Operating System Overview

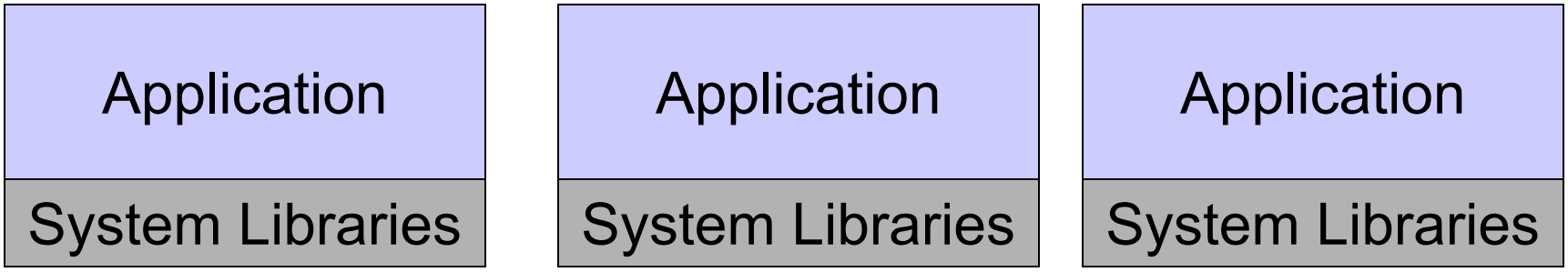
Chapter 1.5 – 1.9

Operating System

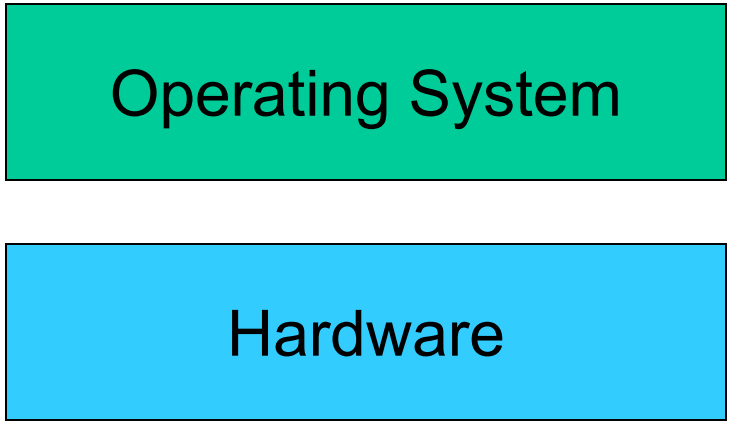
- A program that controls execution of applications
  - The resource manager
- An interface between applications and hardware
  - The extended machine

