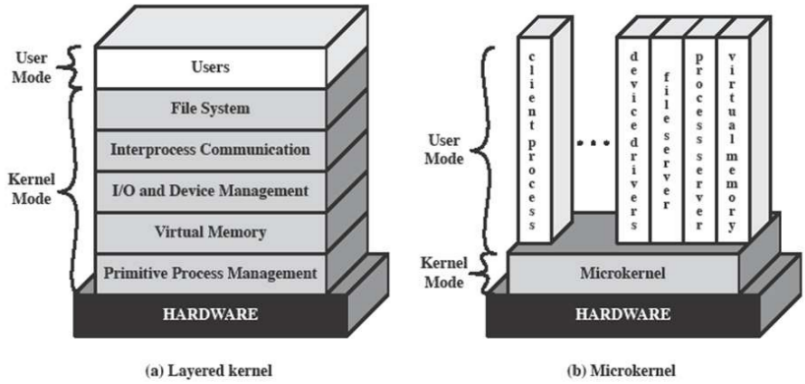


Figure 4.10 Kernel Architecture

Microkernel Design: Memory Management

- Low-level memory management - Mapping each virtual page to a physical page frame
  - Most memory management tasks occur in user space

Microkernel Design: Memory Management

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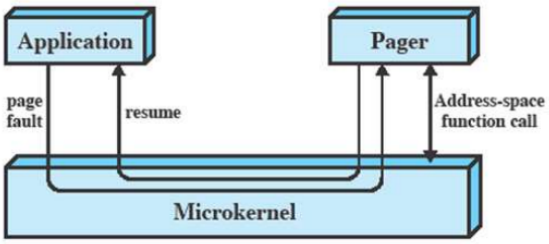


Figure 4.11 Page Fault Processing

Microkernel Design: Interprocess Communication

- Communication between processes or threads in a microkernel OS is via messages.
- A message includes:
  - A header that identifies the sending and receiving process and

    - A body that contains direct data, a pointer to a block of data, or some control information about the process.

Microkernal Design: I/O and interrupt management

- Within a microkernel, it is possible to handle hardware interrupts as messages and to include I/O ports in address spaces.
    - a particular user-level process is assigned to the interrupt and the kernel maintains the mapping.

Benefits of a Microkernel Organization

- Uniform interfaces on requests made by a process.
    - Extensibility
    - Flexibility
    - Portability
    - Reliability
    - Distributed System Support
    - Object Oriented Operating Systems

Comparison Microkernel vs Monolithic kernel

Comparison Microkernel vs Monolitic kernel SEMANG BARU

Criteria	Microkernel	Monolithic Kernel
Architecture	Minimalistic kernel that provides basic services, with additional services implemented as user-space processes	Entire kernel including device drivers, system calls, and other services are executed in kernel space
Security	More secure due to smaller attack surface, as most operating system services are run in user space	Exposes entire kernel to potential security vulnerabilities
Flexibility	More flexible and easier to customize and maintain as new services can be added without modifying the kernel itself	Requires modifications to kernel code to add new functionality
Performance	Generally slower due to increased reliance on interprocess communication and message passing	Better performance due to all system services being executed in kernel space, avoiding the overhead of interprocess communication
Debugging and Maintenance	Easier to debug and maintain due to modular design, where different services run as independent processes	Debugging and maintenance can be more difficult due to all services running in the same kernel space

Which OS uses microkernel / monolithic kernel

- Windows:
    - Windows NT and later versions use a hybrid kernel that combines elements of a microkernel and a monolithic kernel.
    - Earlier versions of Windows (such as Windows 95, 98, and ME) use a monolithic kernel.
- Linux:
    - a monolithic kernel, but it can also support loadable kernel modules that can be dynamically loaded and unloaded at runtime.
- macOS:
    - a hybrid kernel that combines elements of a microkernel and a monolithic kernel.

- iOS:
  - a hybrid kernel that combines elements of a microkernel and a monolithic kernel.
- Android:
  - a monolithic kernel, but it also includes a user-level component called the Binder IPC mechanism that provides some microkernel-like functionality.

