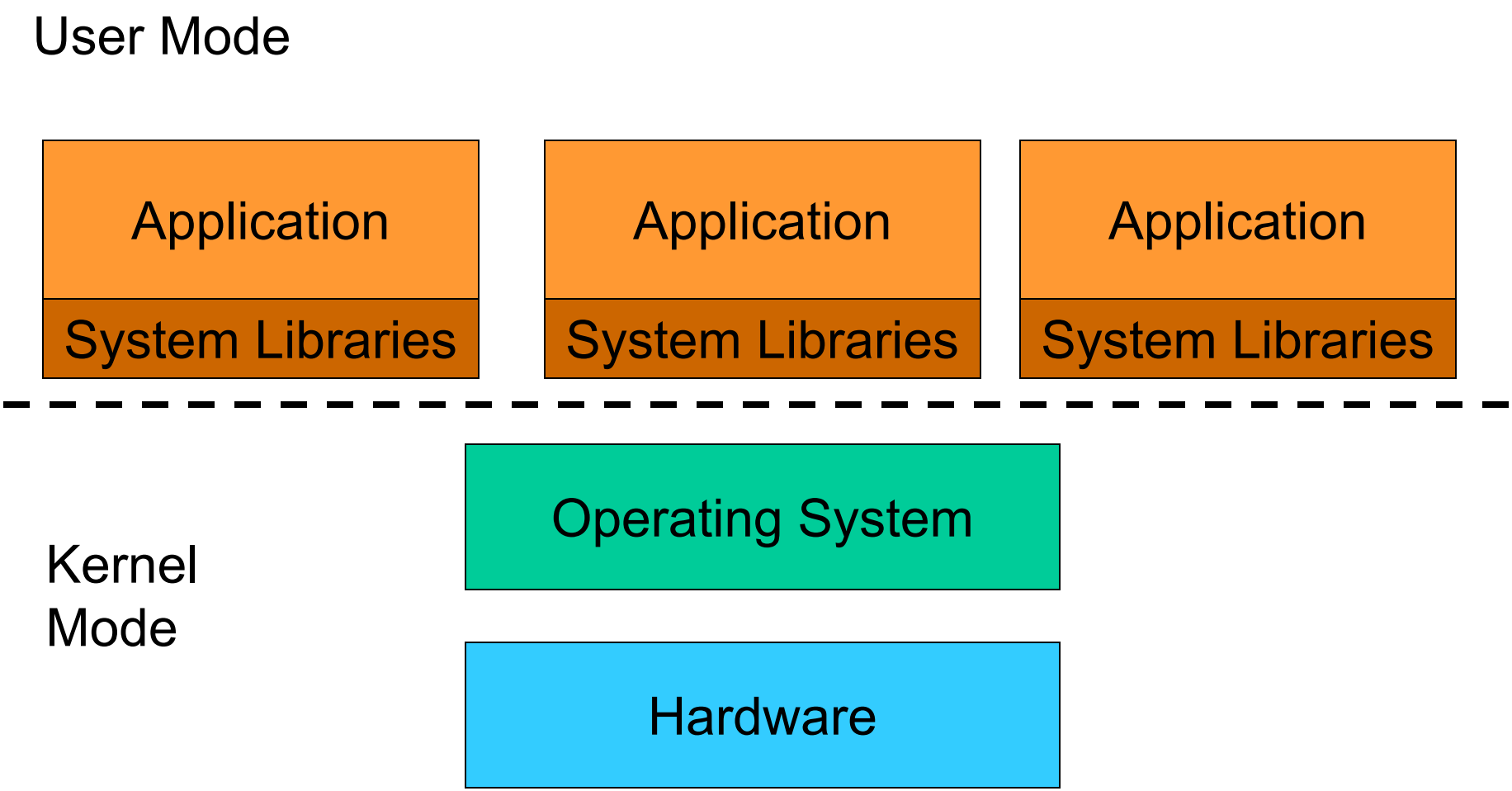
Operating System Overview

Chapter 1.5 – 1.9

Operating System

- A program that controls execution of applications
  - The resource manager
- An interface between applications and hardware
  - The extended machine

