Department of Physics,
Computer Science & Engineering

CPSC 410 – Operating Systems I

Chapter 2: Operating System Overview

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Original slides by Dr. Roberto A. Flores

Chapter 2 Topics

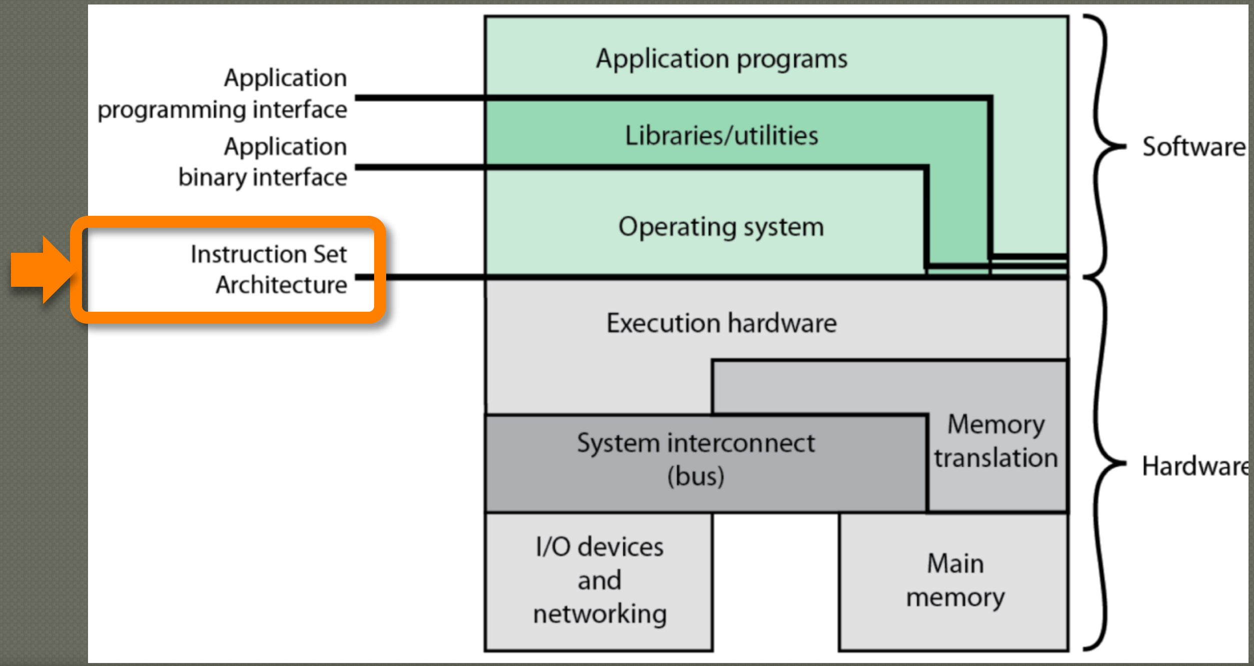
- OS functions
  - Objectives, OS as user/computer interface, OS as resource manager
- OS evolution
  - Serial, Batch, Multi-programming, Time sharing
- Achievements
  - Process, Memory management, Information security, Scheduling, System structure
- Virtual machines
  - Virtualization, Architecture

OS Functions

- Functions
  - User/Computer interface
    - An interface between applications and hardware
  - Resource manager
    - A program controlling execution of application programs
- Objectives
  - Convenience
  - Efficiency
  - Ability to evolve

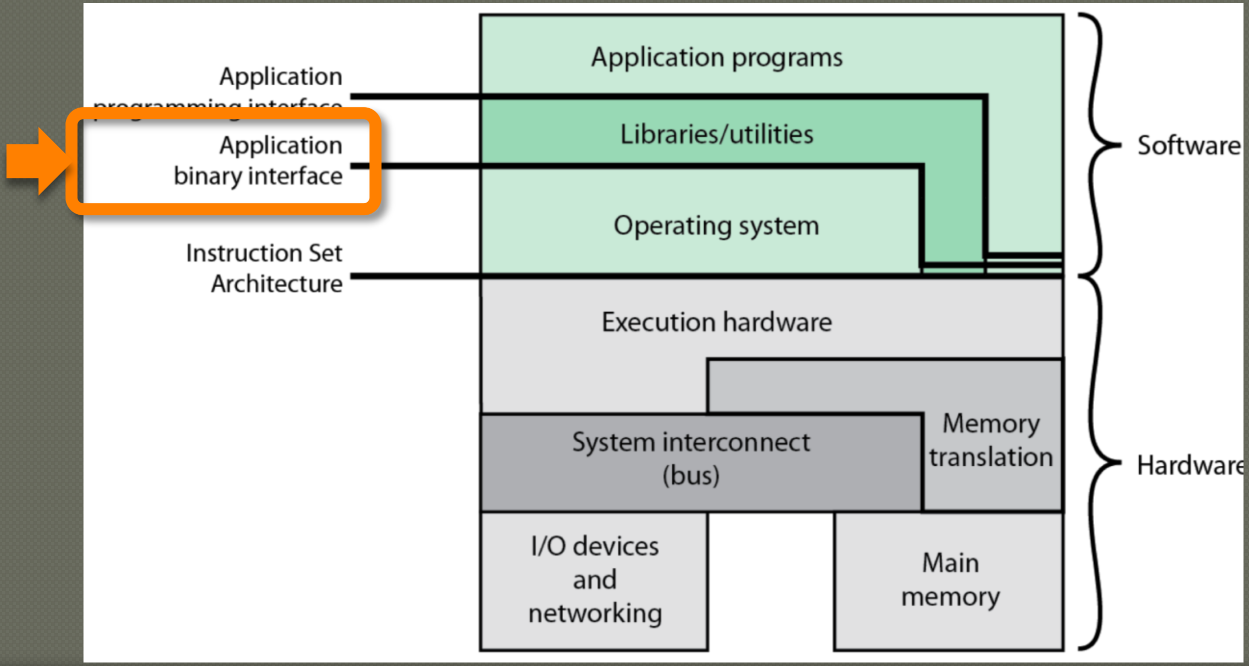
User/Computer Interface

- Key interfaces
  - ISA : Instruction set architecture
    - Machine language instructions hardware can execute
      - add registers, fetch memory, …



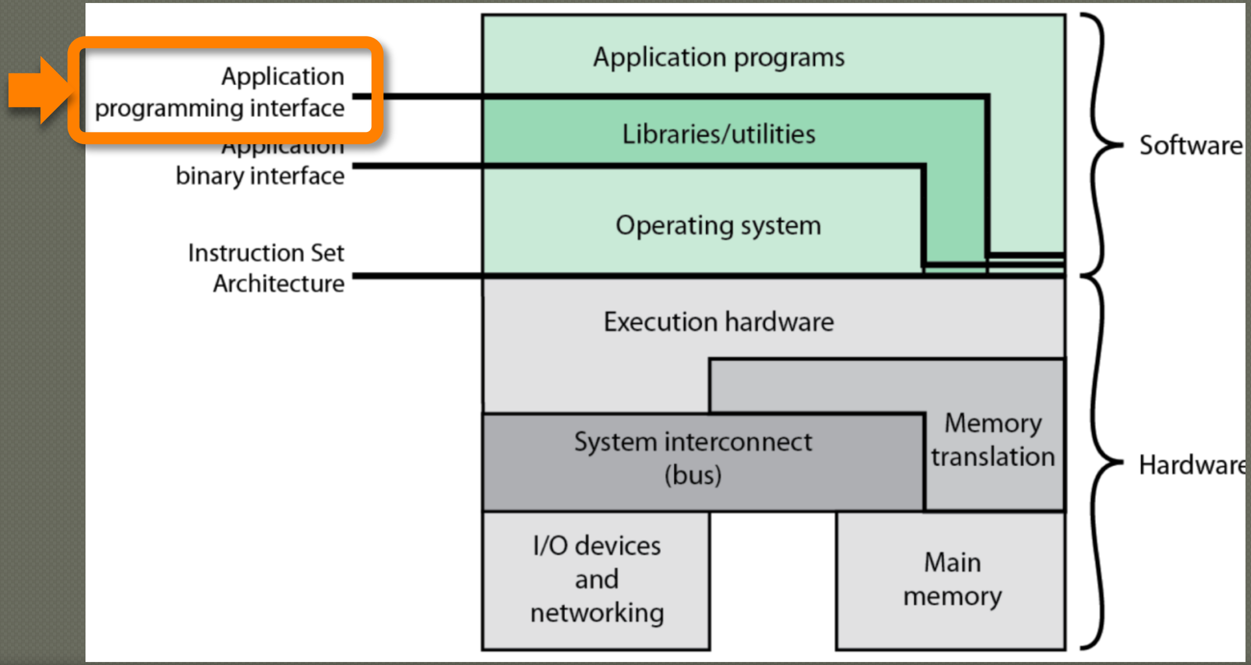
User/Computer Interface

- Key interfaces
  - ABI : Application binary interface
    - Masks hardware details
    - Mediate between programs & computer resources/services