Structure of a Computer System

User Mode

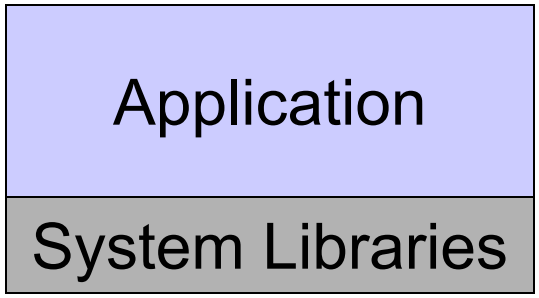


Kernel Mode

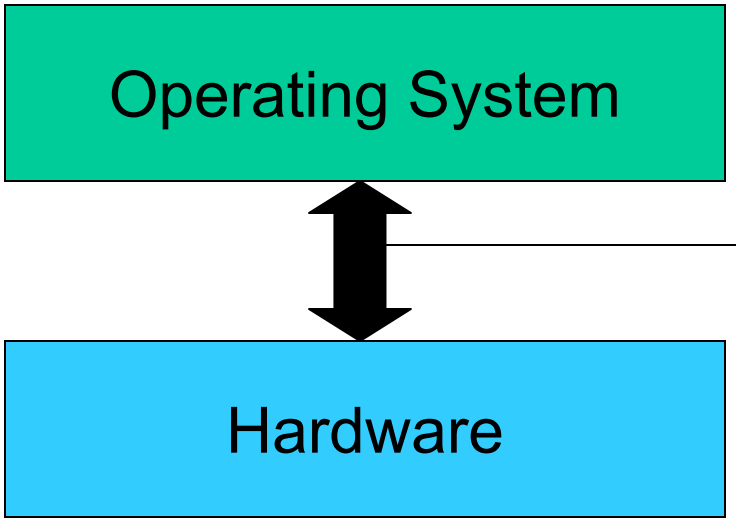


Structure of a Computer System

User Mode

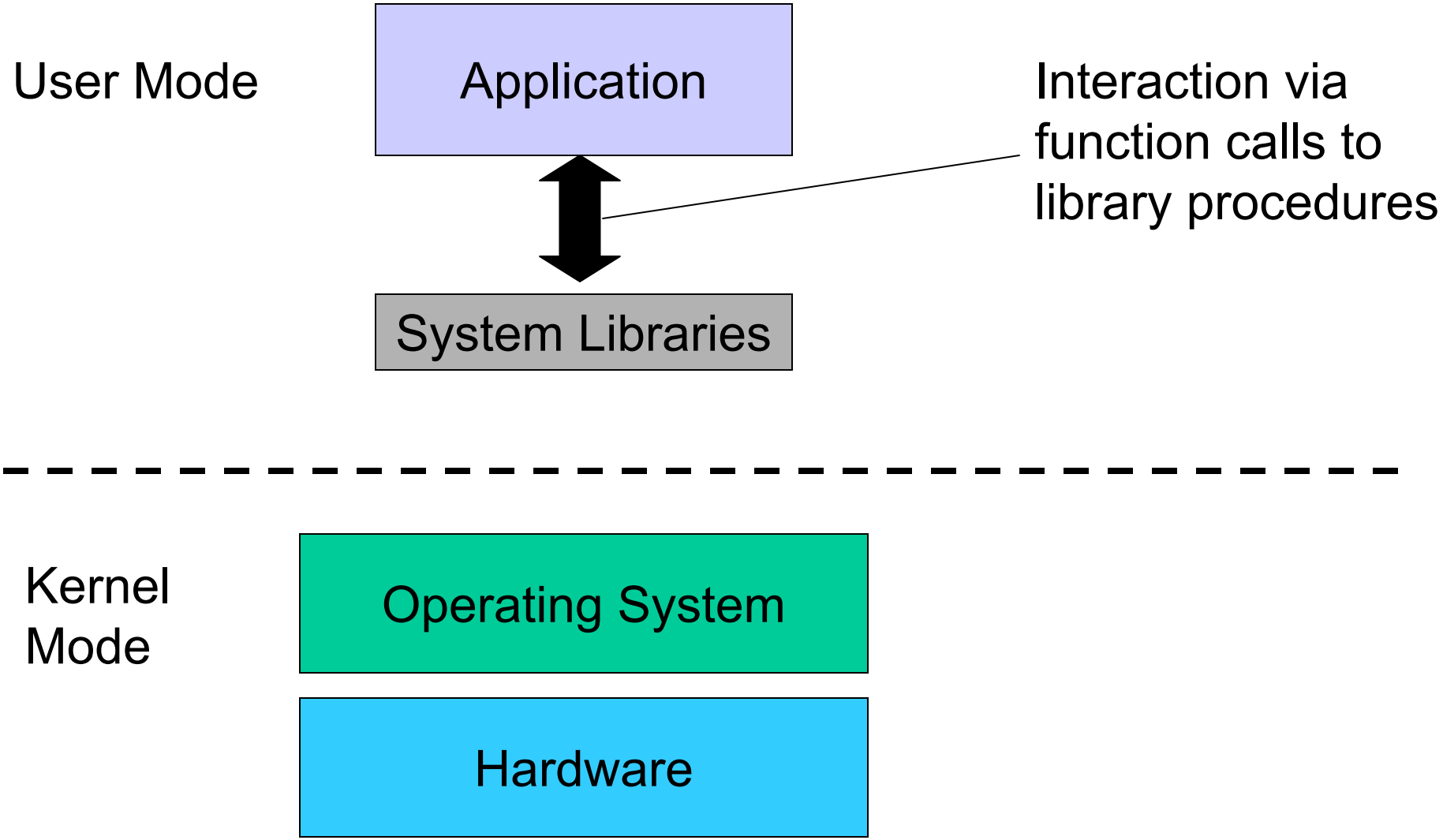


Kernel Mode

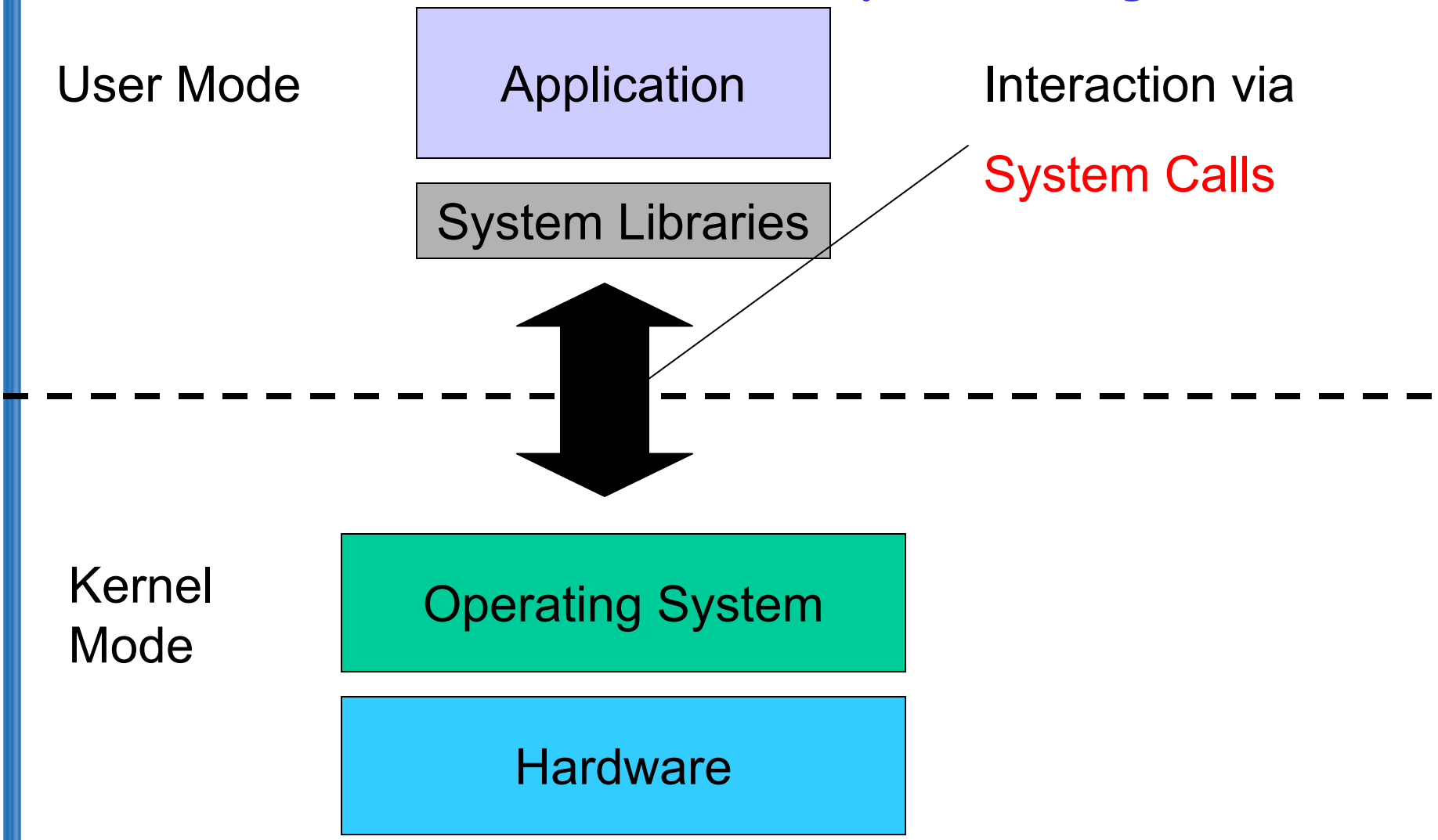


Interacts via load and store instructions to CPU and device registers, and interrupts

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 Software

- Fundamentally, OS functions the same way as ordinary computer software
  - It is a 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

