R

بسم الله الرحمن الرحیم

سیستم عامل

جلسه بیستم – دستگاه‌های ورودی و خروجی

جلسه‌ی گذشته

Local vs. Global Replacement

- Assume several processes: A, B, C, ...
- Some process gets a page fault (say, process A)
- Choose a page to replace.
- *Local page replacement*
  - *Only choose one of A's pages*
- *Global page replacement*
  - *Choose any page*

Proactive Replacement

- Replacing victim frame on each page fault typically requires two disk accesses per page fault
- Alternative → the O.S. can keep several pages free in anticipation of upcoming page faults
- Free List (Inactive list): List of frames that ready for replacement

UNIX Page Replacement

- Some Proactive Page Replacement
- Enable Swapping daemon (kwapd) on low watermark

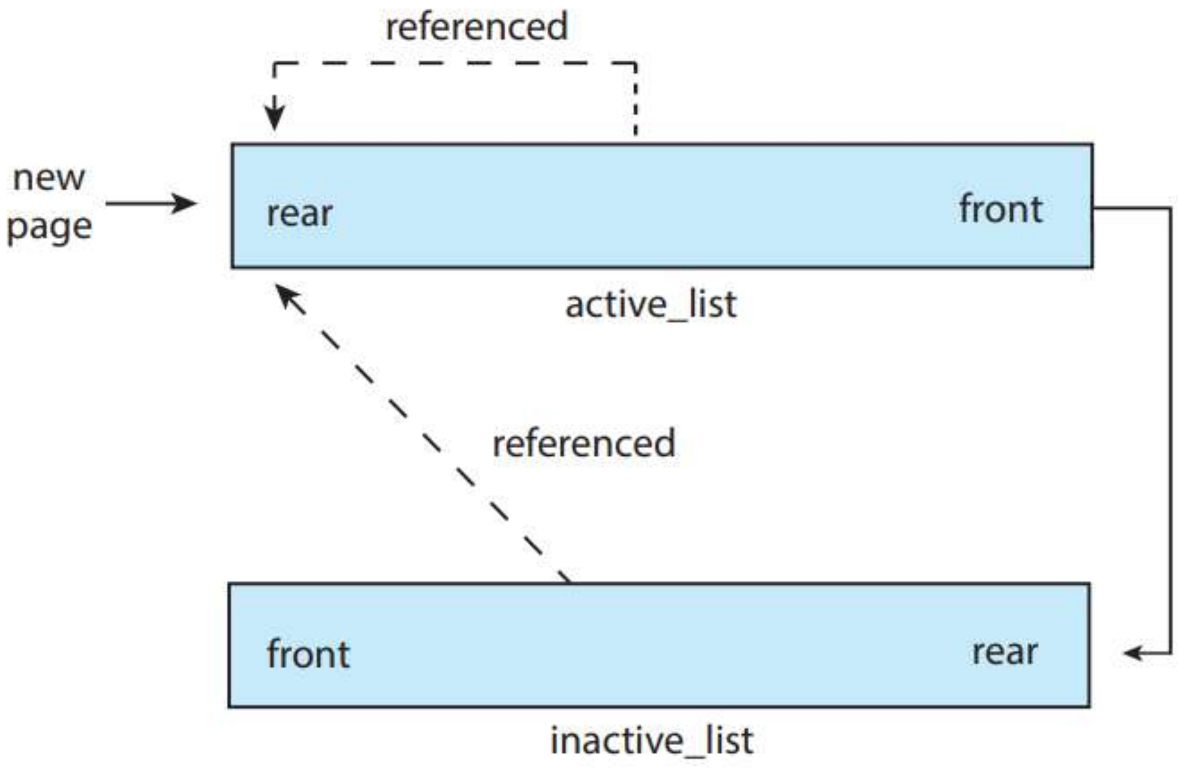


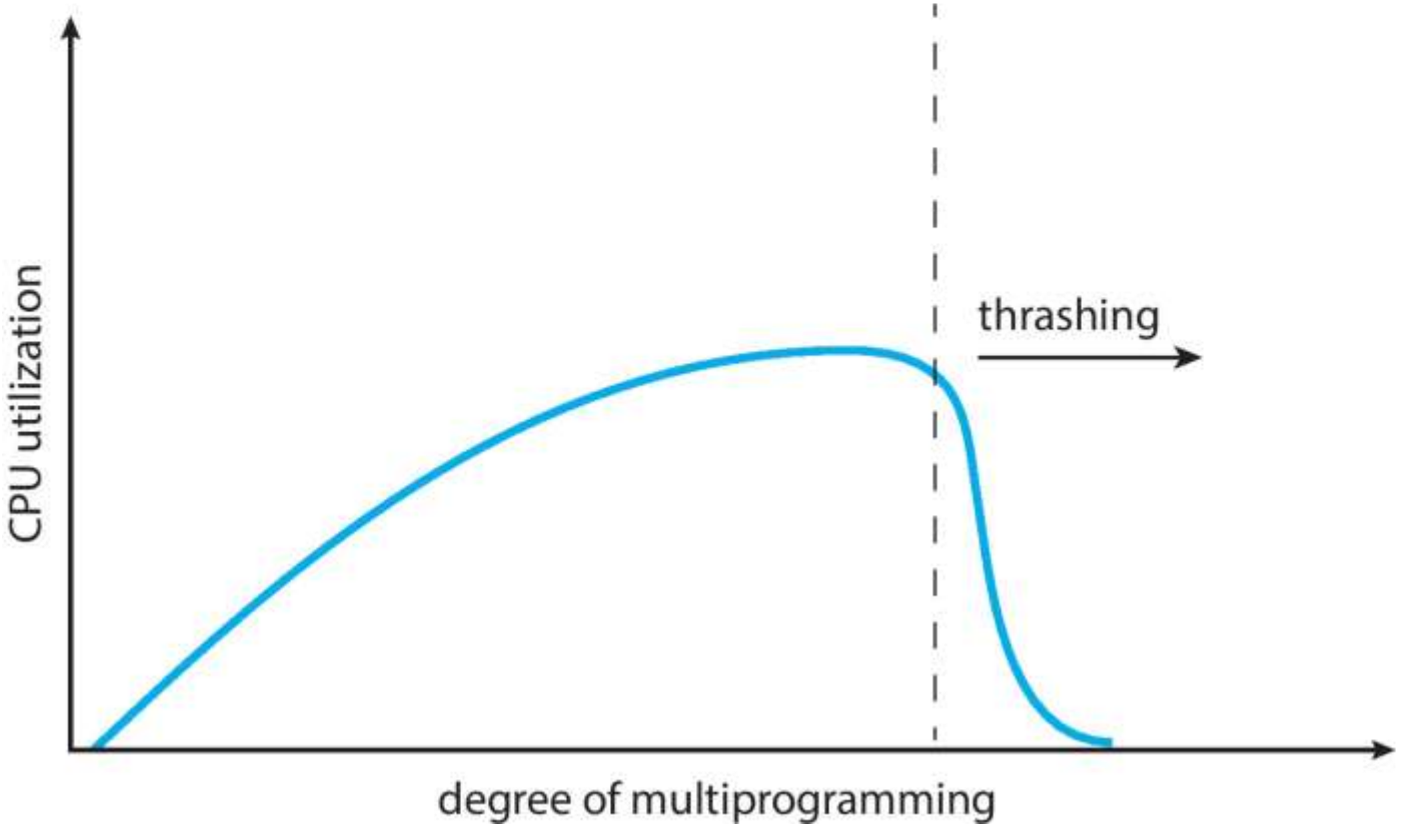
Figure 10.29 The Linux `active_list` and `inactive_list` structures.

UNIX Page Replacement

- Second Chance (Clock) Page replacement used as Approximation of LRU

Thrashing (Cont.)

- **Thrashing**. A process is busy swapping pages in and out



Working Set Algorithm

- *Based on prepaging (prefetching)*
  - *Load pages before they are needed*
- *Main idea:*
  - *Try to identify the process's working set based on time*
  - *Keep track of each page's time since last access*
  - *Assume working set valid for T time units*
  - *Replace pages older than T*

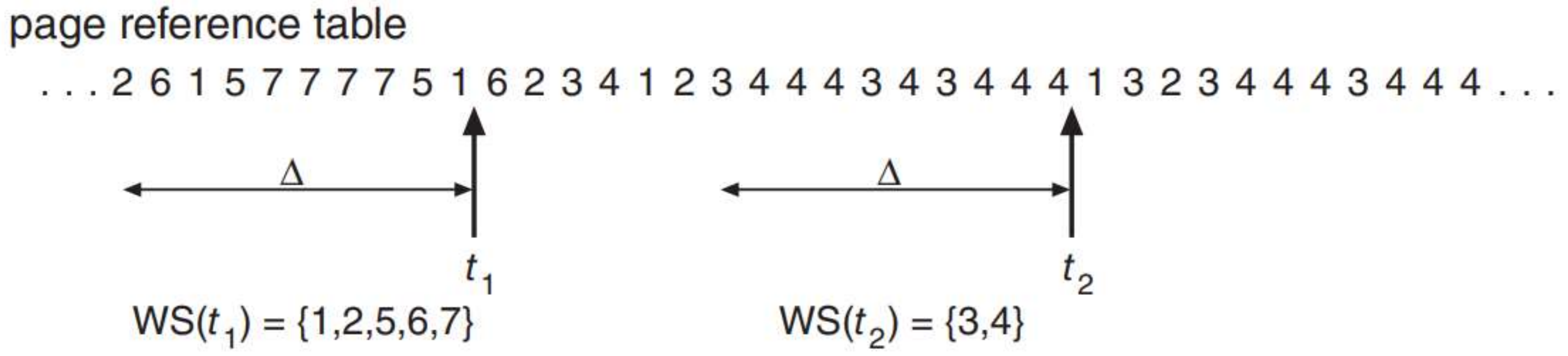


Figure 10.22 Working-set model.

