

# Chapter 13:

# File-System Interface

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# Outline

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- File Concept
- Access Methods
- Disk and Directory Structure
- Protection
- Memory-Mapped Files





# Objectives

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- To explain the function of file systems
- To describe the interfaces to file systems
- To discuss file-system design tradeoffs, including access methods, file sharing, file locking, and directory structures
- To explore file-system protection





# File Concept

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- Contiguous logical address space
- Types:
  - Data
    - ▶ Numeric
    - ▶ Character
    - ▶ Binary
  - Program
- Contents defined by file's creator
  - Many types
    - ▶ **text file,**
    - ▶ **source file,**
    - ▶ **executable file**





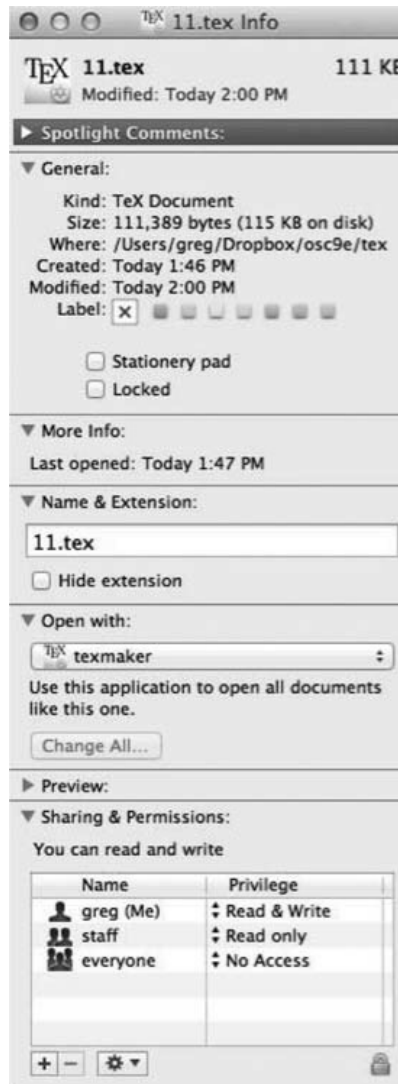
# File Attributes

- **Name** – only information kept in human-readable form
- **Identifier** – unique tag (number) identifies file within file system
- **Type** – needed for systems that support different types
- **Location** – pointer to file location on device
- **Size** – current file size
- **Protection** – controls who can do reading, writing, executing
- **Time, date, and user identification** – data for protection, security, and usage monitoring
- Information about files are kept in the directory structure, which is maintained on the disk
- Many variations, including extended file attributes such as file checksum
- Information kept in the directory structure





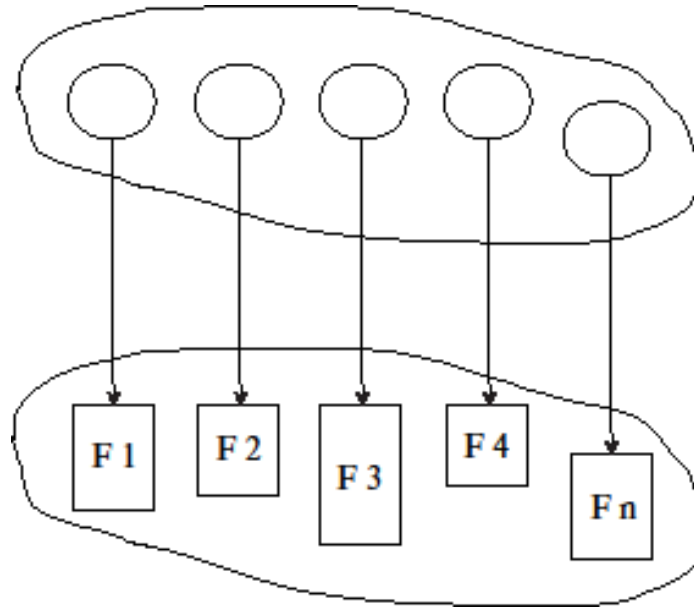
# File info Window on Mac OS X





# Directory Structure

- A collection of nodes containing information about all files



- Both the directory structure and the files reside on disk





# File Operations

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- **Create**
- **Write** – at **write pointer** location
- **Read** – at **read pointer** location
- **Reposition within file - seek**
- **Delete**
- **Truncate**
- ***Open ( $F_i$ )*** – search the directory structure on disk for entry  $F_i$ , and move the content of entry to memory
- ***Close ( $F_i$ )*** – move the content of entry  $F_i$  in memory to directory structure on disk







