Process Description and Control

Chapter 3

Process Related Requirements for an Operating System

- Interleave the execution of multiple processes to maximize processor utilization while providing reasonable response time
- Allocate resources to processes
- Support interprocess communication and user creation of processes

“Operational” Concepts

- Computer platform consists of a collection of hardware resources
- Computer applications are developed to perform some task
- *Inefficient for applications to be written directly for a given hardware platform*

- OS provides a convenient to use, feature rich, secure, and consistent *interface* for applications to use
- OS provides a uniform, *abstract representation* of resources that can be requested and accessed by application

OS Manages Execution of Applications

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

Views of 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

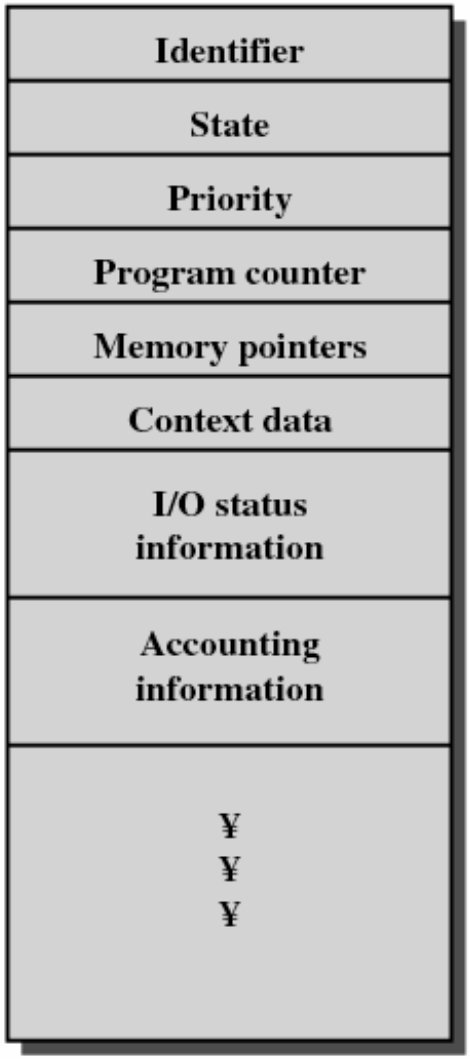
- Identifier – number
- State – run / blocked / eady
- Priority – high / low
- Program counter – next statement to execute
- Memory pointers
- Context data – registers, stack
- I/O status information
- Accounting information

Process Control Block

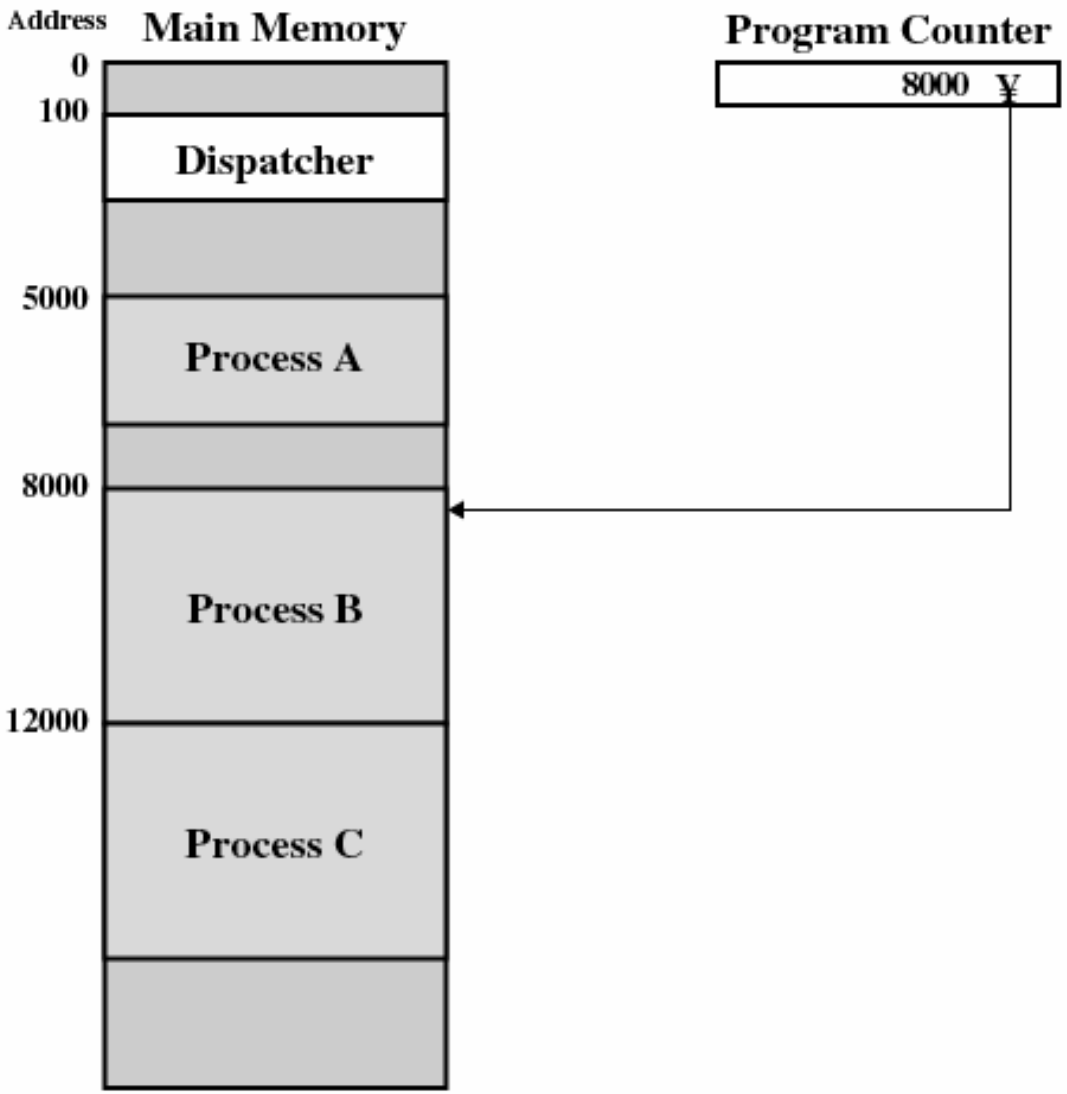
The OS data Structure defining a process

- Contains the process elements
  – id, state, priority, PC
- Created and manage by the operating system
- Allows support for multiple processes
  – One PCB / PD for each process