Modeling Algorithm Performance

- Run a program
  - *Look at all memory references*
  - *Don't need all this data*
  - *Look at which pages are accessed*
  - 0 1 2 3 0 1 4 0 1 2 3 4
  - *0000001222333300114444001123444*
  - *Eliminate duplicates*
  - *012301401234*

- This defines the *Reference String*
  - *Use this to evaluate different algorithms*
  - *Count page faults given the same reference string*

۱۲۸×۱۲۸

Program Structure

i,j

i×۱۲۸+j

- Program structure
  - *int[128,128] data;*
  - *Each row is stored in one page*
  - *Program 1*

```
for (j = 0; j <128; j++)
    for (i = 0; i < 128; i++)
        data[i,j] = 0;
```

128 x 128 = 16,384 page faults

  - *Program 2*

```
for (i = 0; i < 128; i++)
    for (j = 0; j < 128; j++)
        data[i,j] = 0;
```

128 page faults

جلسه‌ی جدید

دستگاه‌های ورودی و خروجی

فصل ۱۲ کتاب

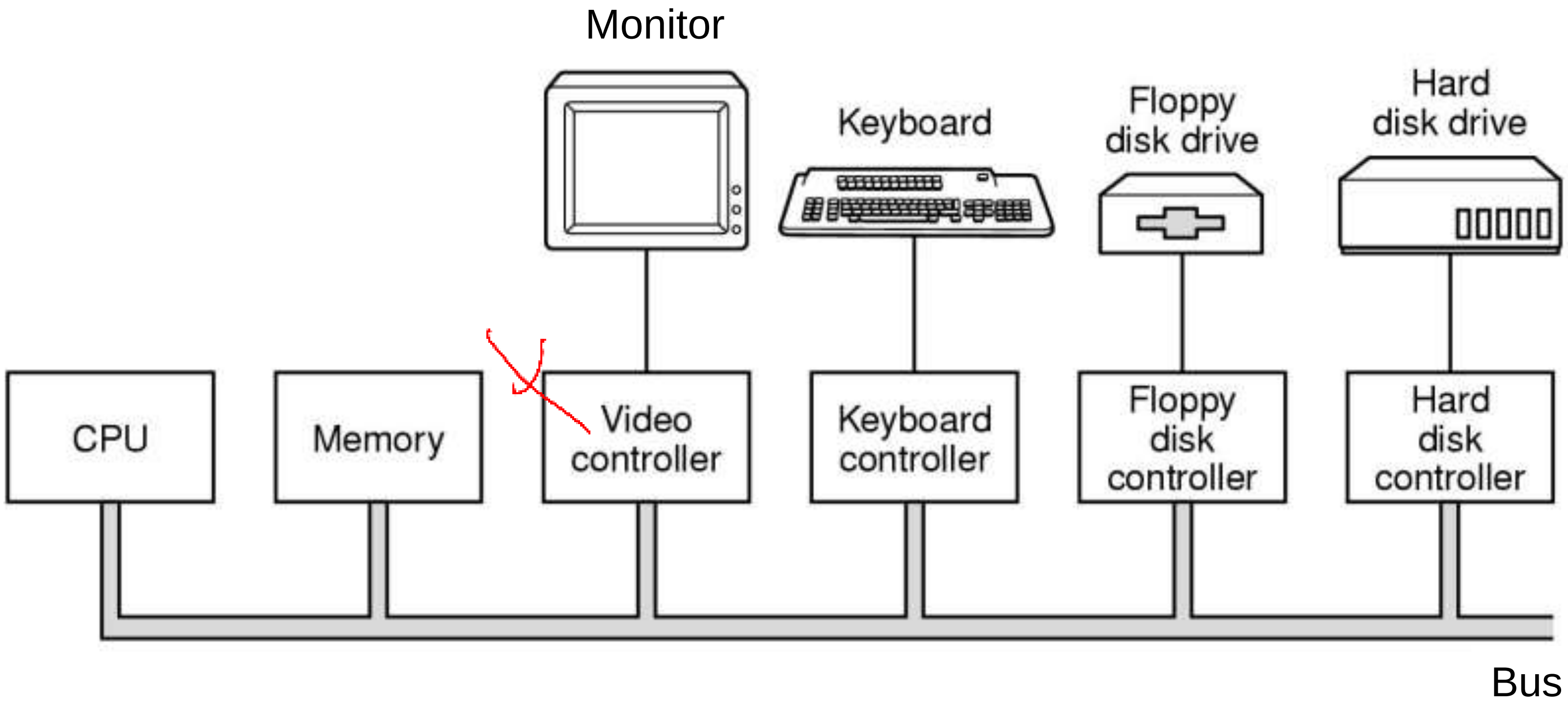
نمای کلی

Device Terminology

- Device (mechanical hardware)
- Device controller (electrical hardware)
- Device driver (software)

Devices & Controllers

- Components of a simple personal computer

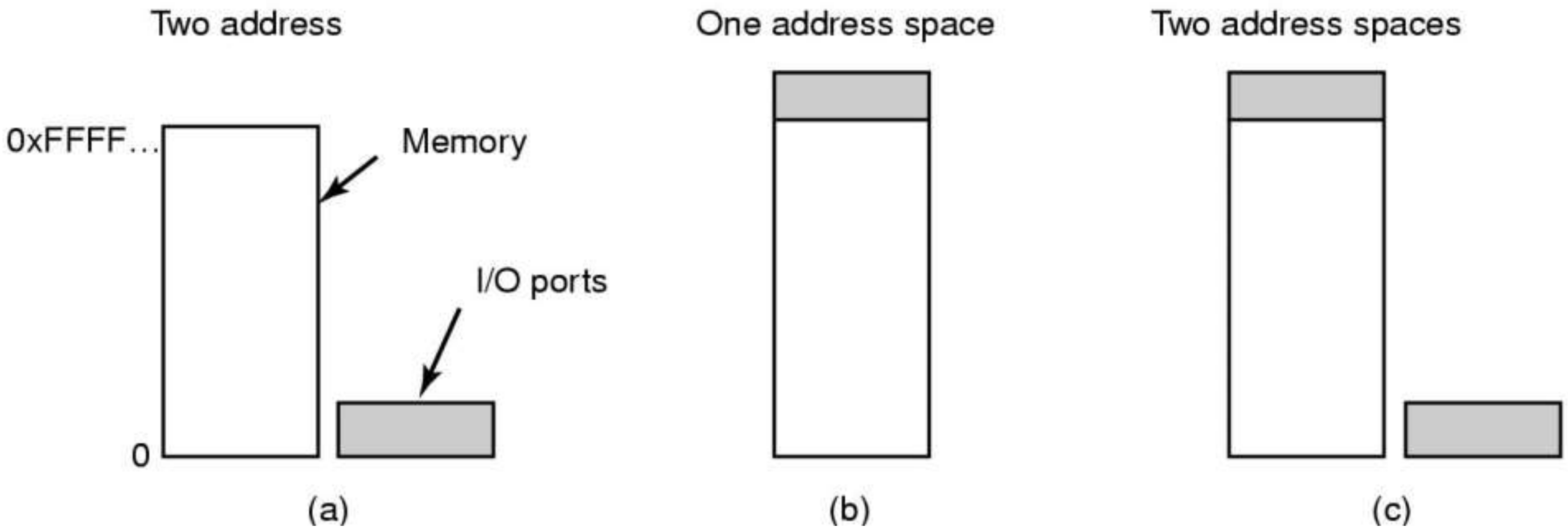


Device Controllers

- The Device vs. its Controller
- Some duties of a device controller:
  - *Interface between CPU and the Device*
  - *Start/Stop device activity*
  - *Convert serial bit stream to a block of bytes*
  - *Deal with error detection/correction*
  - *Move data to/from main memory*
- Some controllers may handle several (similar) devices

Communication With Devices

■Hardware supports I/O ports or memory mapped I/O for accessing device controller registers and buffers



I/O Ports

- Each port has a separate number.
- CPU has special I/O instructions
  - *in   r4,3*
  - *out   3,r4*

The I/O Port Number

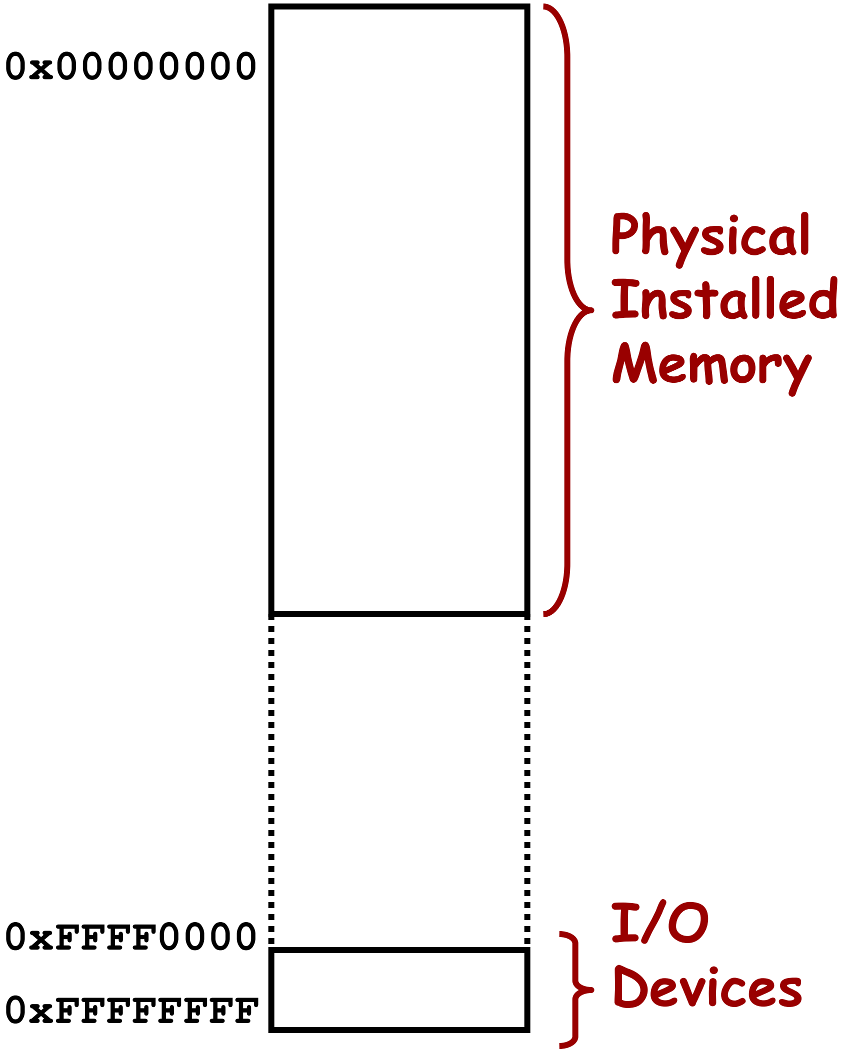
- Port numbers form an “address space”... separate from main memory
- Contrast with
  - *load   r4,3*
  - *store   3,r4*

