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 Programing 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

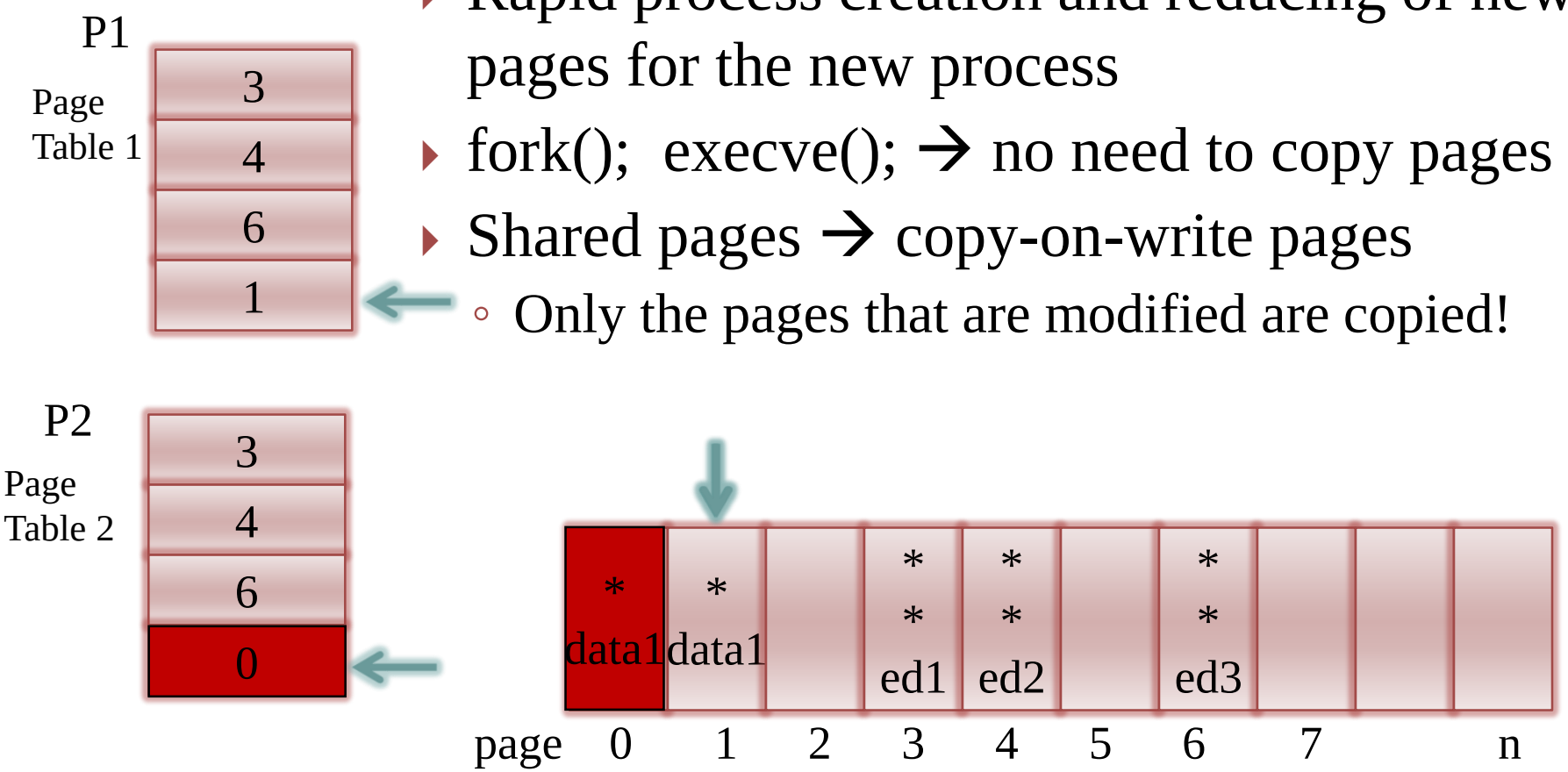
- Virtual Memory Technique
  - A technique that allows the execution of a process that may not be completely in memory
- Potential Benefits
  - Programs can be much larger than the amount of physical memory
  - The level of multiprogramming increases because processes occupy less physical memory
  - 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

