Operating Systems
CS220

Lecture 4

OS Structures

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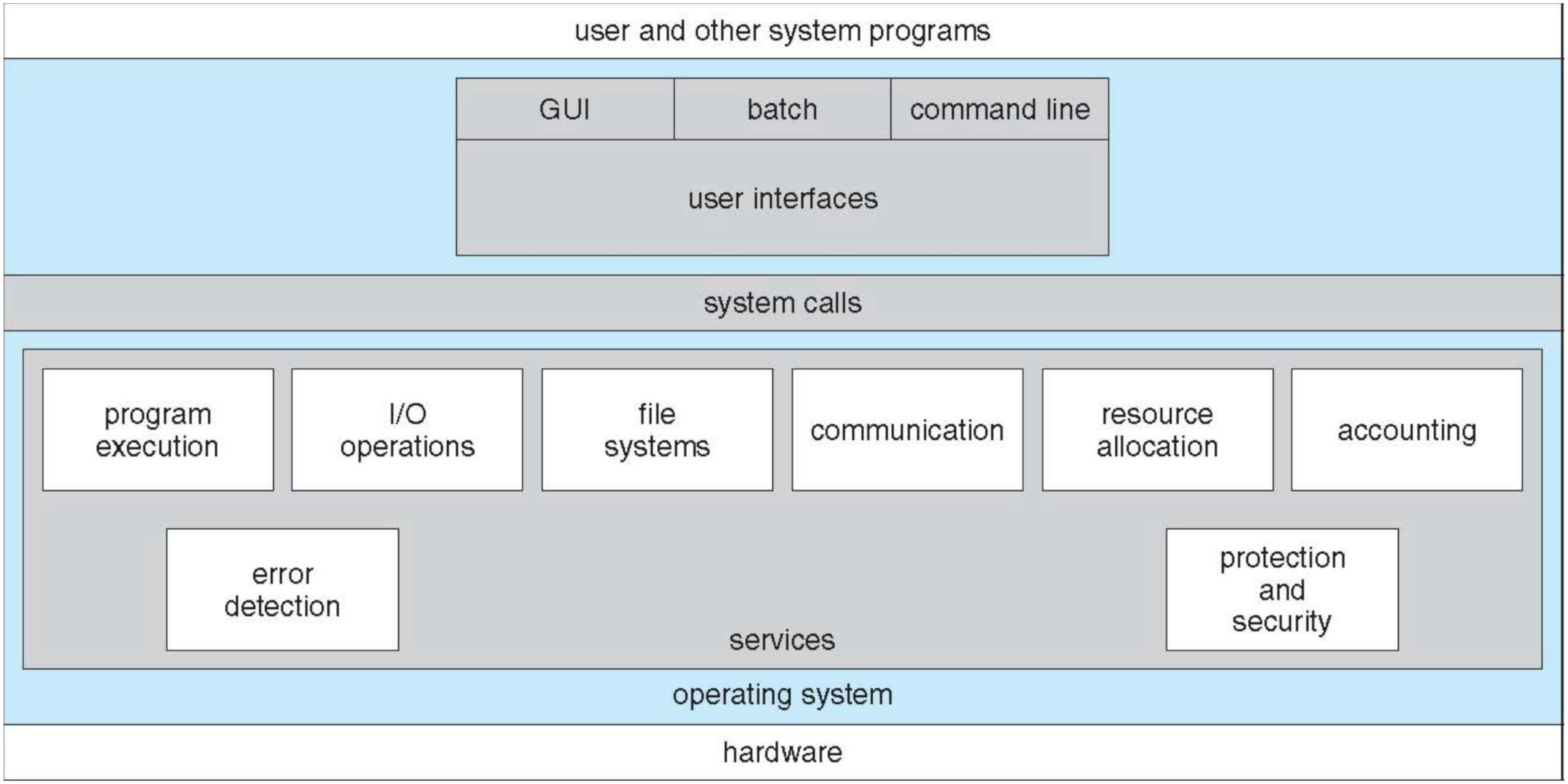
A View of Operating System Services



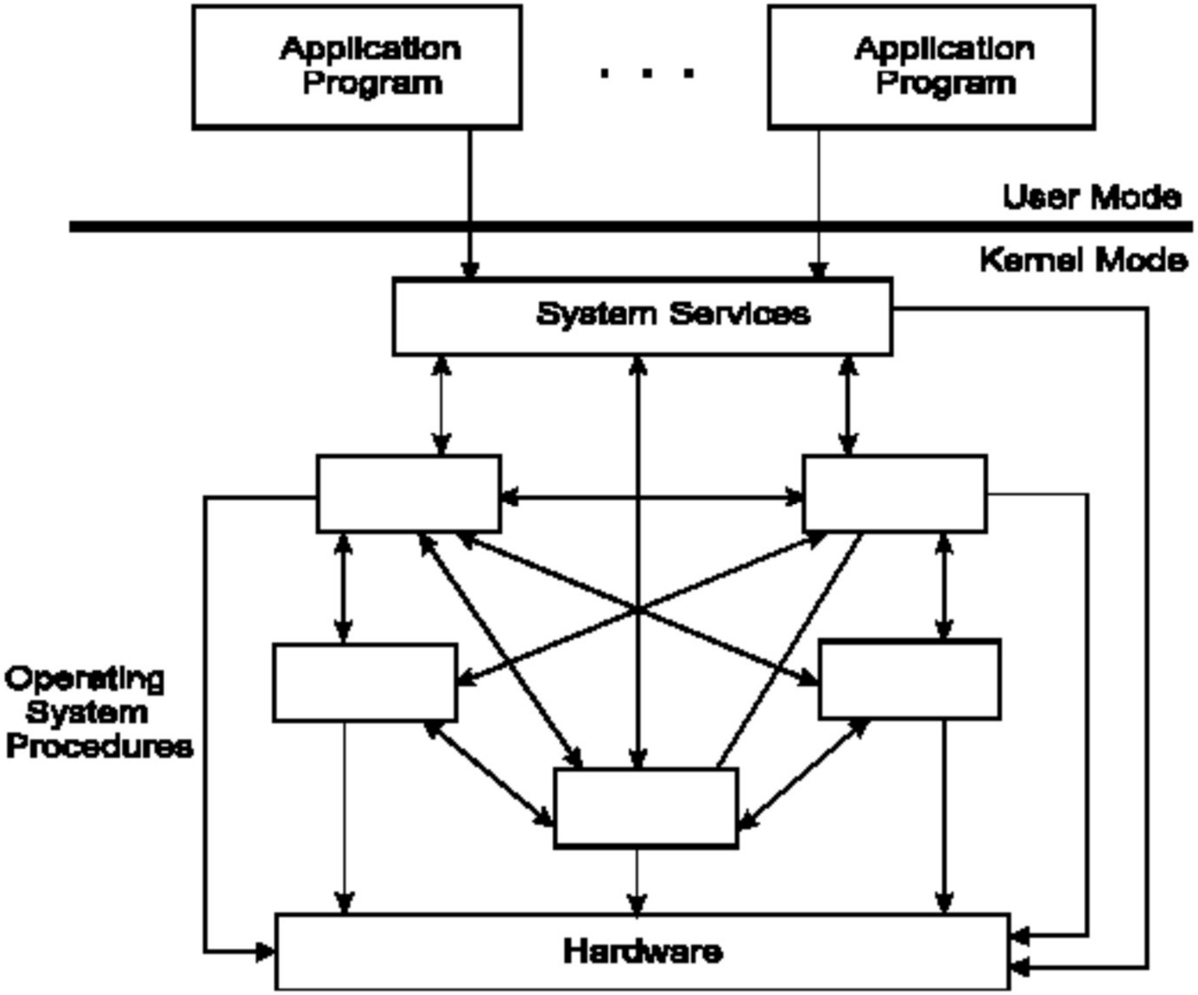
Operating System Design and Implementation

- Affected by choice of hardware, type of system
- *User* goals and *System* goals
  - ***User goals*** – operating system should be convenient to use, easy to learn, reliable, safe, secure, and fast
  - ***System goals*** – operating system should be easy to design, implement, and maintain, as well as flexible, reliable, error free, secure, and efficient
- **Important principle is separation**
  - ***Policy***: What will be done?
  - ***Mechanism***: How to do it?
  - The separation of policy from mechanism is a very important principle, it allows maximum ***flexibility*** if policy decisions are to be changed later

Operating Systems Structures

- Structure/Organization/Layout of OSs:
  - Monolithic (one unstructured program)
  - Layered
  - Microkernel
  - Virtual Machines
- The role of Virtualization

1. Monolithic Operating System

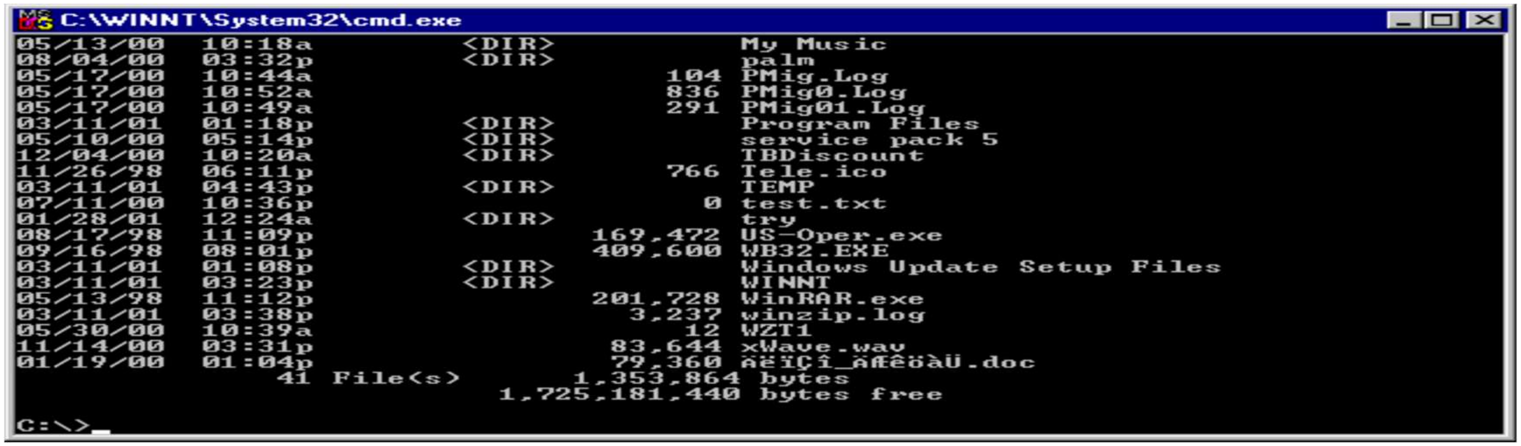


Monolithic OS – Basic Structure

- Application programs that invoke the requested system services.
- A set of system services that carry out the operating system procedures/calls.
- A set of utility procedures that help the system services.