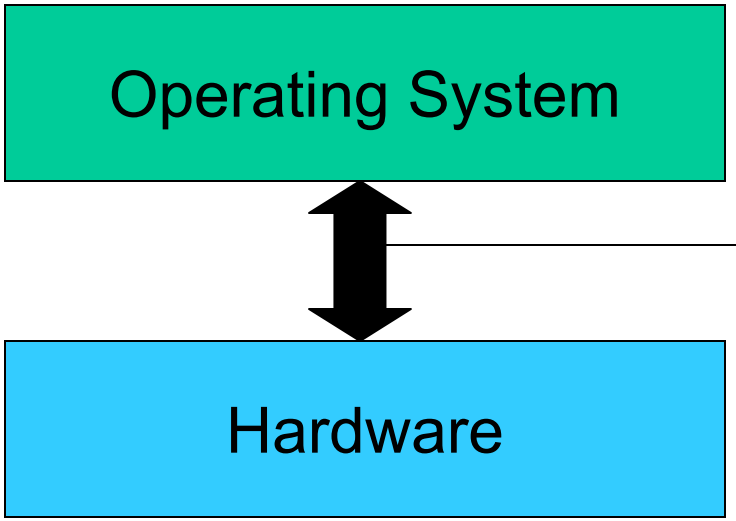
Structure of a Computer System



Structure of a Computer System

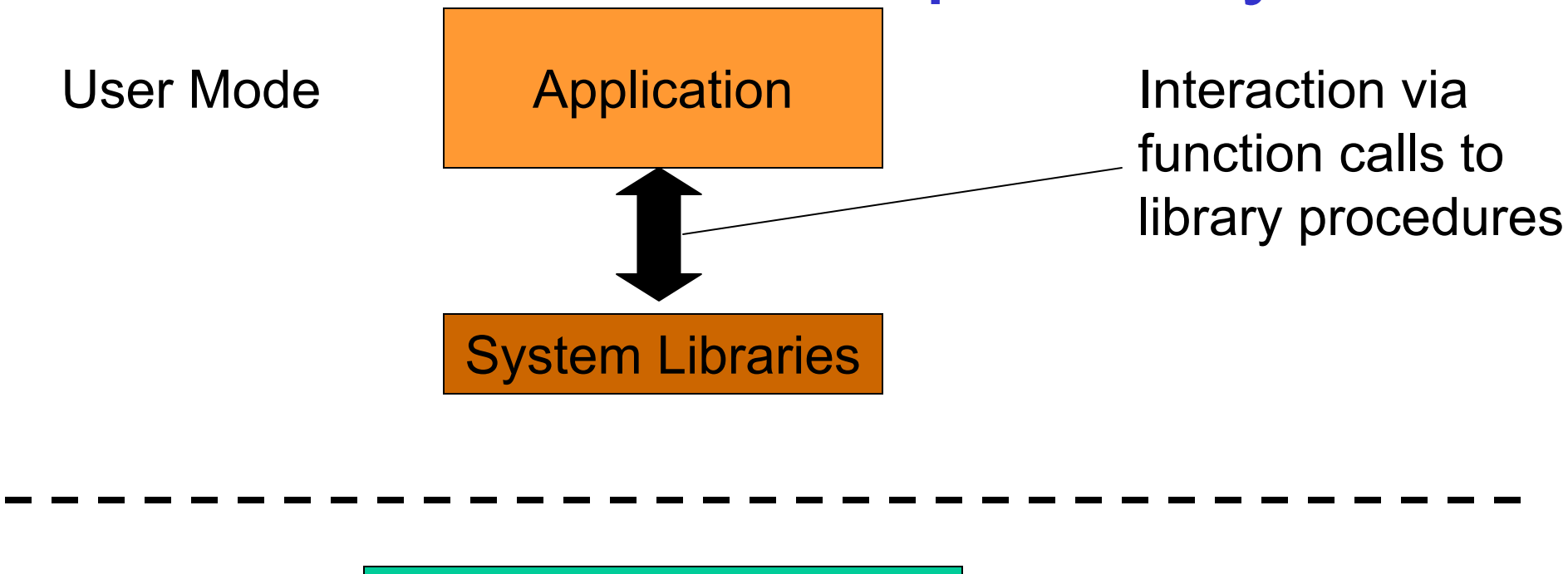
User Mode

Kernel Mode

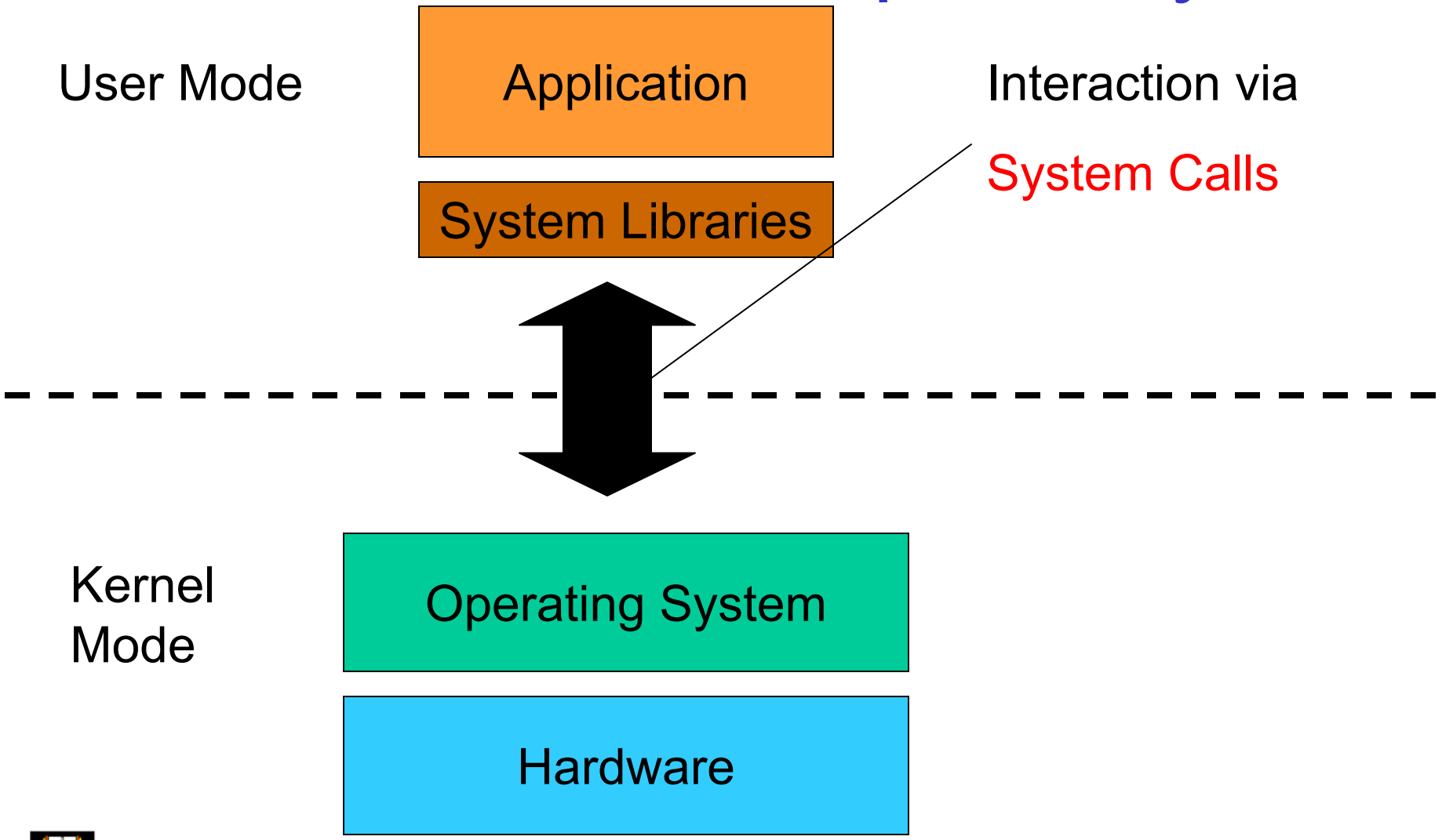


Interacts via load and store instructions to CPU and device registers, and interrupts

Structure of a Computer System



Structure of a Computer System



A note on System Libraries

- System libraries are just that, libraries of support functions (procedures, subroutines)
  - Only a subset of library functions are actually systems calls
    - strcmp(), memcpy(), are pure library functions
    - open(), close(), read(), write() are system calls
  - System call functions are in the library for convenience

Operating System Objectives

- Convenience
  - Make the computer more convenient to use
- Abstraction
  - Hardware-independent programming model
- Efficiency
  - Allows the computer system to be used in an efficient manner
- Ability to evolve
  - Permit effective development, testing, and introduction of new system functions without interfering with existing services
- Protection

Services Provided by the Operating System

- Program development
  - Editors, compilers, debuggers
    - Not so much these days
- Program execution
  - Load a program and its data
- Access to I/O devices
- Controlled access to files
  - Access protection
- System access
  - User authentication

Services Provided by the Operating System

- Error detection and response
  - internal and external hardware errors
    - memory error
    - device failure
  - software errors
    - arithmetic overflow
    - access forbidden memory locations
  - operating system cannot grant request of application

Services Provided by the Operating System

- Accounting
  - collect statistics
  - monitor performance
  - used to anticipate future enhancements
  - used for billing users

Operating System

- Fundamentally, OS functions same way as ordinary computer software
  - It is program that is executed (just like apps)
  - It has more privileges
- Operating system relinquishes control of the processor to execute other programs
  - Reestablishes control after
    - System calls
    - Interrupts (especially timer interrupts)

Kernel

- Portion of the operating system that is running in *privileged mode*
- Usually resident in main memory
- Contains fundamental functionality
  - Whatever is required to implement other services
  - Whatever is required to provide security
- Contains most-frequently used functions
- Also called the nucleus or supervisor

