Chapter 13: I/O Systems

Chapter 13: I/O Systems

- I/O Hardware
- Application I/O Interface
- Kernel I/O Subsystem
- Transforming I/O Requests to Hardware Operations
- Streams
- Performance

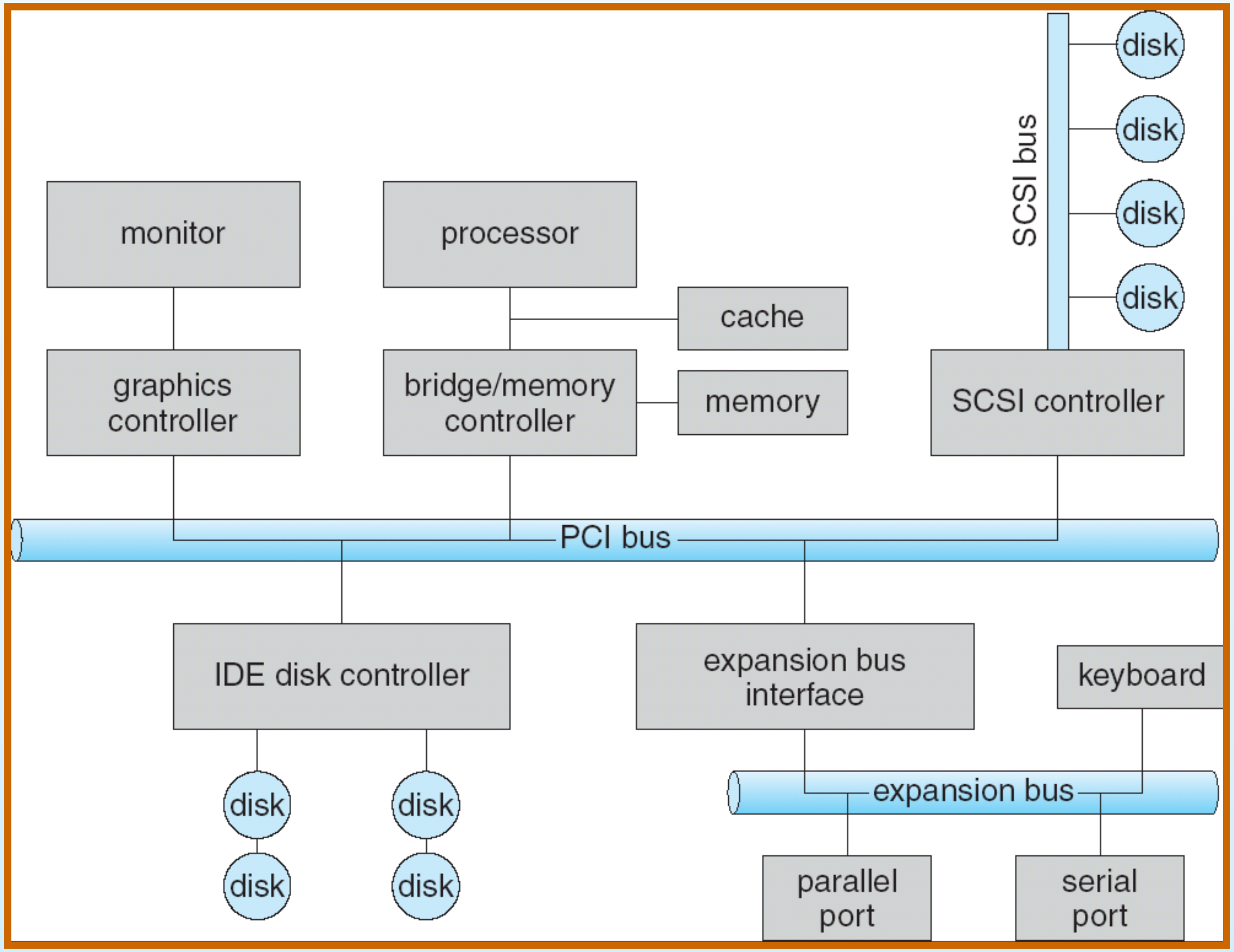
Objectives

- Explore the structure of an operating system's I/O subsystem
- Discuss the principles of I/O hardware and its complexity
- Provide details of the performance aspects of I/O hardware and software

I/O Hardware

- Incredible variety of I/O devices
- Common concepts
  - Port
  - Bus
  - Controller (host adapter)
- I/O instructions control devices
- Devices have addresses, used by
  - Direct I/O instructions
  - Memory-mapped I/O