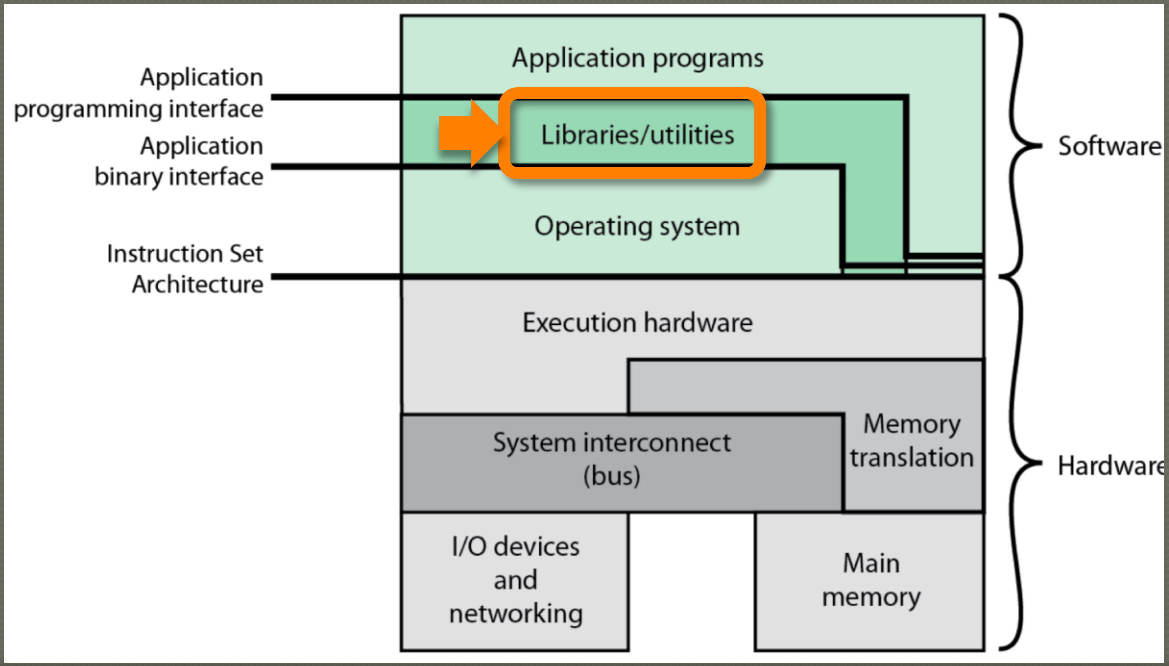
User/Computer Interface

- Key interfaces
  - API : Application programming interface
    - High-level language instructions
    - Facilitates source code portability (re-compilation)



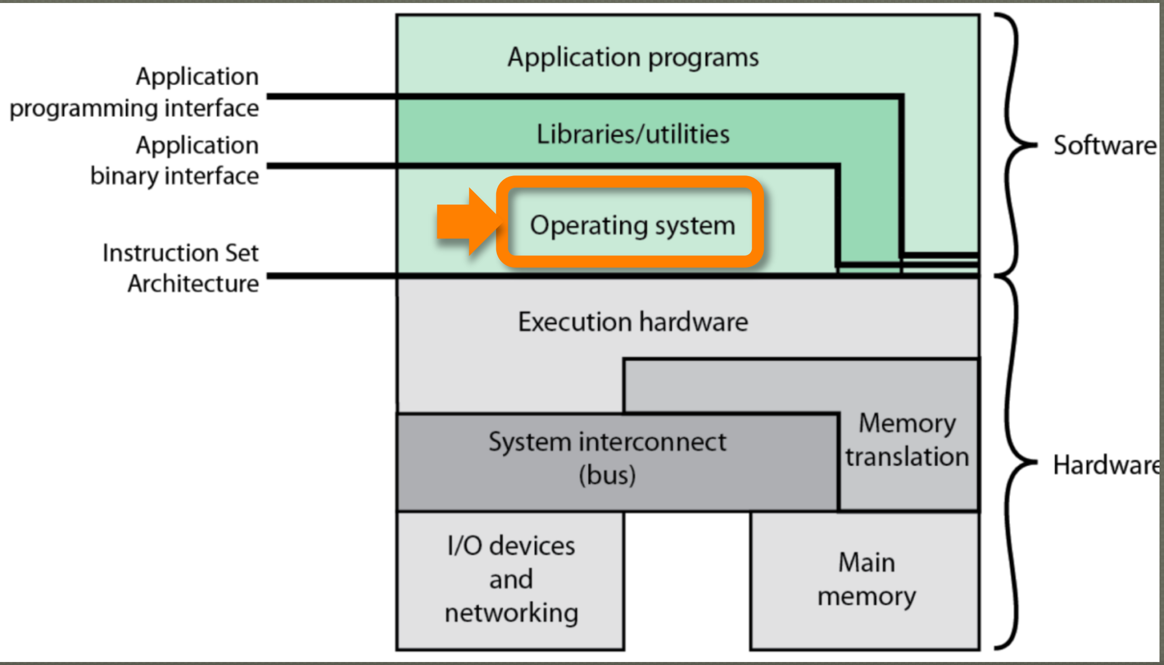
Resource Manager

- OS comes with libraries
  - Implementing functions to support creating programs, managing files, and controlling I/O devices
    - editors, interpreters, I/O modules, …



Resource Manager

- OS
  - Controls hardware resources
  - Manages system services
    - printer spooling, audio, sockets, …



Resource Manager

What is the OS doing for me?

- OS services
  - Program development
    - editors, compilers, debuggers (<u>not OS</u>)
  - Program execution
    - load data & instructions into memory
    - initialize I/O devices & files
  - Access to I/O devices
    - uniform interface to access I/O devices (read, write)
      - Standard API (like read/write) to vendor supplied device drivers
  - Controlled access to files
    - control orderly access to files (<u>data integrity</u>).

Resource Manager

What is the OS doing for me?

- OS services (II)
  - System access
    - control access to resources (permissions)
    - resolve conflicts for resource contention (privileges).
  - Error detection & response
    - minimize disrupting running programs (least disruptive)
      - reporting error, retrying operation, ending erring program
  - Accounting
    - Keeping logs & statistics