# Open Files

- Several pieces of data are needed to manage open files:
  - **Open-file table:** tracks open files
  - File pointer: pointer to last read/write location, per process that has the file open
  - **File-open count:** counter of number of times a file is open – to allow removal of data from open-file table when last processes closes it
  - Disk location of the file: cache of data access information
  - Access rights: per-process access mode information





# File Locking

- Provided by some operating systems and file systems
  - Similar to reader-writer locks
  - **Shared lock** similar to reader lock – several processes can acquire concurrently
  - **Exclusive lock** similar to writer lock
- Mediates access to a file
- Mandatory or advisory:
  - **Mandatory** – access is denied depending on locks held and requested
  - **Advisory** – processes can find status of locks and decide what to do





# File Locking Example – Java API

```
import java.io.*;
import java.nio.channels.*;
public class LockingExample {
    public static final boolean EXCLUSIVE = false;
    public static final boolean SHARED = true;
    public static void main(String arsg[]) throws IOException {
        FileLock sharedLock = null;
        FileLock exclusiveLock = null;
        try {
            RandomAccessFile raf = new RandomAccessFile("file.txt", "rw");
            // get the channel for the file
            FileChannel ch = raf.getChannel();
            // this locks the first half of the file - exclusive
            exclusiveLock = ch.lock(0, raf.length()/2, EXCLUSIVE);
            /** Now modify the data . . . */
            // release the lock
            exclusiveLock.release();
        }
    }
}
```





# File Locking Example – Java API (Cont.)

```
// this locks the second half of the file - shared
sharedLock = ch.lock(raf.length()/2+1, raf.length(),
                    SHARED);

/** Now read the data . . . */
// release the lock
sharedLock.release();
} catch (java.io.IOException ioe) {
    System.err.println(ioe);
}finally {
    if (exclusiveLock != null)
        exclusiveLock.release();
    if (sharedLock != null)
        sharedLock.release();
}
}
```





# File Types – Name, Extension

file type	usual extension	function
executable	exe, com, bin or none	ready-to-run machine-language program
object	obj, o	compiled, machine language, not linked
source code	c, cc, java, pas, asm, a	source code in various languages
batch	bat, sh	commands to the command interpreter
text	txt, doc	textual data, documents
word processor	wp, tex, rtf, doc	various word-processor formats
library	lib, a, so, dll	libraries of routines for programmers
print or view	ps, pdf, jpg	ASCII or binary file in a format for printing or viewing
archive	arc, zip, tar	related files grouped into one file, sometimes compressed, for archiving or storage
multimedia	mpeg, mov, rm, mp3, avi	binary file containing audio or A/V information





# File Structure

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- None - sequence of words, bytes
- Simple record structure
  - Lines
  - Fixed length
  - Variable length
- Complex Structures
  - Formatted document
  - Relocatable load file
- Can simulate last two with first method by inserting appropriate control characters
- Who decides:
  - Operating system
  - Program





# Access Methods

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- A file is fixed length **logical records**
- **Sequential Access**
- **Direct Access**
- **Other Access Methods**

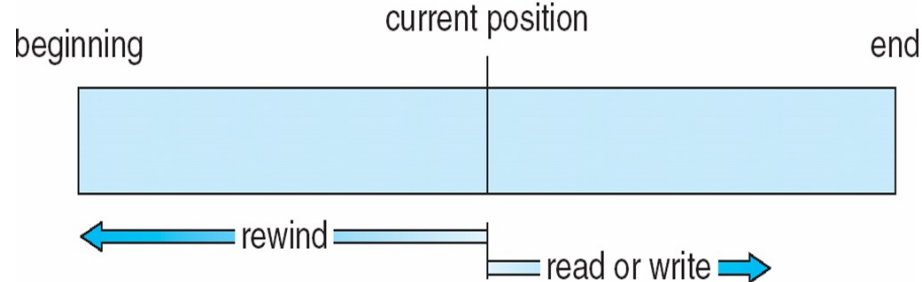




# Sequential Access

- Operations
  - **read next**
  - **write next**
  - **Reset**
  - no read after last write (rewrite)

