Chap. 12) I/O Systems

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조 진 성

Revisited: Computer System Operation

I/O operation

- ✓ I/O request via I/O instruction
  - Direct I/O vs. Memory-mapped I/O
  - Communicates with registers in I/O controller
  - Typically, IR (Instruction Register) & DR (Data Register)

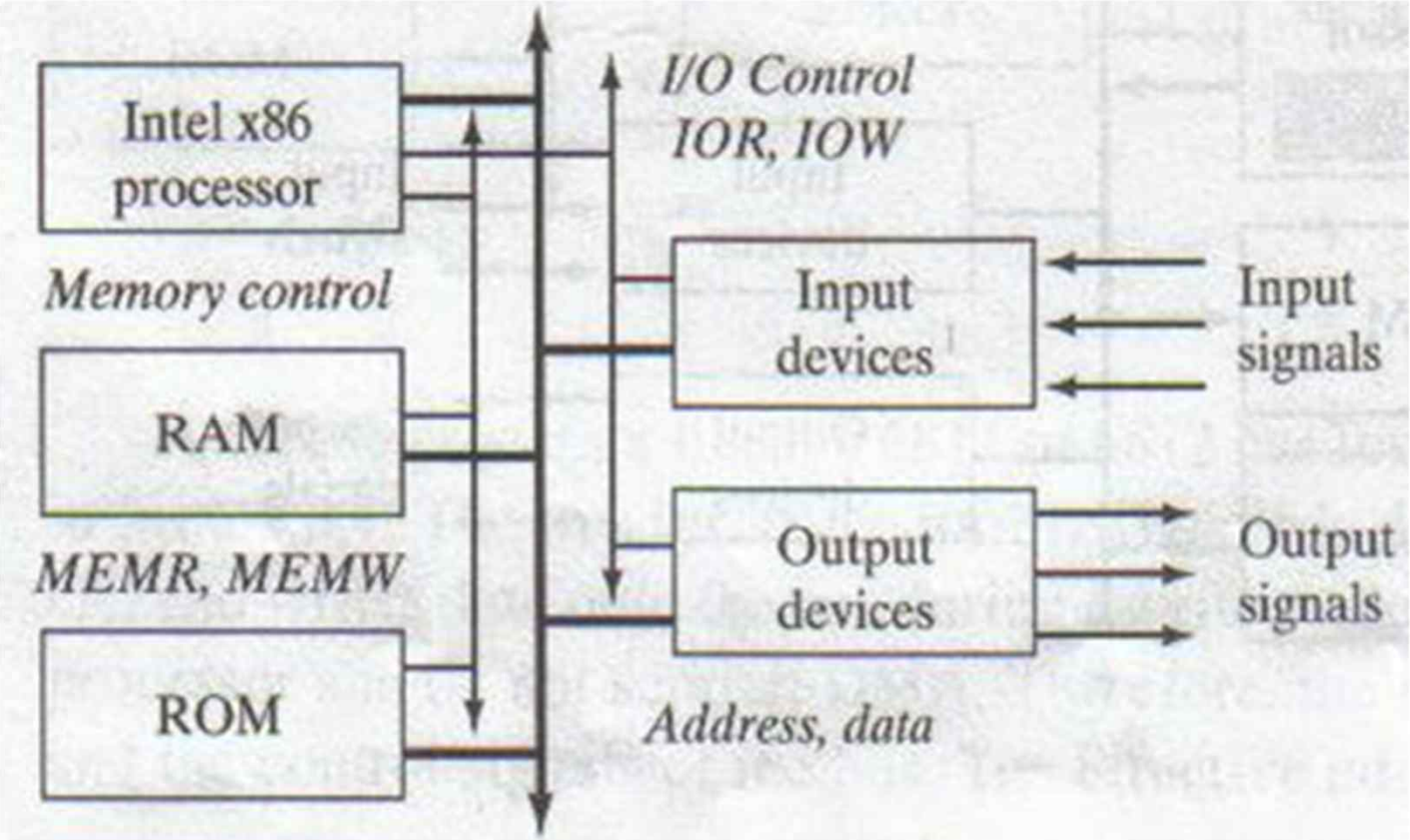
- ✓ I/O method
  - Polling vs. Interrupt
  - Programmed I/O vs. DMA (Direct Memory Access)

Direct I/O

Separate addresses: memory vs. I/O

Separate instructions

- ✓ MEMR / MEMW (Load / Store)
- ✓ IOR / IOW (IN / OUT)