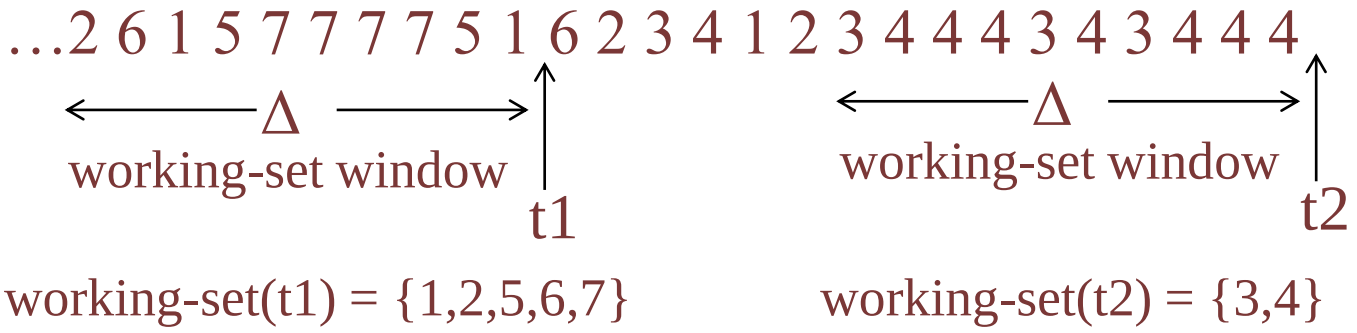
Advanced Memory Management Techniques— Copy on Write

- 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!



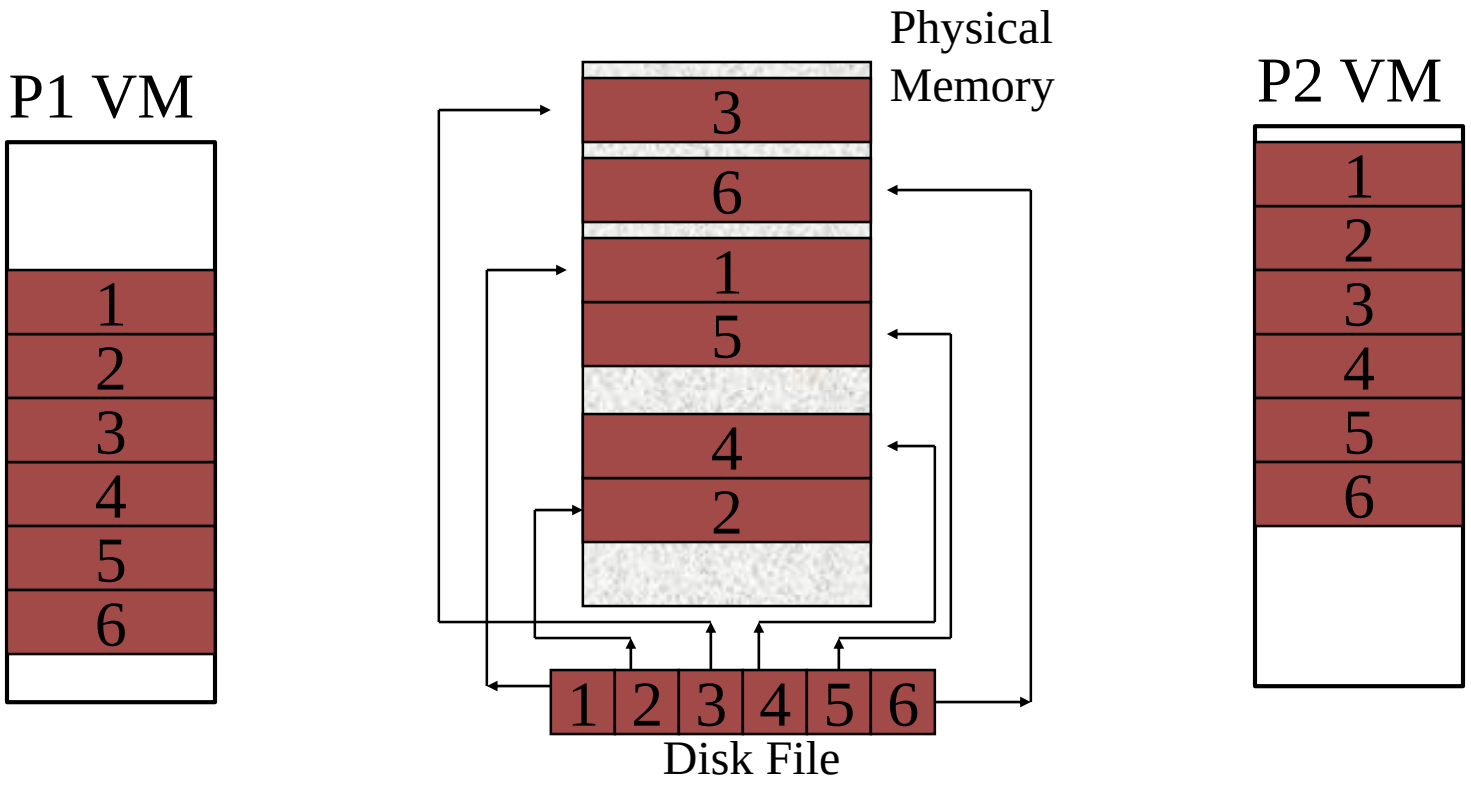
Advanced Memory Management Techniques— Working-Set Model

