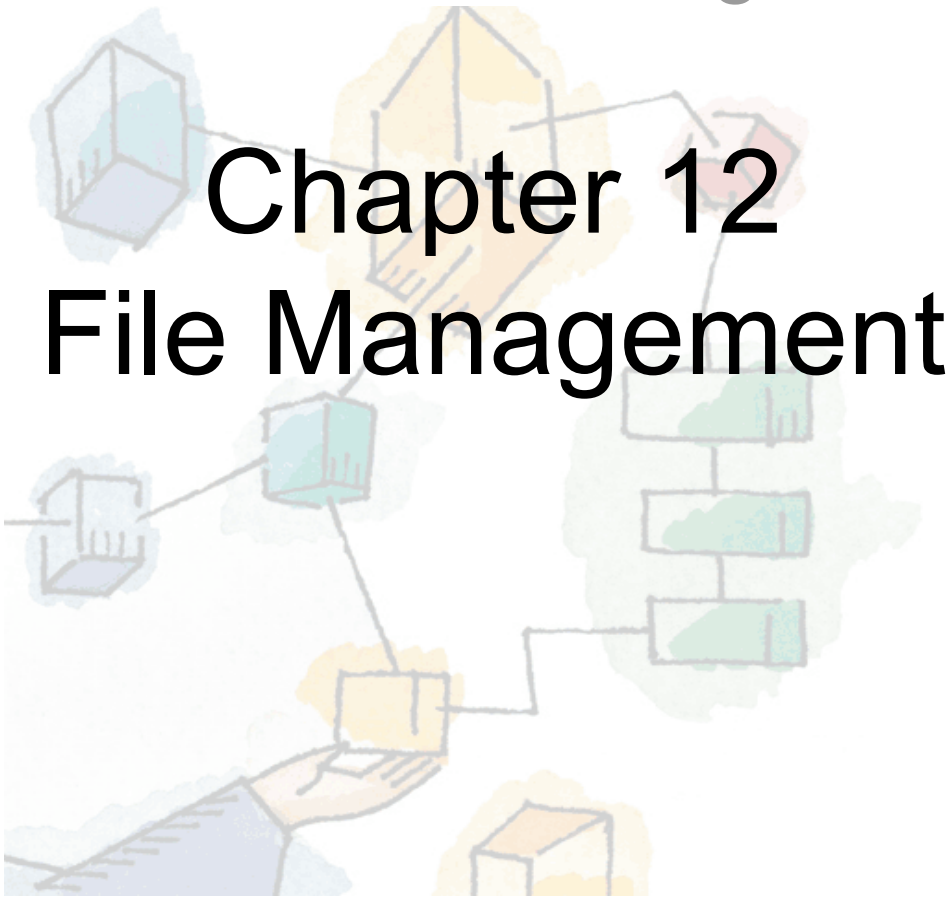
Operating Systems:
Internals and Design Principles, 6/E
William Stallings



Chapter 12
File Management

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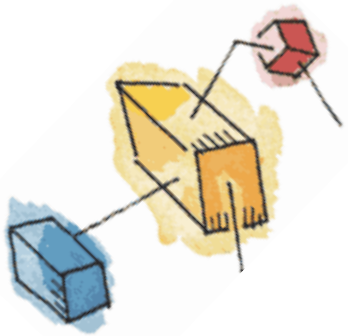
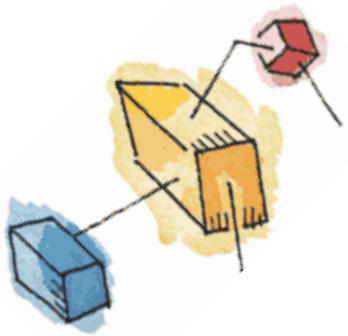


File Management

- File management system consists of system utility programs that run as privileged applications
- Concerned with secondary storage



File System Properties

- Long-term existence
- Sharable between processes
- Structure

File Operations

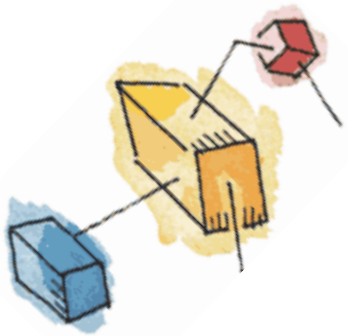
- Create
- Delete
- Open
- Close
- Read
- Write

File Terms

- Field
  - Basic element of data
  - Contains a single value
  - Characterized by its length and data type
- Record
  - Collection of related fields
  - Treated as a unit

File Terms

- File
  - Collection of similar records
  - Treated as a single entity
  - Have file names
  - May restrict access
- Database
  - Collection of related data
  - Relationships exist among elements

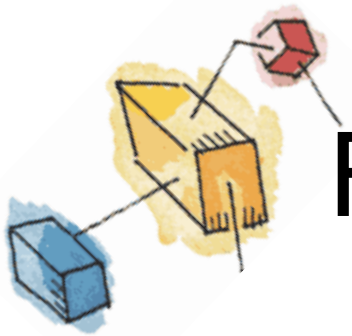


Typical Operations

- Retrieve_All
- Retrieve_One
- Retrieve_Next
- Retrieve_Previous

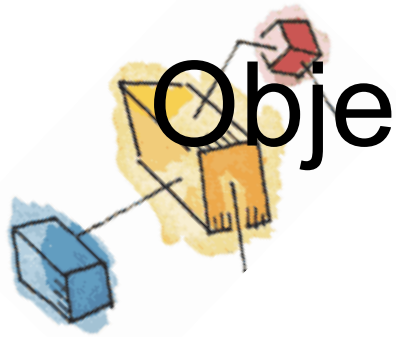
Typical Operations

- Insert_One
- Delete_One
- Update_One
- Retrieve_Few



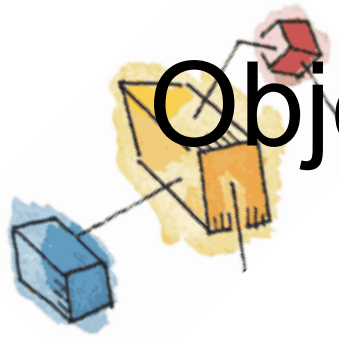
File Management Systems

- The way a user or application may access files
- Programmer does not need to develop file management software



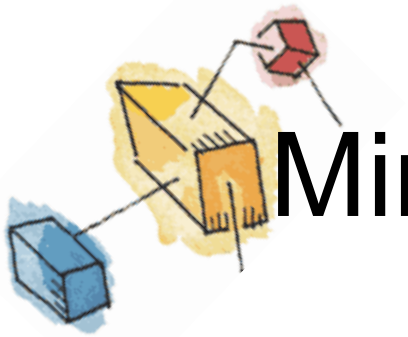
Objectives for a File Management System

- Meet the data management needs and requirements of the user
- Guarantee that the data in the file are valid
- Optimize performance
- Provide I/O support for a variety of storage device types



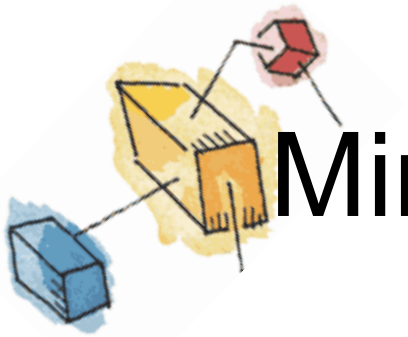
Objectives for a File Management System

- Minimize or eliminate the potential for lost or destroyed data
- Provide a standardized set of I/O interface routines
- Provide I/O support for multiple users



Minimal Set of Requirements

- Each user should be able to create, delete, read, write and modify files
- Each user may have controlled access to other users' files
- Each user may control what type of accesses are allowed to the users' files
- Each user should be able to restructure the user's files in a form appropriate to the problem



Minimal Set of Requirements

- Each user should be able to move data between files
- Each user should be able to back up and recover the user's files in case of damage
- Each user should be able to access the user's files by using symbolic names