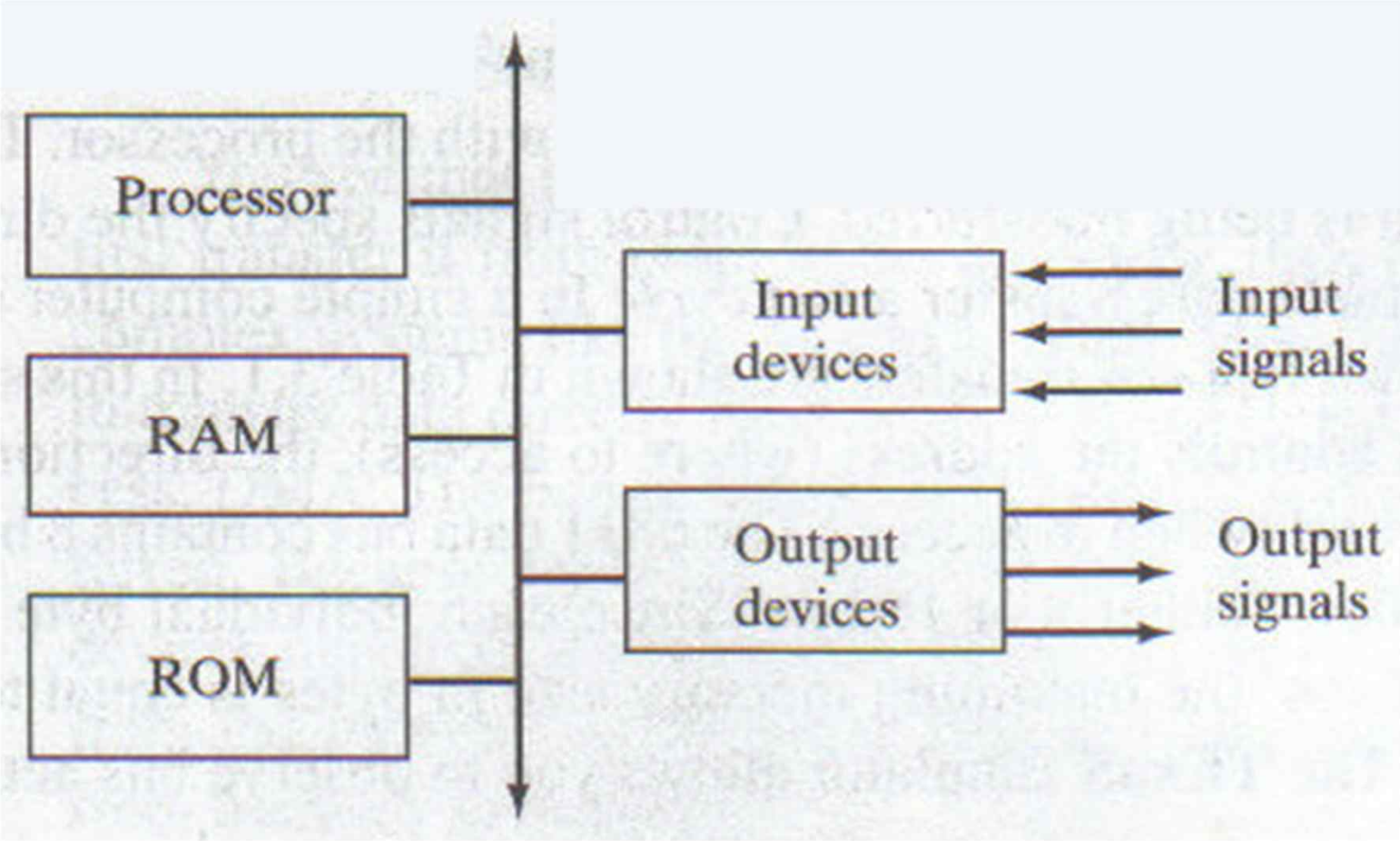


Memory-Mapped I/O

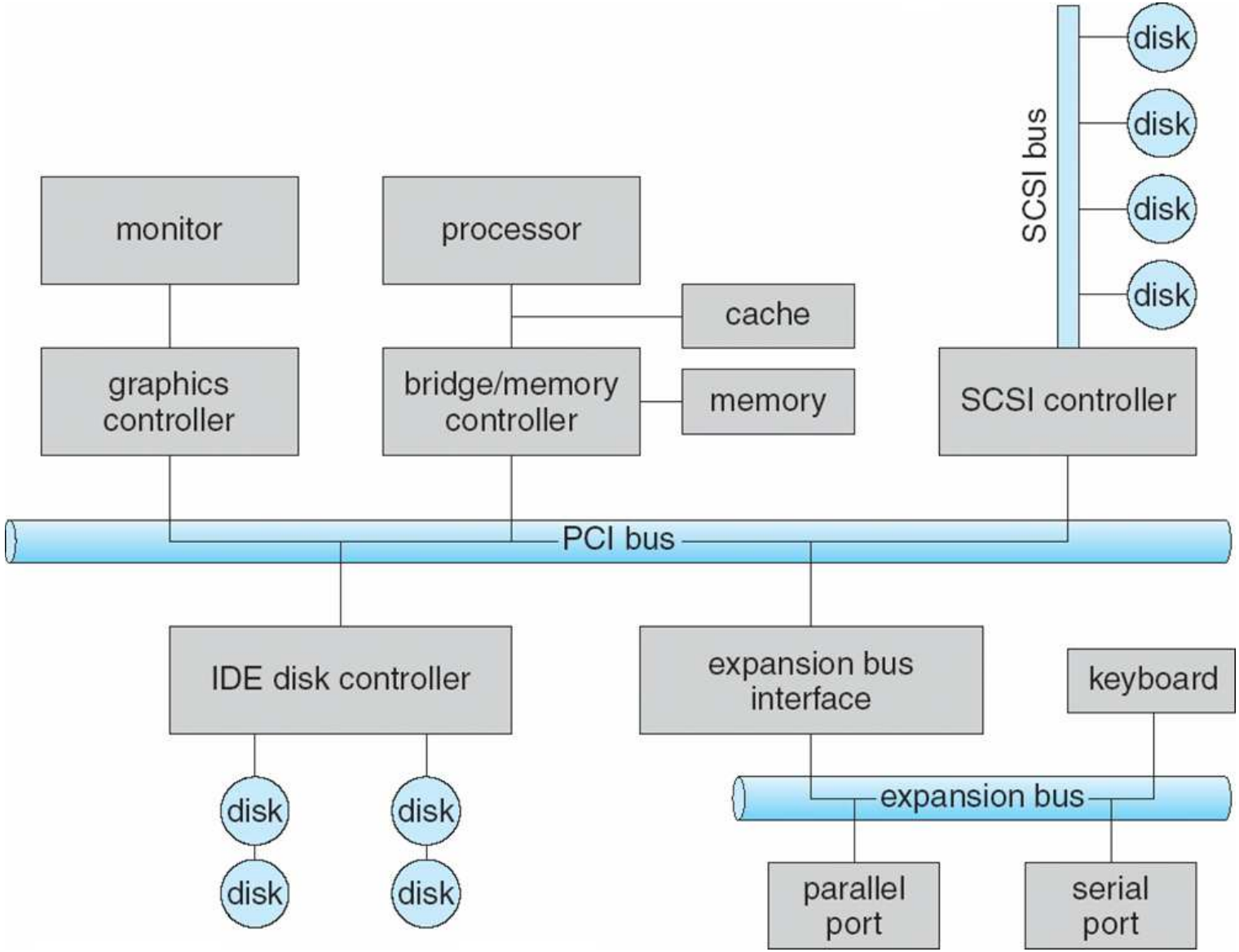
Integrated addresses: memory & I/O

Integrated instructions

- ✓ MEMR / MEMW (Load / Store)



