File Systems

A file system is a clearly-defined method that the computer's operating system uses to store, catalog, and retrieve files.

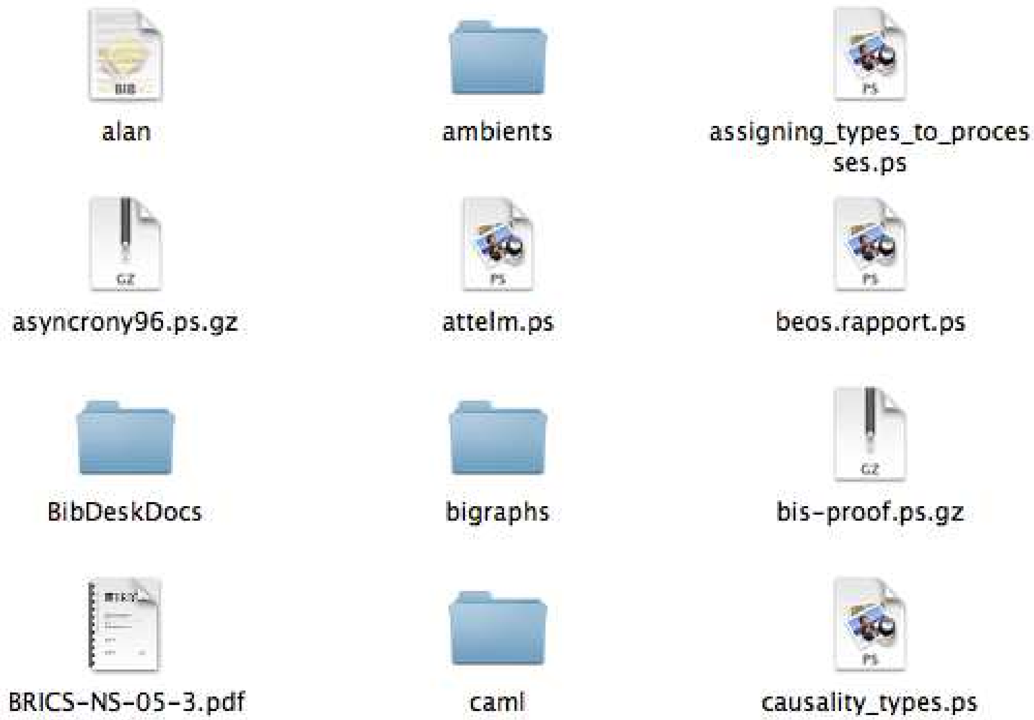
Module 11: File-System Interface

- File Concept
- Access :Methods
- Directory Structure
- Protection
- Consistency Semantics

Files & File Systems

- File
  - data, in some format
- File System
  - Set of named files, maybe organized (directories)
  - Information on files (metadata)

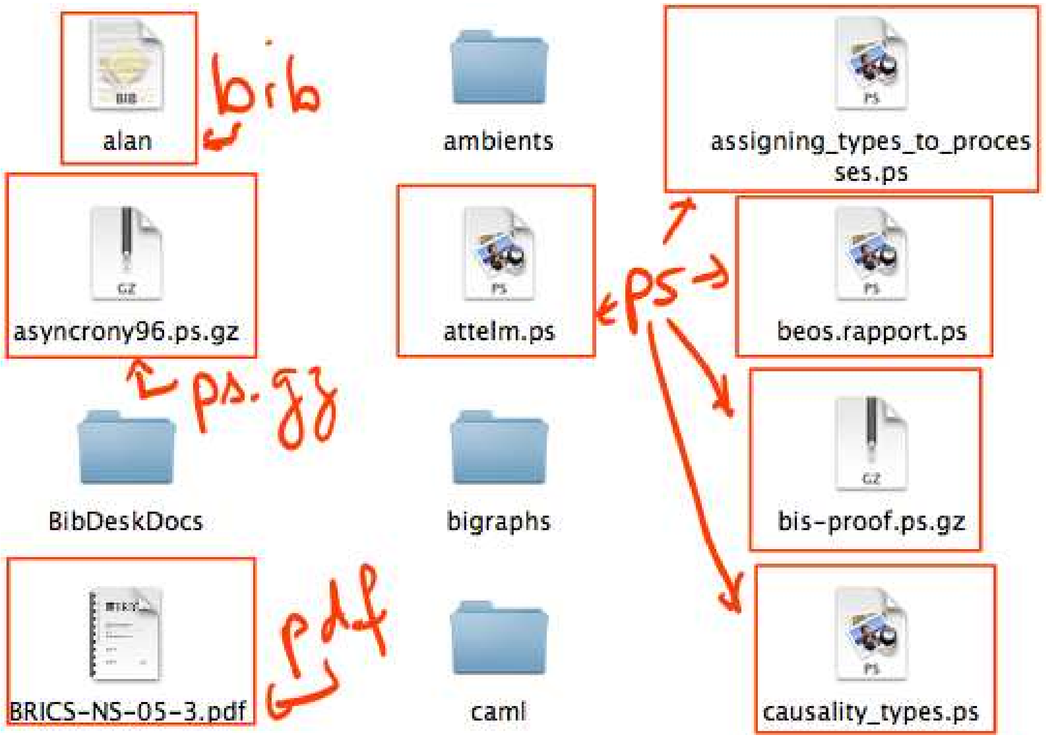
Files & File Systems



File Concept

- Contiguous logical address space
- Types:
  - Data
    - numeric
    - character
    - binary
  - Program

File Types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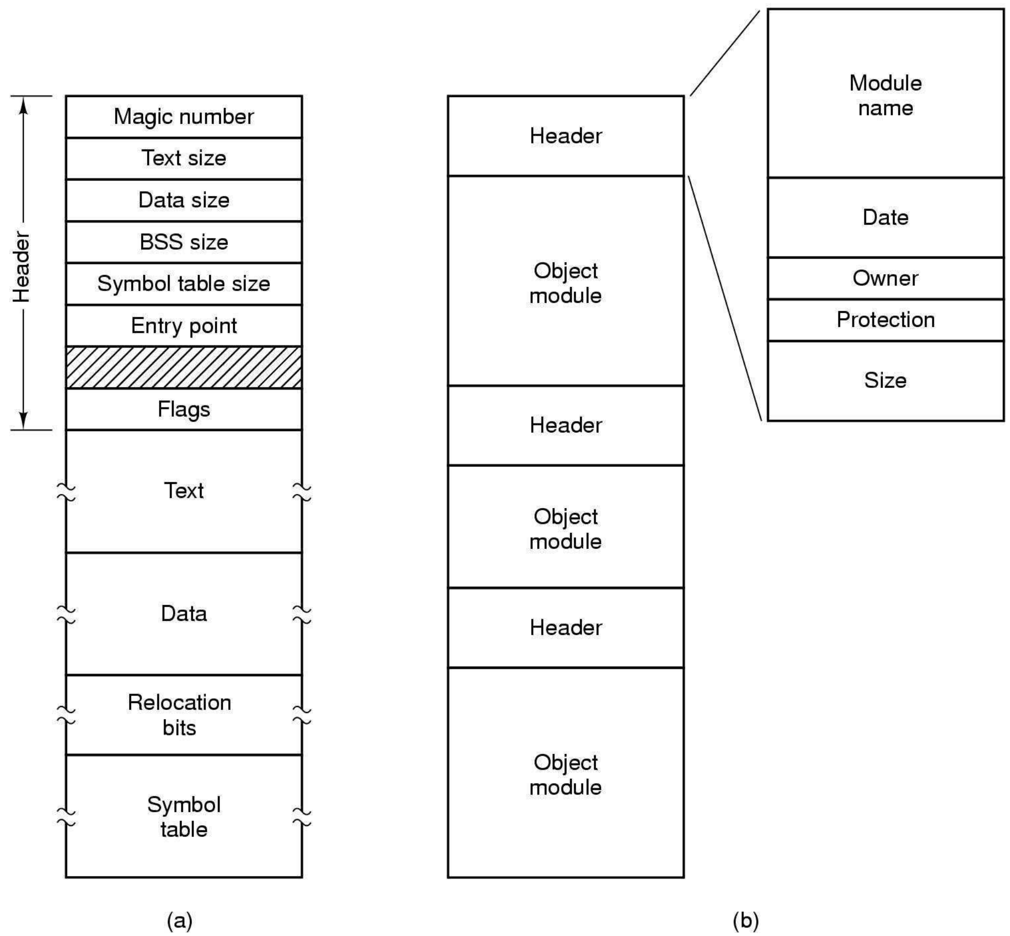
File Types – name, extension

File Type	Usual extension	Function
Executable	exe, com, bin or none	ready-to-run machine-language program
Object	obj, o	complied, machine language, not linked
Source code	c, p, pas, 177, 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, rrf, etc.	various word-processor formats
Library	lib, a	libraries of routines
Print or view	ps, dvi, gif, pdf	ASCII or binary file
Archive	arc, zip, tar, gz	related files grouped into one file, sometimes compressed.