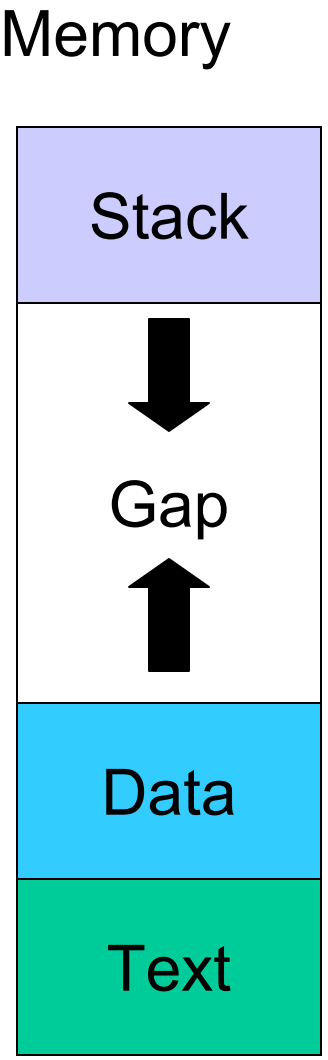
- Processes
- Concurrency and deadlocks
- Memory management
- Files
- Information Security and Protection
- Scheduling and resource management

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

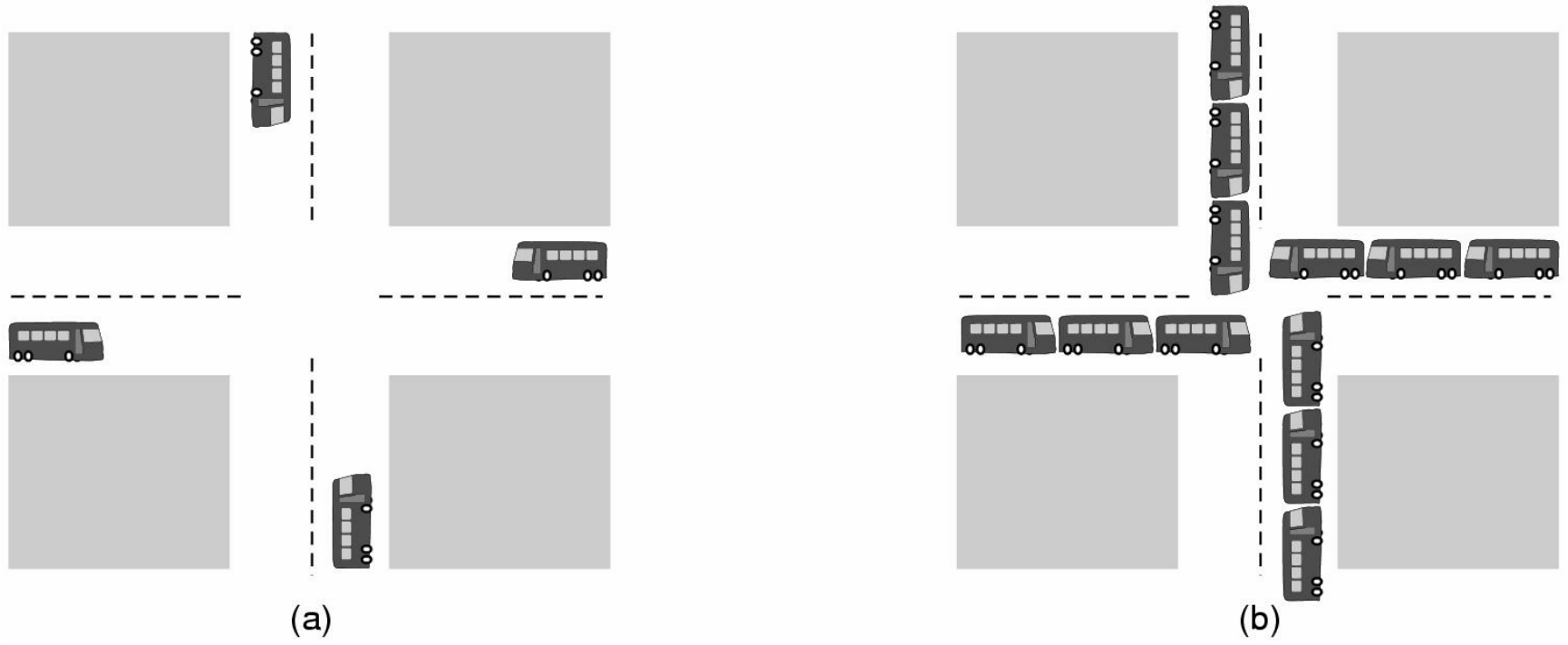
- Consist of three segments
  - Text
    - contains the code (instructions)
  - Data
    - Global variables
  - Stack
    - Activation records of procedure
    - Local variables
- Note:
  - data can dynamically grow up
  - The stack can dynamically grow down