A Typical PC Bus Structure

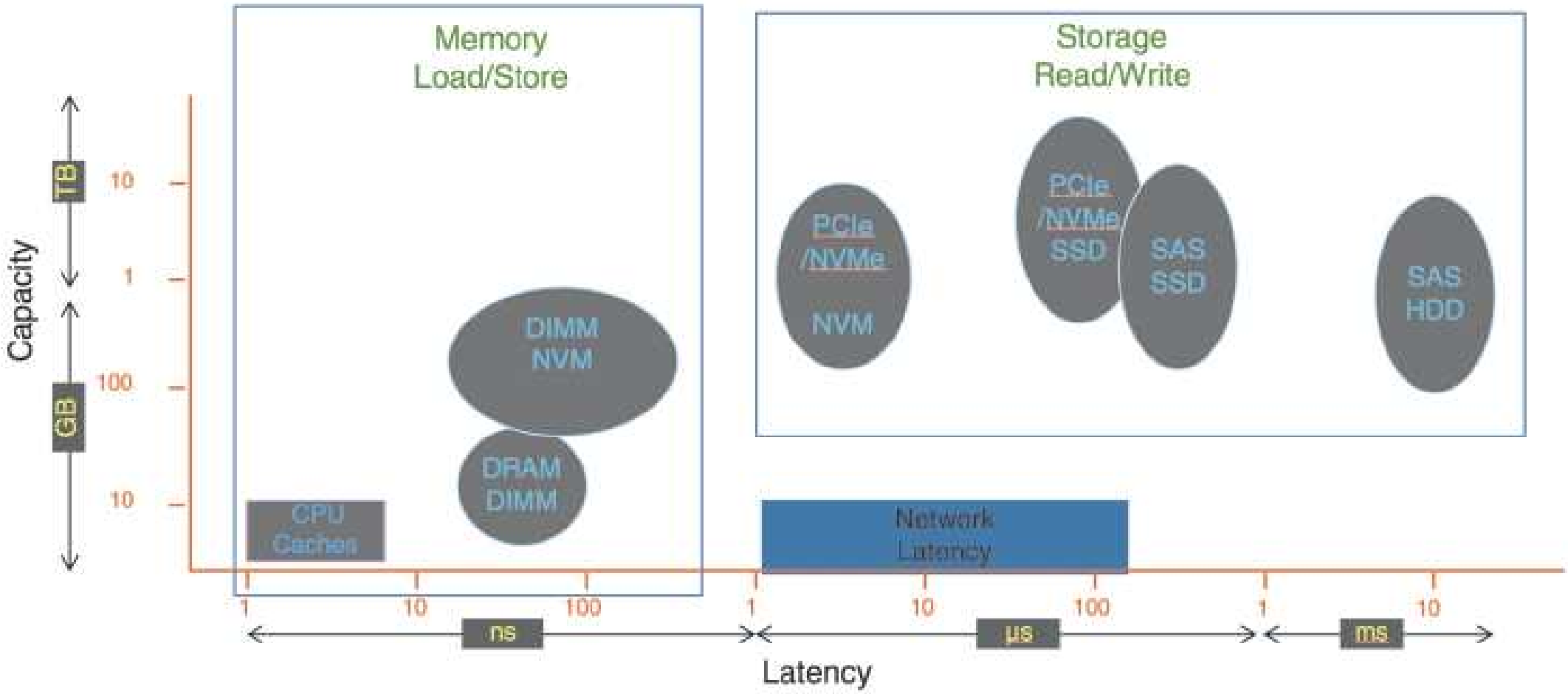


I/O Device Controller

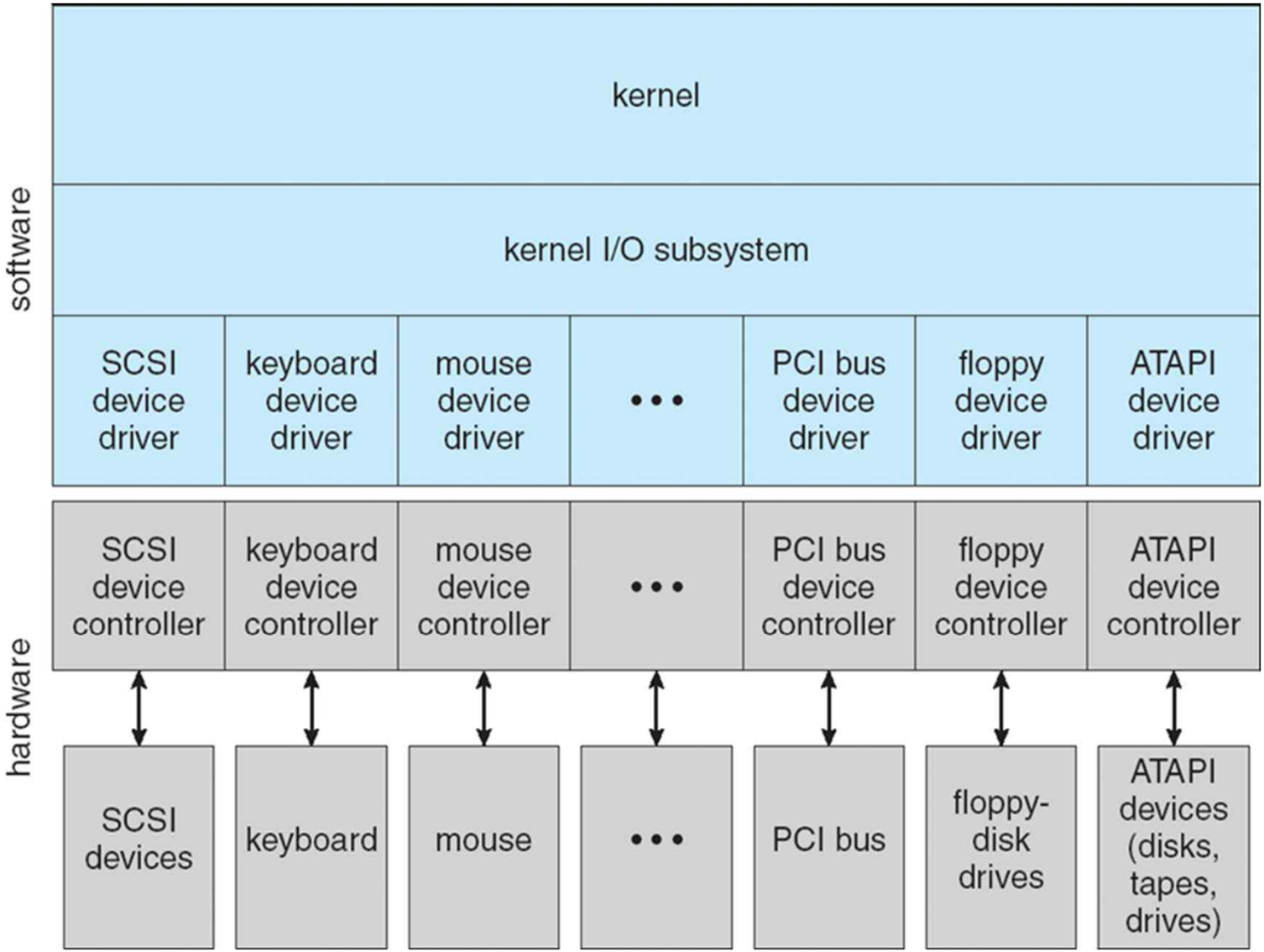
Device controller (or host adapter)

- ✓ I/O devices have components:
  - Mechanical component
  - Electronic component
- ✓ The electronic component is the device controller
  - May be able to handle multiple devices
- ✓ Controller's tasks
  - Convert serial bit stream to block of bytes
  - Perform error correction as necessary
  - Make available to main memory