Major OS Concepts

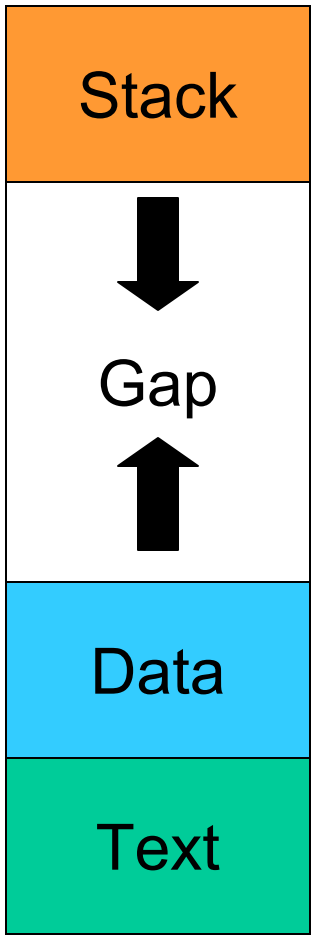
- Processes
- Concurrency and deadlocks
- Memory management
- Files
- Information Security and Protection
- Scheduling and resource management

Processes

- A program in execution
- An instance of a program running on a computer
- The entity that can be assigned to and executed on a processor
- A unit of resource ownership
- A unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources
  - Nowadays the execution abstraction is separated out: *Thread*
  - Single process can contain many threads

Process

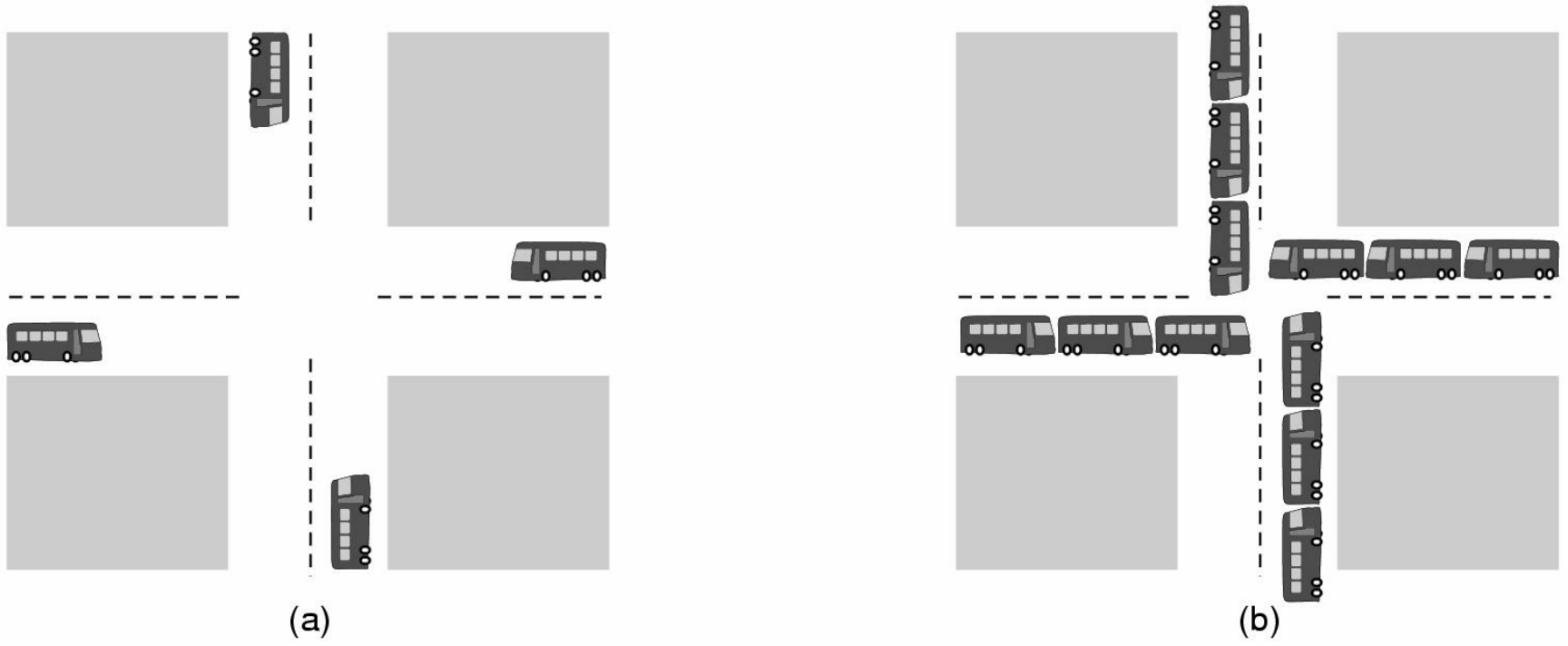
- Consist of three segments
  - Text
    - contains the code (instructions)
  - Data
    - Global variables
  - Stack
    - Activation records of procedure
    - Local variables
- Note:
  - data can dynamically grow up
  - The stack can dynamically grow down



Process

- Consists of three components
  - An executable program
    - text
  - Associated data needed by the program
    - Data and stack
  - Execution context of the program
    - All information the operating system needs to manage the process
      - Registers, program counter, stack pointer, etc…
    - A multithread program has a stack and execution context for each thread

Multiple processes creates concurrency issues



(a) A potential deadlock. (b) an actual deadlock.

Memory Management

- The view from thirty thousand feet
  - Process isolation
    - Prevent processes from accessing each others data
  - Automatic allocation and management
    - Don't want users to deal with physical memory directly
  - Support for modular programming
  - Protection and access control
    - Still want controlled sharing
  - Long-term storage
  - OS services
    - Virtual memory
    - File system

Virtual Memory

- Allows programmers to address memory from a logical point of view
  - Gives apps the illusion of having RAM to themselves
  - Logical addresses are independent of other processes
  - Provides isolation of processes from each other
- Can overlap execution of one process while swapping in/out others.