A Typical PC Bus Structure



Device I/O Port Locations on PCs (partial)

I/O address range (hexadecimal)	device
000–00F	DMA controller
020–021	interrupt controller
040–043	timer
200–20F	game controller
2F8–2FF	serial port (secondary)
320–32F	hard-disk controller
378–37F	parallel port
3D0–3DF	graphics controller
3F0–3F7	diskette-drive controller
3F8–3FF	serial port (primary)

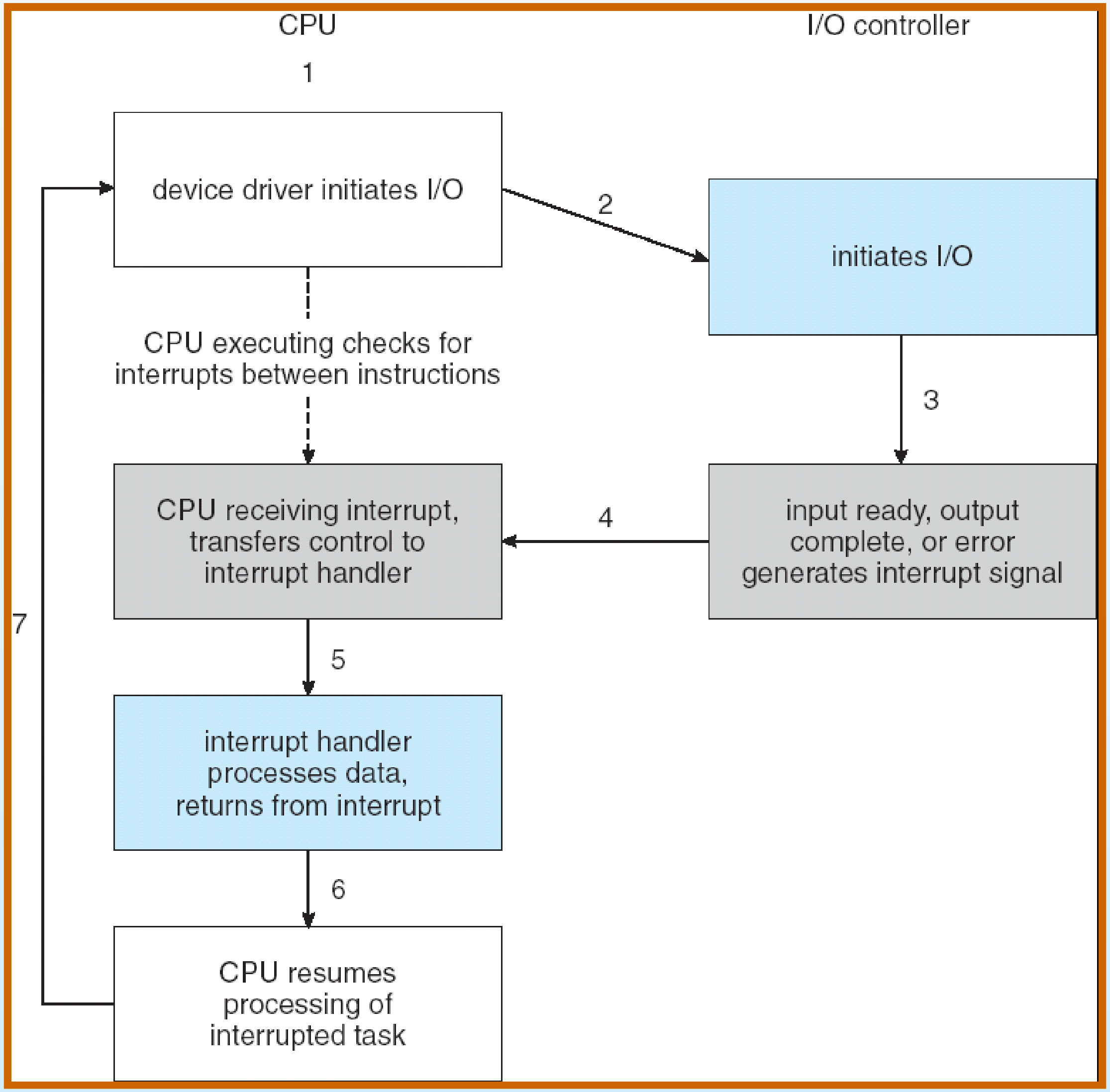
Polling

- Determines state of device
  - command-ready
  - busy
  - Error
- Busy-wait cycle to wait for I/O from device