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



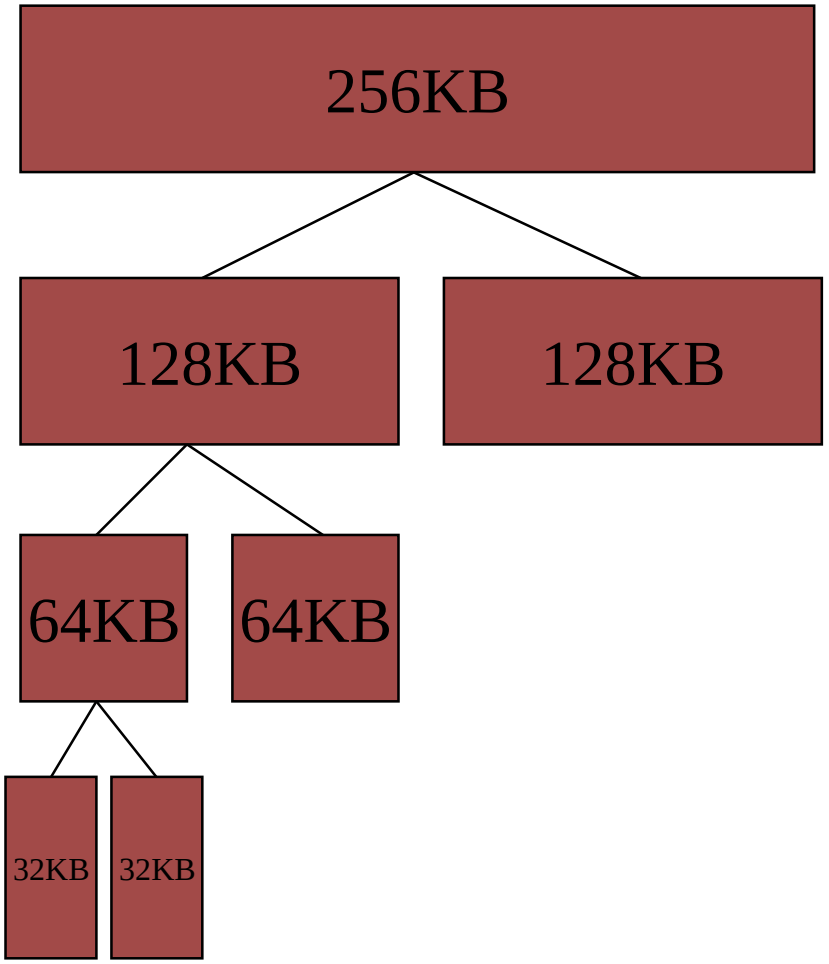
Memory Mapped Files

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



Kernel Memory Allocation—Buddy System

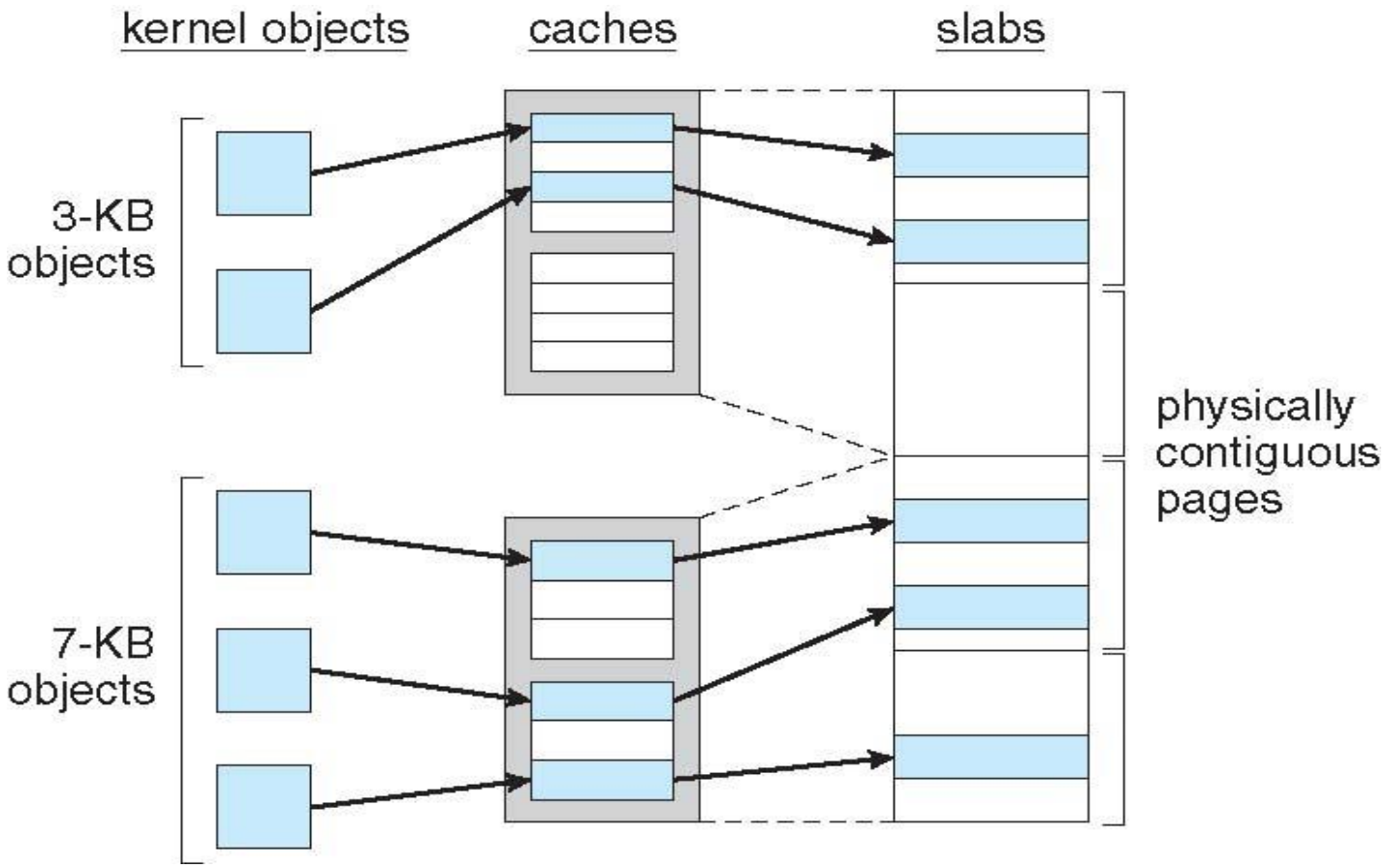
- A Fixed-Size Segment of Physically Contiguous Pages
- A Power-of-2 Allocator
- Advantage: Quick Coalescing Algorithms
- Disadvantage: Internal Fragmentation