File Types

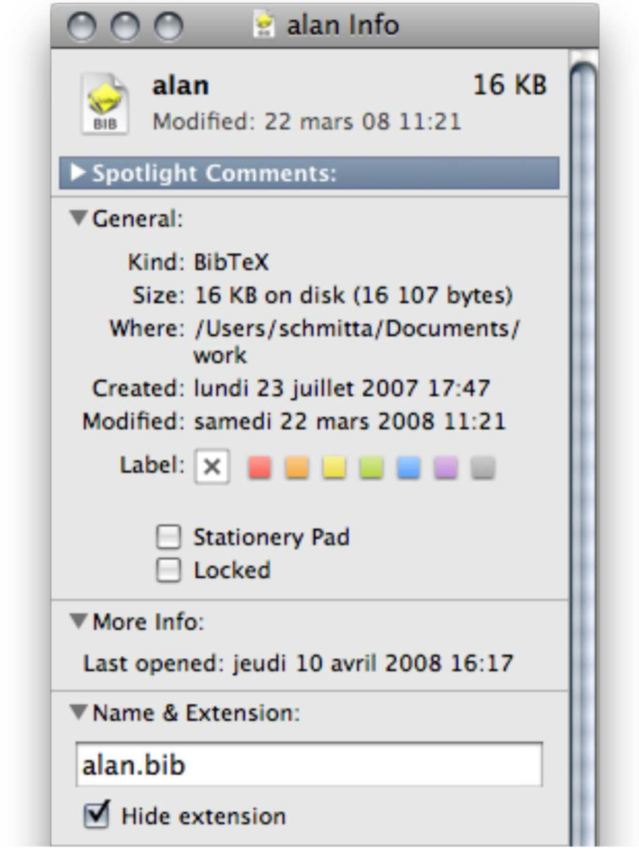


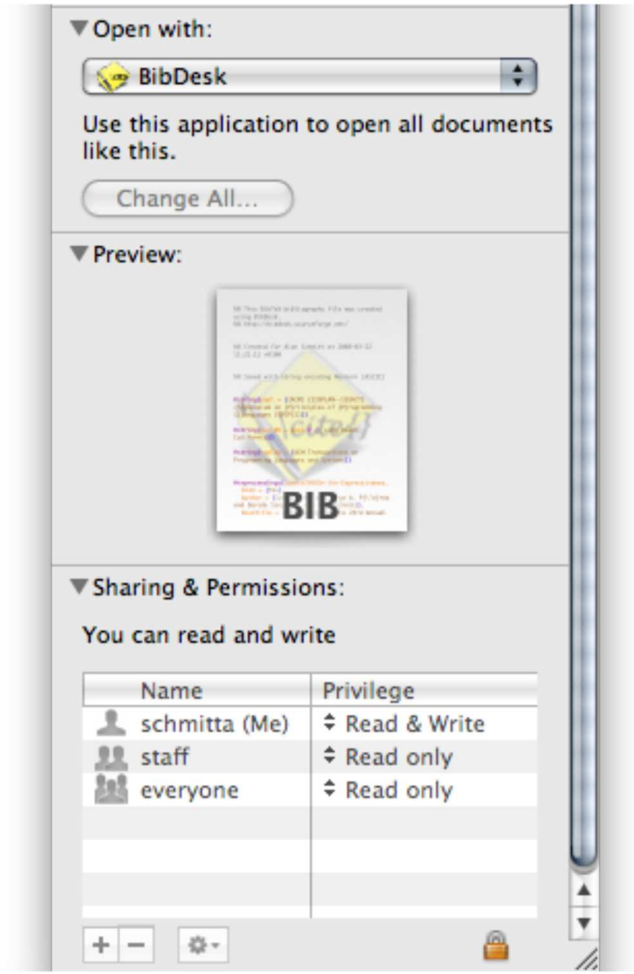
(a) An executable file (b) An archive

File Structure

- 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

File Metadata

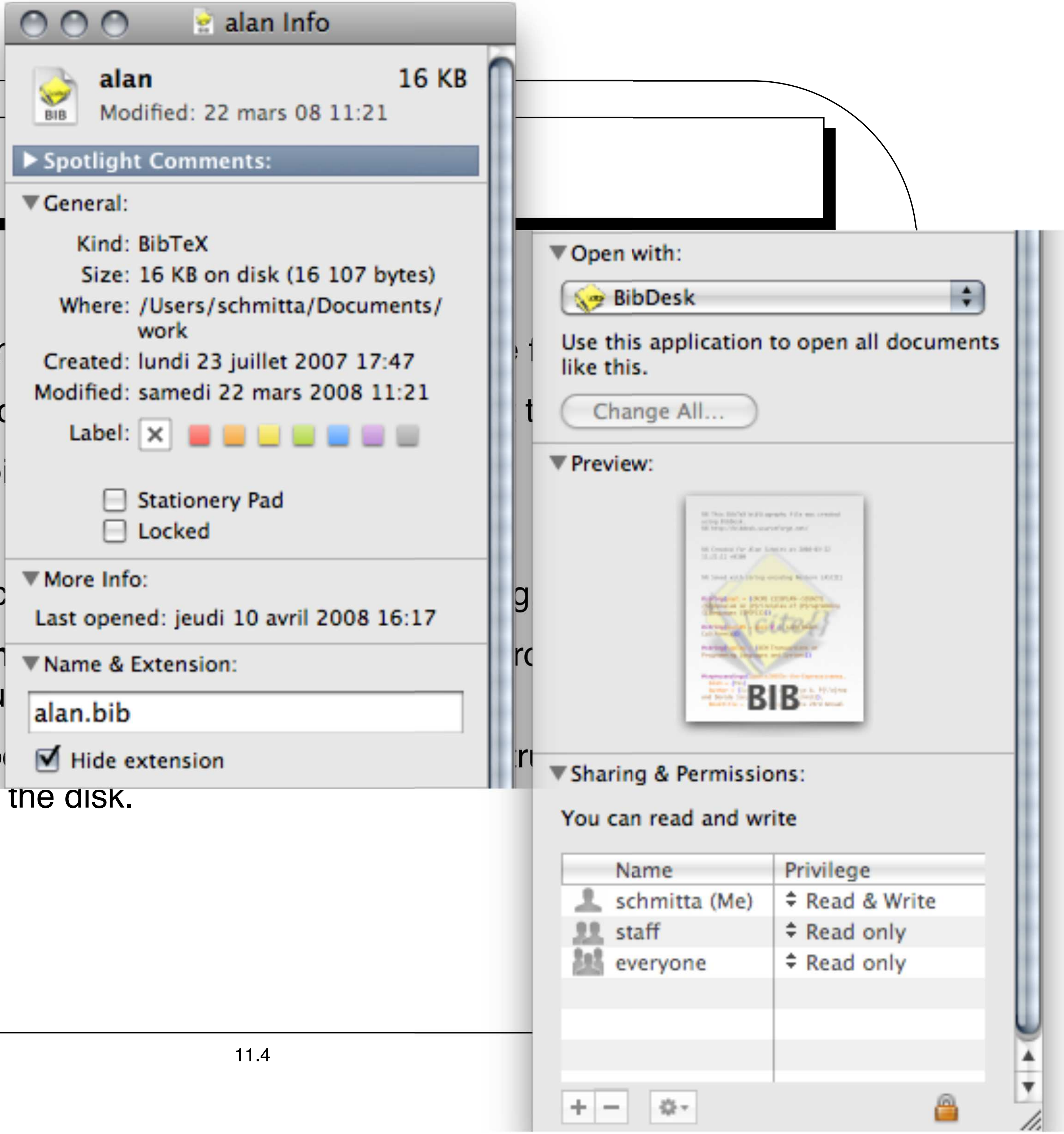




File Attributes

- **Name** – only information kept in human-readable form.
- **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.

- **Name** – only i
- **Type** – neede
- **Location** – po
- **Size** – current
- **Protection** – c
- **Time**, **date**, **an** security, and u
- Information ab maintained on the disk.



File Operations

- create
- write
- read
- reposition within file – 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.

Access Methods

- Sequential Access

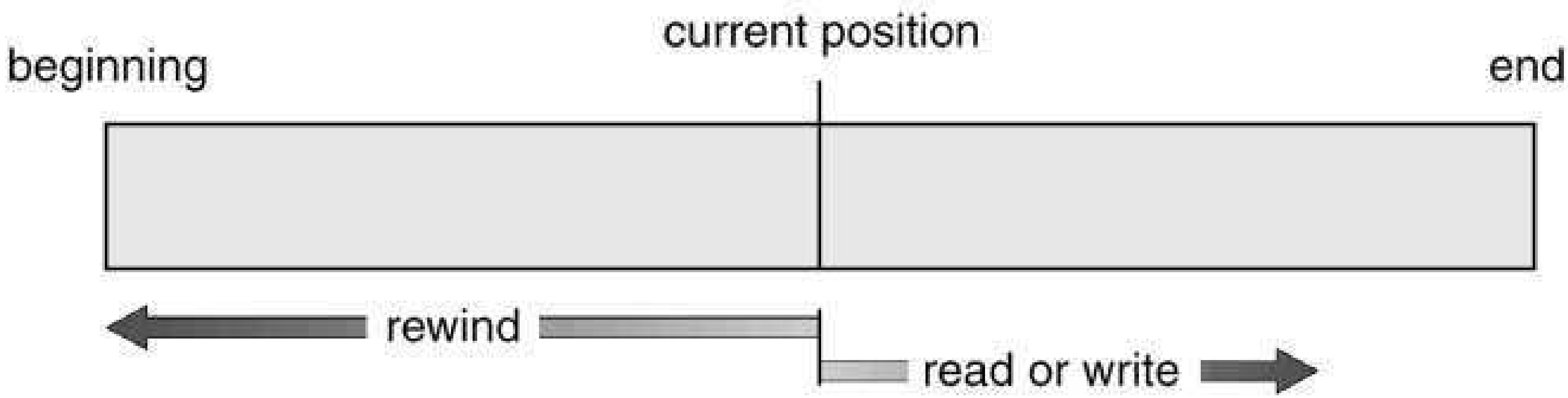
  read next
  write next
  reset
  no *read after last write*
  (rewrite)

