Operating Systems

"Process Description and Control"

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Roadmap

- How are processes represented and controlled by the OS.
- **Process states** which characterize the behaviour of processes.
- **Data structures** used to manage processes.
- Ways in which the OS uses these data structures to control process execution.

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Operating System

- How are processes represented and controlled by the OS.
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Requirements of an Operating System

- *Fundamental Task: Process Management*
- The Operating System must
  - Interleave the execution of multiple processes
  - Allocate resources to processes, and protect the resources of each process from other processes,
  - Enable processes to share and exchange information,
  - Enable synchronization among processes.

The OS Manages Execution of Applications

- Resources are made available to multiple applications
- The processor is switched among multiple application
- The processor and I/O devices can be used efficiently

What is a *"process"*?

- *A program in execution*
- An instance of a program running on a computer
- The entity that can be assigned to and executed on a processor
- A unit of activity characterized by the execution of a sequence of instructions, a current state, and an associated set of system instructions

Process Elements

- A process is comprised of:
  - Program code (possibly shared)
  - A set of data
- A number of elements including
  - Identifier
  - State
  - Priority
  - Program counter
  - Memory pointers
  - Context data
  - I/O status information
  - Accounting information

Process Control Block

- Contains the process elements
- Created and manage by the operating system
- Allows support for multiple processes

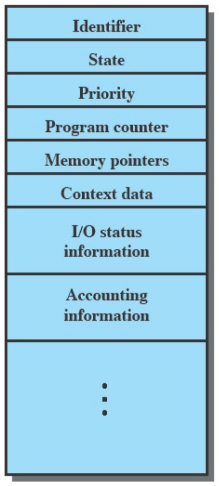
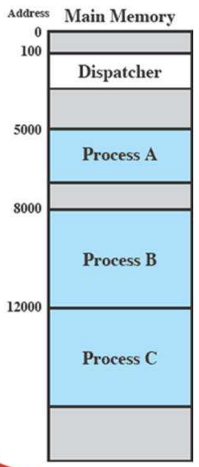


Figure 3.1 Simplified Process Control Block

Trace of the Process

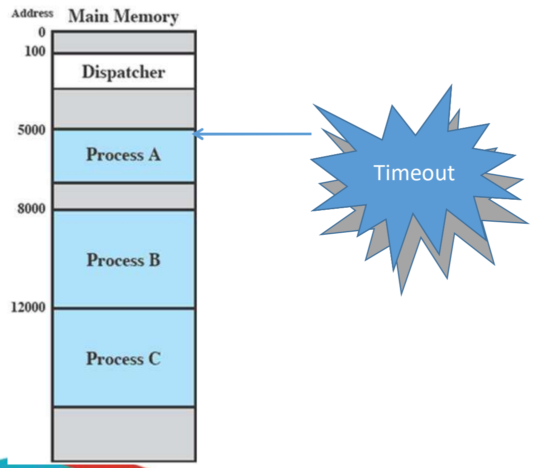
- The behavior of an individual process is shown by listing the sequence of instructions that are executed
- This list is called a ***Trace***
- ***Dispatcher*** is a small program which switches the processor from one process to another

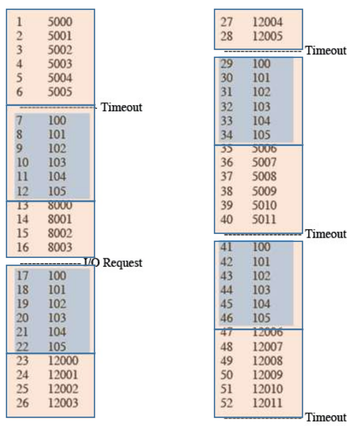
Process Execution



- Consider three processes being executed
- All are in memory (plus the dispatcher)
- Lets ignore virtual memory for this.

Trace from Processors point of view





```
 1   5000                     27  12004
 2   5001                     28  12005
 3   5002                     ------------------ Timeout
 4   5003                     29  100
 5   5004                     30  101
 6   5005                     31  102
 ------------------ Timeout   32  103
 7   100                      33  104
 8   101                      34  105
 9   102                      35  5006
10   103                      36  5007
11   104                      37  5008
12   105                      38  5009
13   8000                     39  5010
14   8001                     40  5011
15   8002                     ------------------ Timeout
16   8003                     41  100
 --------------- I/O Request  42  101
17   100                      43  102
18   101                      44  103
19   102                      45  104
20   103                      46  105
21   104                      47  12006
22   105                      48  12007
23   12000                    49  12008
24   12001                    50  12009
25   12002                    51  12010
26   12003                    52  12011
                              ------------------ Timeout
```

100 = Starting address of dispatcher program

Shaded areas indicate execution of dispatcher process;
first and third columns count instruction cycles;
second and fourth columns show address of instruction being executed

Figure 3.4 Combined Trace of Processes of Figure 3.2

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Roadmap

- How are processes represented and controlled by the OS.
- ***Process states*** which characterize the behaviour of processes.
- ***Data structures*** used to manage processes.
- Ways in which the OS uses these data structures to control process execution.
- Discuss process management in UNIX SVR4.

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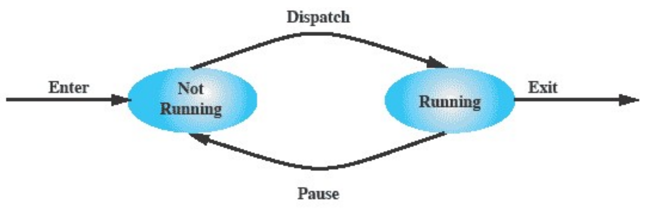
Two-State Process Model

- Process may be in one of two states
  - Running
  - Not-running



(a) State transition diagram

Process creation and termination

Creation	Termination
New batch job	Normal Completion
Interactive Login	Memory unavailable
Created by OS to provide a service	Protection error
Spawned by existing process	Operator or OS Intervention

See tables 3.1 and 3.2 for more

Process Creation

- The OS builds a data structure to manage the process
- Traditionally, the OS created all processes
    - But it can be useful to let a running process create another
- This action is called ***process spawning***
    - ***Parent Process*** is the original, creating, process
    - ***Child Process*** is the new process

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Process Termination

- There must be some way that a process can indicate completion.
- This indication may be:
    - A HALT instruction generating an interrupt alert to the OS.
    - A user action (e.g. log off, quitting an application)
    - A fault or error
    - Parent process terminating