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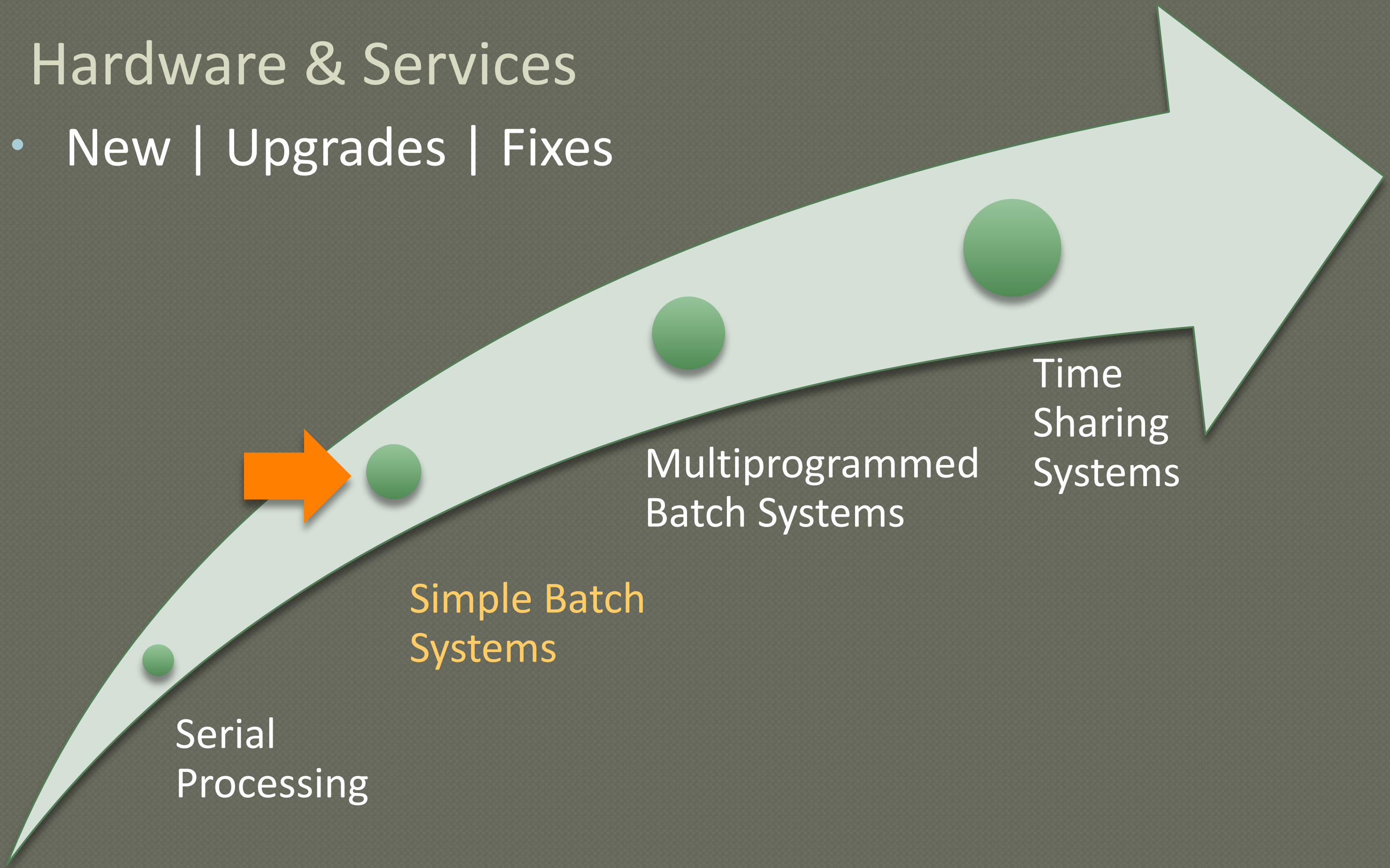
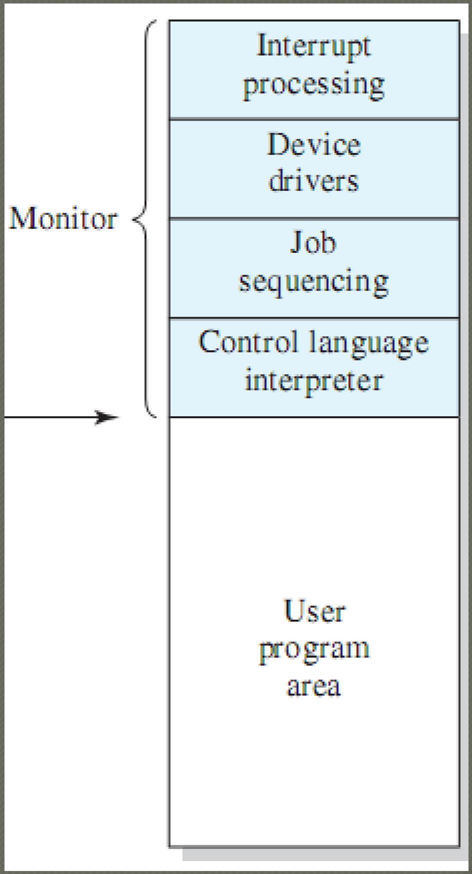
Evolution

- Reasons for OS to evolve
  - Hardware & Services
    - New | Upgrades | Fixes



OS Evolution

- Simple Batch Systems
  - improving computer utilization
    - programmer has no direct access to computer
    - operator batches jobs, feeds them to an input device, then…
  - Monitor (aka Batch OS)
    - program controlling the execution of jobs
    - 1. monitor reads next job & yields control of CPU to the job
      - "control is passed to a job" : CPU starts running user program
    - 2. user program ends & monitor continues running again
      - "control is returned to the monitor" : CPU runs monitor



OS Evolution

- Simple Batch Systems (II)
  - Job Control Language (JCL)
    - Instructions meant for the monitor (like pre-processing)
      - $JOB $FTN <source code> $LOAD $RUN <data> $END
  - Hardware support of Monitor
    - Memory protection
      - Memory where monitor resides is out-of-bounds for jobs
    - Timer
      - Notifies when jobs run longer than anticipated
    - Privileged instructions
      - Instructions that only the monitor can execute (e.g., load job)
    - Interrupts
      - Signals giving CPU a degree of flexibility

OS Evolution

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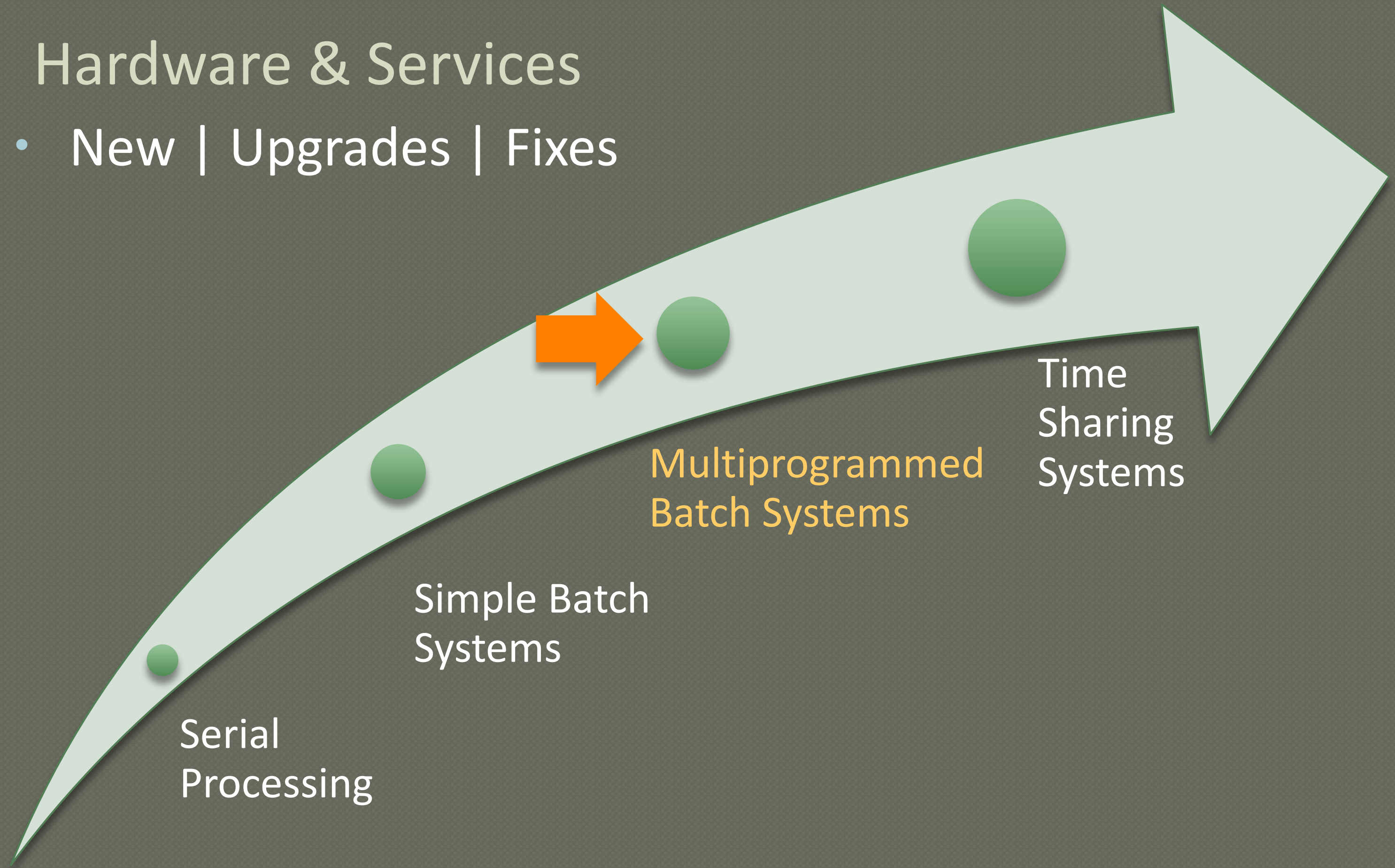
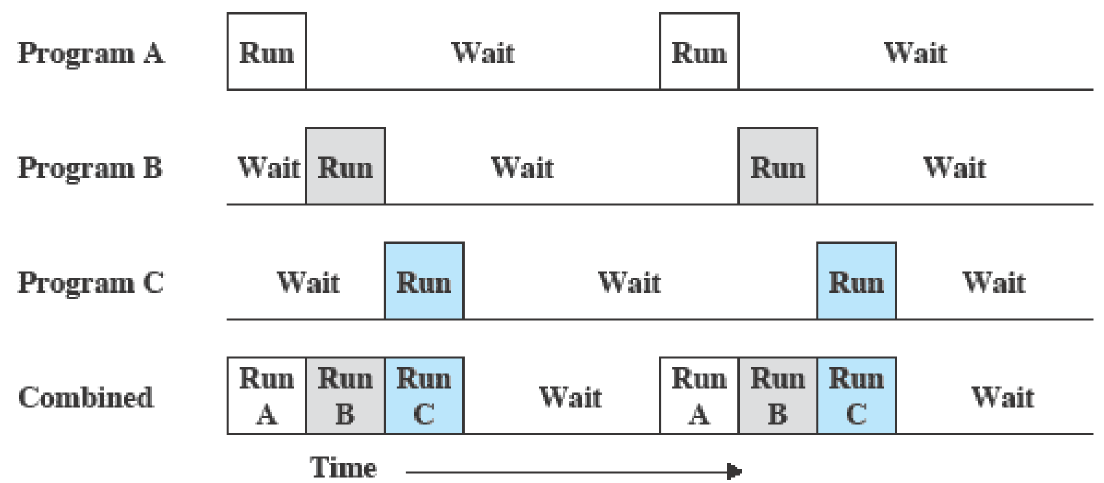
	User Mode	Kernel Mode
Applies to…	User programs	Monitor
Memory access	Restricted	Unrestricted
Instructions	Limited	Unlimited