MS-DOS System Structure

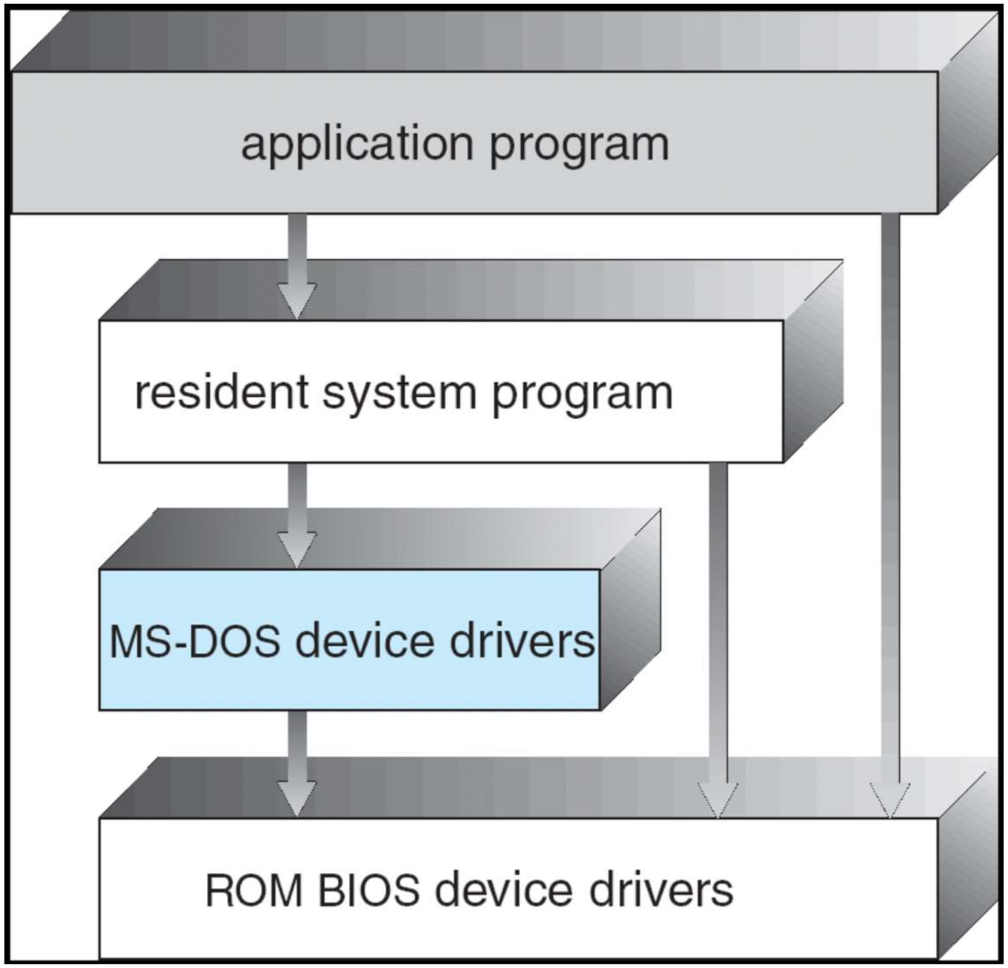
- MS-DOS – written to provide functionality in the least space:
  - not divided into modules (monolithic).
  - Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated.



```
05/13/00   10:18a        <DIR>          My Music
08/04/00   03:32p        <DIR>          palm
05/17/00   10:44a                   104 PMig.Log
05/17/00   10:52a                   836 PMig0.Log
05/17/00   10:49a                   291 PMig01.Log
03/11/01   01:18p        <DIR>          Program Files
05/10/00   05:14p        <DIR>          service pack 5
12/04/00   10:20a        <DIR>          TBDiscount
11/26/98   06:11p                   766 Tele.ico
03/11/01   04:43p        <DIR>          TEMP
07/11/00   10:36p                     0 test.txt
01/28/01   12:24a        <DIR>          try
08/17/98   11:09p               169,472 US-Oper.exe
09/16/98   08:01p               409,600 WB32.EXE
03/11/01   01:08p        <DIR>          Windows Update Setup Files
03/11/01   03:23p        <DIR>          WINNT
05/13/98   11:12p               201,728 WinRAR.exe
03/11/01   03:38p                 3,237 winzip.log
05/30/00   10:39a                    12 WZT1
11/14/00   03:31p                83,644 xWave.wav
01/19/00   01:04p                79,360 ãëïÇî_ãÆêöàÜ.doc
              41 File(s)      1,353,864 bytes
                          1,725,181,440 bytes free

C:\>_
```

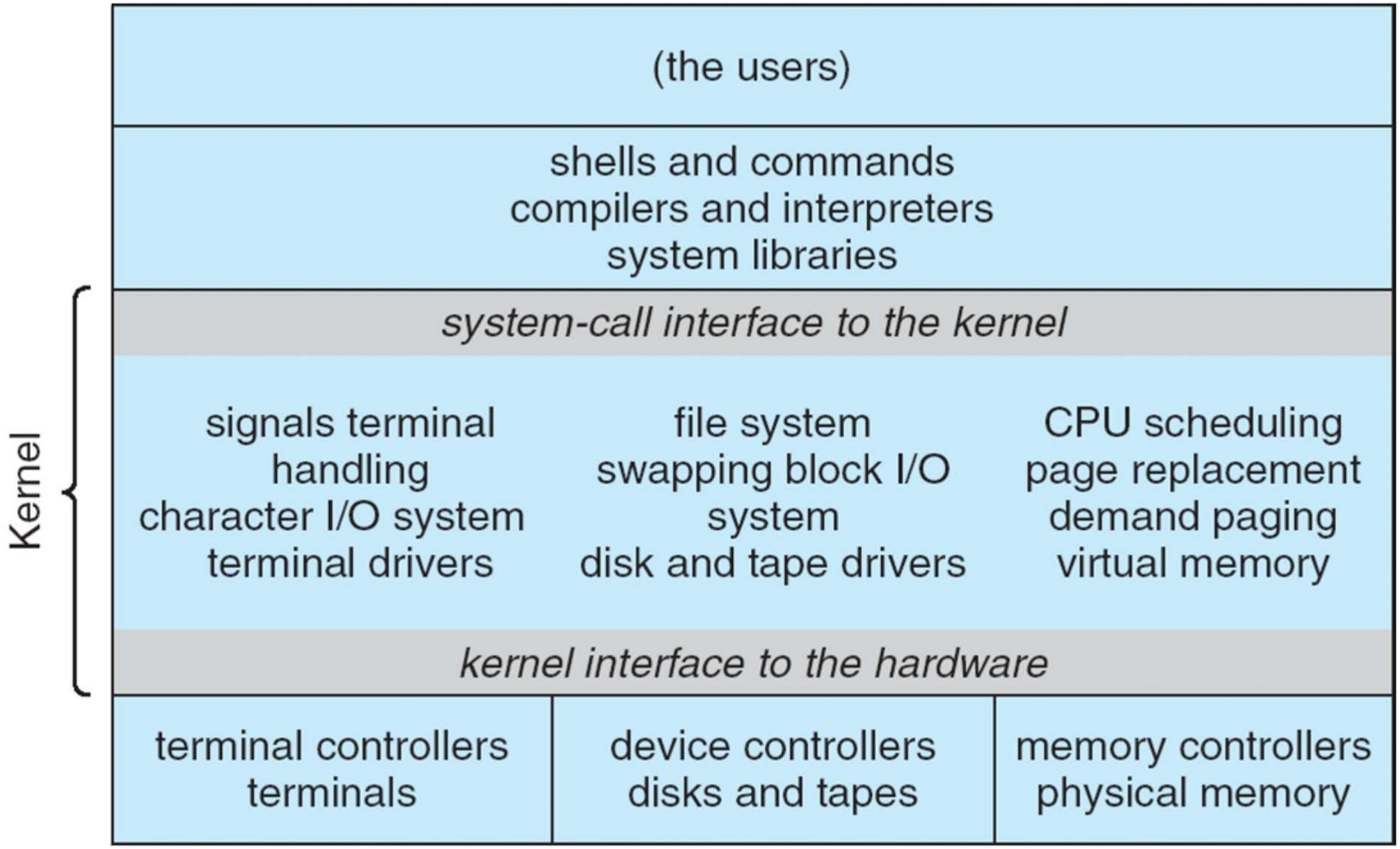
MS-DOS Layer Structure



UNIX System Structure

- UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts
- **The kernel**
  - Consists of everything below the system-call interface and above the physical hardware
  - Provides the file system, CPU scheduling, memory management, and other operating-system functions; a large number of functions for one level
- **Systems programs**

Traditional UNIX System Structure



(the users)