Memory-Mapped I/O

- One address space for
  - *main memory*
  - *I/O devices*

- CPU has no special instructions
  - `load    r4,addr`
  - `store   addr,r4`

- I/O devices are "mapped" into
  - *very high addresses*



I/O Device Speed

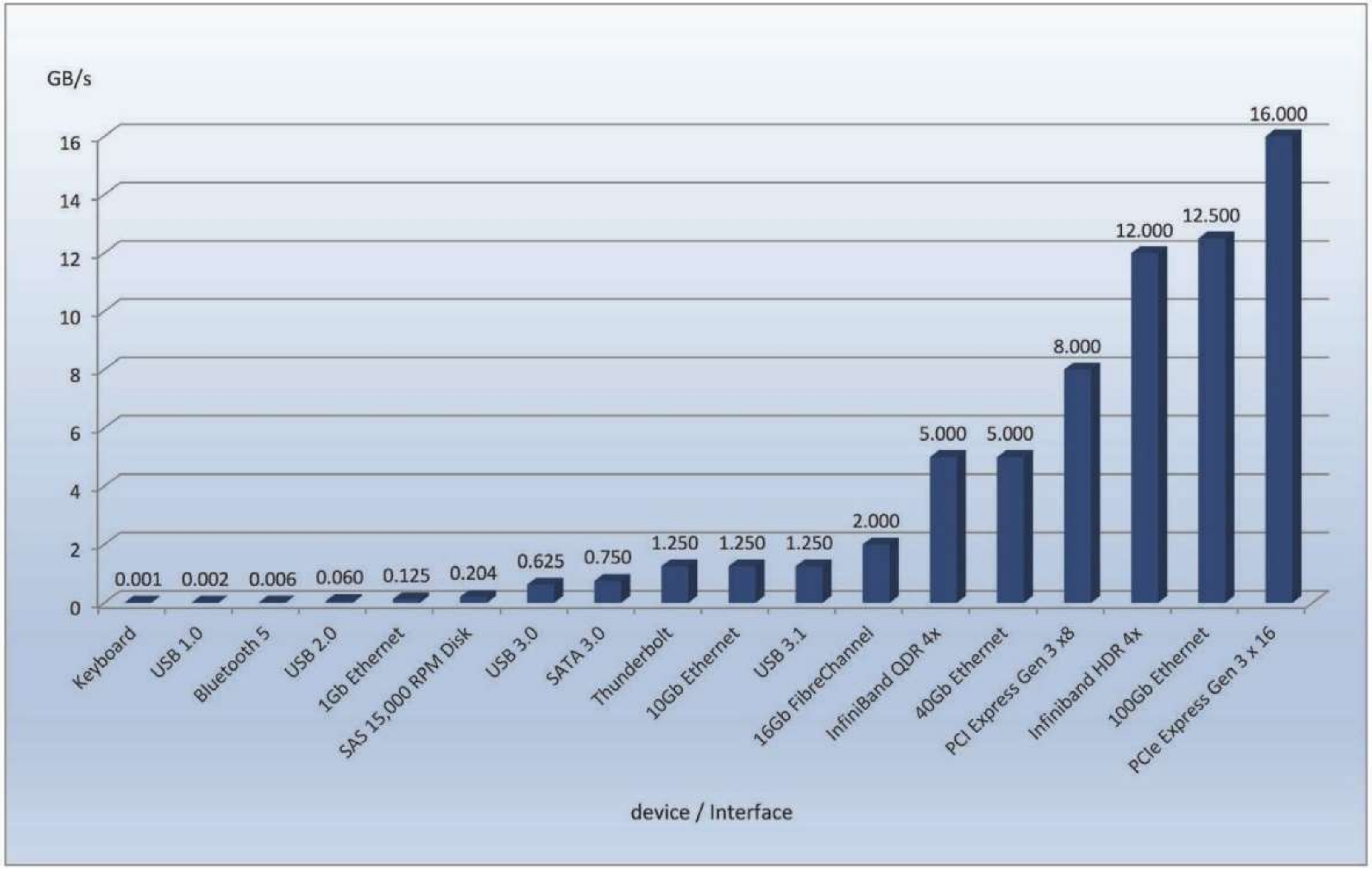


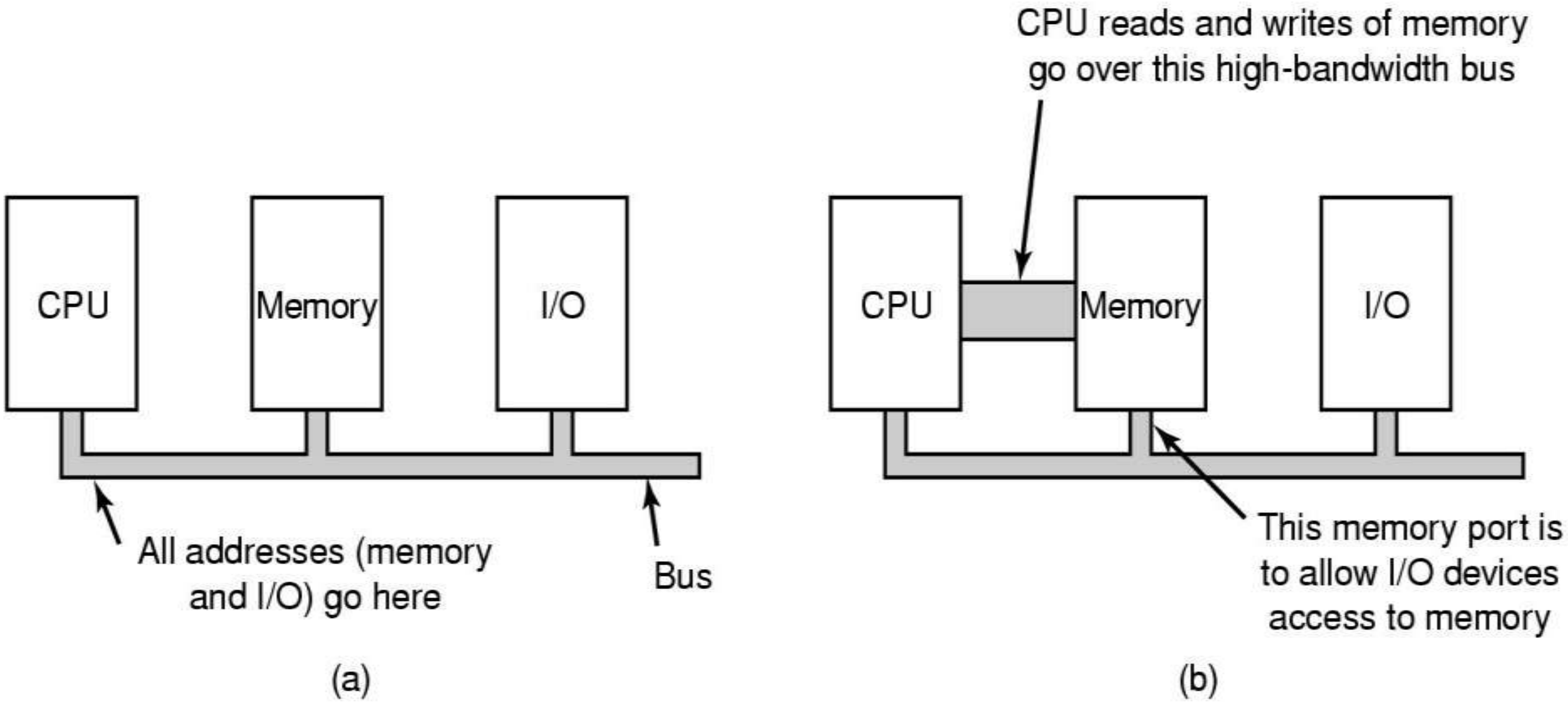
Figure 12.11 Common PC and data-center I/O device and interface speeds.

Hardware Performance Challenges

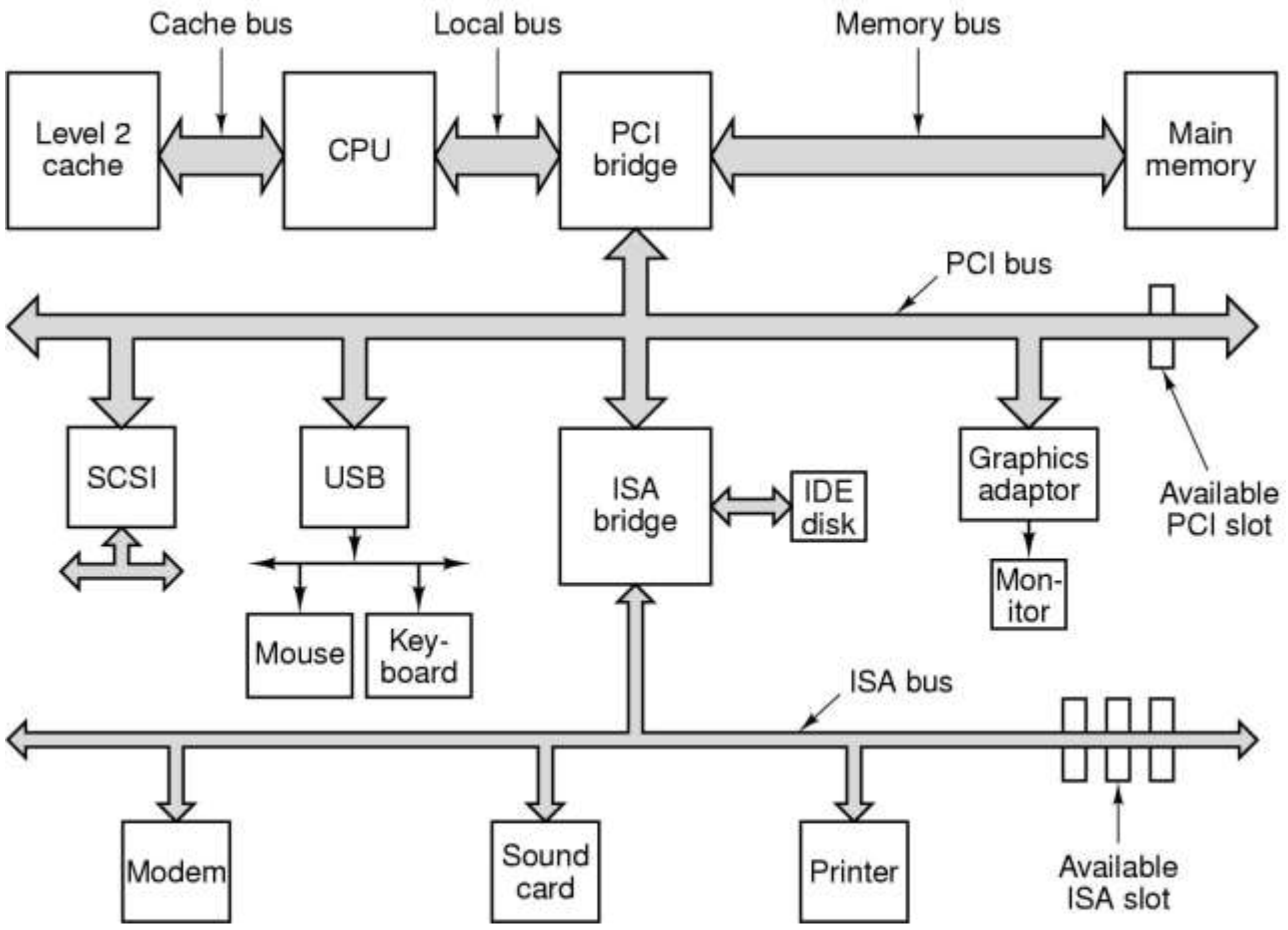
- How to prevent slow devices from slowing down memory due to bus contention
  - *What is bus contention?*