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Five-State Process Model

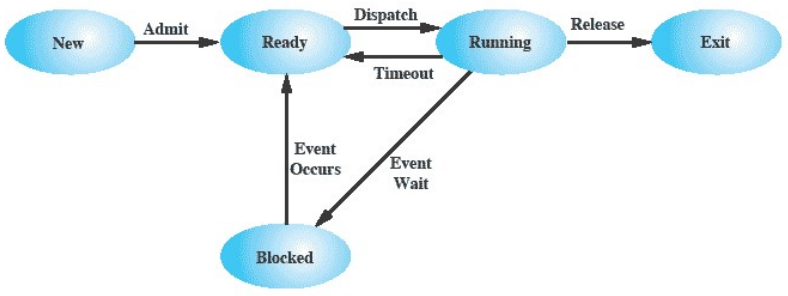

Figure 3.6 Five-State Process Model

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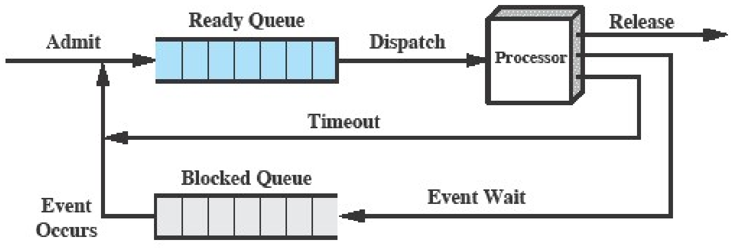
Using Two Queues



(a) Single blocked queue

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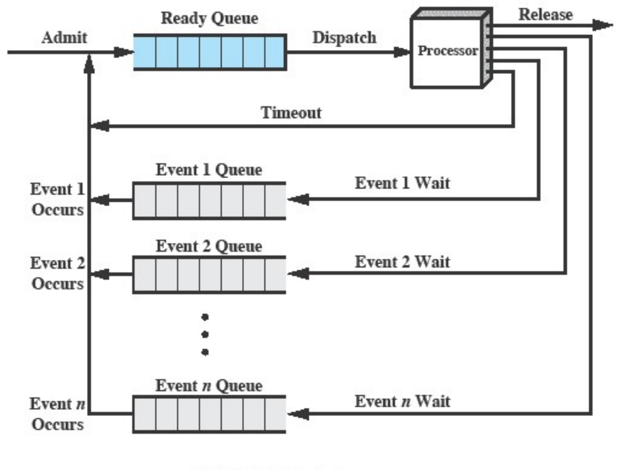
Multiple Blocked Queues

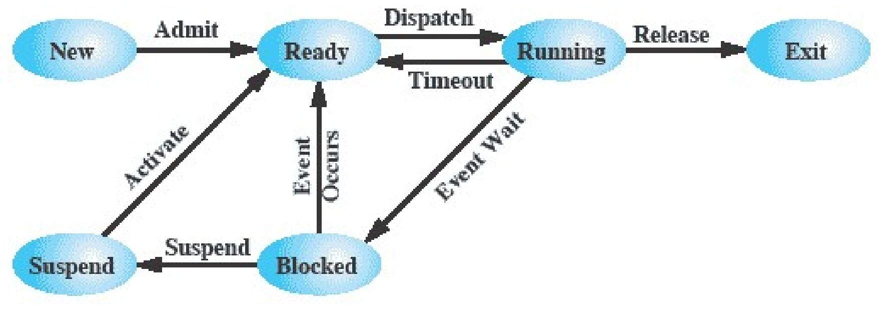


(b) Multiple blocked queues

Suspended Processes

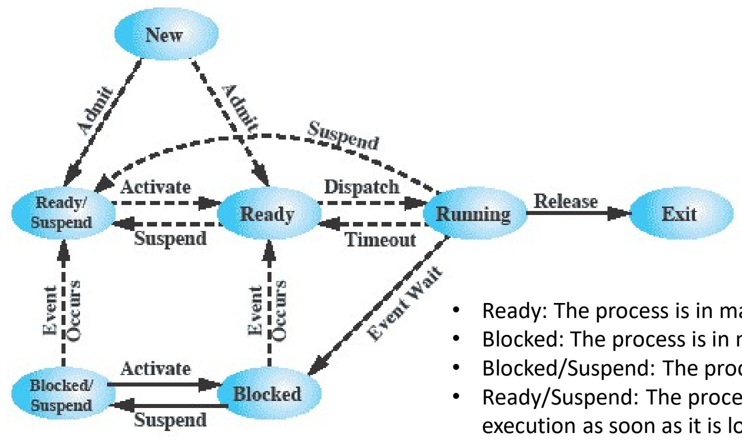
- Processor is faster than I/O so all processes could be waiting for I/O
  - Swap these processes to disk to free up more memory and use processor on more / other processes
- Blocked state becomes ***suspend*** state when swapped to disk (secondary storage)
- Two new states
  - Blocked/Suspend … from memory → disc
  - Ready/Suspend … from disc → memory

One Suspend State



(a) With One Suspend State

Two Suspend States



(b) With Two Suspend States

- Ready: The process is in main memory and available for execution.
- Blocked: The process is in main memory and awaiting an event.
- Blocked/Suspend: The process is in secondary memory and awaiting an event.
- Ready/Suspend: The process is in secondary memory but is available for execution as soon as it is loaded into main memory.

Reason for Process Suspension

Reason	Comment
Swapping	The OS needs to release sufficient main memory to bring in a process that is ready to execute.
Other OS Reason	OS suspects process of causing a problem.
Interactive User Request	e.g. debugging or in connection with the use of a resource.
Timing	A process may be executed periodically (e.g., an accounting or system monitoring process) and may be suspended while waiting for the next time.
Parent Process Request	A parent process may wish to suspend execution of a descendent to examine or modify the suspended process, or to coordinate the activity of various descendants.

Table 3.3 Reasons for Process Suspension

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Roadmap

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Processes and Resources

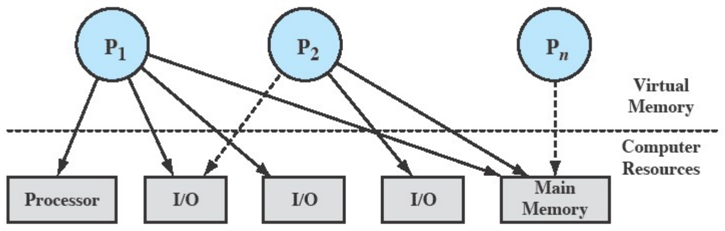


Figure 3.10 Processes and Resources (resource allocation at one snapshot in time)

Operating System Control Structures

- For the OS is to manage processes and resources, it must have information about the current status of each process and resource.
- Tables are constructed for each entity the operating system manages