shells and commands
compilers and interpreters
system libraries

system-call interface to the kernel

signals terminal handling
character I/O system
terminal drivers

file system
swapping block I/O system
disk and tape drivers

CPU scheduling
page replacement
demand paging
virtual memory

kernel interface to the hardware

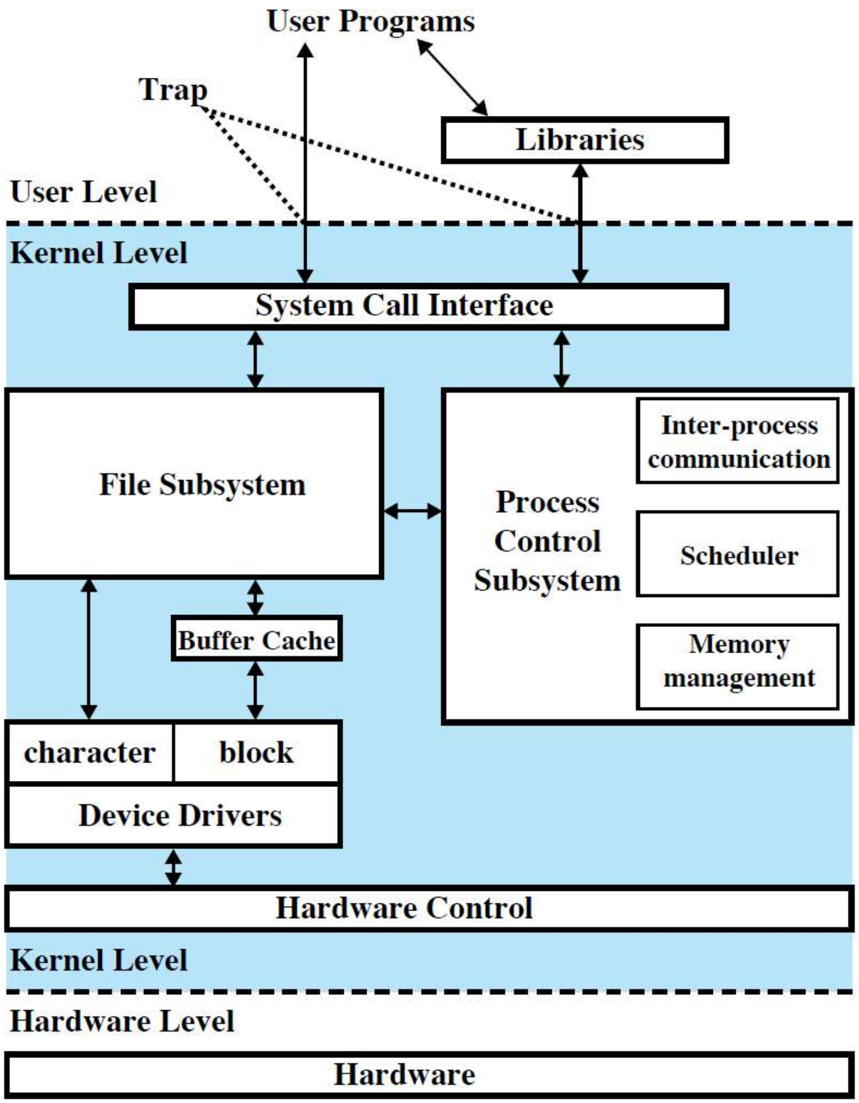
terminal controllers
terminals

device controllers
disks and tapes

memory controllers
physical memory

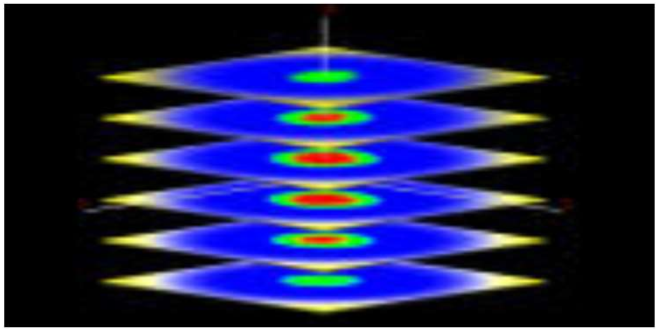
Kernel

Traditional UNIX Kernel [Bach86]

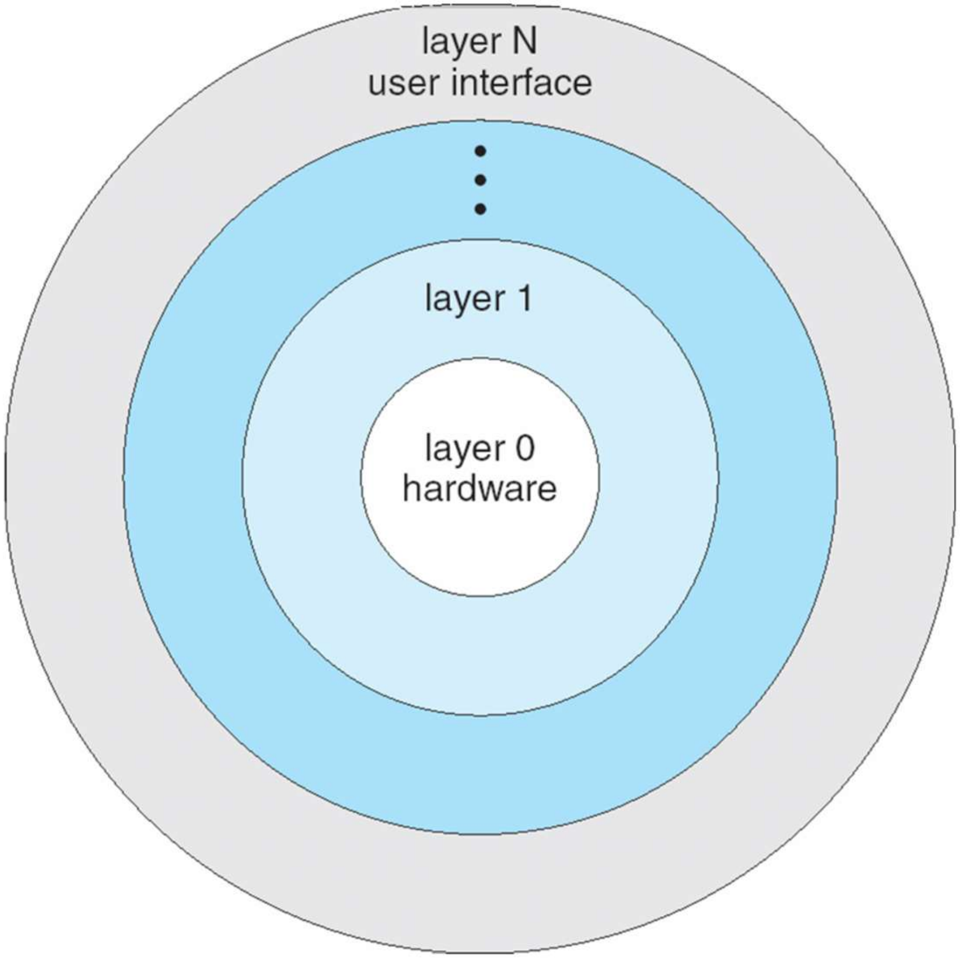


2. Layered Approach

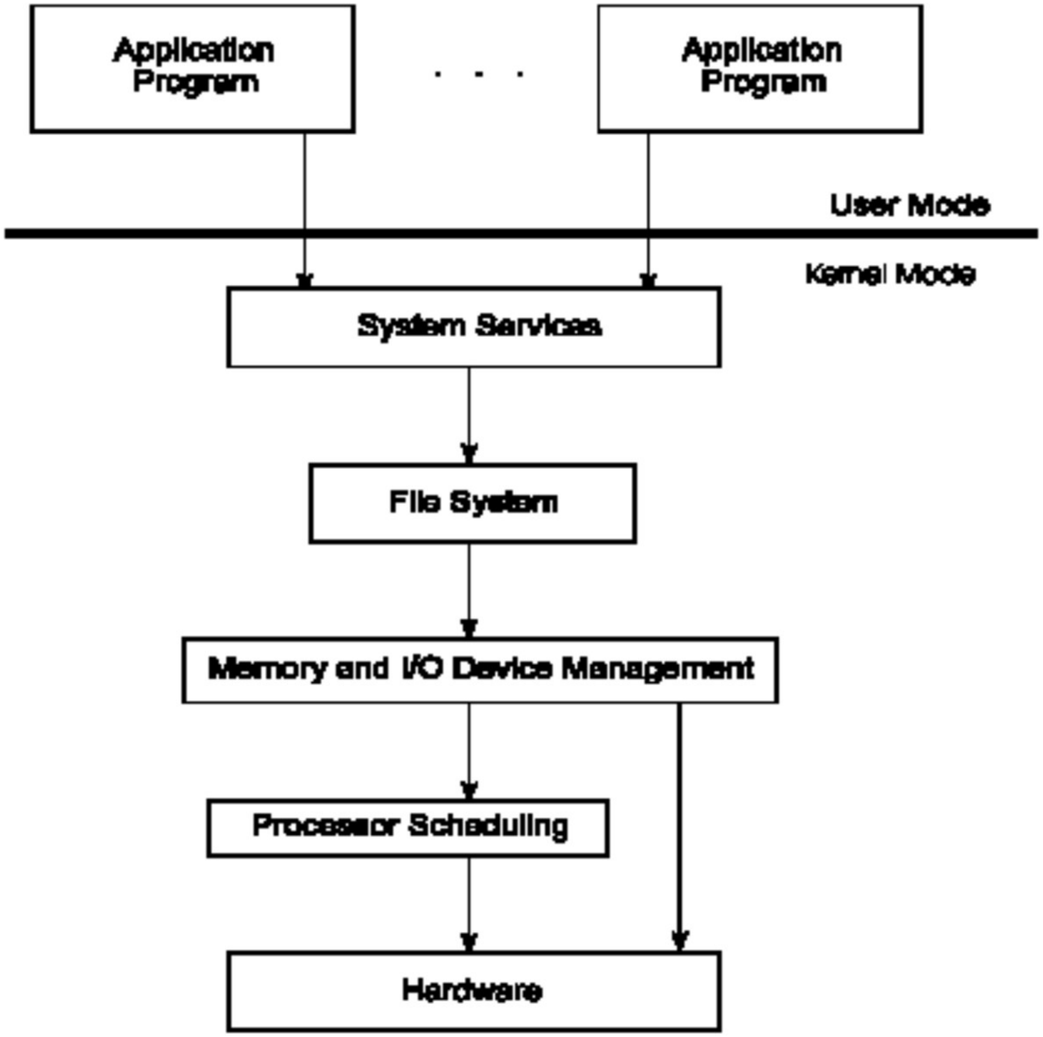
- The operating system is divided into a number of layers (levels), each built on top of lower layers
- The bottom layer (layer 0) is the hardware; the highest (layer N) is the user interface
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers



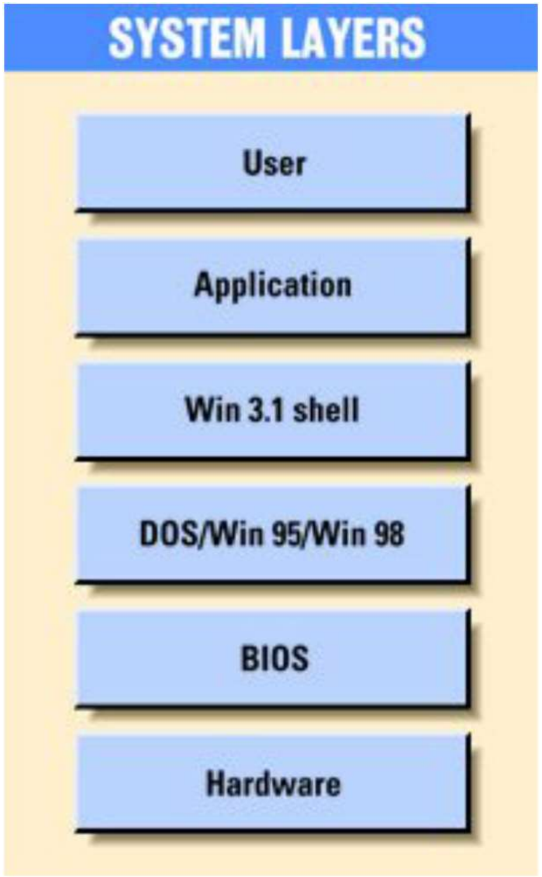
Layered Operating System



Operating System Layers



Older Windows System Layers



SYSTEM LAYERS

User

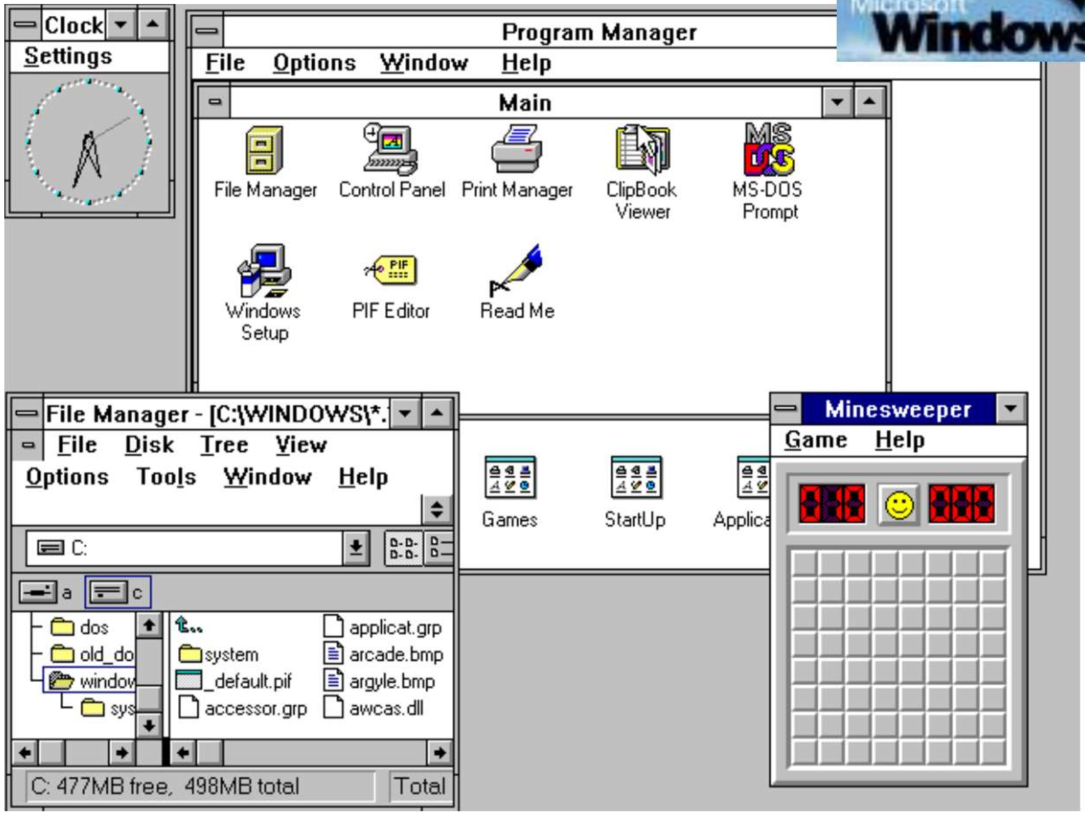
Application

Win 3.1 shell

DOS/Win 95/Win 98

BIOS

Hardware

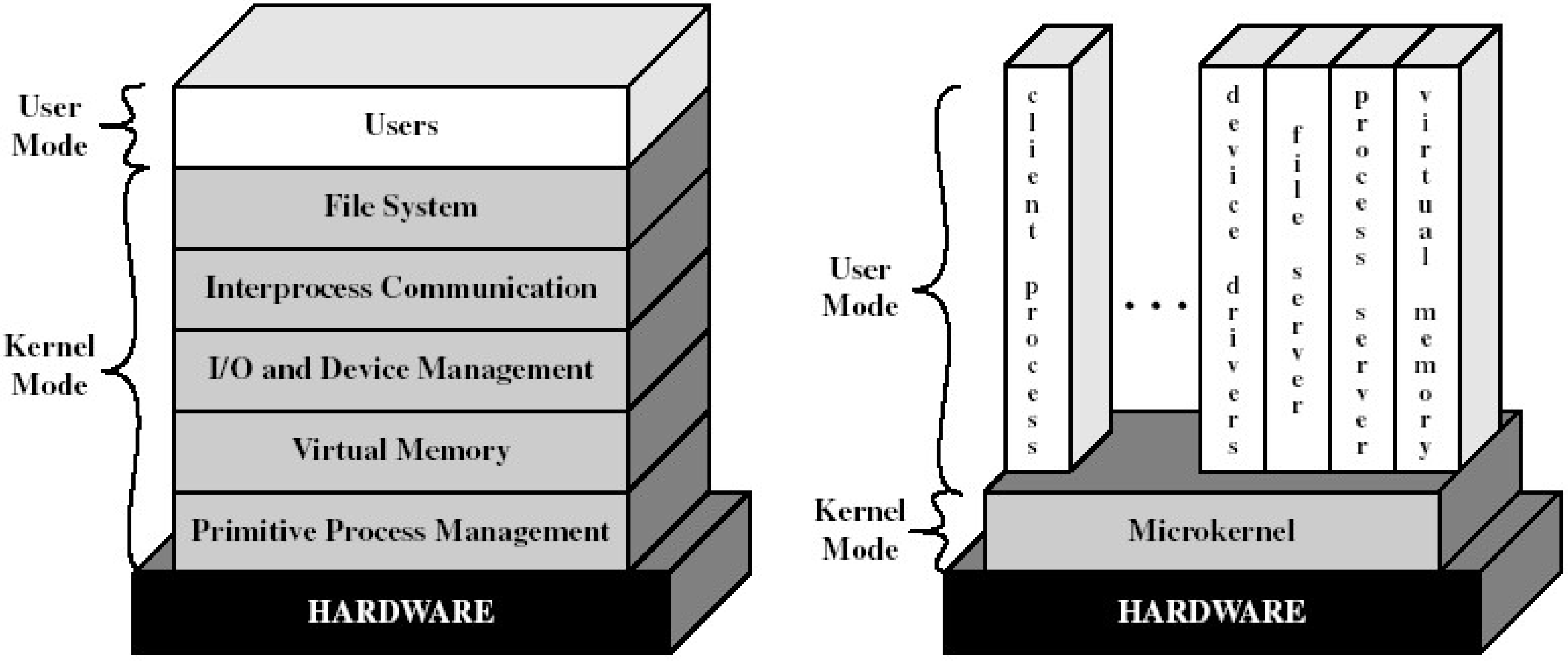


C: 477MB free, 498MB total

3. Microkernel System Structure

- Move as much functionality as possible from the kernel into “user” space.
- Only a few essential functions in the kernel:
  - primitive memory management (address space)
  - I/O and interrupt management
  - Inter-Process Communication (IPC)
  - basic scheduling
- Other OS services are provided by processes running in user mode (vertical servers):
  - device drivers, file system, virtual memory…

Layered vs. Microkernel Architecture

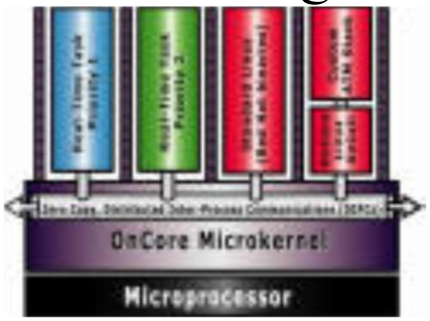


(a) Layered kernel

(b) Microkernel

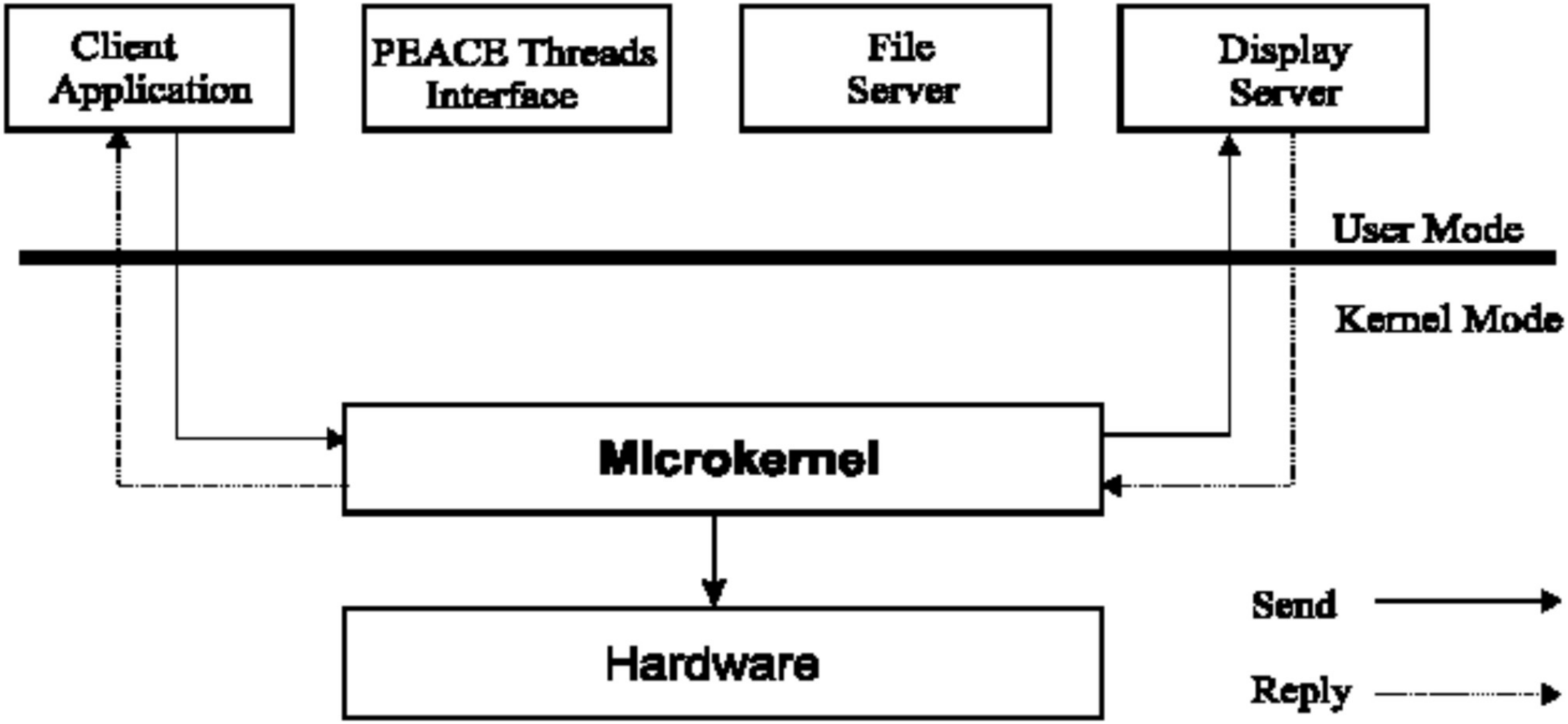
Microkernel System Structure

- Communication takes place between user modules using message passing



- Benefits:
  - Easier to extend a microkernel
  - Easier to port the operating system to new architectures
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication

Microkernel Operating System



Benefits of a Microkernel Organization

- Extensibility/Reliability
  - modular design
  - easier to extend a microkernel
  - more reliable (less code is running in kernel mode)
  - more secure (less code to be validated in kernel)
  - small microkernel can be rigorously tested
- Portability
  - changes needed to port the system to a new processor is done in the microkernel, not in the other services.