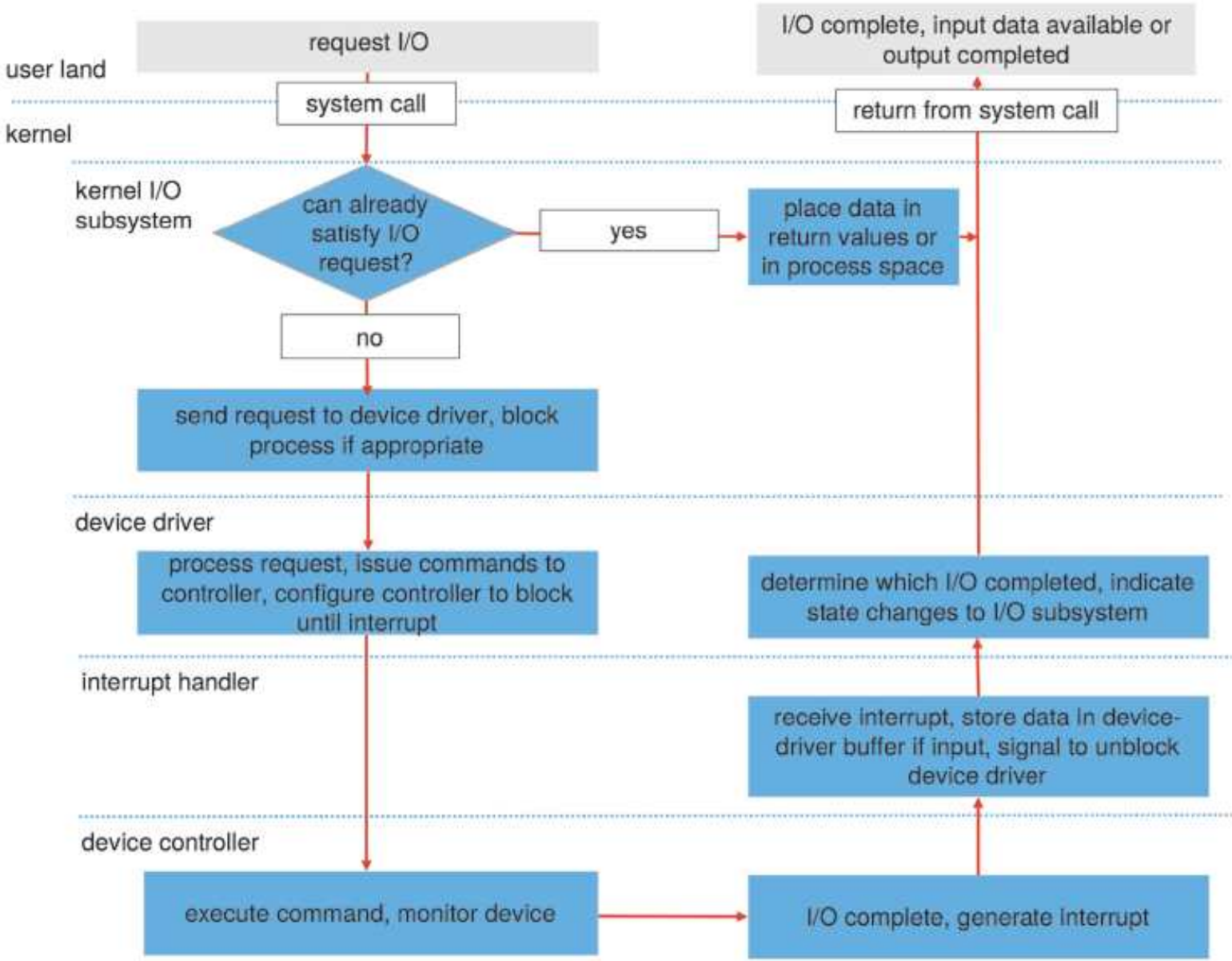
I/O Performance of Storage and Network Latency