- How to access I/O addresses without interfering with memory performance

Dual Bus Architecture



Pentium Bus Architecture

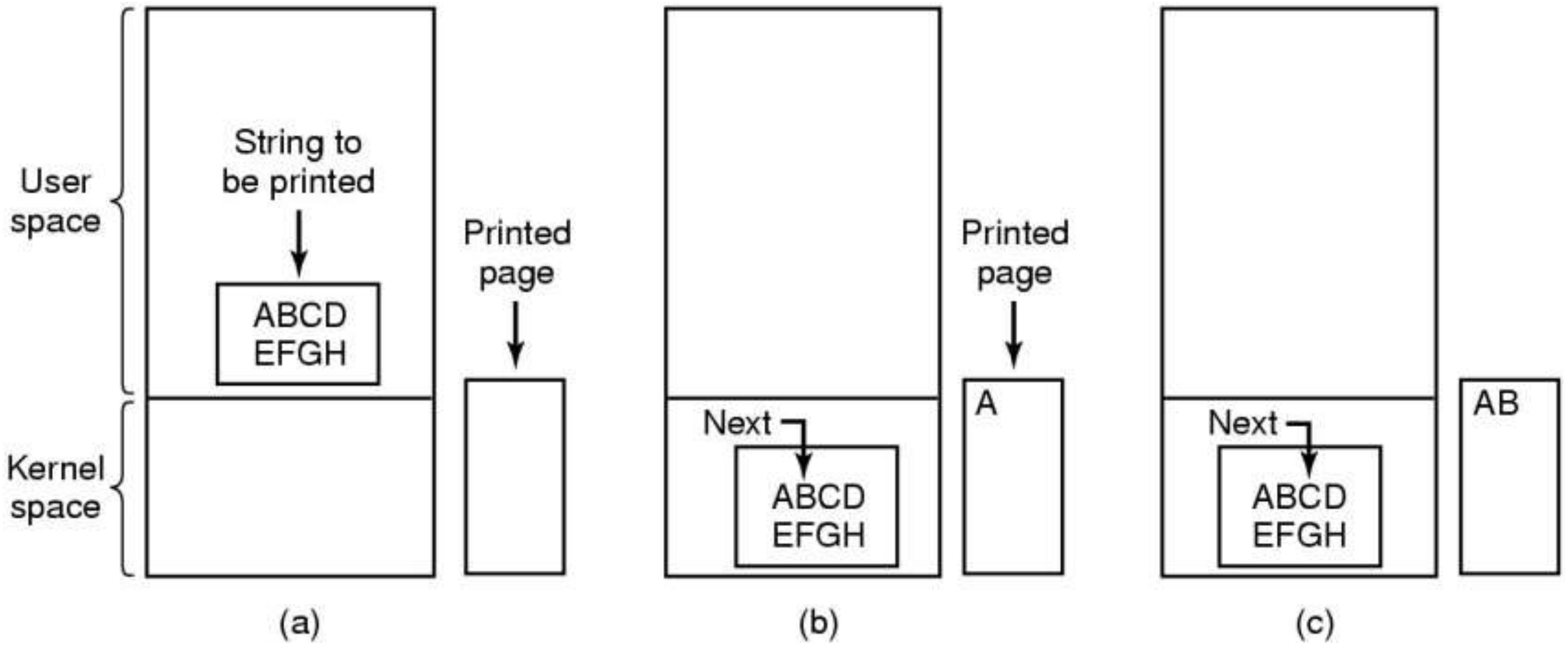


Software Performance Challenges

- How to prevent CPU throughput from being limited by I/O device speed (for *slow devices*)
  - *Why would slow devices affect the CPU?*
- How to prevent I/O throughput from being limited by CPU speed (for *fast devices*)
  - *Why would device throughput be limited by the CPU?*
- How to achieve good utilization of CPU and I/O devices
- How to meet the real-time requirements of devices

ارتباط با دستگاه‌های ورودی و خروجی

Programmed I/O



Steps in printing a string

Programmed I/O

- Example: Writing a string to a serial output or printing a string

```
CopyFromUser(virtAddr, kernelBuffer, byteCount)
for i = 0 to byteCount-1
    while *serialStatusReg != READY
    endWhile
    *serialDataReg = kernelBuffer[i]
endFor
return
```

- Called "Busy Waiting" or "Polling"
- Problem: CPU is continually busy working on I/O!

Interrupt-Driven I/O

- Getting the I/O started:

```
CopyFromUser(virtAddr, kernelBuffer,
byteCount)

EnableInterrupts()

while *serialStatusReg != READY

endWhile

*serialDataReg = kernelBuffer[0]

Sleep ()
```

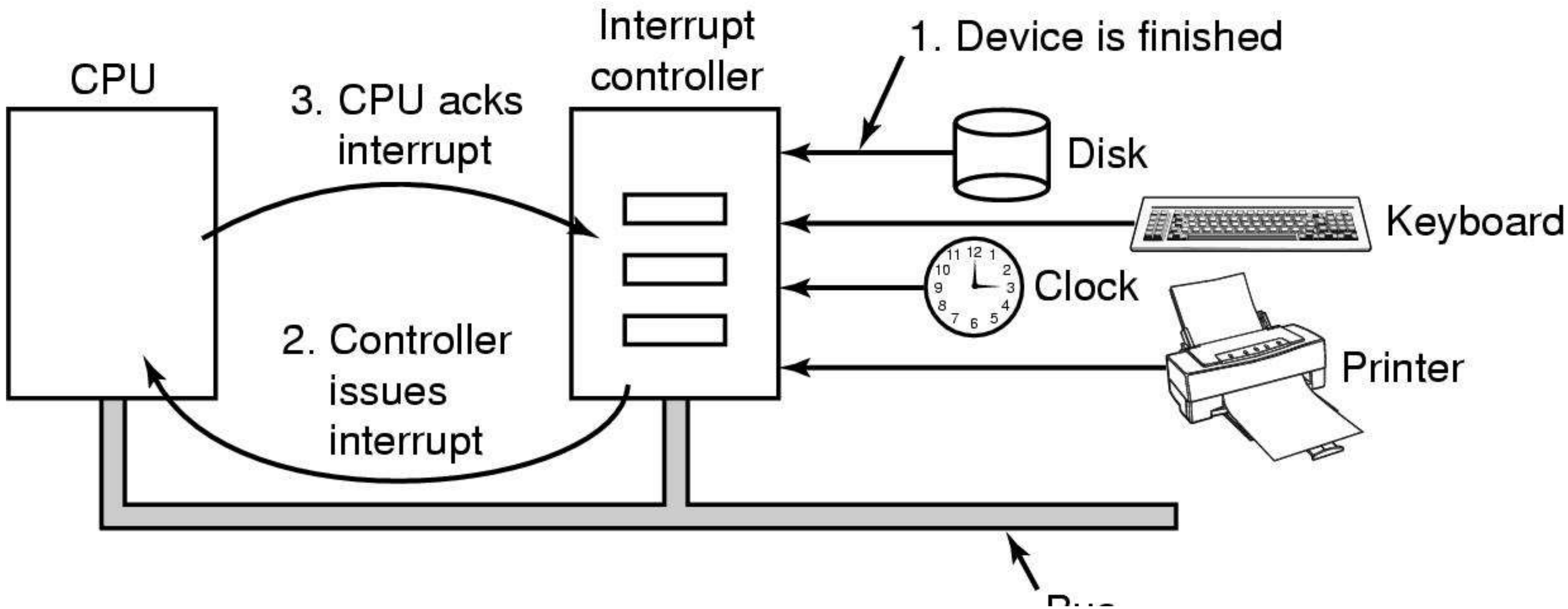
Interrupt-Driven I/O

- The Interrupt Handler:

```
if i == byteCount
  Wake up the user process
else
  *serialDataReg = kernelBuffer[i]
  i = i + 1
endIf
Return from interrupt
```

Hardware Support For Interrupts

How interrupts happen. Connections between devices and interrupt controller actually use interrupt lines on the bus rather than dedicated wires



Interrupt Driven I/O Problem

- Problem:
  - *CPU is still involved in every data transfer*
  - *Interrupt handling overhead is high*
  - *Overhead cost is not amortized over much data*
  - *Overhead is too high for fast devices*
    - Gbps networks
    - Disk drives

Direct Memory Access (DMA)

- Data transferred from device straight to/from memory
- CPU not involved
- *The DMA controller:*
  - *Does the work of moving the data*
  - *CPU sets up the DMA controller ("programs it ")*
  - *CPU continues*
  - *The DMA controller moves the bytes*

Sending Data Using DMA

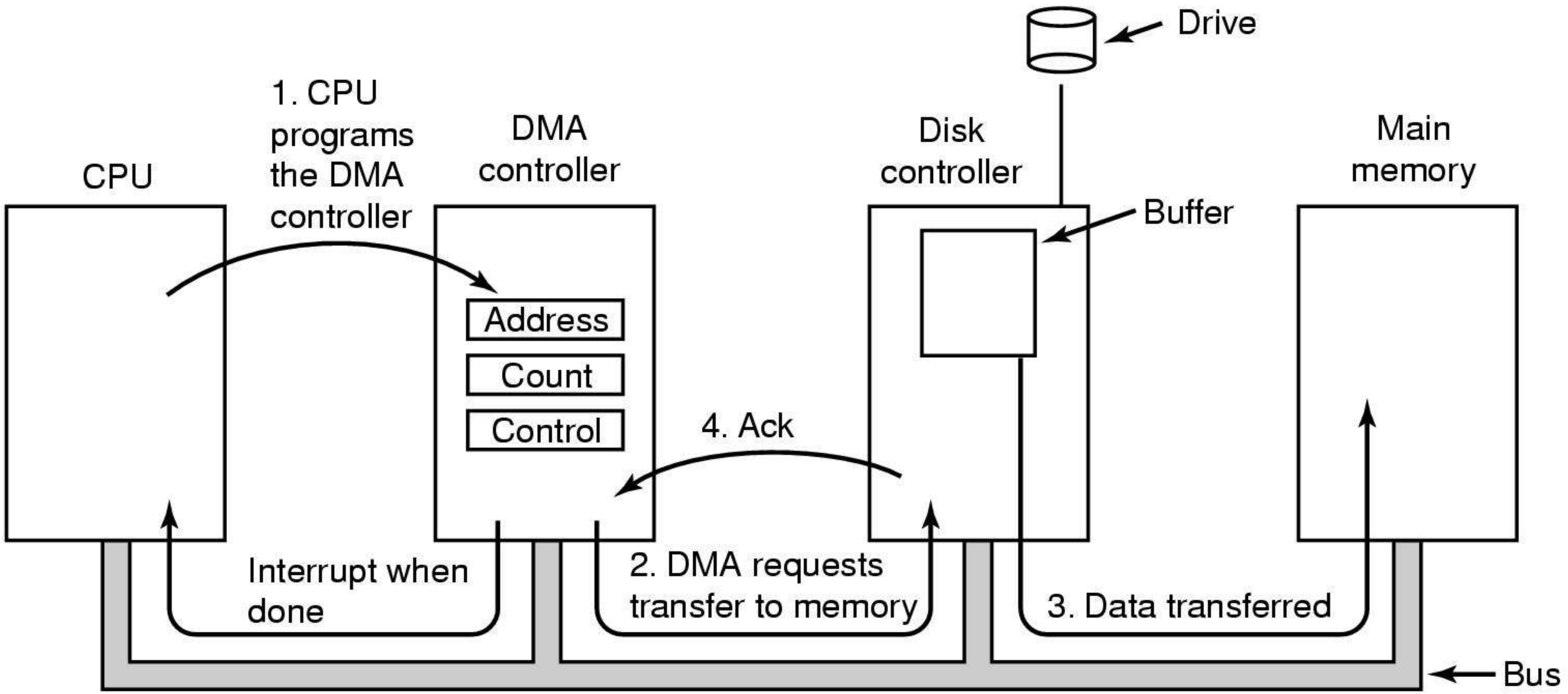
- Getting the I/O started:

```
CopyFromUser(virtAddr, kernelBuffer,
byteCount)
Set up DMA controller
Sleep ()
```