OS Control Tables

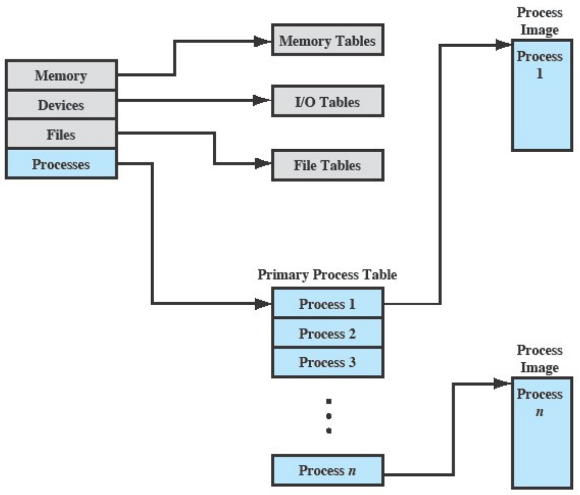
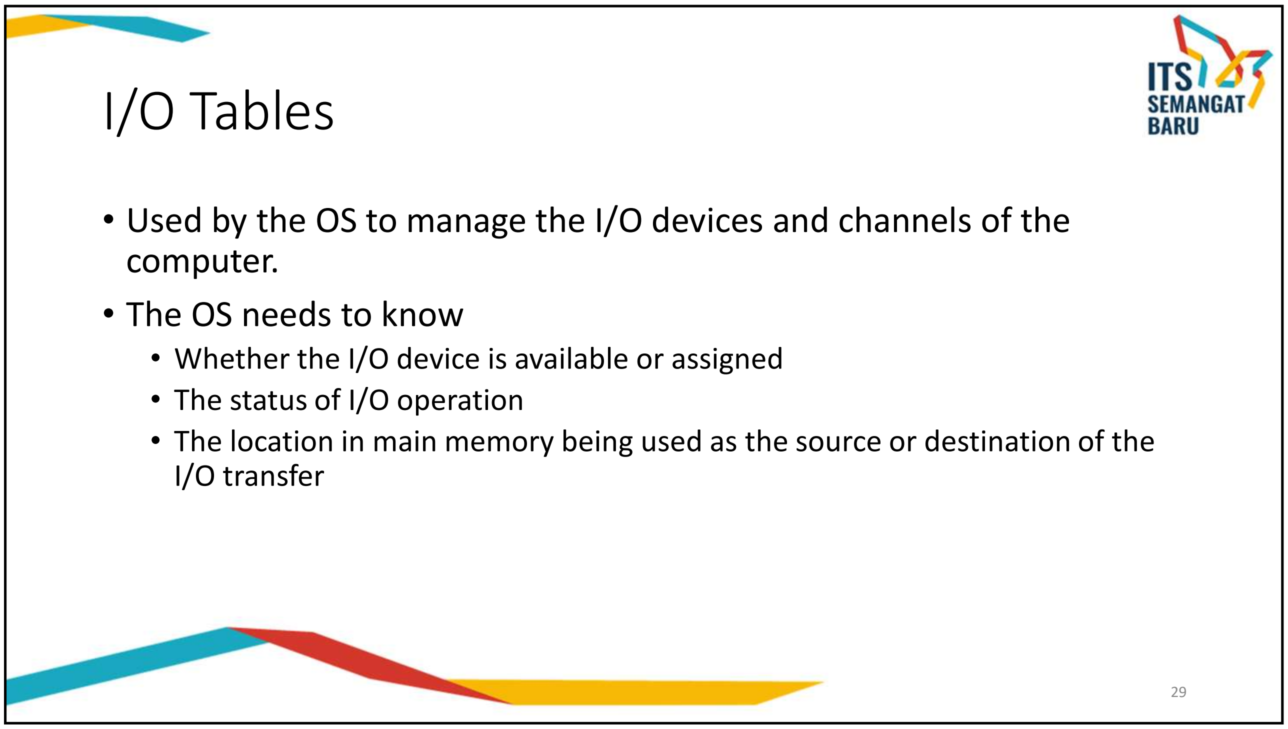


Figure 3.11 General Structure of Operating System Control Tables

Memory Tables

- Memory tables are used to keep track of both main and secondary memory.
- Must include this information:
  - Allocation of main memory to processes
  - Allocation of secondary memory to processes
  - Protection attributes for access to shared memory regions
  - Information needed to manage virtual memory



I/O Tables

- Used by the OS to manage the I/O devices and channels of the computer.
- The OS needs to know
  - Whether the I/O device is available or assigned
  - The status of I/O operation
  - The location in main memory being used as the source or destination of the I/O transfer

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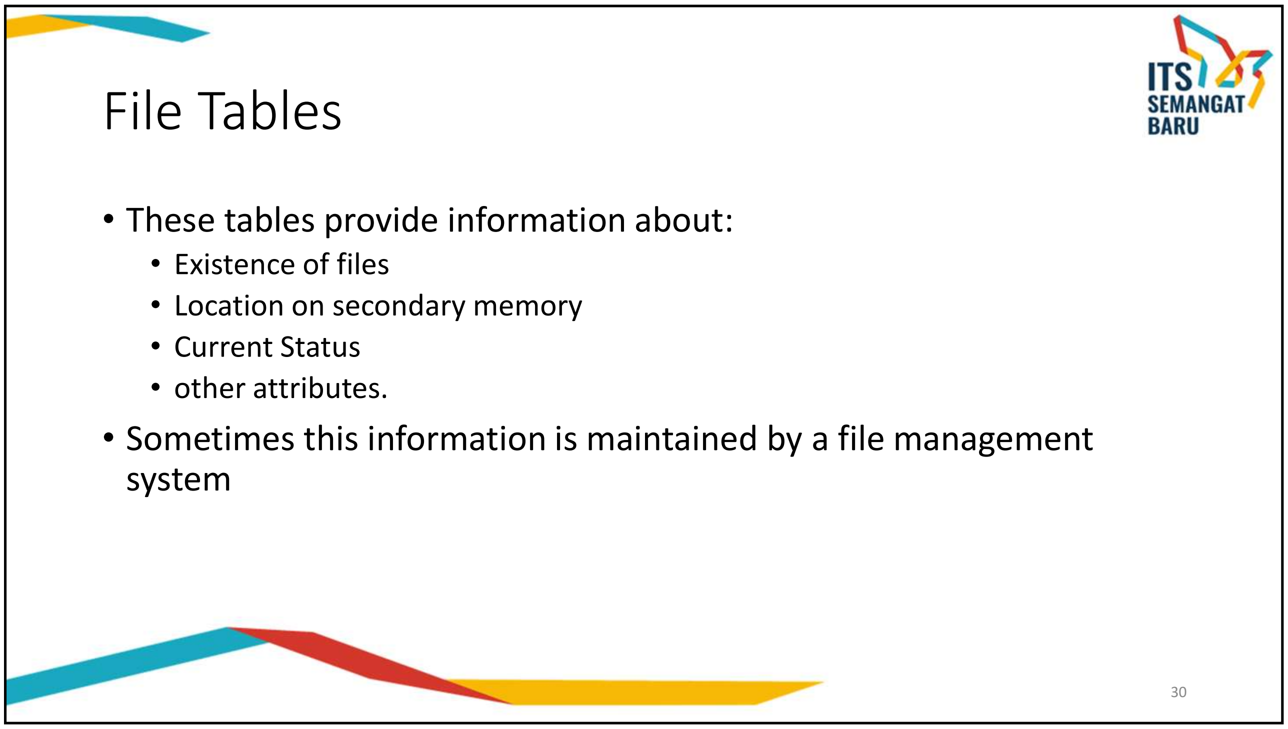