- Figure







# Direct Access

- Operations
  - `read  $n$`
  - `write  $n$`
  - `position to  $n$` 
    - ▶ `read next`
    - ▶ `write next`
    - ▶ `rewrite  $n$`

$n$  = **relative block number**
- Relative block numbers allow OS to decide where file should be placed





# Simulation of Sequential Access on Direct-access File

sequential access	implementation for direct access
<i>reset</i>	<i>cp</i> = 0;
<i>read next</i>	<i>read cp</i> ; <i>cp</i> = <i>cp</i> + 1;
<i>write next</i>	<i>write cp</i> ; <i>cp</i> = <i>cp</i> + 1;





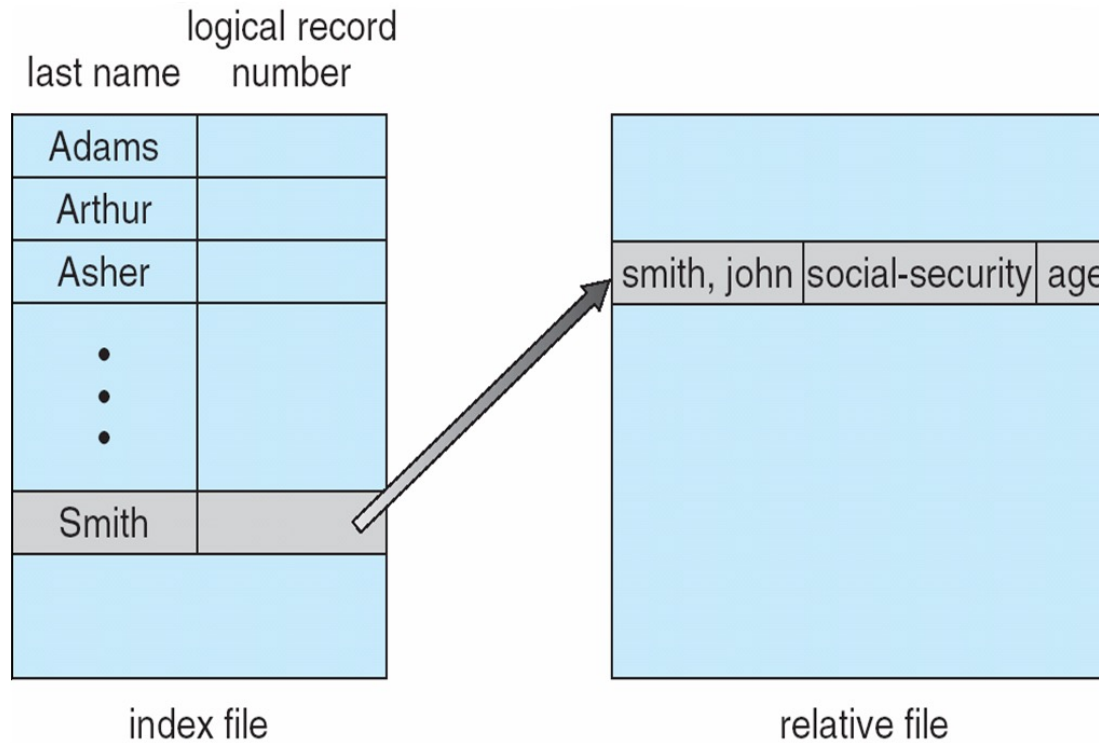
# Other Access Methods

- Can be other access methods built on top of base methods
- General involve creation of an **index** for the file
- Keep index in memory for fast determination of location of data to be operated on (consider Universal Produce Code (UPC code) plus record of data about that item)
- If the index is too large, create an in-memory index, which an index of a disk index
- IBM indexed sequential-access method (ISAM)
  - Small master index, points to disk blocks of secondary index
  - File kept sorted on a defined key
  - All done by the OS
- VMS operating system provides index and relative files as another example (see next slide)