Files System Software Architecture

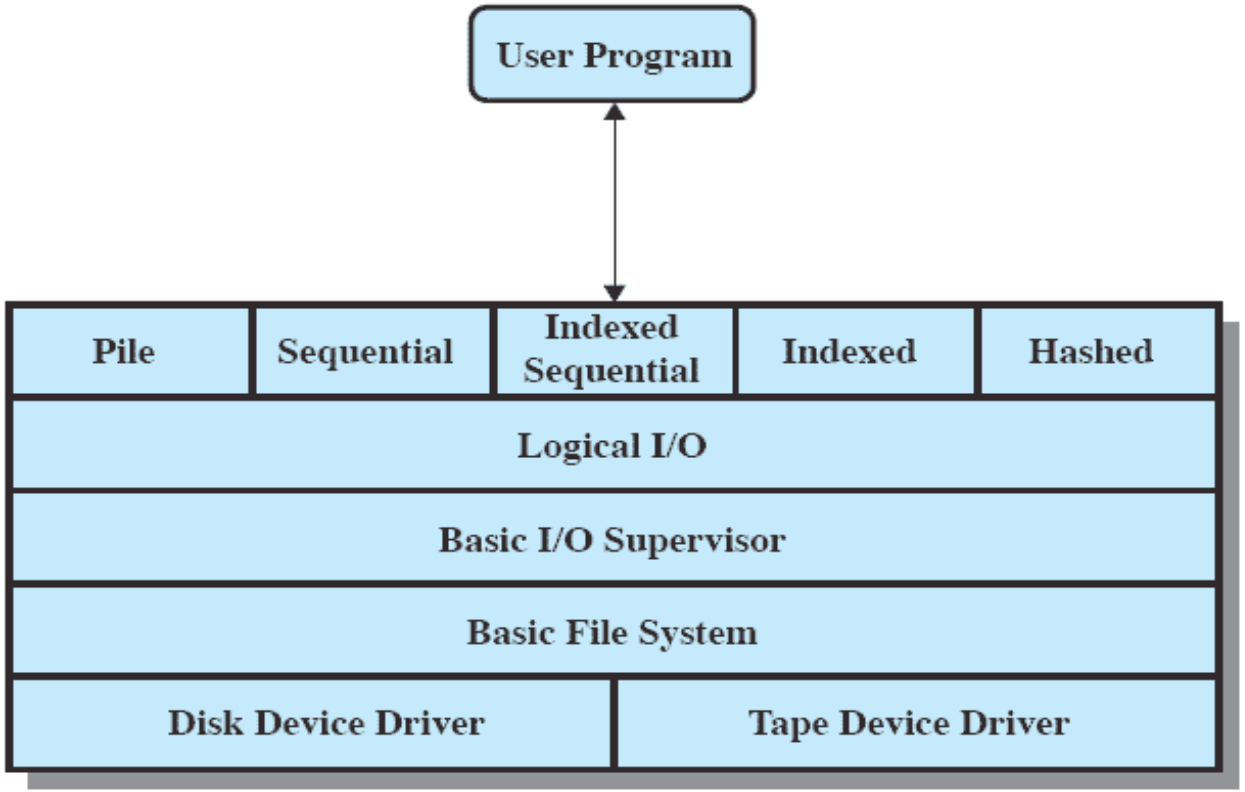
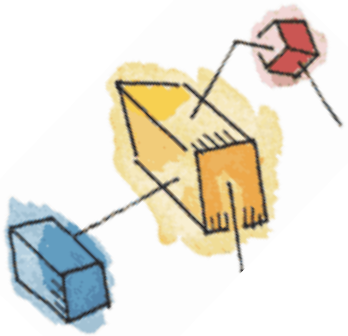
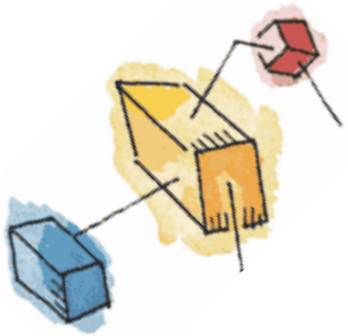


Figure 12.1 File System Software Architecture



Device Drivers

- Lowest level
- Communicates directly with peripheral devices
- Responsible for starting I/O operations on a device
- Processes the completion of an I/O request



Basic File System

- Physical I/O
- Deals with exchanging blocks of data
- Concerned with the placement of blocks
- Concerned with buffering blocks in main memory

Logical I/O

- Enables users and applications to access records
- Provides general-purpose record I/O capability
- Maintains basic data about file

Access Method

- Reflect different file structures
- Different ways to access and process data

Elements of File Management

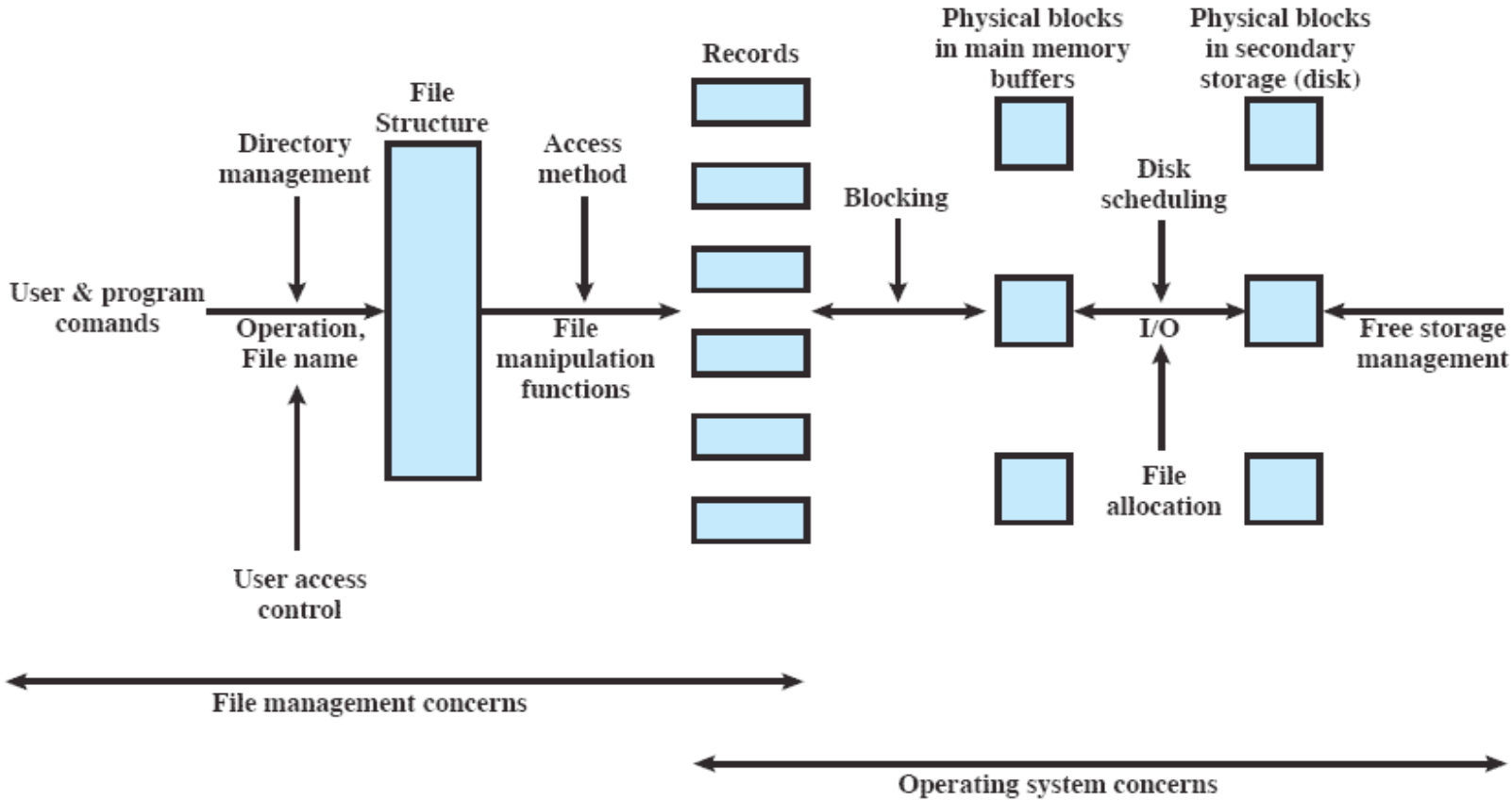
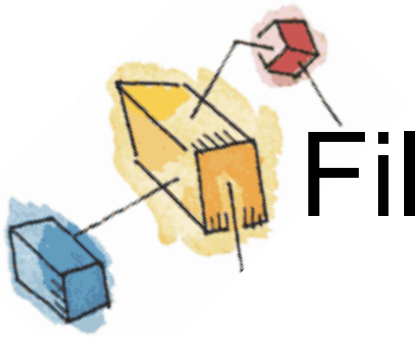
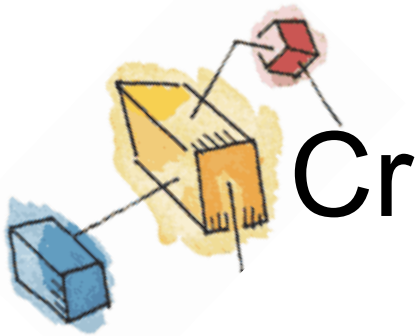