File Tables

- These tables provide information about:
  - Existence of files
  - Location on secondary memory
  - Current Status
  - other attributes.
- Sometimes this information is maintained by a file management system

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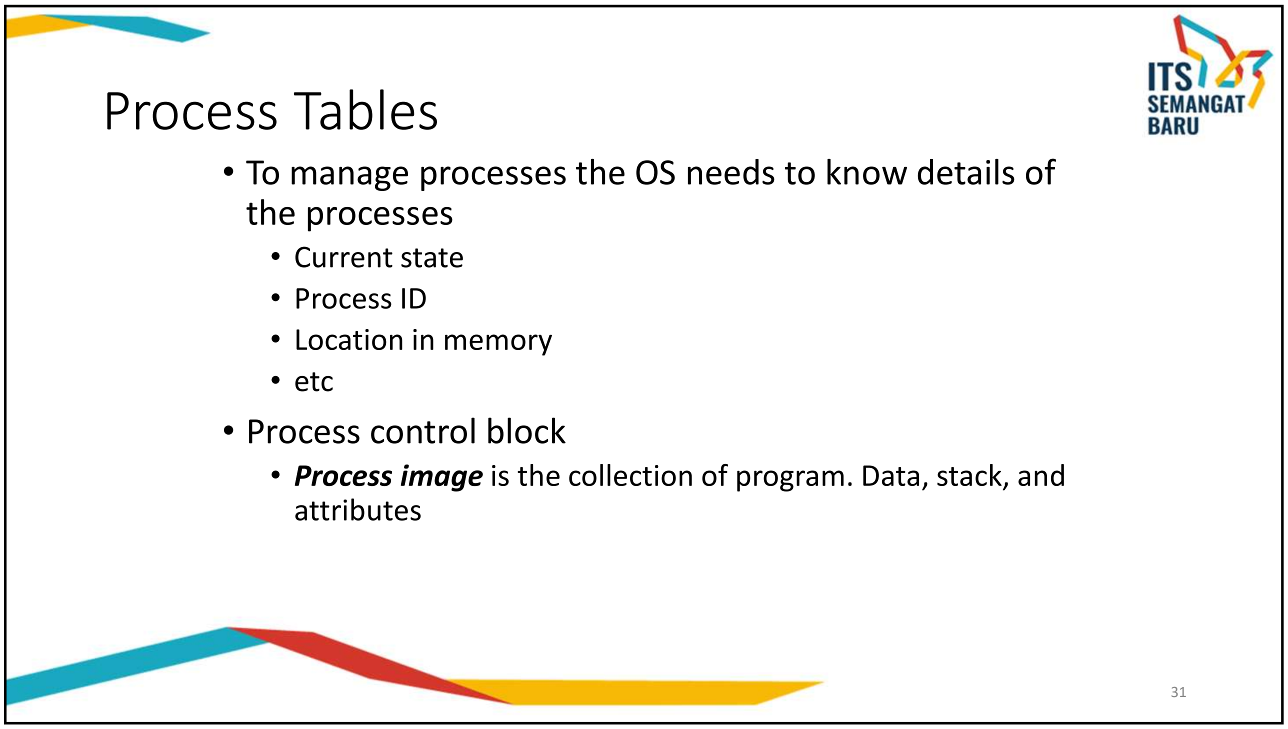
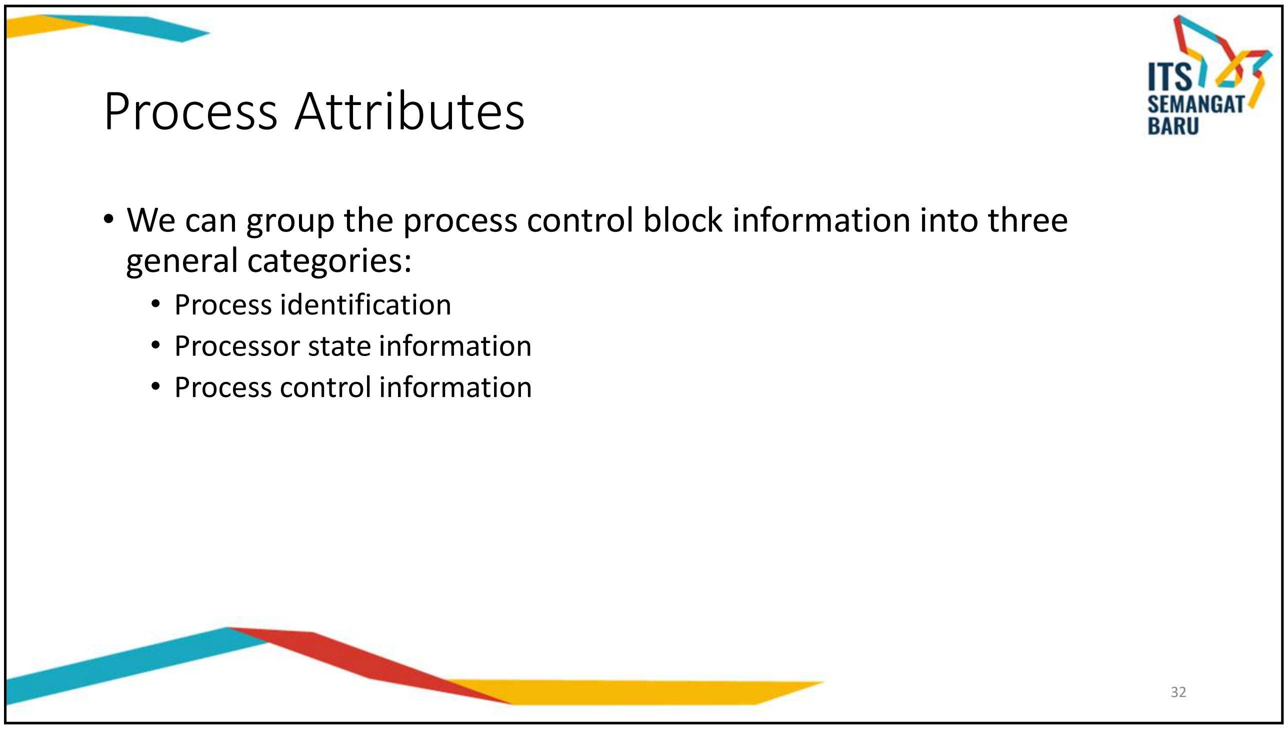