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

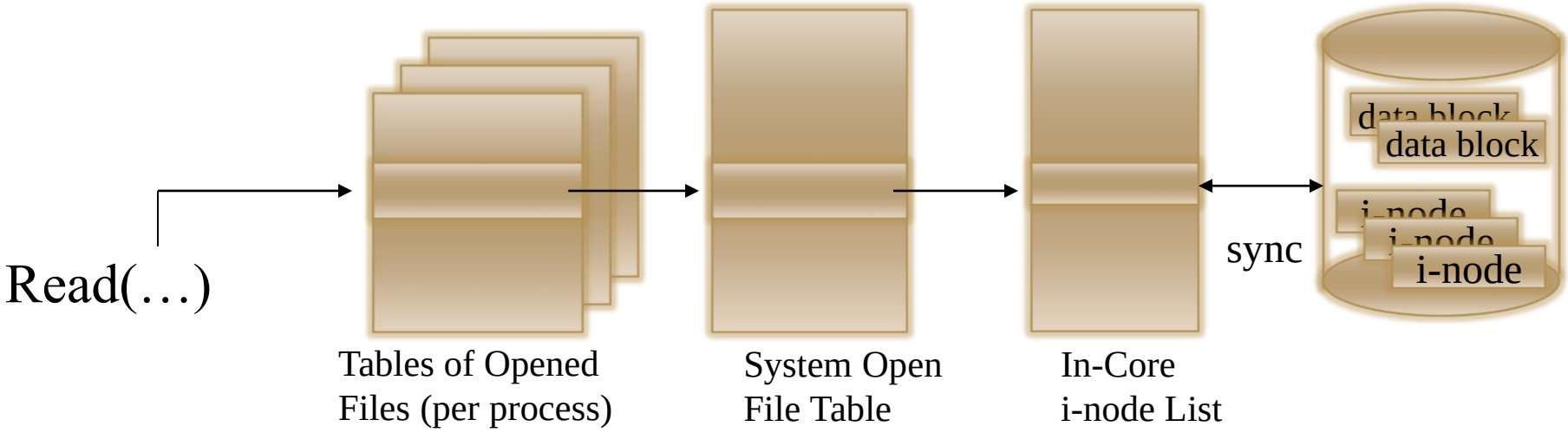
- File attributes vary from one OS to another:
  - Name: Case-sensitive or not
    - The only information must be kept in human-readable form
  - Identifier: A unique tag
  - Type: It is only for systems that support file types
  - Location
  - Size: Current and max sizes
  - Protection: access control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

