Process Management

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Outline

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Overview of OS Services

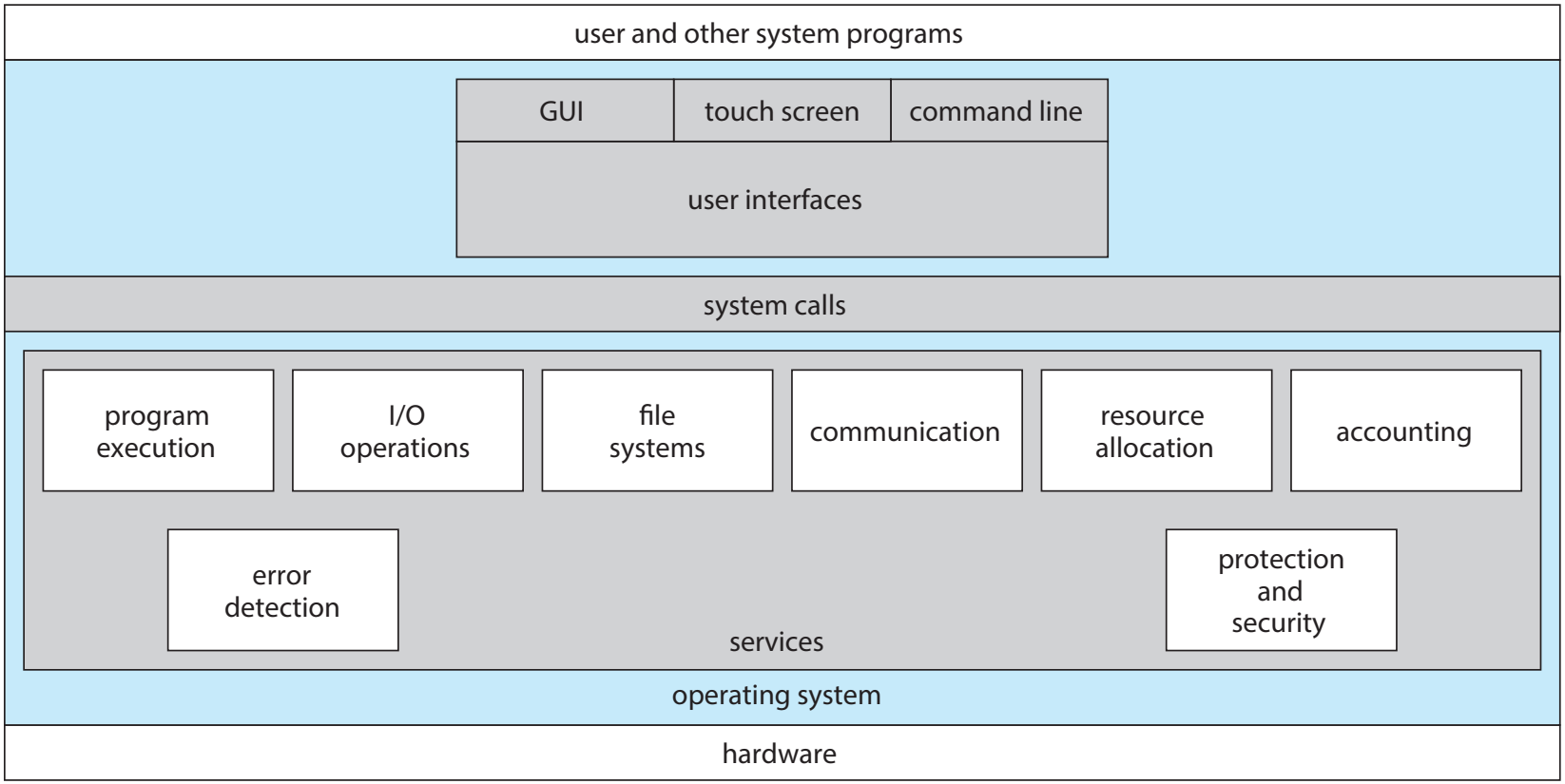


Figure: A view of operating system services[1].