Virtual Memory Addressing

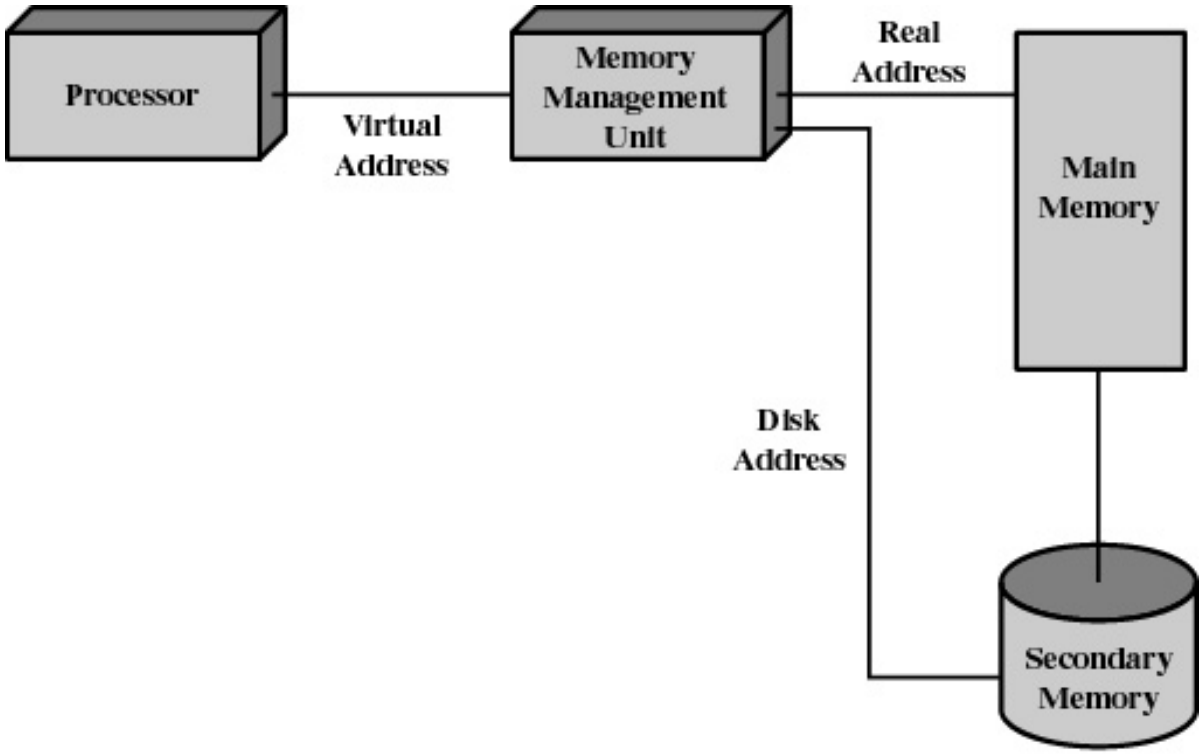


Figure 2.10 Virtual Memory Addressing

Paging

- Allows process to be comprised of a number of fixed-size blocks, called pages
- Virtual address is a page number and an offset within the page
- Each page may be located any where in main memory
- A page may actually exist only on disk

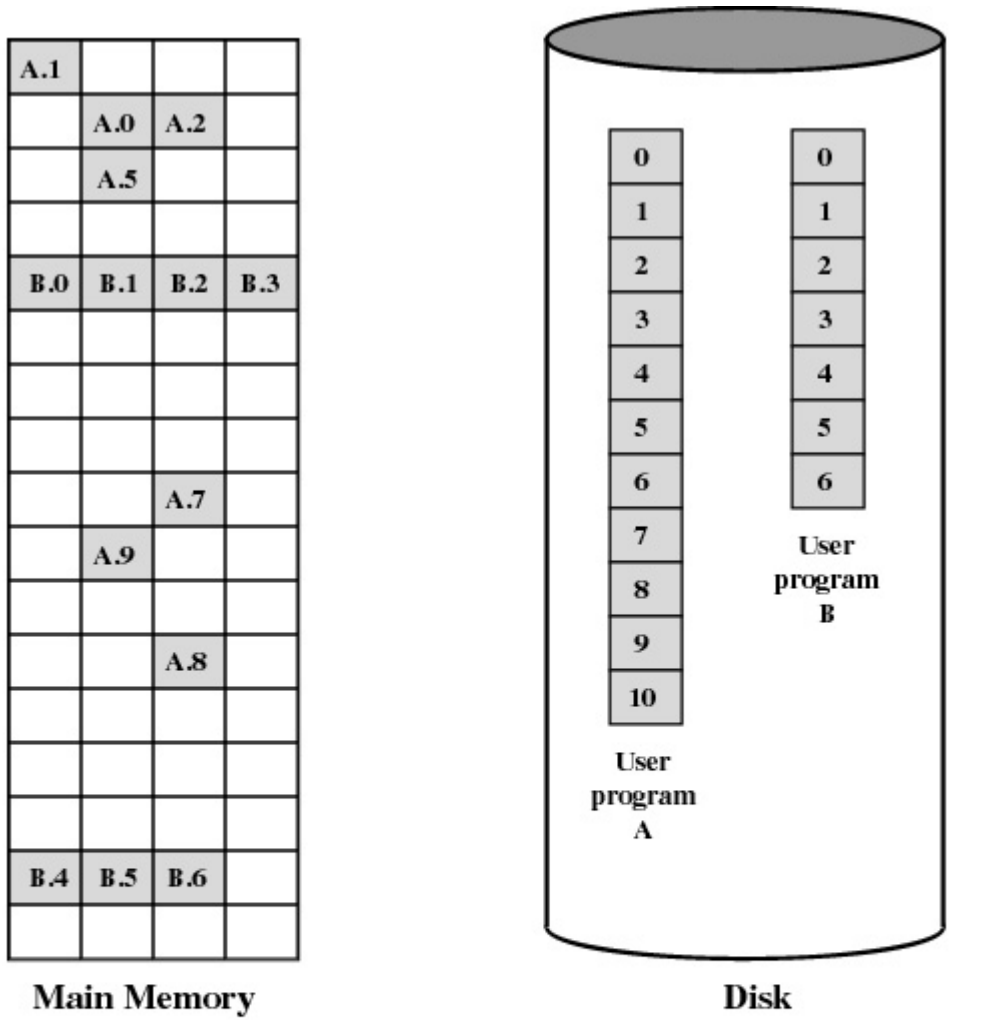
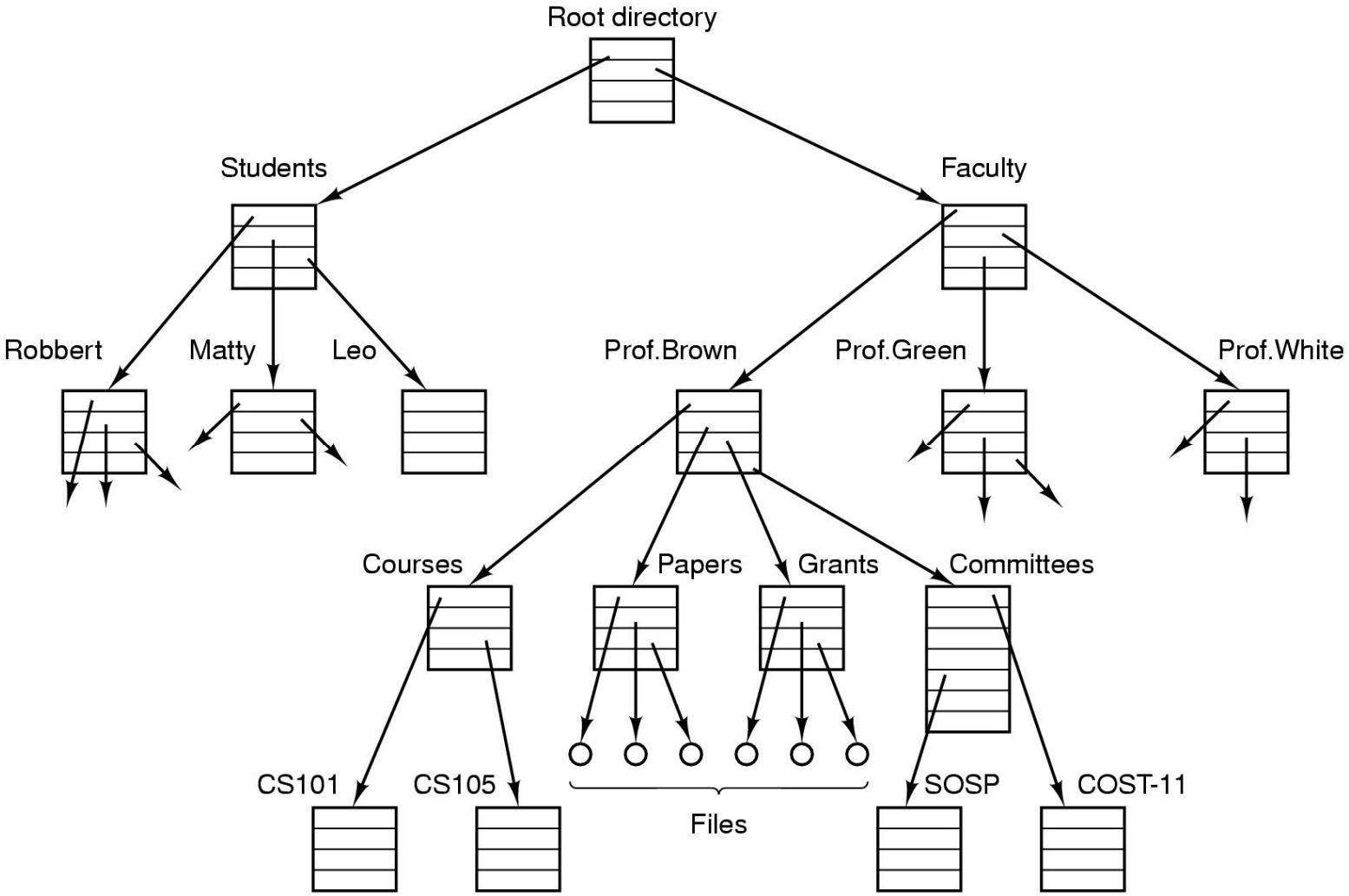


