Today's Plan

Upcoming:

- Assignment 1

Last time:

- Operating system duties

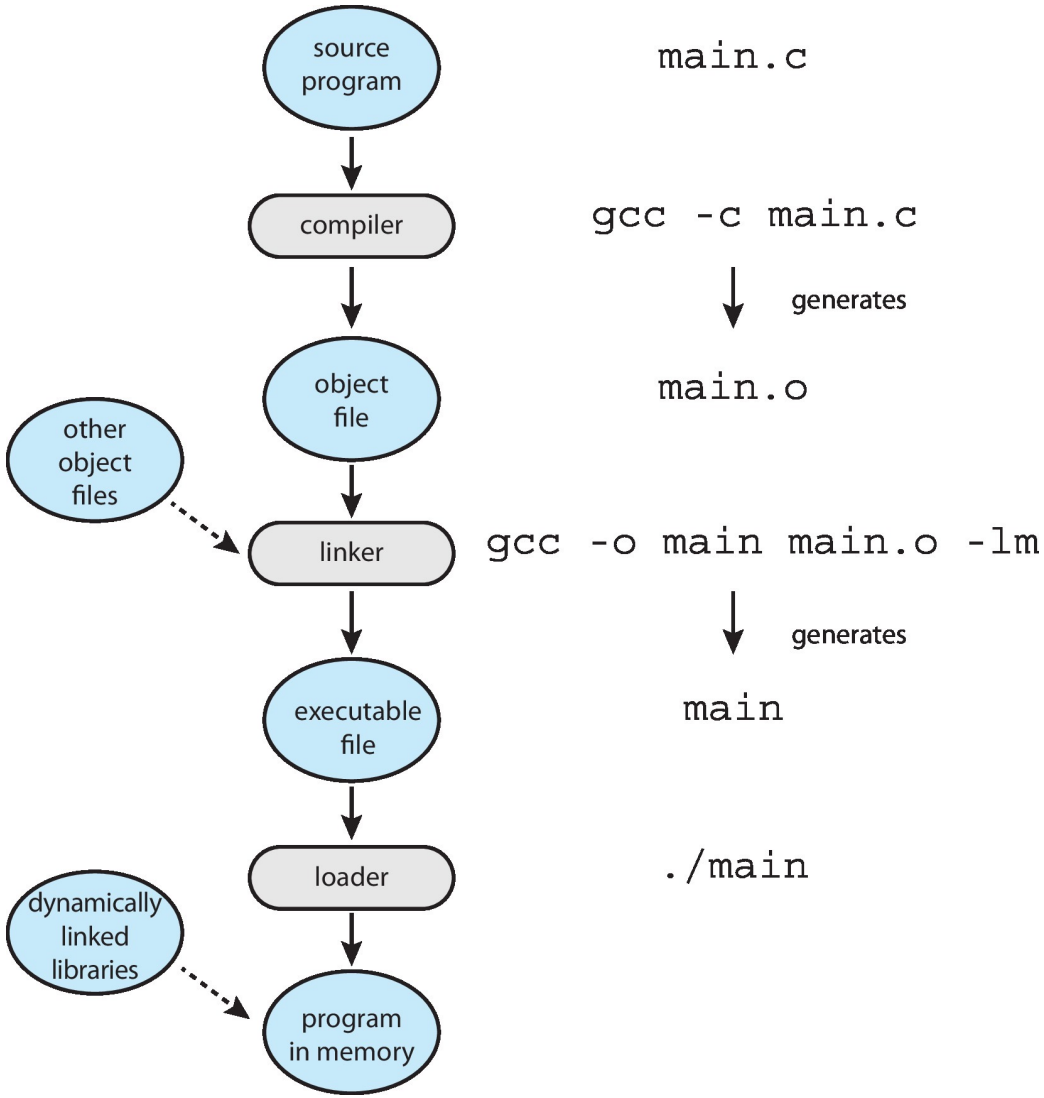
Today's topics:

- From last time:
  - OS Services
  - System Call Implementation
- Operating System Design and Implementation
- Operating System Structure
- Virtual Machines

System Programs

- System programs provide a convenient environment for program development and execution. Examples:
  - File manipulation
  - Status information
  - File modification
  - Programming language support
  - Program loading and execution
  - Communications
  - Application programs
- Most users' view of the operating system is defined by system programs, not the actual system calls.