Interprocess Communication

Multiple Processes

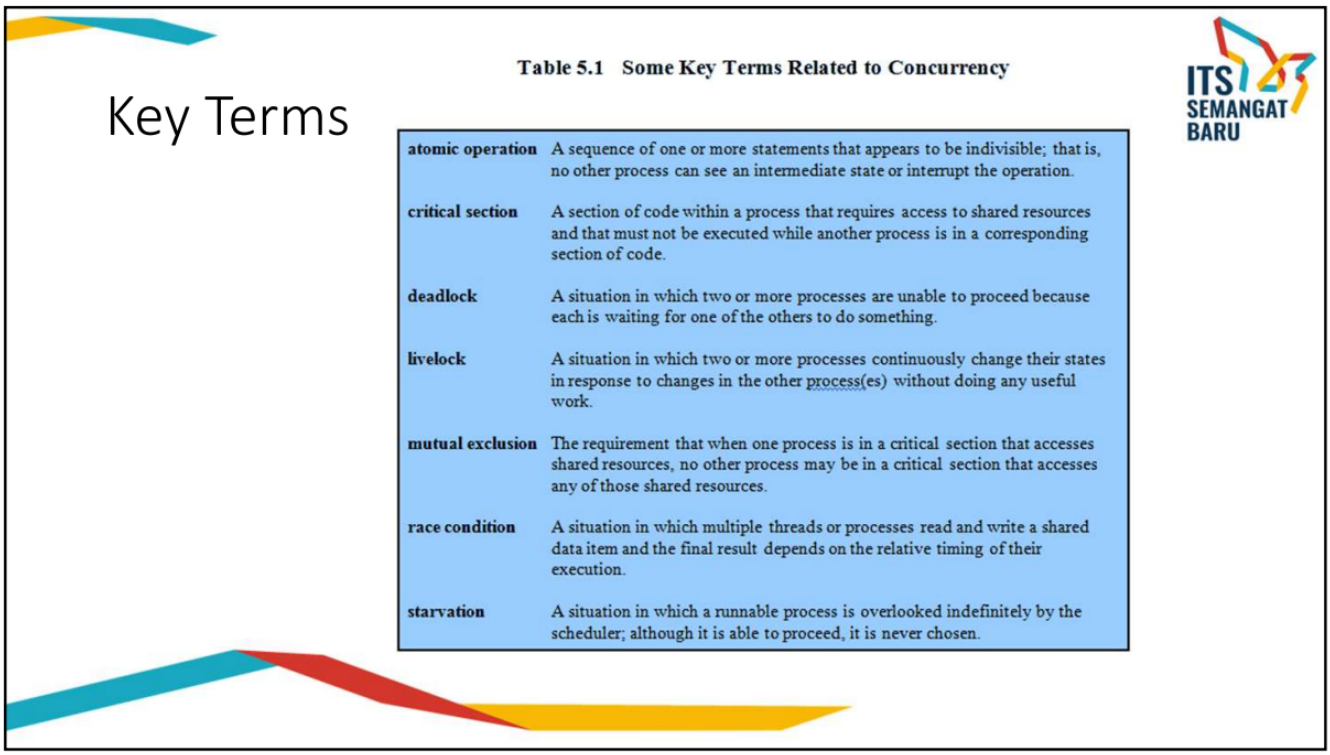
- Central to the design of modern Operating Systems is managing multiple processes
- Multiprogramming
- Multiprocessing
- Distributed Processing
- Big Issue is Concurrency - Managing the interaction of all of these processes

Concurrency

Concurrency arises in:

- Multiple applications
  - Sharing time
- Structured applications
  - Extension of modular design
- Operating system structure
  - OS themselves implemented as a set of processes or threads