Evolution

- Reasons for OS to evolve
  - Hardware & Services
    - New | Upgrades | Fixes



Multiprogramming



(c) Multiprogramming with three programs

- Multiprogramming
  - also known as multitasking
  - memory is expanded to hold three, four, or more programs and switch among all of them

Multiprogramming Example

Table 2.1 Sample Program Execution Attributes

	JOB1	JOB2	JOB3
Type of job	Heavy compute	Heavy I/O	Heavy I/O
Duration	5 min	15 min	10 min
Memory required	50 M	100 M	75 M
Need disk?	No	No	Yes
Need terminal?	No	Yes	No
Need printer?	No	No	Yes

Utilization Histograms

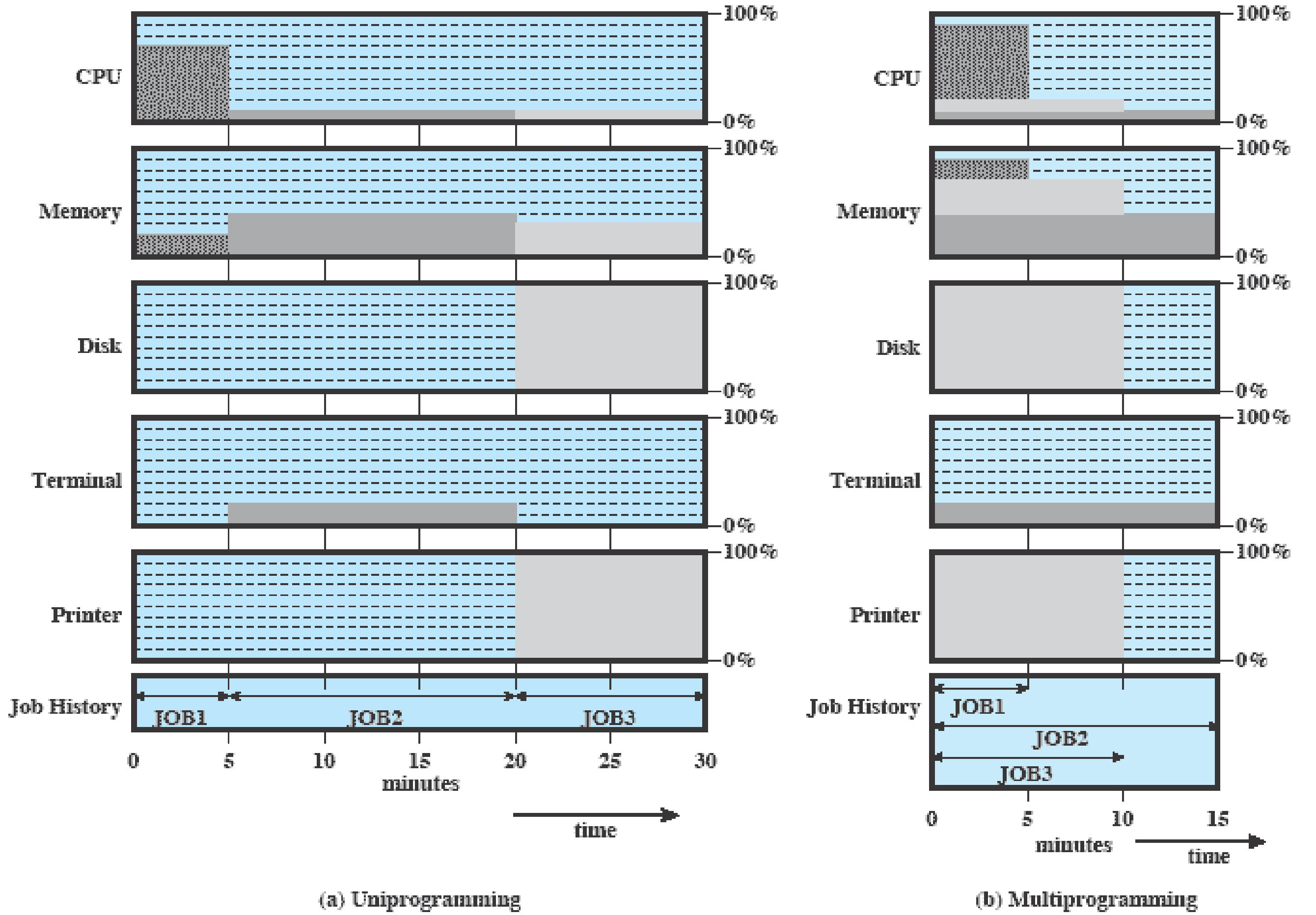


Figure 2.6 Utilization Histograms

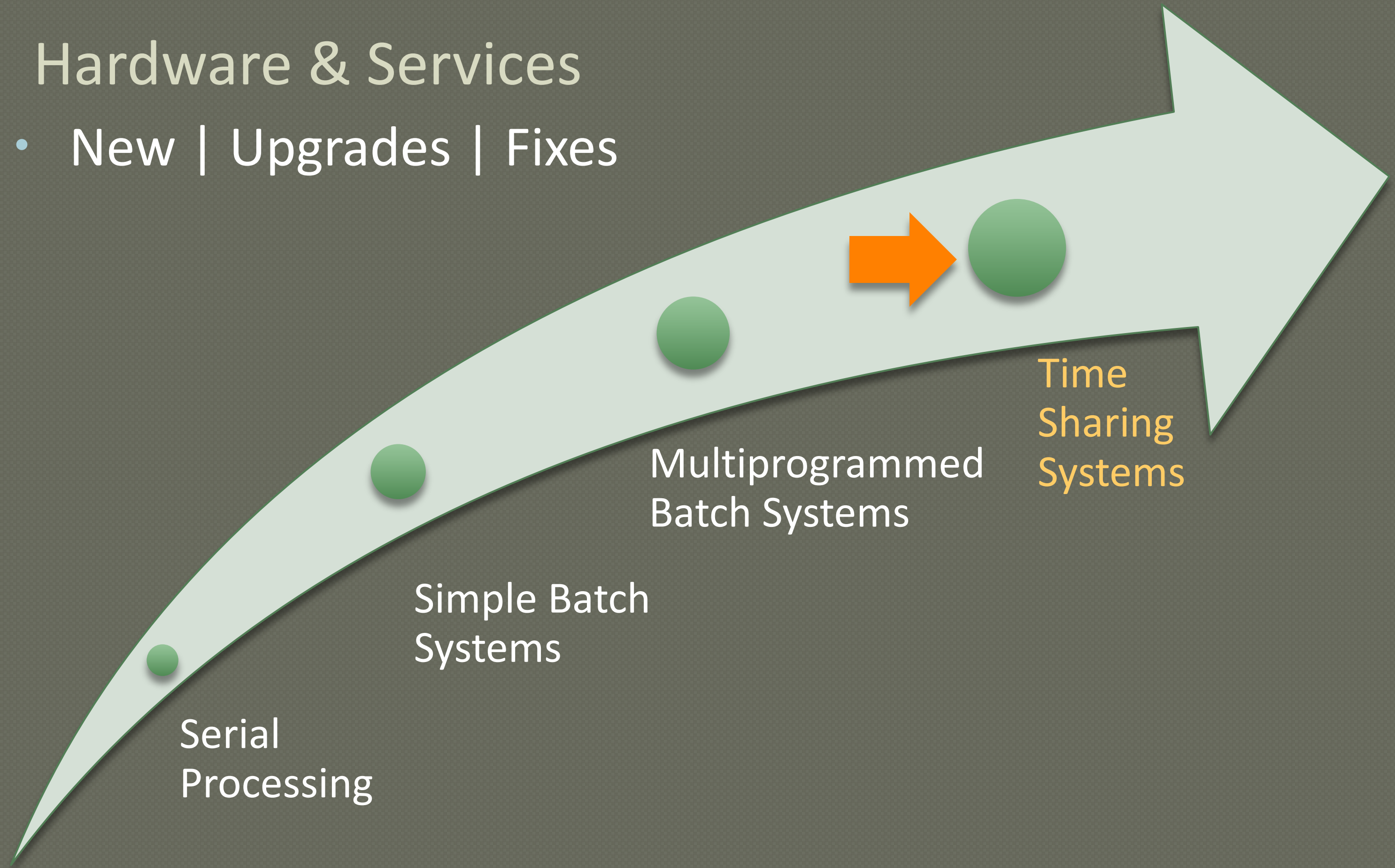
Effects on Resource Utilization

	Uniprogramming	Multiprogramming
Processor use	20%	40%
Memory use	33%	67%
Disk use	33%	67%
Printer use	33%	67%
Elapsed time	30 min	15 min
Throughput	6 jobs/hr	12 jobs/hr
Mean response time	18 min	10 min

Know how to calculate these numbers please

Evolution

- Reasons for OS to evolve
  - Hardware & Services
    - New | Upgrades | Fixes



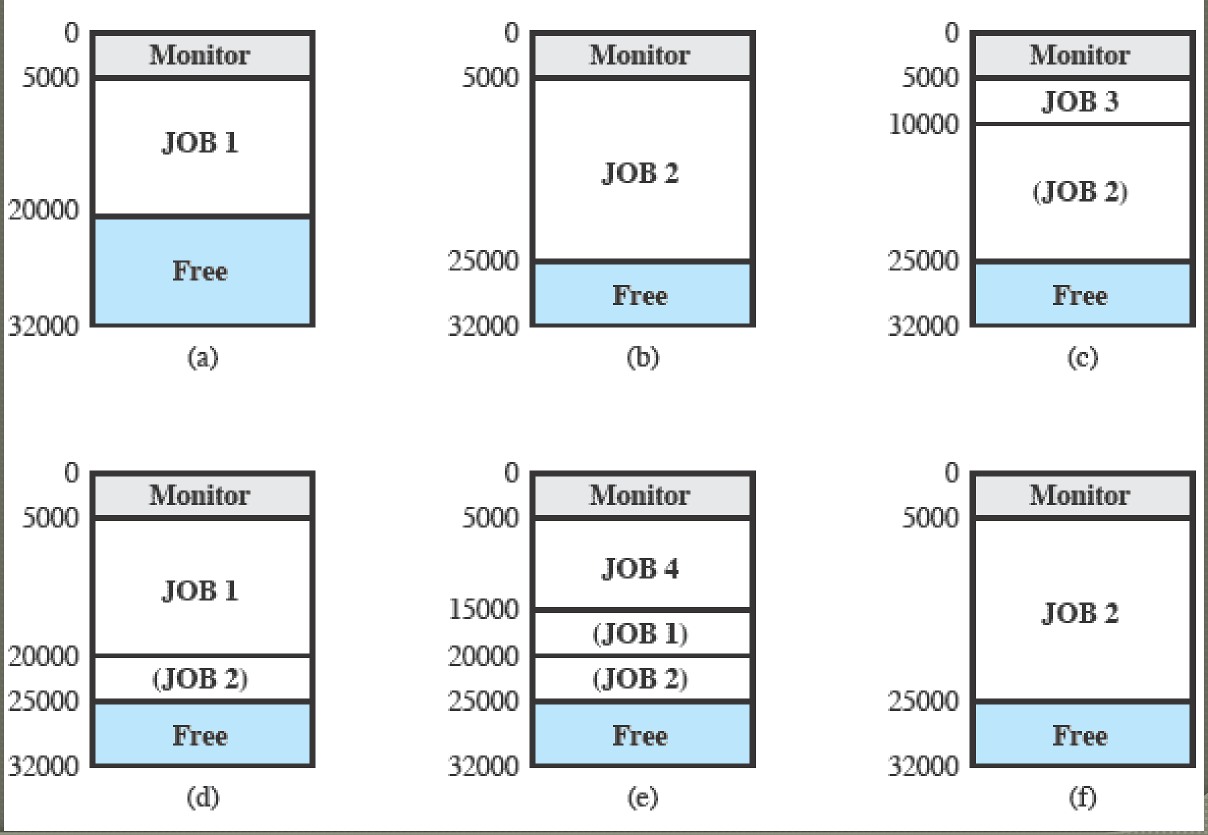
OS Evolution

- Time Sharing Systems
  - Users access system simultaneously using terminals
  - Time Slicing
    - Timer generates interrupts every 0.x seconds (small number)
    - OS preempts current program and loads in another
    - Preempted program & data are stored to disk (in old days)
    - *(but keep an eye on swapping overhead!)*
  - Multi-Programming vs. Time sharing

	Batch Multi-programming	**Time sharing**
Objective	Maximize processor use	Minimize response time