Example: The Linker and Loader



Operating System Design & Implementation

- *User goals* – operating system should be:
  - Convenient to use, easy to learn
  - Reliable, safe, and fast
- *System goals* – operating system should be:
  - Easy to design, implement, and maintain
  - Flexible, reliable, error-free
  - Efficient!

Operating System Design & Implementation

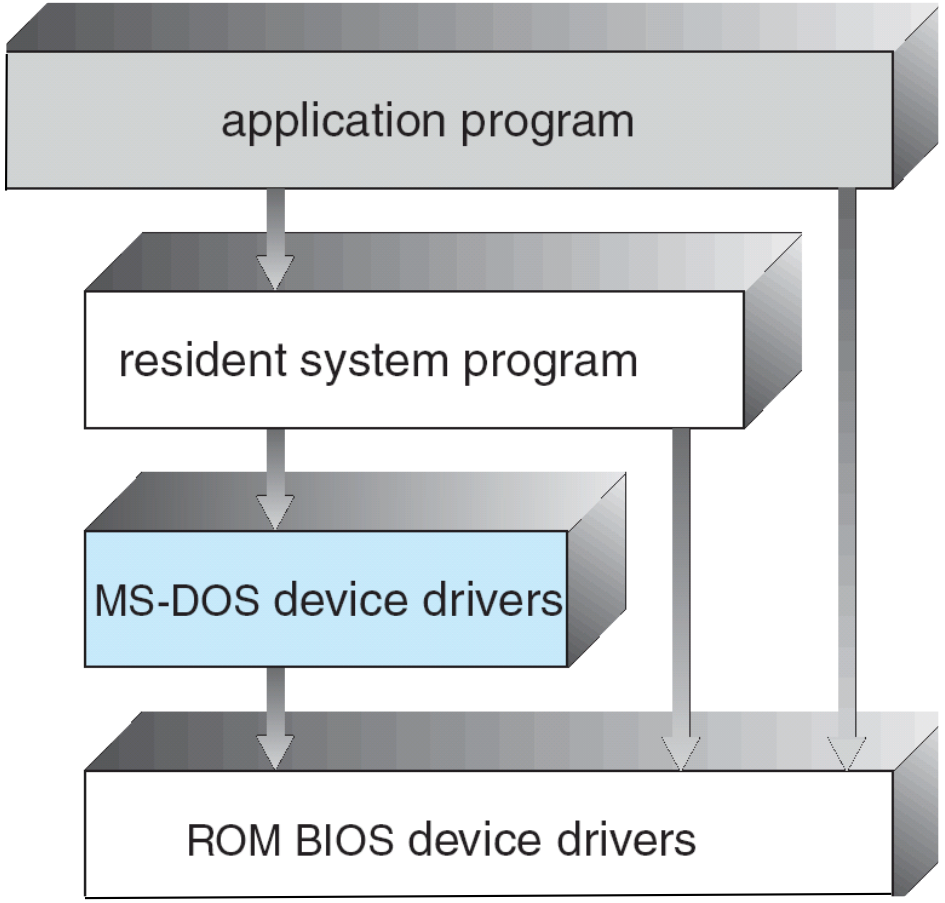
- Important principle to separate
  - **Policy:** What will be done?
  - **Mechanism:** How to do it?
- Why have this separation?
  - Allows maximum flexibility if either policy or mechanism need to be changed later

Operating System Implementation

- Much variation
  - Early OSes in assembly language
  - Then system programming languages like Algol, PL/1
  - Now C, C++
- Actually usually a mix of languages
  - Lowest levels in assembly
  - Main body in C
  - Systems programs in C, C++, scripting languages like PERL, Python, shell scripts
- High-level languages easier to port to other hardware
  - But slower
- Emulation can allow an OS to run on non-native hardware