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

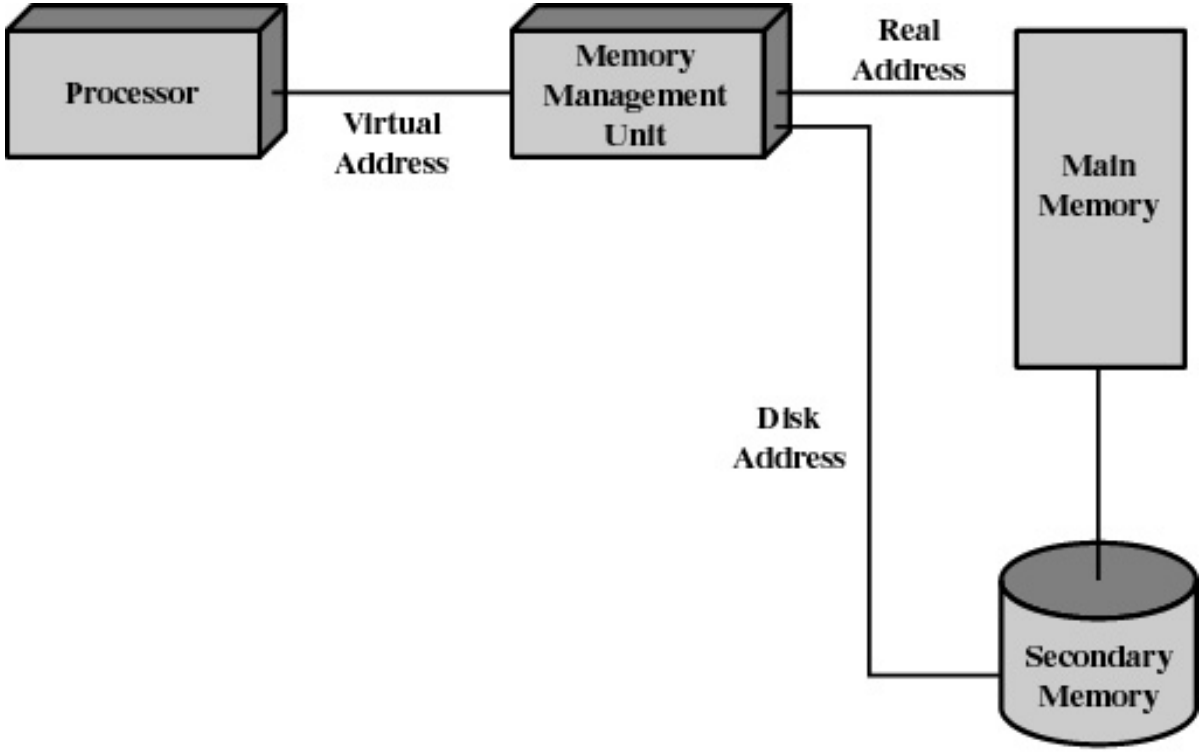


Figure 2.10 Virtual Memory Addressing

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

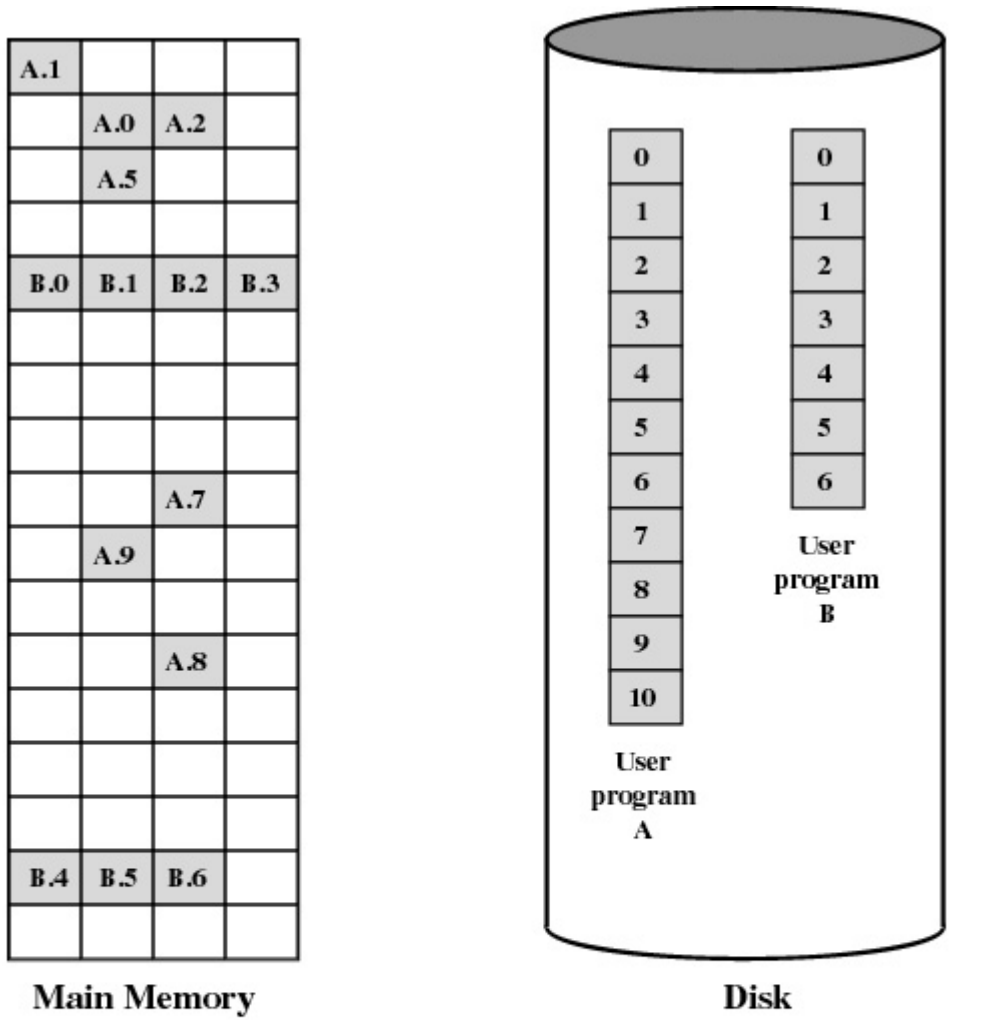
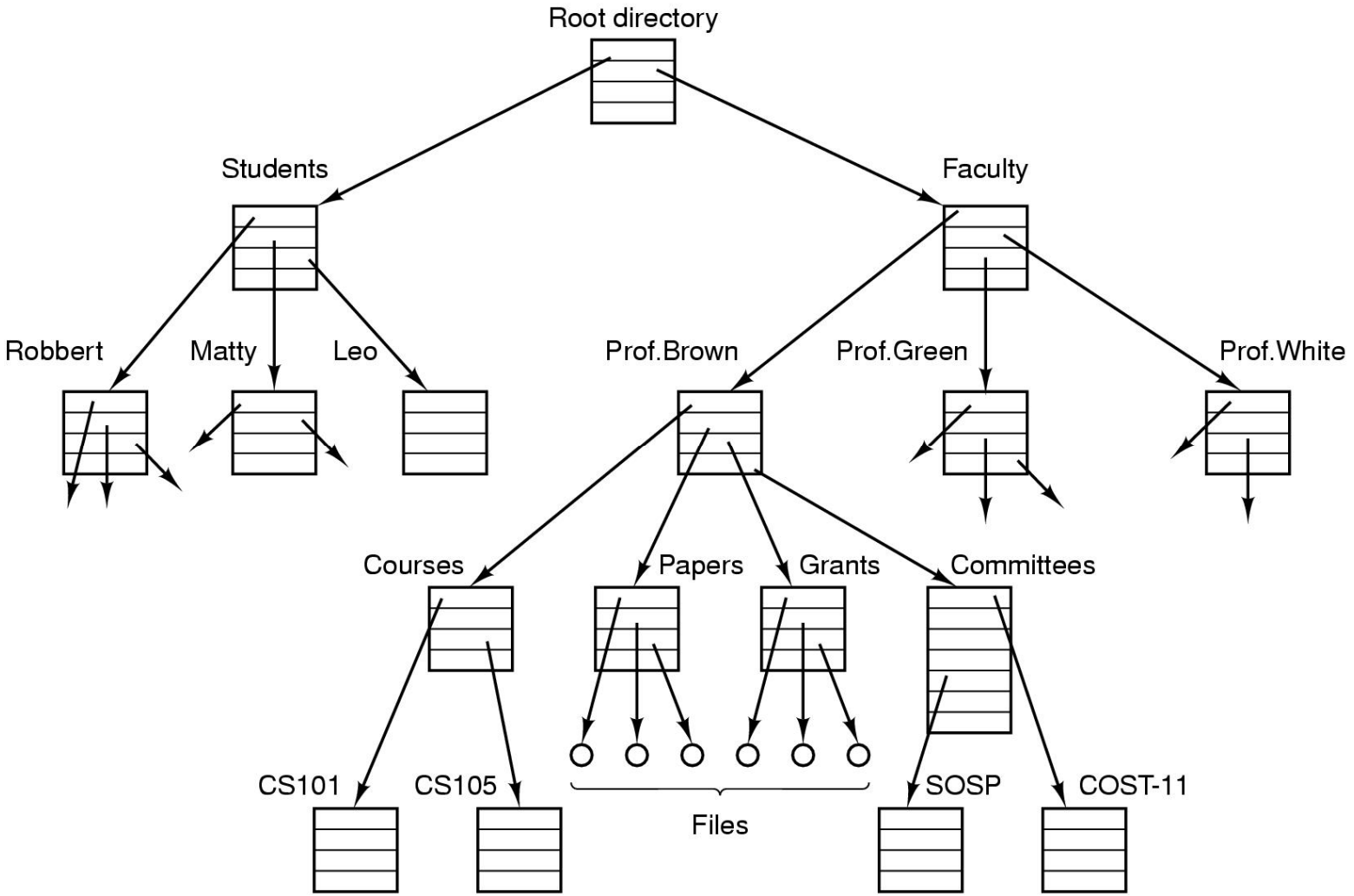