- The Interrupt Handler:

```
Acknowledge interrupt
Wake up the user process
Return from interrupt
```

Direct Memory Access (DMA)



Direct Memory Access (DMA)

- Cycle Stealing
  - *DMA Controller acquires control of bus*
  - *Transfers a single byte (or word)*
  - *Releases the bus*
  - *The CPU is slowed down due to bus contention*

- Burst Mode
  - *DMA Controller acquires control of bus*
  - *Transfers all the data*
  - *Releases the bus*
  - *The CPU operation is temporarily suspended*

Principles of I/O Software

- Device Independence
  - *Programs can access any I/O device*
    - Hard Drive, CD-ROM, Floppy,...
    - ... without specifying the device in advance
- Uniform Naming
  - *Devices / Files are named with simple strings*
  - *Names should not depend on the device*
- Error Handling
  - *Should be as close to the hardware as possible because its often device-specific*

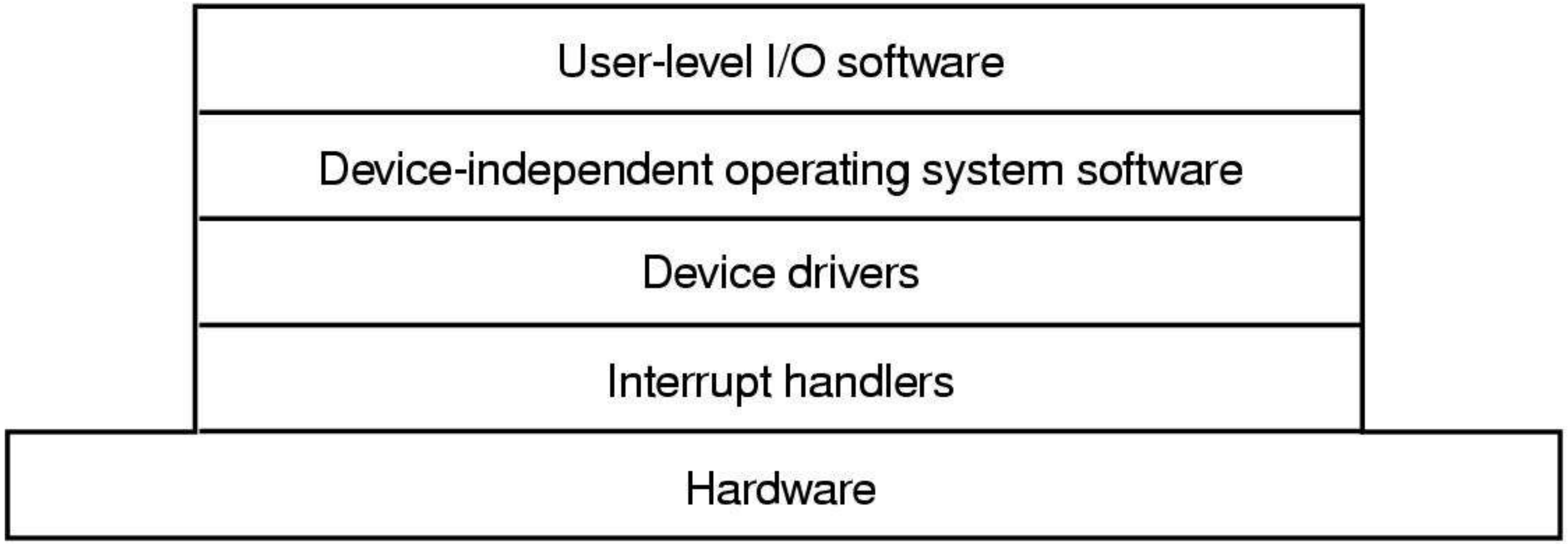
Principles of I/O Software

- Synchronous vs. Asynchronous Transfers
  - *Process is blocked vs. interrupt-driven or polling approaches*
- Buffering
  - *Data comes off a device*
  - *May not know the final destination of the data*
    - e.g., a network packet... Where to put it???
- Sharable vs. Dedicated Devices
  - *Disk should be sharable*
  - *Keyboard, Screen dedicated to one process*

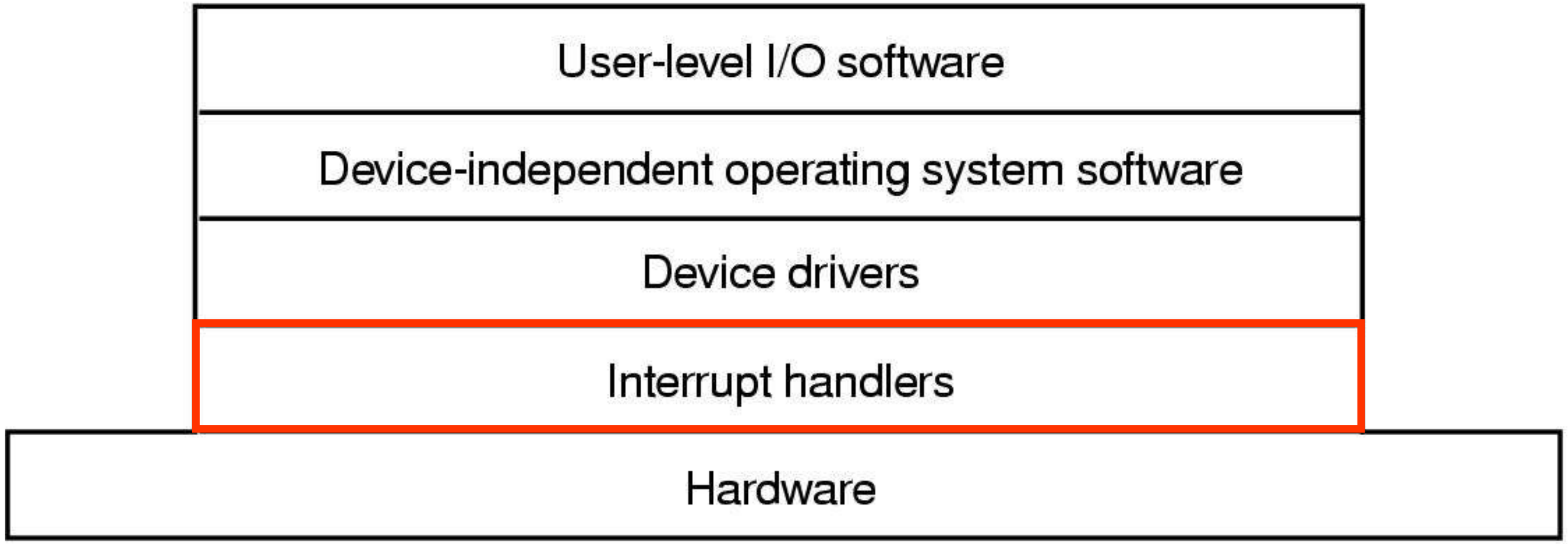
Software Engineering Challenges

- How to remove the complexities of I/O handling from application programs
  - Standard I/O APIs (libraries and system calls)
- How to support a wide range of device types on a wide range of operating systems
  - Standard interfaces for device drivers (DDI)
  - Standard/published interfaces for access to kernel facilities (DKI)

I/O Software Layers



I/O Software Layers



Interrupt Handling

- I/O Device Driver starts the operation
  - *Then blocks until an interrupt occurs*
  - *Then it wakes up, finishes, & returns*
- The Interrupt Handler
  - *Does whatever is immediately necessary*
  - *Then unblocks the driver*
- Example: The BLITZ "DiskDriver"
  - *Start I/O and block (waits on semaphore)*
  - *Interrupt routine signals the semaphore & returns*

