



# Operating System Practice

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# Course Roadmap

## Advanced Operating System Concepts

- Concepts and Implementation of File System
- Storage Management and I/O Devices
- System Protection and Security

## Exercises on PC and Emulators

- Understanding the Linux Kernel
- Customizing the Linux Kernel and Implementing of System Calls
- Android Programming on Android Emulator

## Embedded System Exercises

- Introduction to Embedded System
- Tools and Techniques to Build Embedded Systems
- Implementation on Embedded System Evaluation Boards

# Advanced Operating System Concepts



- Chapter 10: File System
- Chapter 11: Implementing File-Systems
- Chapter 12: Mass-Storage Structure
- Chapter 13: I/O Systems
- Chapter 14: System Protection
- Chapter 15: System Security





# Review of Virtual- Memory Management

# Virtual Memory

- ▶ Virtual Memory Technique
  - A technique that allows the execution of a process that may not be completely in memory
- ▶ Potential Benefits
  - Programs can be much larger than the amount of physical memory
  - The level of multiprogramming increases because processes occupy less physical memory
  - Each user program may run faster because less I/O is needed for loading or swapping user programs
- ▶ Implementation: Demand Paging

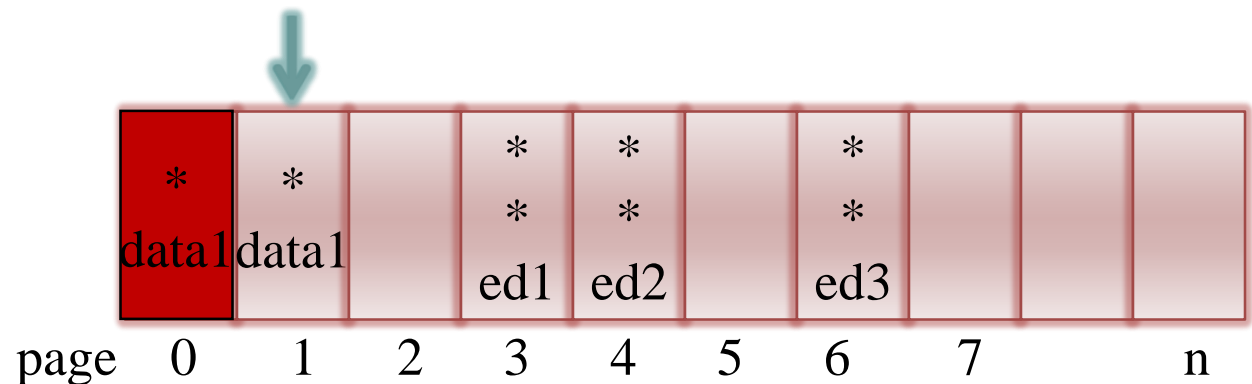
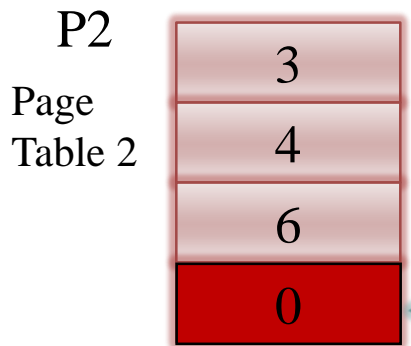
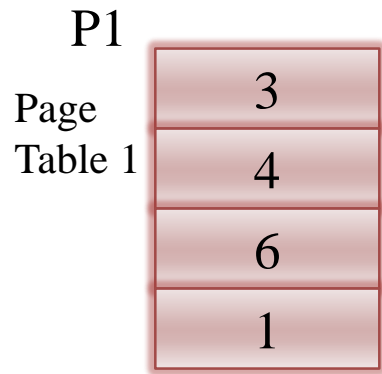


# Frame Allocation for Applications

- ▶ Global Allocation
  - Processes can take frames from others
- ▶ Local Allocation
  - Processes can only select frames from their own allocated frames → Fixed Allocation
  - The set of pages in memory for a process is affected by the paging behavior of only that process
- ▶ Remarks
  - Global replacement generally results in a better system throughput
  - Processes might not control their own page fault rates such that a process can affect each another easily under global replacement

# Advanced Memory Management Techniques— Copy on Write

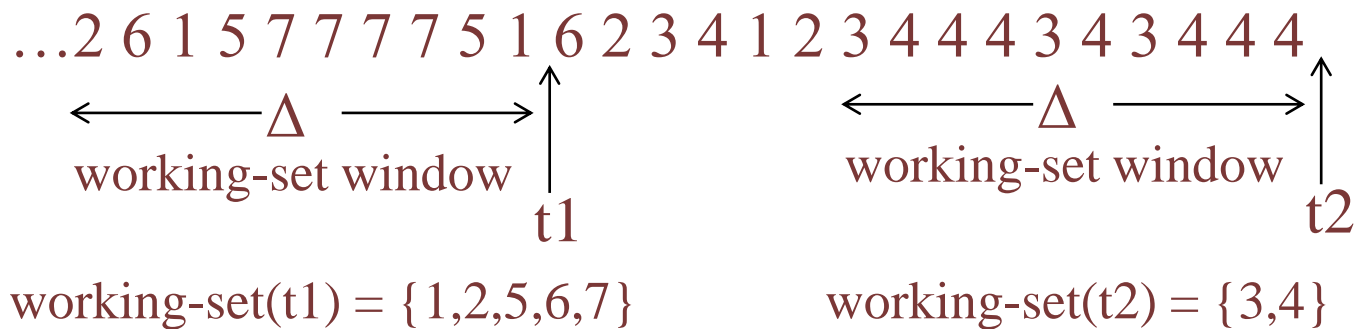
- ▶ Rapid process creation and reducing of new pages for the new process
- ▶ `fork()`; `execve()`; → no need to copy pages
- ▶ Shared pages → copy-on-write pages
  - Only the pages that are modified are copied!