Process Control Block



Example Execution



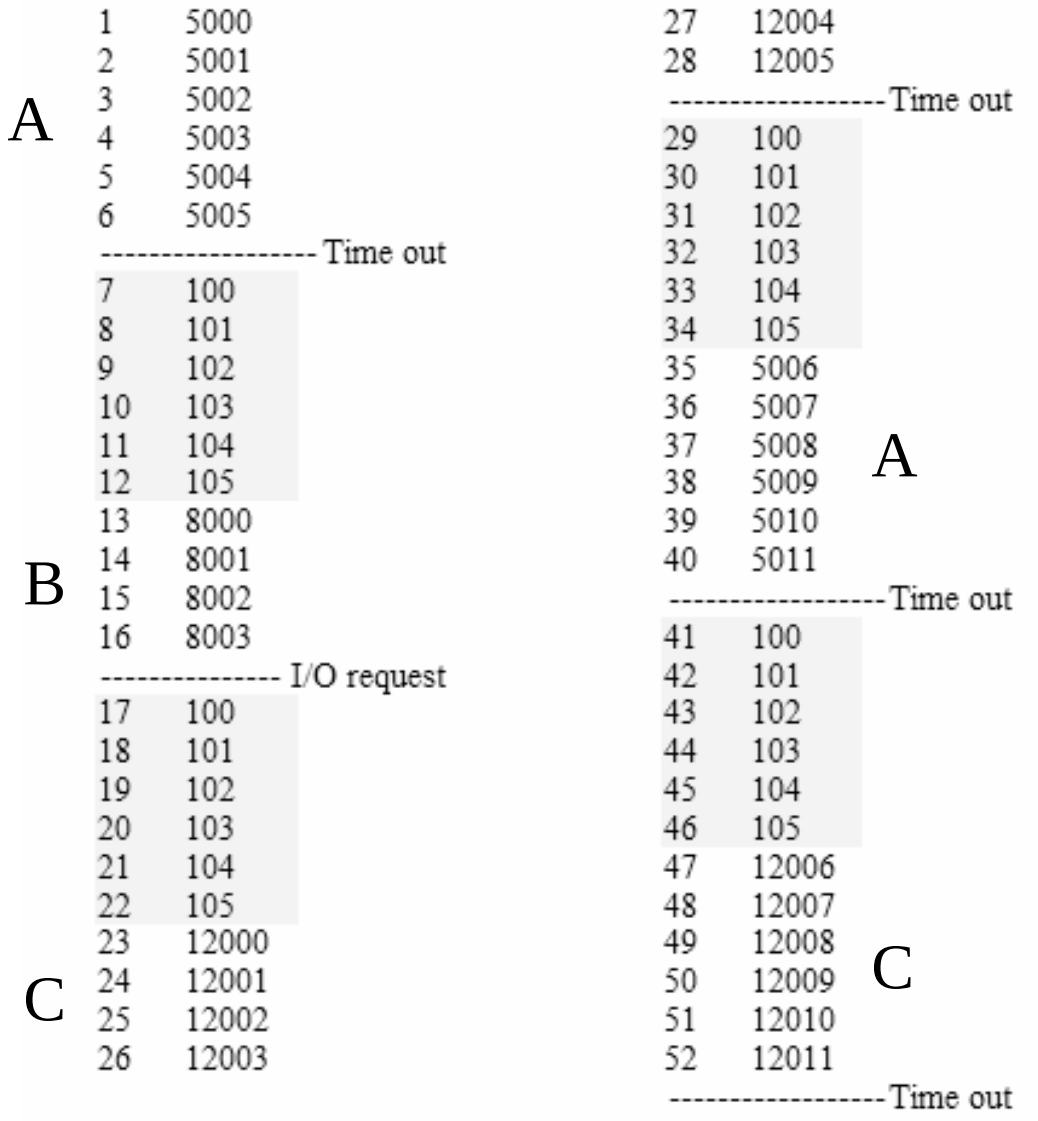
Trace of Processes

(a) Trace of Process A	(b) Trace of Process B	(c) Trace of Process C
5000	8000	12000
5001	8001	12001
5002	8002	12002
5003	8003	12003
5004		12004
5005		12005
5006		12006
5007		12007
5008		12008
5009		12009
5010		12010
5011		12011

5000 = Starting address of program of Process A
8000 = Starting address of program of Process B
12000 = Starting address of program of Process C

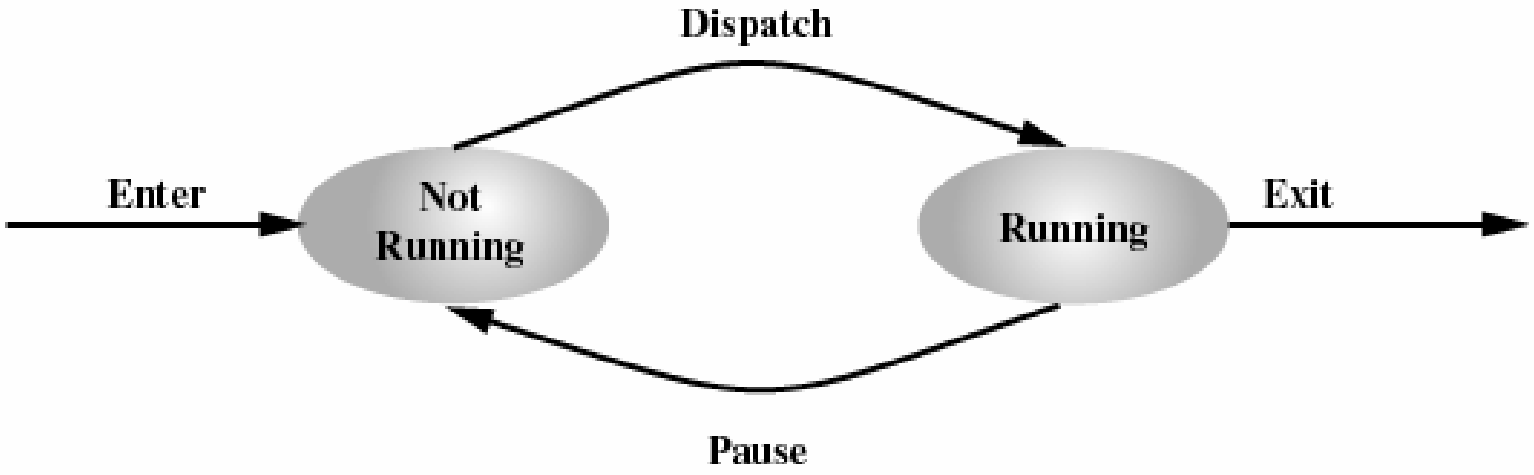
Processes Traces w/ Interleaving

Dispatcher
100 - 105



Two-State Process Model

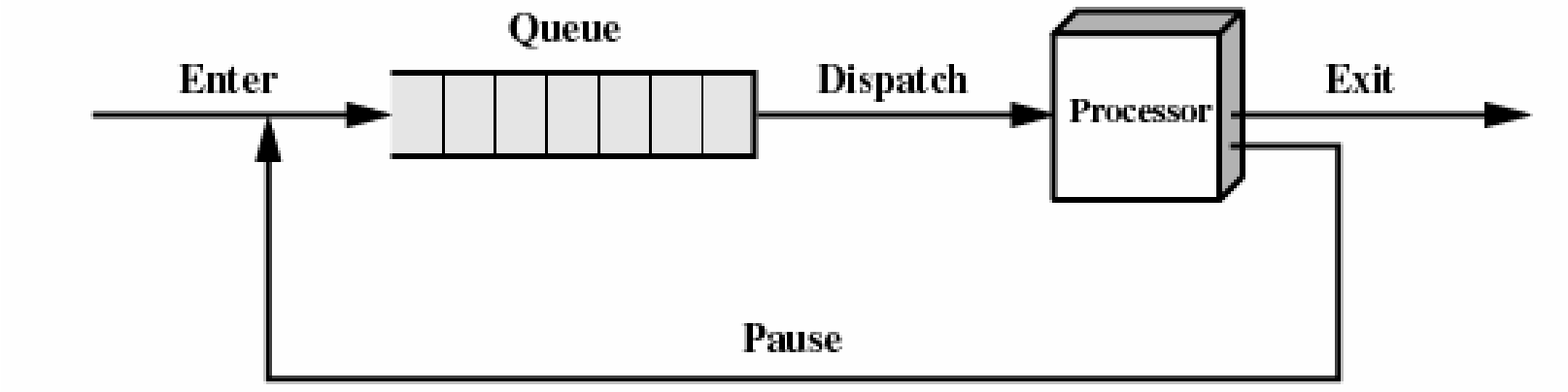
- In an FSM each state has a **unique** meaning
- Process may be in one of two states
  - Running
  - Not-running



Not-Running Processes in a Queue (Ready Queue)

Ready
But not running

Run



(b) Queuing diagram

Reasons for Process Creation

New batch job	The operating system is provided with a batch job control stream, usually on tape or disk. When the operating system is prepared to take on new work, it will read the next sequence of job control commands.
Interactive logon	A user at a terminal logs on to the system.
Created by OS to provide a service	The operating system can create a process to perform a function on behalf of a user program, without the user having to wait (e.g., a process to control printing).
Spawned by existing process	For purposes of modularity or to exploit parallelism, a user program can dictate the creation of a number of processes.