Process Tables

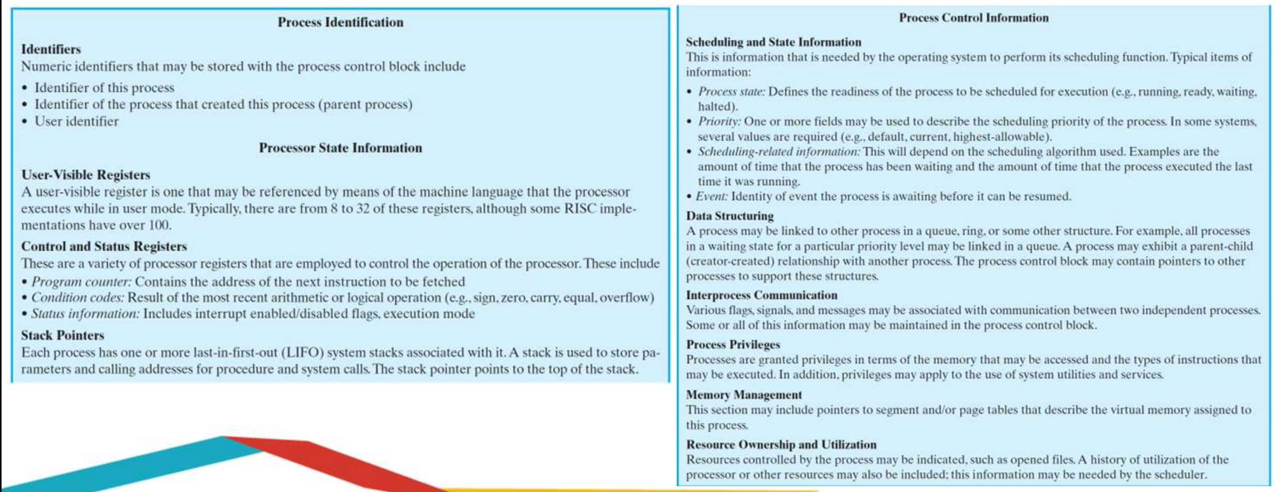
- To manage processes the OS needs to know details of the processes
  - Current state
  - Process ID
  - Location in memory
  - etc
- Process control block
  - ***Process image*** is the collection of program. Data, stack, and attributes



Process Attributes

- We can group the process control block information into three general categories:
  - Process identification
  - Processor state information
  - Process control information

Typical Elements of a Process Control Block



Process Identification

Identifiers
Numeric identifiers that may be stored with the process control block include
- Identifier of this process
- Identifier of the process that created this process (parent process)
- User identifier

Processor State Information

User-Visible Registers
A user-visible register is one that may be referenced by means of the machine language that the processor executes while in user mode. Typically, there are from 8 to 32 of these registers, although some RISC implementations have over 100.

Control and Status Registers
These are a variety of processor registers that are employed to control the operation of the processor. These include
- *Program counter:* Contains the address of the next instruction to be fetched
- *Condition codes:* Result of the most recent arithmetic or logical operation (e.g., sign, zero, carry, equal, overflow)
- *Status information:* Includes interrupt enabled/disabled flags, execution mode

Stack Pointers
Each process has one or more last-in-first-out (LIFO) system stacks associated with it. A stack is used to store parameters and calling addresses for procedure and system calls. The stack pointer points to the top of the stack.

Process Control Information

Scheduling and State Information
This is information that is needed by the operating system to perform its scheduling function. Typical items of information:
- *Process state:* Defines the readiness of the process to be scheduled for execution (e.g., running, ready, waiting, halted).
- *Priority:* One or more fields may be used to describe the scheduling priority of the process. In some systems, several values are required (e.g., default, current, highest-allowable).
- *Scheduling-related information:* This will depend on the scheduling algorithm used. Examples are the amount of time that the process has been waiting and the amount of time that the process executed the last time it was running.
- *Event:* Identity of event the process is awaiting before it can be resumed.

Data Structuring
A process may be linked to other process in a queue, ring, or some other structure. For example, all processes in a waiting state for a particular priority level may be linked in a queue. A process may exhibit a parent-child (creator-created) relationship with another process. The process control block may contain pointers to other processes to support these structures.

Interprocess Communication
Various flags, signals, and messages may be associated with communication between two independent processes. Some or all of this information may be maintained in the process control block.

Process Privileges
Processes are granted privileges in terms of the memory that may be accessed and the types of instructions that may be executed. In addition, privileges may apply to the use of system utilities and services.

Memory Management
This section may include pointers to segment and/or page tables that describe the virtual memory assigned to this process.

Resource Ownership and Utilization
Resources controlled by the process may be indicated, such as opened files. A history of utilization of the processor or other resources may also be included; this information may be needed by the scheduler.

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Process Identification

- Each process is assigned a unique numeric identifier.
- Many of the other tables controlled by the OS may use process identifiers to cross-reference process tables

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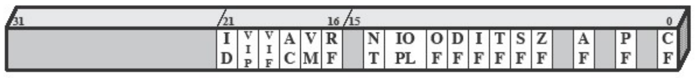
Processor State Information

- This consists of the contents of processor registers.
  - User-visible registers
  - Control and status registers
  - Stack pointers
- Program status word (PSW)
  - contains status information
  - Example: the EFLAGS register on Pentium processors

Pentium II EFLAGS Register



ID	=	Identification flag	DF	=	Direction flag
VIP	=	Virtual interrupt pending	IF	=	Interrupt enable flag
VIF	=	Virtual interrupt flag	TF	=	Trap flag
AC	=	Alignment check	SF	=	Sign flag
VM	=	Virtual 8086 mode	ZF	=	Zero flag
RF	=	Resume flag	AF	=	Auxiliary carry flag
NT	=	Nested task flag	PF	=	Parity flag
IOPL	=	I/O privilege level	CF	=	Carry flag
OF	=	Overflow flag			

Also see Table 3.6

Figure 3.12 Pentium II EFLAGS Register

Process Control Information

- This is the additional information needed by the OS to control and coordinate the various active processes.
  - See table 3.5 for scope of information