[1] Abraham Silberschatz, Peter B. Galvin, and Greg Gagne. *Operating system concepts*. 10th edition. John Wiley & Sons, 2018.

Evolved to *Process*

- Early computers run a single program at a time.
- Contemporary computer systems allow multiple programs to be loaded into memory and executed concurrently.
- This evolution results in the notation of a process, i.e., a program in execution.

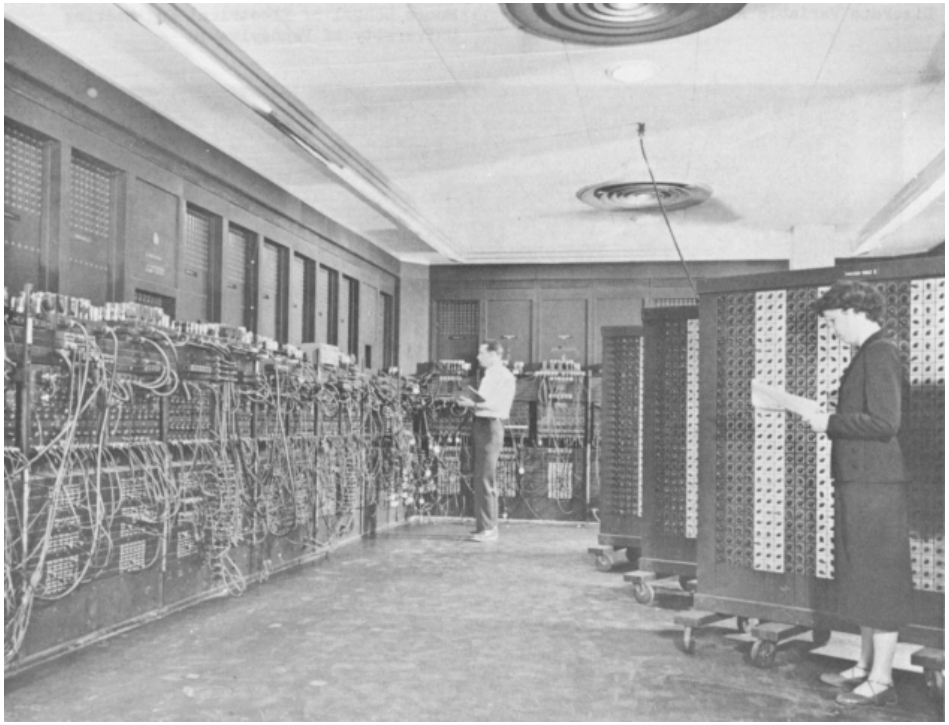


Figure: From US Army Photo Archive

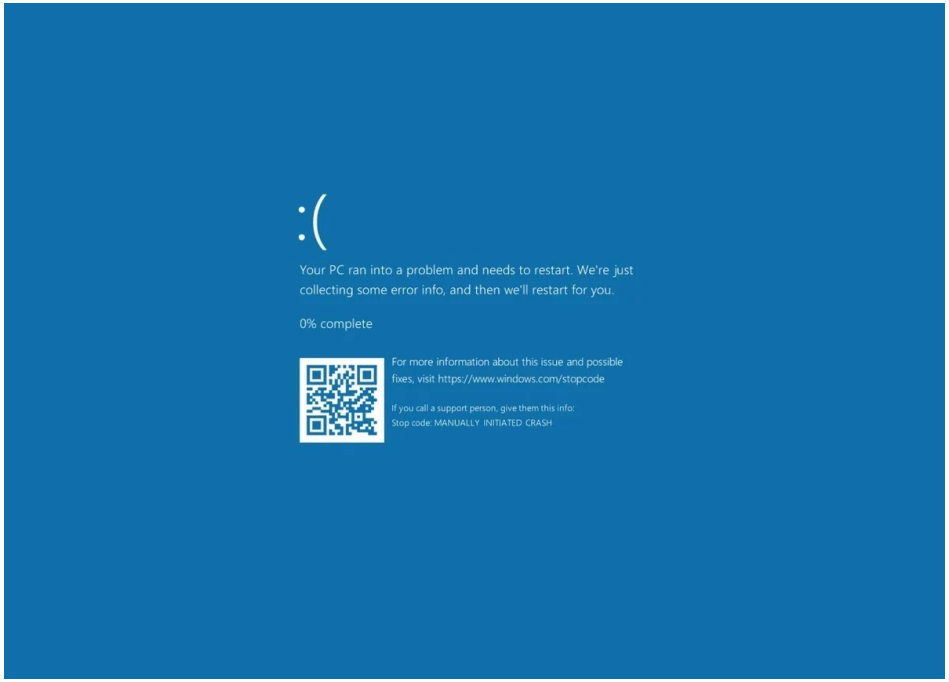
Process Management

- Why?
- What?
- How?

Outline

Need for Reliability and Protection

- Programs can fail.
- Programs may access other programs' code and data, intentionally or unintentionally.
- ...



Need for Efficient Use of Resources