Figure 2.9 Virtual Memory Concepts

File System

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

Example File System



Information Protection and Security

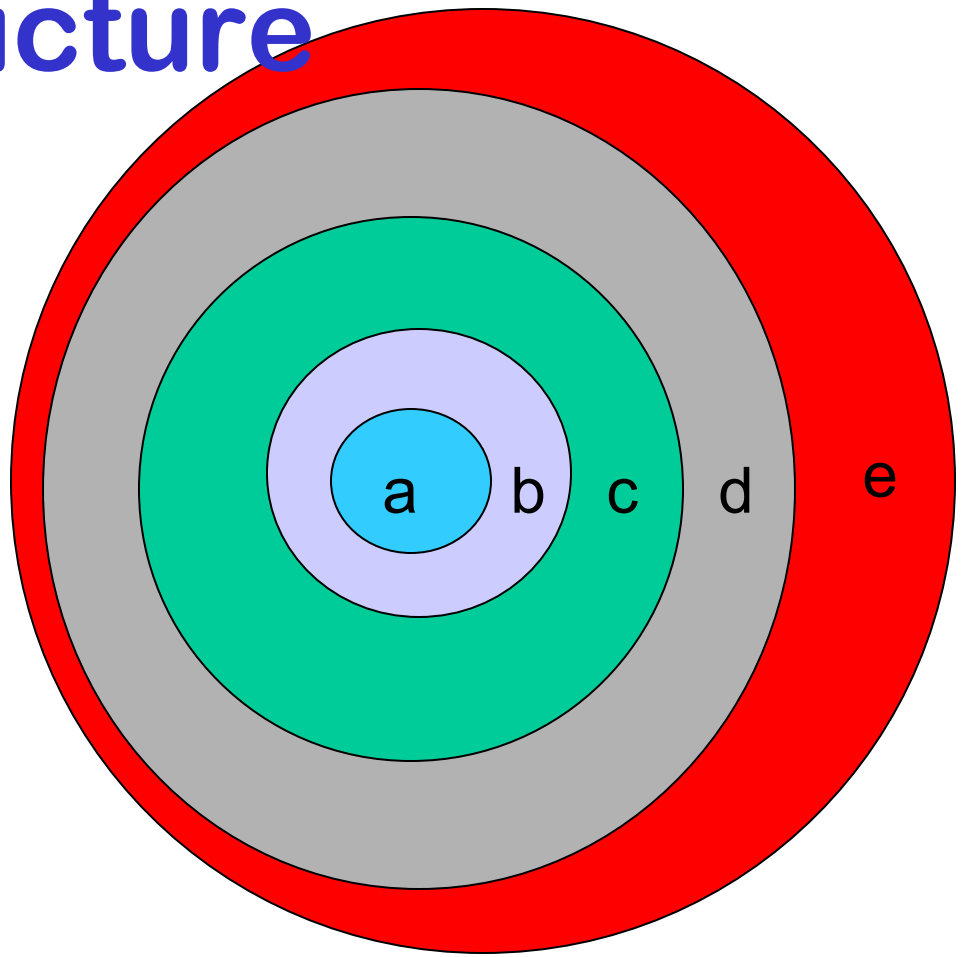
- Access control
  - regulate user access to the system
  - Involves authentication
- Information flow control
  - regulate flow of data within the system and its delivery to users