Source of instructions	Job Control Language (JCL)	Commands entered in terminal

OS Evolution

- Time Sharing Systems (II)
  - CTSS: Compatible Time Sharing System
    - MIT (1961)
    - 32 users



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Achievements

- Major advances in OS development
  - Processes
    - Definition, Errors, Components
  - Memory management
    - OS responsibilities, Virtual memory
  - Information protection & security
  - Scheduling & resource management
  - System structure

Process

- Fundamental to the structure of operating systems

A *process* can be defined as:

a program in execution

an instance of a running program

the entity that can be assigned to, and executed on, a processor

a unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources

Development of the Process

- Three major lines of computer system development created problems in timing and synchronization that contributed to the development:

multiprogramming batch operation

- processor is switched among the various programs residing in main memory with a goal of maximum efficiency

time sharing

- be responsive to the individual user but be able to support many users simultaneously

real-time transaction systems

- a number of users are entering queries or updates against a database

Causes of Errors

- **Improper synchronization**
  - a program must wait until the data are available in a buffer
  - improper design of the signaling mechanism can result in loss or duplication

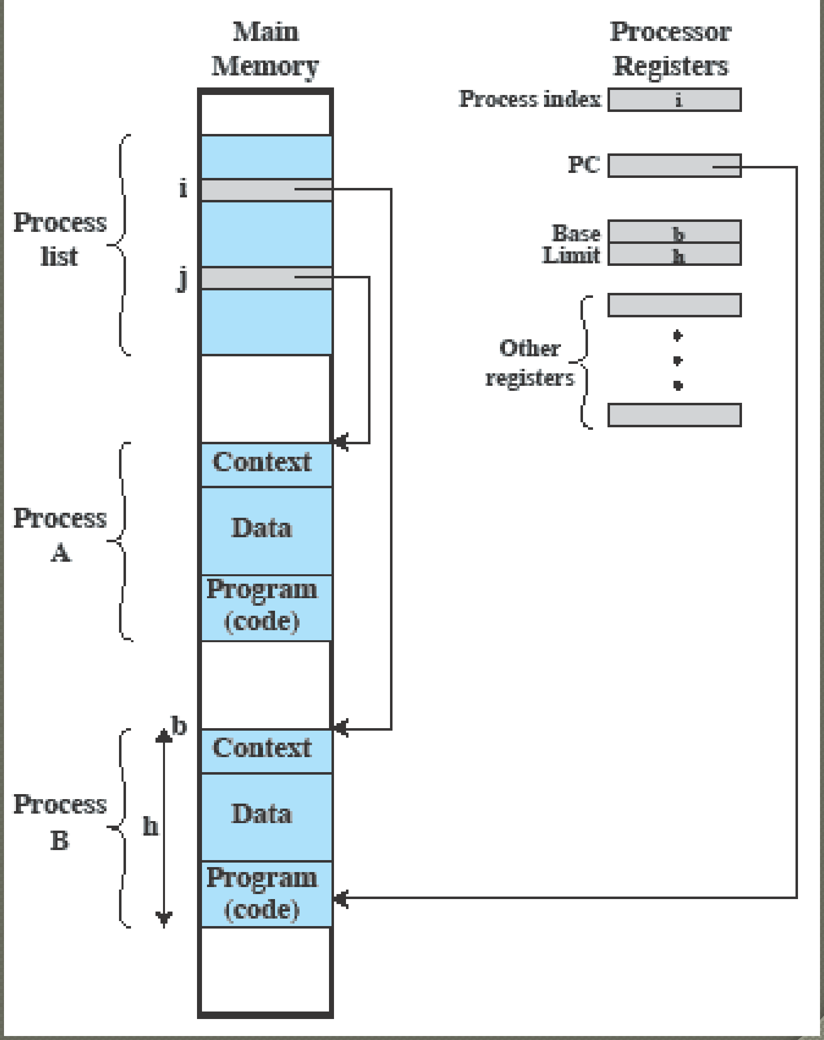
- **Failed mutual exclusion**
  - more than one user or program attempts to make use of a shared resource at the same time