Mach 3 Microkernel Structure

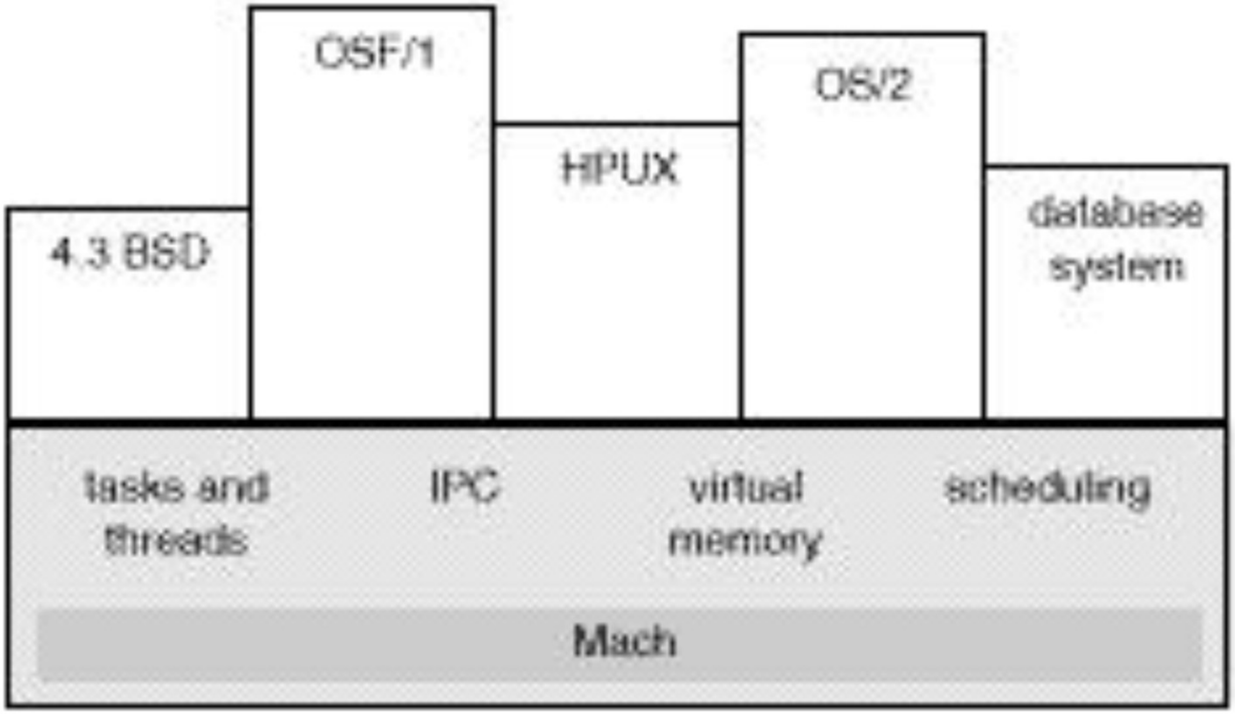
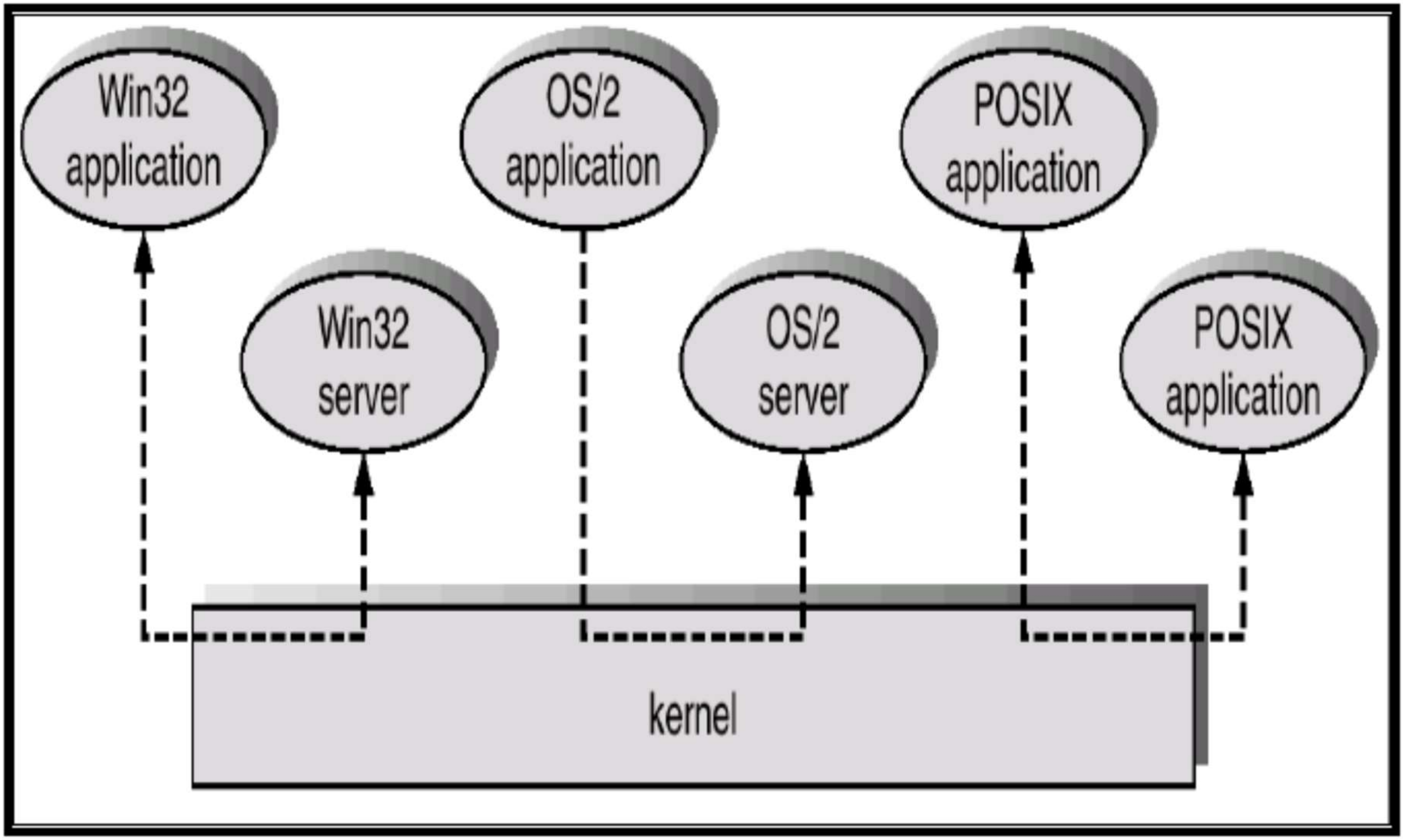


Figure A.1 Mach 3 structure.