Key terms related to concurrency



Interleaving and Overlapping Processes

Interleaving and Overlapping Processes

- Earlier (Ch2) we saw that processes may be interleaved on uniprocessors

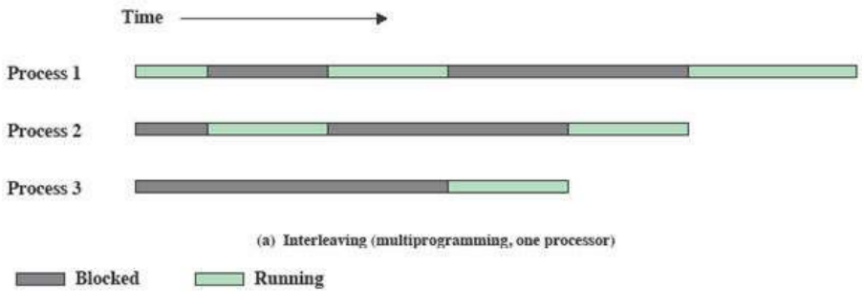


Figure 2.12 Multiprogramming and Multiprocessing

Interleaving and Overlapping Processes

- And not only interleaved but overlapped on multi-processors

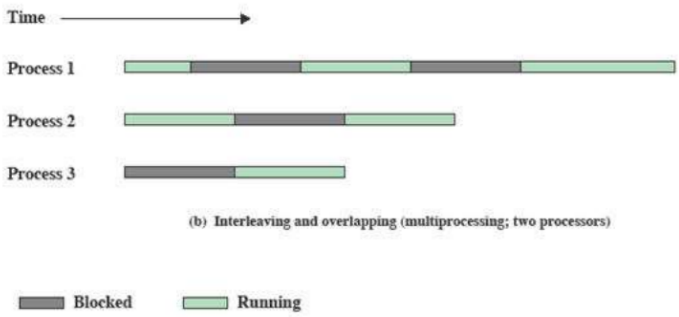


Figure 2.12 Multiprogramming and Multiprocessing

Difficulties of Concurrency

- Sharing of global resources
- Optimally managing the allocation of resources
- Difficult to locate programming errors as results are not deterministic and reproducible.

Race Condition

- A race condition occurs when
  - Multiple processes or threads read and write data items
  - They do so in a way where the final result depends on the order of execution of the processes.

    - The output depends on who finishes the race last.

Operating System Concerns

- What design and management issues are raised by the existence of concurrency?
- The OS must
    - Keep track of various processes
    - Allocate and de-allocate resources
    - Protect the data and resources against interference by other processes.
    - Ensure that the processes and outputs are independent of the processing speed