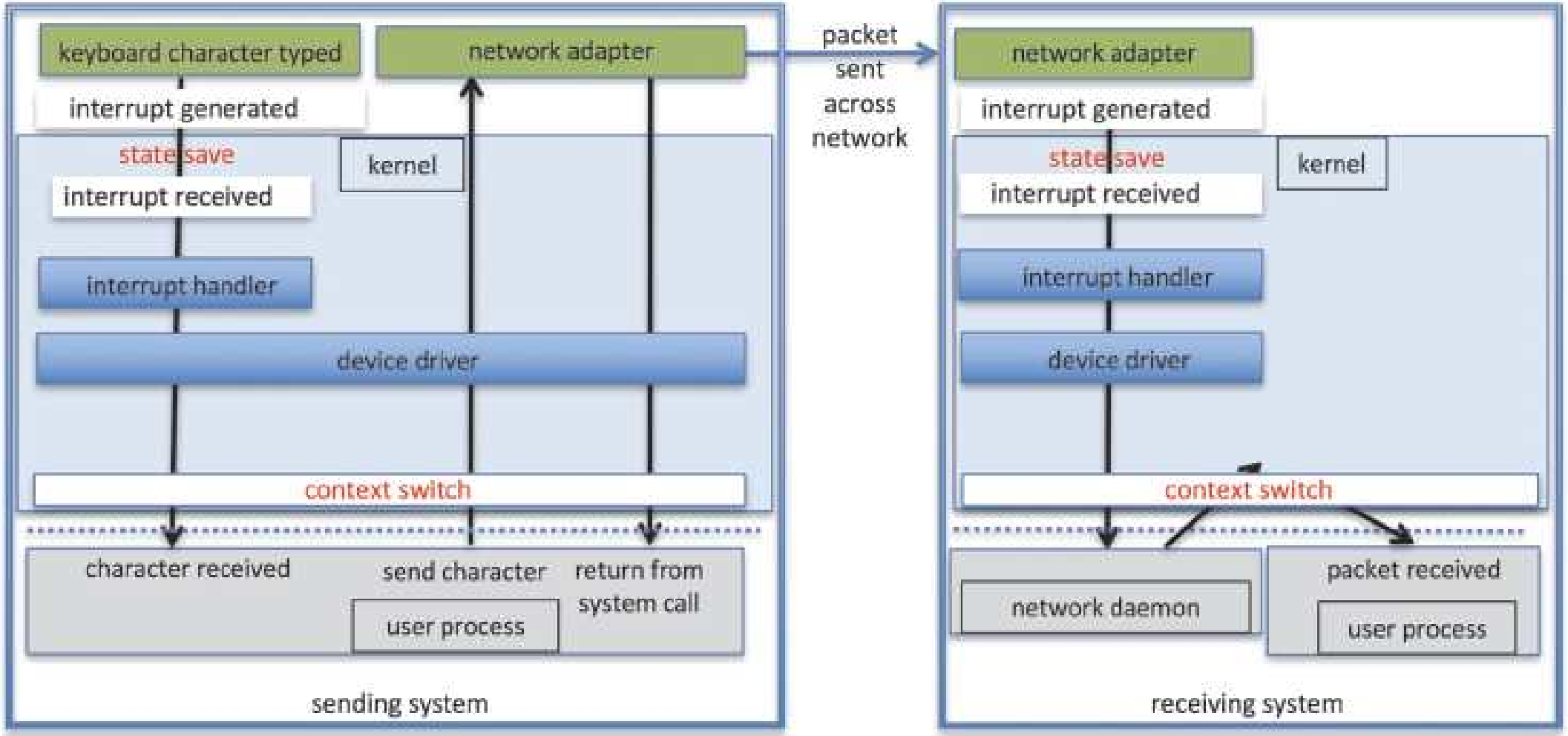
Kernel I/O Structure



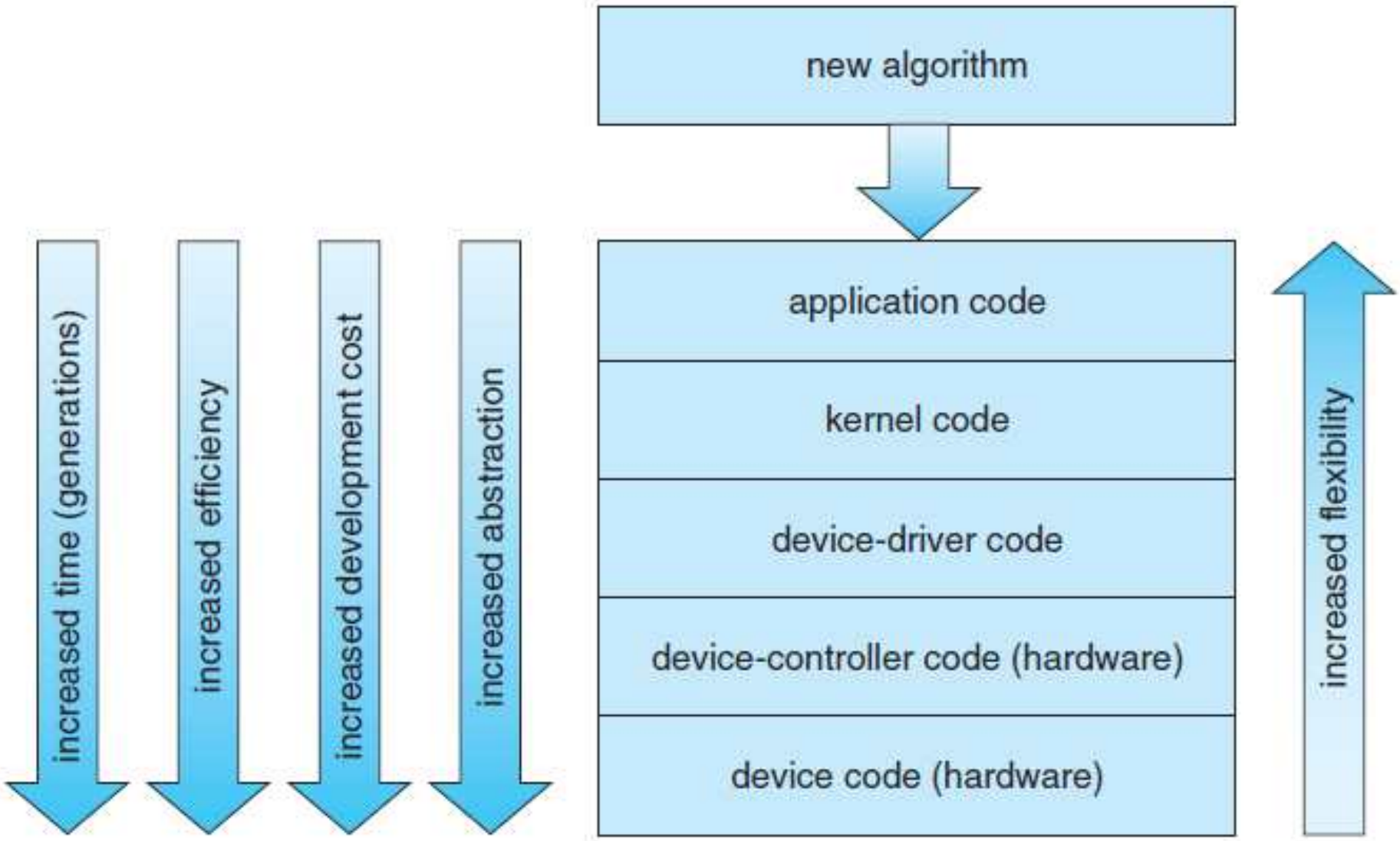
Life Cycle of An I/O Request



Intercomputer Communications



Device-Functionality Progression

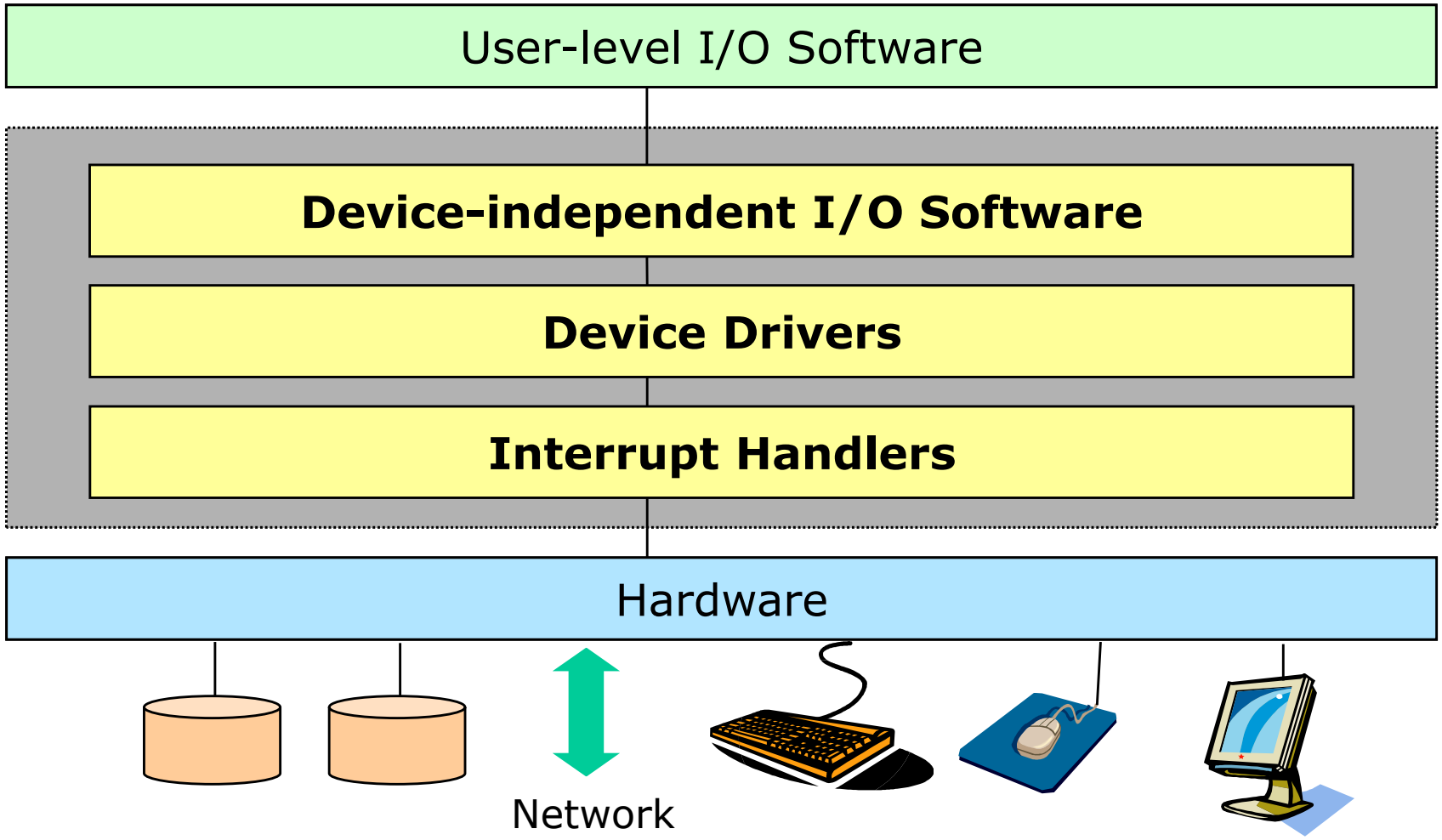


Goals of I/O Software

Goals

- ✓ Device independence
  - Programs can access any I/O device without specifying device in advance
- ✓ Uniform naming
  - Name of a file or device should simply be a string or an integer
- ✓ Error handling
  - Handle as close to the hardware as possible
- ✓ Synchronous vs. asynchronous
  - blocked transfers vs. interrupt-driven
- ✓ Buffering
  - Data coming off a device cannot be stored in final destination
- ✓ Sharable vs. dedicated devices
  - Disks vs. tape drives
  - Unsharable devices introduce problems such as deadlocks

I/O Software Layers



Interrupt Handlers

Handling interrupts

Critical actions

: Acknowledge an interrupt to the PIC.
: Reprogram the PIC or the device controller.
: Update data structures accessed by both the device and the processor.