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

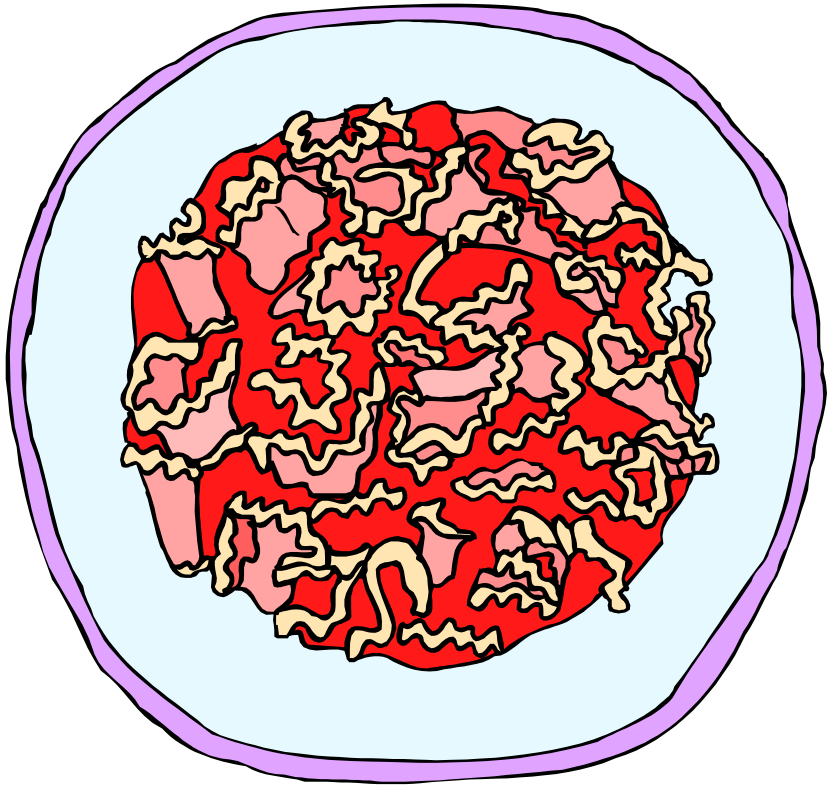


Operating System Structure

- 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…

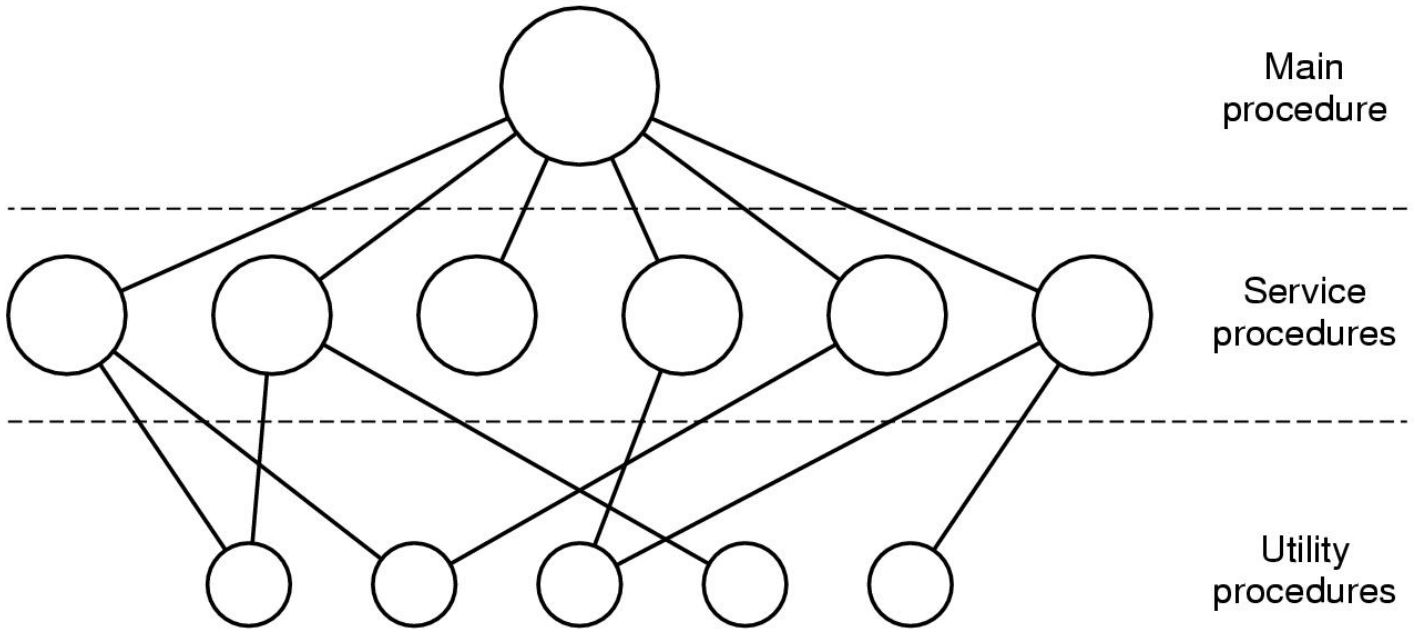
The Monolithic Operating System Structure