Structure of Process Images in Virtual Memory

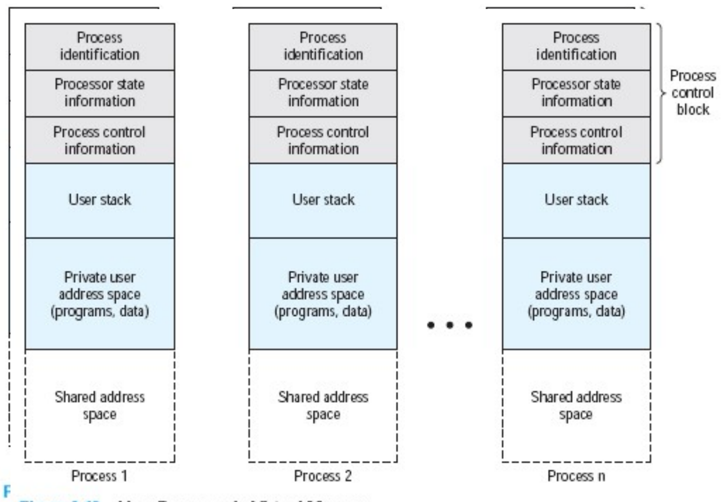
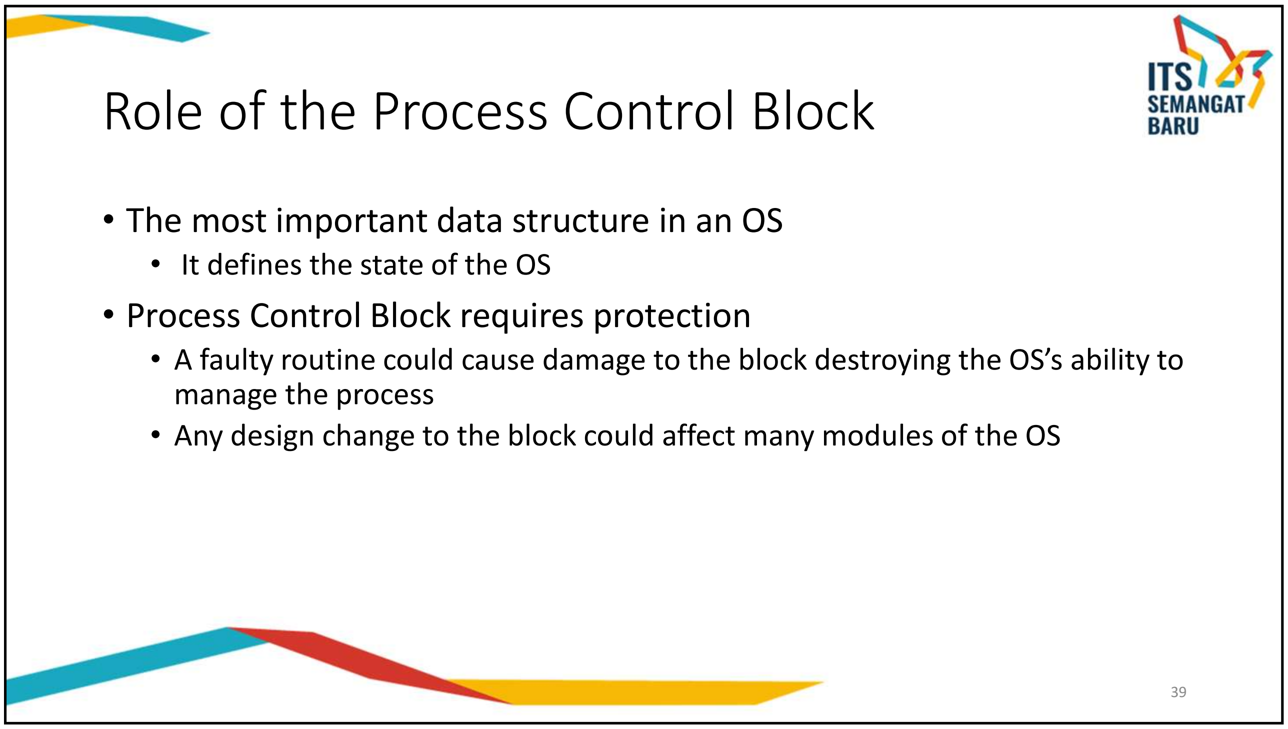


Figure 3.13 User Processes in Virtual Memory



Role of the Process Control Block

- The most important data structure in an OS
  - It defines the state of the OS
- Process Control Block requires protection
  - A faulty routine could cause damage to the block destroying the OS’s ability to manage the process
  - Any design change to the block could affect many modules of the OS

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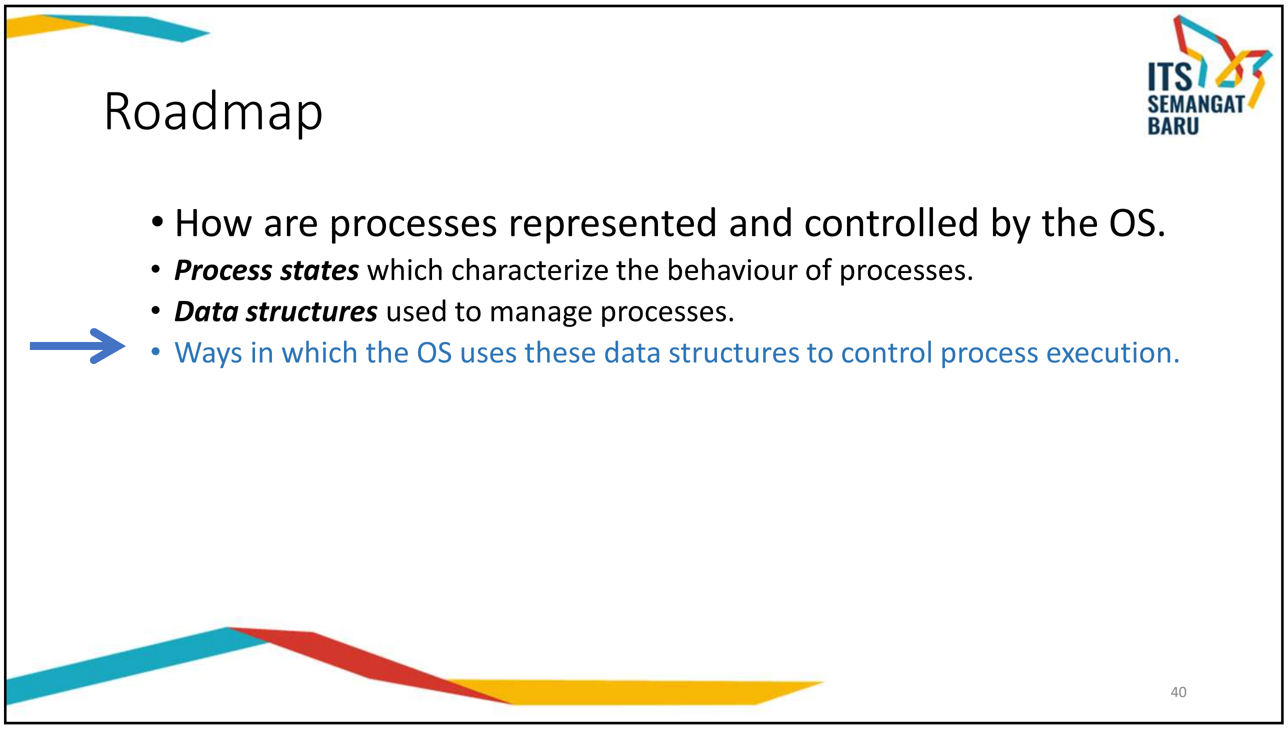