# Advanced Memory Management Techniques— Working-Set Model

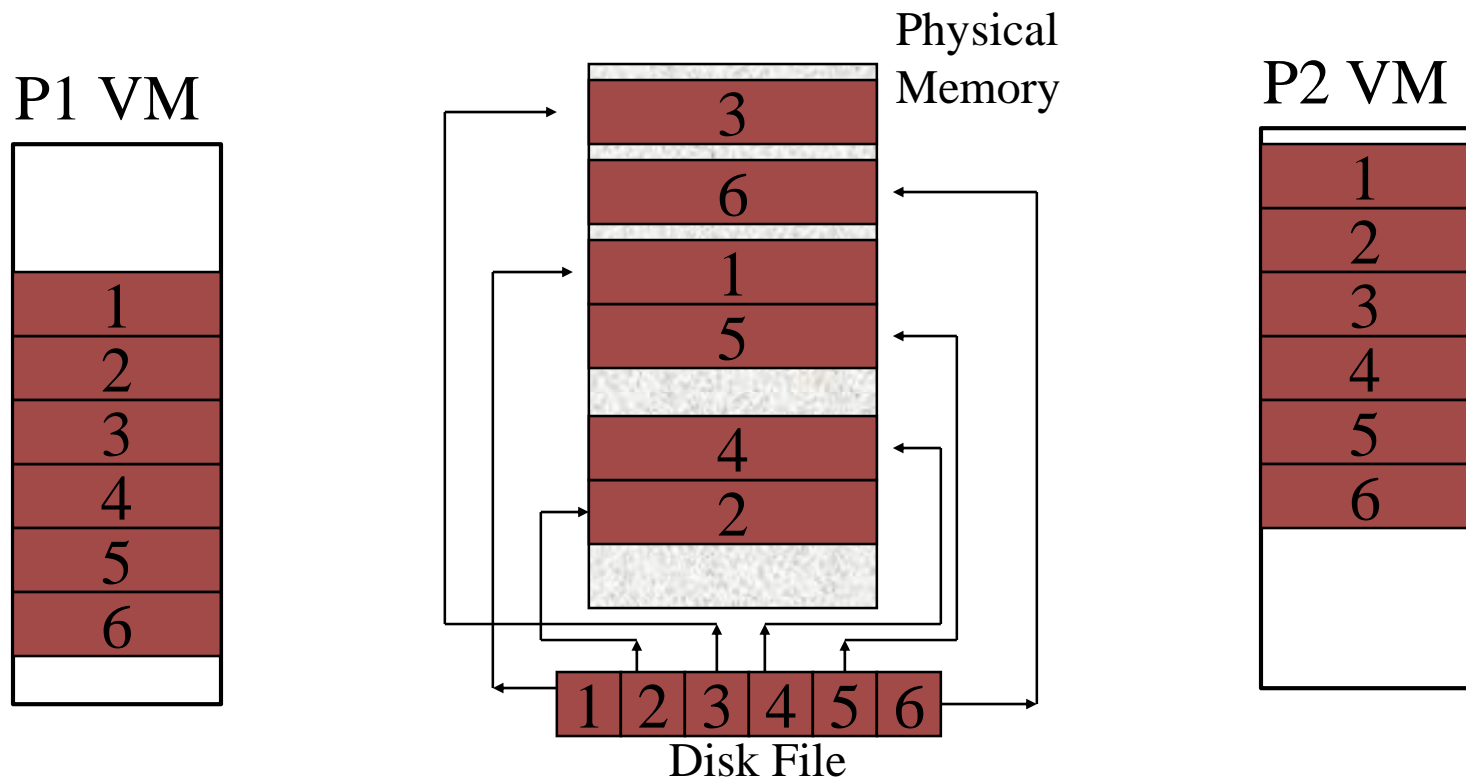
- ▶ Locality Model
  - **Spatial Locality**: adjacent pages
  - **Temporal Locality**: recently used pages
- ▶ Working Set: Approximation of a Program's Locality