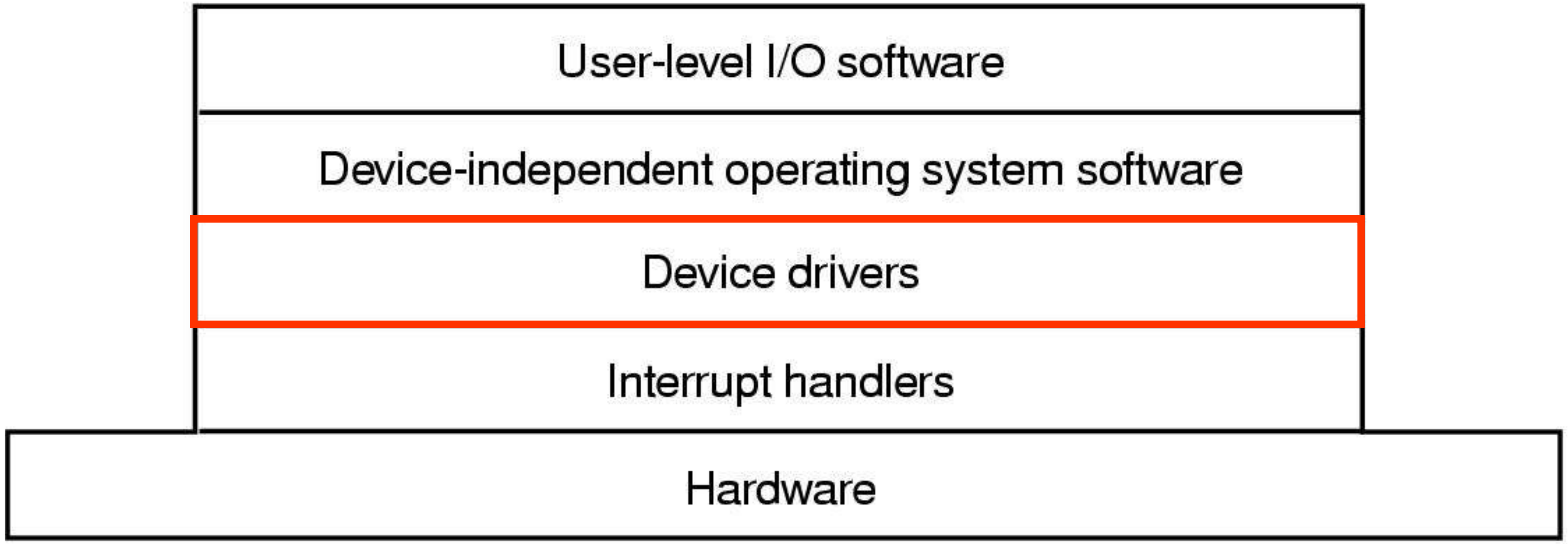
Top and Bottom Halves

- Interrupt handlers are divided into *scheduled* and *non scheduled* tasks
- Non-scheduled tasks execute immediately on interrupt and run in the context of the interrupted thread
  - *Ie. There is no VM context switch*
  - *They should do a minimum amount of work so as not to disrupt progress of interrupted thread*
  - *They should minimize time during which interrupts are disabled*
- Scheduled tasks are queued for processing by a thread
  - *This thread will be scheduled to run later*
  - *May be scheduled preemptively or non-preemptively*

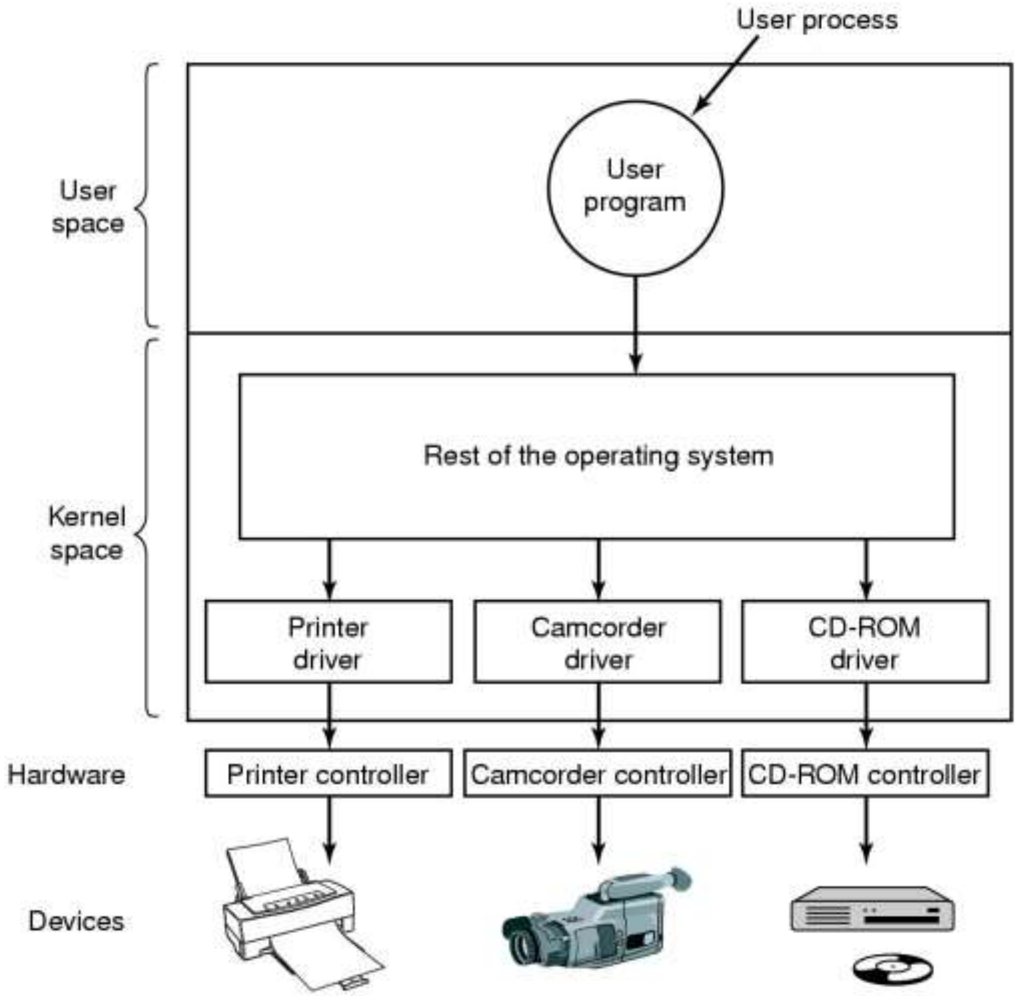
Interrupt Handler’s Jobs

- Set up stack for interrupt service procedure
- Ack interrupt controller, re-enable interrupts
- Copy registers from where saved
- Run service procedure

I/O Software Layers



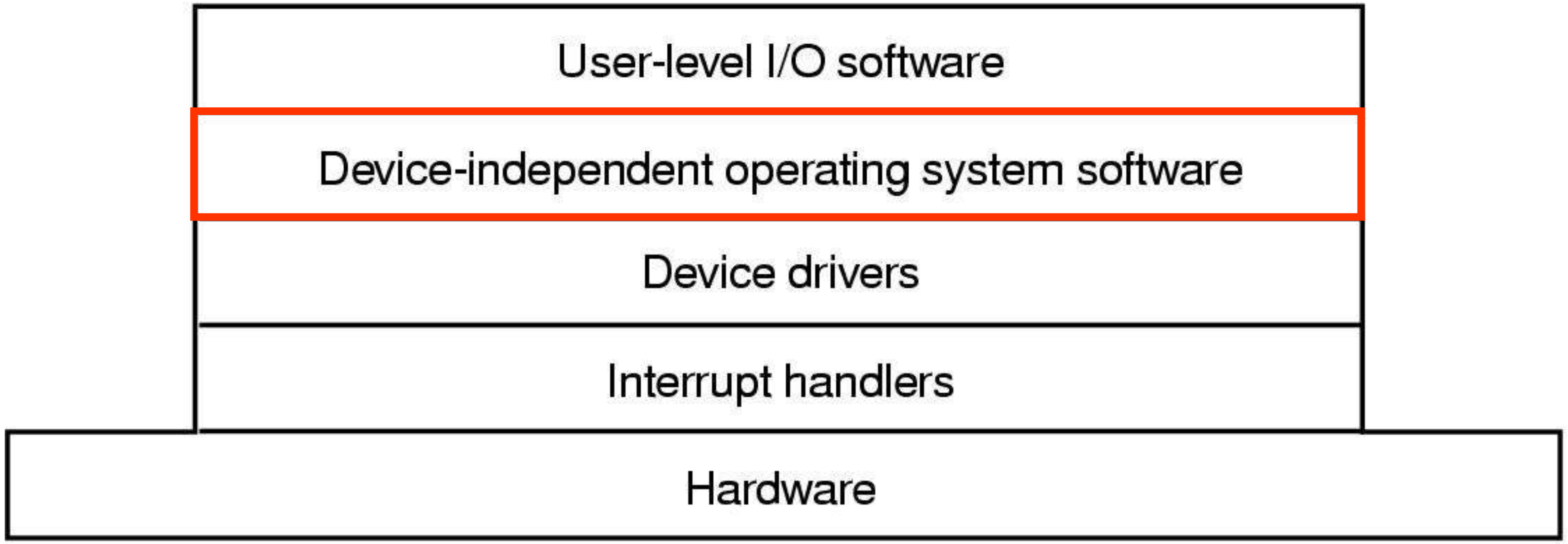
Device drivers in kernel space



Device Drivers

- Device drivers are device-specific software that connects devices with the operating system
  - *Typically an assembly-level job*
    - Must deal with hardware-specific details
    - Must deal with O.S. specific details
  - *Goal: hide as many device-specific details as possible from higher level software*
- Device drivers are typically given kernel privileges for efficiency
  - *Bugs can bring down the O.S.!*
  - *Open challenge: how to provide efficiency <u>and</u> safety?*

I/O Software Layers



Device-Independent I/O Software

- Functions and responsibilities
  - *Uniform interfacing for device drivers*
  - *Buffering*
  - *Error reporting*
  - *Allocating and releasing dedicated devices*
  - *Providing a device-independent block size*