- **Nondeterminate program operation**
  - program execution is interleaved by the processor when memory is shared
  - the order in which programs are scheduled may affect their outcome

- **Deadlocks**
  - it is possible for two or more programs to be hung up waiting for each other
  - may depend on the chance timing of resource allocation and release

Process Management

- Processes (components)
  - Executable code
  - Data
    - e.g., variables, buffers, …
  - Execution context (aka "process state")
    - internal data used by the OS to control the process
      - e.g., registers, priority, whether it is waiting for an I/O event



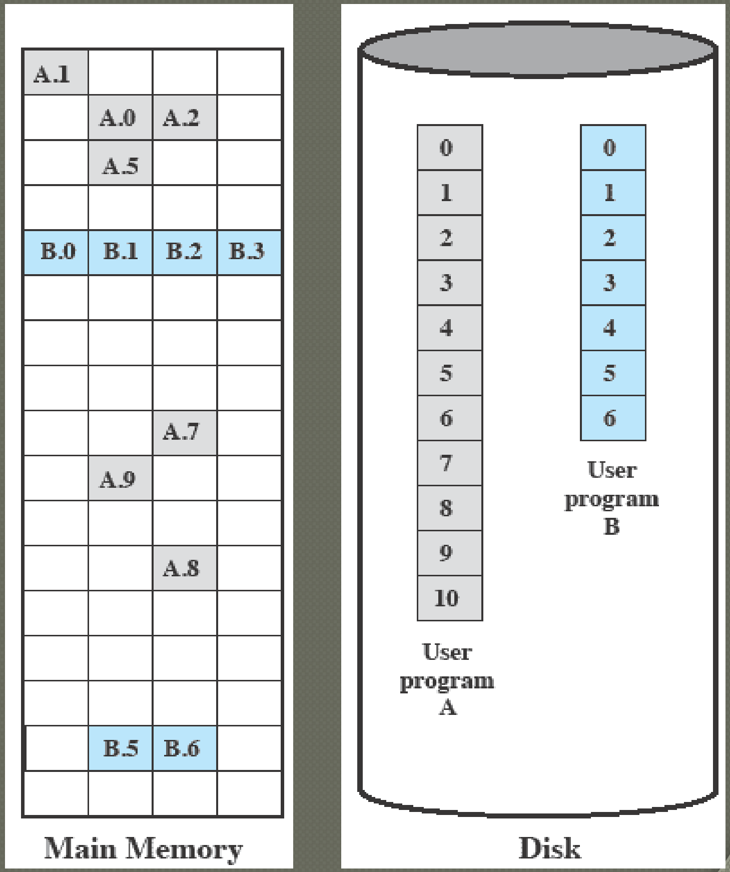
Achievements

- Memory management (OS responsibilities)
  - Process isolation
    - Processes… …are prevented from interfering with each other
  - Automatic allocation & management
    - …are not concerned about their own allocation
  - Support of modular programming
    - …are able to add/remove modules
  - Protection & access control
    - …are assured the integrity of data in shared memory
  - Long-term storage
    - …are able to store data for later runs (including power down)

How to handle simultaneous processes if they do not fit all in main memory?

Achievements

- Memory management (Virtual Memory)
  - Handling many processes with limited memory
  - Paging
    - Processes are broken into blocks (aka pages)
      - Pages can be anywhere in main memory
    - CPU uses virtual addresses to find instructions/data
      - Addresses are page number + offset within page



Virtual Memory Addressing

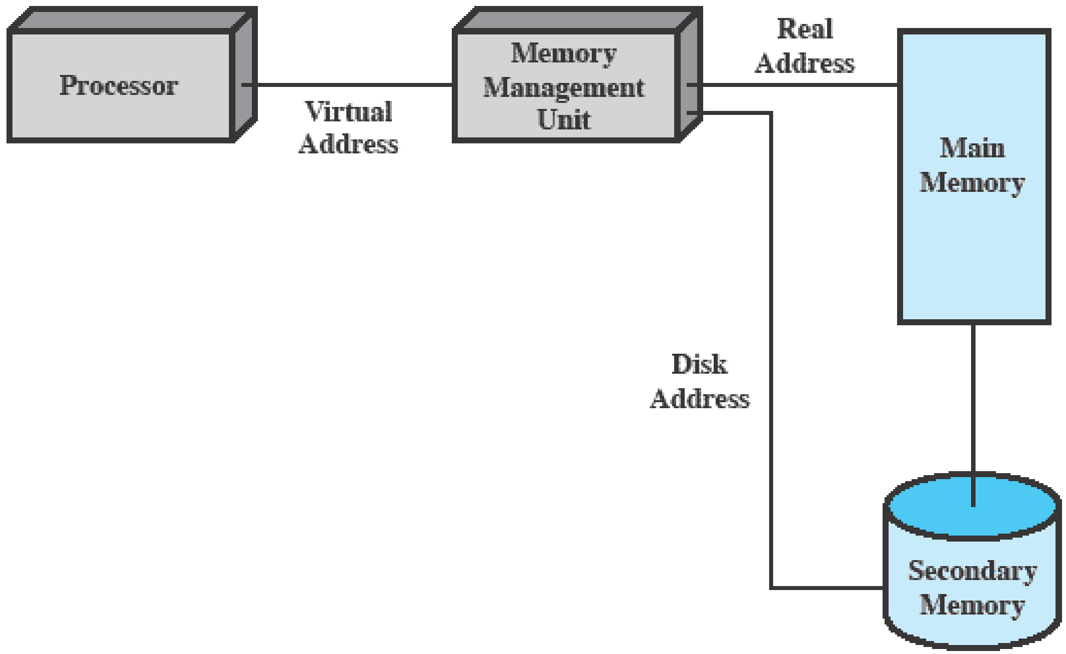
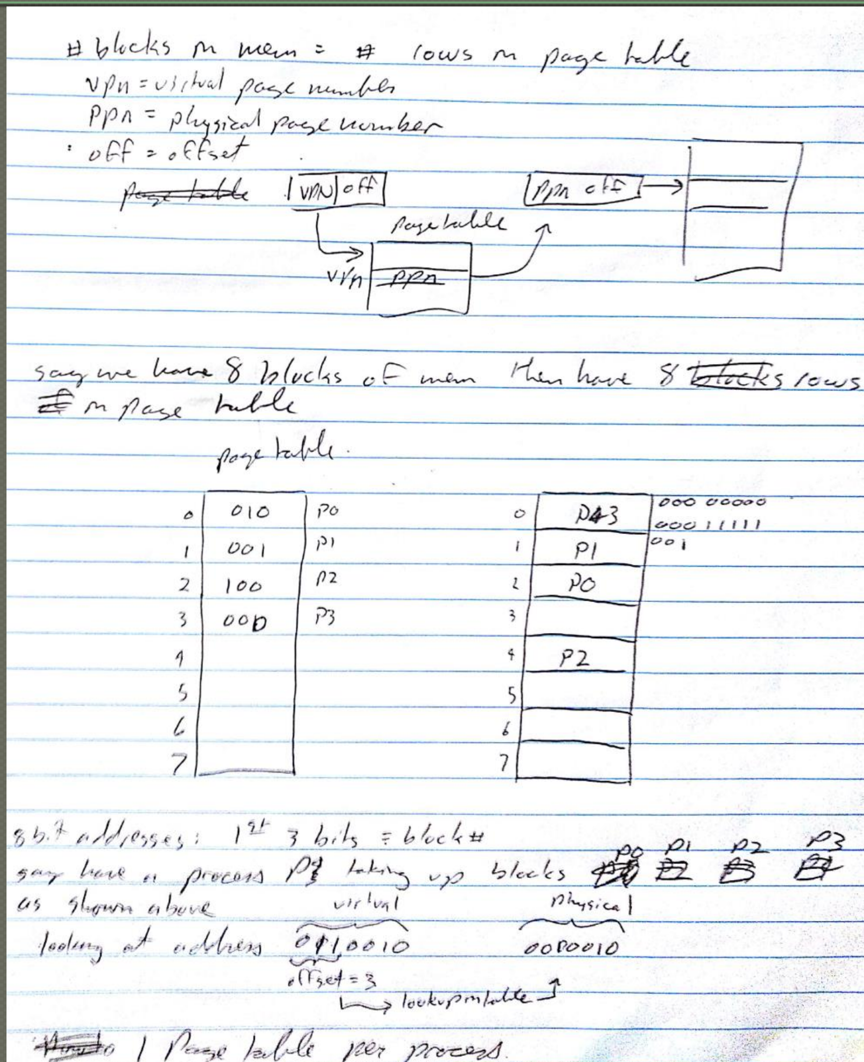