Page references



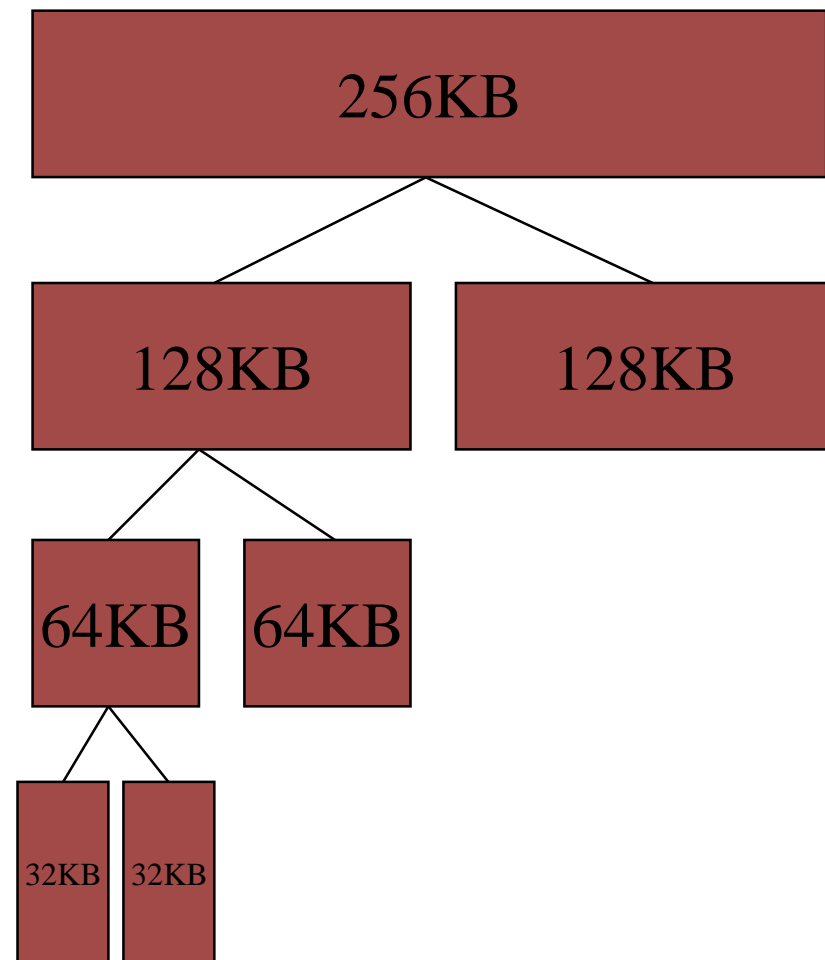
# Memory Mapped Files

- ▶ File writes might not cause any disk write!
- ▶ Mapped files can be used for memory sharing!



# Kernel Memory Allocation— Buddy System

- ▶ A Fixed-Size Segment of Physically Contiguous Pages
- ▶ A Power-of-2 Allocator
- ▶ Advantage: Quick Coalescing Algorithms
- ▶ Disadvantage: Internal Fragmentation

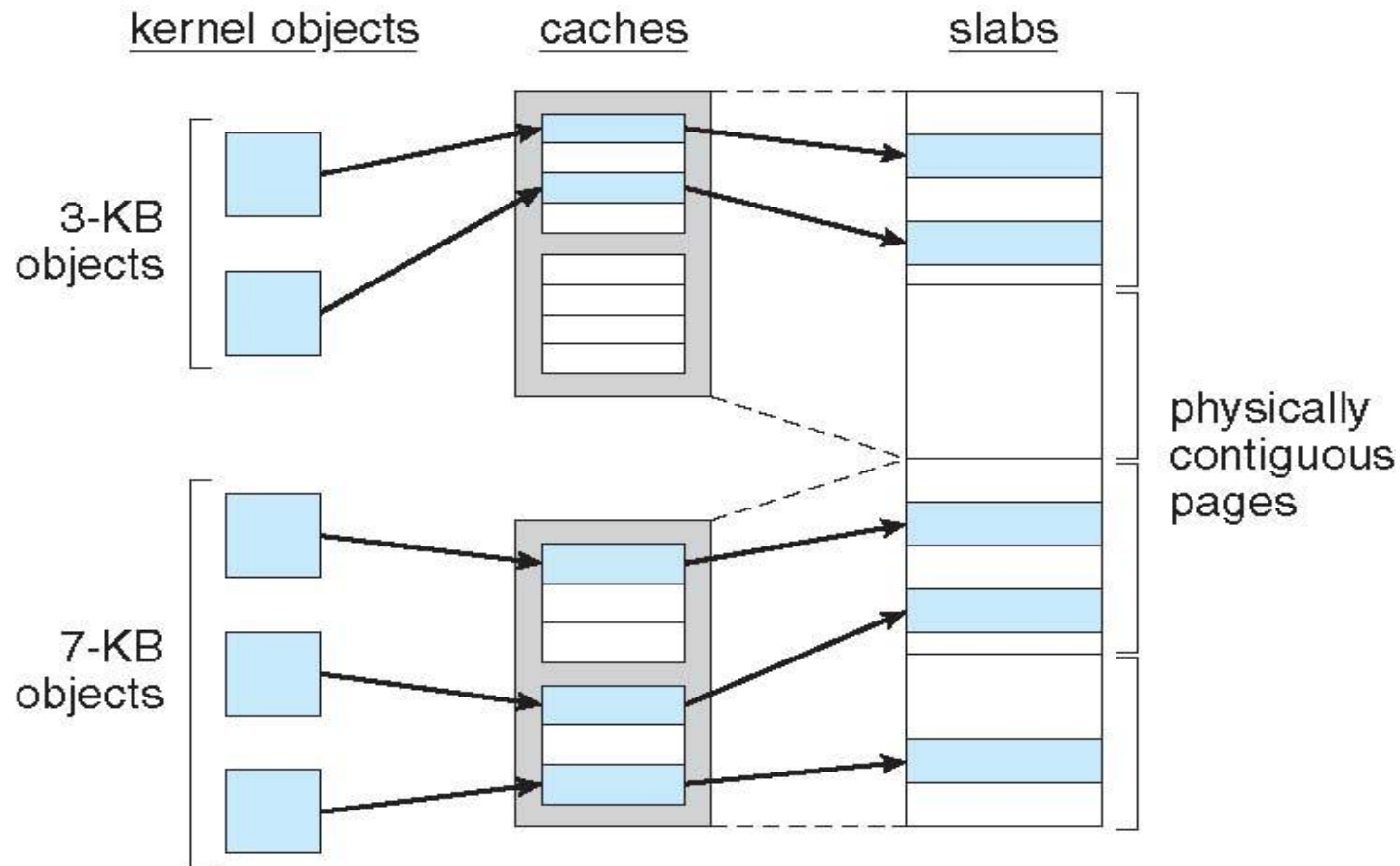


# Kernel Memory Allocation— Slab Allocator (1 / 2)

- ▶ Slab: one or more physically contiguous pages
- ▶ Cache: one or more slabs
- ▶ Slab States
  - Full
  - Empty
  - Partial
- ▶ Slab Allocator
  - Look for a free object in a partial slab
  - Otherwise, allocate a new slab and assign it to a cache
- ▶ Benefits
  - No space wasted in fragmentation
  - Memory requests are satisfied quickly