Process Interaction

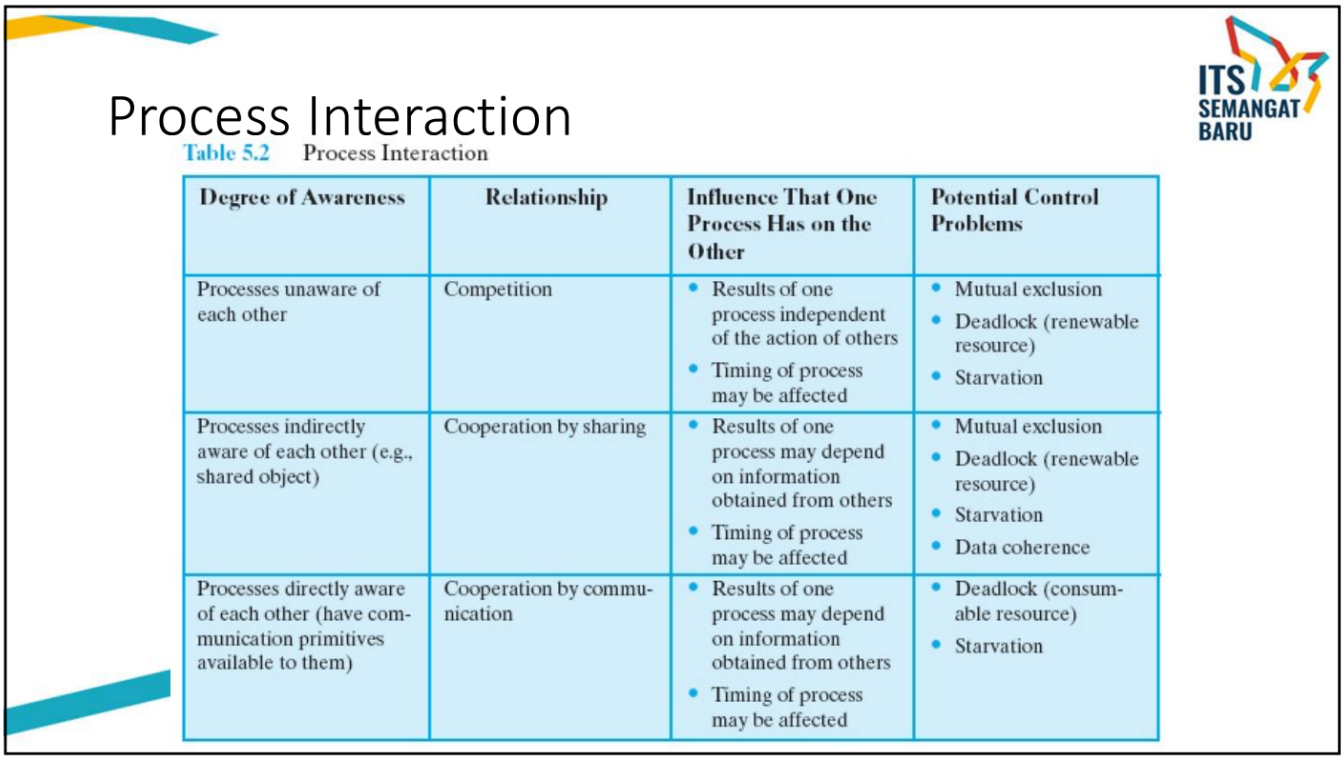


Table 5.2 Process Interaction

Degree of Awareness	Relationship	Influence That One Process Has on the Other	Potential Control Problems
Processes unaware of each other	Competition	• Results of one process independent of the action of others • Timing of process may be affected	• Mutual exclusion • Deadlock (renewable resource) • Starvation
Processes indirectly aware of each other (e.g., shared object)	Cooperation by sharing	• Results of one process may depend on information obtained from others • Timing of process may be affected	• Mutual exclusion • Deadlock (renewable resource) • Starvation • Data coherence
Processes directly aware of each other (have communication primitives available to them)	Cooperation by communication	• Results of one process may depend on information obtained from others • Timing of process may be affected	• Deadlock (consumable resource) • Starvation

Competition among Processes for Resources

Three main control problems:

- Need for Mutual Exclusion
    - Critical sections
- Deadlock
- Starvation

Requirement for Mutual Exclusion

- Only one process at a time is allowed in the critical section for a resource
- A process that halts in its noncritical section must do so without interfering with other processes
- No deadlock or starvation
- A process must not be delayed access to a critical section when there is no other process using it
- No assumptions are made about relative process speeds or number of processes
- A process remains inside its critical section for a finite time only

Mutual Exclusion: Hardware Support

Disabling Interrupts

- Uniprocessors only allow interleaving
- Interrupt Disabling
- A process runs until it invokes an operating system service or until it is interrupted
- Disabling interrupts guarantees mutual exclusion
- Will not work in multiprocessor architecture

Special Machine Instruction

- Compare&Swap Instruction - also called a “compare and exchange instruction”
- Exchange Instruction

Pseudo-code

```
while (true) {
/* disable interrupts */;
/* critical section */;
/* enable interrupts */;
/* remainder */;
}
```

```
int compare_and_swap (int *word,
int testval, int newval)
{
int oldval;
oldval = *word;
if (oldval == testval) *word = newval;
return oldval;
}
```

Mutual Exclusion

Mutual Exclusion (fig 5.2)

```
/* program mutualexclusion */
const int n = /* number of processes */;
int bolt;
void P(int i)
{
   while (true) {
     while (compare_and_swap(bolt, 0, 1) == 1)
          /* do nothing */;
      /* critical section */;
      bolt = 0;
      /* remainder */;
   }
}
void main()
{
   bolt = 0;
   parbegin (P(1), P(2), ... ,P(n));

}
```

(a) Compare and swap instruction

Exchange Instruction

Exchange Instruction (fig 5.2)

```
   /* program mutualexclusion */
int const n = /* number of processes**/;
int bolt;
void P(int i)
{
   int keyi = 1;
   while (true) {
      do exchange (keyi, bolt)
      while (keyi != 0);
      /* critical section */;
      bolt = 0;
      /* remainder */;
   }
}
void main()
{
   bolt = 0;
   parbegin (P(1), P(2), ..., P(n));
}
```

(b) Exchange instruction

```
void exchange (int register, int memory){
int temp;
temp = memory;
memory = register;
register = temp;
}
```

Semaphore

- Semaphore: - An integer value used for signalling among processes. - Only three operations may be performed on a semaphore, all of which are atomic:
    - initialize,
    - Decrement (semWait)
    - increment. (semSignal)

Semaphore Primitives

```
struct semaphore{
    int count;
    queueType queue;
};

void semWait(semaphore s){
    s.count--;
    if (s.count < 0) {
        /*
        place this process in s.queue
        block this process
        */
    }
}

void semSignal(semaphore s){
    s.count++;
    if (s.count <= 0){
        /*
        remove a process P from s.queue
        place process P on ready list*/
    }
}
```