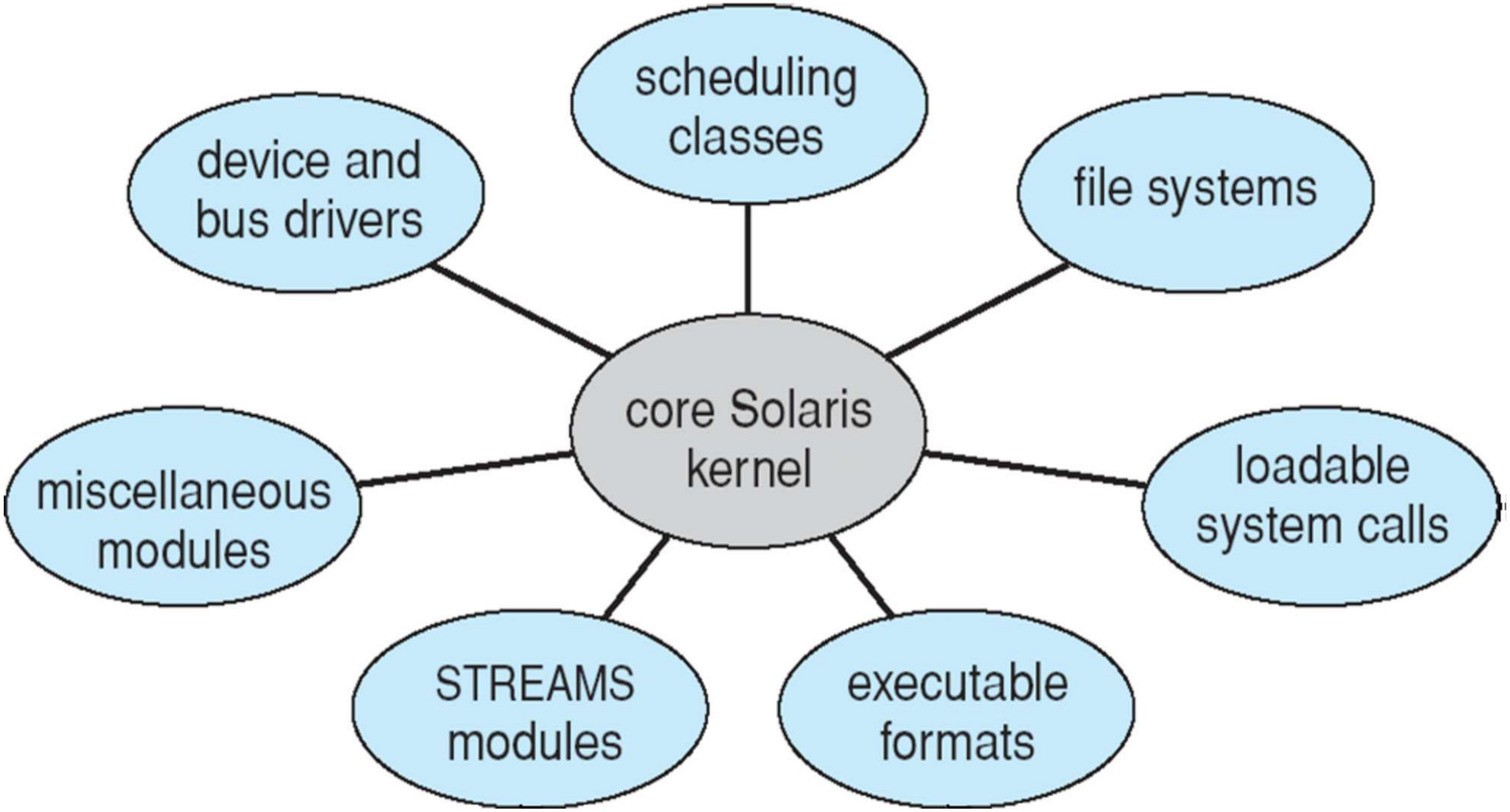
Windows NT Client-Server Structure



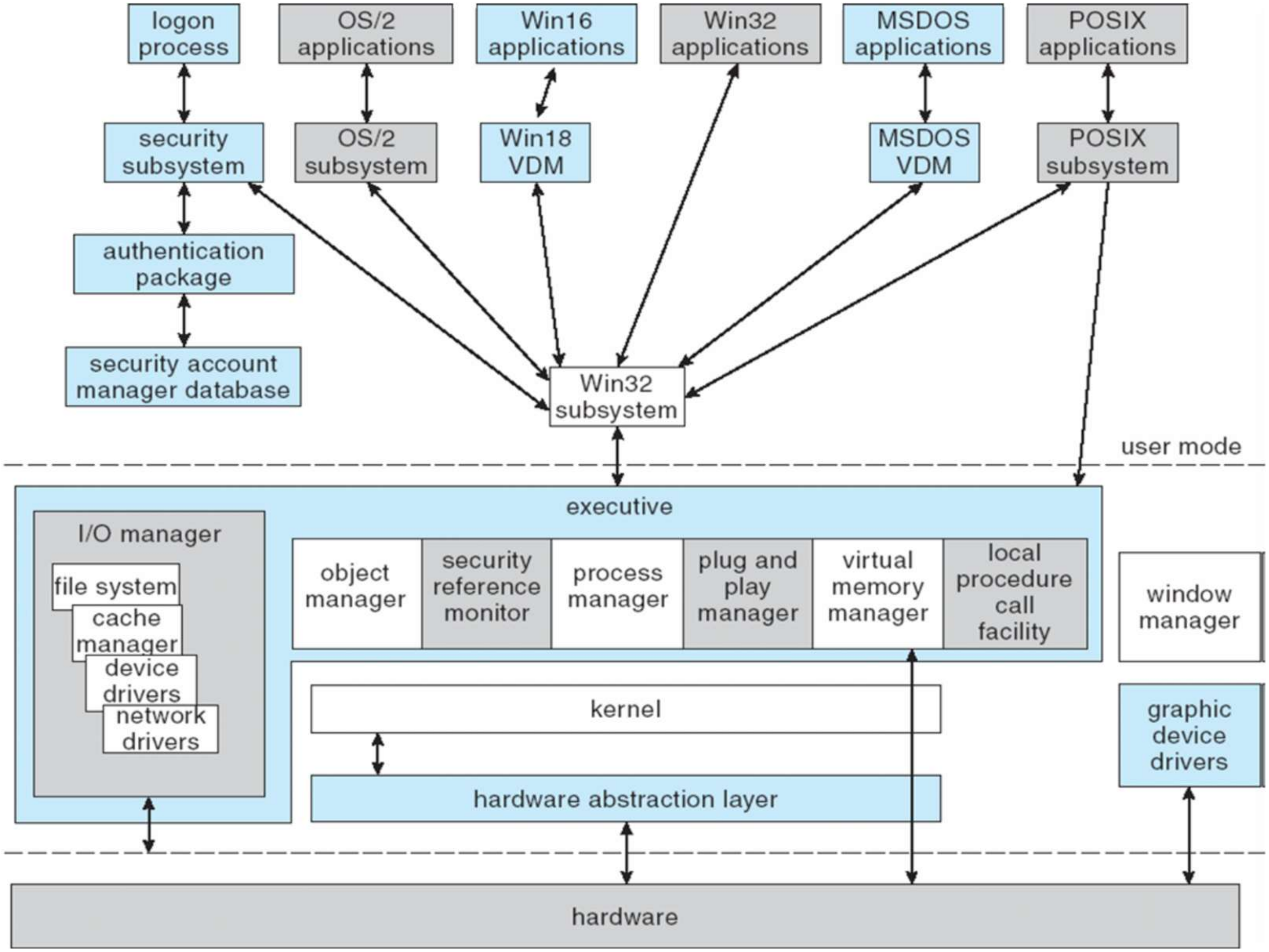
Kernel Modules

- Most modern operating systems implement kernel modules
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
- Overall, similar to layers but more flexible