Interrupts

- CPU Interrupt-request line triggered by I/O device
- Interrupt handler receives interrupts
- Maskable to ignore or delay some interrupts
- Interrupt vector to dispatch interrupt to correct handler
  - Based on priority
  - Some nonmaskable
- Interrupt mechanism also used for exceptions

Interrupt-Driven I/O Cycle



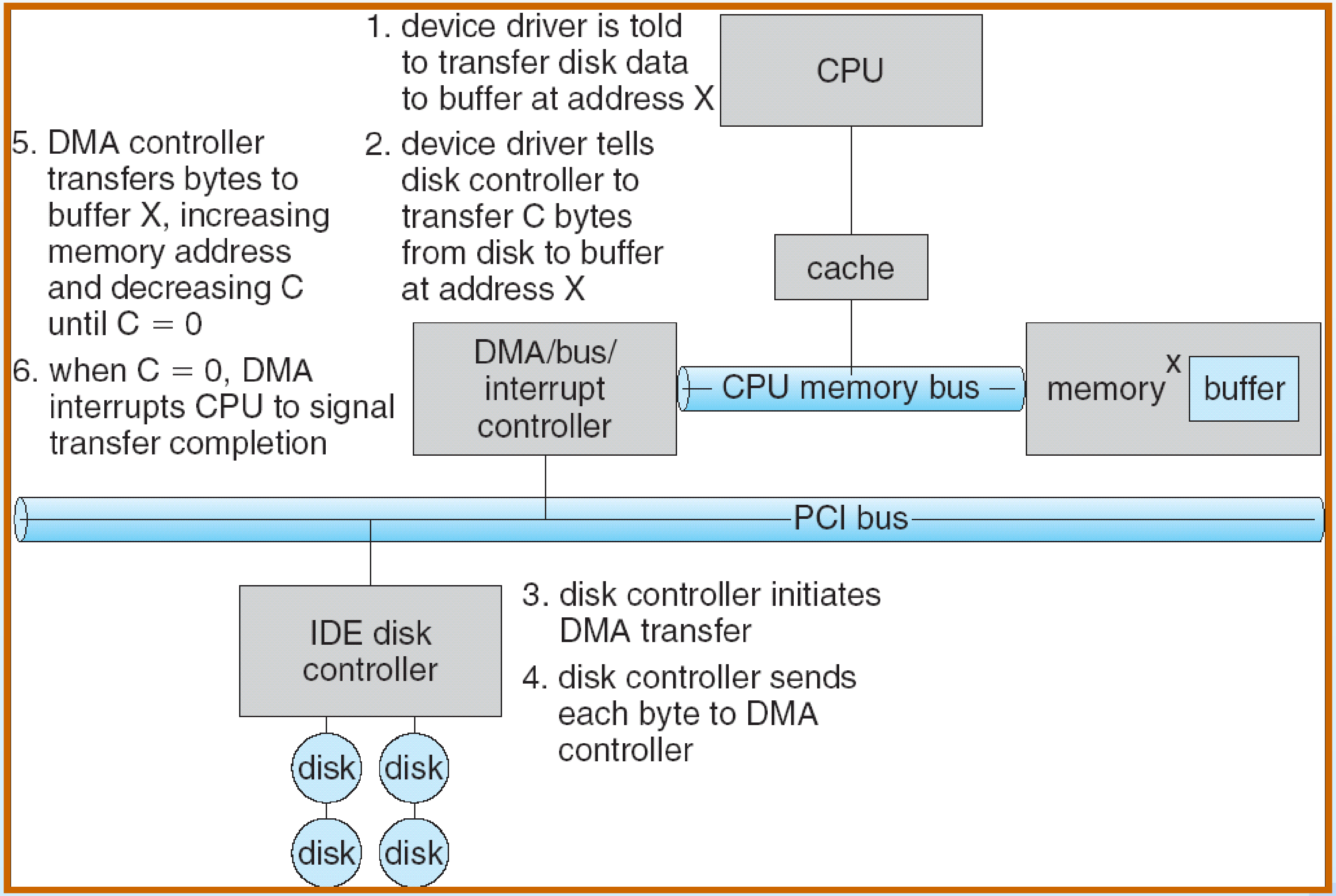
Intel Pentium Processor Event-Vector Table

vector number	description
0	divide error
1	debug exception
2	null interrupt
3	breakpoint
4	INTO-detected overflow
5	bound range exception
6	invalid opcode
7	device not available
8	double fault
9	coprocessor segment overrun (reserved)
10	invalid task state segment
11	segment not present
12	stack fault
13	general protection
14	page fault
15	(Intel reserved, do not use)
16	floating-point error
17	alignment check
18	machine check
19–31	(Intel reserved, do not use)
32–255	maskable interrupts