Reasons for Process Termination

Normal completion	The process executes an OS service call to indicate that it has completed running.
Time limit exceeded	The process has run longer than the specified total time limit. There are a number of possibilities for the type of time that is measured. These include total elapsed time ("wall clock time"), amount of time spent executing, and, in the case of an interactive process, the amount of time since the user last provided any input.
Memory unavailable	The process requires more memory than the system can provide.
Bounds violation	The process tries to access a memory location that it is not allowed to access.
Protection error	The process attempts to use a resource such as a file that it is not allowed to use, or it tries to use it in an improper fashion, such as writing to a read-only file.
Arithmetic error	The process tries a prohibited computation, such as division by zero, or tries to store numbers larger than the hardware can accommodate.

....

2 State Process Model Insufficient

- Not-running
  - ready to execute
- Blocked
  - waiting for I/O

Non-executing process can be in either state

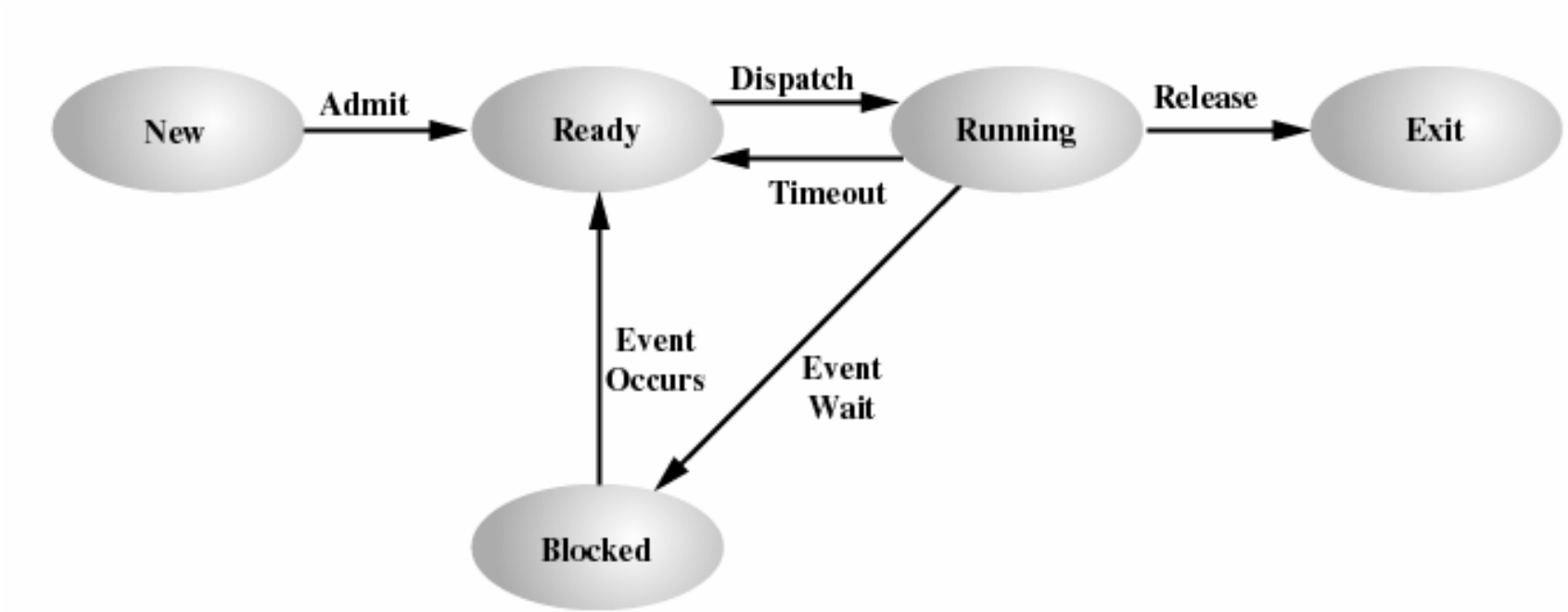
A single queue for both is not sufficient

- Dispatcher cannot just select the process that has been in the queue the longest because it may be blocked