- Computer systems has rather limited and also "expensive" resources
  - CPU cycles
  - Main memory (RAM)
  - I/O devices (secondary storage, network, ...)
  - ...

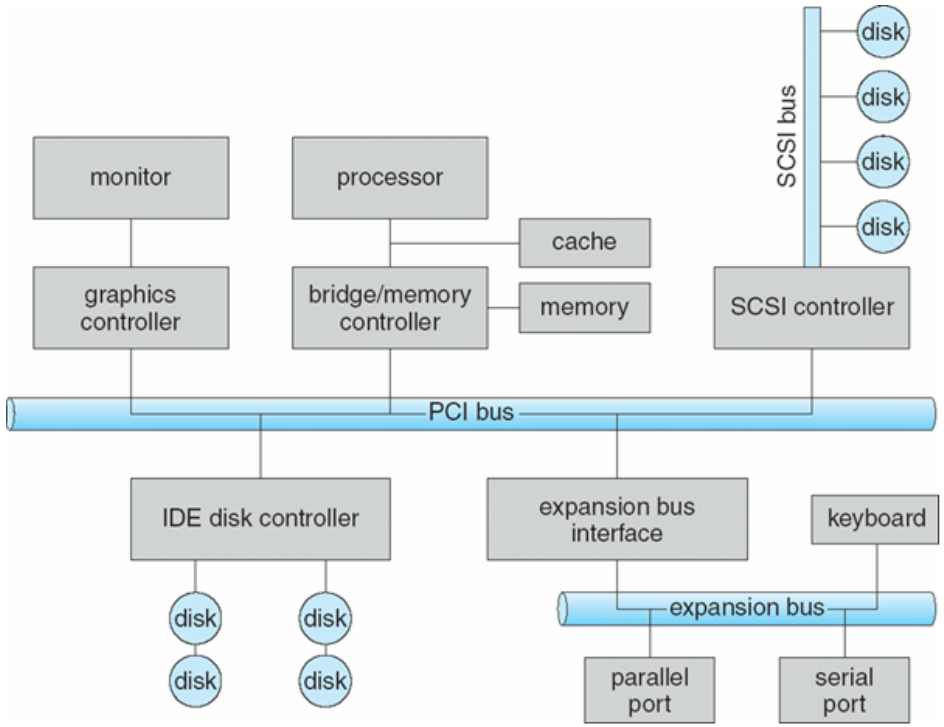


Figure: Source: Figure 12-1 in Silberschatz et al., 2018[a]

[a] Abraham Silberschatz, Peter B. Galvin, and

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Policy

- Policy (What do we want?). The OS should provide *efficient and protected* access to shared resources.
  - Programs can run concurrently to utilize resources.
  - No program can read or write memory of another program or of the OS (what memory?).
  - *Additionally*, do we wish to have better utilization of system resources, e.g., do we wish to have better (small) response time?