# Example of Index and Relative Files





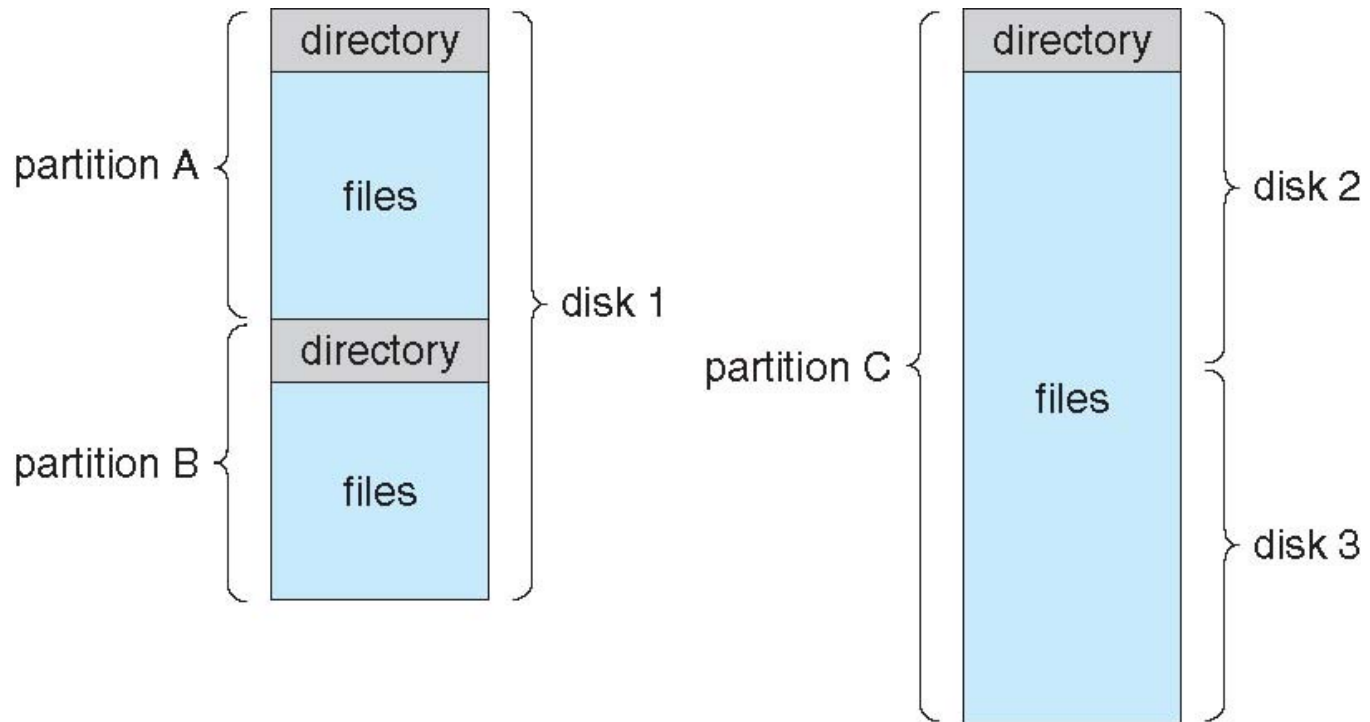
# Disk Structure

- Disk can be subdivided into **partitions**
- Disks or partitions can be **RAID** protected against failure
- Disk or partition can be used **raw** – without a file system, or **formatted** with a file system
- Partitions also known as minidisks, slices
- Entity containing file system is known as a **volume**
- Each volume containing a file system also tracks that file system's info in **device directory** or **volume table of contents**
- In addition to **general-purpose file systems** there are many **special-purpose file systems**, frequently all within the same operating system or computer