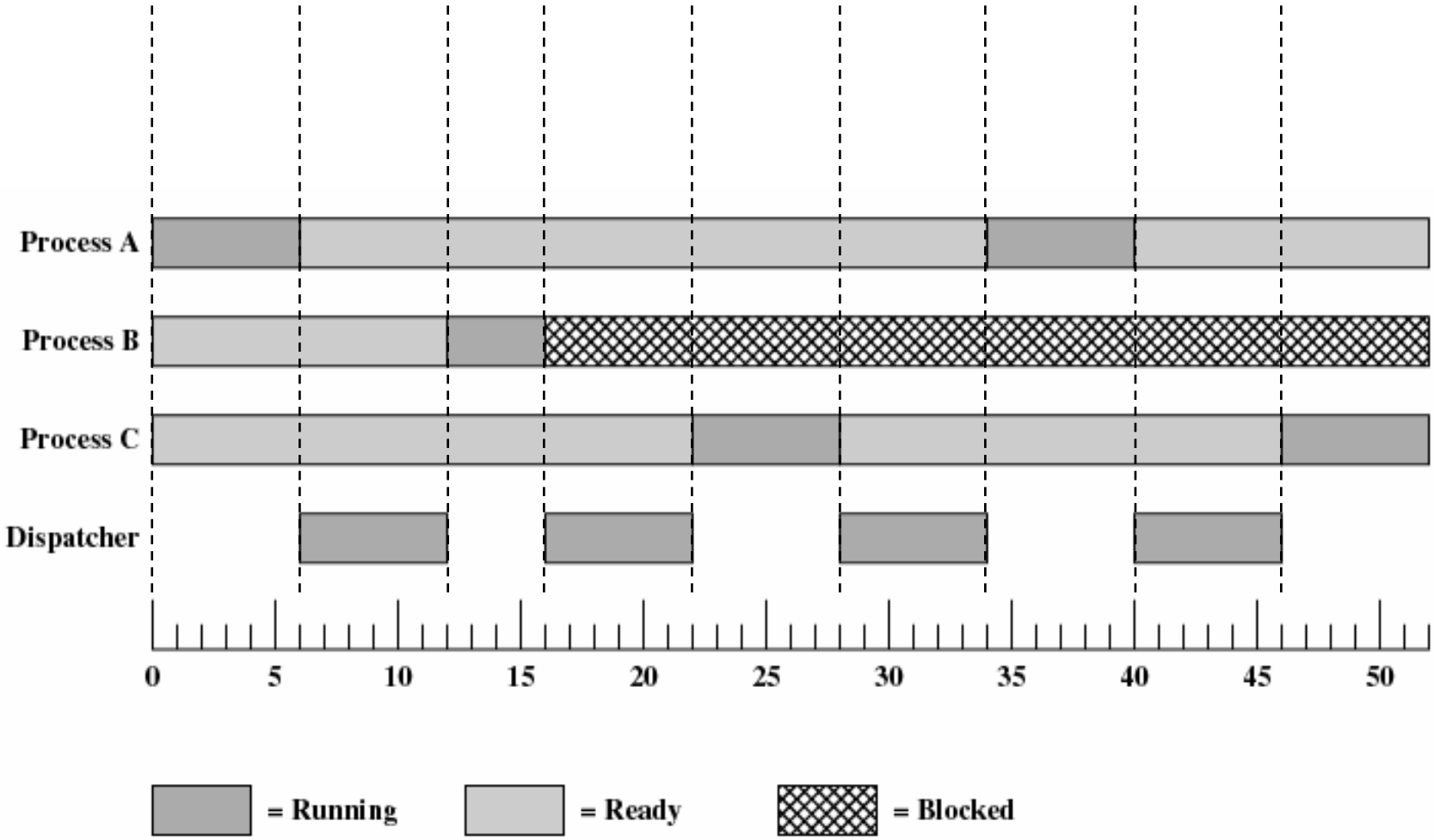
A Five-State Model

- Running
  - Memory + Processor
- Ready
  - Memory, *not* Blocked, not in Processor
- Blocked
  - Memory + Blocked
- New
  - Job arrival, PCB(?), *no memory allocated*
- Exit

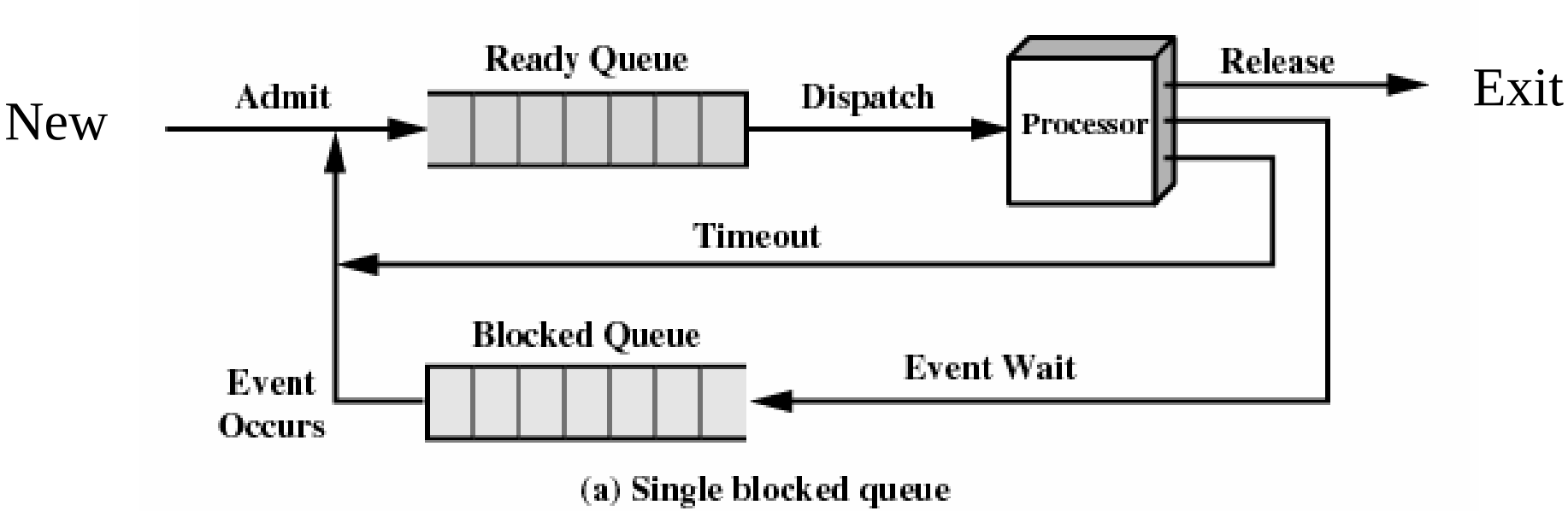
Five-State Process Model



Process States



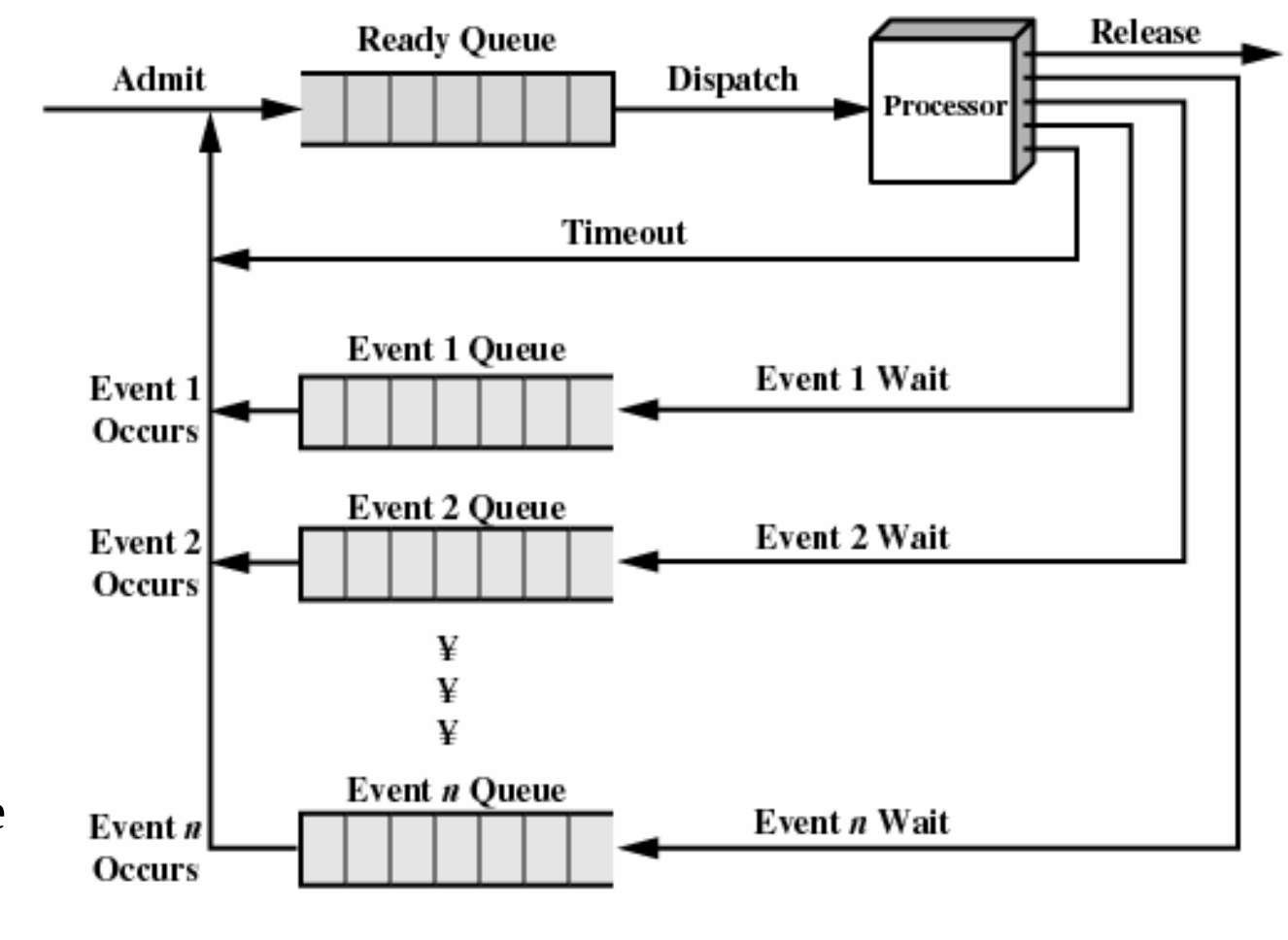
5-State Process Model
(An Implementation Perspective)