Binary Semaphore Primitves

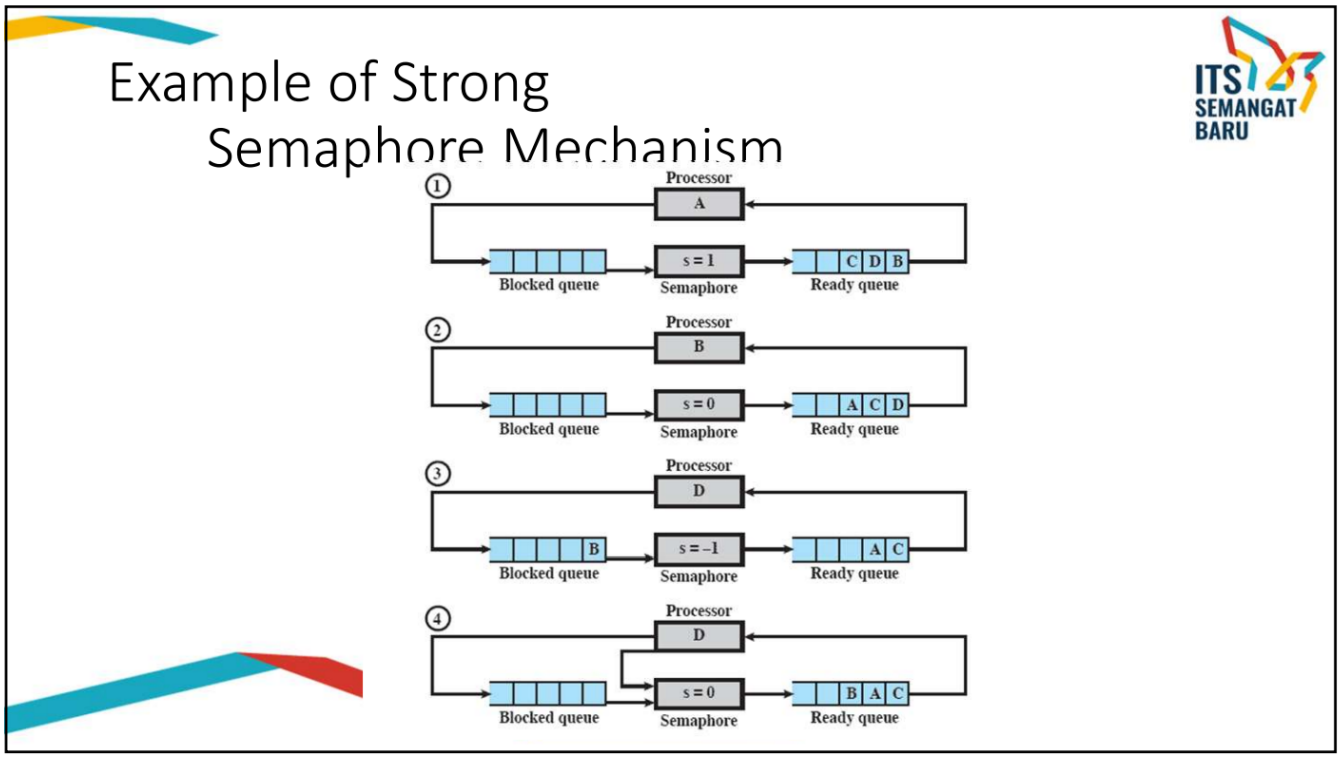
```
struct binary_semaphore{
    enum {zero, one} value;
    queueType queue;
};

void semWait(binary_semaphore s){
    if (s.value == one)
    s.value = zero;
    else {
        /*
        place this process in s.queue
        block this process
        */
    }
}
```

```
void semSignalB(semaphore s){
    if (s.queue is empty())
        s.value = one;
    else{
        /*
        remove a process P from s.queue
        place process P on ready list
        */
    }
}
```

Strong/Weak Semaphore

- A queue is used to hold processes waiting on the semaphore
  - In what order are processes removed from the queue?
- Strong Semaphores use FIFO
- Weak Semaphores don't specify the order of removal from the queue