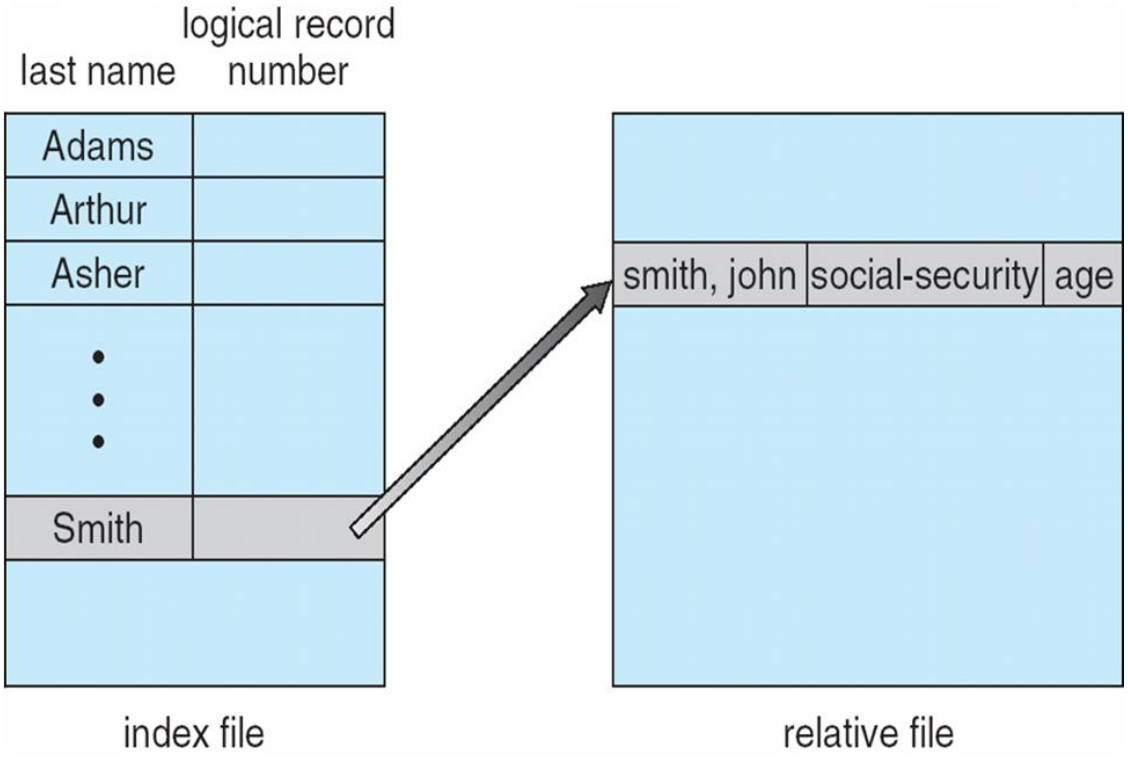
- Key Issue
  - The Recognition of File Types by OS
- Common Techniques
  - Types as Parts of File Names
    - .doc, .txt, .rtf, .mpeg, .mp3, .avi, .pdf, .ps, .tex, .exe, .com, .bin, .c, .cc, .java, .asm, .a, .bat, .sh, .o, .obj, .lib, .dll, .zip, .tar, .arc, etc.
  - A Magic Number at the Beginning 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