Direct Memory Access

- Used for large data movement
- Requires DMA controller
- Transfer data directly between I/O device and memory
  - bypass CPU

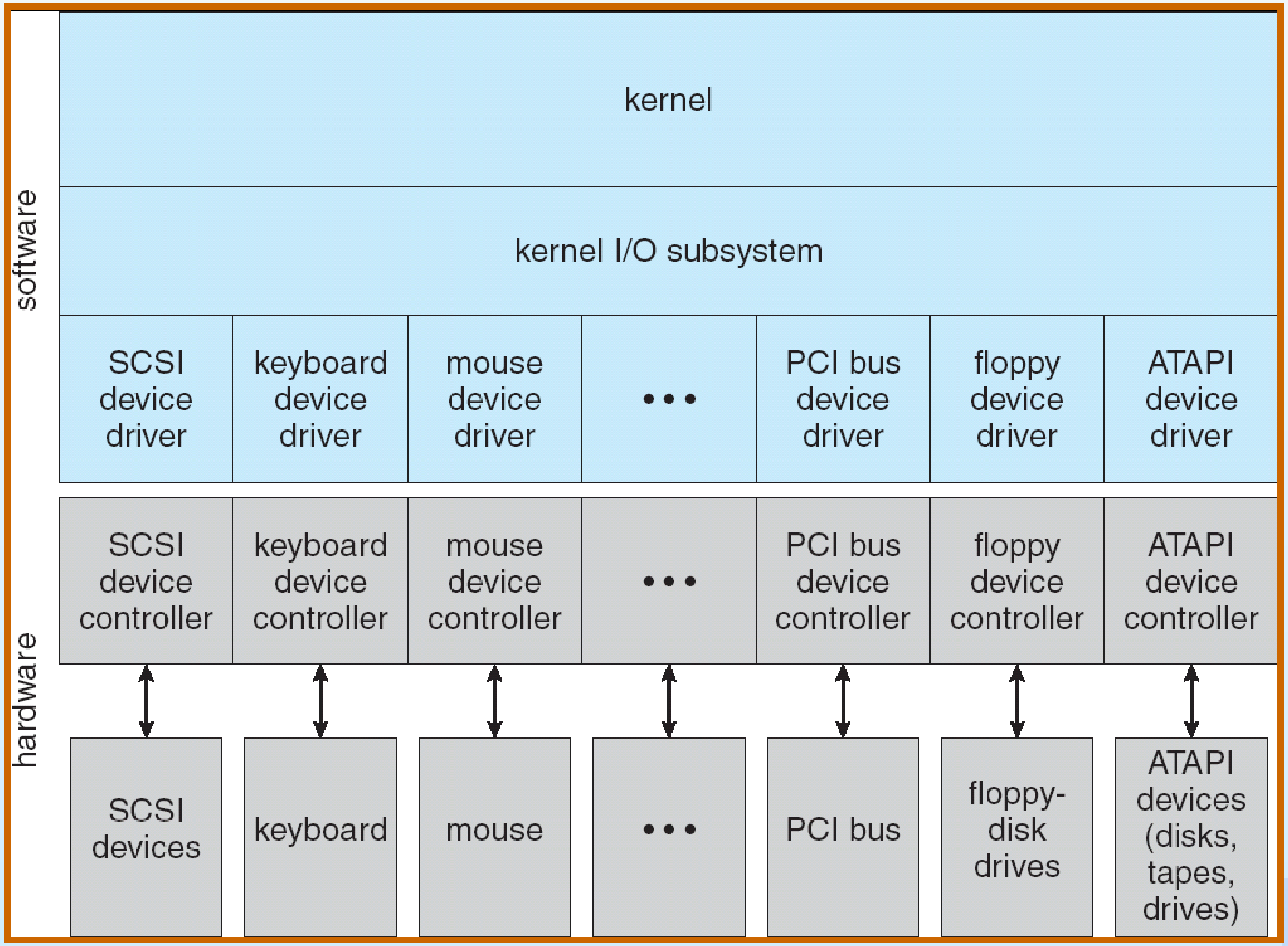
Six Step Process to Perform DMA Transfer



Application I/O Interface

- Devices vary in many dimensions
  - Character-stream or block
  - Sequential or random-access
  - Sharable or dedicated
  - Speed of operation
  - read-write, read only, or write only
- I/O system calls encapsulate device behaviors in generic classes
  - open(), read(), write(), close()......
  - ioctl() & DeviceIoControl()
- Device-driver layer hides differences among I/O controllers from kernel