Mechanism

- Policy (What?). The OS should provide *efficient and protected* access to shared resources.
- Mechanism (How?). Hardware, OS kernel, and *process*.
  - Realizing "Virtual" resources, e.g., address translation. Each process has its isolated logical (or virtual address space), and hardware translates virtual address to physical address.
  - Supporting dual mode operating. Processes run in user or kernel mode, i.e., to restrict process in user mode from accessing privileged instructions (which needs both hardware and software support)

Outline

Concepts of Multiprogramming and Time-Sharing

- Multiprogramming
- Time-sharing

Multiprogramming

- A technique in OS that OS organizes a collection of processes in such a way that the processes run concurrently (in parallel or in pseudo-parallel) and the CPU always has a process to execute.
- Multiprogramming can increase CPU utilization.
- Why?

Time-Sharing

- A technique in OS that OS used a timer and cycle processes rapidly through the CPU, giving each user a share of the resources.
- Time-sharing can decrease response time to make system more responsive.

A Simple Model of Multiprogramming

$$\text{CPU Utilization} = 1 - p^n \tag{1}$$

where

- n. There are n processes in memory, and we call it the degree of multiprogramming.
- p. The fraction of time that a process spends in waiting for I/O to complete.

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Process in Memory

OS creates an illusion that a process runs as if the process ran on its own CPU and had its own memory, i.e., a process gets its own

- "virtual CPU", and
- "virtual memory address space"

Layout of Process in Memory

The layout of a process in memory consists of multiple parts, generally,

- Text. The text section is the program code.
- Stack. The stack section contains temporary data, such as, function parameters, return addresses, local variables.
- Data. The data section containing global variables
- Heap. The heap section containing memory dynamically allocated during run time.

Memory Layout of a C Program

Let's take a look at a C program ...

Multiple Processes in Memory

Consider that there are now multiple processes in memory.

- But there is only one single physical memory address space in the machine, how do we create the *illusion* that each has its own memory address space?

Address Translation

A process operates in the memory address space distinct from the physical memory space of the machine

- Address translation. Hardware translates a memory address the process operates on to a memory address in the physical memory.
- Shall discuss in detail later ...

Recall Discussion: Kernel and Process

- Policy. The OS should provide efficient and protected access to shared resources.
  - No program can read or write memory of another program or of the OS.
  - Programs can run concurrently to utilize resources efficiently.
- Mechanism. Hardware, OS kernel, and process.
  - Dual mode operating. Processes run in user or kernel mode. Restrict process in user mode from accessing privileged instructions.
  - Address translation. Each process has its isolated logical (or virtual address space), and hardware translates virtual address to physical address.

Outline

Running Multiple Processes?

Consider that two processes run concurrently (in pseudo-parallel) in a single CPU core system ...

- These two processes switch on and off the CPU for many rounds ... how do we create the *illusion* that each has its own CPU?

Two processes are running ...

Consider

- At T_1, Process P_1 is active (on the physical CPU), and Process P_2 is inactive.
- At T_2, Process P_2 is active (on the physical CPU), and Process P_1 is inactive.

Two processes are running ...

How?

1. OS maintains a data structure in memory (its own address space), when the OS runs, it switches P_1 off the CPU and P_2 on the CPU, i.e., it
2. saves registers Program Counter (PC) and Stack Pointer (SP) in the data structure for P_1 in memory
3. loads PC and SP from the data structure for P_2 in memory

Supporting Data Structure: Process Control Block

A process control block (also called task control block or thread control block) is a data structure for information associated with each process including the process's execution context.