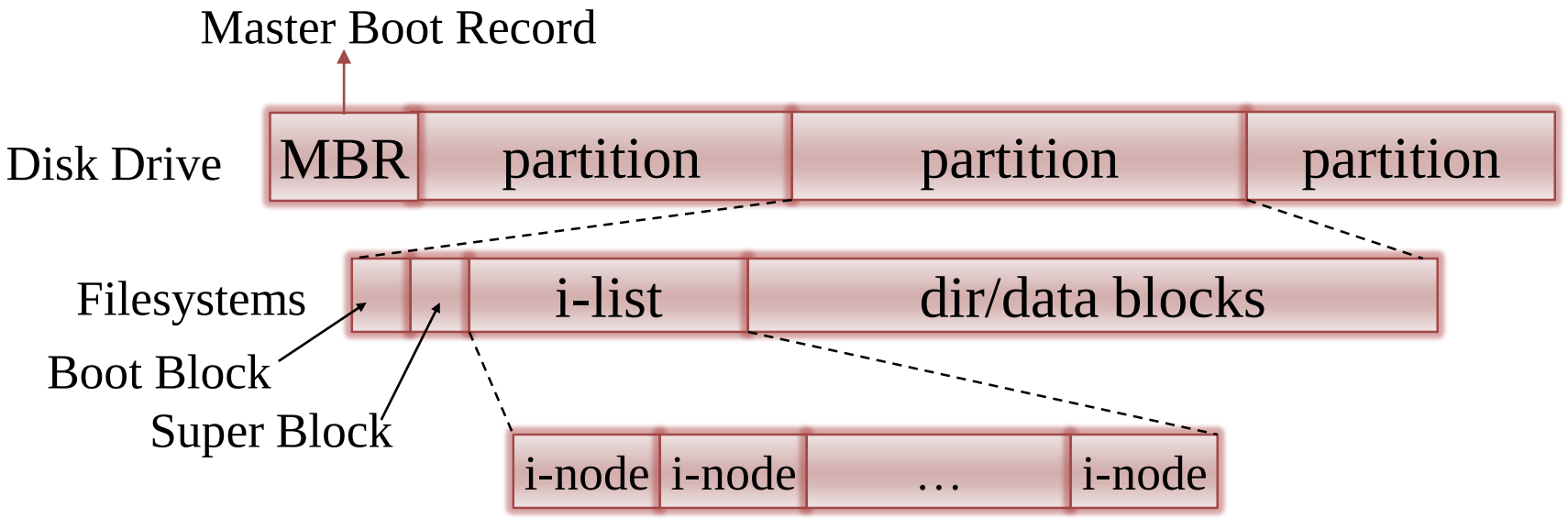
Access Methods (2/2)

- 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

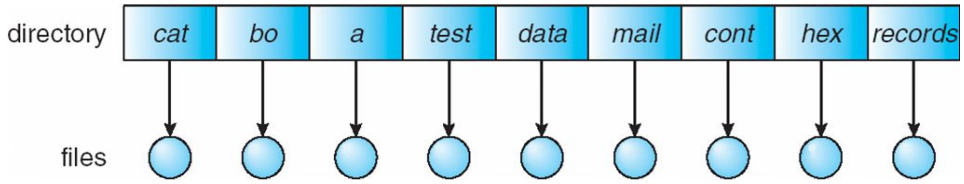


Directory Overview

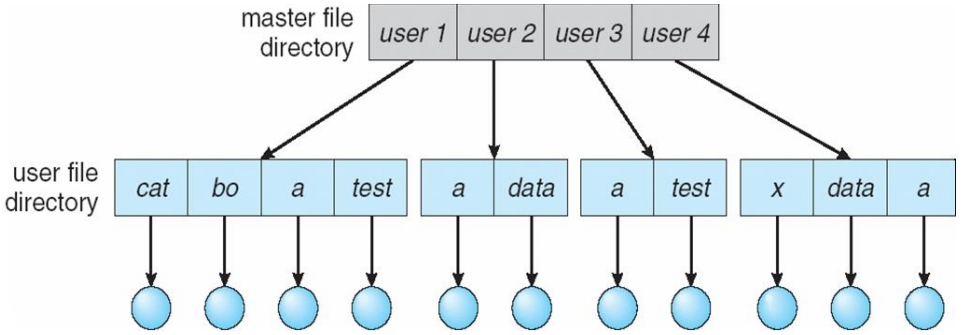
- Directory – A Symbol Table that Translate File Names into Their Directory Entries
- Operations on a Directory
  - Searching for a File
  - Create a File
  - Delete a File
  - List a Directory
  - Rename a File
  - Traverse the File System

Simple Directories

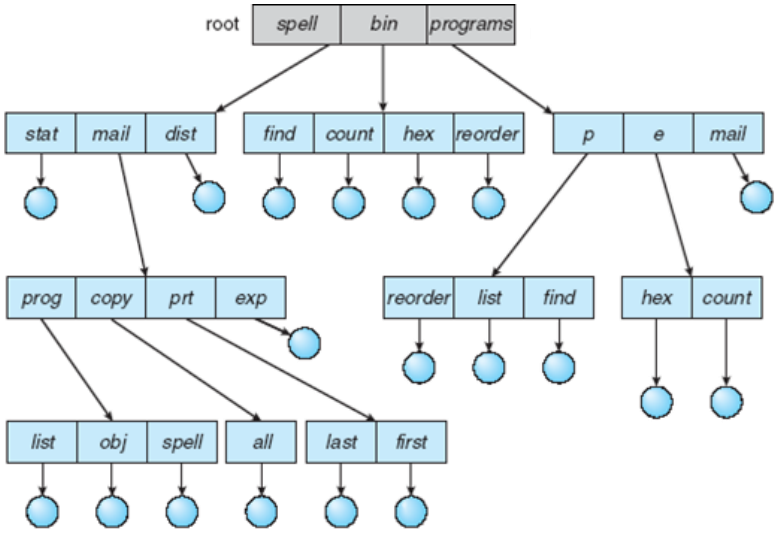
- Single-Level Directory
  - All files are in the same directory
    - Problems occur when the number of files increases or when the system has more than one user