Multiple Blocked Queues

More Efficient

Check queue associated with event occurrence



Suspended Processes

- Processor is faster than I/O so **all** processes could be waiting for I/O
- Swap one or more processes to disk to *free up more memory*
  - Swap out process in Blocked or Ready
    - Memory taken away
  - Bring in a **NEW** process

Reasons for Process Suspension

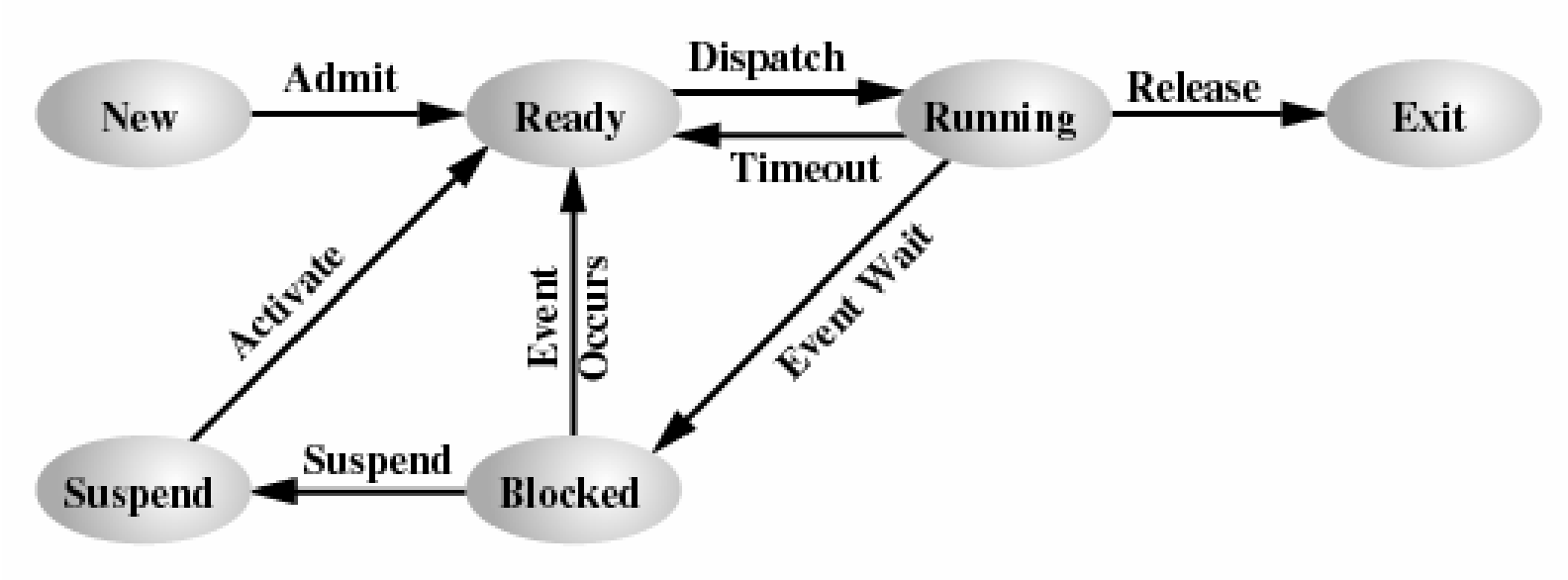
Swapping	The operating system needs to release sufficient main memory to bring in a process that is ready to execute.
Other OS reason	The operating system may suspend a background or utility process or a process that is suspected of causing a problem.
Interactive user request	A user may wish to suspend execution of a program for purposes of 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 interval.
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 descendents.

Suspended Processes

- Blocked state becomes suspend state when swapped to disk
- Can suspend process from either the Block or Ready state

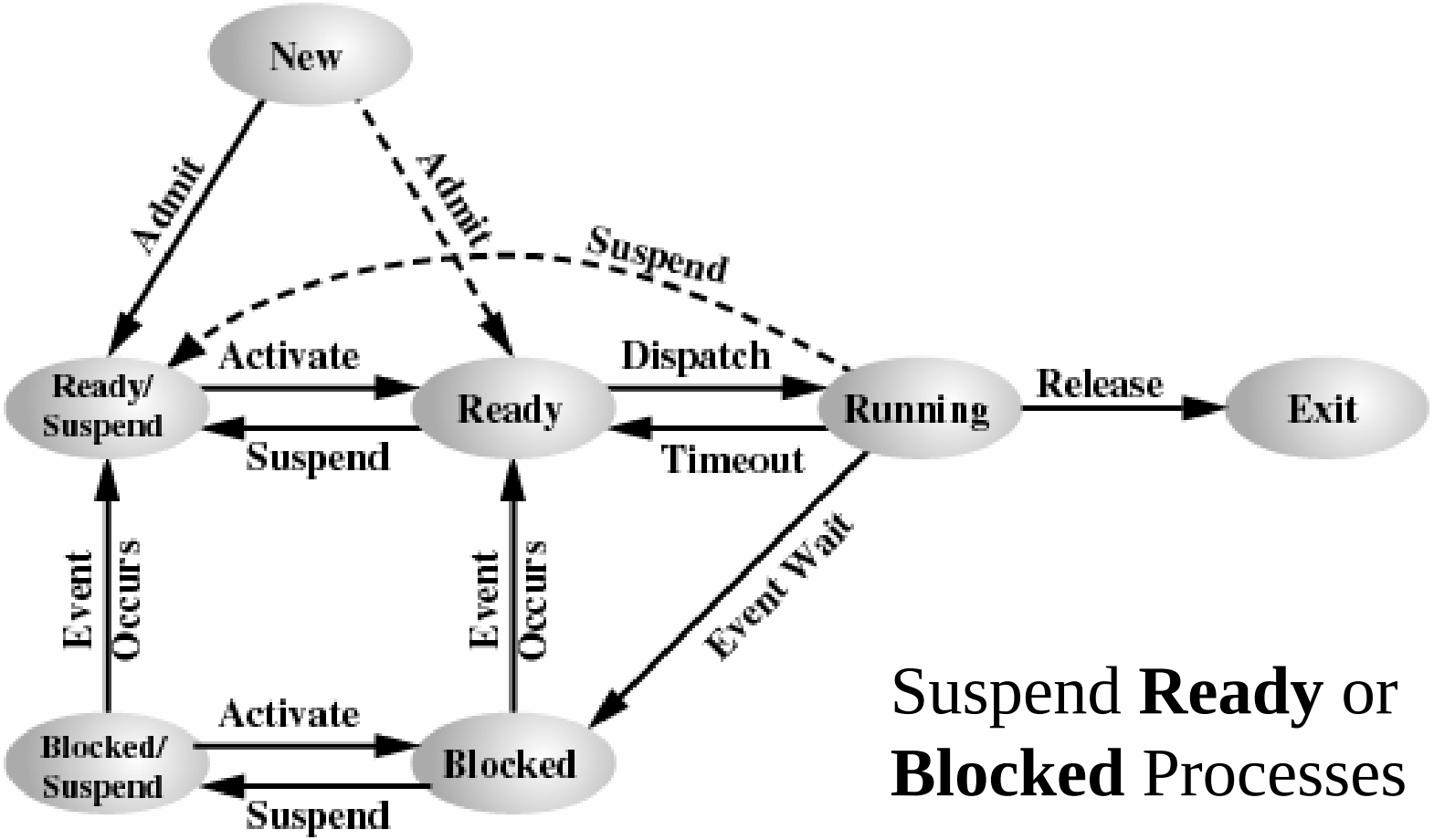
- Two new states
  - Blocked/Suspend
  - Ready/Suspend