Solaris Modular Approach



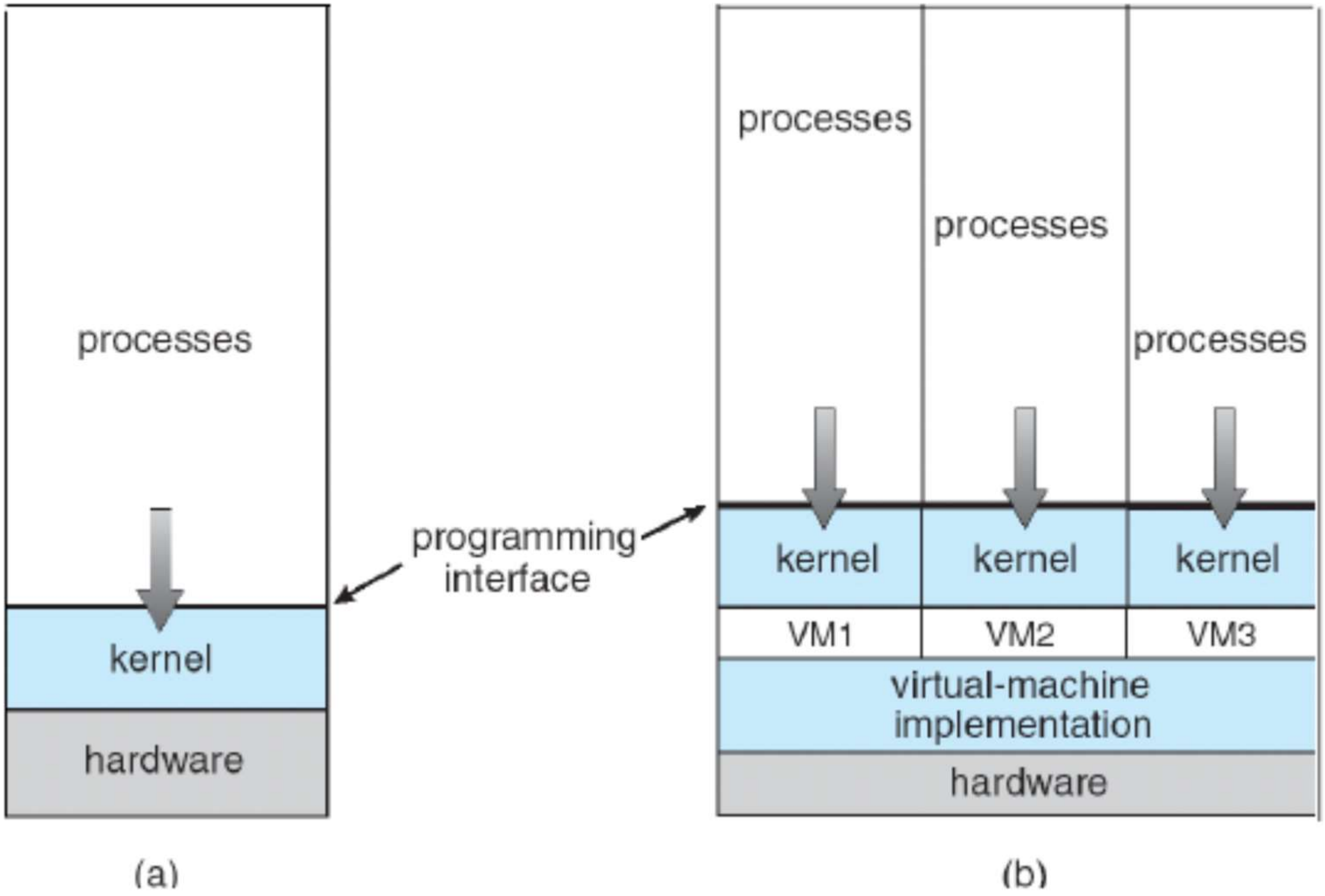
XP Architecture



4. Virtual Machines

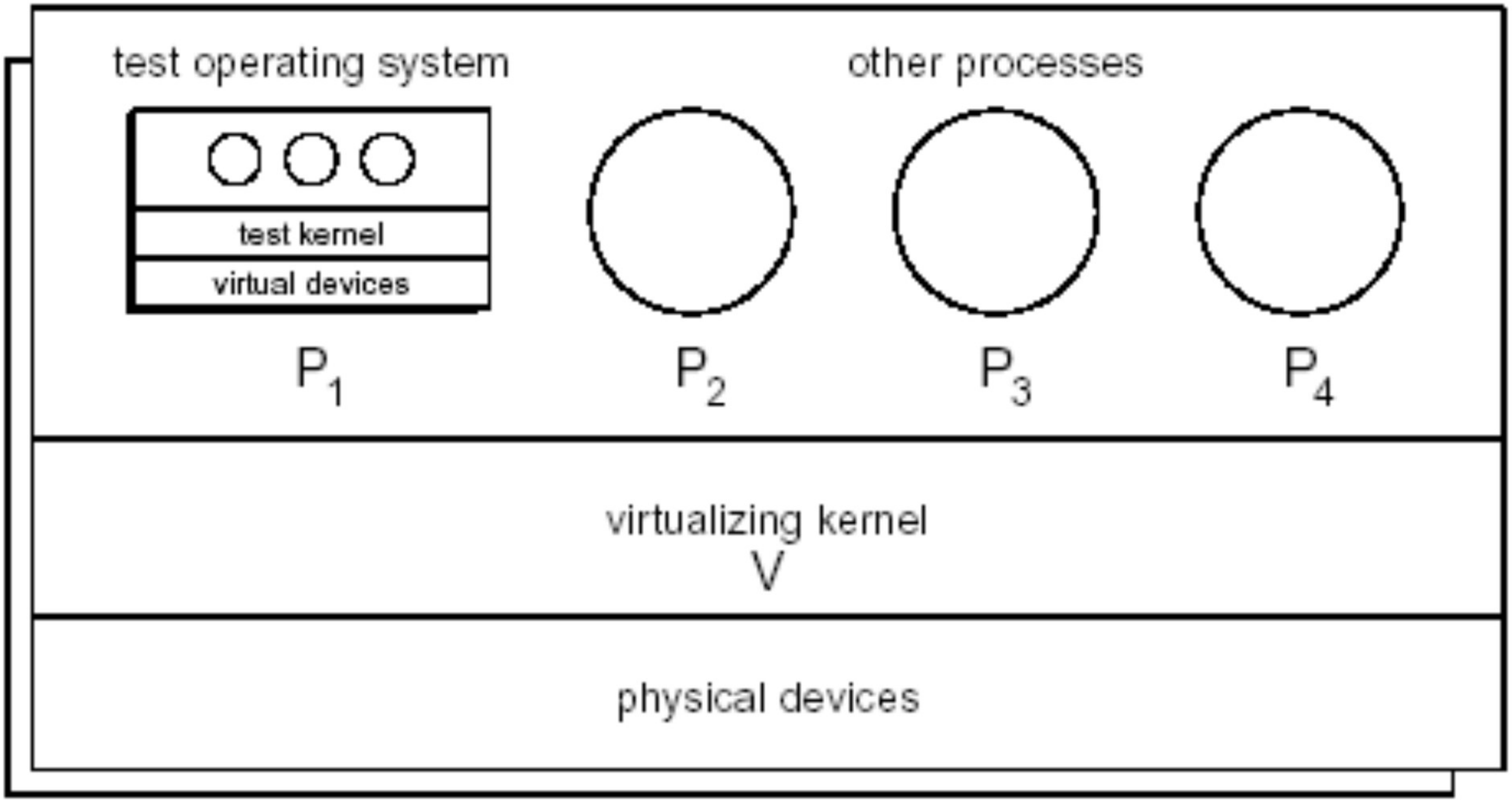
- A **virtual machine** takes the layered approach to its logical next step. It treats hardware and the operating system kernel as though they were all hardware
- A virtual machine provides an interface identical to the underlying bare hardware
- The operating system **host** creates the illusion that a process has its own processor (and virtual memory)
- Each **guest** provided with a (virtual) copy of underlying computer

Virtual Machines (Cont.)

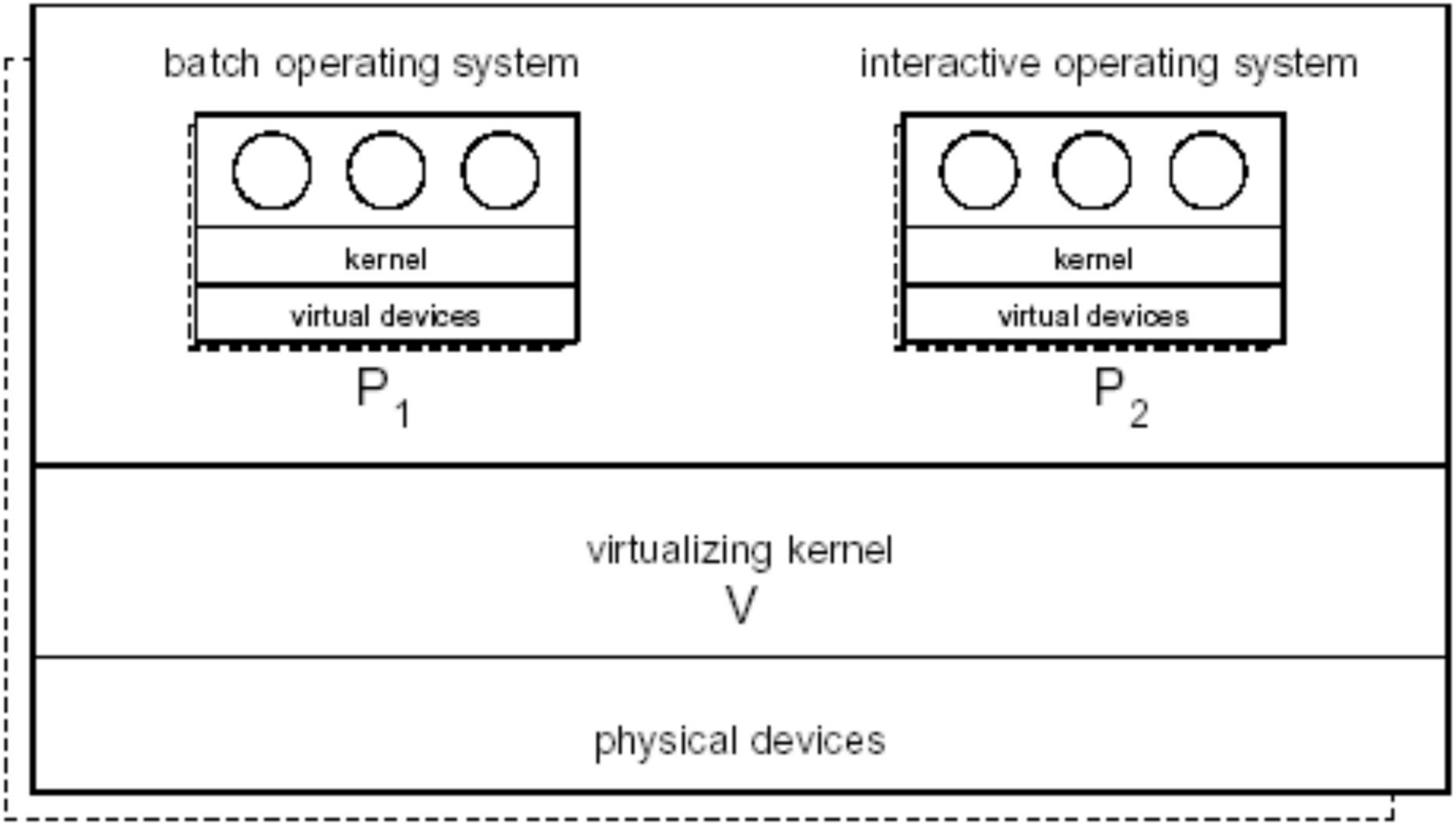


(a) Non-virtual machine (b) virtual machine

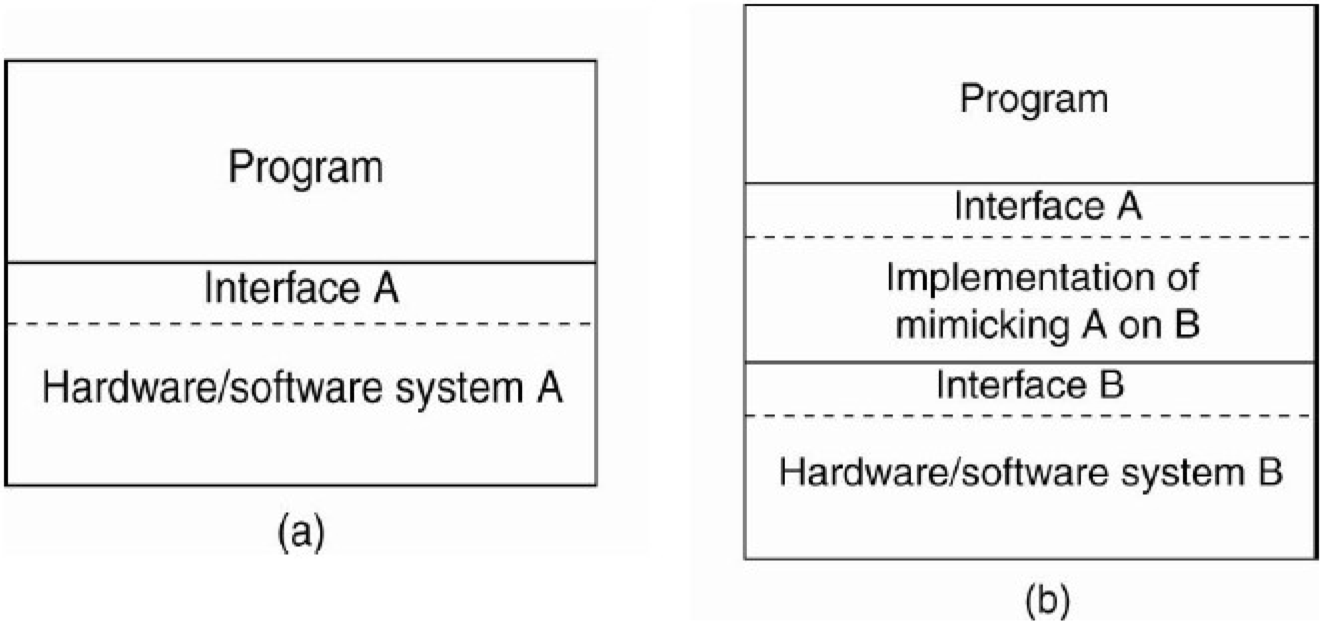
Testing a new Operating System



Integrating two Operating Systems



The Role of Virtualization


Program
Interface A
Hardware/software system A
(a)
Program
Interface A
Implementation of mimicking A on B
Interface B
Hardware/software system B
(b)