- Direct Access

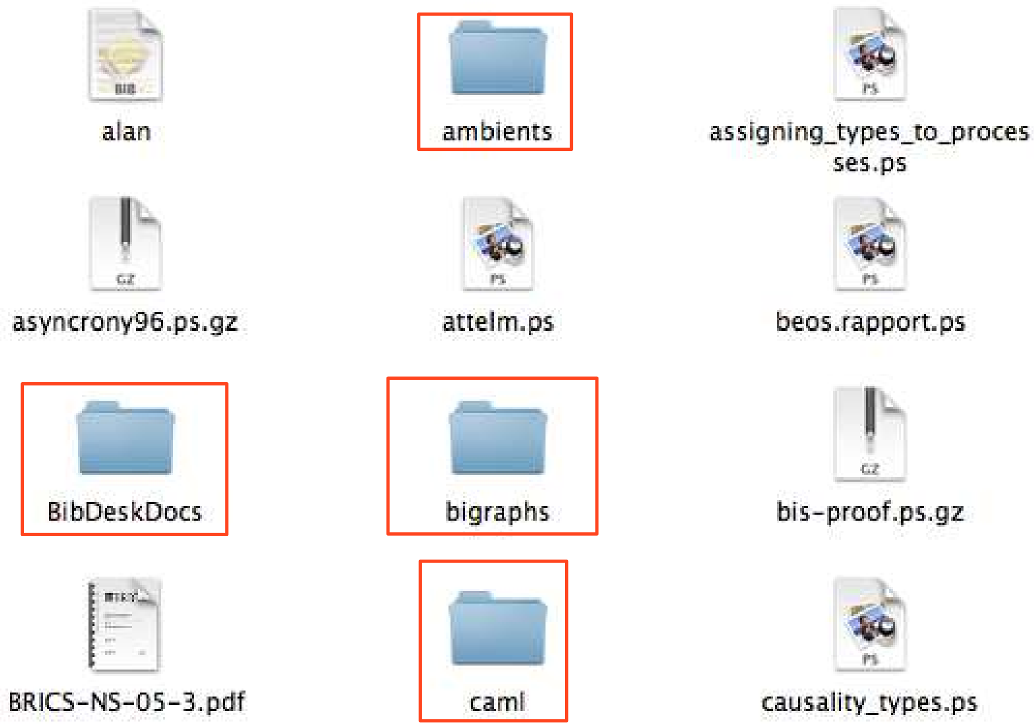
  read n
  write n
  position to n
  read next
  write next
  rewrite n

n = relative block number

Sequential-access File

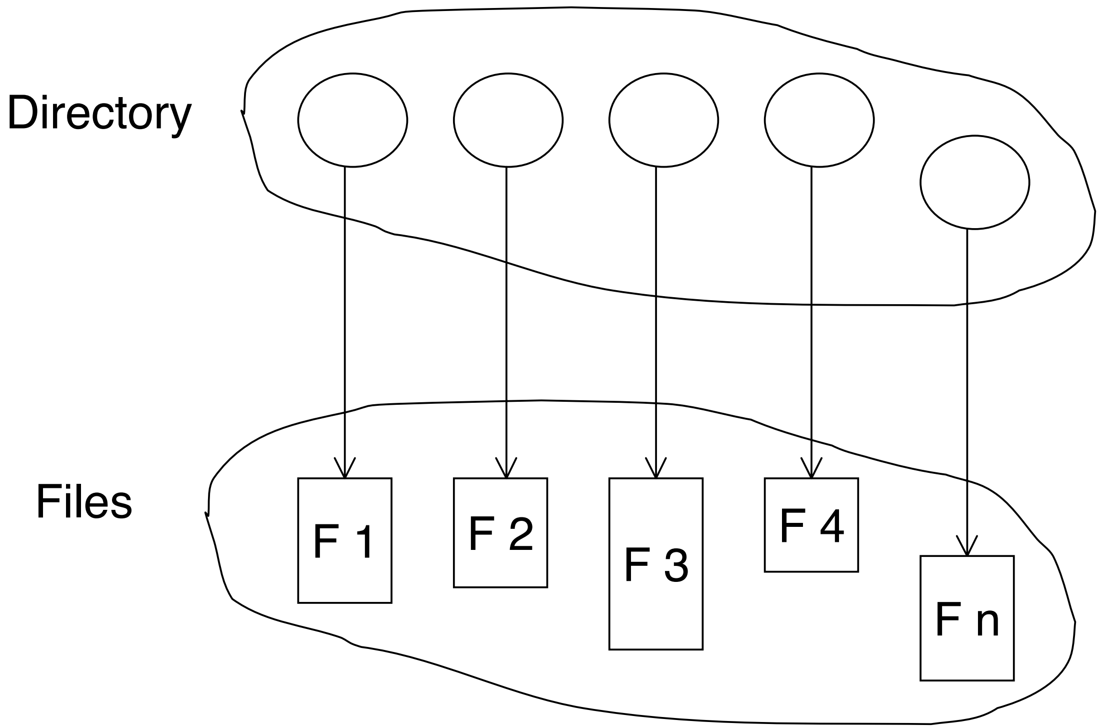


Directories



Directory Structure

- A collection of nodes containing information about all files.



- Both the directory structure and the files reside on disk.

Information in a Device Directory

- Name
- Type
- Address
- Current length
- Maximum length
- Date last accessed (for archival)
- Date last updated (for dump)
- Owner ID (who pays)
- Protection information (discuss later)

Operations Performed on Directory

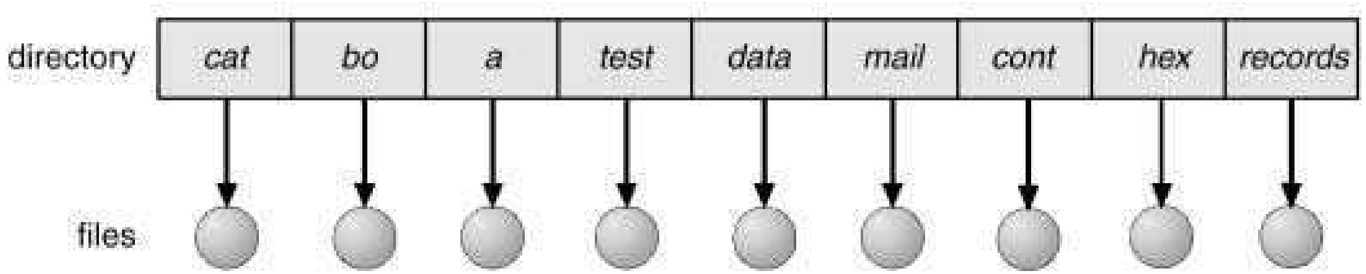
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

Organize the Directory (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 Pascal programs, all games, …)

Single-Level Directory

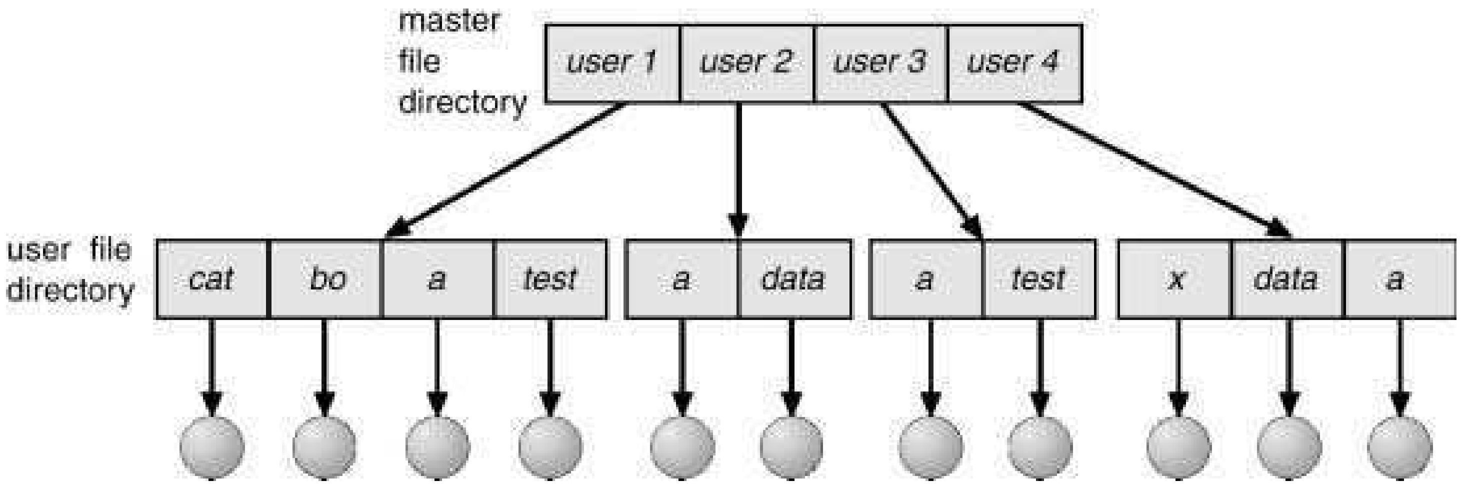
- A single directory for all users.