# A Typical File-system Organization





# Types of File Systems

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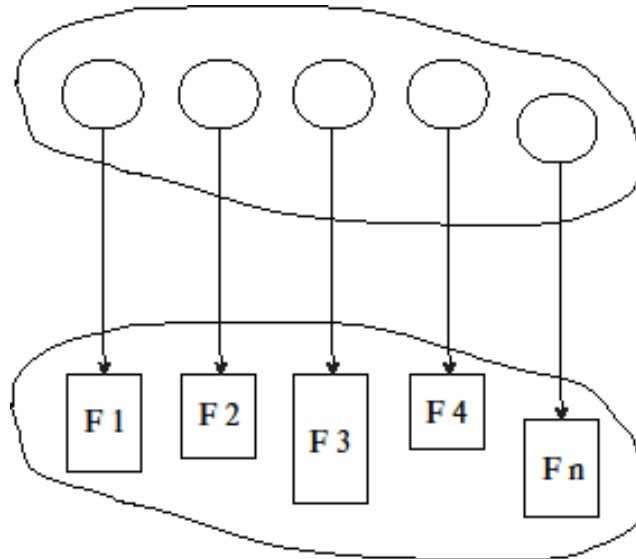
- We mostly talk of general-purpose file systems
- But systems frequently have many file systems, some general- and some special- purpose
- Consider Solaris has
  - tmpfs – memory-based volatile FS for fast, temporary I/O
  - objfs – interface into kernel memory to get kernel symbols for debugging
  - ctfs – contract file system for managing daemons
  - lofs – loopback file system allows one FS to be accessed in place of another
  - procfs – kernel interface to process structures
  - ufs, zfs – general purpose file systems





# Directory Structure

- A collection of nodes containing information about all files



- Both the directory structure and the files reside on disk







# Operations Performed on Directory

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- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system





# Directory Organization

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The directory is organized logically to obtain

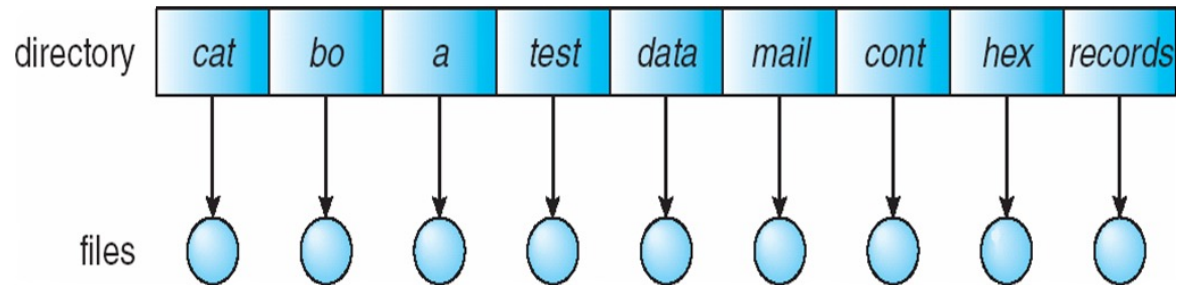
- Efficiency – locating a file quickly
- Naming – convenient to users
  - Two users can have same name for different files
  - The same file can have several different names
- Grouping – logical grouping of files by properties, (e.g., all Java programs, all games, ...)