Figure 2.10 Virtual Memory Addressing

Board – Paged memory



Does require 2 memory lookups
1 to the page table and 1 to the real mem

What happens if all slots of page table are Full? Page miss
Just like cache Memory Management Unit (MMU)swaps out stale block of mem for new block of mem

Achievements

- Information protection & security
  - controlling access to processes & data
  - Availability
    - Protection against interruption
  - Confidentiality
    - Protection against unauthorized access
  - Data integrity
    - Protection against unauthorized modification
  - Authenticity
    - Protection against misrepresentation & data validation

Achievements

- Scheduling & resource management
  - OS manages resources (main memory, I/O devices, processors) and schedules their use by processes
  - Fairness
    - Equal processes given equal and fair access to resources.
  - Differential responsiveness
    - Different processes treated differently according to their needs.
  - Efficiency
    - Overall performance is a goal
      - maximize throughput
      - minimize response time
      - accommodate as many users as possible

These criteria conflict (what's the right balance?)

Key Elements of Schedule and Dispatch

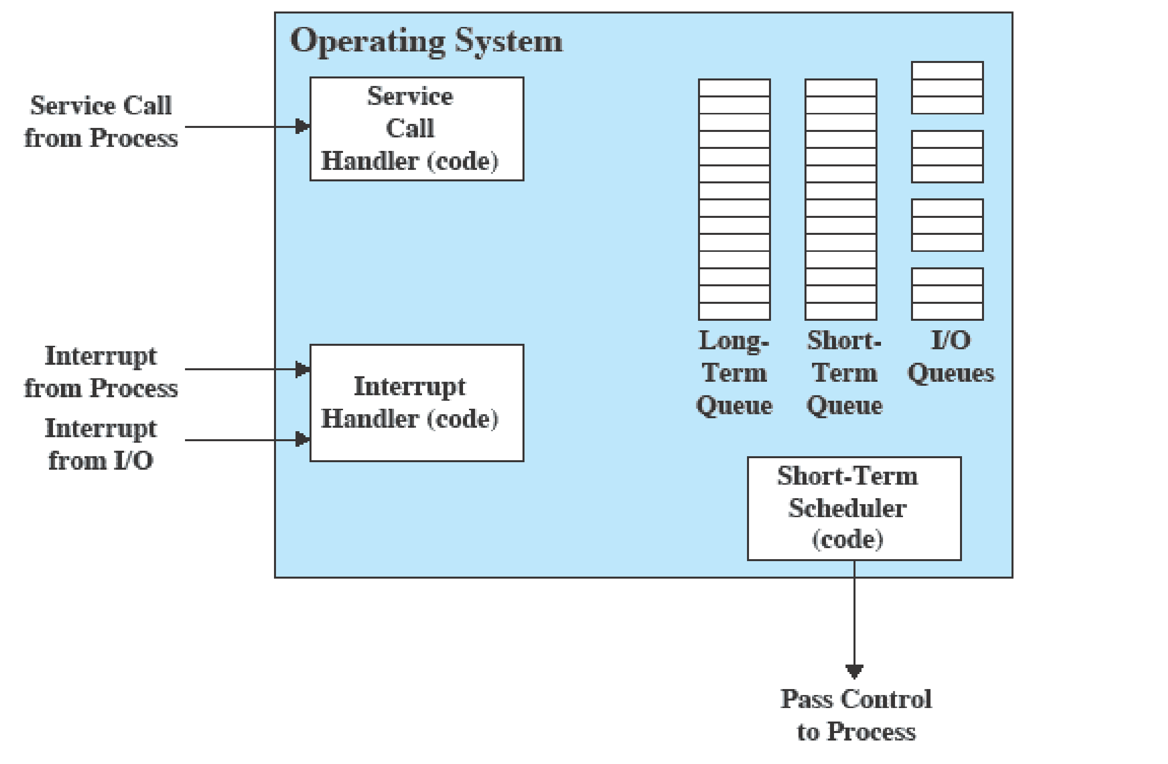


Figure 2.11 Key Elements of an Operating System for Multiprogramming

Achievements

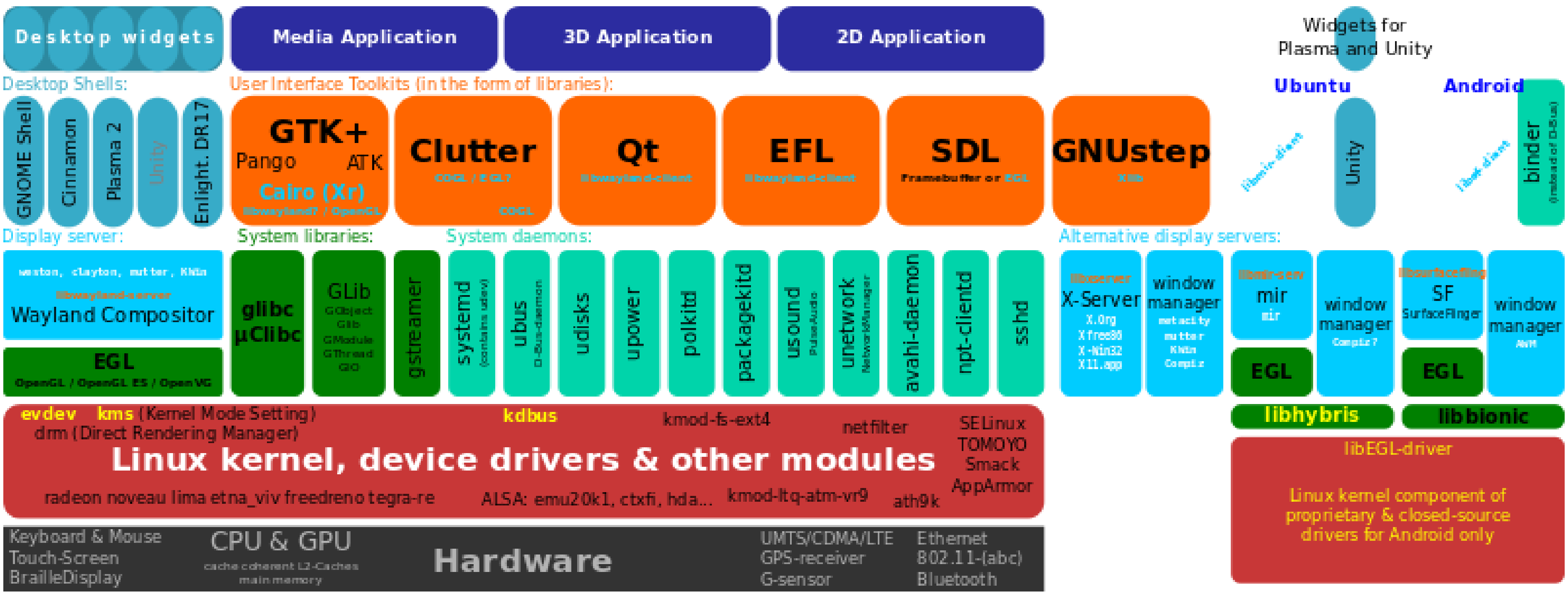
- System structure
  - Up to now
    - OS are monolithic programs
    - processes are linearly executed

What to do about it?