A Kernel I/O Structure



Block and Character Devices

- Block devices include disk drives
  - Commands include read, write, seek
  - Raw I/O or file-system access
  - Memory-mapped file access possible
- Character devices include keyboards, mice, serial ports
  - Commands include `get`, `put`
  - Libraries layered on top allow line editing

Network Devices

- Have own interface
- Unix and Windows NT/9*x*/2000/XP include socket interface
  - Separates network protocol from network operation
  - Includes `select` functionality

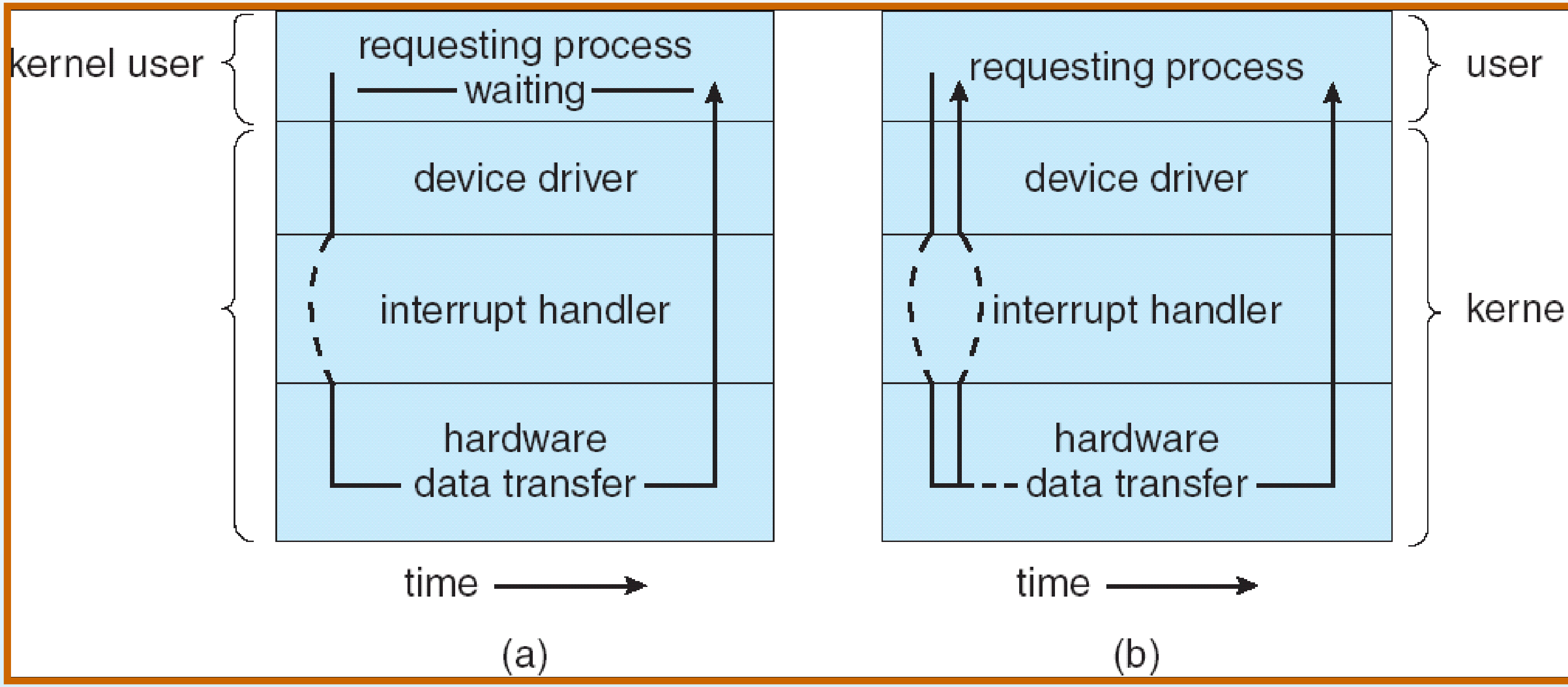
Clocks and Timers

- Provide current time, elapsed time, timer
- Programmable interval timer used for timings, periodic interrupts
- `ioctl` (on UNIX) covers odd aspects of I/O such as clocks and timers

Blocking and Nonblocking I/O

- **Blocking - process suspended until I/O completed**
  - Easy to use and understand
  - Insufficient for some needs
- **Nonblocking - I/O call returns as much as available**
  - Returns quickly with count of bytes read or written
  - Implemented via multi-threading
- **Asynchronous - process runs while I/O executes**
  - Difficult to use
  - I/O subsystem signals process when I/O completed