# Kernel Memory Allocation— Slab Allocator (2/2)





# Chapter 10: File System

# Why Storage Management

## ▶ Motivations

- Main memory is too small to accommodate all the data and programs permanently

→ Secondary Storage

- A mechanism is needed for on-line storage access to both programs and data residing on the secondary storage

→ File System

## ▶ Device Variety

- Speed, Dedication, Read/Write, Char/Block Transfer, Synchronous Mode, etc.



# File Concepts

- ▶ Files
  - Each is a named collection of related information
  - Each is a logical unit often with its interpretation left for applications, creators, or users
    - Text, Source, Object, Executable Files
- ▶ A Directory Structure
  - Meta Data & File Organization



# File Attributes

- ▶ File attributes vary from one OS to another:
  - Name: Case-sensitive or not
    - The only information must be kept in human-readable form
  - Identifier: A unique tag
  - Type: It is only for systems that support file types
  - Location
  - Size: Current and max sizes
  - Protection: access control
  - Time, date, and user identification
- ▶ File attributes are usually kept in the directory structure



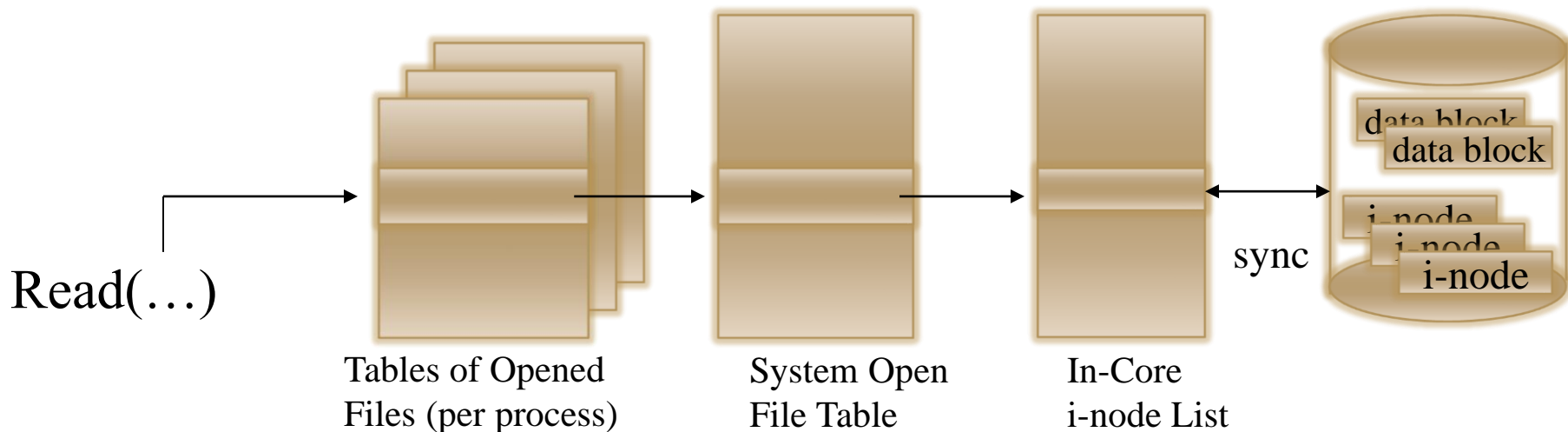
# File Operations (1 / 3)

- ▶ Basic Directory Operations:
  - File creation: Space allocation & directory-structure-entry creation
  - File open and close
  - File writing: Write pointer
  - File reading: Read pointer
  - File reposition: Seek-like operations
    - File-position pointer
  - File deletion: Space reclaiming & directory-structure-entry deletion
  - File truncating: File-length resetting



# File Operations (2/3)

- ▶ Open, Close, Read and Write among Multiple Processes
  - File Descriptors and Tables
  - File Position Pointer, File-Open Count
  - Disk Location and Access Rights



# File Operations (3 / 3)

## ▶ Extensions

- File Renaming, Appending, Copying, etc.

## ▶ Other Operations

- Attribute Retrieval and Setting
- File Locking
  - Shared or Exclusive Locks
    - Mandatory (Windows) Locks— access is denied depending on locks held and requested
    - Advisory (Unix) Locks— processes can find status of locks and decide what to do
- Search of a File
  - A File-System Traversal



# File Types

## ▶ Key Issue

- The Recognition of File Types by OS

## ▶ Common Techniques

- Types as Parts of File Names
  - .doc, .txt, .rtf, .mpeg, .mp3, .avi, .pdf, .ps, .tex, .exe, .com, .bin, .c, .cc, .java, .asm, .a, .bat, .sh, .o, .obj, .lib, .dll, .zip, .tar, .arc, etc.
- A Magic Number at the Beginning of a File
  - Enforcement or Hints? → Application Duty