# Single-Level Directory

- A single directory for all users



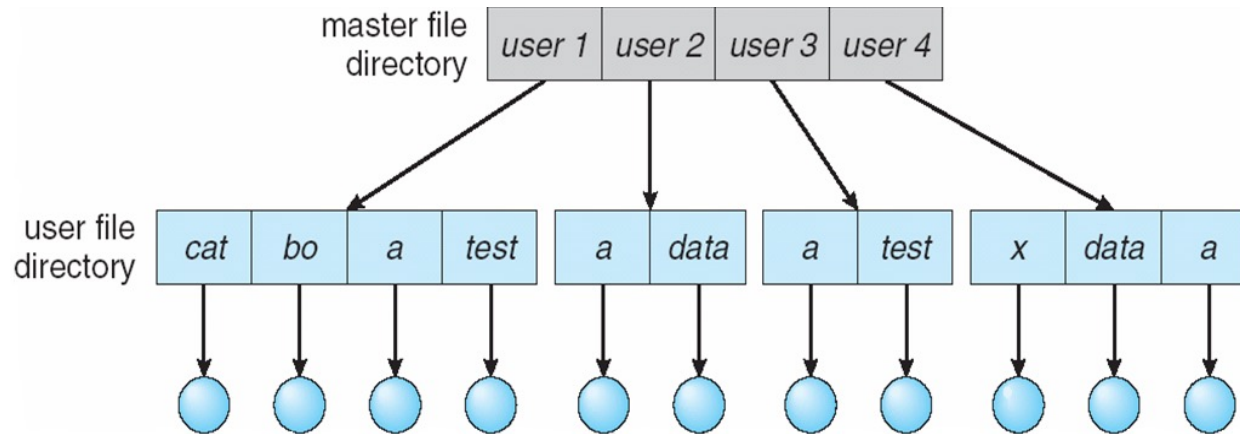
- Naming problem
- Grouping problem





# Two-Level Directory

- Separate directory for each user

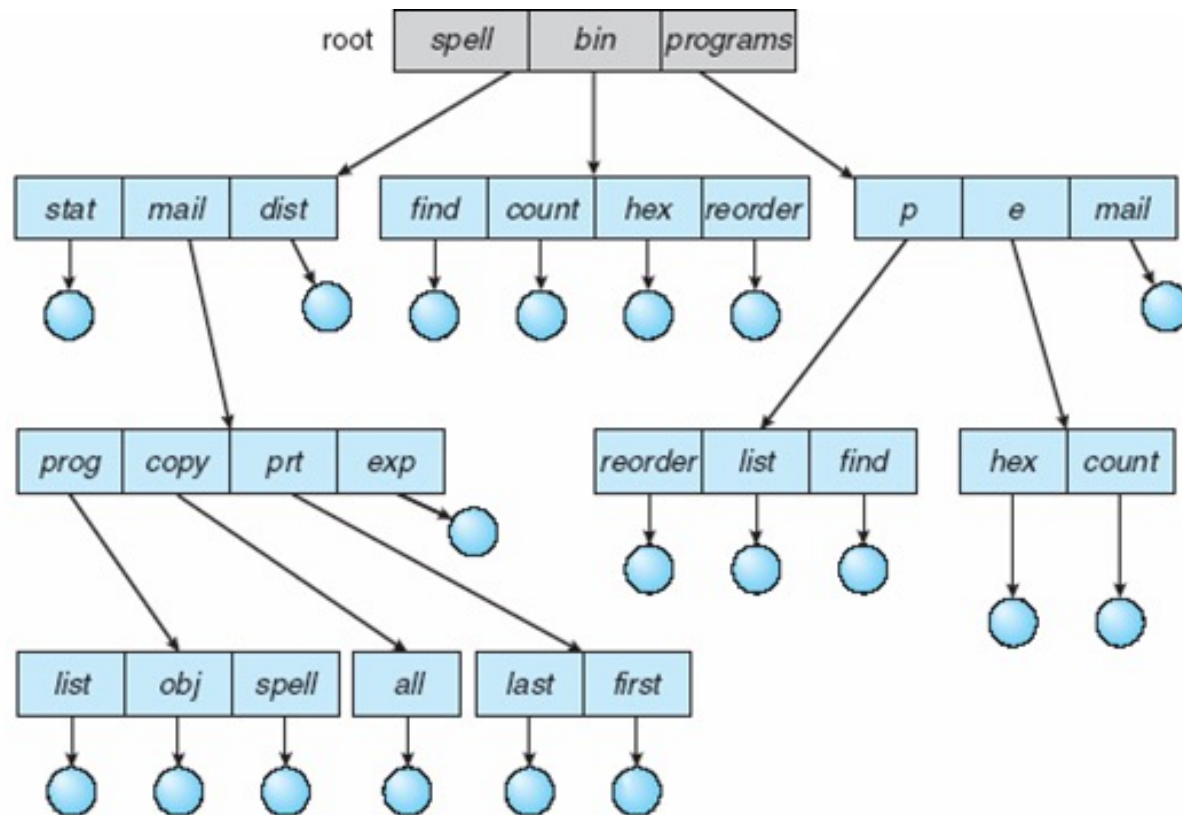


- Path name
- Can have the same file name for different user
- Efficient searching
- No grouping capability





# Tree-Structured Directories





- 
- ```

graph TD
    Root["root"] --> Dict["dict"]
    Root --> Spell["spell"]
    Dict --> DictOutputs["list | all | w | count"]
    Spell --> SpellOutputs["count | words | list"]
    DictOutputs -- list --> S1(( ))
    DictOutputs -- all --> S2(( ))
    DictOutputs -- w --> DictOutputs2["list | rade | w7"]
    DictOutputs -- count --> S3(( ))
    SpellOutputs -- count --> S4(( ))
    SpellOutputs -- words --> S5(( ))
    SpellOutputs -- list --> S6(( ))
    DictOutputs2 -- list --> S7(( ))
    DictOutputs2 -- rade --> S8(( ))
    DictOutputs2 -- w7 --> S9(( ))
    DictOutputs -- list --> S10(( ))
    DictOutputs -- all --> S10
    DictOutputs -- w --> S10
  