Figure 12.2 Elements of File Management



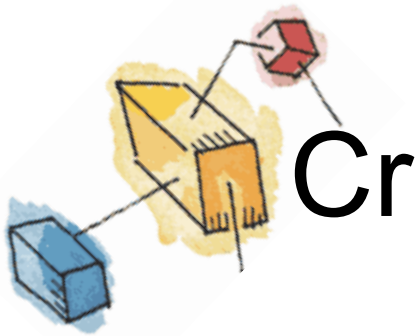
File Management Functions

- Identify and locate a selected file
- Use a directory to describe the location of all files plus their attributes
- On a shared system describe user access control



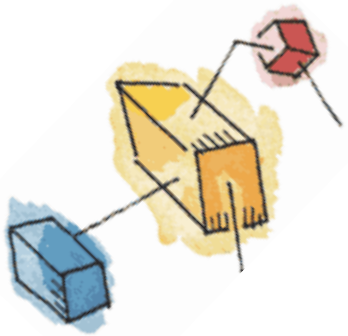
Criteria for File Organization

- Short access time
  - Needed when accessing a single record
- Ease of update
  - File on CD-ROM will not be updated, so this is not a concern



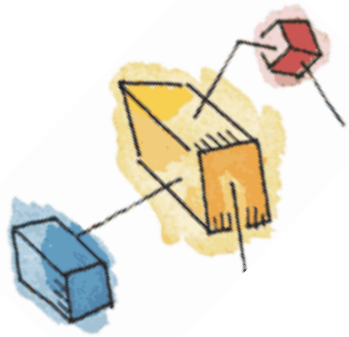
Criteria for File Organization

- Economy of storage
  - Should be minimum redundancy in the data
  - Redundancy can be used to speed access such as an index
- Simple maintenance
- Reliability

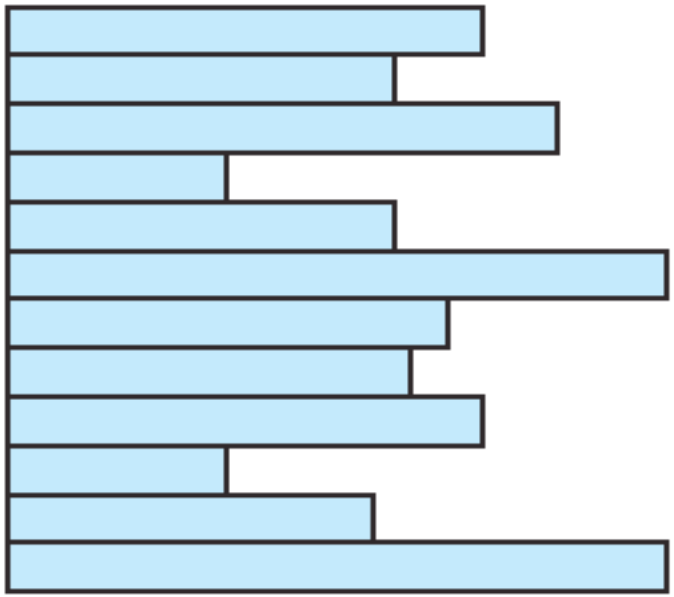


File Organization

- The Pile
  - Data are collected in the order they arrive
  - Purpose is to accumulate a mass of data and save it
  - Records may have different fields
  - No structure
  - Record access is by exhaustive search



The Pile

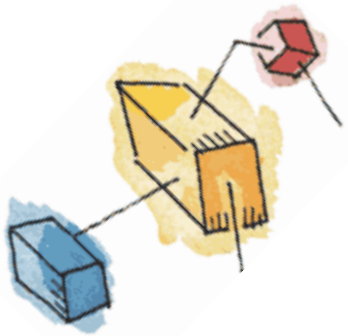


Variable-length records
Variable set of fields
Chronological order

(a) Pile File

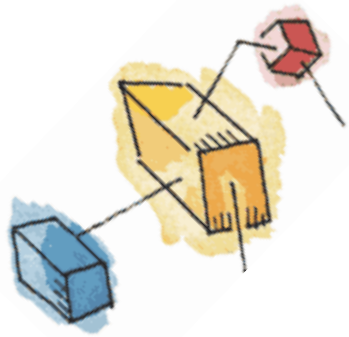
File Organization

- The Sequential File
  - Fixed format used for records
  - Records are the same length
  - All fields the same (order and length)
  - Field names and lengths are attributes of the file

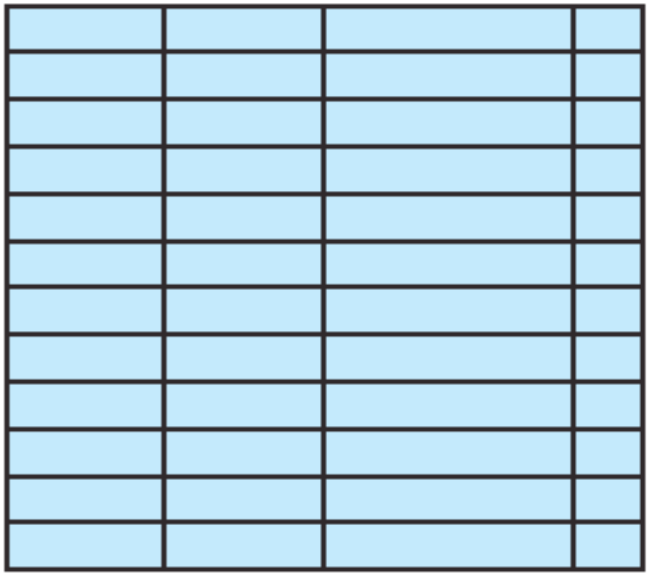


File Organization

- The Sequential File
  - One field is the key filed
    - Uniquely identifies the record
    - Records are stored in key sequence

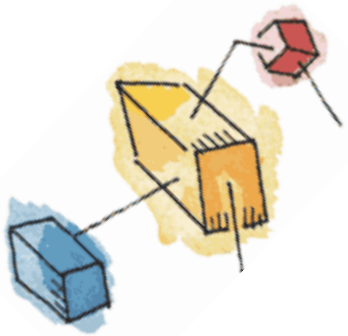


The Sequential File



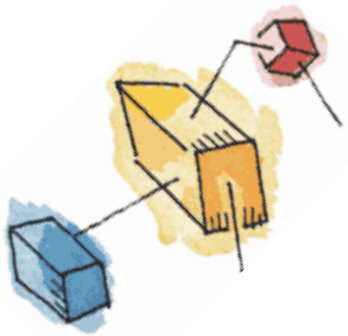
Fixed-length records
Fixed set of fields in fixed order
Sequential order based on key field

(b) Sequential File



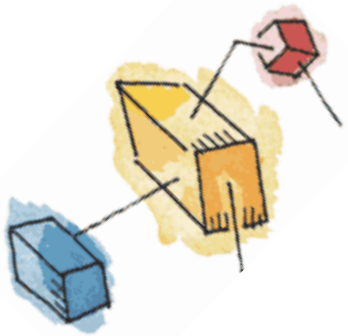
File Organization

- Indexed Sequential File
  - Index provides a lookup capability to quickly reach the vicinity of the desired record
    - Contains key field and a pointer to the main file
    - Indexed is searched to find highest key value that is equal to or precedes the desired key value
    - Search continues in the main file at the location indicated by the pointer



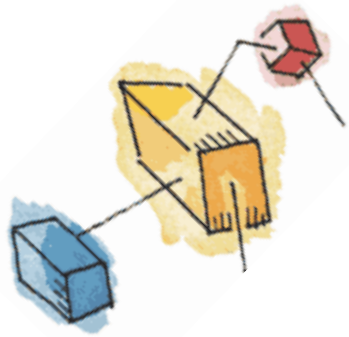
File Organization

- Comparison of sequential and indexed sequential
  - Example: a file contains 1 million records
  - On average 500,00 accesses are required to find a record in a sequential file
  - If an index contains 1000 entries, it will take on average 500 accesses to find the key, followed by 500 accesses in the main file. Now on average it is 1000 accesses