- Naming problem
- Grouping problem

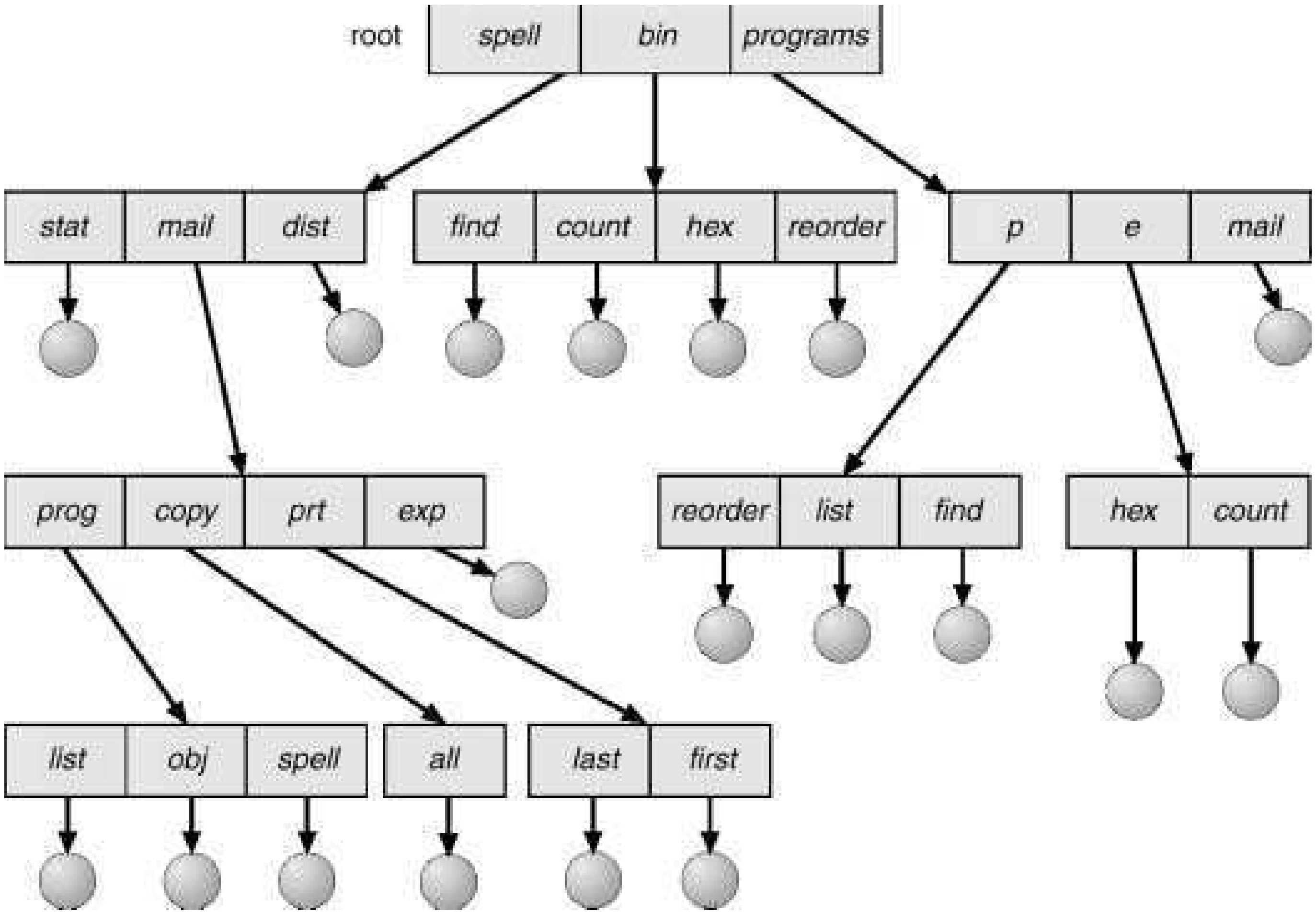
Two-Level Directory

- Separate directory for each user.



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

Tree-Structured Directories



Tree-Structured Directories (Cont.)

- Efficient searching
- Grouping Capability
- Current directory (working directory)
  - **cd** /spell/mail/prog
  - **type** list

Tree-Structured Directories (Cont.)

- Absolute or relative path name
- Creating a new file is done in current directory.
- Delete a file

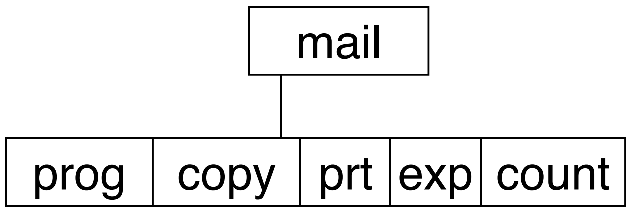
  rm <file-name>

- Creating a new subdirectory is done in current directory.

  mkdir <dir-name>

  Example: if in current directory /spell/mail

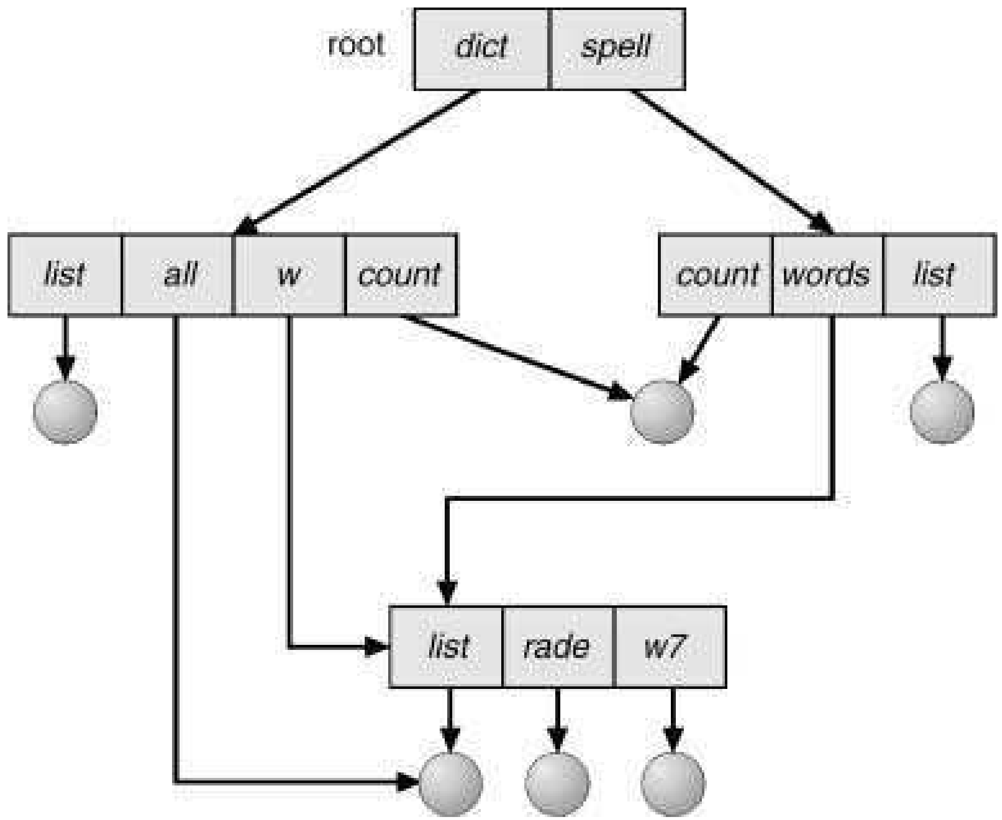
  mkdir count



- Deleting “mail” ⇒ deleting the entire subtree rooted by “mail”.

Acyclic-Graph Directories

- Have shared subdirectories and files.



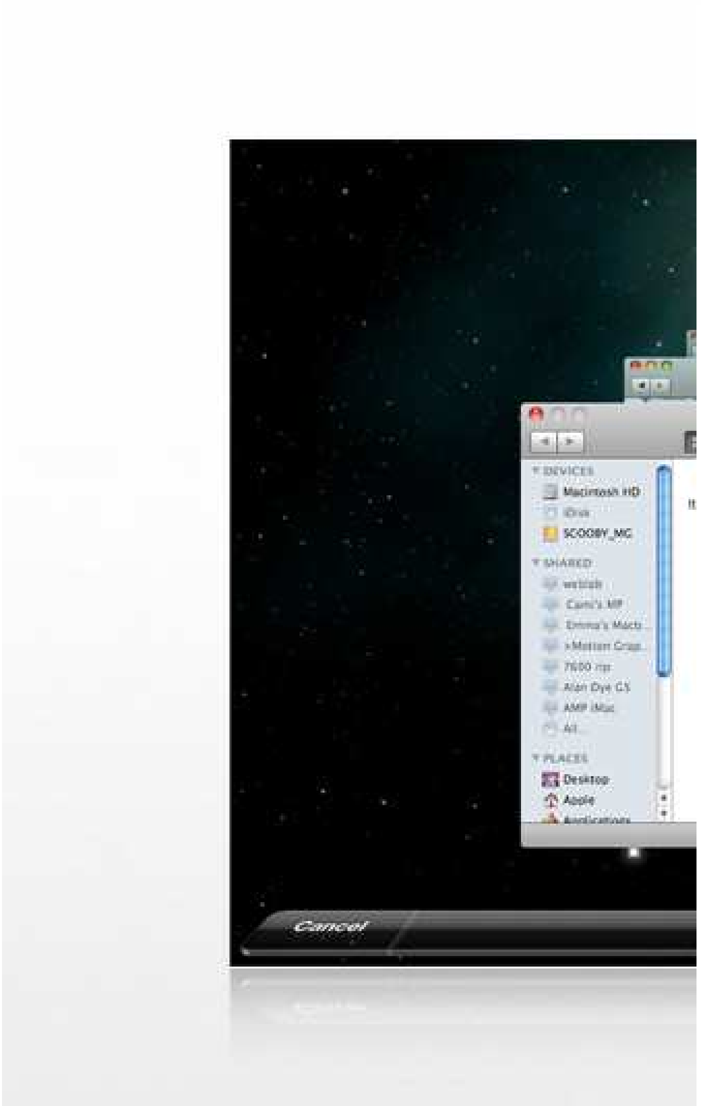
Acyclic-Graph Directories (Cont.)