- Process state, i.e., running, waiting, etc
- Program counter, i.e., location of instruction to next execute
- Stack pointer, i.e., top of the process stack
- other CPU registers if necessary, i.e., contents of all process-centric registers
- CPU scheduling information, i.e., priorities, scheduling queue pointers
- Memory-management information, i.e., memory allocated to the process
- Accounting information, i.e., CPU used, clock time elapsed since start, time limits
- I/O status information, i.e., I/O devices allocated to process, list of open files

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Queues and Transition

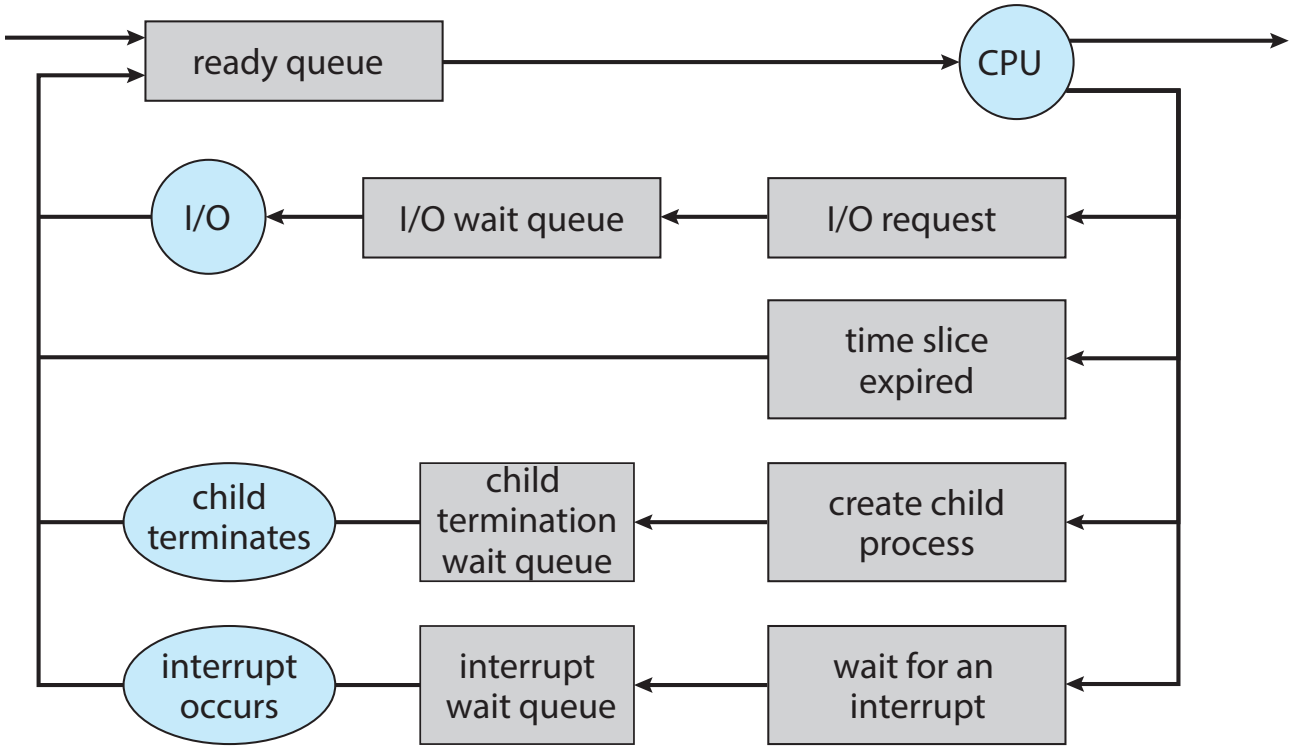

Figure: Process queues and transitions[2].

[2] Abraham Silberschatz, Peter B. Galvin, and Greg Gagne. *Operating system concepts*. 10th edition. John Wiley & Sons, 2018.