- 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

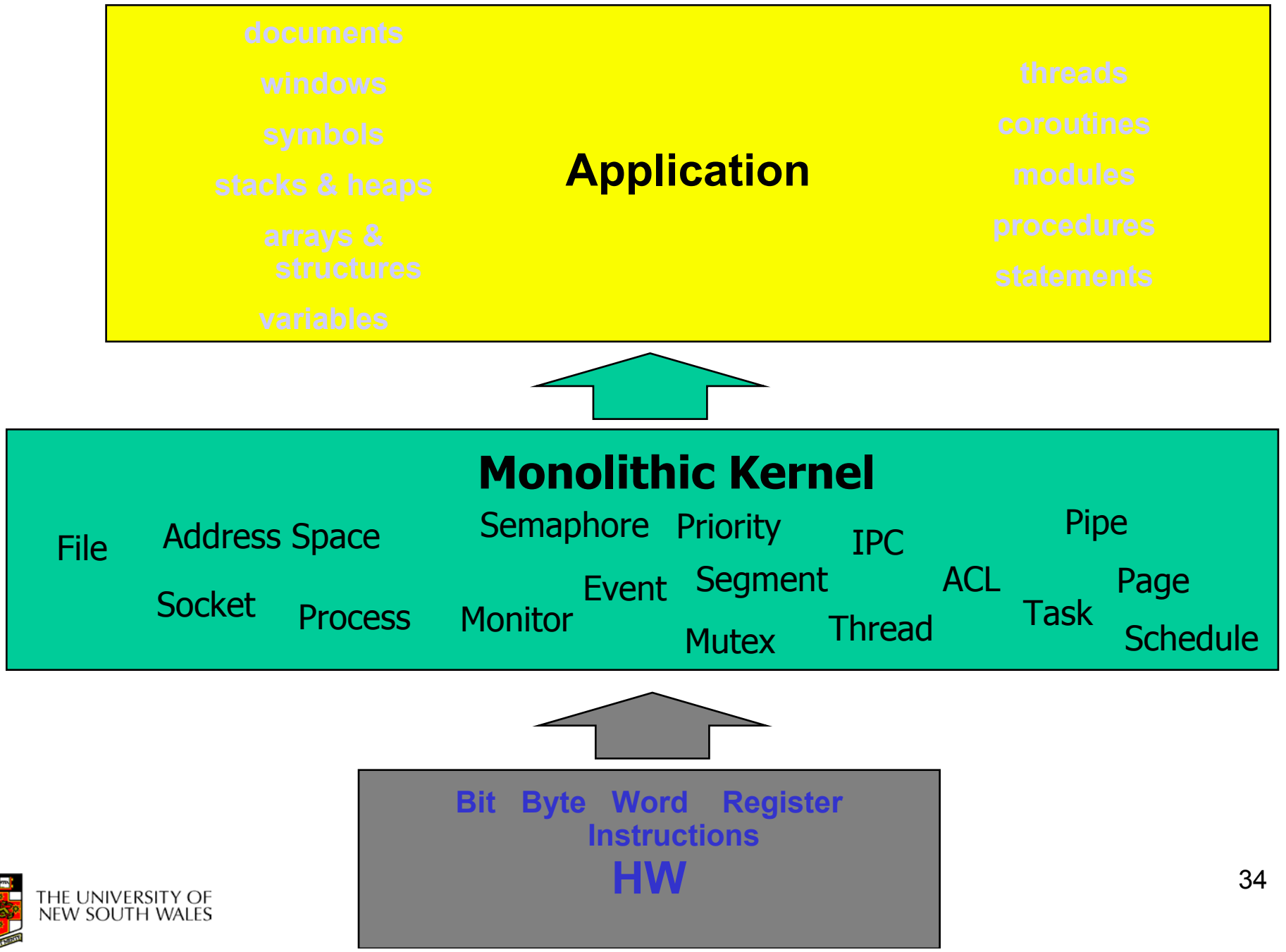


OS Complexity is a major issue

- 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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stacks & heaps
arrays & structures
variables
Application
threads
coroutines
modules
procedures
statements
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Address Space
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Process
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Event
Segment
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Mutex
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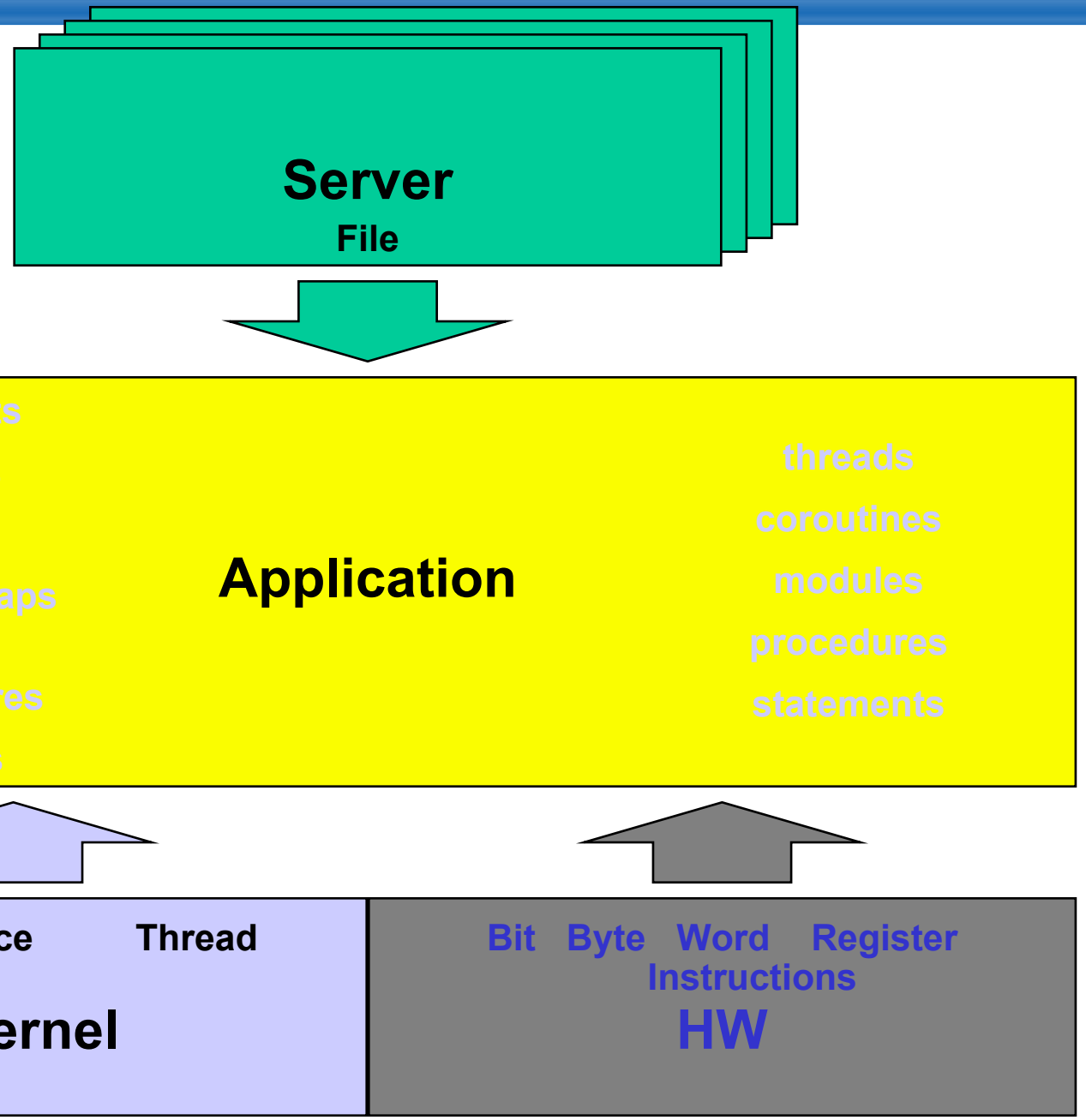
Bit Byte Word Register
Instructions
HW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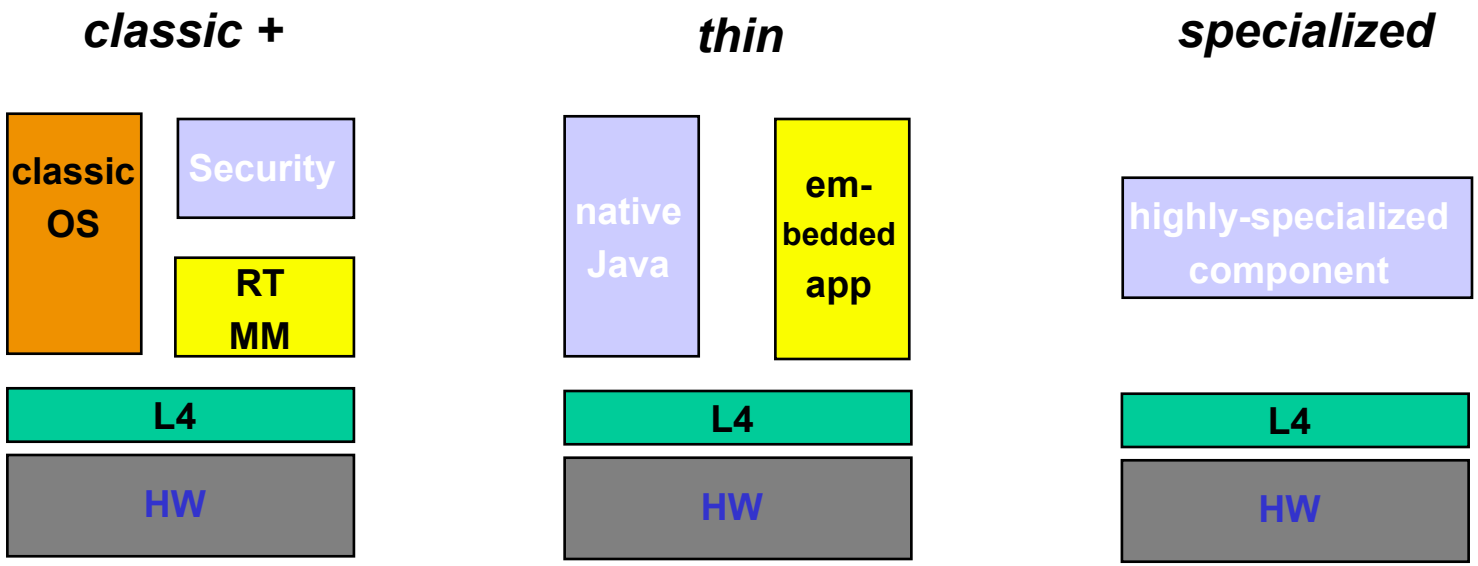
classic +
classic OS
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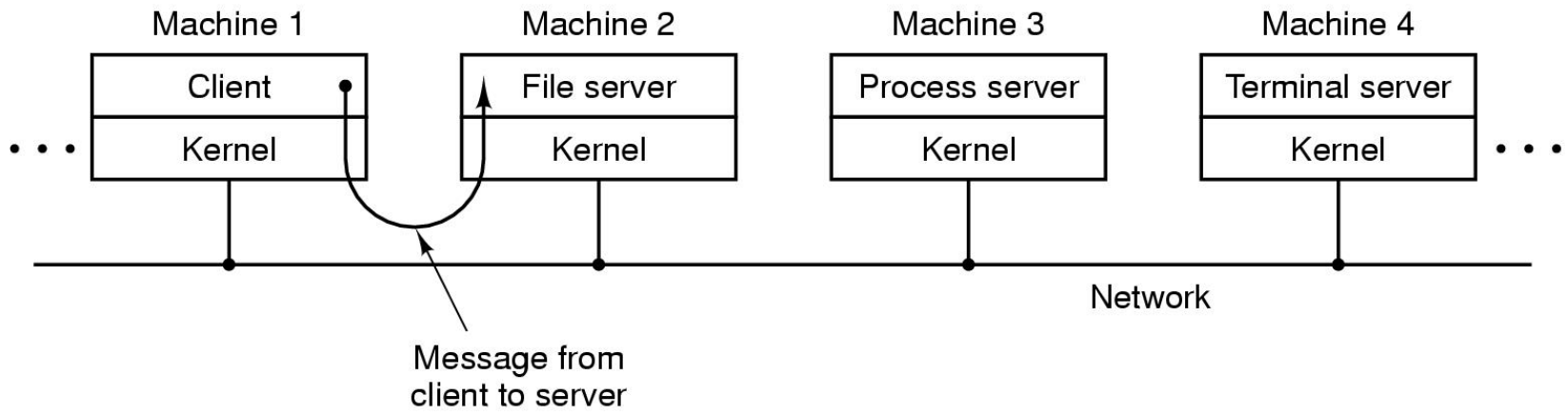
L4
HW
thin
native Java
em-bedded app
L4
HW
specialized
highly-specialized component
L4
HW