Two I/O Methods



Synchronous

Asynchronous

Kernel I/O Subsystem

- Scheduling
  - Some I/O request ordering via per-device queue
  - Some OSs try fairness
- Buffering - store data in memory while transferring between devices
  - To cope with device speed mismatch
    - Double buffering
  - To cope with device transfer size mismatch
  - To maintain “copy semantics”

Kernel I/O Subsystem

- Caching - fast memory holding copy of data
  - Always just a copy
  - Key to performance
- Spooling - hold output for a device
  - If device can serve only one request at a time
  - i.e., Printing
- Device reservation - exclusive access to a device
  - System calls for allocation and deallocation
  - Watch out for deadlock

Error Handling

- OS can recover from disk read, device unavailable, transient write failures
- Most return an error number or code when I/O request fails
- System error logs hold problem reports

I/O Protection

- User process may accidentally or purposefully attempt to disrupt normal operation via illegal I/O instructions
  - All I/O instructions defined to be privileged
  - I/O must be performed via system calls
    - Memory-mapped and I/O port memory locations must be protected too
  - However, DirectX

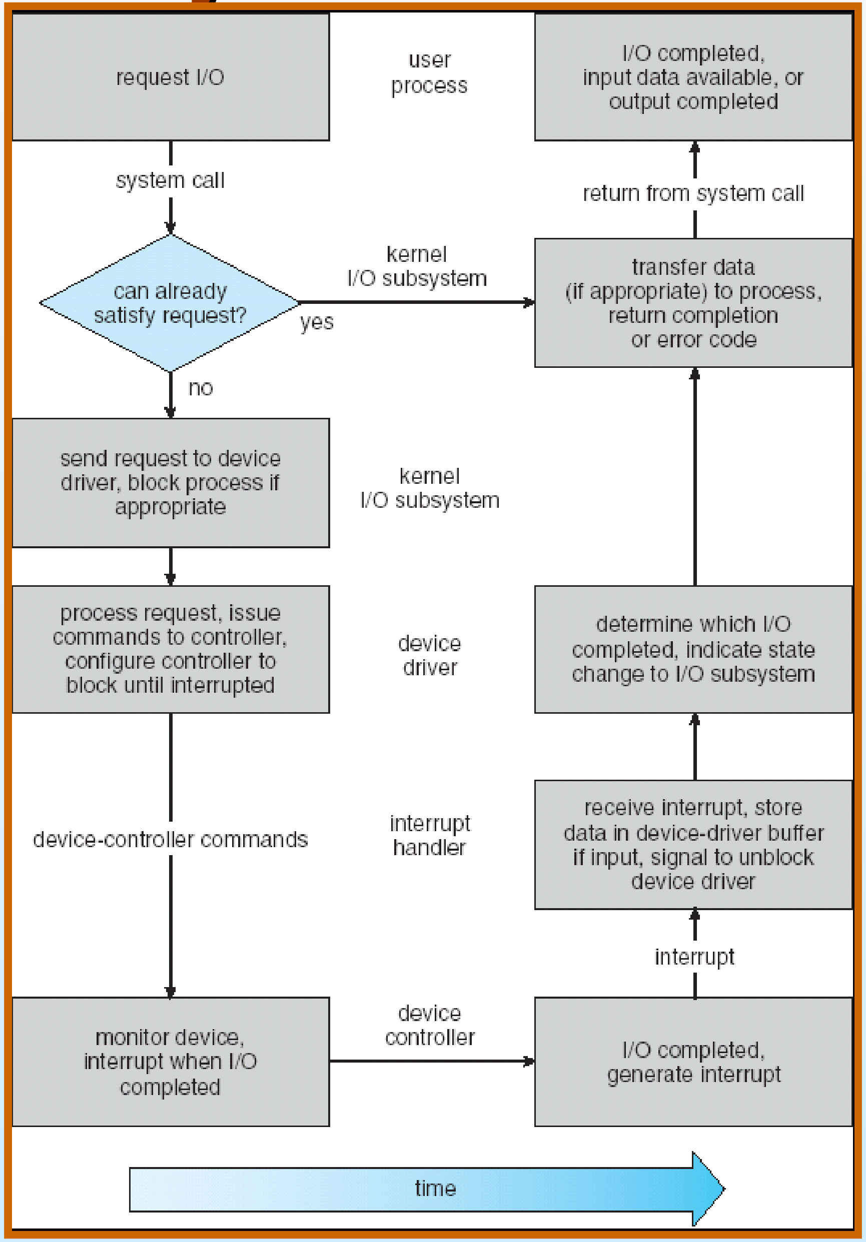
Kernel Data Structures

- Kernel keeps state info for I/O components
  - Open file tables
  - Network connections
  - Character device state
- Many, many complex data structures to track buffers, memory allocation, “dirty” blocks
- Some use object-oriented methods and message passing to implement I/O