  - Microkernel Architecture
    - Keep essential functions in kernel
      - memory addressing, inter-process communication (IPC), scheduling
    - Modularize the rest (towards object-oriented approach)
      - modules dynamically linked, easier to replace
  - Advantages
    - Flexibility: low coupling/high cohesion (props up distributed OS – illusion of unified memory & resources [in progress])

Achievements

Linux (flavor)



source: wikipedia.org

- Advantages
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Achievements

- System structure
  - Up to now
    - OS are monolithic programs
    - processes are linearly executed
  - What to do about it?
  - Symmetric multiprocessing (add CPUs)
    - 2+ CPU run in parallel (hardware + OS exploiting it)
    - Processes scheduled to separate CPU (but share resources)
  - Multi-threading (divide processes)
    - Process broken into parts that run concurrently (own thread)
    - Process = ∑ (threads = concurrent unit of work)
    - Programmers control scope & timing of concurrency

Multiprogramming

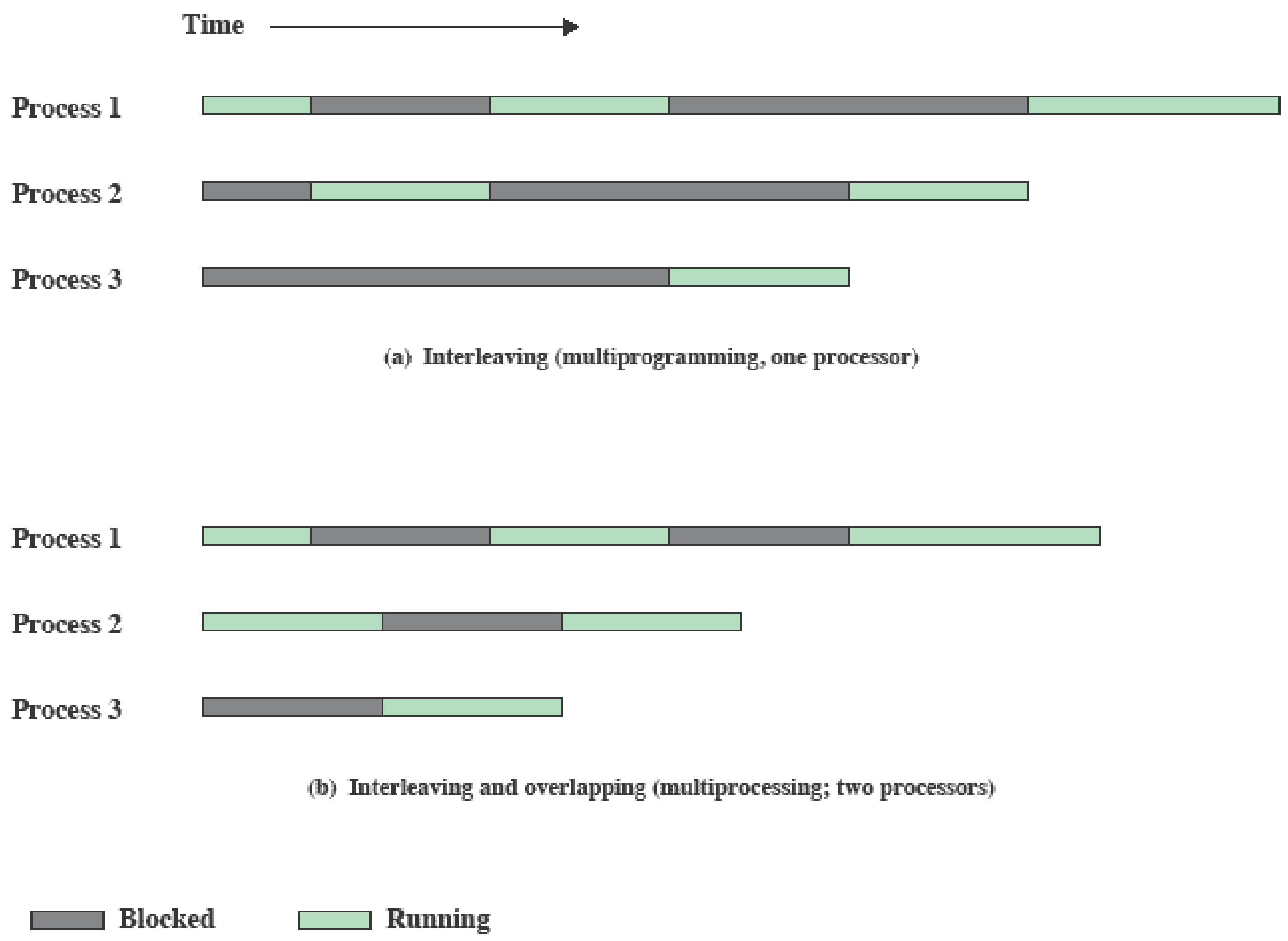

Figure 2.12 Multiprogramming and Multiprocessing

Symmetric multiprocessing

Challenges

- Kernel concurrency: Kernel processes allow concurrent CPU access (state integrity)
- Scheduling: Scheduling across CPUs must be coordinated (avoid duplicated runs)
- Synchronization: Access to resources must be synchronized (use locks)
- Memory management: Page reuse (coordinating page replacements)
- Fault tolerance: Graceful degradation

Parallelism opportunities

- Multiprogramming & multi-threading in each processor
- A process could have its threads executed in different CPUs

- Processes scheduled to separate CPU (but share resources)
- Multi-threading (divide processes)
  - Process broken into parts that run concurrently (own thread)
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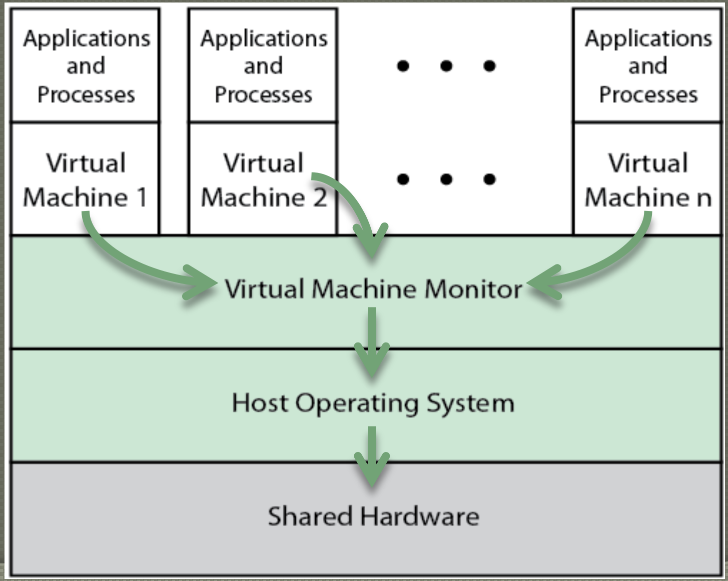
Virtual Machines

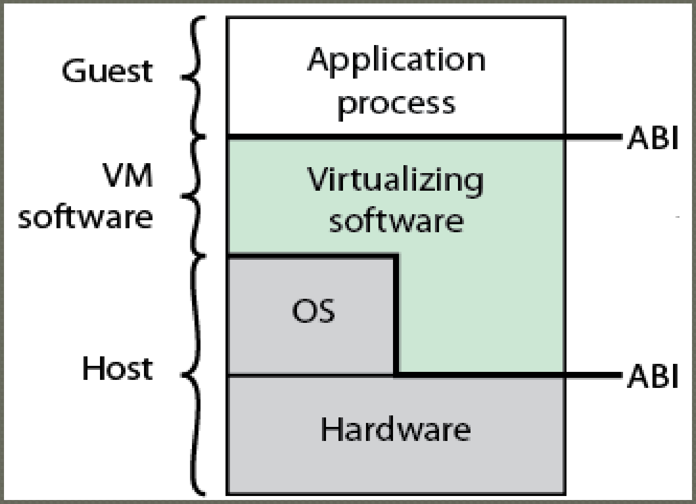
- Virtualization
  - [applies to OS | hardware]
  - when a computer runs (simultaneously or not) 2+ OS (different OS or different sessions of the same OS)
  - OS can run 1+ virtual machines (VM)
    - Software implementing a particular OS or hardware
  - Virtual Machine Monitor (VMM) (aka hypervisor)
    - Typical structure



Virtual Machines

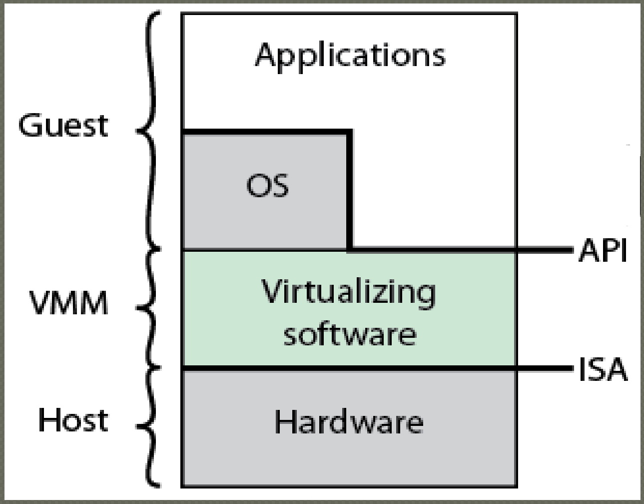
Process VM

- Each VM runs 1 process only
  - Process + VM start/stop as one
  - Portability through VM ABI
  - e.g., Java VM, MS .NET



System VM

- Each VM runs 1+ processes
  - VM Monitor controls 1+ OS
  - Portability through VM API
  - Hosted VM: host has an OS
    - e.g., VMWare



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Done!