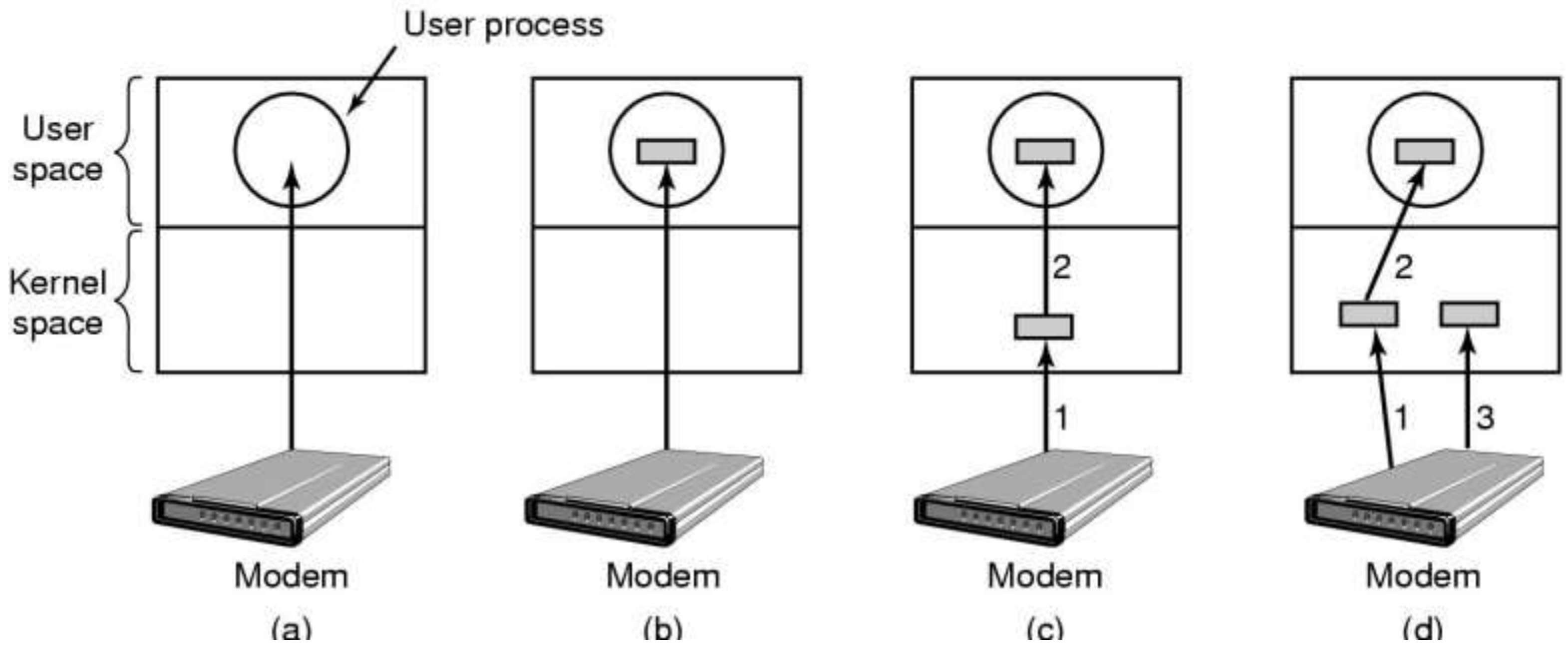
Device-Independent I/O Buffering

(a) Unbuffered input

(b) Buffering in user space

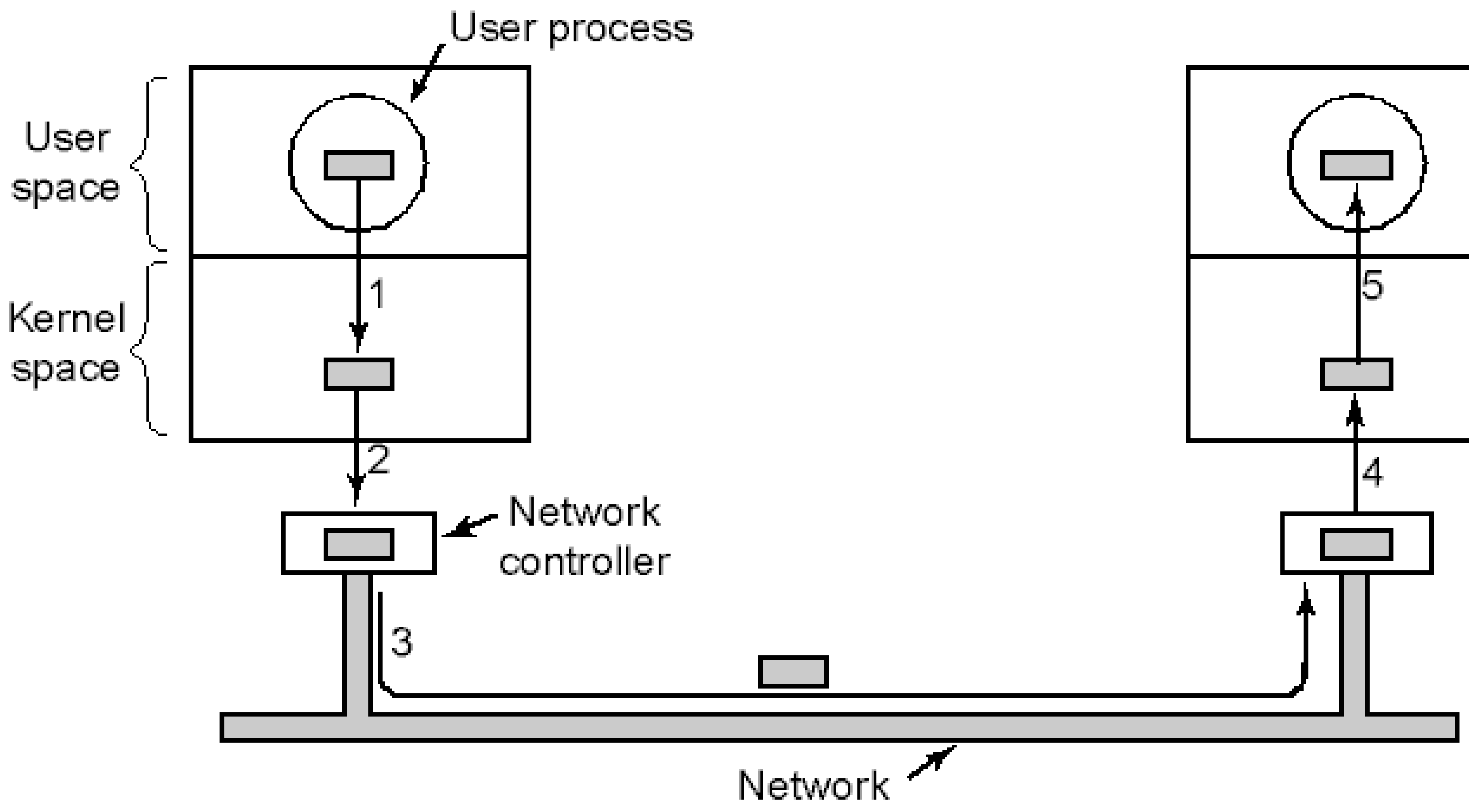
(c) Buffering in the kernel followed by copying to user space

(d) Double buffering in the kernel



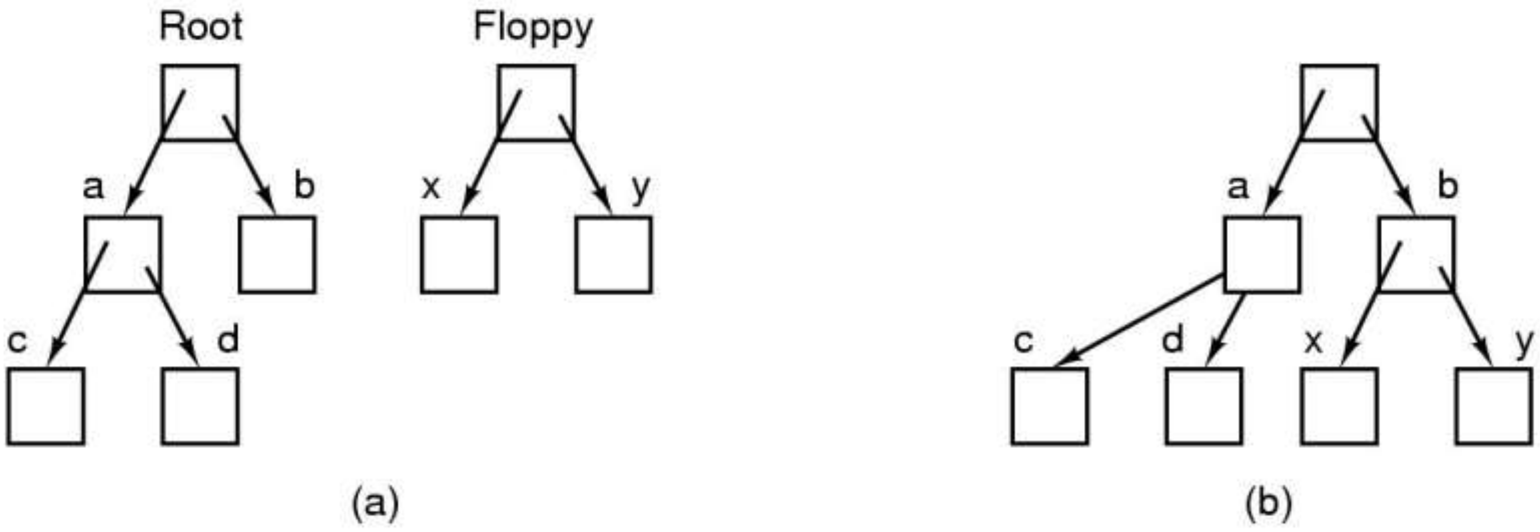
Copying Overhead in Network I/O

Networking may involve many copies

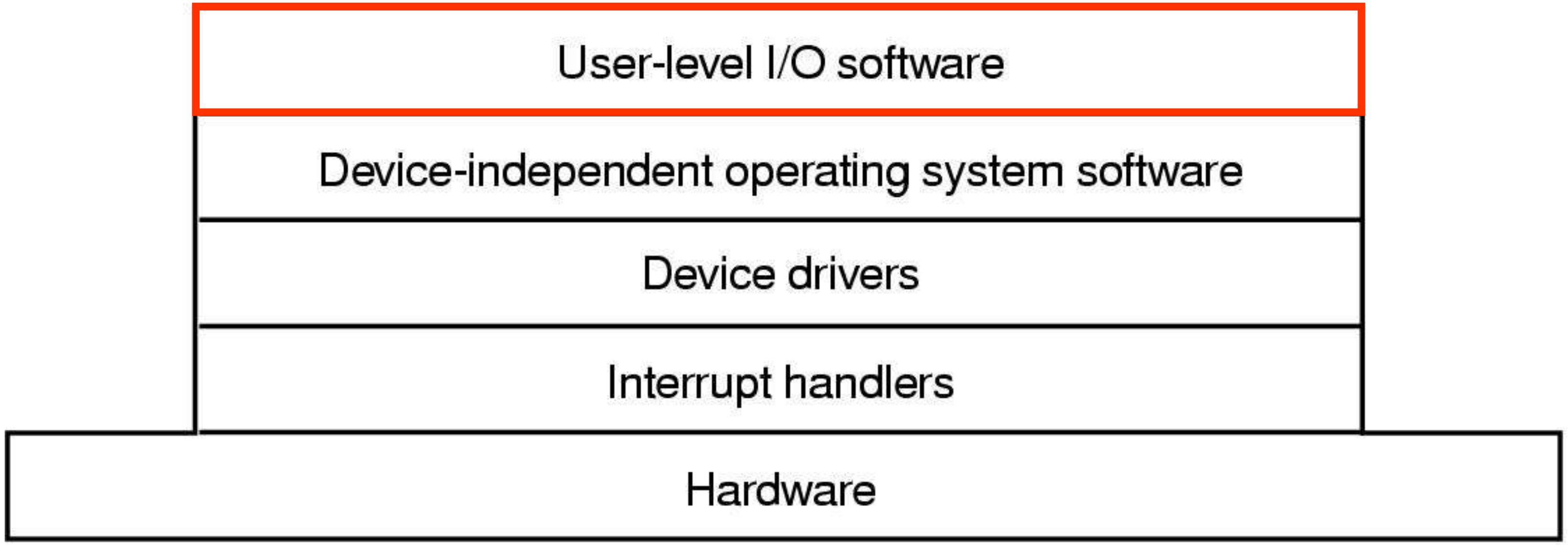


Devices As Files

- Before mounting,
  - *files on floppy are inaccessible*
- After mounting floppy on b,
  - *files on floppy are part of file hierarchy*