Data Structures for Process Queues

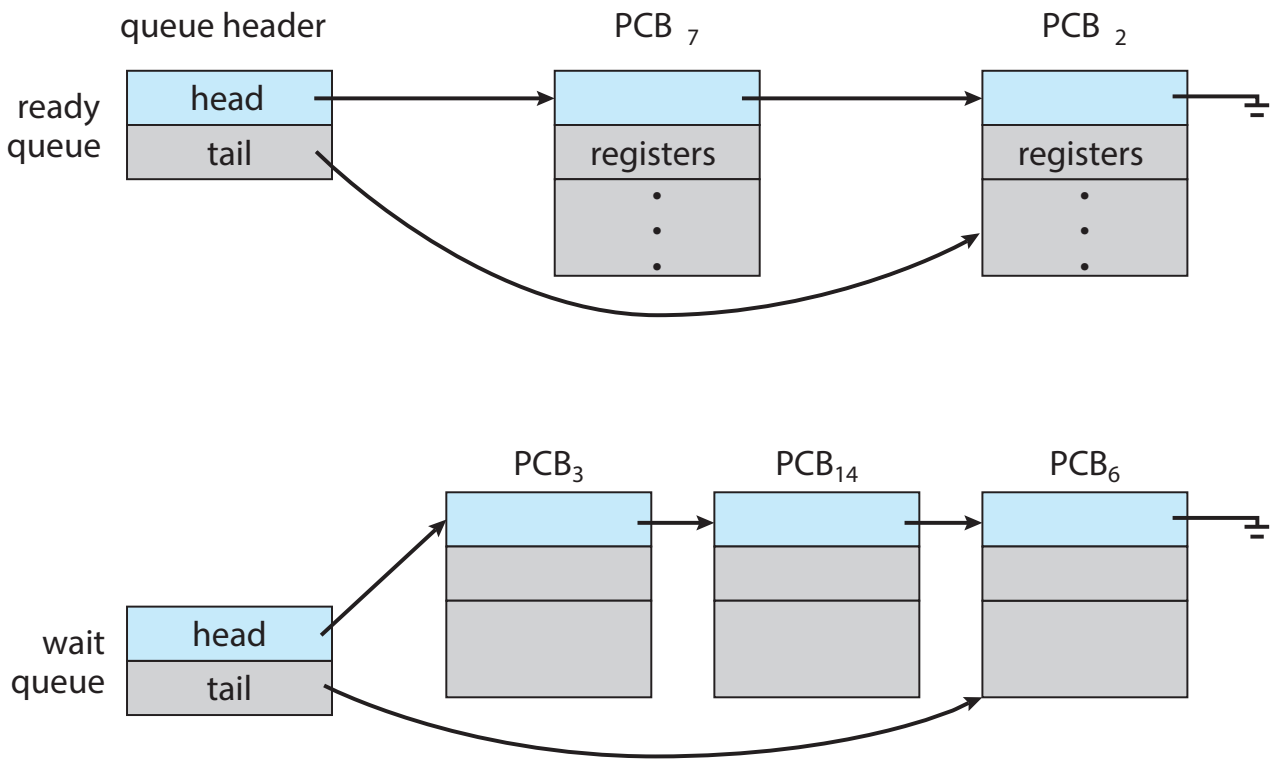

Figure: The *ready* and *wait* queues[3].

[3] Abraham Silberschatz, Peter B. Galvin, and Greg Gagne. *Operating system concepts*. 10th edition. John Wiley & Sons, 2018.