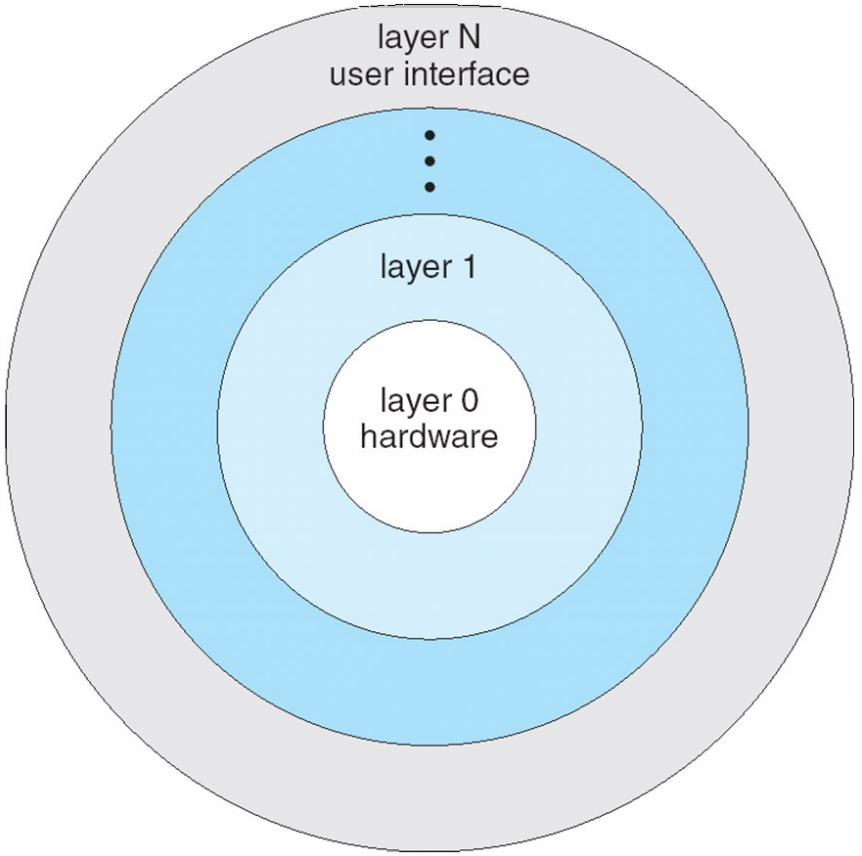
Simple Structure

- MS-DOS – written to provide the most functionality in the least space
  - Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated



Layered Approach

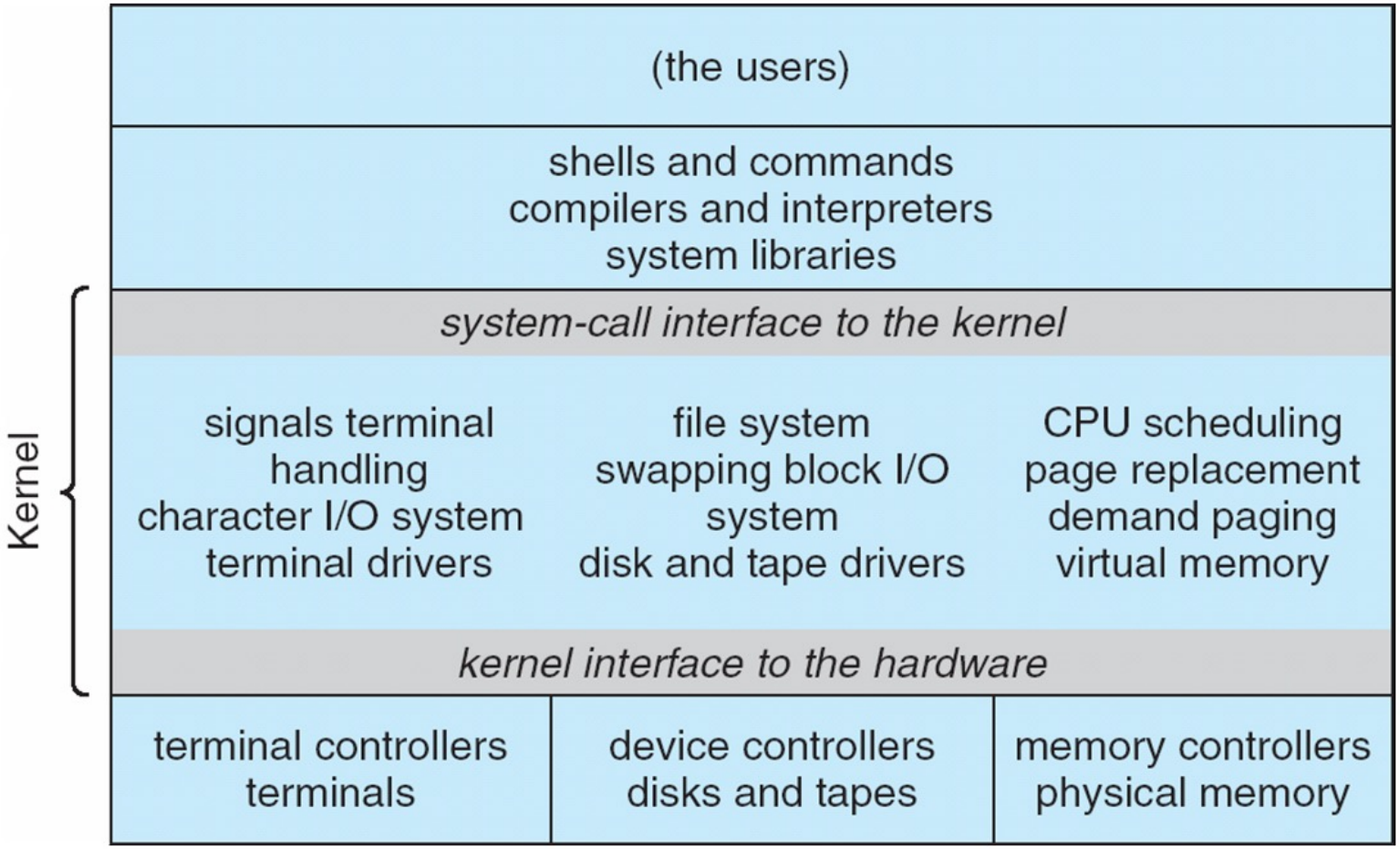
- The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface.
- With modularity, layers are selected such that each uses functions and services of only lower-level layers