Figure 2.9 Virtual Memory Concepts

File System

- Implements long-term store
- Information stored in named objects called files

Example File System



Information Protection and Security

- Access control
  - regulate user access to the system
  - Involves authentication
- Information flow control
  - regulate flow of data within the system and its delivery to users

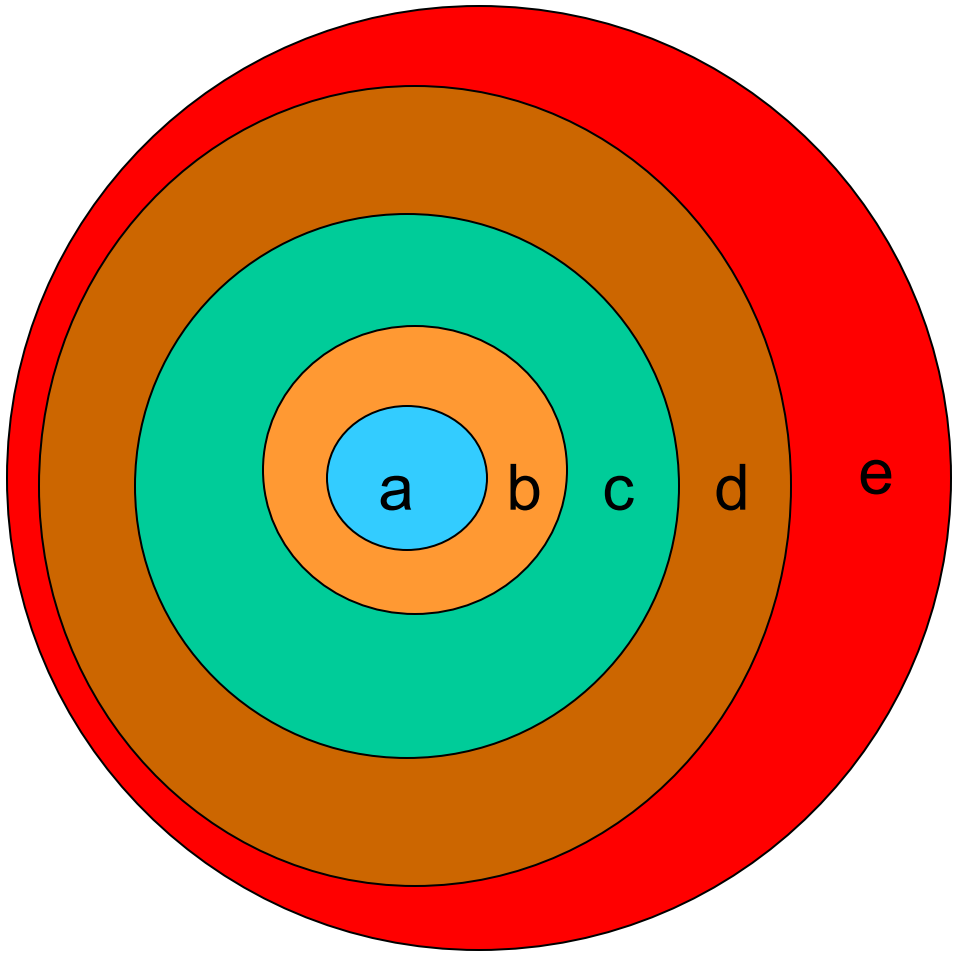
Scheduling and Resource Management

- Fairness
  - give equal and fair access to all processes
- Differential responsiveness
  - discriminate between different classes of jobs
- Efficiency
  - maximize throughput, minimize response time, and accommodate as many uses as possible

Operating System Structure

- The layered approach
  a) Processor allocation and multiprogramming
  b) Memory Management
  c) Devices
  d) File system
  e) Users

– Each layer depends on the the inner layers

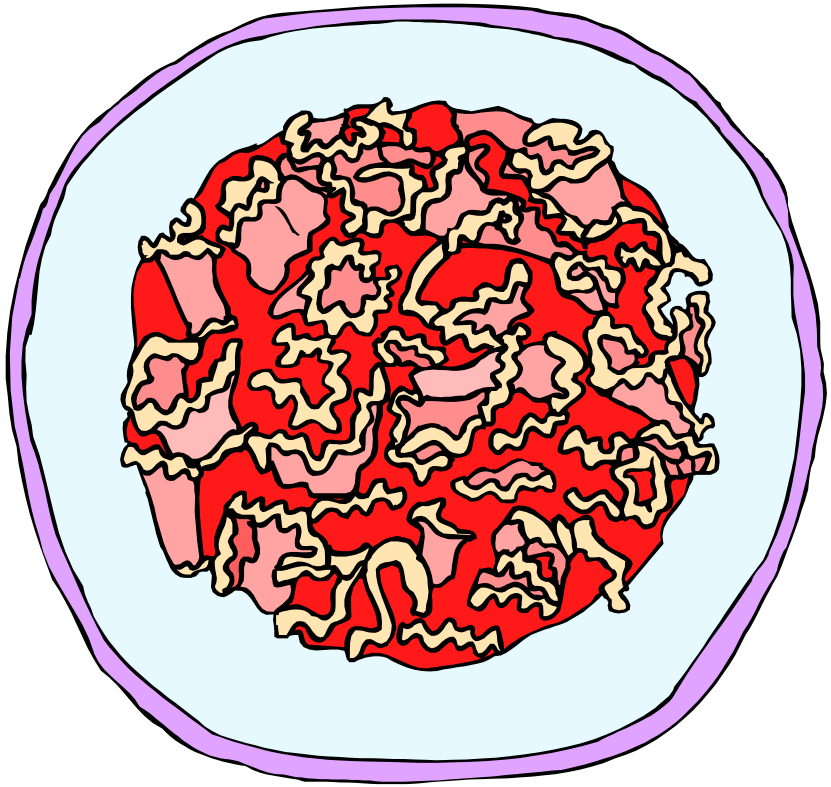


Operating System Structure

- In practice, layering is only a guide
  - Operating Systems have many interdependencies
    - Scheduling on virtual memory
    - Virtual memory on I/O to disk
    - VM on files (page to file)
    - Files on VM (memory mapped files)
    - And many more…