Process States and Transition

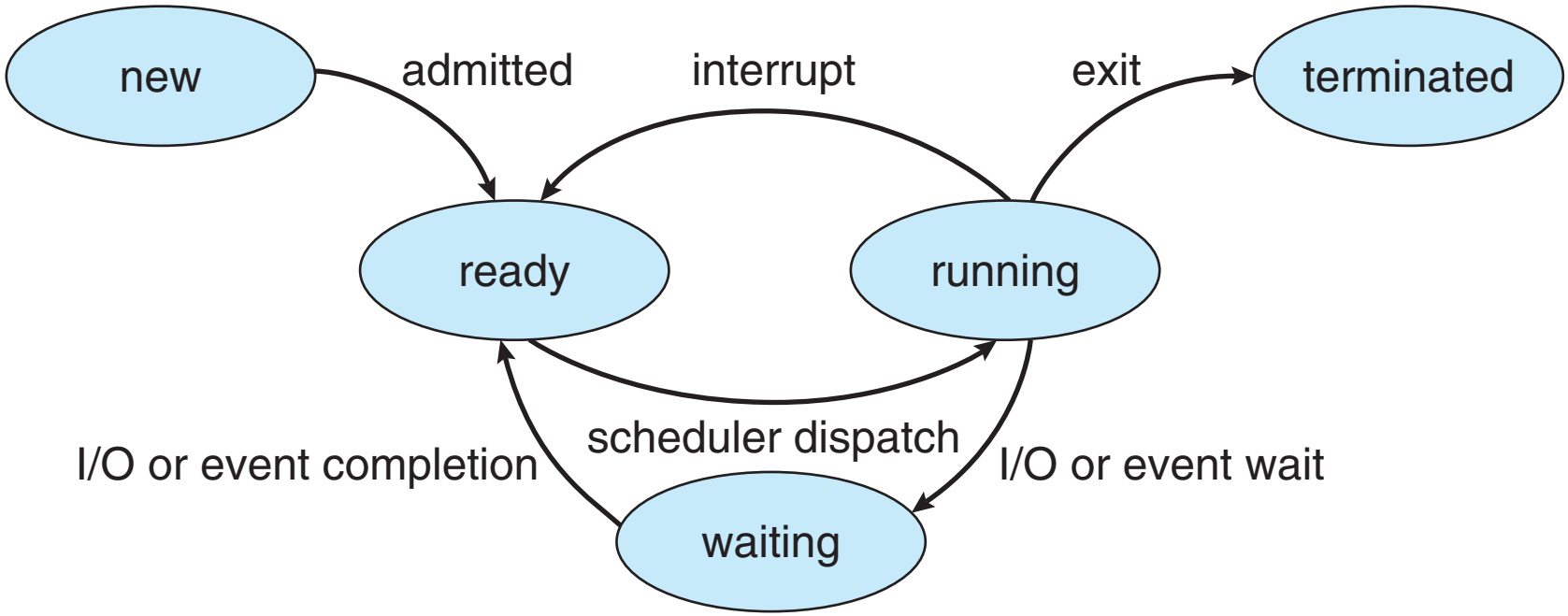

Figure: Process transitions in an OS[4].

[4] Abraham Silberschatz, Peter B. Galvin, and Greg Gagne. *Operating system concepts*. 10th edition. John Wiley & Sons, 2018.

Outline

Multiprogramming and Time-Sharing

- The objective of multiprogramming is to have some process running at all times to maximize CPU utilization.
- The objective of time-sharing is to switch a CPU core among processes so frequently that users can interact with each program while it is running.

Questions. How do we support these objectives?

CPU Scheduler

- The CPU scheduler is to select from among the processes that are in the ready queue and allocate a CPU core to one of them.
- Different CPU scheduling algorithms help OSes meet different objectives.