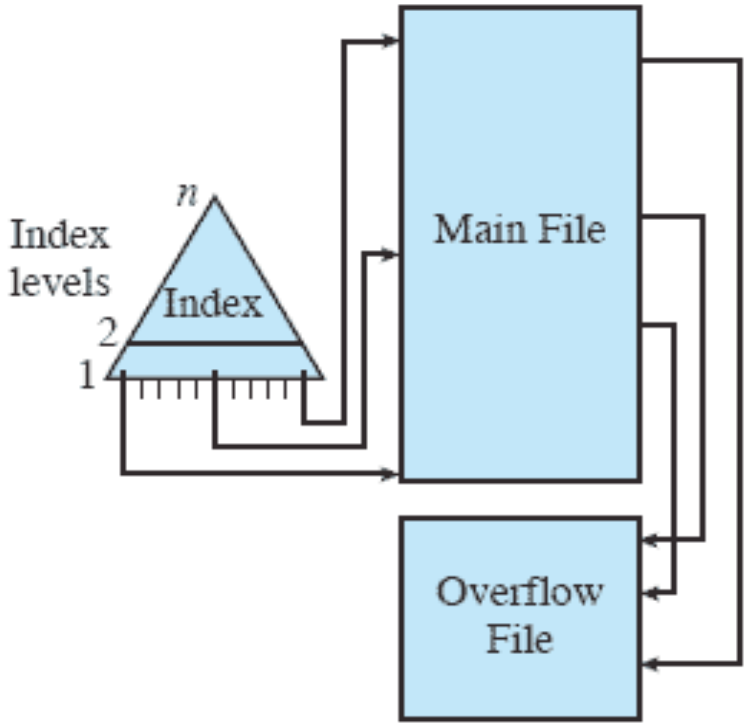


File Organization

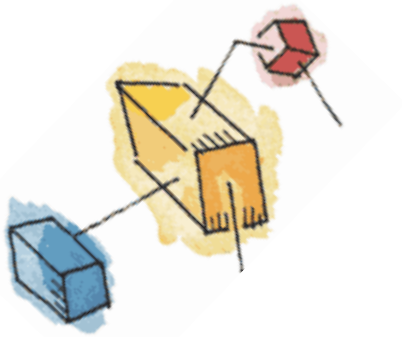
- Indexed Sequential File
  - New records are added to an overflow file
  - Record in main file that precedes it is updated to contain a pointer to the new record
  - The overflow is merged with the main file during a batch update
  - Multiple indexes for the same key field can be set up to increase efficiency



Indexed Sequential File

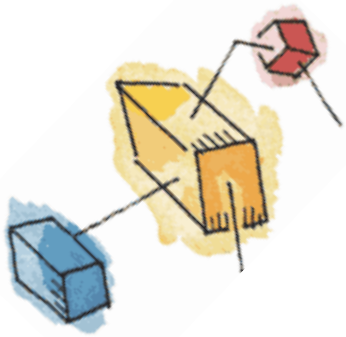


(c) Indexed Sequential File

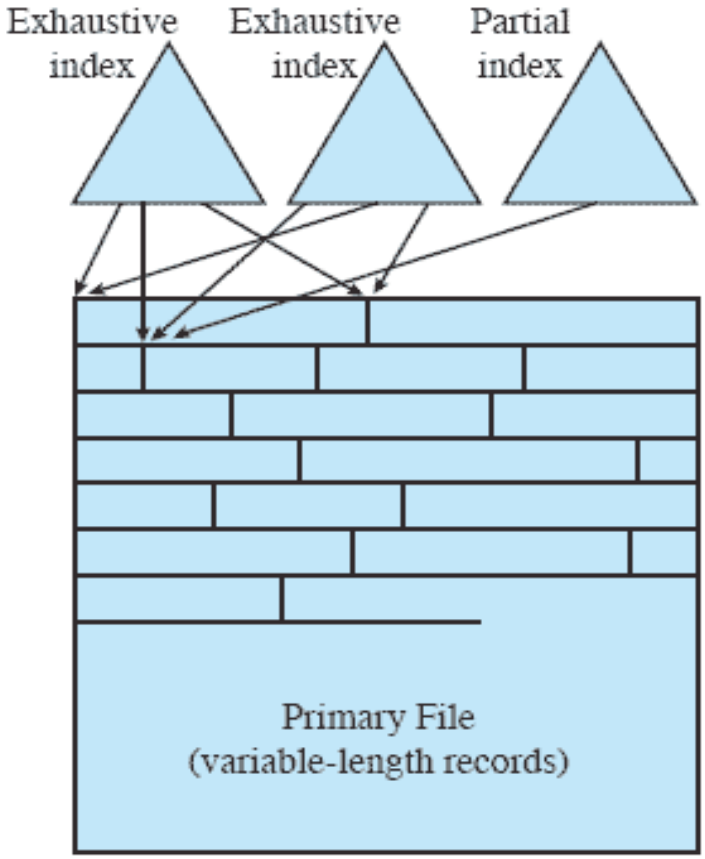


File Organization

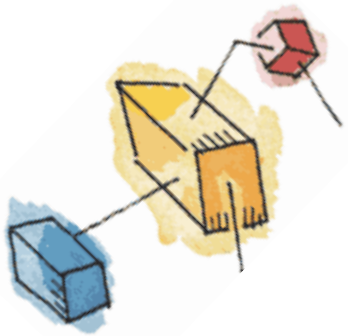
- Indexed File
  - Uses multiple indexes for different key fields
  - May contain an exhaustive index that contains one entry for every record in the main file
  - May contain a partial index



Indexed File

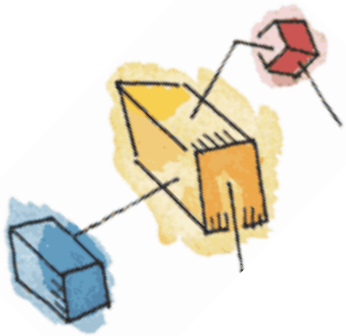


(d) Indexed File



File Organization

- The Direct or Hashed File
  - Directly access a block at a known address
  - Key field required for each record



Performance

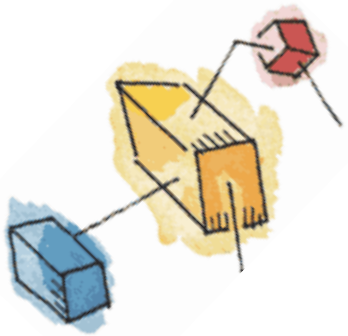
Table 12.1 Grades of Performance for Five Basic File Organizations [WIED87]

	Space		Update		Retrieval		
	Attributes		Record Size				
File Method	Variable	Fixed	Equal	Greater	Single record	Subset	Exhaustive
Pile	A	B	A	E	E	D	B
Sequential	F	A	D	F	F	D	A
Indexed sequential	F	B	B	D	B	D	B
Indexed	B	C	C	C	A	B	D
Hashed	F	B	B	F	B	F	E

A	=	Excellent, well suited to this purpose	$\approx O(r)$
B	=	Good	$\approx O(o \times r)$
C	=	Adequate	$\approx O(r \log n)$
D	=	Requires some extra effort	$\approx O(n)$
E	=	Possible with extreme effort	$\approx O(r \times n)$
F	=	Not reasonable for this purpose	$\approx O(n^{>1})$

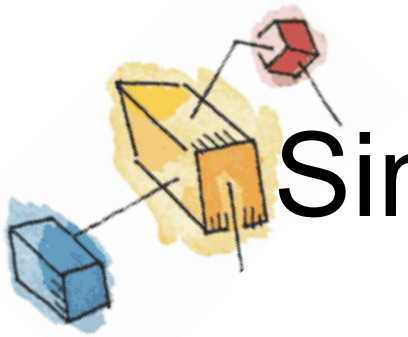
where

r = size of the result
o = number of records that overflow
n = number of records in file



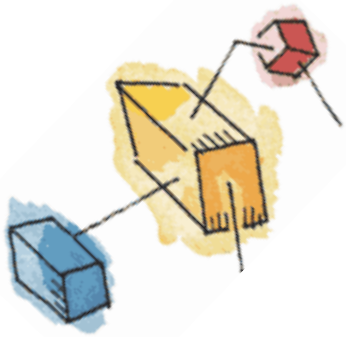
File Directories

- Contains information about files
  - Attributes
  - Location
  - Ownership
- Directory itself is a file owned by the operating system
- Provides mapping between file names and the files themselves



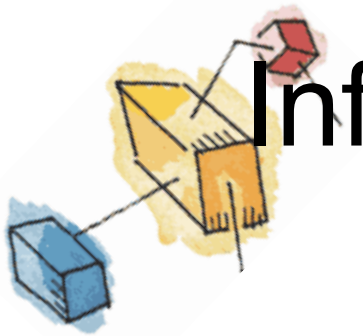
Simple Structure for a Directory

- List of entries, one for each file
- Sequential file with the name of the file serving as the key
- Provides no help in organizing the files
- Forces user to be careful not to use the same name for two different files



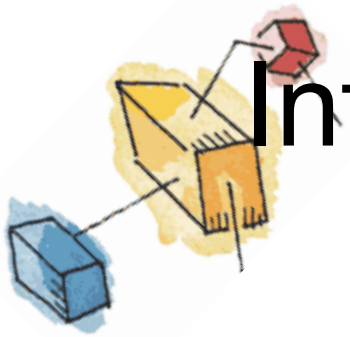
Information Elements of a File Directory