Modeling Process Suspension



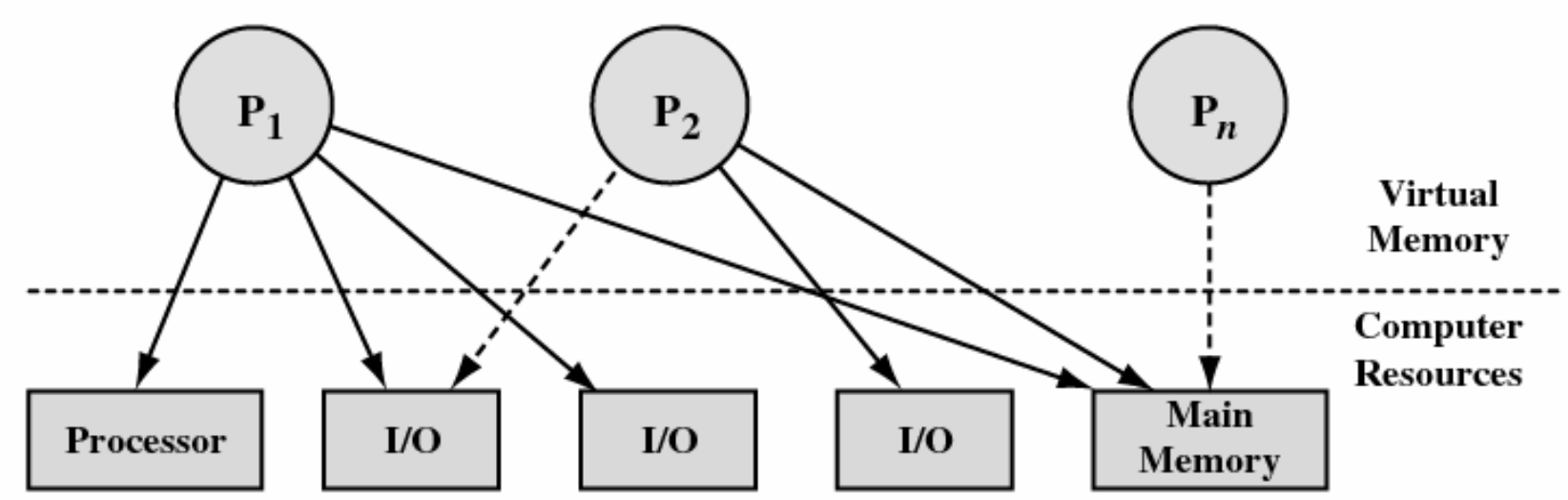
Suspend ONLY Blocked Processes

Modeling Process Suspension



Suspend **Ready** or **Blocked** Processes

Processes and Resources



- Processes P1 and P2 are in Memory
- Process P2 is blocked waiting for I/O resource held by P1
- Process Pn is awaiting memory allocation
  - Suspended or New Job Arrival

Operating System Control Structures

Contain information about the current status of each process and resource

- Tables are constructed for each entity the operating system manages
  - Memory Tables, I/O Tables, File Tables, Process Tables
  - DESCRIPTORS

Tables $\equiv$ (linked) Data structures in the OS

Memory Tables

- 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

Tables $\equiv$ (linked) Data structures in the OS

I/O Tables

- I/O device is available or assigned
- Status of I/O operation
- Location in main memory being used as the source or destination of the I/O transfer

Tables $\equiv$ (linked) Data structures in the OS

File Tables

- Existence of files
- Location on secondary memory
- Current Status
- Attributes
- Sometimes this information is maintained by a file management system

Tables $\equiv$ (linked) Data structures in the OS

Process Table

- Where process is located
- Attributes in the process control block
  - Program
  - Data
  - Stack

Tables $\equiv$ (linked) Data structures in the OS

Process Image

User Data

The modifiable part of the user space. May include program data, a user stack area, and programs that may be modified.

User Program

The program to be executed.

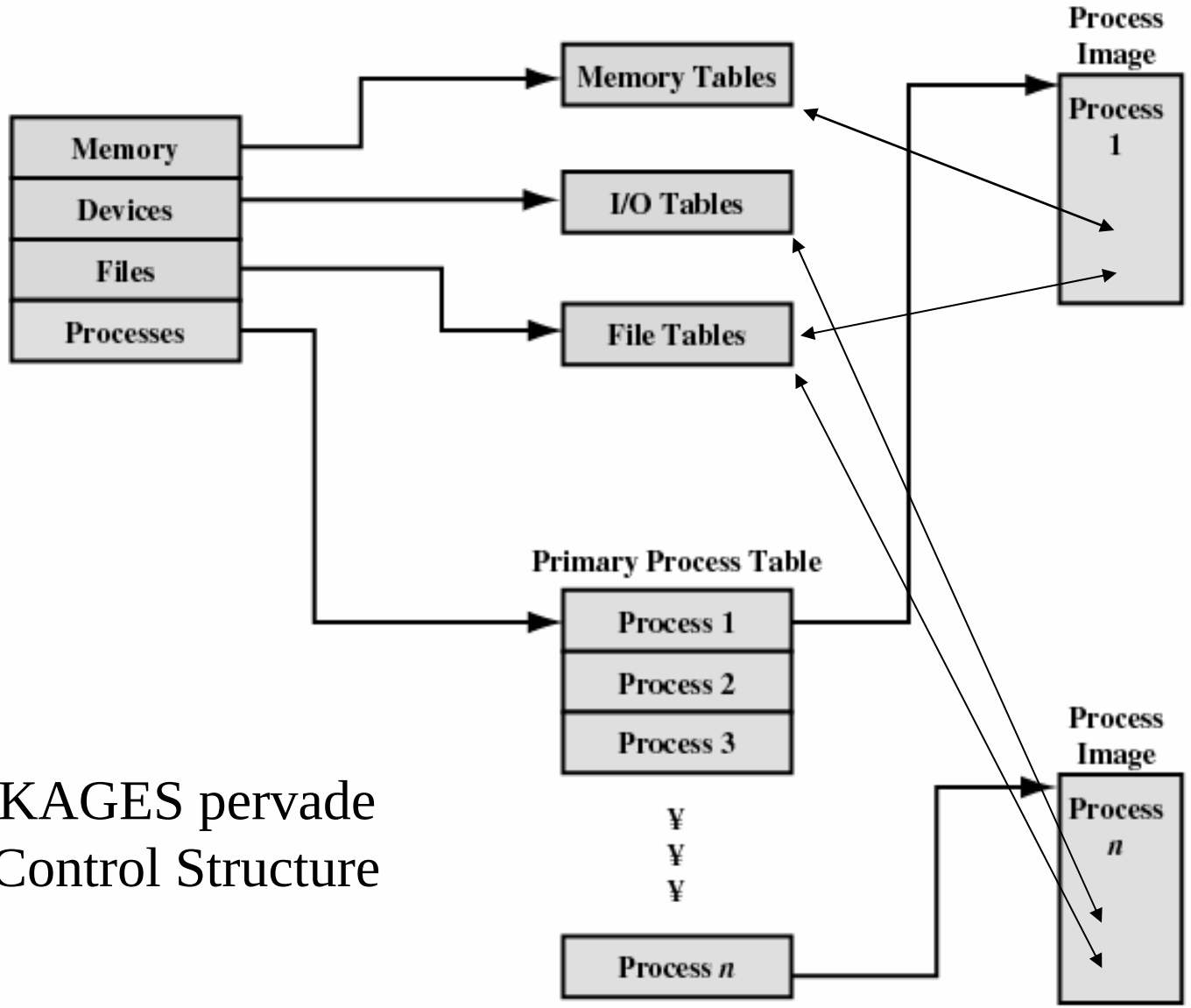
System Stack

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.