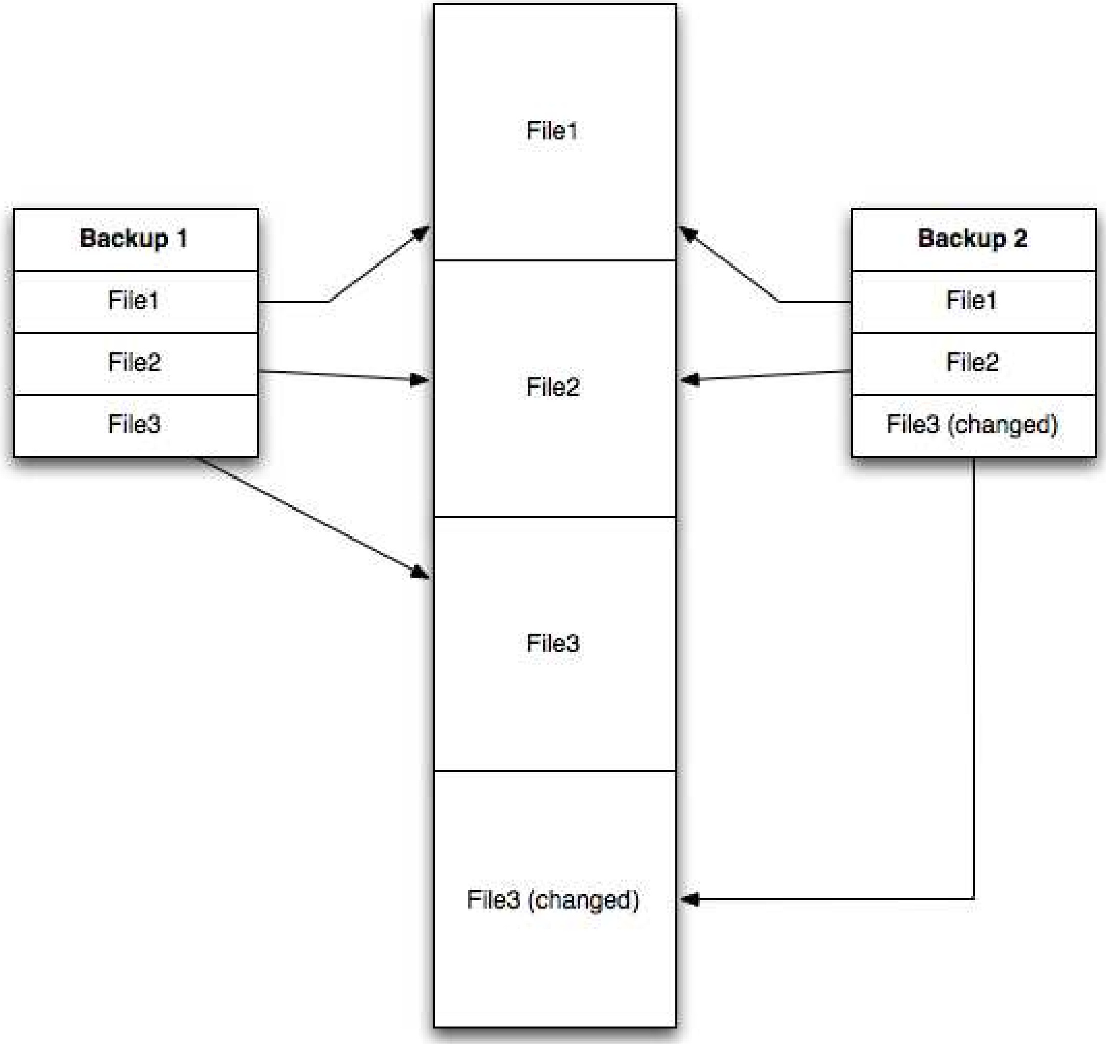
- Two different names (aliasing)
- If *dict* deletes *list* $\Rightarrow$ dangling pointer.

  Solutions:
  - Backpointers, so we can delete all pointers. Variable size records a problem.
  - Backpointers using a daisy chain organization.
  - Entry-hold-count solution.

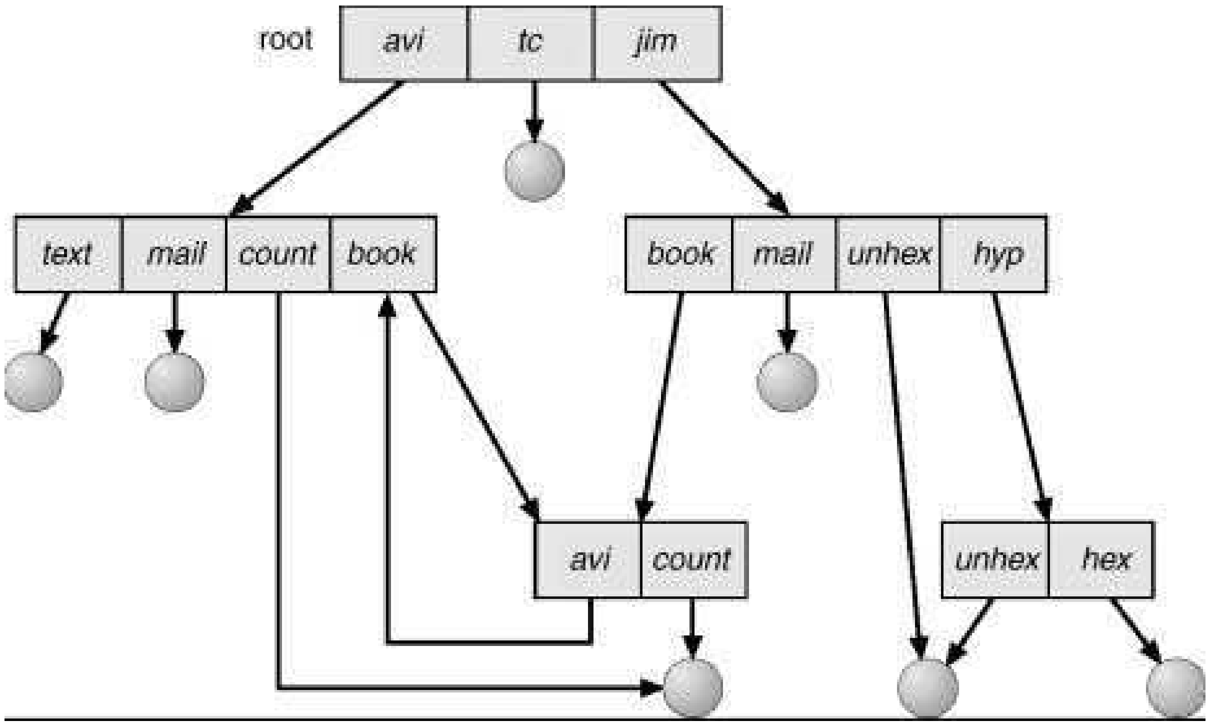
Using hard links: Time Machine

Using hard links: Time Machine





General Graph Directory



General Graph Directory (Cont.)

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

Protection

- 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

- Mode of access: read, write, execute
- Three classes of users

			RWX
a) owner access	7	$\Rightarrow$	1 1 1
			RWX
b) groups access	6	$\Rightarrow$	1 1 0
			RWX
c) public access	1	$\Rightarrow$	0 0 1