I/O Software Layers



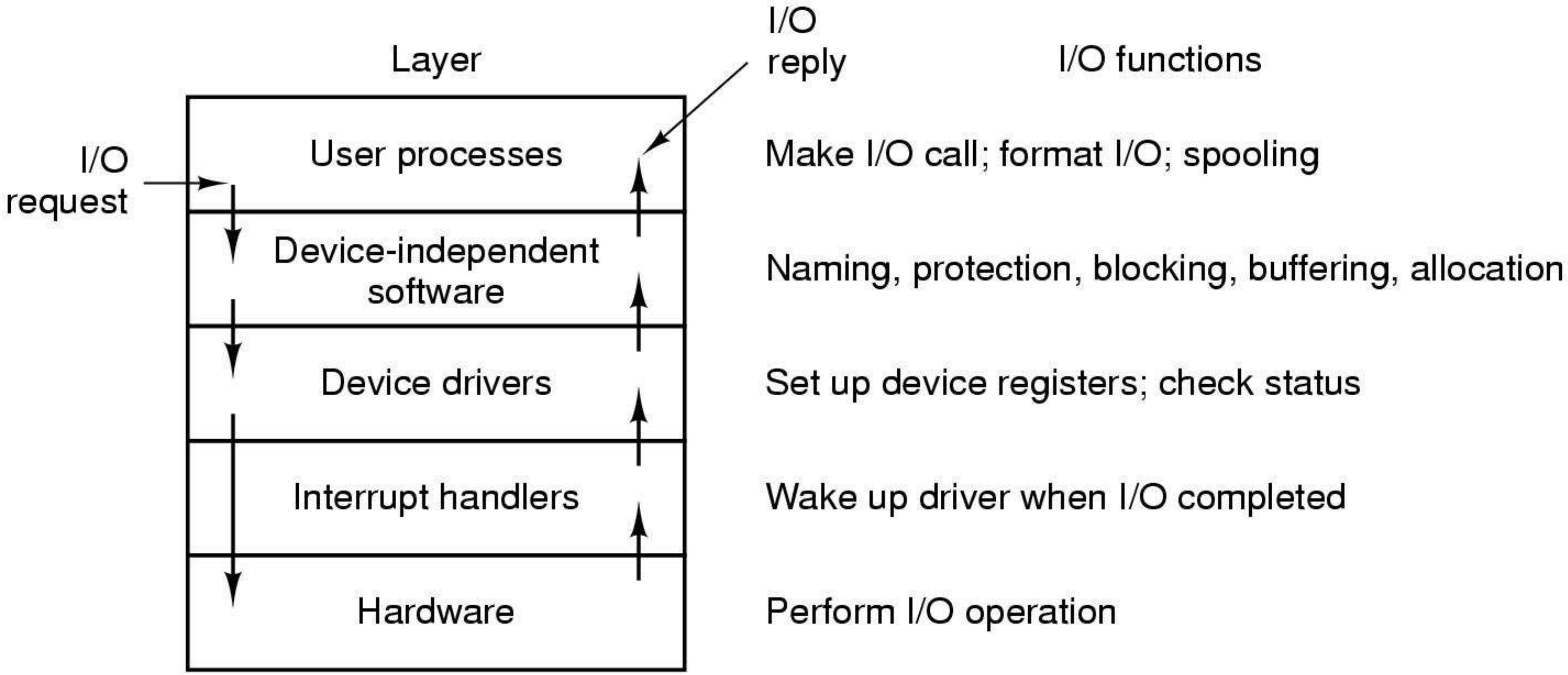
User-Space I/O Software

- In user’s (C) program

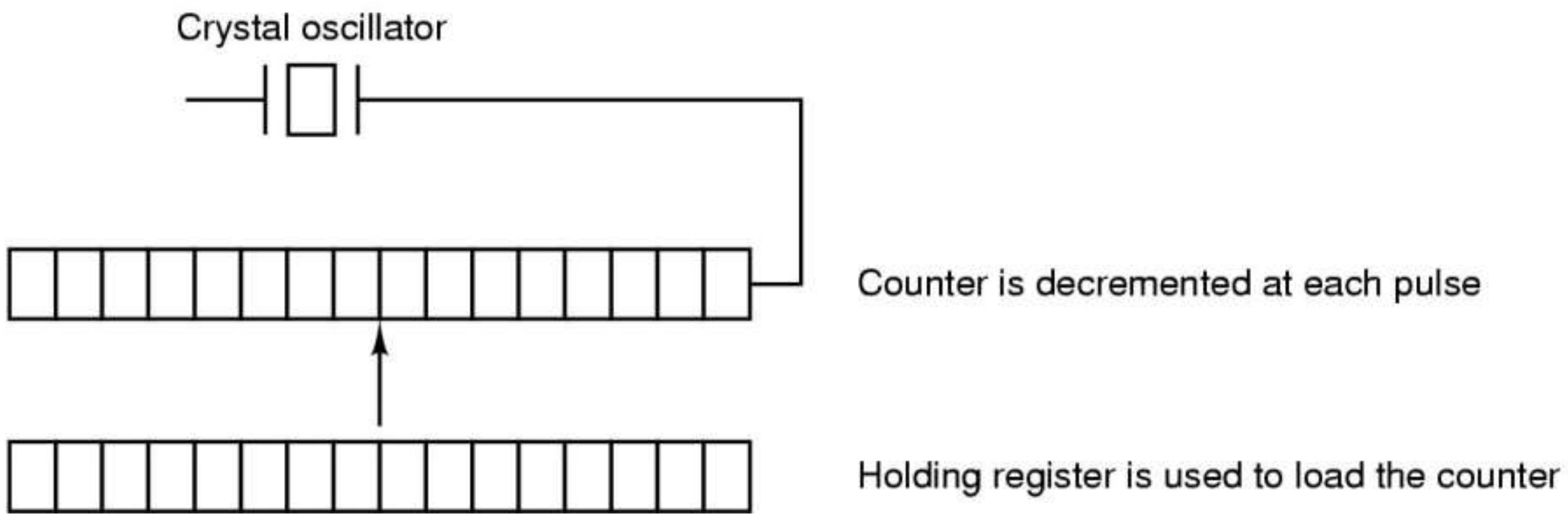
```
count = write (fd, buffer, nbytes);
printf (“The value of %s is %d\n”, str, i);
```

- Linked with library routines.
- The library routines contain:
  - *Lots of code*
  - *Buffering*
  - *The syscall to trap into the kernel*

Communicating Across I/O Layers



Programmable Timer



- One-shot mode:
  - *Counter initialized then decremented until zero*
  - *At zero a single interrupt occurs*
- Square wave mode:
  - *At zero the counter is reinitialized with the same value*
  - *Periodic interrupts (called "clock ticks") occur*

Time

- 500 MHz Crystal (oscillates every 2 nanoseconds)
- 32 bit register overflows in 8.6 seconds
  - *So how can we remember what the time is?*

- Backup clock
  - *Similar to digital watch*
  - *Low-power circuitry, battery-powered*
  - *Periodically reset from the internet*
  - *UTC: Universal Coordinated Time*
  - *Unix: Seconds since Jan. 1, 1970*
  - *Windows: Seconds since Jan. 1, 1980*

Goals of Timer Software

- Maintain time of day
  - *Must update the time-of-day every tick*
- Prevent processes from running too long
- Account for CPU usage
  - *Separate timer for every process*
  - *Charge each tick to the current process*
- Handling the “Alarm” syscall
  - *User programs ask to be sent a signal at a given time*
- Providing watchdog timers for the OS itself
  - *When to stop the disk, switch to low power mode, etc*
- Doing profiling, monitoring, and statistics gathering

Software Timers

- A process can ask for notification (alarm) at time T
  - *At time T, the OS will signal the process*

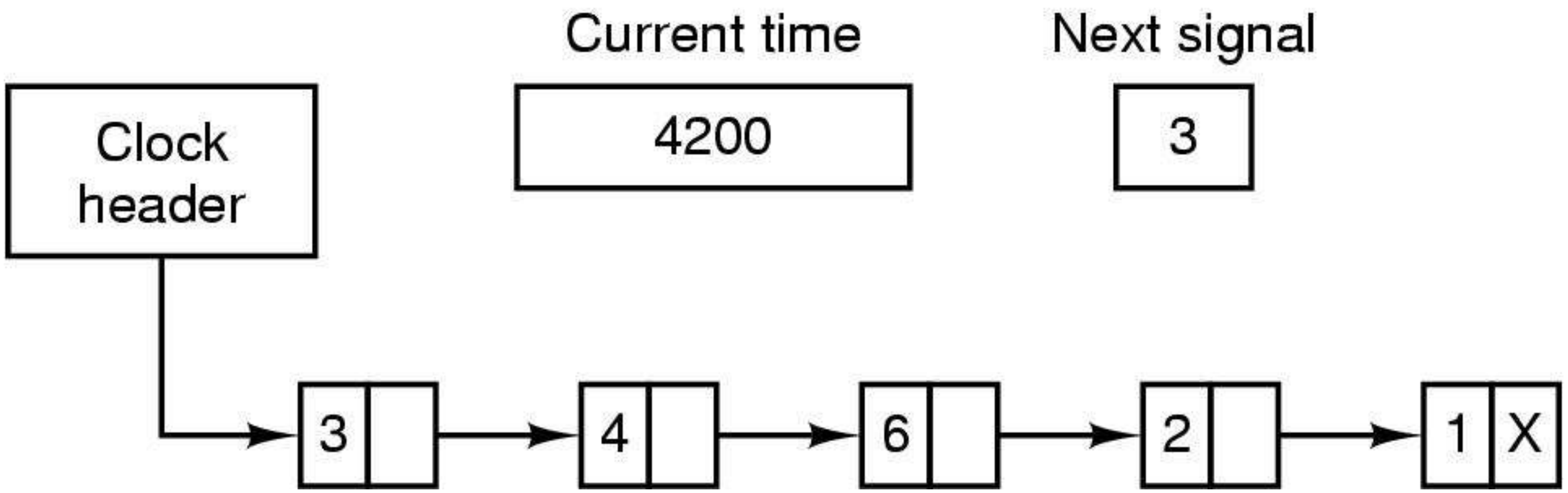
- Processes can “go to sleep until time T”

- Several processes can have active timers

- The CPU has only one clock
  - *Must service the “alarms” in the right order*

- Keep a sorted list of all timers
  - *Each entry tells when the alarm goes off and what to do then*

Software Timers



- Alarms set for 4203, 4207, 4213, 4215 and 4216.
- Each entry tells how many ticks past the previous entry.
- On each tick, decrement the "NextSignal".
- When it gets to 0, then signal the process.