UNIX

- UNIX – limited by hardware functionality, the original UNIX operating system was a *monolithic kernel*.
- The UNIX OS consists of two separable parts:
  - Systems programs
  - 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

Traditional UNIX Structure

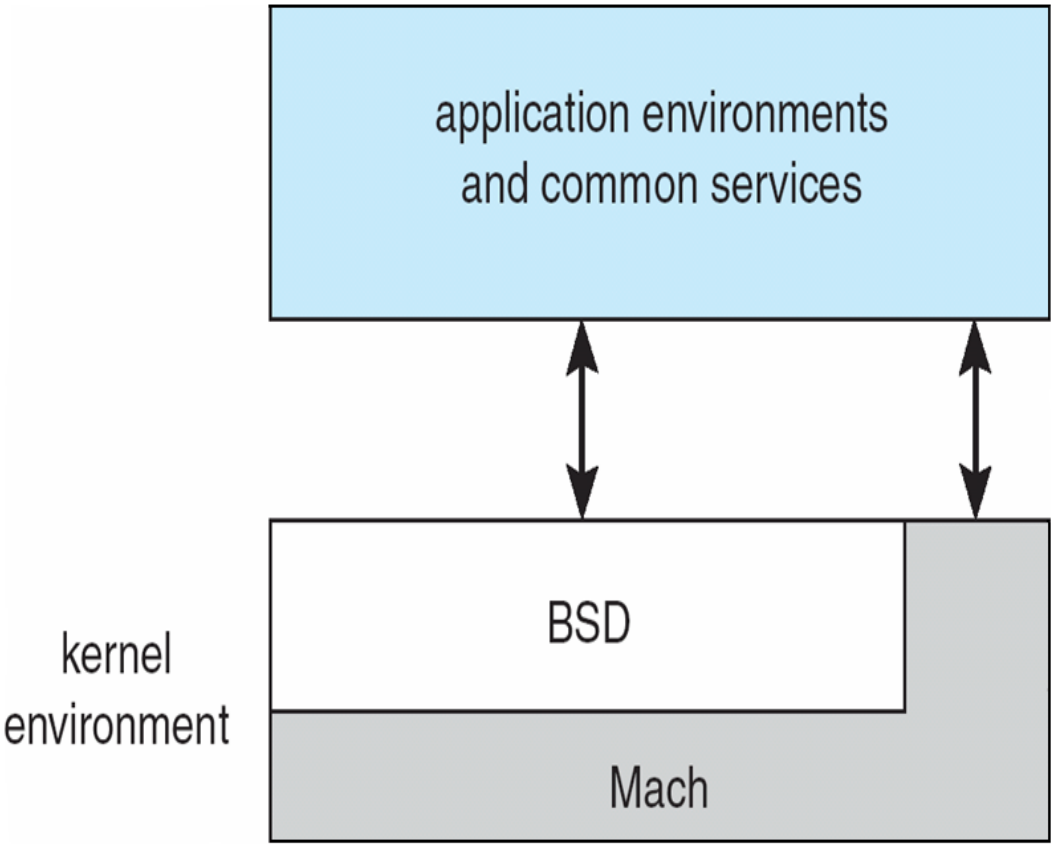


Microkernel System Structure

- Moves as much from the kernel into "*user*" space
- Benefits:
  - Easier to extend a microkernel
  - Easier to port the OS to new architectures
  - More reliable
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication

Monolithic vs. Microkernel Structure

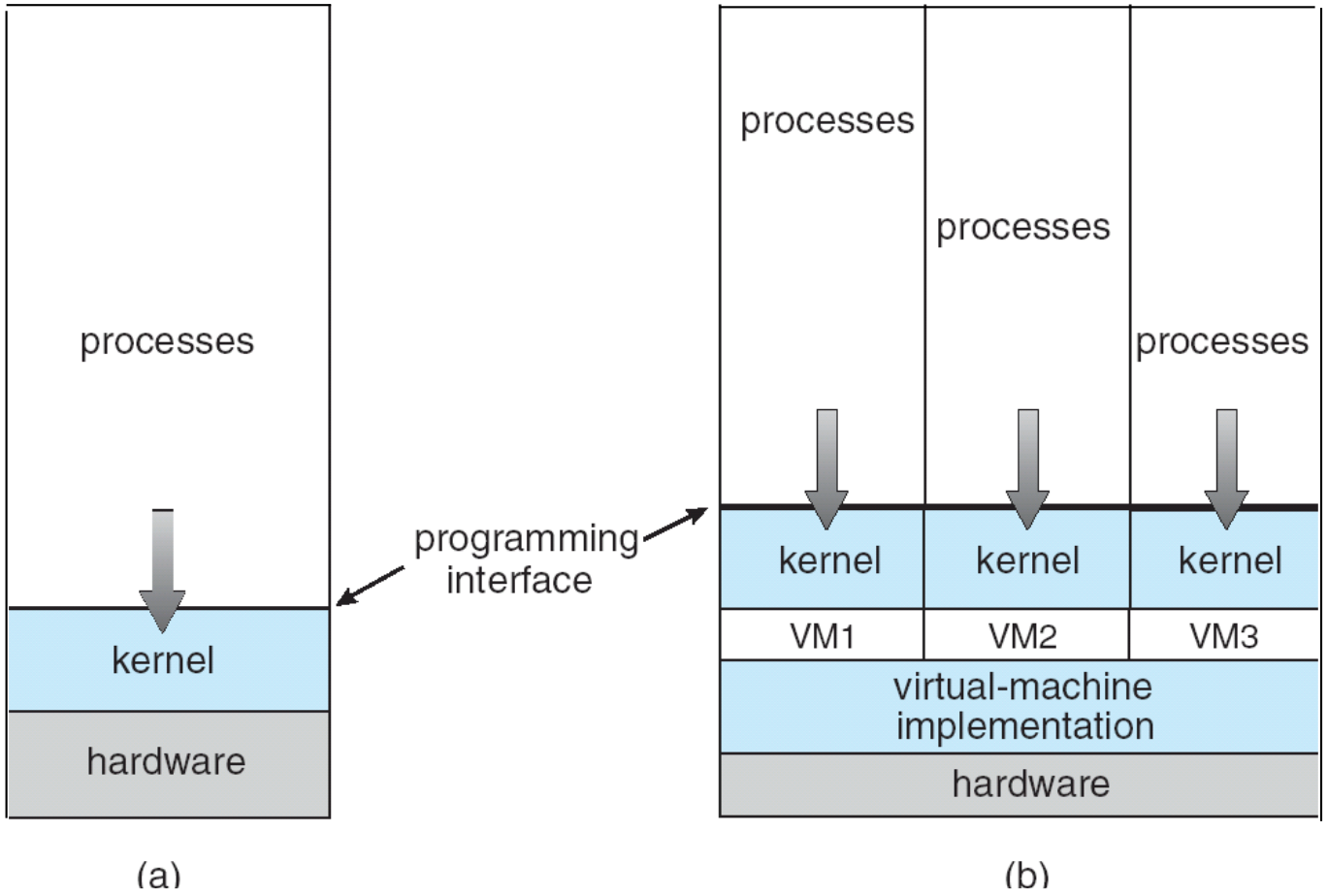
- Most popular modern OSes are actually hybrids of the monolithic and microkernel structures:
  - Many functions are moved into “user” space
  - Some are kept in the kernel for performance reasons
  - E.g. Mac OS/X structure:



Virtual Machines

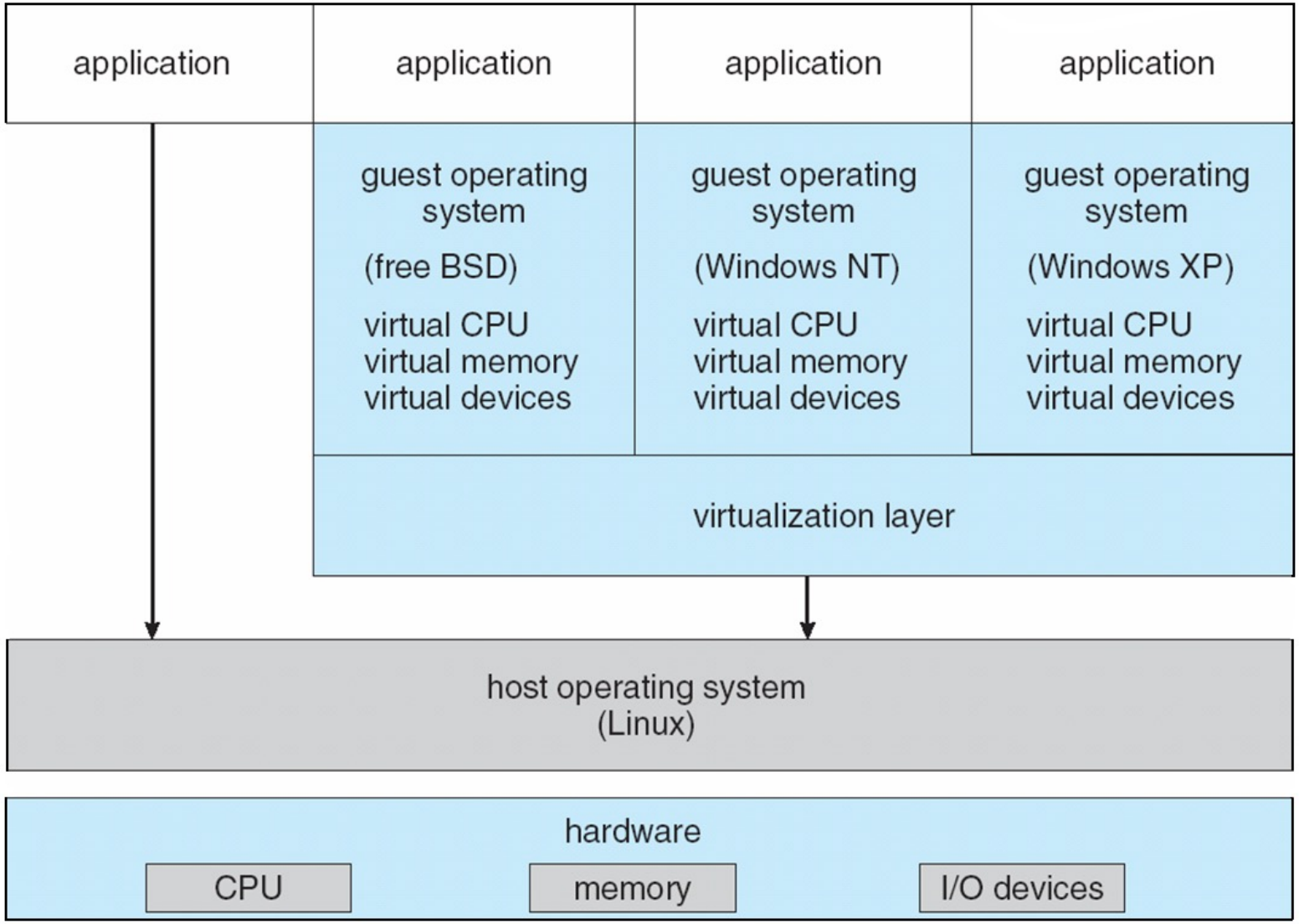
- A *virtual machine* takes the layered approach to its logical conclusion. It treats hardware and the operating system kernel as though they were all hardware
- A virtual machine provides an interface *identical* to the underlying hardware
- The operating system host creates the illusion that a process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