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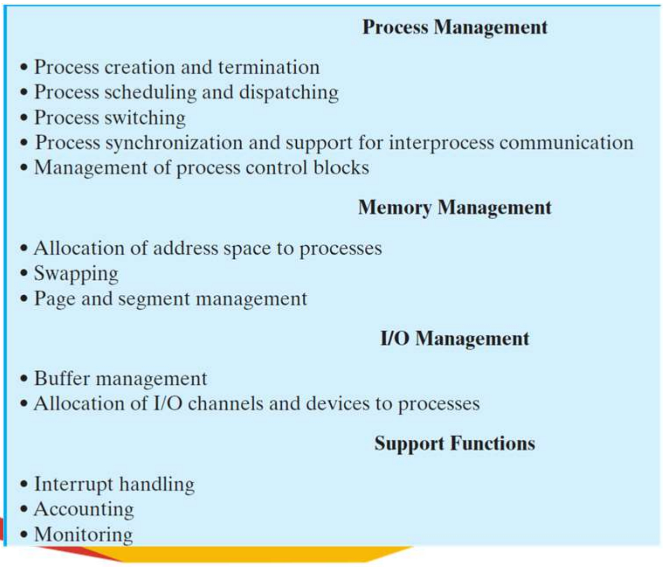
Modes of Execution

- Most processors support at least two modes of execution
- User mode
  - Less-privileged mode
  - User programs typically execute in this mode
- System mode
  - More-privileged mode
  - Kernel of the operating system

Typical Functions of an Operating System Kernel



Process Management

- Process creation and termination
- Process scheduling and dispatching
- Process switching
- Process synchronization and support for interprocess communication
- Management of process control blocks

Memory Management

- Allocation of address space to processes
- Swapping
- Page and segment management

I/O Management

- Buffer management
- Allocation of I/O channels and devices to processes

Support Functions

- Interrupt handling
- Accounting
- Monitoring

Process Creation

- Once the OS decides to create a new process it:
  - Assigns a unique process identifier
  - Allocates space for the process
  - Initializes process control block
  - Sets up appropriate linkages
  - Creates or expand other data structures

Switching Processes

- Several design issues are raised regarding process switching
  - What events trigger a process switch?
  - We must distinguish between mode switching and process switching.
  - What must the OS do to the various data structures under its control to achieve a process switch?

When to switch processes

A process switch may occur any time that the OS has gained control from the currently running process. Possible events giving OS control are:

Mechanism	Cause	Use
Interrupt	External to the execution of the current instruction	Reaction to an asynchronous external event
Trap	Associated with the execution of the current instruction	Handling of an error or an exception condition
Supervisor call	Explicit request	Call to an operating system function

Table 3.8 Mechanisms for Interrupting the Execution of a Process

Change of Process State …

- The steps in a process switch are:
  1. Save context of processor including program counter and other registers
  2. Update the process control block of the process that is currently in the Running state
  3. Move process control block to appropriate queue – ready; blocked; ready/suspend
  4. Select another process for execution
  5. Update the process control block of the process selected
  6. Update memory-management data structures
  7. Restore context of the selected process

Is the OS a Process?

- If the OS is just a collection of programs and if it is executed by the processor just like any other program, is the OS a process?
- If so, how is it controlled?
  - Who (what) controls it?

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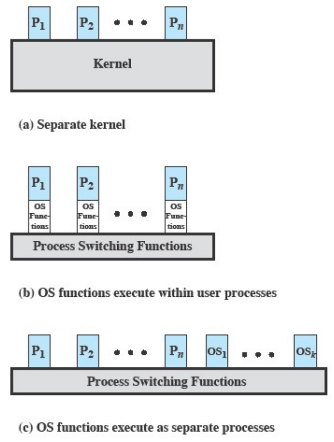
Execution of the Operating System



P_1
P_2
P_n
Kernel
(a) Separate kernel
OS Func-tions
Process Switching Functions
(b) OS functions execute within user processes
OS_1
OS_k
Process Switching Functions
(c) OS functions execute as separate processes

Figure 3.15 Relationship Between Operating System and User Processes

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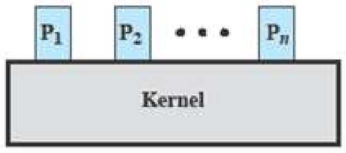
Non-process Kernel

- Execute kernel outside of any process
- The concept of process is considered to apply only to user programs
  - Operating system code is executed as a separate entity that operates in privileged mode



(a) Separate kernel

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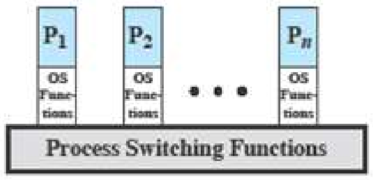
Execution *Within* User Processes

- Execution Within User Processes
  - Operating system software within context of a user process
  - No need for Process Switch to run OS routine



(b) OS functions execute within user processes

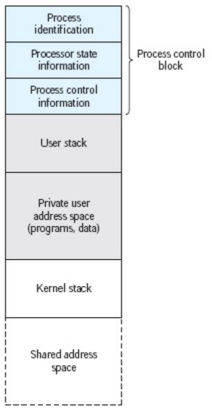

Process identification
Processor state information
Process control information
Process control block
User stack
Private user address space (programs, data)
Kernel stack
Shared address space

Figure 3.16 Process Image: Operating System Executes within User Space

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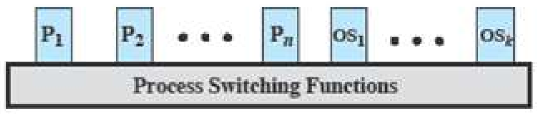
Process-based Operating System