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

owner group public

chmod 761 game

- Attach a group to a file

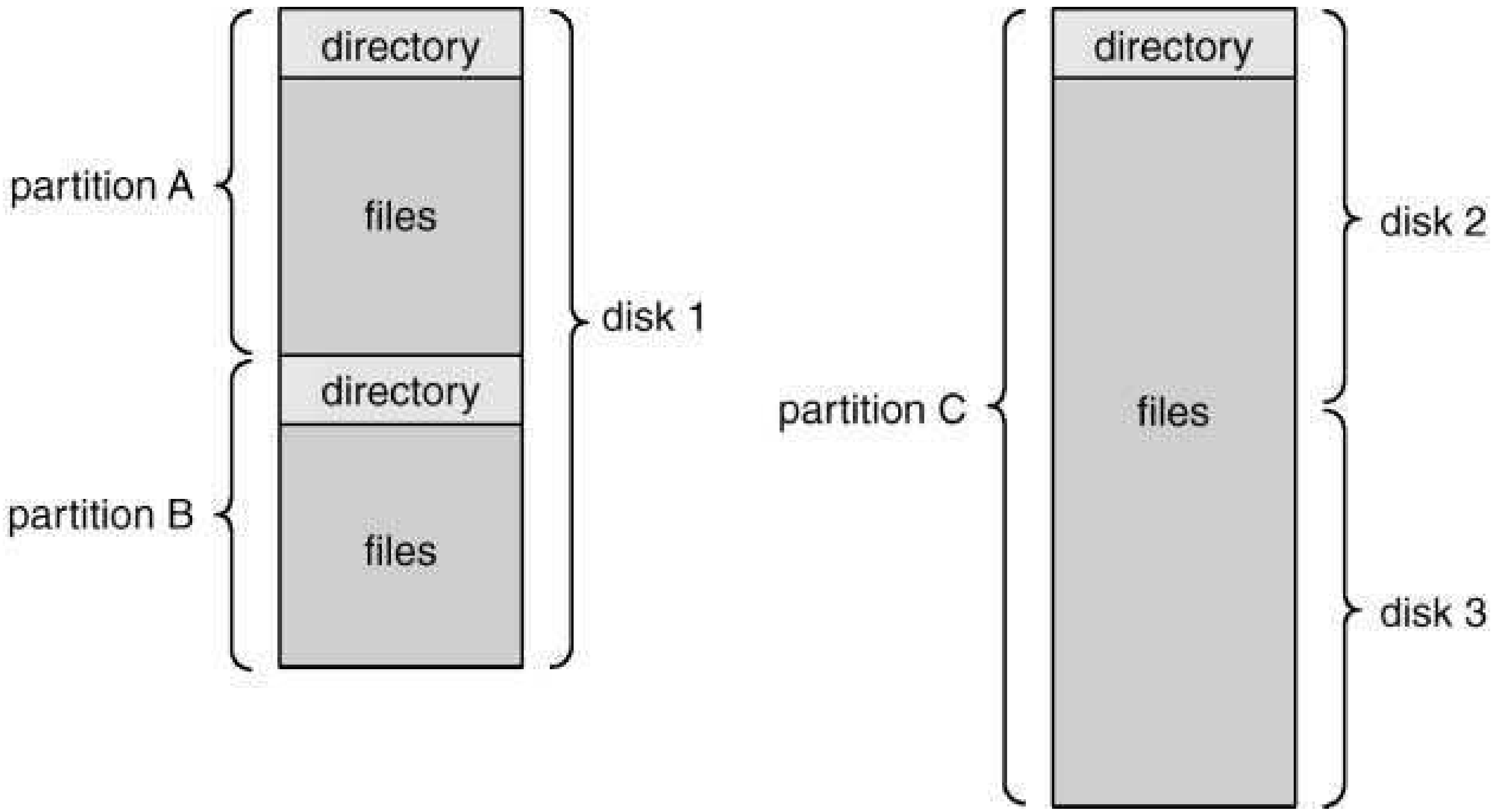
chgrp *G* *game*

- File-System Structure
- Allocation Methods
- Free-Space Management
- Directory Implementation
- Efficiency and Performance
- Recovery

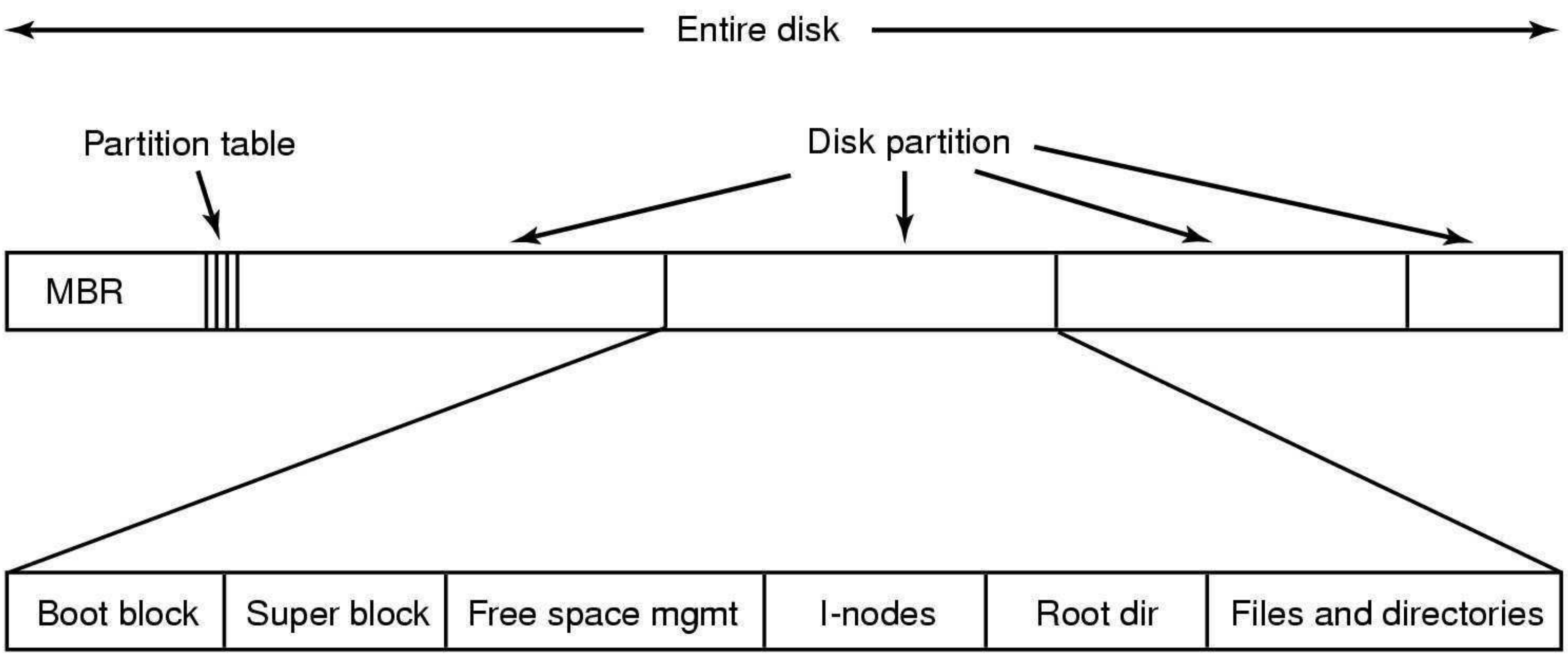
File-System Structure

- File structure
  - Logical storage unit
  - Collection of related information
- File system resides on secondary storage (disks).
- File system organized into layers.
- *File control block* – storage structure consisting of information about a file.

Typical File-System Organization



File System Implementation



A possible file system layout

Allocation

Putting Bytes on Disk

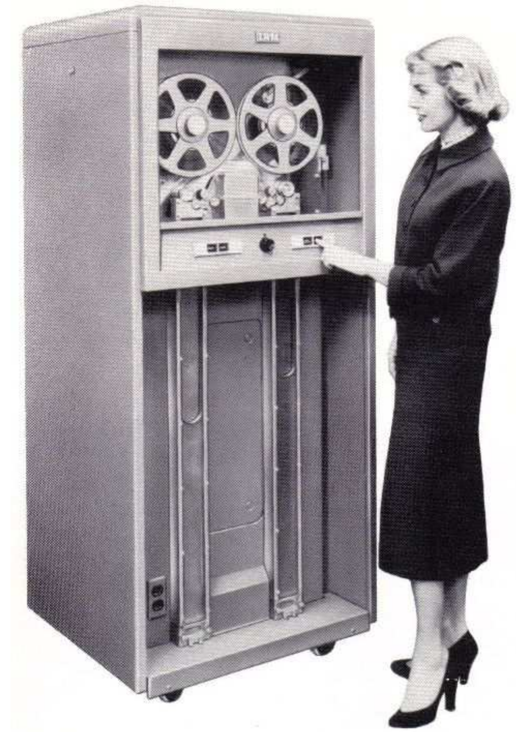
- File *viewed* as a contiguous sequence of bytes
- Allocation is actually *storing* the bytes

Fragmentation Types

- Data: file not contiguous
- External: unusable empty space between files
- Internal: allocated but unused space
  → file smaller than block

Random Access

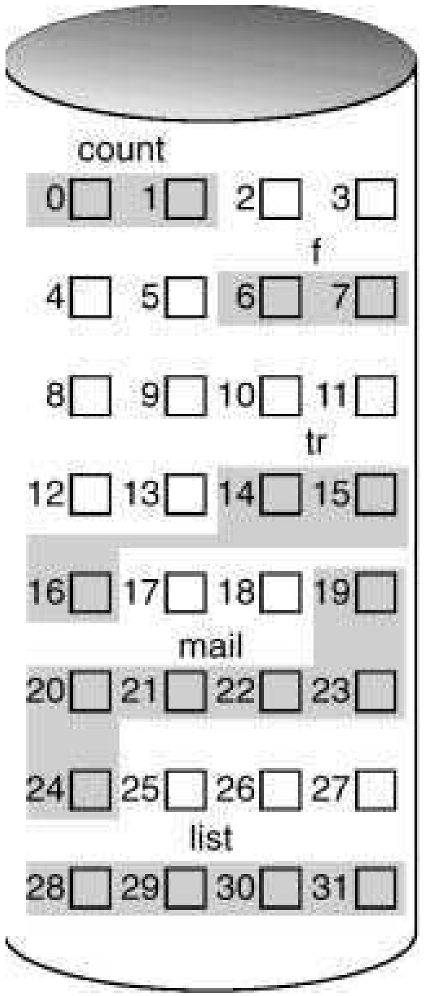
- Access time *independent* of the current block
- Also called *Direct Access*
- RAM: Random Access Memory
- Tape: no direct access



Contiguous Allocation

- Each file occupies a set of contiguous blocks on the disk.
- Simple – only starting location (block #) and length (number of blocks) are required.
- Random access.
- Wasteful of space (dynamic storage-allocation problem).
- Files cannot grow.