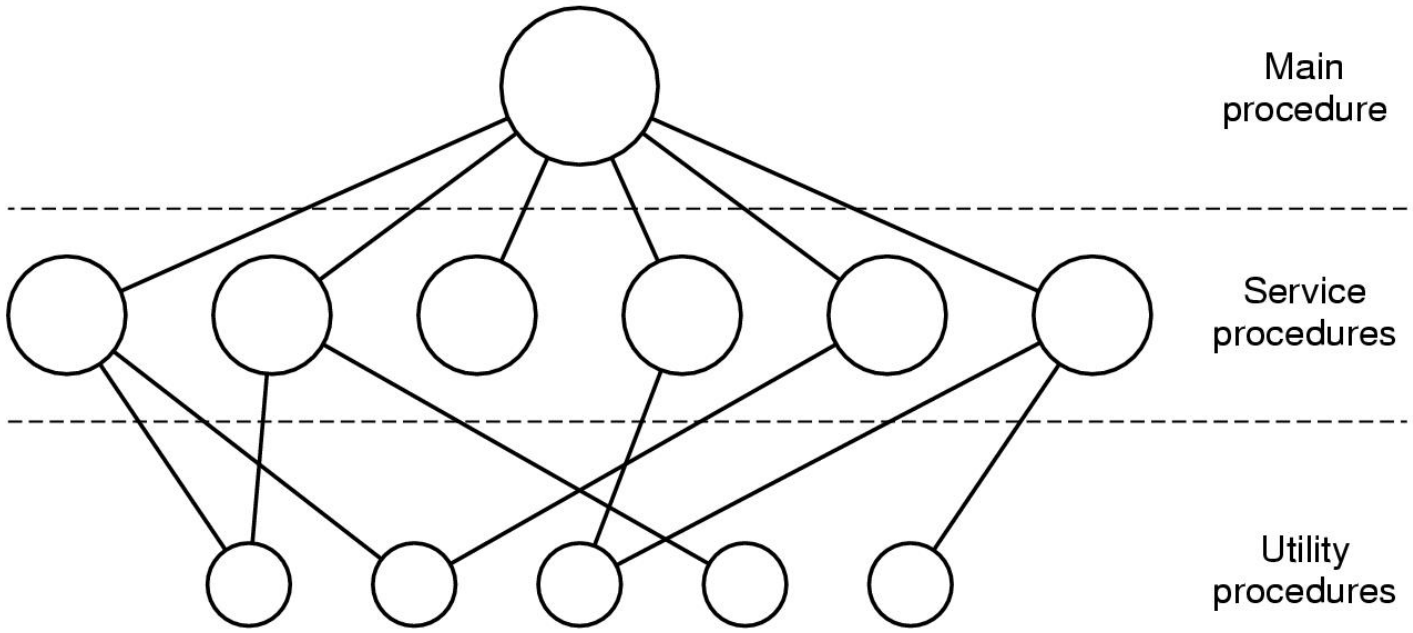
The Monolithic Operating System Structure

- Also called the "spaghetti nest" approach
  - Everything is tangled up with everything else.
- Linux, Windows, ….