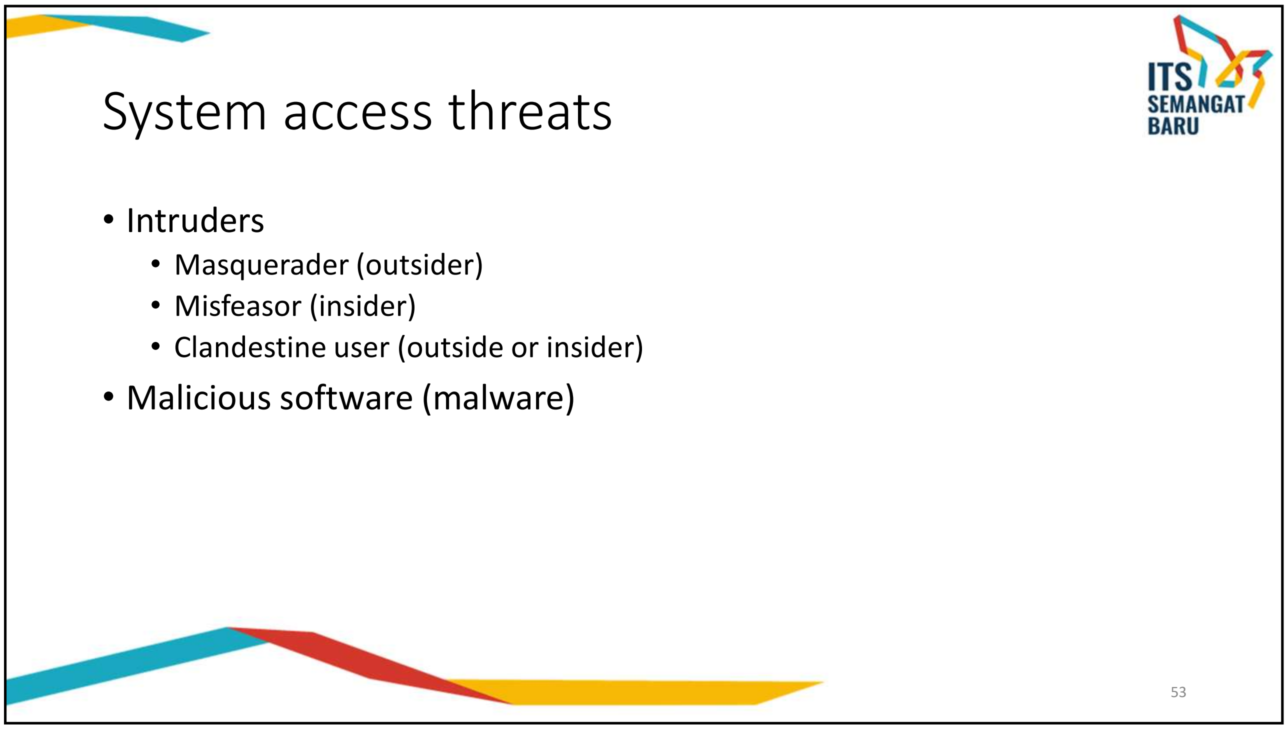
- Process-based operating system
  - Implement the OS as a collection of system process



(c) OS functions execute as separate processes

Security Issues

- An OS associates a set of privileges with each process.
  - Highest level being administrator, supervisor, or root, access.
- A key security issue in the design of any OS is to prevent anything (user or process) from gaining unauthorized privileges on the system
  - Especially - from gaining root access.



System access threats

- Intruders
  - Masquerader (outsider)
  - Misfeasor (insider)
  - Clandestine user (outside or insider)
- Malicious software (malware)

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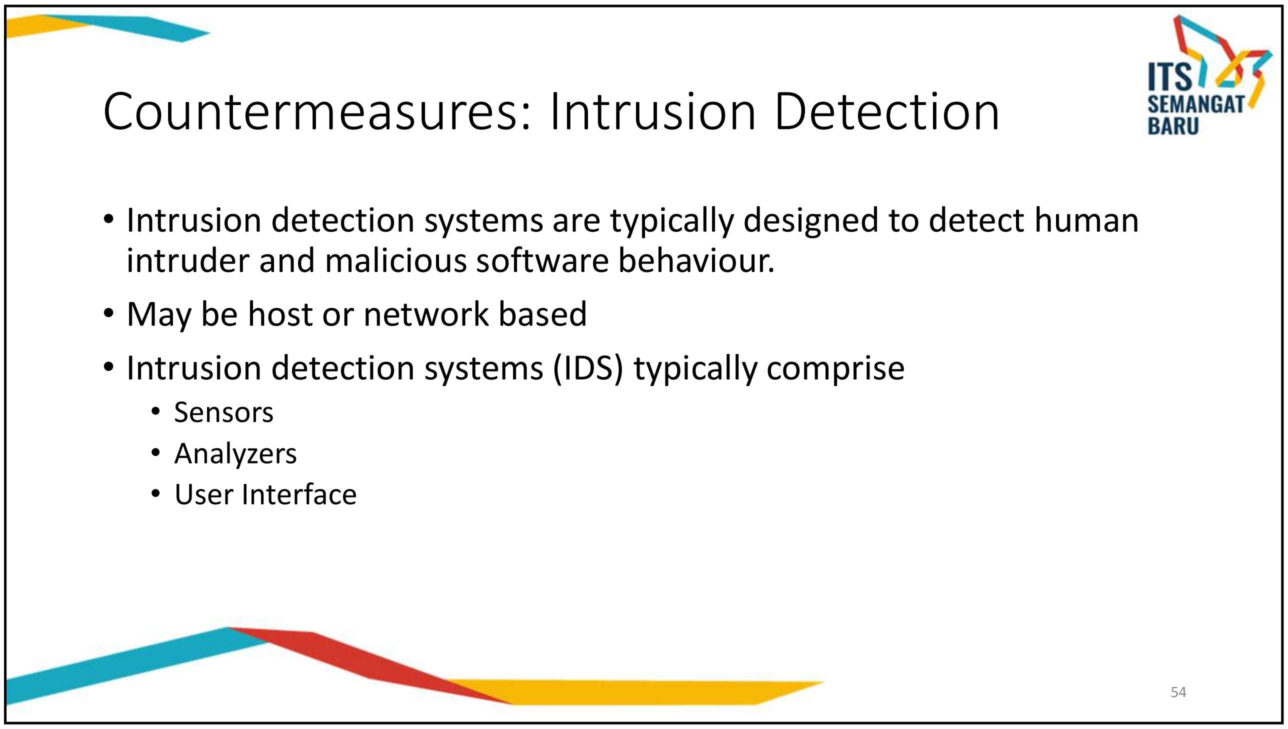

Countermeasures: Intrusion Detection

- Intrusion detection systems are typically designed to detect human intruder and malicious software behaviour.
- May be host or network based
- Intrusion detection systems (IDS) typically comprise
  - Sensors
  - Analyzers
  - User Interface

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Countermeasures: Authentication

- Two Stages:
  - Identification
  - Verification
- Four Factors:
  - Something the individual ***knows***
  - Something the individual ***possesses***
  - Something the individual ***is*** (static biometrics)
  - Something the individual ***does*** (dynamic biometrics)

Countermeasures: Access Control

- A policy governing access to resources
- A security administrator maintains an authorization database
  - The access control function consults this to determine whether to grant access.
- An auditing function monitors and keeps a record of user accesses to system resources.

Countermeasures: Firewalls

- Traditionally, a firewall is a dedicated computer that:
  - interfaces with computers outside a network
  - has special security precautions built into it to protect sensitive files on computers within the network.

Thank You