Contiguous Allocation of Disk Space

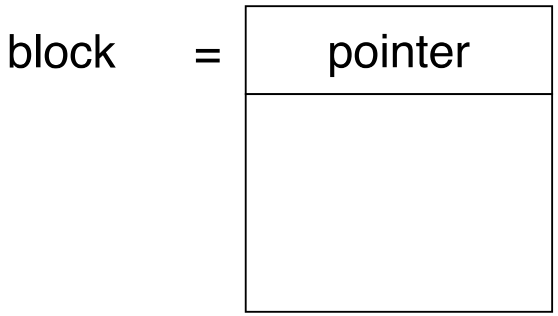


directory

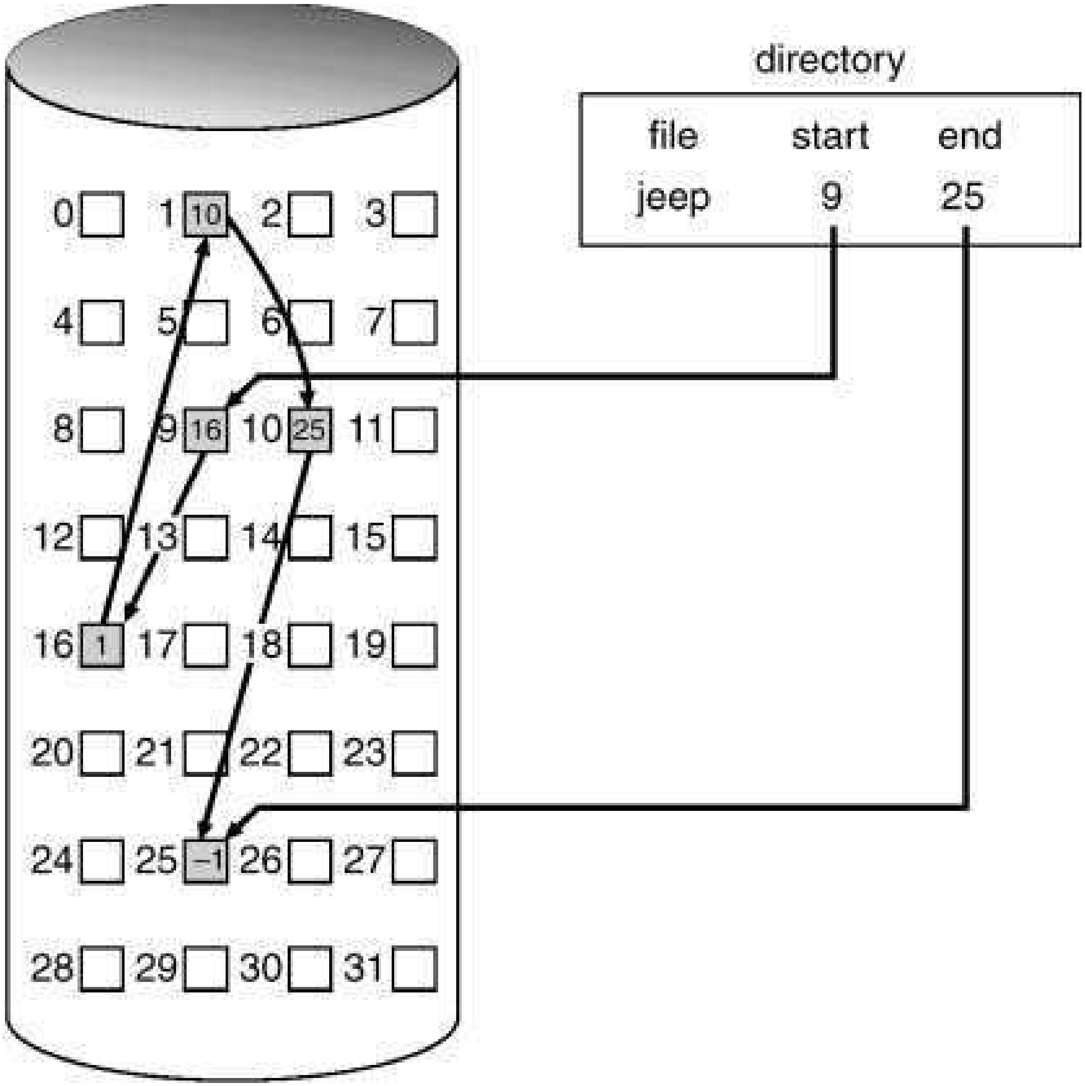
file	start	length
count	0	2
tr	14	3
mail	19	6
list	28	4
f	6	2

Linked Allocation

- Each file is a linked list of disk blocks: blocks may be scattered anywhere on the disk.



- Allocate as needed, link together; e.g., file starts at block 9



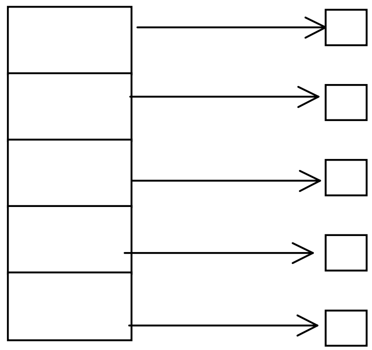
Linked Allocation (Cont.)

- Simple – need only starting address
- Free-space management system – no waste of space
- No random access
- Clusters of blocks
  - → for better performance (disk head moving)
  - → to have fewer pointers
- *File-allocation table (FAT)*: disk-space allocation used by MS-DOS and OS/2.
  The table is a list of entries that maps each cluster number to:
  - the cluster number of the next entry, or
  - an indication this is the last cluster (end of file), or
  - a special entry to mark bad clusters, or
  - a 0 to mark the cluster is unused

(some cluster may be reserved and are marked in the FAT)

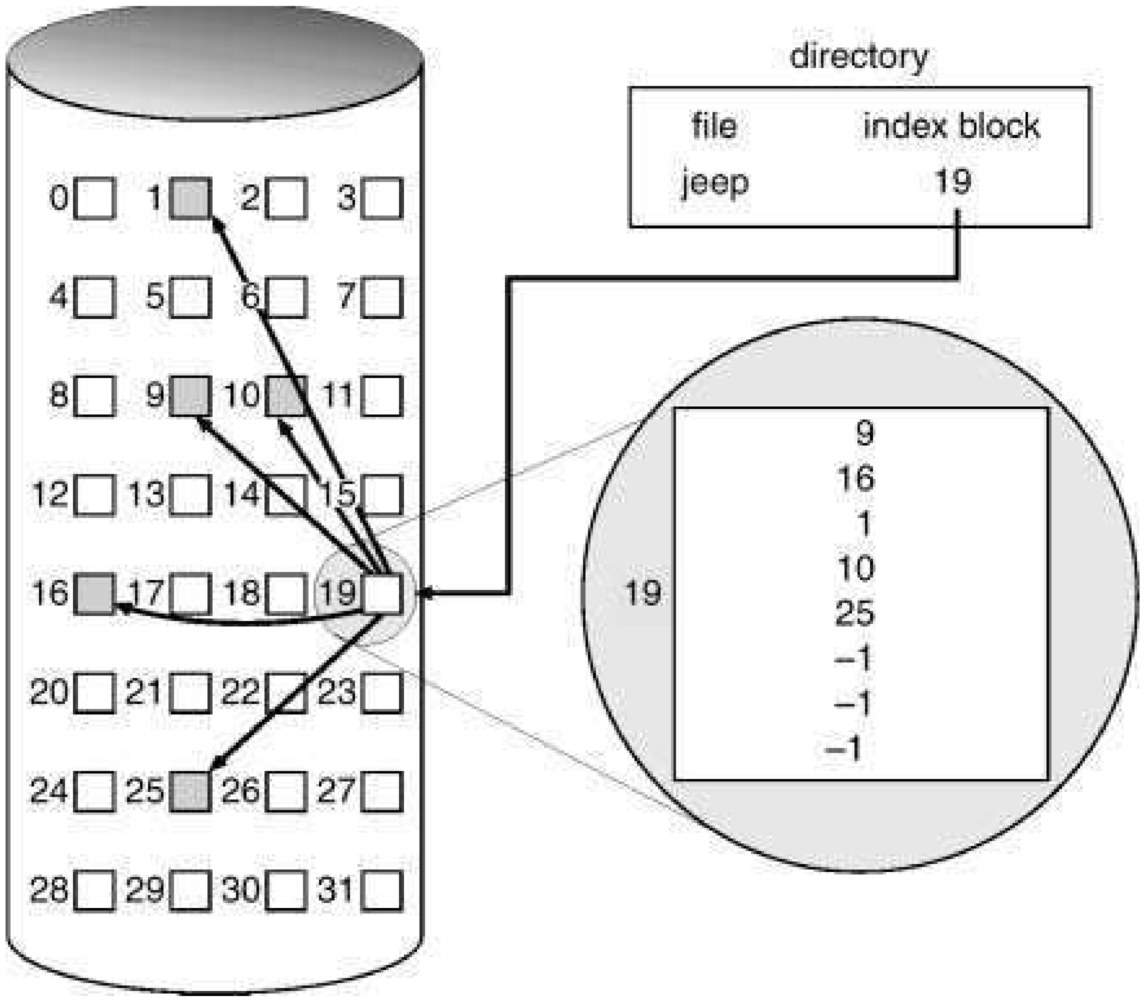
Indexed Allocation

- Brings all pointers together into the *index block.*
- Logical view.