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



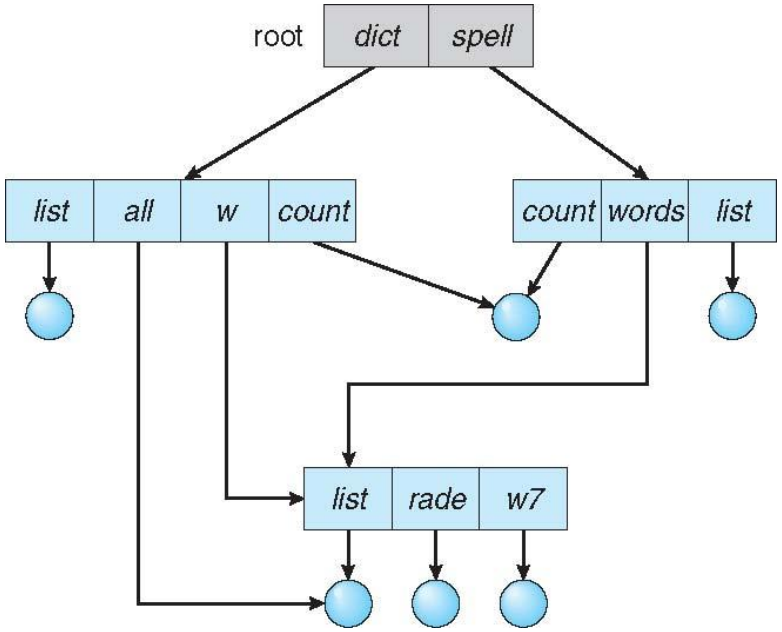
Tree-Structured Directories



- 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

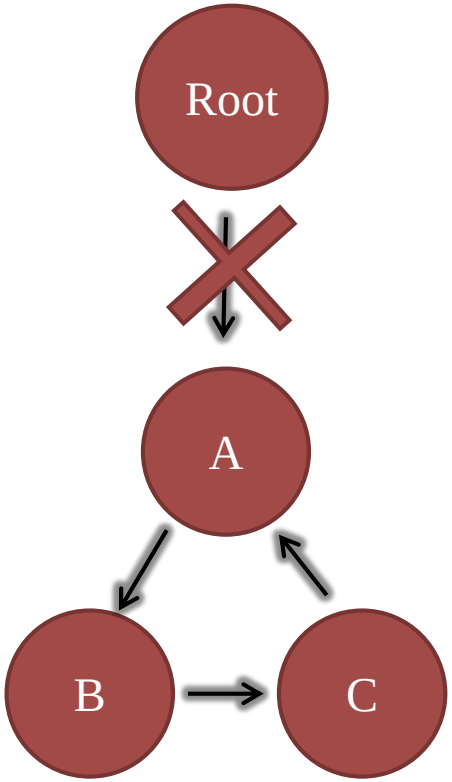
Acyclic-Graph Directories

- 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



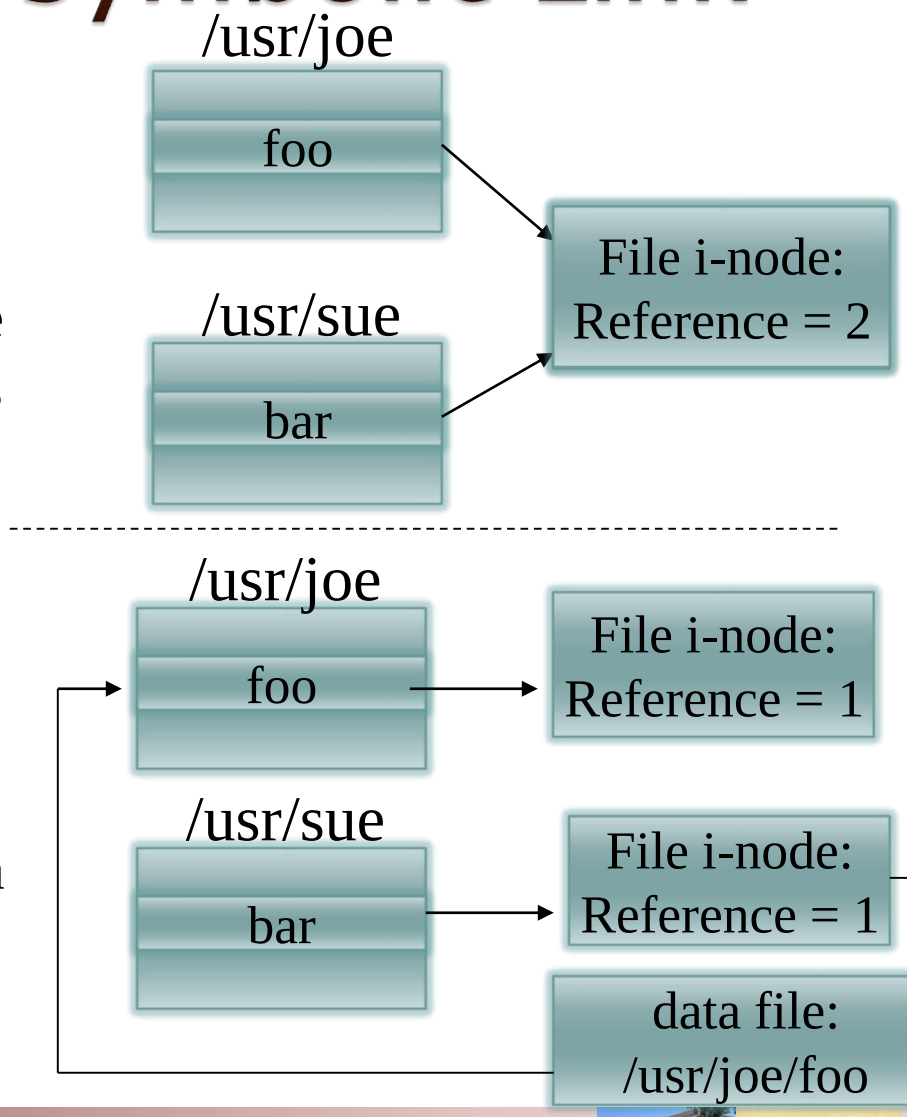
General Graph Directory

- 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