```





# Acyclic-Graph Directories (Cont.)

- Two different names (aliasing)
- If **dict** deletes **w/list**  $\Rightarrow$  dangling pointer

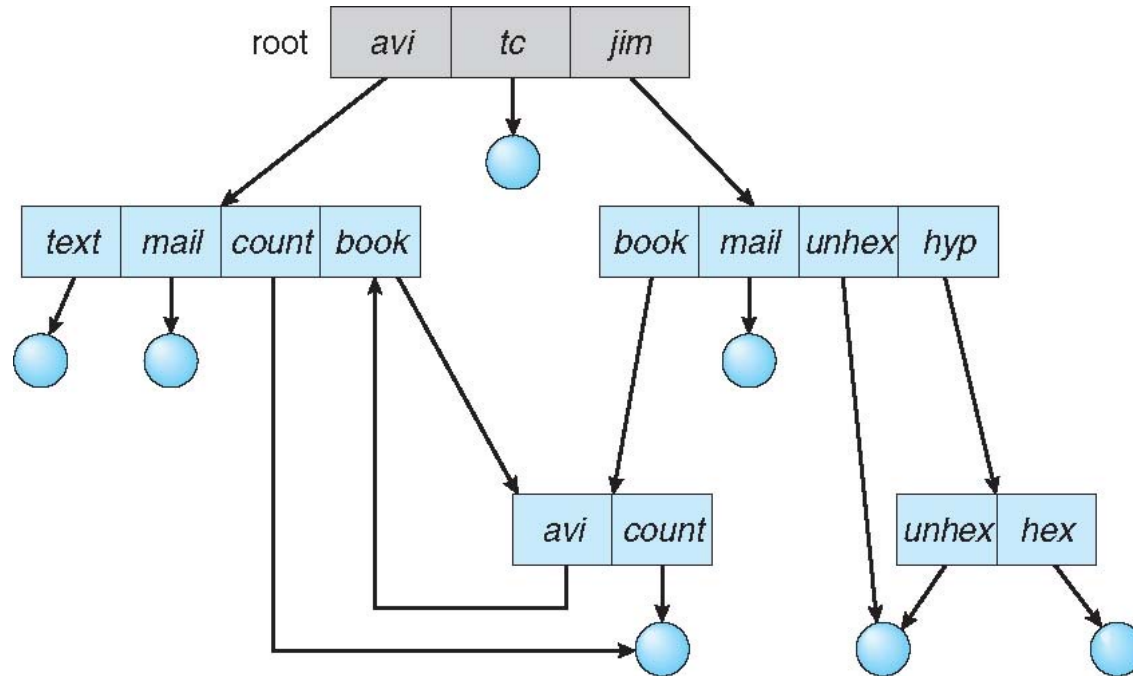
Solutions:

- Backpointers, so we can delete all pointers.
  - ▶ Variable size records a problem
- Backpointers using a daisy chain organization
- Entry-hold-count solution
- New directory entry type
  - **Link** – another name (pointer) to an existing file
  - **Resolve the link** – follow pointer to locate the file





# General Graph Directory







# General Graph Directory (Cont.)

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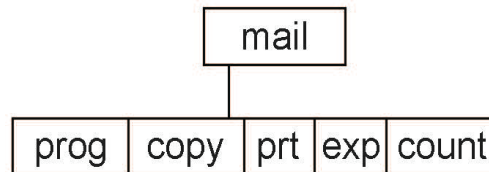
- How do we guarantee no cycles?
  - Allow only links to files not subdirectories
  - **Garbage collection**
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK





# Current Directory

- Can designate one of the directories as the current (working) directory
  - `cd /spell/mail/prog`
  - `type list`
- Creating and deleting a file is done in current directory
- Example of creating a new file
  - If in current directory is `/mail`
  - The command  
**`mkdir <dir-name>`**
  - Results in:



- Deleting “mail”  $\Rightarrow$  deleting the entire subtree rooted by “mail”





# Protection

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



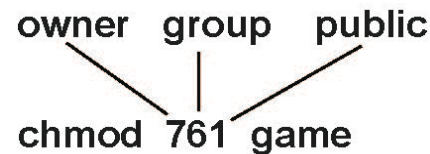


# Access Lists and Groups in Unix

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

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

- Ask manager to create a group (unique name), say G, and add some users to the group.
- For a file (say *game*) or subdirectory, define an appropriate access.