Reenable interrupts

Noncritical actions

: Update data structures that are accessed only by the processor.
(e.g., reading the scan code from the keyboard)

Return from interrupts

Noncritical deferred actions

: Actions may be delayed.
: Copy buffer contents into the address space of some process (e.g., sending the keyboard line buffer to the terminal handler process).
Bottom half (Linux)

Device Drivers

Device drivers

- ✓ Device-specific code to control each I/O device interacting with device-independent I/O software and interrupt handlers
- ✓ Requires to define a well-defined model and a standard interface of how they interact with the rest of the OS
- ✓ Implementing device drivers:
  - Statically linked with the kernel
  - Selectively loaded into the system during boot time
  - Dynamically loaded into the system during execution (especially for hot pluggable devices)

Device-Independent I/O Software

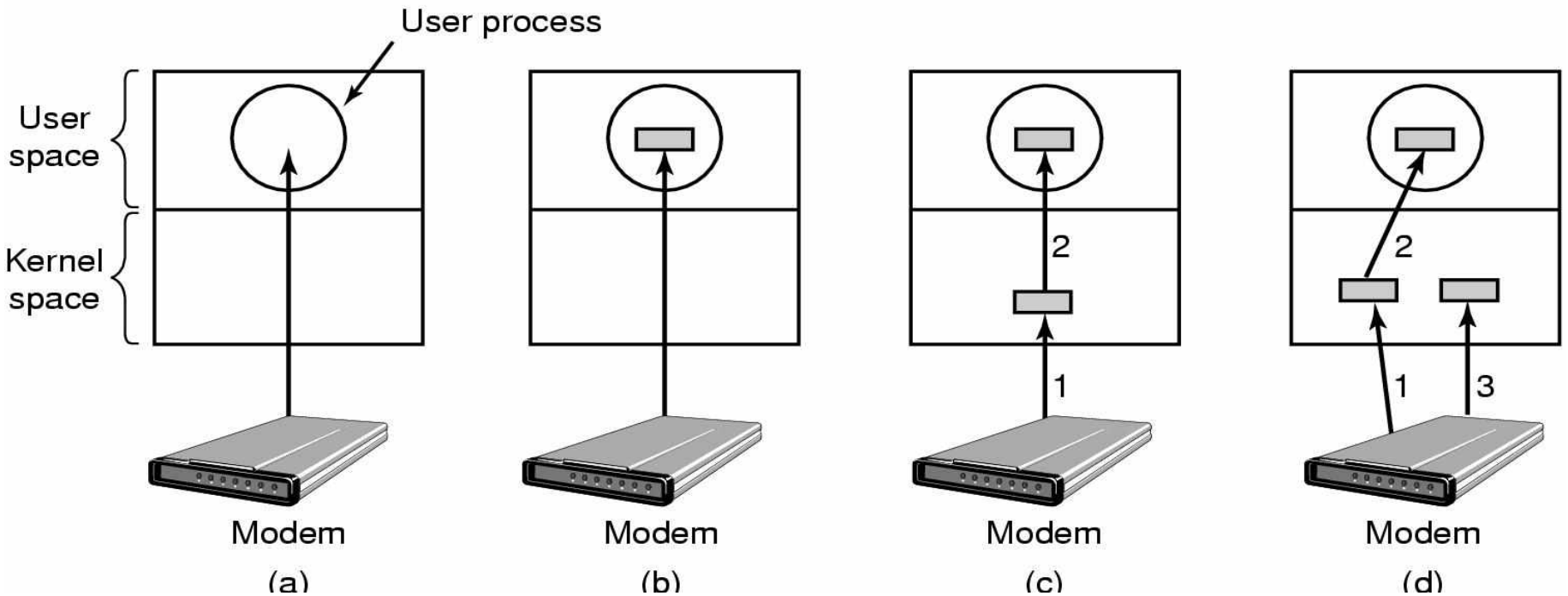
Uniform interfacing for device drivers

- ✓ In Unix, devices are modeled as special files
  - They are accessed through the use of system calls such as open(), read(), write(), close(), ioctl(), etc.
  - A file name is associated with each device
- ✓ Major device number locates the appropriate driver
  - Minor device number (stored in i-node) is passed as a parameter to the driver in order to specify the unit to be read or written
- ✓ The usual protection rules for files also apply to I/O devices

Device-Independent I/O Software

Buffering

- ✓ (a) Unbuffered
- ✓ (b) Buffered in user space
- ✓ (c) Buffered in the kernel space
- ✓ (d) Double buffering in the kernel



Device-Independent I/O Software

Error reporting

- ✓ Many errors are device-specific and must be handled by the appropriate driver, but the framework for error handling is device independent
- ✓ Programming errors vs. actual I/O errors
- ✓ Handling errors
  - Returning the system call with an error code
  - Retrying a certain number of times
  - Ignoring the error
  - Killing the calling process
  - Terminating the system

Device-Independent I/O Software

Allocating and releasing dedicated devices

- ✓ Some devices cannot be shared

(1) Require processes to perform open()'s on the special files for devices directly

- The process retries if open() fails

(2) Have special mechanisms for requesting and releasing dedicated devices

- An attempt to acquire a device that is not available blocks the caller

Device-independent block size

- ✓ Treat several sectors as a single logical block
- ✓ The higher layers only deal with abstract devices that all use the same block size

User-Space I/O Software

Provided as a library

- ✓ Standard I/O library in C
  - fopen() vs. open()

Spooling

- ✓ A way of dealing with dedicated I/O devices in a multiprogramming system
- ✓ Implemented by a daemon and a spooling directory
- ✓ Printers, network file transfers, USENET news, mails, etc.

I/O Systems Layers