Process Control Block

Data needed by the operating system to control the process (see Table 3.5).

Control Tables, Processes and Process Images



Note:

LINKAGES pervade OS Control Structure

Process Control Block: Categories of Information

- Process Identification
  - Process Id…..
- Processor State Information
  - Registers, Stack pointers…
- Process Control Information
  - State Information, Resource ownership…

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

Process Control Block

- Processor State Information
  - User-Visible Registers
  - Control and Status Registers
    - *Program counter*, *condition codes*, *status information*
  - Stack Pointers
    - Each process has an associated system/runtime stack
  - Program Status Word (PSW)
    - Example: the EFLAGS register on Pentium machines

Process Control Block

- Process Control Information
  - Scheduling and State Information
    - Process state (ready, running…)
    - Priority
    - Scheduling info (time used, waiting…)
  - Granted Privileges
    - Shared memory, system utility access
  - VM Page Map Tables
  - Resource Ownership and Utilization
  - Data Structuring
    - Data structures indicating relationships
      - parent/child, threads, shared resources
  - IPC Information

When to Switch a Process (Context Switch)

- Clock interrupt
  - process has executed for the maximum allowable time slice
- I/O interrupt
- Memory fault
  - memory address is in virtual memory so it must be brought into main memory

When to Switch a Process (Context Switch)

- Trap
  - error or exception occurred
  - may cause process to be moved to Exit state
- Supervisor call
  - such as file open

Change of Process State: Performing the Context Switch

- Save context of processor including program counter and other registers
- Update the process control block of the process that is currently in the Running state
- Move process control block to appropriate queue – ready; blocked; ready/suspend
- Select another process for execution

Change of Process State: Performing the Context Switch

- Update the process control block of the process selected
- Update memory-management data structures
- Restore context of the selected process

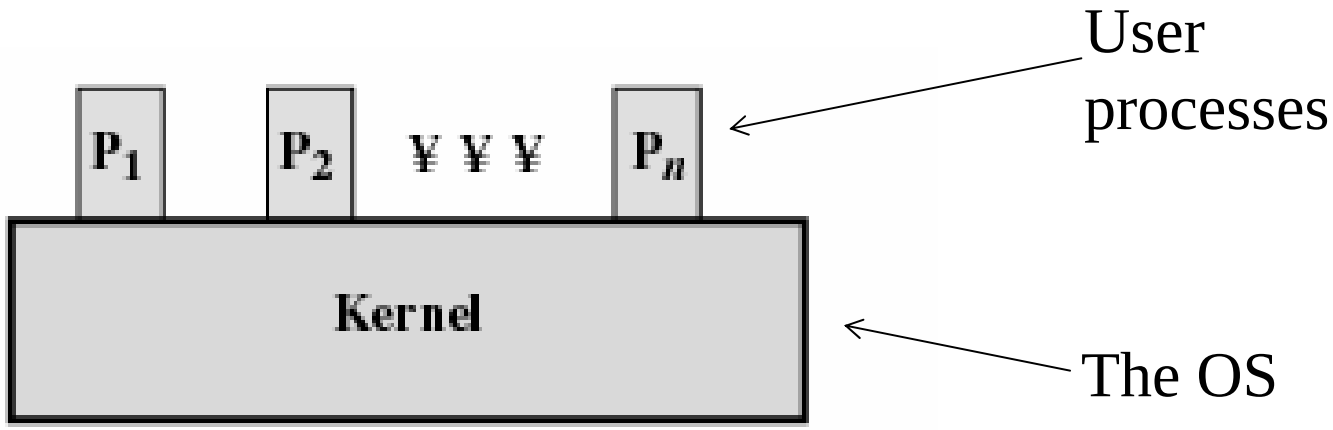
OS Design

OS can be integrated into the execution framework in 3 distinct ways

- Executing as a Non-Process Kernel
- Execution within User Processes
- Process-Based execution

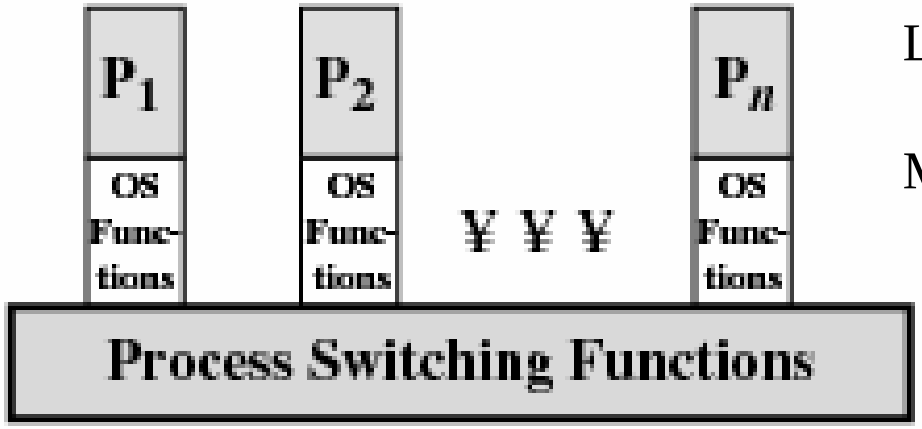
Execution of the Operating System

- Non-process Kernel
  - Execute kernel outside of any process
  - Operating system code is executed as a separate entity that operates in privileged mode



Execution of the Operating System

- Execution Within User Processes
  - Operating system software within context of a user process
  - Process executes in privileged mode when executing operating system code

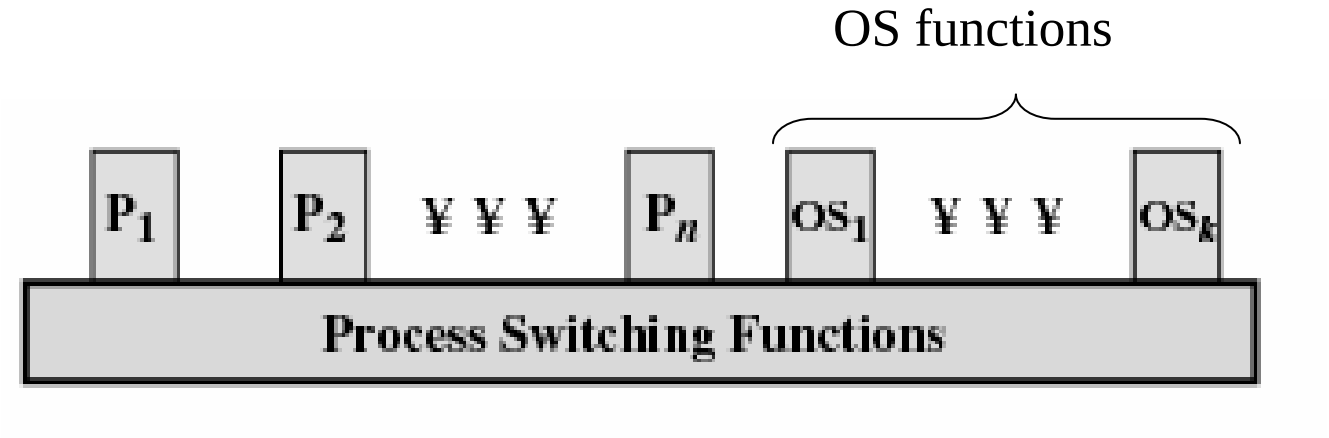


OS is a collection of routines LINKED to user processes

Minimal CTX time!