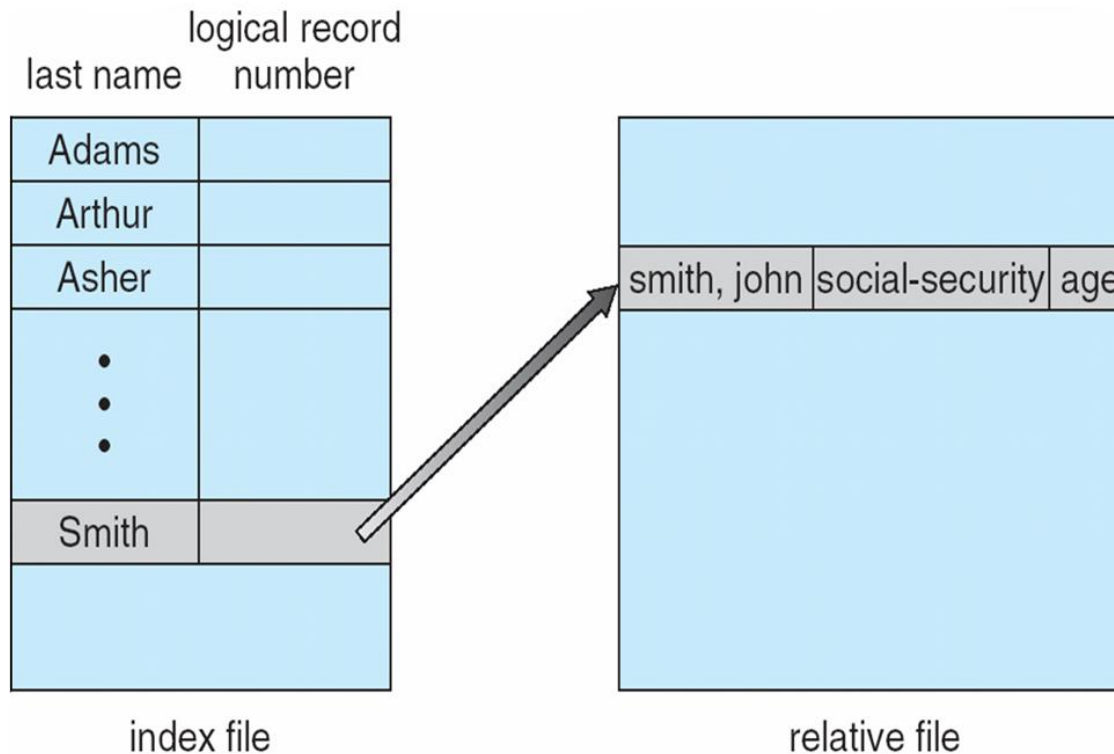
# Access Methods (1 / 2)

- ▶ Sequential Access
  - Read-Next and Write-Next Operations
  - Reset or N-Record Skipping/Rewinding
- ▶ Direct Access (or Relative Access)
  - A file is considered as a numbered sequence of blocks or records
  - Read-N, Write-N, and Position-N Operations
    - Relative Block/Record Number
  - Easy Simulation of Sequential Access



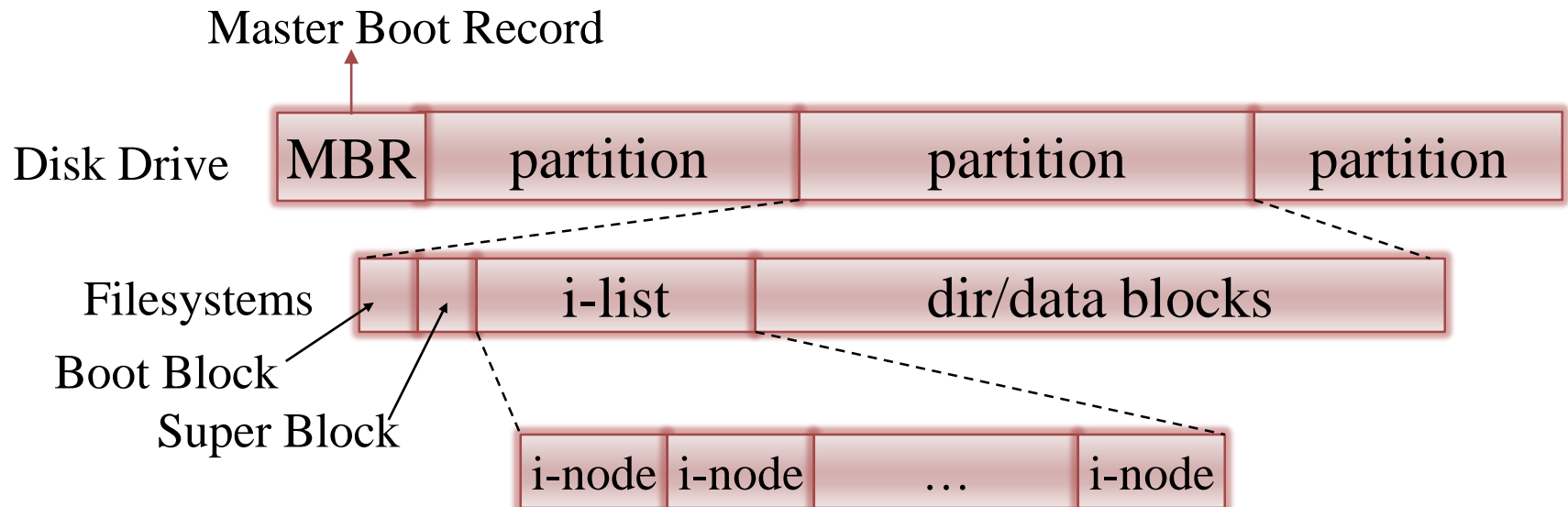
# Access Methods (2 / 2)