I/O Requests to Hardware Operations

- **Consider reading a file from disk for a process:**
  - **Determine device holding file**
  - **Translate name to device representation**
  - **Physically read data from disk into buffer**
  - **Make data available to requesting process**
  - **Return control to process**

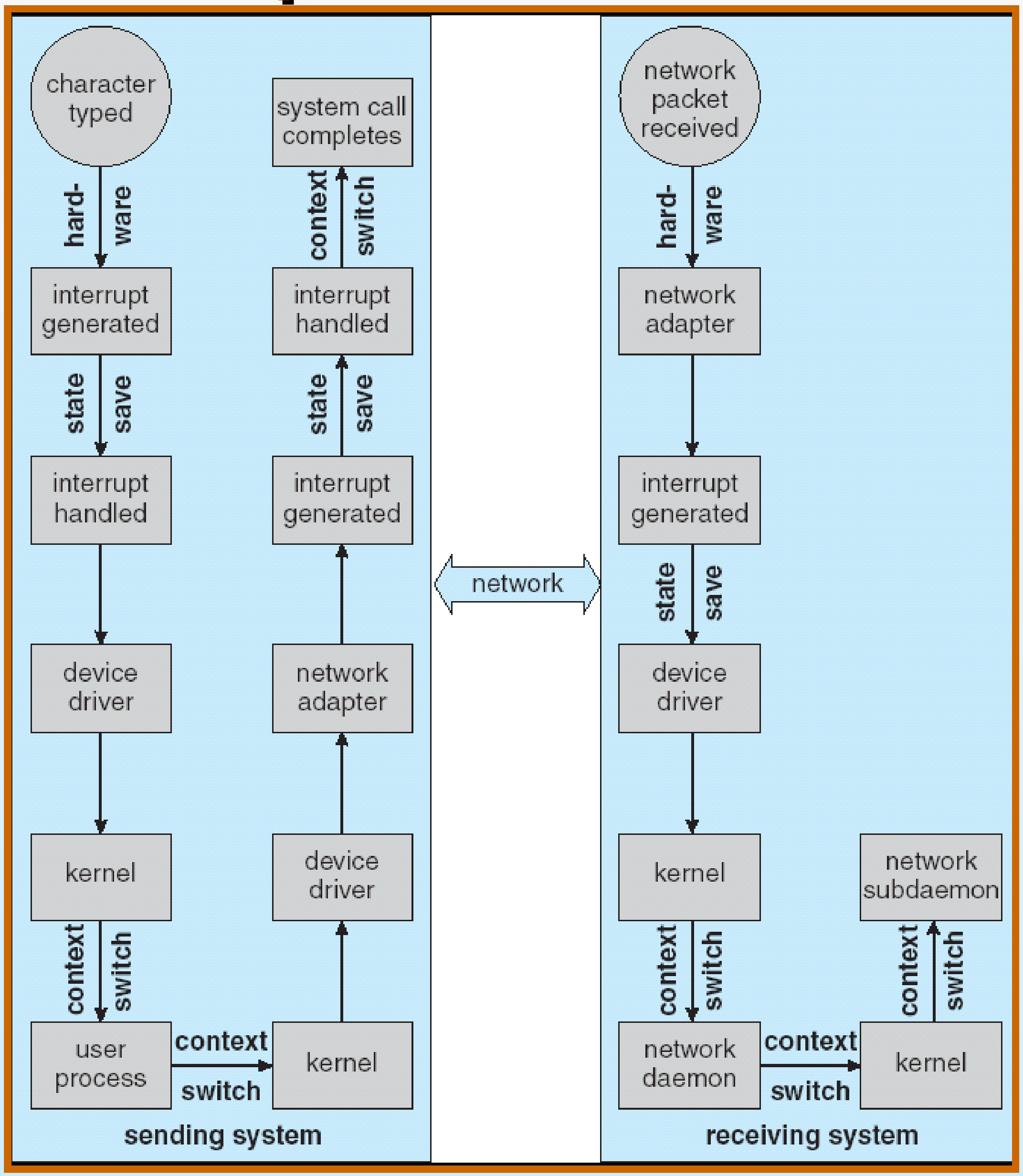
Life Cycle of An I/O Request



Performance

- I/O, a major factor in system performance:
  - Heavily demands CPU to execute device driver, kernel I/O code
  - Context switches due to interrupts
  - Data copying
  - Network traffic especially stressful