The Monolithic Operating System Structure

- However, some reasonable structure usually prevails

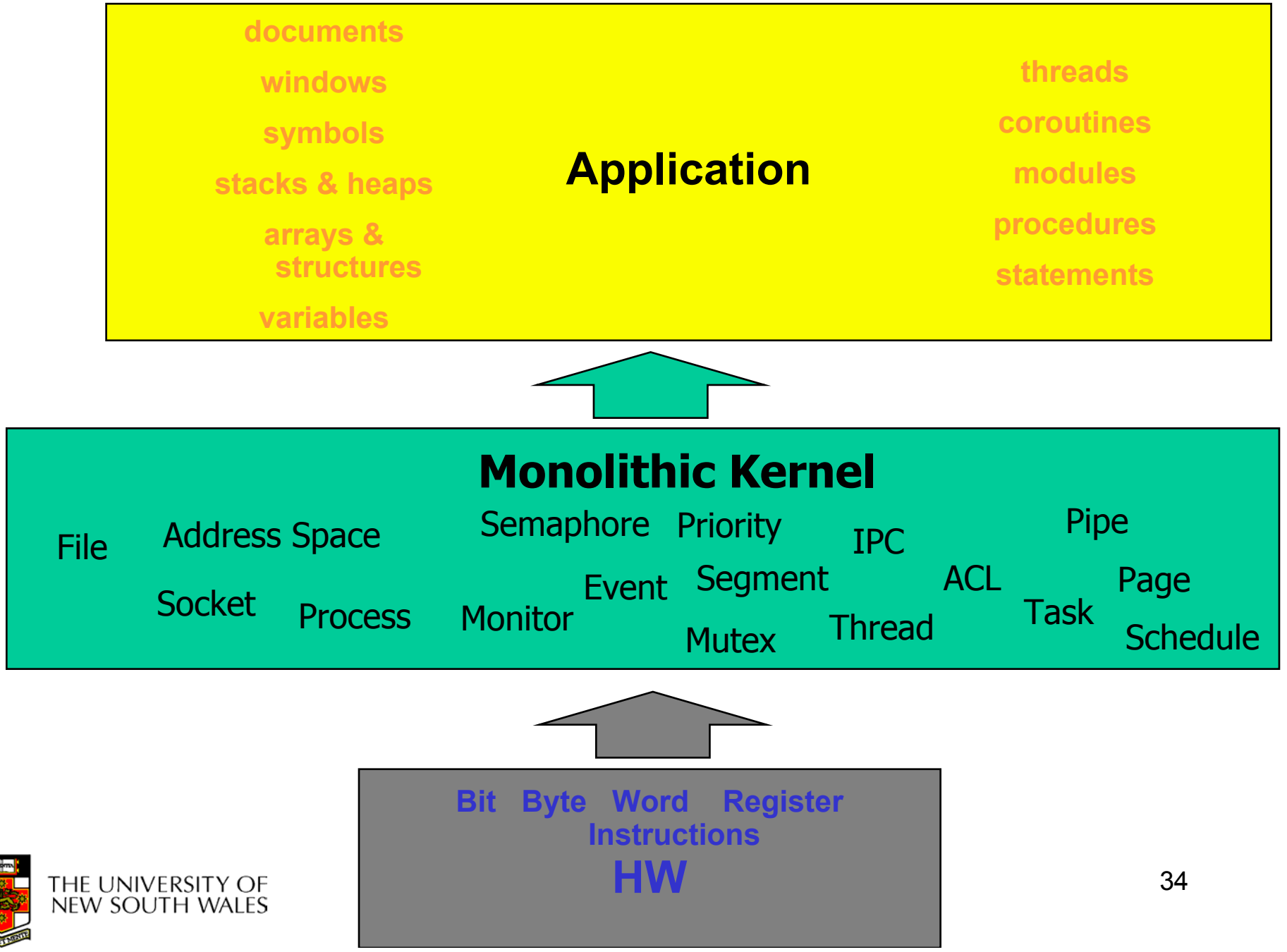


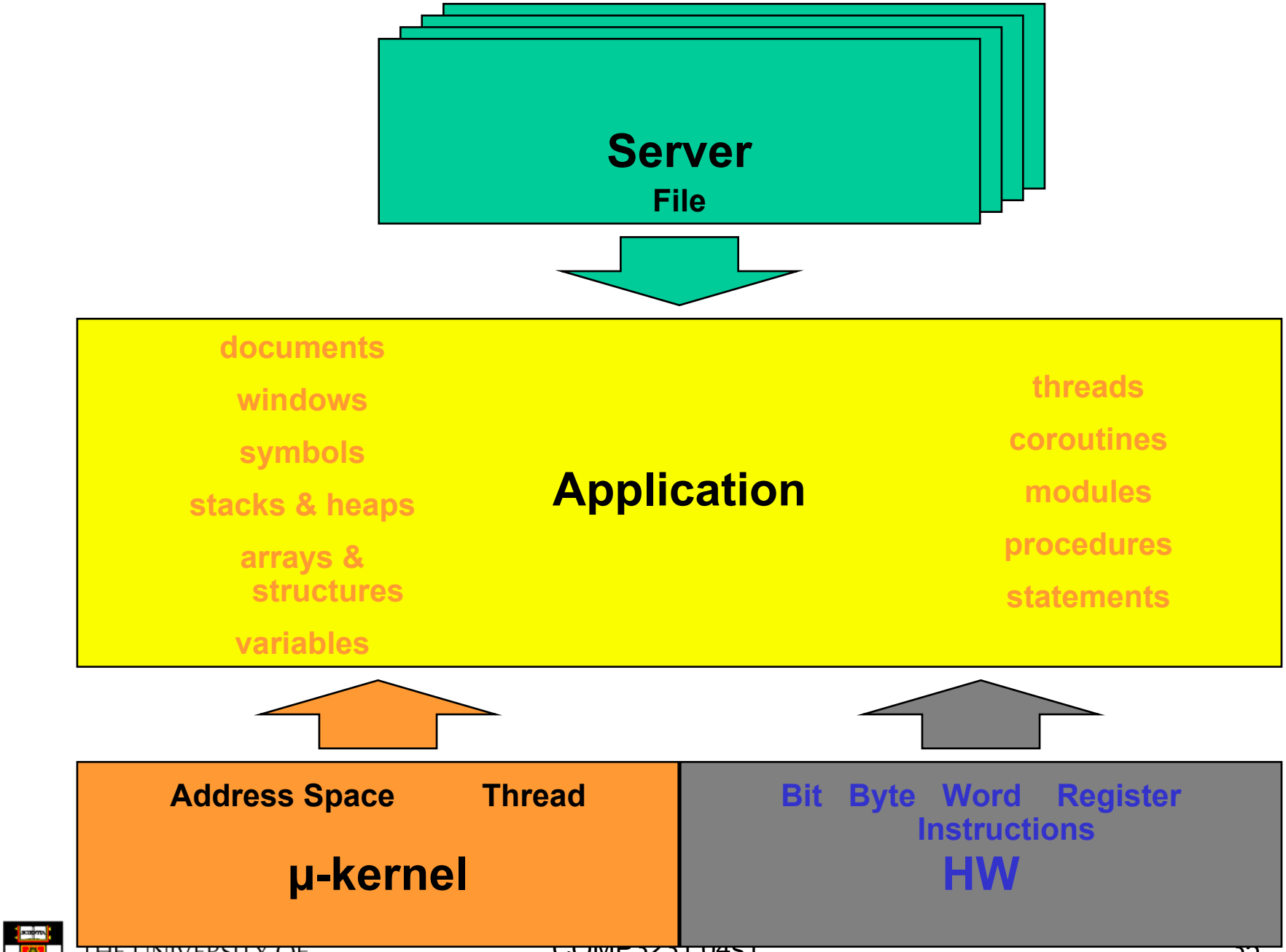
OS Complexity is a major issue

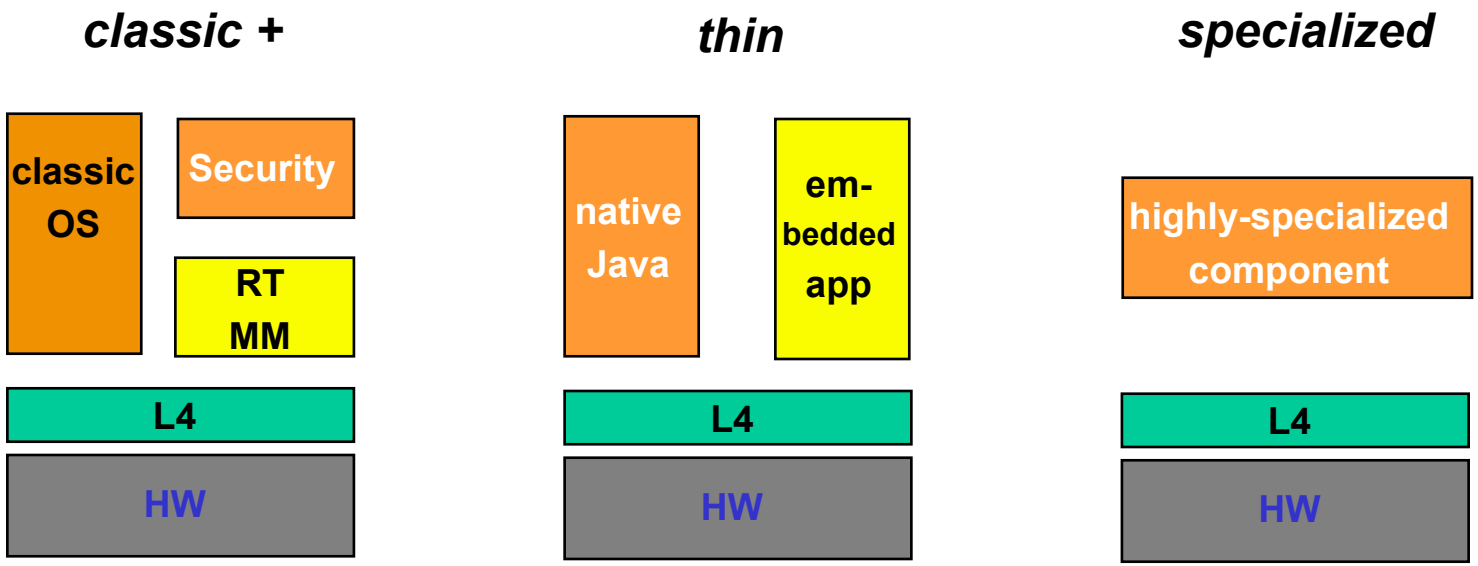
- Approaches to tackling the problem
  - Safe kernel extensions
    - SPIN - safe programming language
    - VINO – sandboxing (hardware protection)
  - Microkernels
  - Exokernels