## ▶ Index-Based Access



# Directory Structure

- ▶ A hierarchical arrangement of directories and files – starting at root “/”
  - File: An abstract data type
  - Volume: A chunk of storage that holds a file system



# Directory Overview

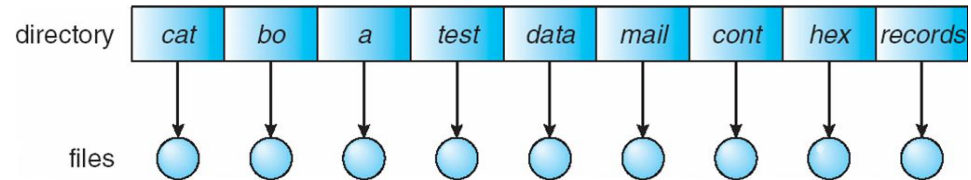
- ▶ Directory – A Symbol Table that Translate File Names into Their Directory Entries
- ▶ Operations on a Directory
  - Searching for a File
  - Create a File
  - Delete a File
  - List a Directory
  - Rename a File
  - Traverse the File System



# Simple Directories

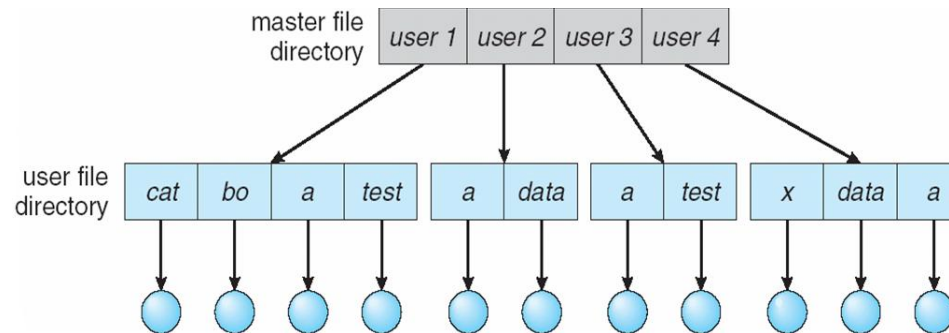
## ▶ Single-Level Directory

- All files are in the same directory
  - Problems occur when the number of files increases or when the system has more than one user



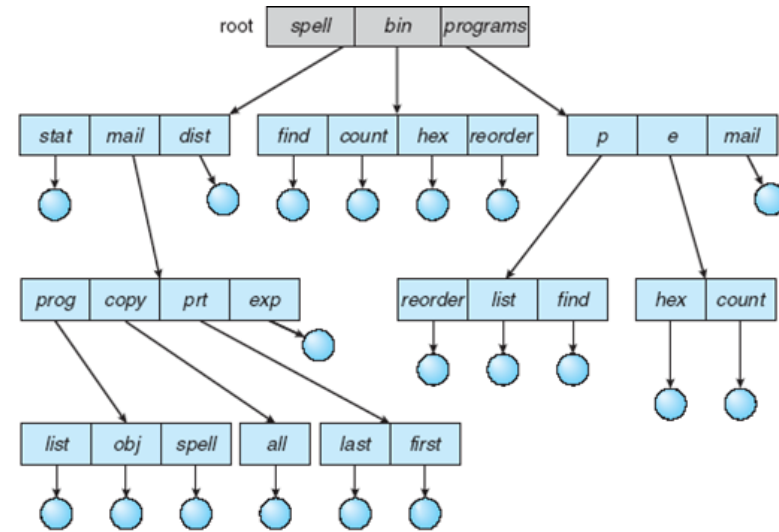
## ▶ Two-Level Directory

- The Master File Directory (MFD) → Multiple User File Directories (UFD's) → Files



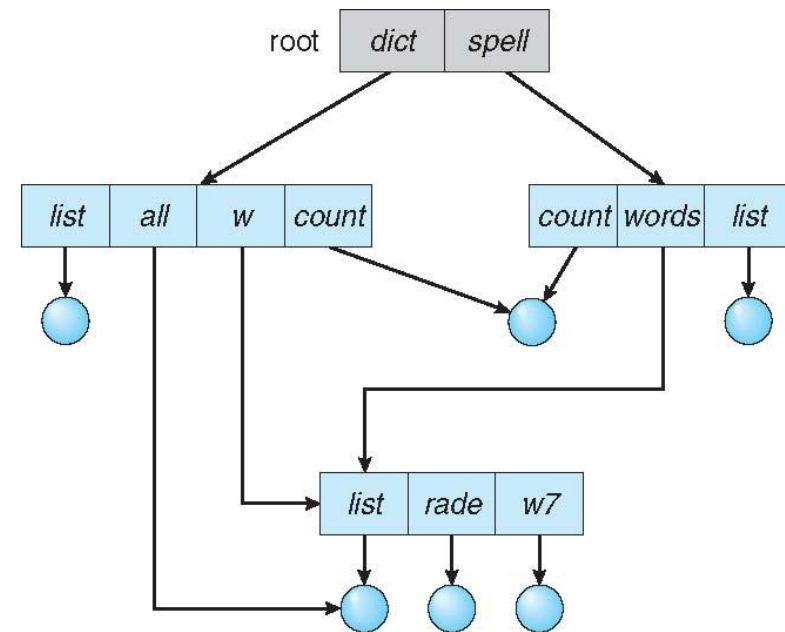
# Tree-Structured Directories

- ▶ The Root Directory → Subdirectories and/or files
  - Example: MS-DOS
- ▶ Current and Home Directories
  - A child process usually inherits the current directory of its parent
- ▶ Absolute and Relative Path Names
  - Examples: /root/spell/mail and spell/mail
- ▶ Policies
  - Directory Deletion: Only Empty Directories?
    - `rm -r file-name`