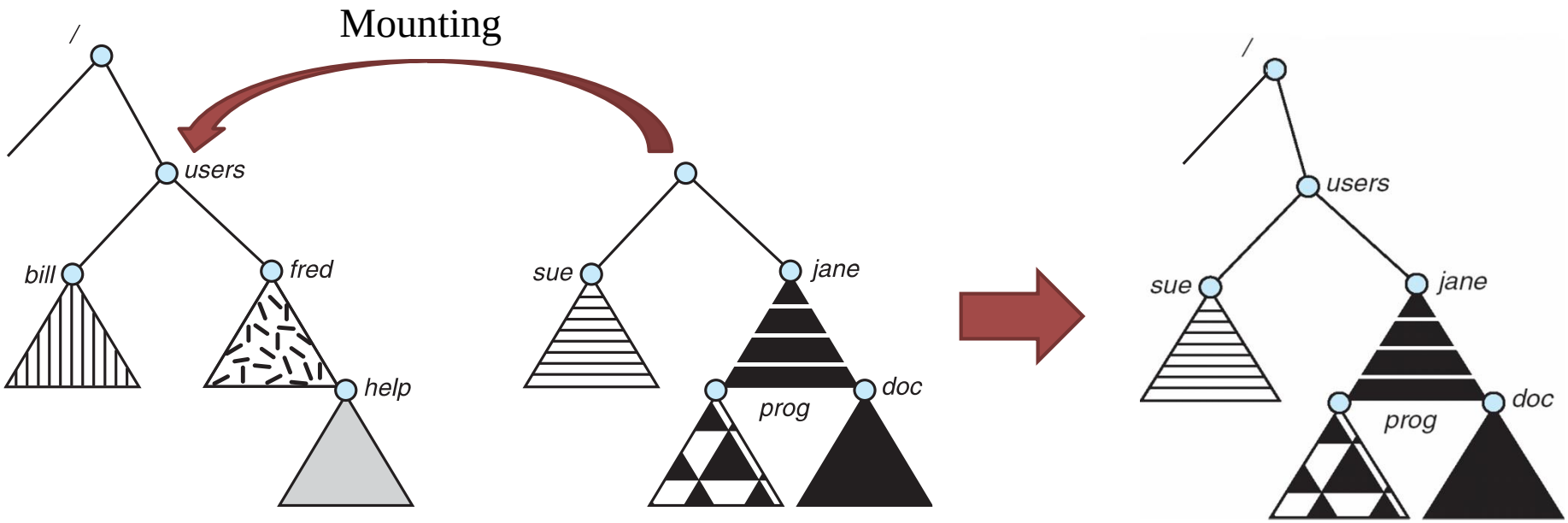
Hard Link and Symbolic Link

- 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
- A 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
  - Client and user-on-client identification is insecure or complicated
  - 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

			RWX
a) **owner access**	7	➔	1 1 1
b) **group access**	6	➔	RWX 1 1 0
c) **public access**	1	➔	RWX 0 0 1