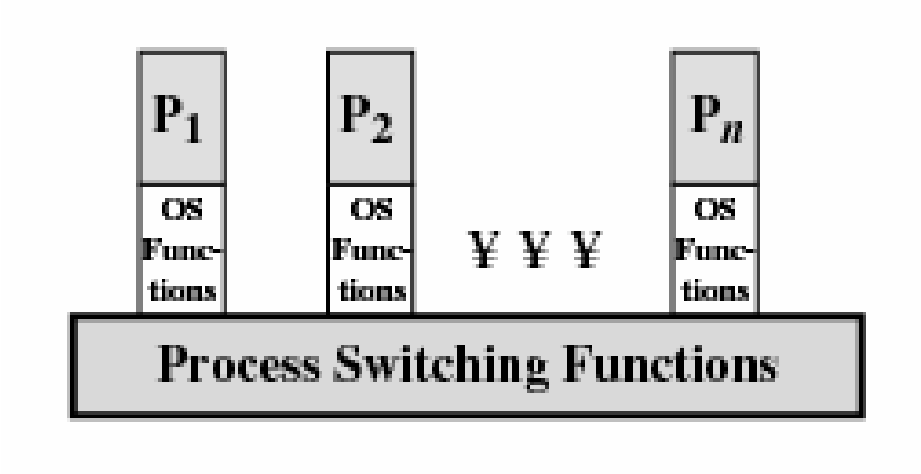
Execution of the Operating System

- Process-Based Operating System
  - Implement operating system as a collection of system processes
  - Useful in multi-processor or multi-computer environment



UNIX SVR4 Process Management

- Most of the operating system executes within the environment of a user process



UNIX Process States

Table 3.9 UNIX Process States

User Running	Executing in user mode.
Kernel Running	Executing in kernel mode.
Ready to Run, in Memory	Ready to run as soon as the kernel schedules it.
Asleep in Memory	Unable to execute until an event occurs; process is in main memory (a blocked state).
Ready to Run, Swapped	Process is ready to run, but the swapper must swap the process into main memory before the kernel can schedule it to execute.
Sleeping, Swapped	The process is awaiting an event and has been swapped to secondary storage (a blocked state).
Preempted	Process is returning from kernel to user mode, but the kernel preempts it and does a process switch to schedule another process.
Created	Process is newly created and not yet ready to run.
Zombie	Process no longer exists, but it leaves a record for its parent process to collect.

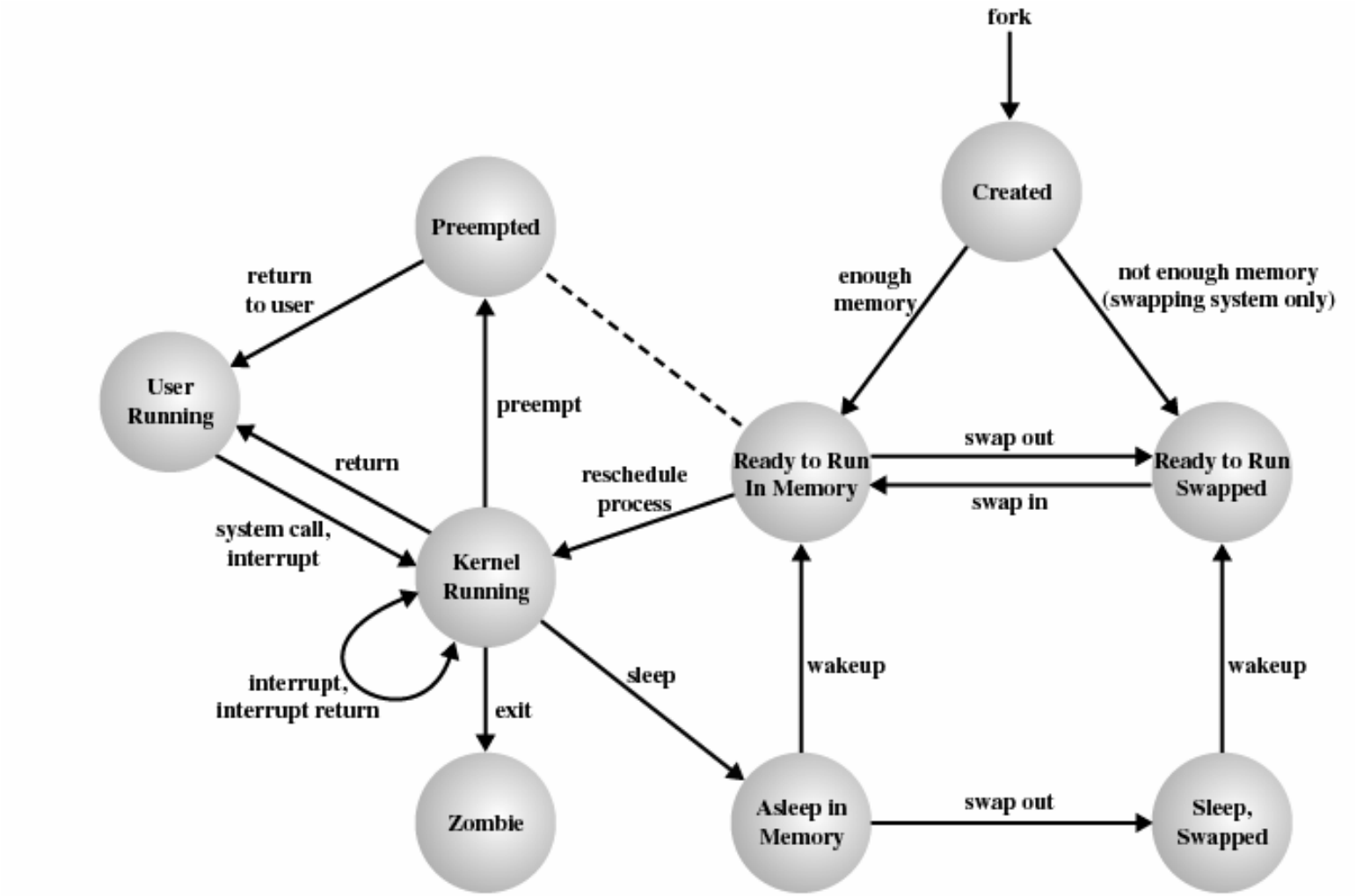


Figure 3.17 UNIX Process State Transition Diagram

Modes of Execution

- User mode
  - Less-privileged mode
  - User programs typically execute in this mode
- System mode, control mode, or kernel mode
  - More-privileged mode
  - Kernel of the operating system

Process Creation

- Assign a unique process identifier
- Allocate space for the process
- Initialize process control block
- Set up appropriate linkages
  - Ex: add new process to linked list used for scheduling queue
- Create of expand other data structures
  - Ex: maintain an accounting file