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

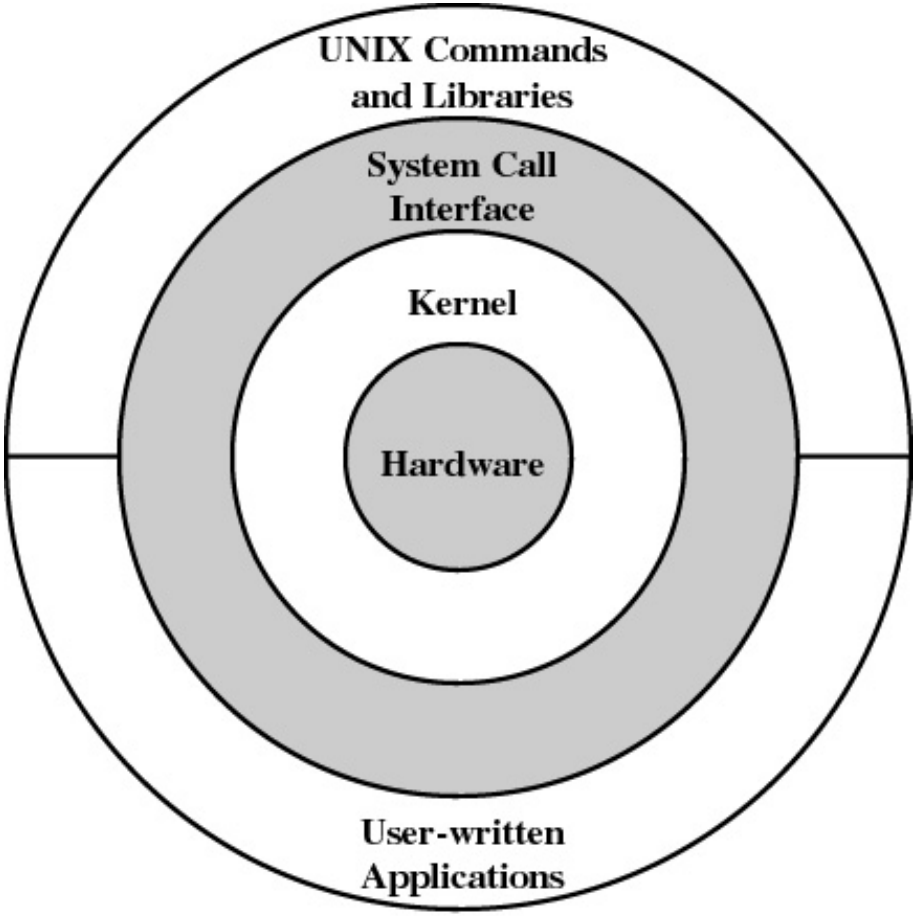


Figure 2.15 General UNIX Architecture

Traditional UNIX Kernel