Basic Information	
File Name	Name as chosen by creator (user or program). Must be unique within a specific directory.
File Type	For example: text, binary, load module, etc.
File Organization	For systems that support different organizations
Address Information	
Volume	Indicates device on which file is stored
Starting Address	Starting physical address on secondary storage (e.g., cylinder, track, and block number on disk)
Size Used	Current size of the file in bytes, words, or blocks
Size Allocated	The maximum size of the file



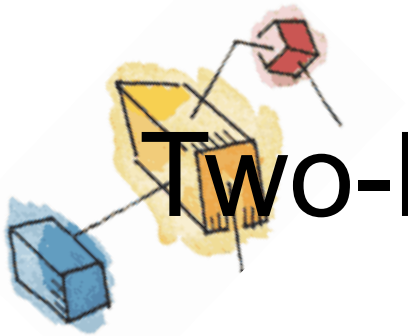
Information Elements of a File Directory

Access Control Information	
Owner	User who is assigned control of this file. The owner may be able to grant/deny access to other users and to change these privileges.
Access Information	A simple version of this element would include the user's name and password for each authorized user.
Permitted Actions	Controls reading, writing, executing, transmitting over a network



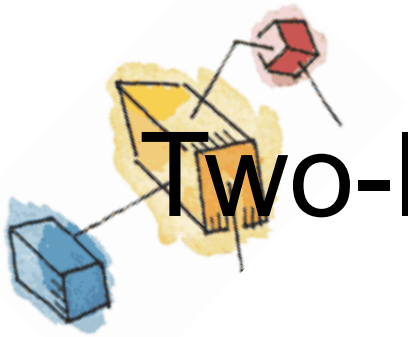
Information Elements of a File Directory

Usage Information	
Date Created	When file was first placed in directory
Identity of Creator	Usually but not necessarily the current owner
Date Last Read Access	Date of the last time a record was read
Identity of Last Reader	User who did the reading
Date Last Modified	Date of the last update, insertion, or deletion
Identity of Last Modifier	User who did the modifying
Date of Last Backup	Date of the last time the file was backed up on another storage medium
Current Usage	Information about current activity on the file, such as process or processes that have the file open, whether it is locked by a process, and whether the file has been updated in main memory but not yet on disk



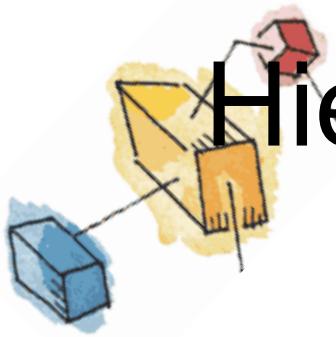
Two-Level Scheme for a Directory

- One directory for each user and a master directory
- Master directory contains entry for each user
  - Provides address and access control information



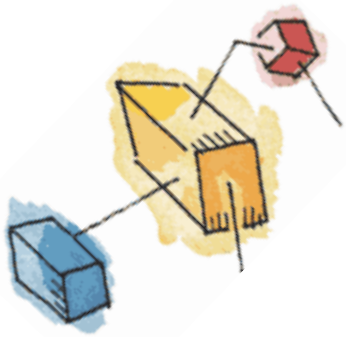
Two-Level Scheme for a Directory

- Each user directory is a simple list of files for that user
- Still provides no help in structuring collections of files



Hierarchical, or Tree-Structured Directory

- Master directory with user directories underneath it
- Each user directory may have subdirectories and files as entries



Tree-Structured Directory

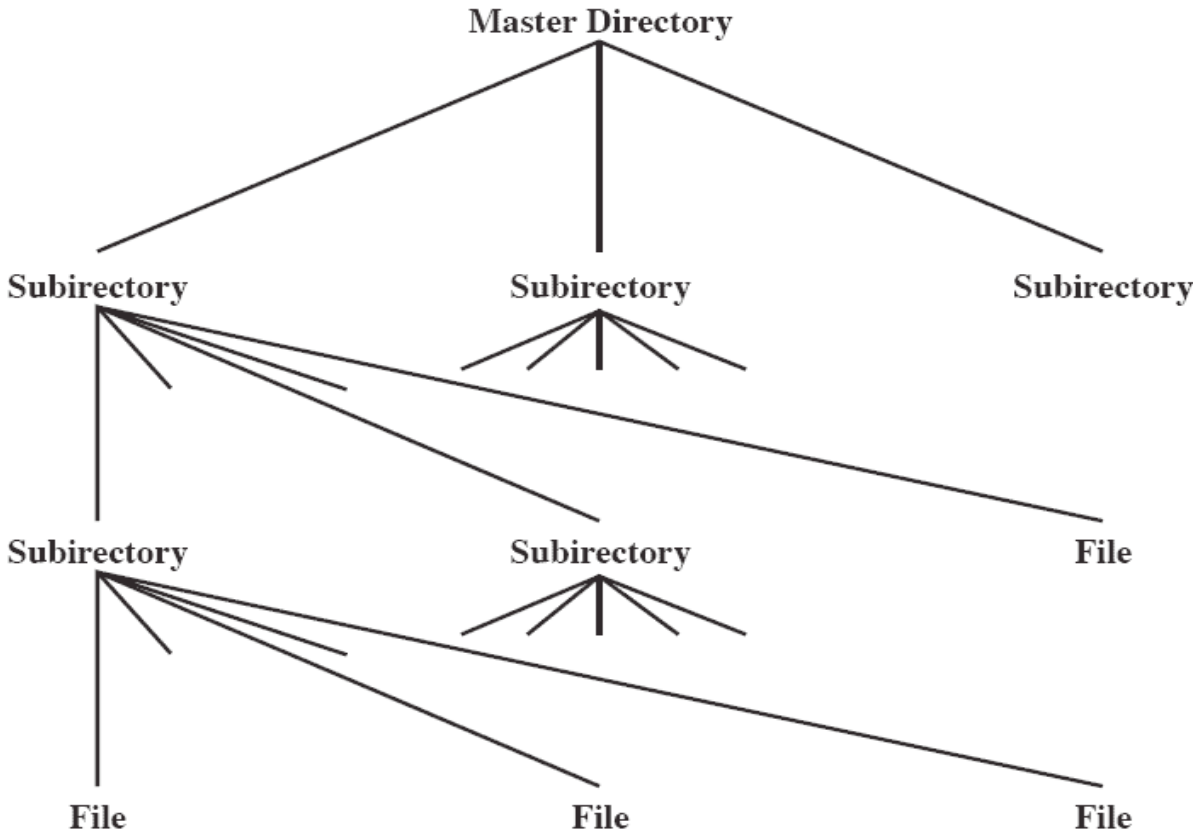


Figure 12.4 Tree-Structured Directory

Example of Tree-Structured Directory

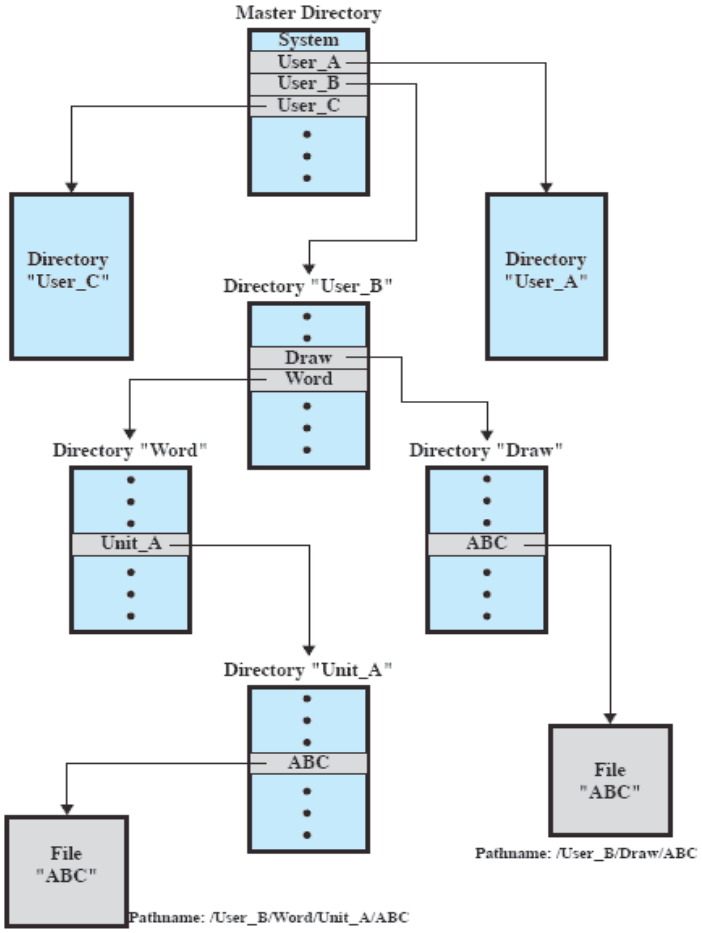
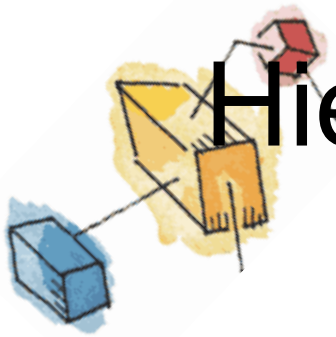
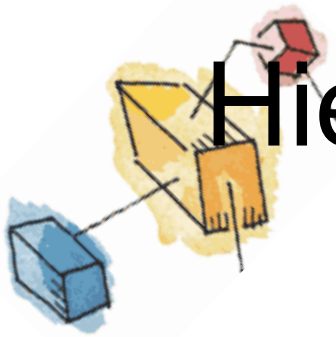