Example of Strong Semaphore Mechanism



Example of Semaphore Mechanism

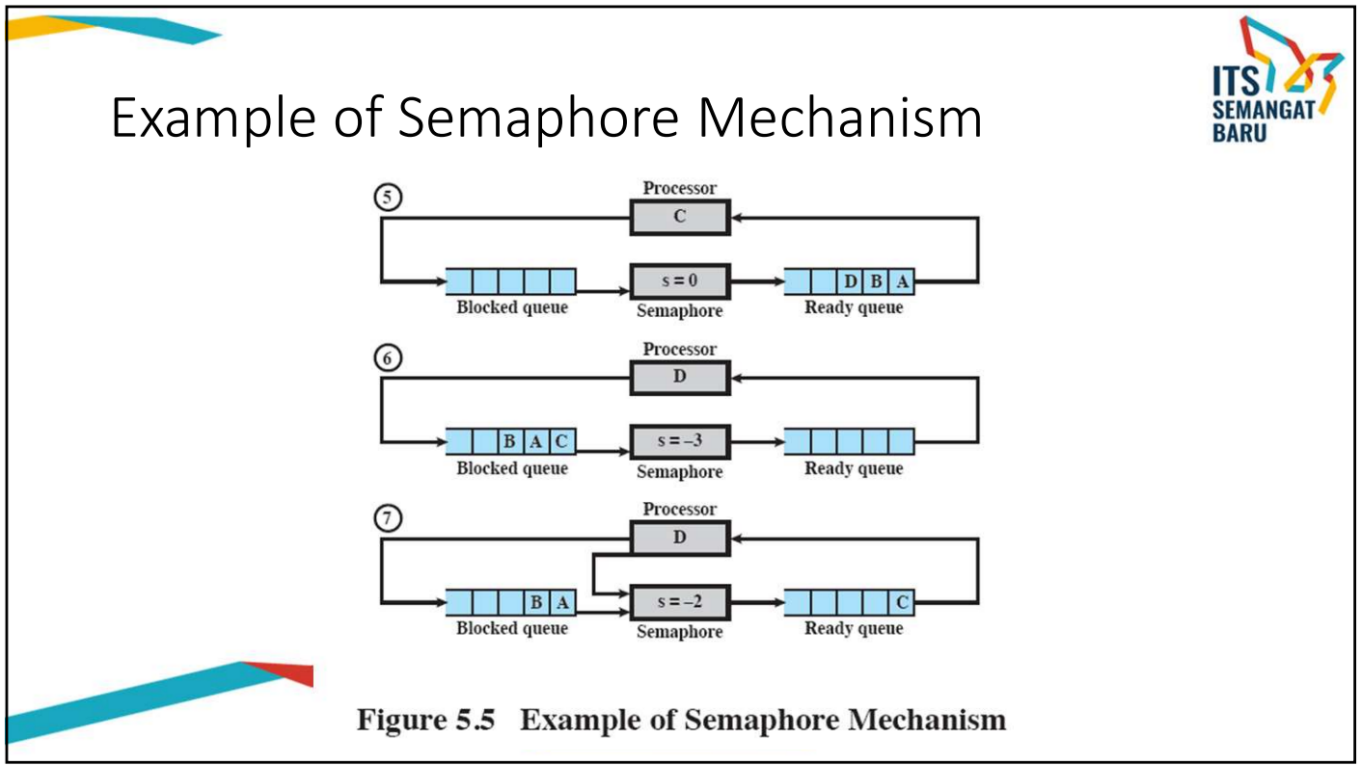


Figure 5.5 Example of Semaphore Mechanism

Mutual Exclusion Using Semaphores

```
// program mutualexclusion

const int n = /* number of processes */
semaphore s = 1
void P (int i){
    while(true){
        semWait(s);
        /* critical section */
        semSignal(s);
        /* remainder */
    }
}

void main(){
    parbegin(P(1), P(2), ..., P(n));
}
```

Processes using semaphore

Processes Using Semaphore

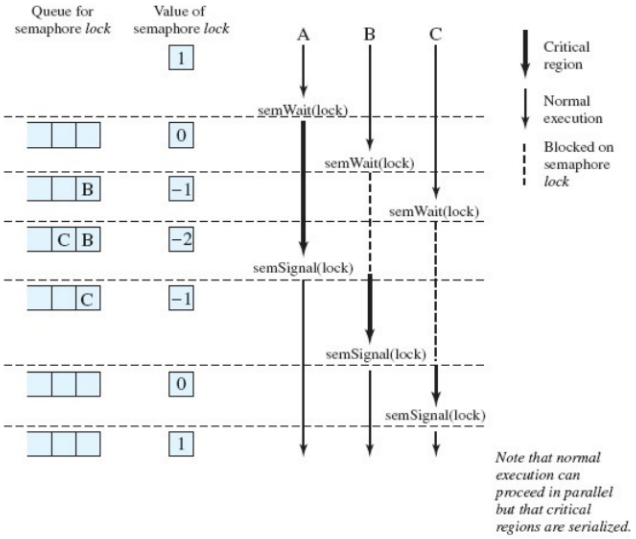


Figure 5.7 Processes Accessing Shared Data Protected by a Semaphore