# Acyclic-Graph Directories

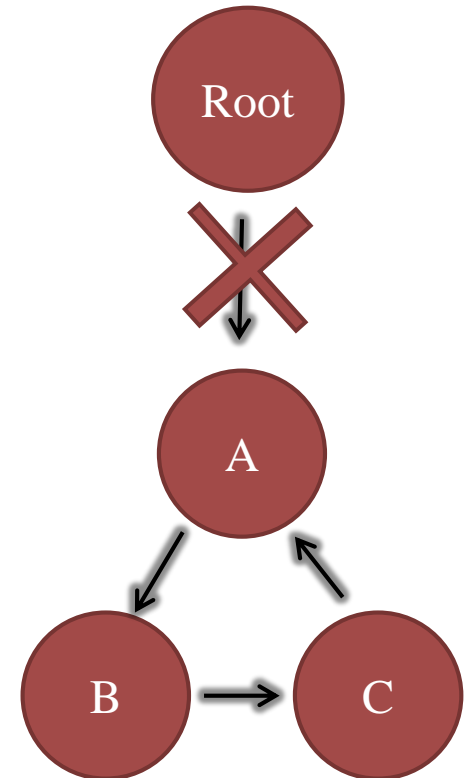
- ▶ Motivation— Allow the Sharing of Files, Compared to Tree-Structured Directories
- ▶ File-Sharing Implementations
  - Links – A pointer to another file or subdirectory
    - Hard and soft links
  - Information Duplication
    - Consistency issue
  - Potential Problems
    - Multiple path names
      - Traversal and deletion problems



# General Graph Directory

## ▶ Potential Problems:

- Problems in Correctness and Performance in Searching Any Components
  - Limitation on the Number of Accessed Directories?
- Problems in File Deletion
  - Self-Referencing or a Cycle
    - Garbage Collection: Traversing, Marking and Deletion → Extremely Time-Consuming
    - Bypassing Links during Directory Traversal



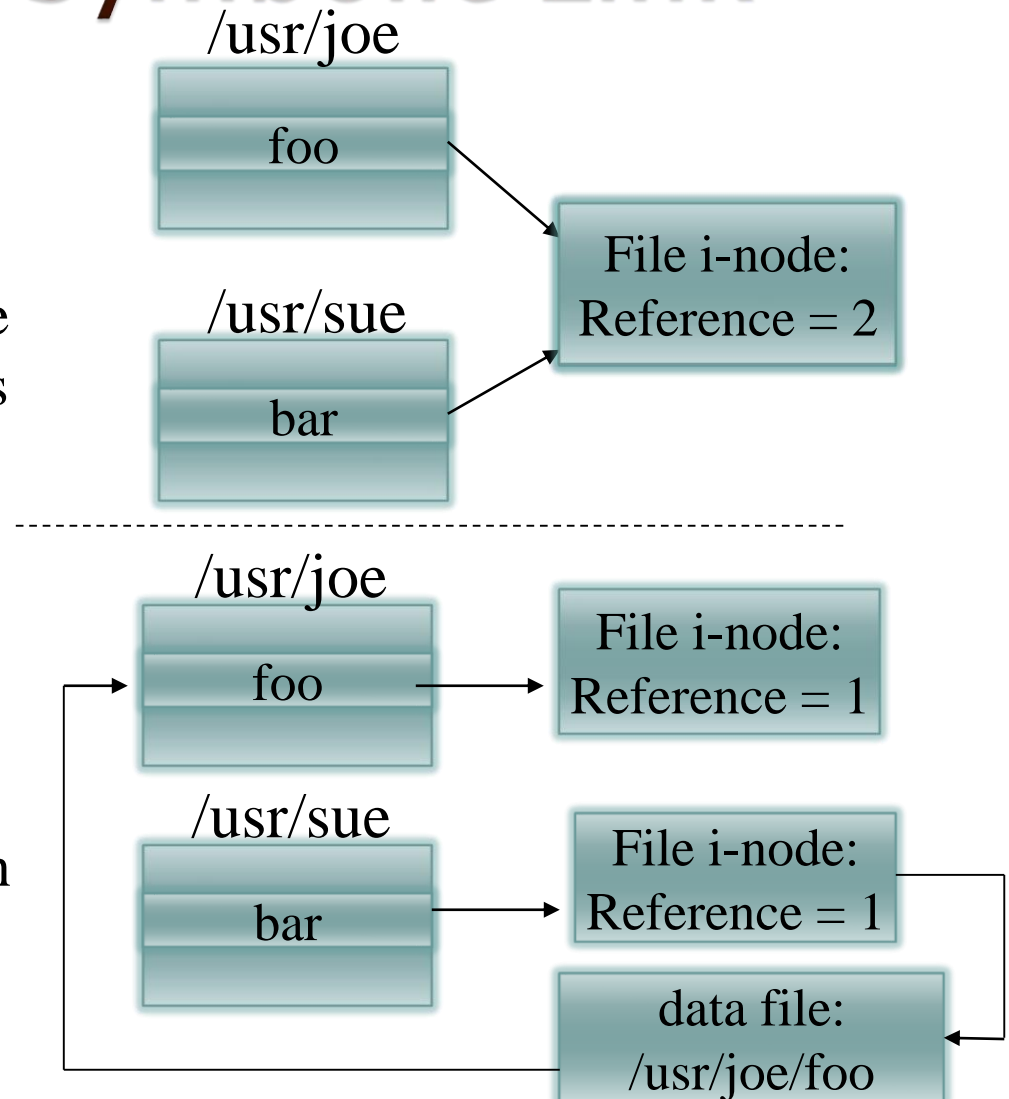
# Hard Link and Symbolic Link

## ▶ Hard Link

- Each directory entry creates a link of a filename to the i-node that describes the file's contents