Figure 12.5 Example of Tree-Structured Directory



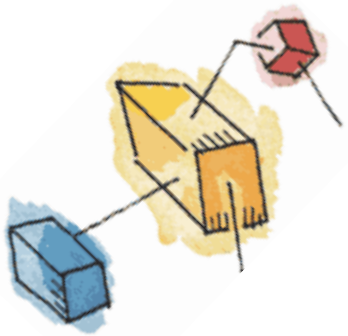
Hierarchical, or Tree-Structured Directory

- Files can be located by following a path from the root, or master, directory down various branches
  - This is the pathname for the file
- Can have several files with the same file name as long as they have unique path names



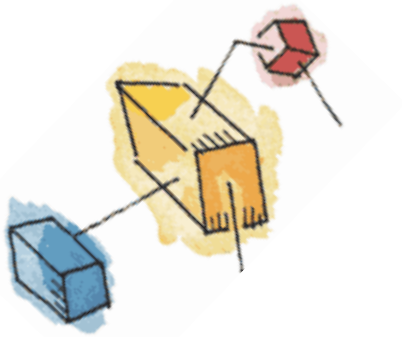
Hierarchical, or Tree-Structured Directory

- Current directory is the working directory
- Files are referenced relative to the working directory



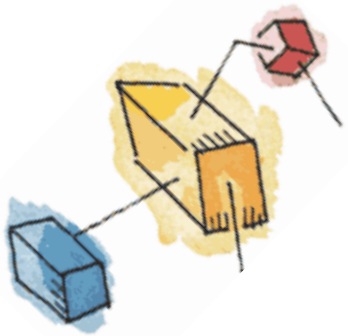
File Sharing

- In multiuser system, allow files to be shared among users
- Two issues
  - Access rights
  - Management of simultaneous access



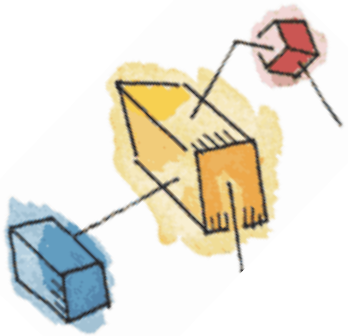
Access Rights

- None
  - User may not know of the existence of the file
  - User is not allowed to read the user directory that includes the file
- Knowledge
  - User can only determine that the file exists and who its owner is



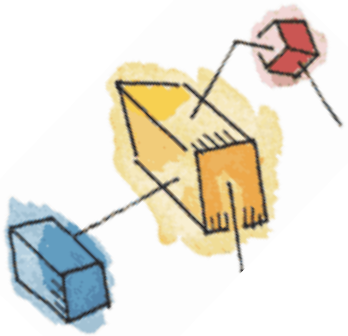
Access Rights

- Execution
  - The user can load and execute a program but cannot copy it
- Reading
  - The user can read the file for any purpose, including copying and execution
- Appending
  - The user can add data to the file but cannot modify or delete any of the file's contents



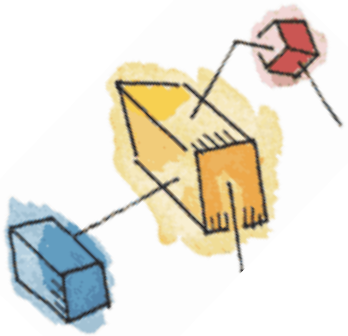
Access Rights

- Updating
  - The user can modify, deleted, and add to the file's data. This includes creating the file, rewriting it, and removing all or part of the data
- Changing protection
  - User can change access rights granted to other users
- Deletion
  - User can delete the file



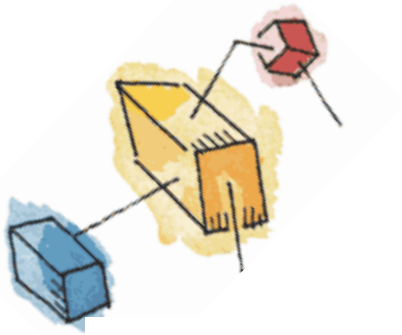
Access Rights

- Owners
  - Has all rights previously listed
  - May grant rights to others using the following classes of users
    - Specific user
    - User groups
    - All for public files

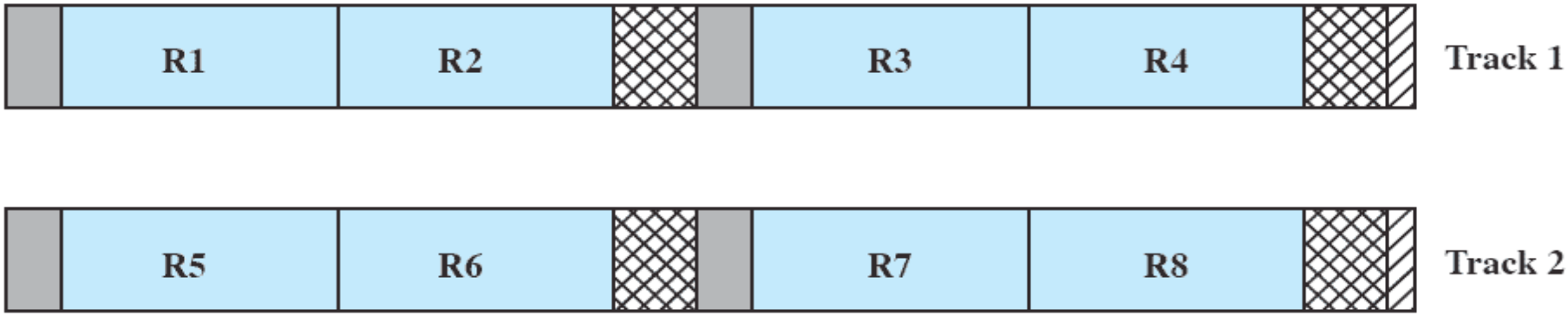


Simultaneous Access

- User may lock entire file when it is to be updated
- User may lock the individual records during the update
- Mutual exclusion and deadlock are issues for shared access