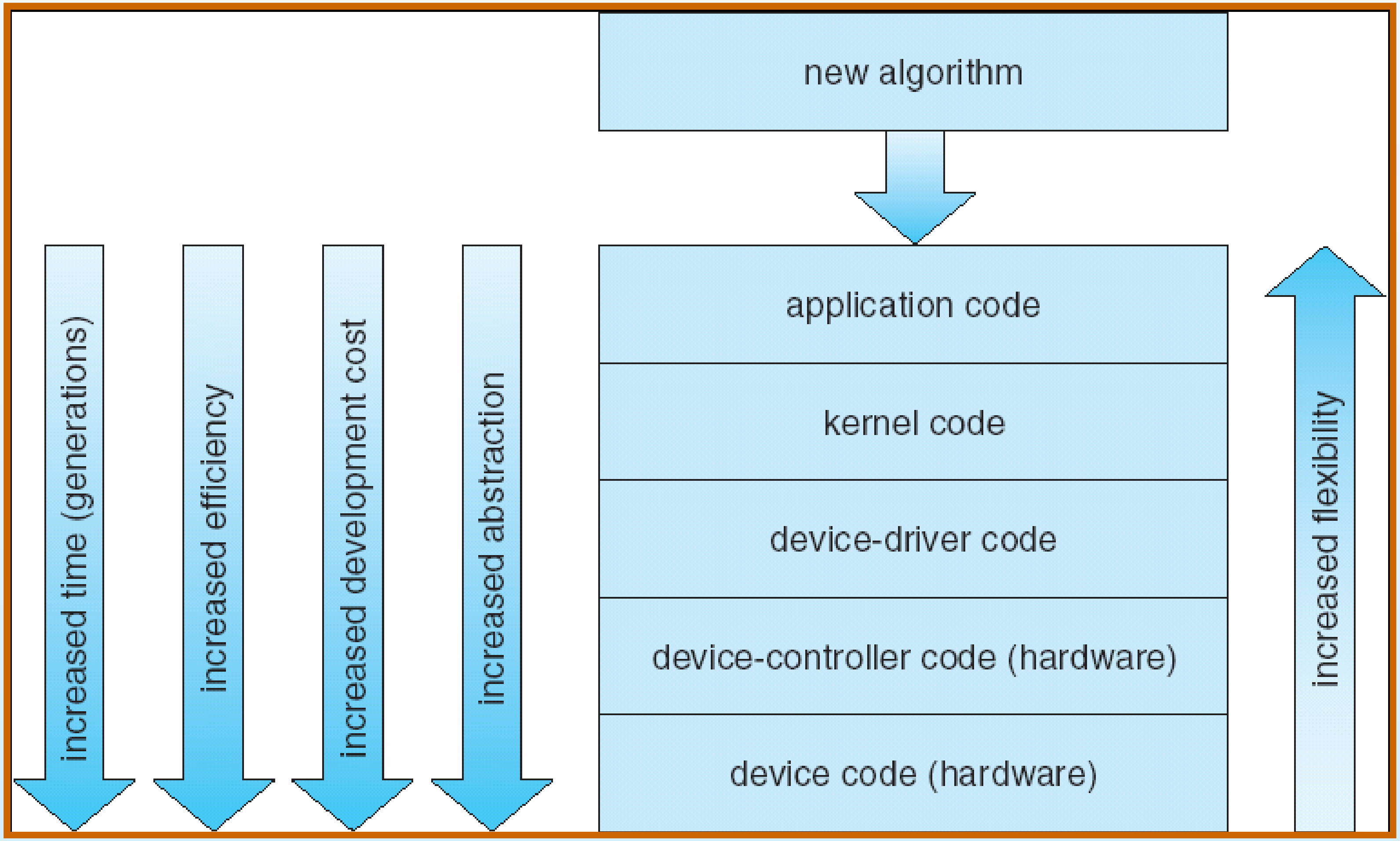
Intercomputer Communications



Improving Performance

- Reduce number of context switches
- Reduce data copying
- Reduce interrupts by using large transfers, smart controllers, polling
- Use DMA
- Balance CPU, memory, bus, and I/O performance for highest throughput

Device-Functionality Progression



End of Chapter 13