Virtual Machines

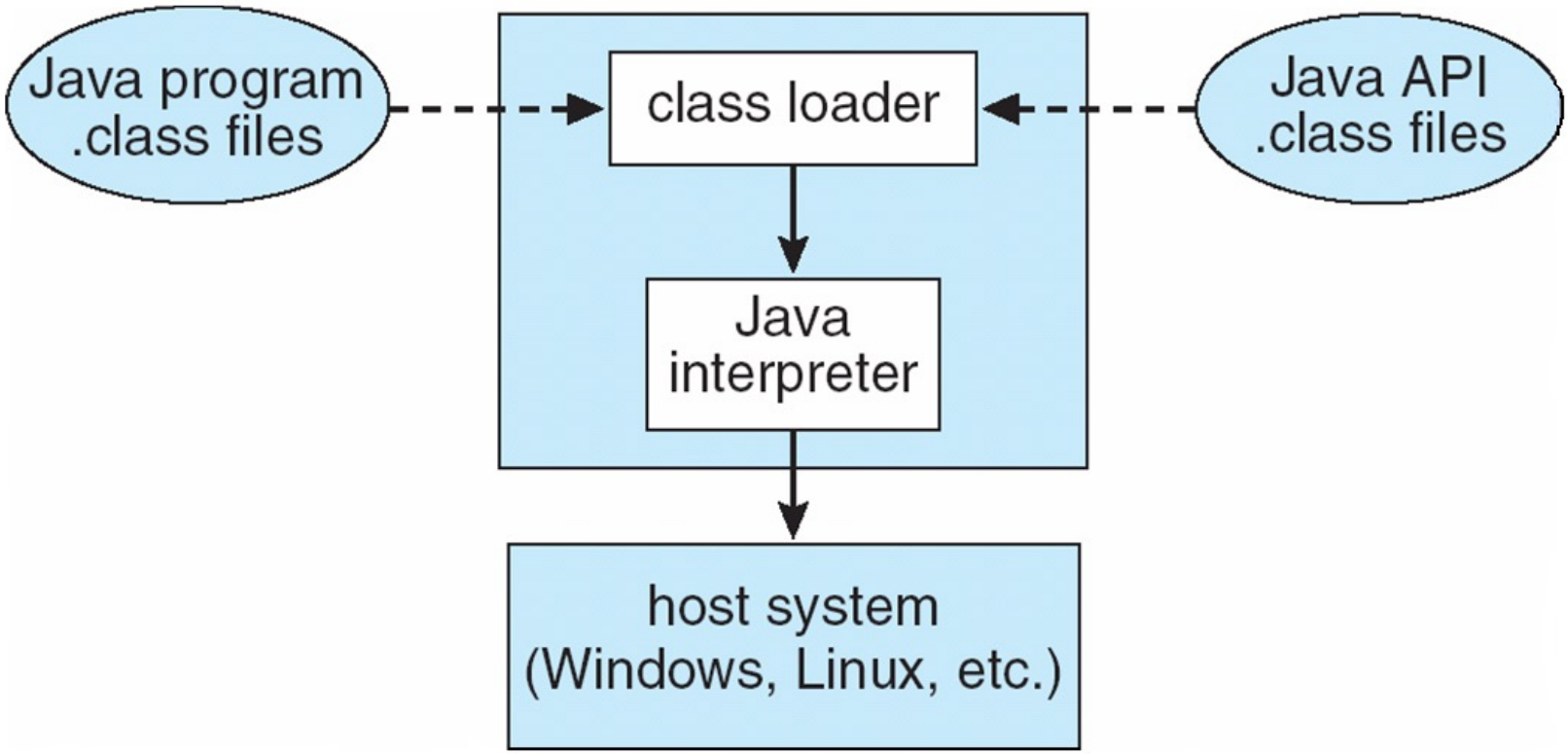


(a) Nonvirtual machine (b) virtual machine

VMWare Architecture



Java Virtual Machine



Operating-System Debugging

- *Debugging* is finding and fixing errors, or bugs
- OSes generate log files containing error information
- Failure of an application can generate **core dump** file capturing memory of the process
- Operating system failure can generate **crash dump** file containing kernel memory
- Kernighan's Law: "*Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it.*"