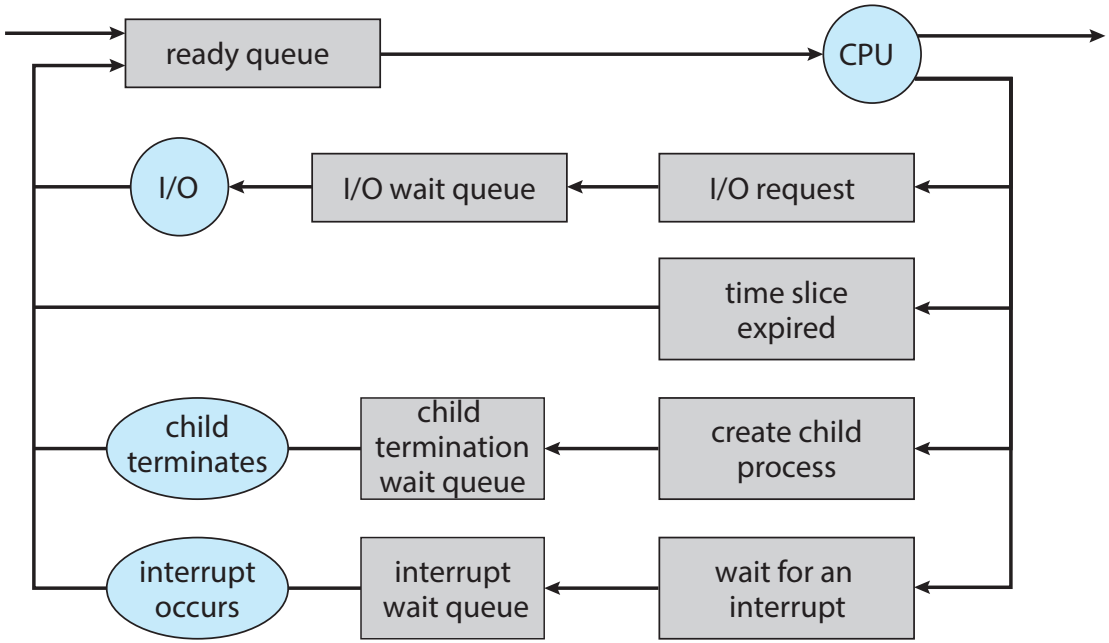

Figure: Process queues and transitions[5].

Outline

Process Operations

- An OS must provide services for,
  - process creation,
  - process termination, and
  - others
- Design considerations and related concepts.

System Calls for Process Operations in UNIX

- Process creation. `fork()`, `exec()`, `wait()` ...
- Process termination. `exit()`, `wait()`, `abort()` ...

Multiprocess Architecture

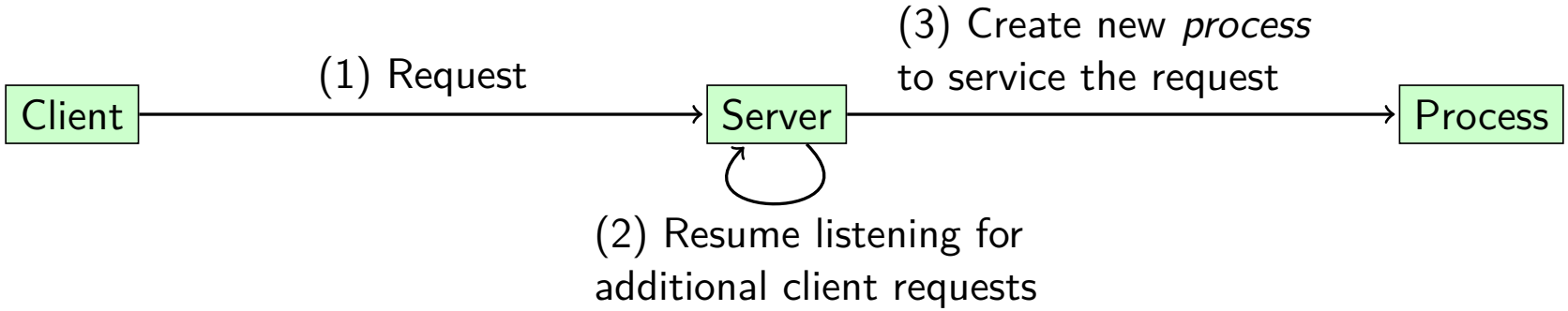

Figure: A multiprocess architecture server program

Design Multiprocess Architecture Programs

Design programs of multiprocess architecture on UNIX ...

- Observe the example programs and consider rationale behind the design ...

Outline

Examining Process States on Linux Systems

- Recall previous discussion ...
  - `ps`, `pstree`, `top`, `vmstat`, `iostat`, `lsof`

  , ...
- The `/proc` file system

  `man proc`

References I


Silberschatz, Abraham, Peter B. Galvin, and Greg Gagne. *Operating system concepts*. 10th edition. John Wiley & Sons, 2018.