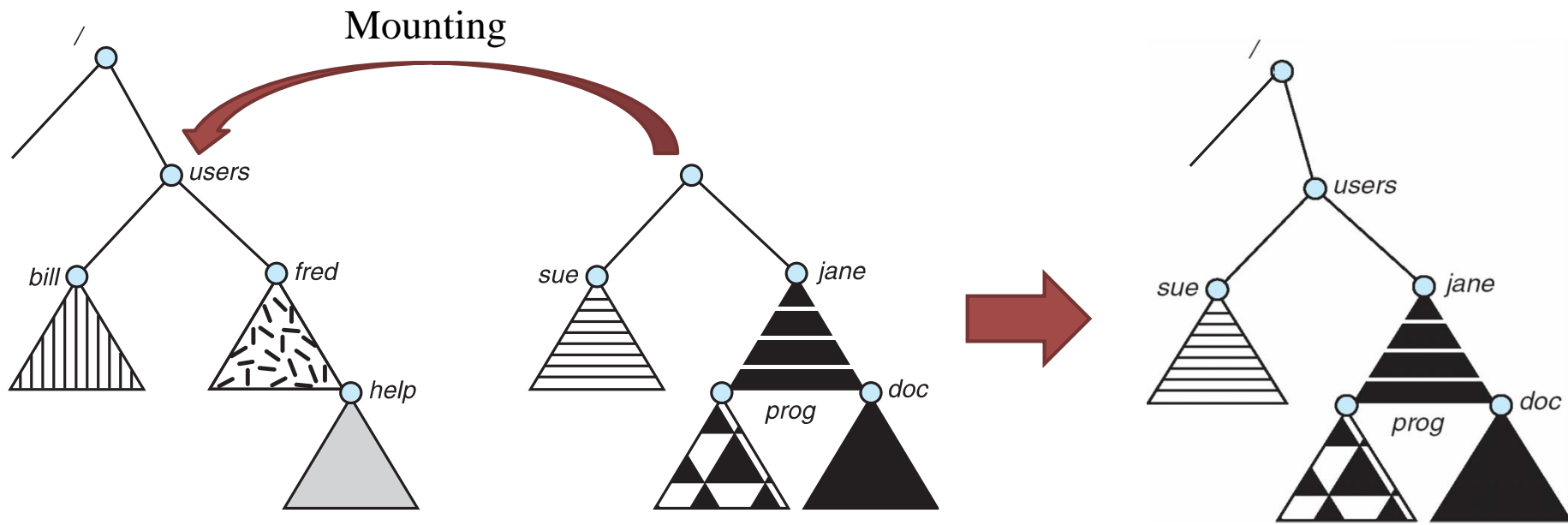
## ▶ Symbolic Link (Soft Link)

- It is implemented as a file that contains a pathname
- Filesize = pathname length
- Example: shortcut on Windows



# File System Mounting

- ▶ A file system must be **mounted** before it can be accessed
- ▶ An unmounted file system is mounted at a **mount point**



# File Sharing

- ▶ Sharing of files on multi-user systems is desirable
- ▶ Sharing may be done through a **protection** scheme
- ▶ On distributed systems, files may be shared across a network
- ▶ Network File System (NFS) is a common distributed file-sharing method
- ▶ If multi-user system
  - **User IDs** identify users, allowing permissions and protections to be per-user
  - **Group IDs** allow users to be in groups, permitting group access rights
  - Owner of a file/directory
  - Group of a file/directory



# Remote File Systems

- ▶ Uses networking to allow file system access between systems
  - Manually via programs like FTP
  - Automatically, seamlessly using distributed file systems
  - Semi automatically via the world wide web
- ▶ Client-server model allows clients to mount remote file systems from servers
  - Server can serve multiple clients
  - NFS is standard UNIX client-server file sharing protocol
  - CIFS is standard Windows protocol
  - Standard operating system file calls are translated into remote calls
- ▶ Distributed Information Systems: such as DNS (Domain Name System), NIS (Network Information Service), ... implement unified access to information needed for remote computing



# File Sharing— Failure Modes

- ▶ All file systems have failure modes
- ▶ Remote file systems add new failure modes, due to network failure, server failure
  - Recovery from failure can involve **state information** about status of each remote request



# File Sharing— Consistency Semantics

- ▶ Specify how multiple users access a shared file simultaneously
  - Similar to process synchronization algorithms
  - Unix File System (UFS) implements:
    - Writes to an open file visible immediately to other users of the same open file
    - Sharing a file pointer to allow multiple users to read and write concurrently
  - Andrew File System (AFS) implemented complex remote file sharing semantics
    - Writes to an open file is not visible immediately to other users
    - Writes only visible to sessions starting after the file is closed



# Protection

- ▶ File owner/creator should be able to control:
  - What can be done by whom
- ▶ Types of access
  - Read
  - Write
  - Execute
  - Append
  - Delete
  - List



# Protection on Unix

- ▶ Mode of access: read, write, execute
- ▶ Three classes of users on Unix / Linux

a) <b>owner access</b>	7	➔	RWX 1 1 1
b) <b>group access</b>	6	➔	RWX 1 1 0
c) <b>public access</b>	1	➔	RWX 0 0 1