Fixed Blocking



Fixed Blocking

Data

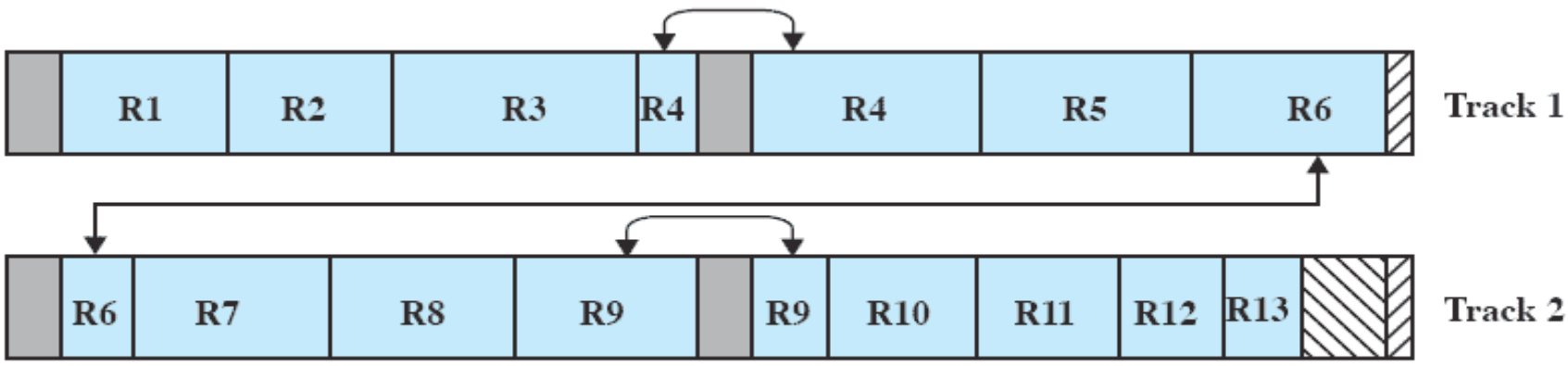
Gaps due to hardware design

Waste due to block fit to track size

Waste due to record fit to block size

Waste due to block size constraint from fixed record size

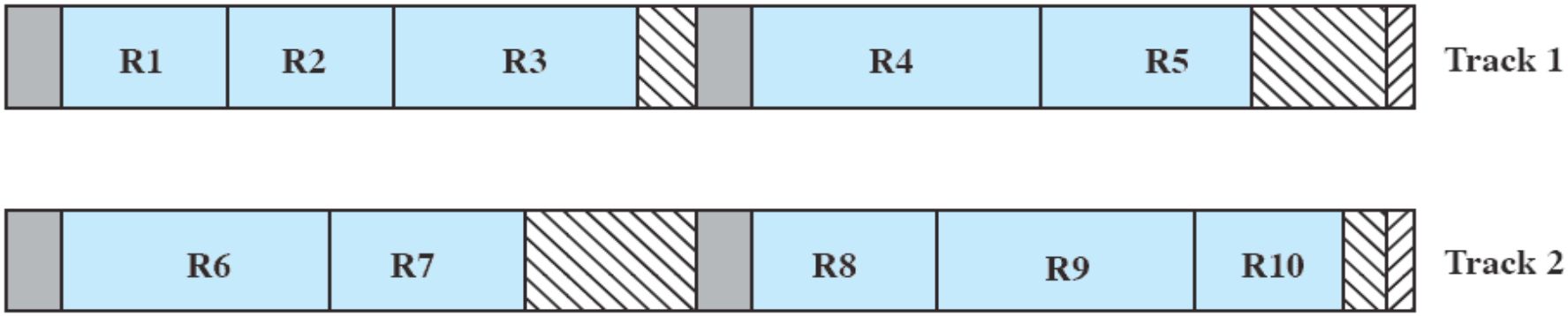
Variable Blocking: Spanned



Variable Blocking: Spanned

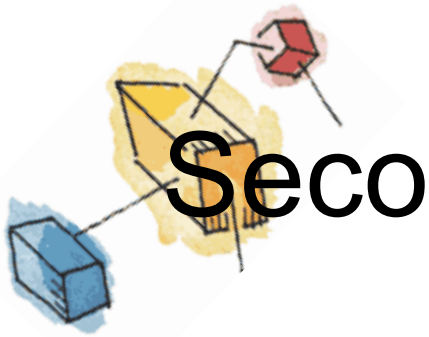
- Data
- Gaps due to hardware design
- Waste due to block fit to track size
- Waste due to record fit to block size
- Waste due to block size constraint from fixed record size

Variable Blocking: Unspanned



Variable Blocking: Unspanned

- Data
- Gaps due to hardware design
- Waste due to block fit to track size
- Waste due to record fit to block size
- Waste due to block size constraint from fixed record size

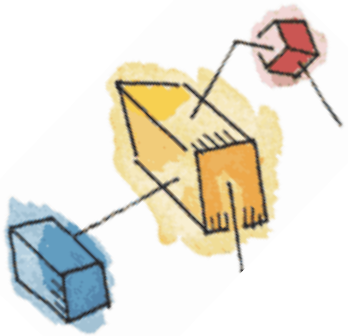


Secondary Storage Management

- Space must be allocated to files
- Must keep track of the space available for allocation

Preallocation

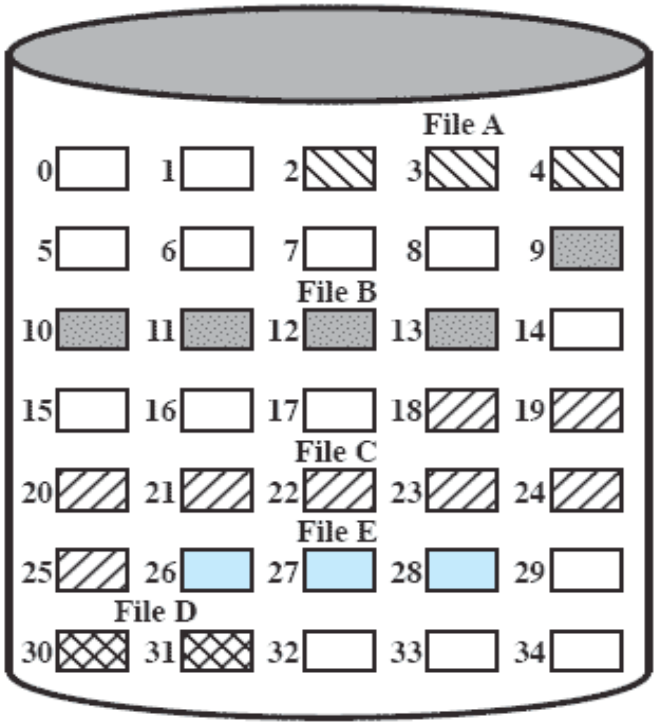
- Need the maximum size for the file at the time of creation
- Difficult to reliably estimate the maximum potential size of the file
- Tend to overestimated file size so as not to run out of space



Contiguous Allocation

- Single set of blocks is allocated to a file at the time of creation
- Only a single entry in the file allocation table
  - Starting block and length of the file
- External fragmentation will occur
  - Need to perform compaction

Contiguous File Allocation

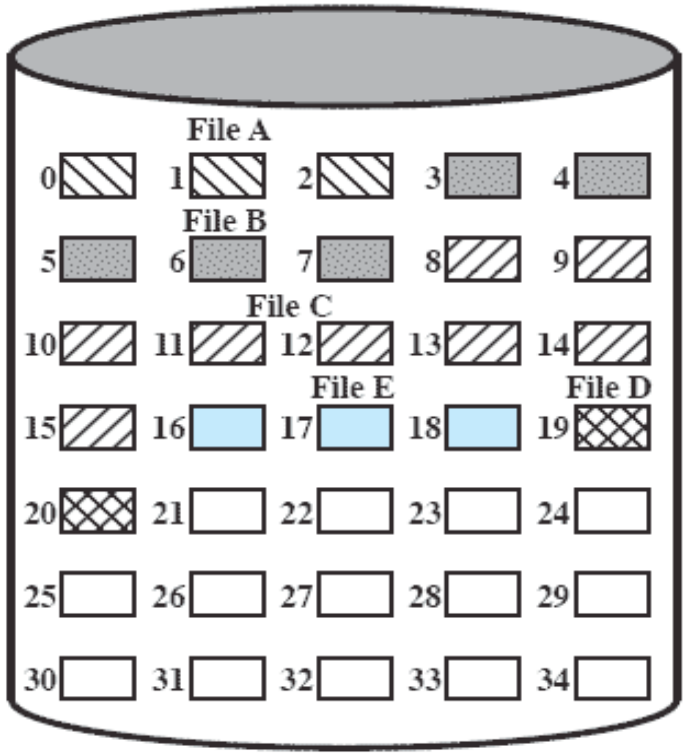


File Allocation Table

File Name	Start Block	Length
File A	2	3
File B	9	5
File C	18	8
File D	30	2
File E	26	3

Figure 12.7 Contiguous File Allocation

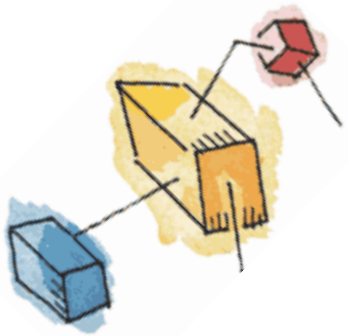
Contiguous File Allocation



File Allocation Table

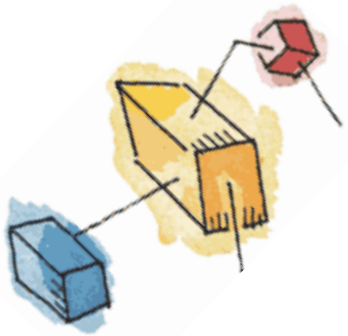
File Name	Start Block	Length
File A	0	3
File B	3	5
File C	8	8
File D	19	2
File E	16	3

Figure 12.8 Contiguous File Allocation (After Compaction)



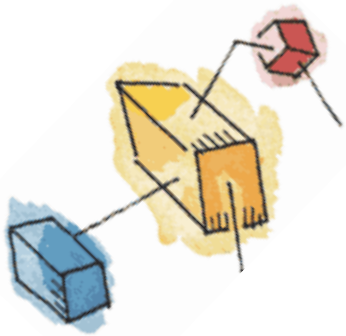
Chained Allocation

- Allocation on basis of individual block
- Each block contains a pointer to the next block in the chain
- Only single entry in the file allocation table
  - Starting block and length of file