index table

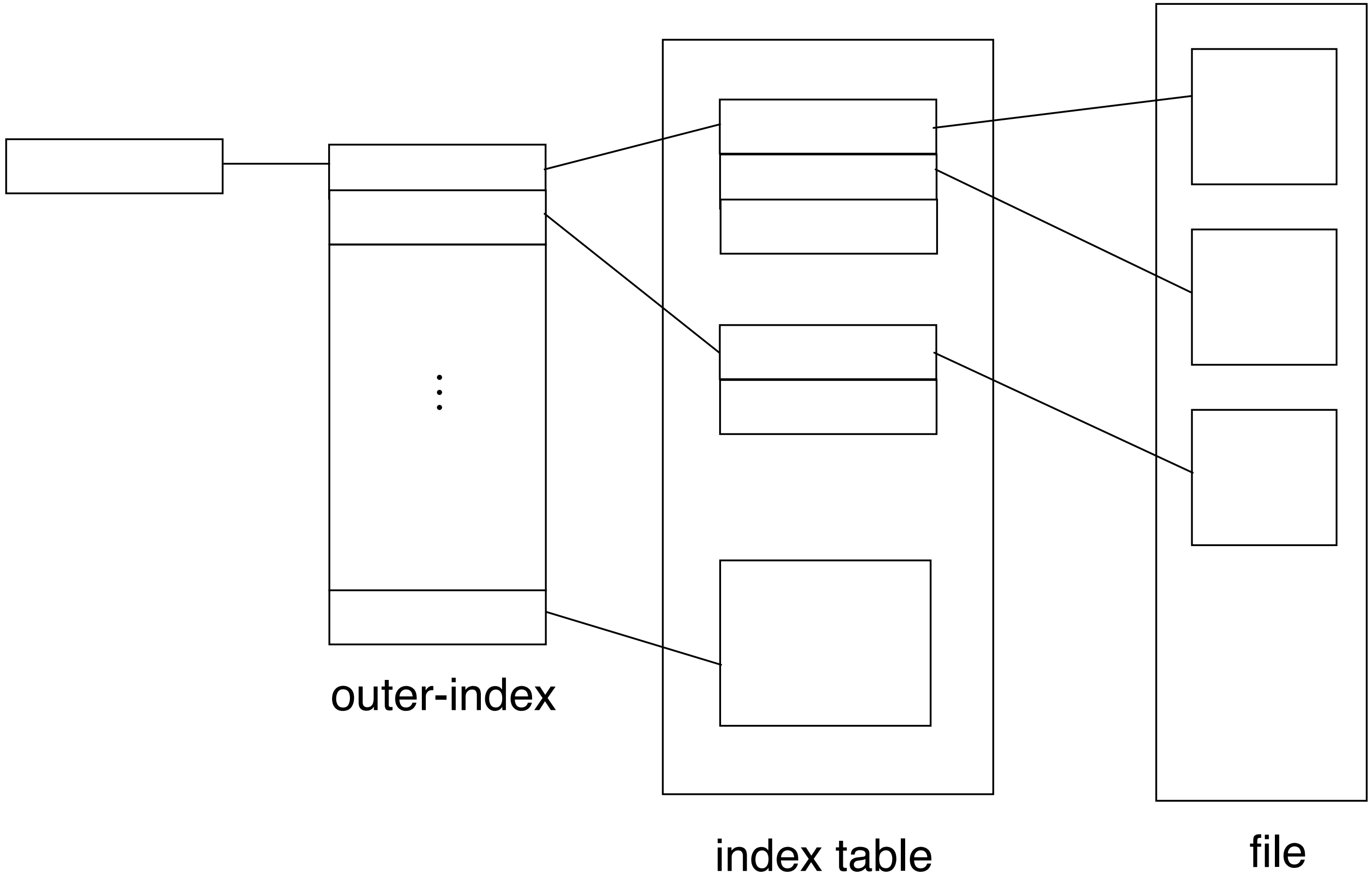
Example of Indexed Allocation



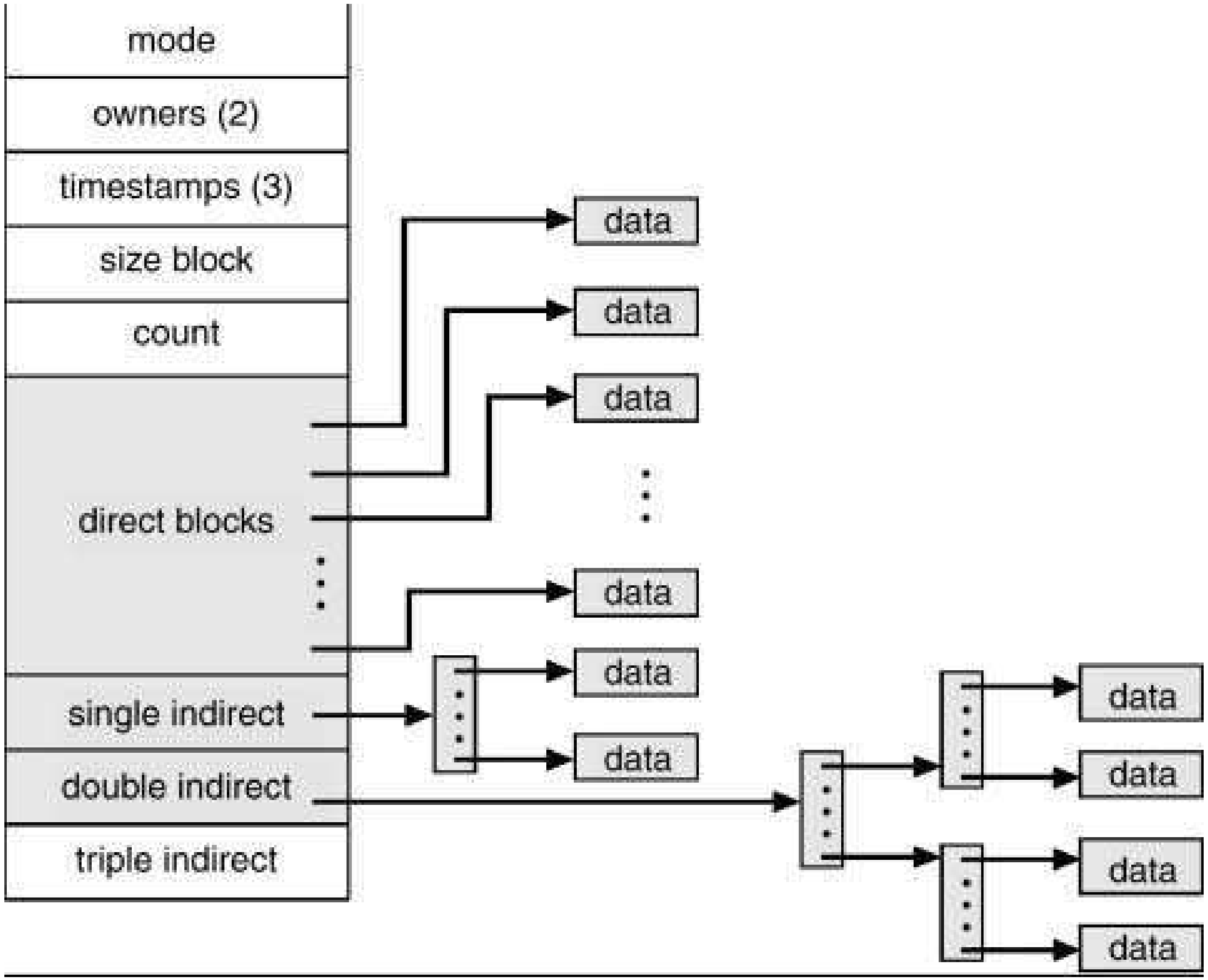
Indexed Allocation (Cont.)

- Need index table
- Random access
- Random access without external fragmentation, but have overhead of index block.

Indexed Allocation – Mapping (Cont.)



Combined Scheme: UNIX (4K bytes per block)

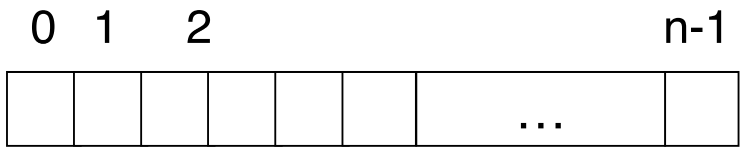


Comparing Allocation

	Random Access	No Data Frag	No External Frag	Space Waste
Contiguous	✔	✔	✘	0
Linked	✘	✘	✔	# clusters
Indexed	✔	✘	✔	> # clusters

Free-Space Management

- Bit vector (*n* blocks)



$$\text{bit}[i] = \begin{cases} 1 \Rightarrow \text{block}[i] \text{ free} \\ 0 \Rightarrow \text{block}[i] \text{ occupied} \end{cases}$$

- Block number calculation

(number of bits per word) *
(number of 0-value words) +
offset of first 1 bit

Free-Space Management (Cont.)

- Bit map requires extra space. Example:

  block size = 2^{12} bytes (4K bytes)

  disk size = 2^{30} bytes (1 gigabyte)

  $n = 2^{30}/2^{12} = 2^{18}$ bits (or 32K bytes)

- Easy to get contiguous files
- Linked list (free list)
  - Cannot get contiguous space easily
  - No waste of space
- Grouping
- Counting

Linked Free-Space List on Disk