Microkernel-based Systems

- Assigns only a few essential functions to the kernel
  - Address space
  - Interprocess Communication (IPC)
  - Basic scheduling
  - Minimal hardware abstraction
- Other services implemented by user-level servers
- Traditional “system calls” become IPC requests to servers
- Extreme view of a microkernel
  - A feature is only allowed in the kernel if required for security


documents
windows
symbols
stacks & heaps
arrays & structures
variables
Application
threads
coroutines
modules
procedures
statements
Monolithic Kernel
File
Address Space
Socket
Process
Monitor
Semaphore
Priority
Event
Segment
IPC
Mutex
Thread
ACL
Pipe
Task
Page
Schedule
Bit Byte Word Register
Instructions
HW

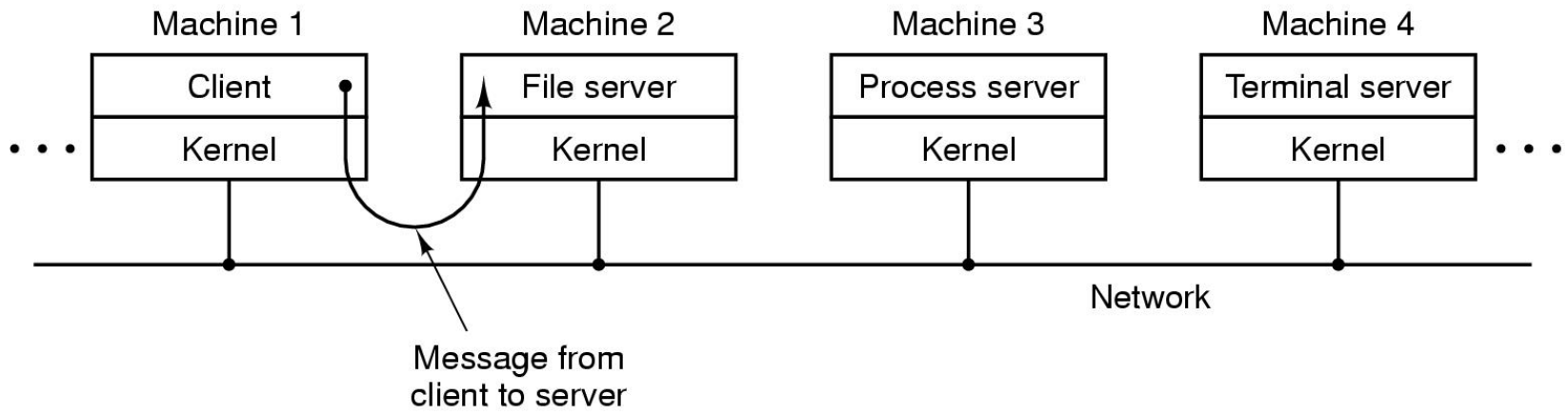

Server
File
documents
windows
symbols
stacks & heaps
arrays & structures
variables
Application
threads
coroutines
modules
procedures
statements
Address Space
Thread
µ-kernel
Bit
Byte
Word
Register
Instructions
HW


classic +
classic OS
Security
RT MM
L4
HW
thin
native Java
em-bedded app
L4
HW
specialized
highly-specialized component
L4
HW

Client/Server Model

- Simplifies the Executive
  - Possible to construct a variety of APIs
- Improves reliability
  - Each service runs as a separate process with its own memory partition
- Provides a uniform means for applications to communicate via IPC
- Provides a base for distributed computing

The client/server model



The client-server model of microkernel make it easier to extend to a distributed system

UNIX

- Provides a good hardware abstraction
  - Everything is a file (mostly)
- Runs on most hardware
- Comes with a number of user services and interfaces
  - shell
  - C compiler

Traditional UNIX Structure

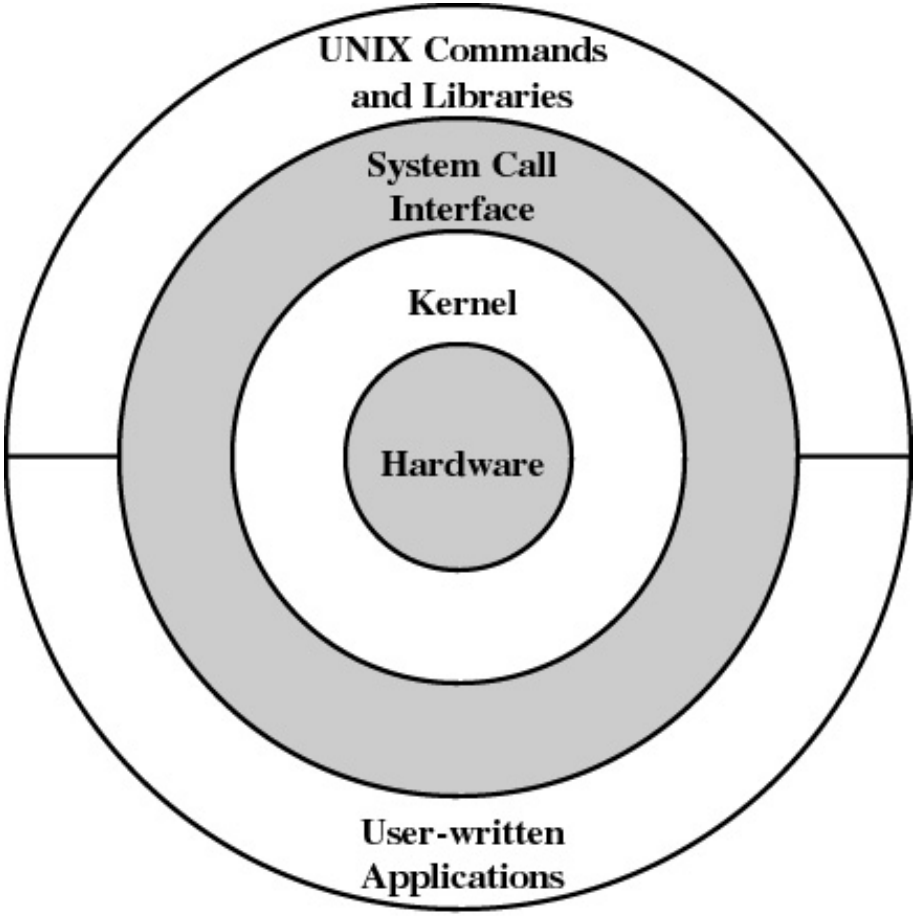


Figure 2.15 General UNIX Architecture

Traditional UNIX Kernel