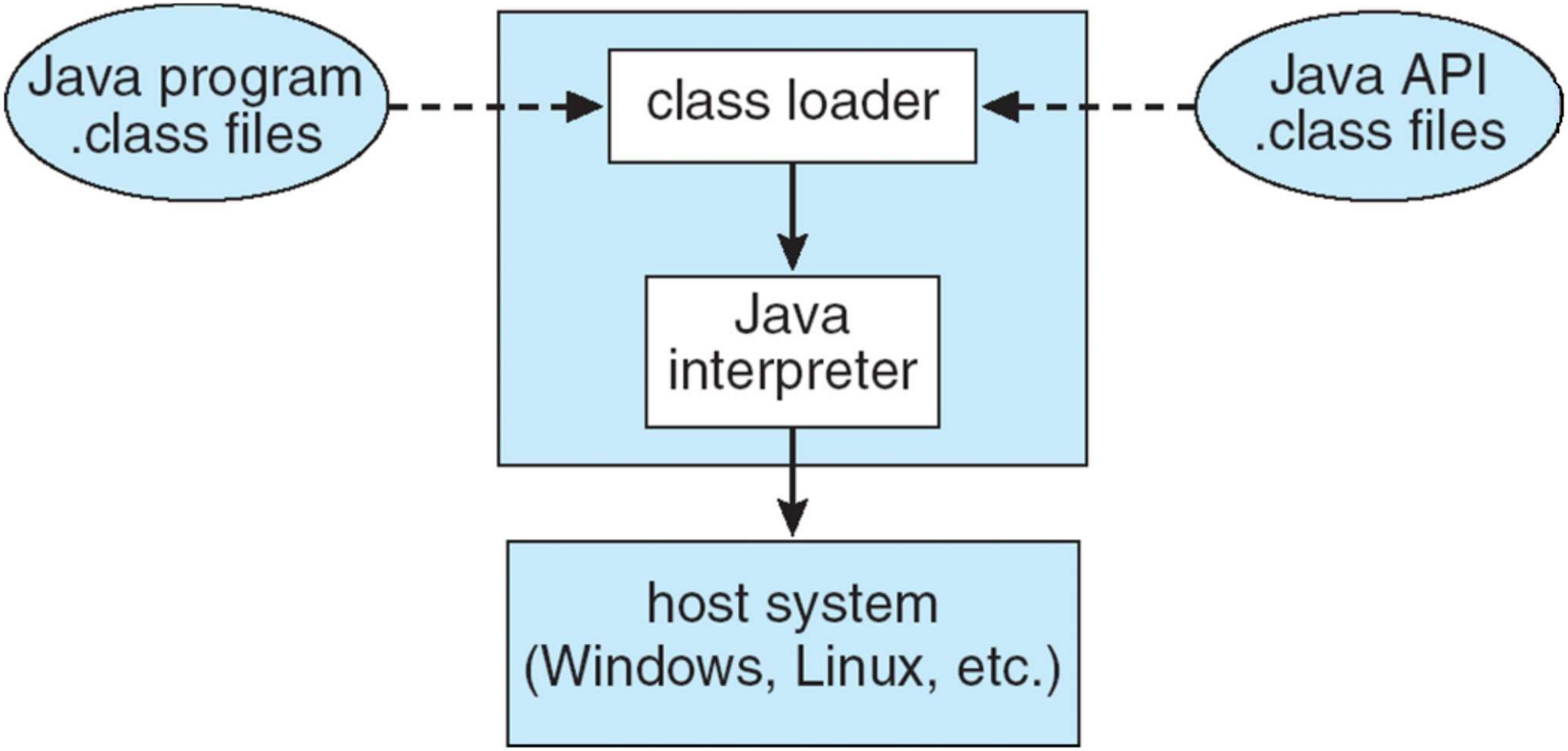
(a) General organization between a program, interface, and system.

(b) General organization of virtualizing system A on top of system B.

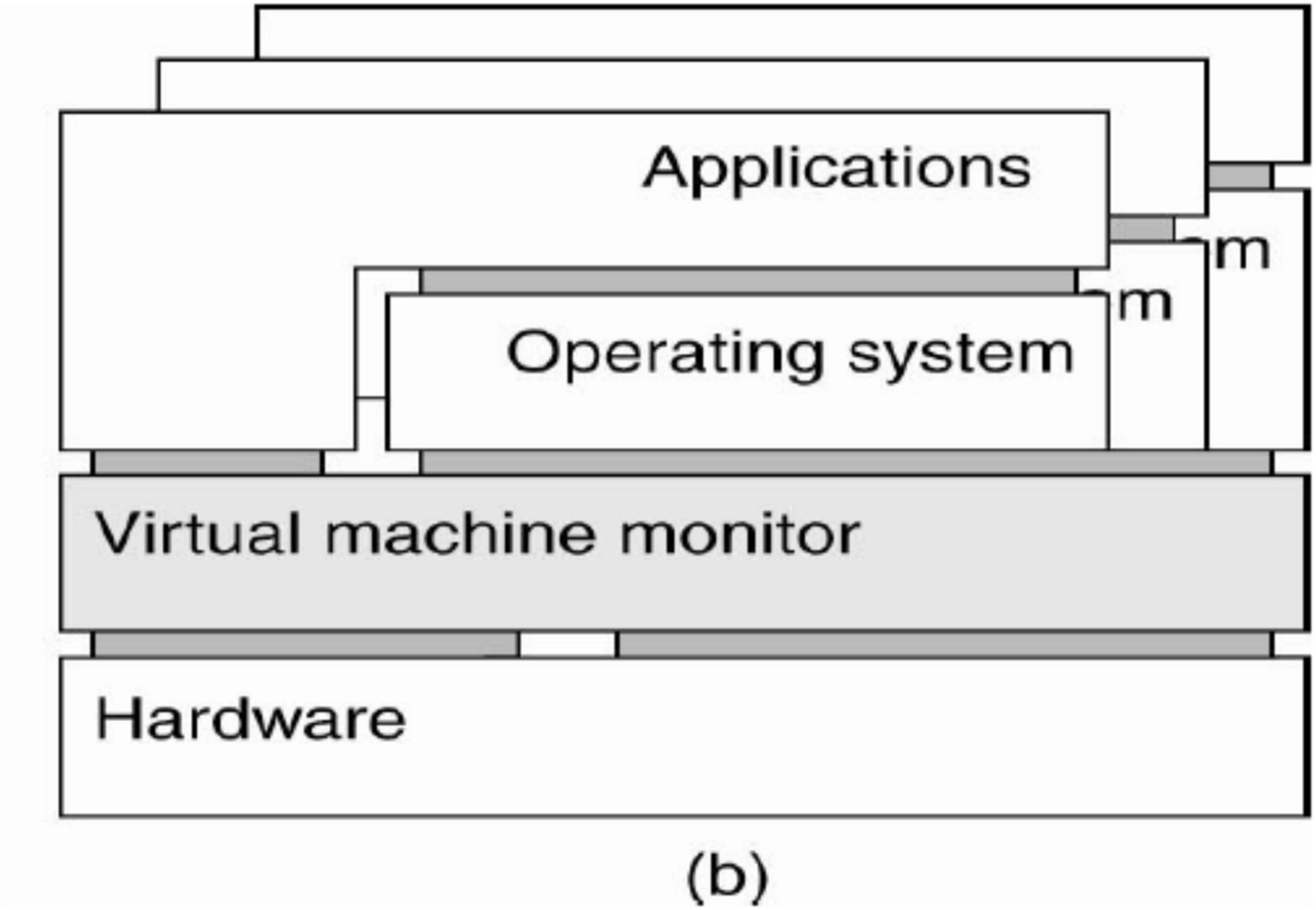
Java Virtual Machine

- Compiled Java programs are platform-neutral bytecode executed by a Java Virtual Machine (JVM).
- JVM consists of:
  - class loader
  - class verifier
  - runtime interpreter
- Just-In-Time (JIT) compilers increase performance.

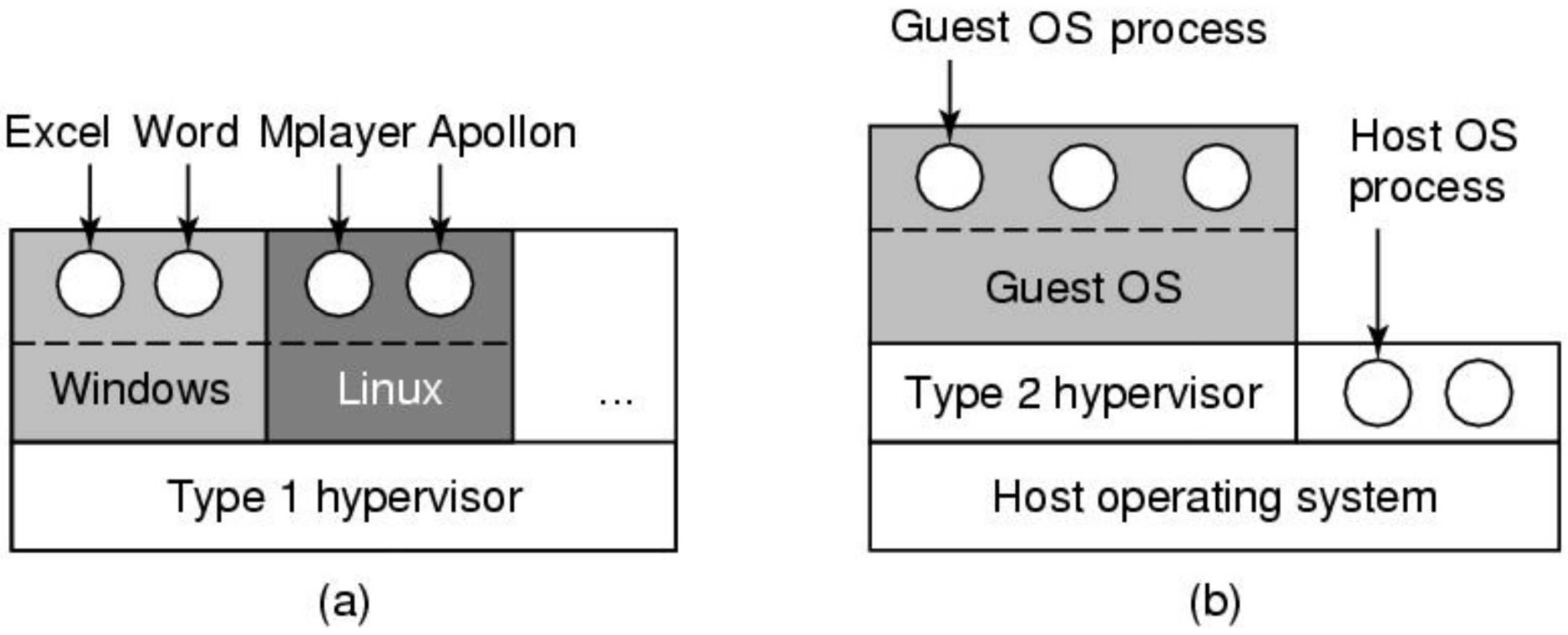
The Java Virtual Machine



Hypervisor / VMM



Types of Hypervisors



(a) A type 1 hypervisor

(b) A type 2 hypervisor

Para- vs. Full-virtualization

- Presents guest with system similar but not identical to hardware
- Guest must be modified to run on paravirtualized hardware
- Guest can be an OS, or in the case of Solaris 10 applications running in containers
- Full-virtualization: unmodified guest OSes

References

- Operating System Concepts (Silberschatz, 9th edition) Chapter 1, 2.1-2.5