- Attach a group to a file

**chgrp**      **G**      **game**





# A Sample UNIX Directory Listing

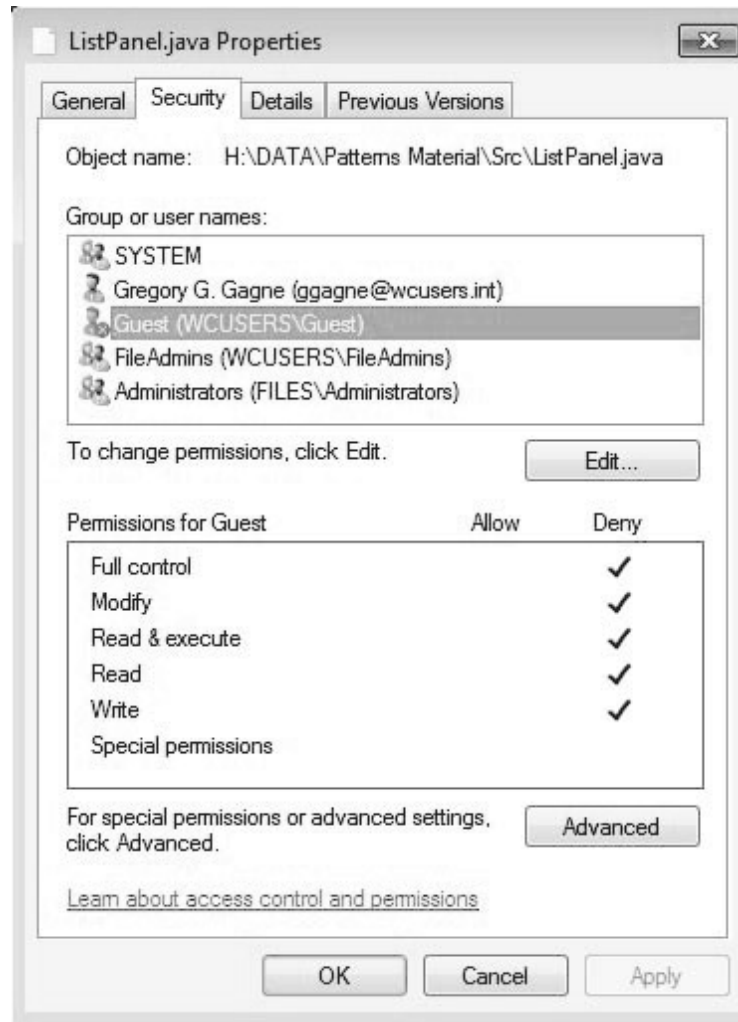
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|            |   |     |         |       |              |               |
|------------|---|-----|---------|-------|--------------|---------------|
| -rw-rw-r-- | 1 | pbg | staff   | 31200 | Sep 3 08:30  | intro.ps      |
| drwx-----  | 5 | pbg | staff   | 512   | Jul 8 09:33  | private/      |
| drwxrwxr-x | 2 | pbg | staff   | 512   | Jul 8 09:35  | doc/          |
| drwxrwx--- | 2 | pbg | student | 512   | Aug 3 14:13  | student-proj/ |
| -rw-r--r-- | 1 | pbg | staff   | 9423  | Feb 24 2003  | program.c     |
| -rwxr-xr-x | 1 | pbg | staff   | 20471 | Feb 24 2003  | program       |
| drwx--x--x | 4 | pbg | faculty | 512   | Jul 31 10:31 | lib/          |
| drwx-----  | 3 | pbg | staff   | 1024  | Aug 29 06:52 | mail/         |
| drwxrwxrwx | 3 | pbg | staff   | 512   | Jul 8 09:35  | test/         |





# Windows 7 Access-Control List Management





# Memory-Mapped Files



# End of Chapter 13

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