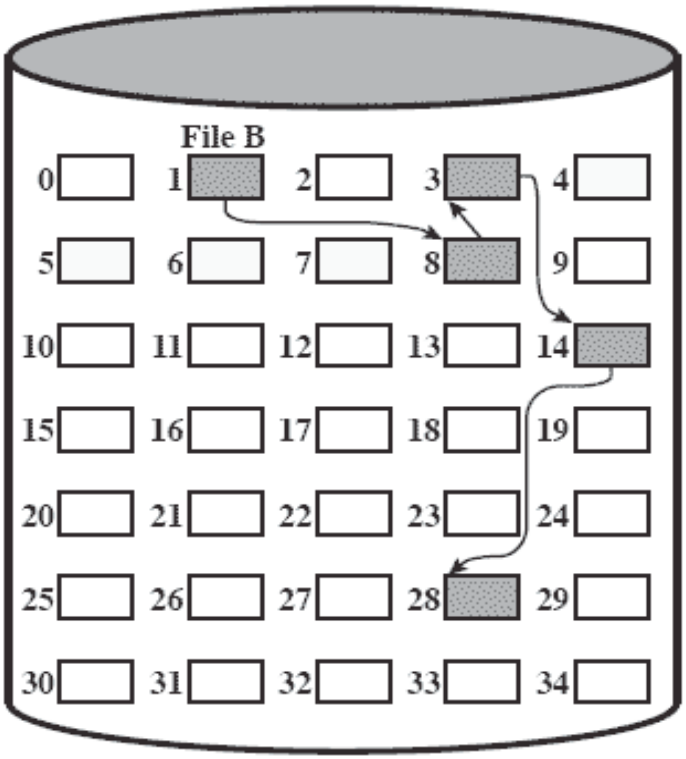


Chained Allocation

- No external fragmentation
- Best for sequential files
- No accommodation of the principle of locality



Chained Allocation

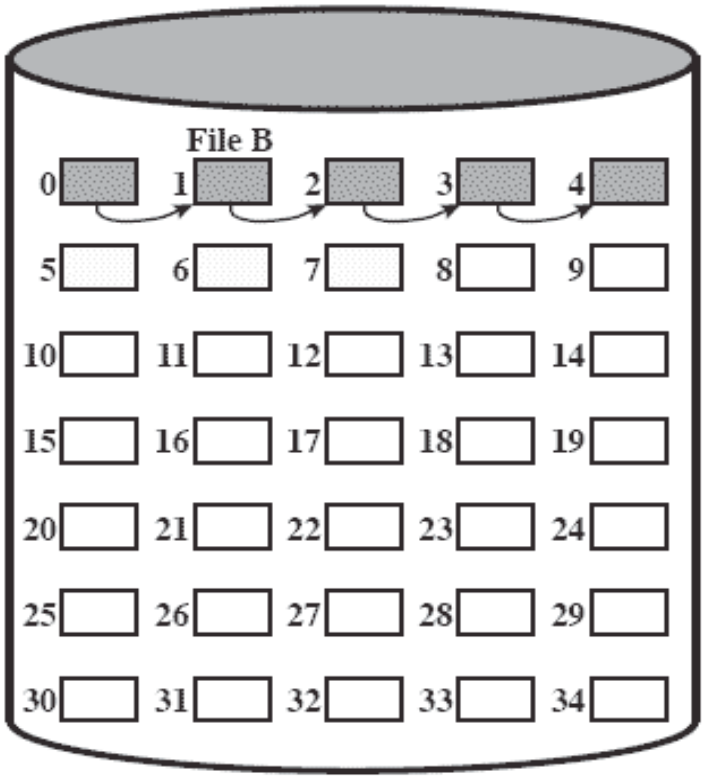


File Allocation Table

File Name	Start Block	Length
• • •	• • •	• • •
File B	1	5
• • •	• • •	• • •

Figure 12.9 Chained Allocation

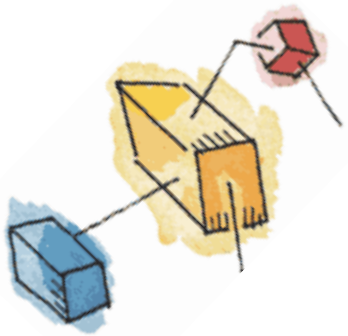
Chained Allocation



File Allocation Table

File Name	Start Block	Length
• • •	• • •	• • •
File B	0	5
• • •	• • •	• • •

Figure 12.10 Chained Allocation (After Consolidation)



Indexed Allocation

- File allocation table contains a separate one -level index for each file
- The index has one entry for each portion allocated to the file
- The file allocation table contains block number for the index

Indexed Allocation

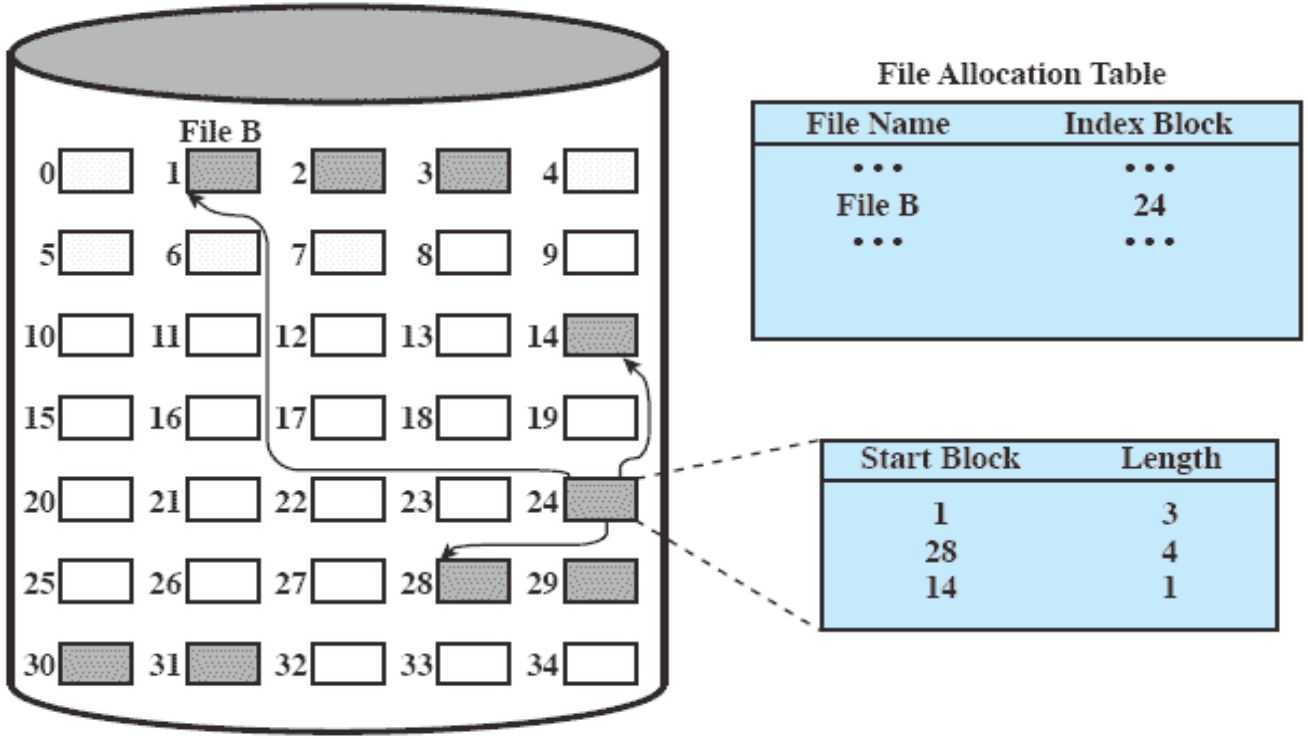
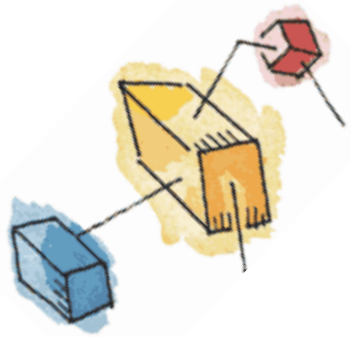


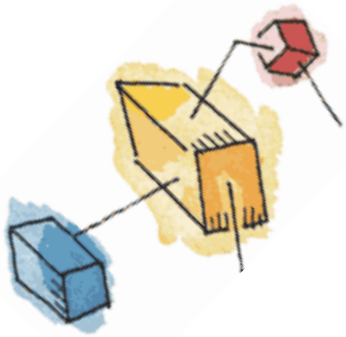
Figure 12.12 Indexed Allocation with Variable-Length Portions



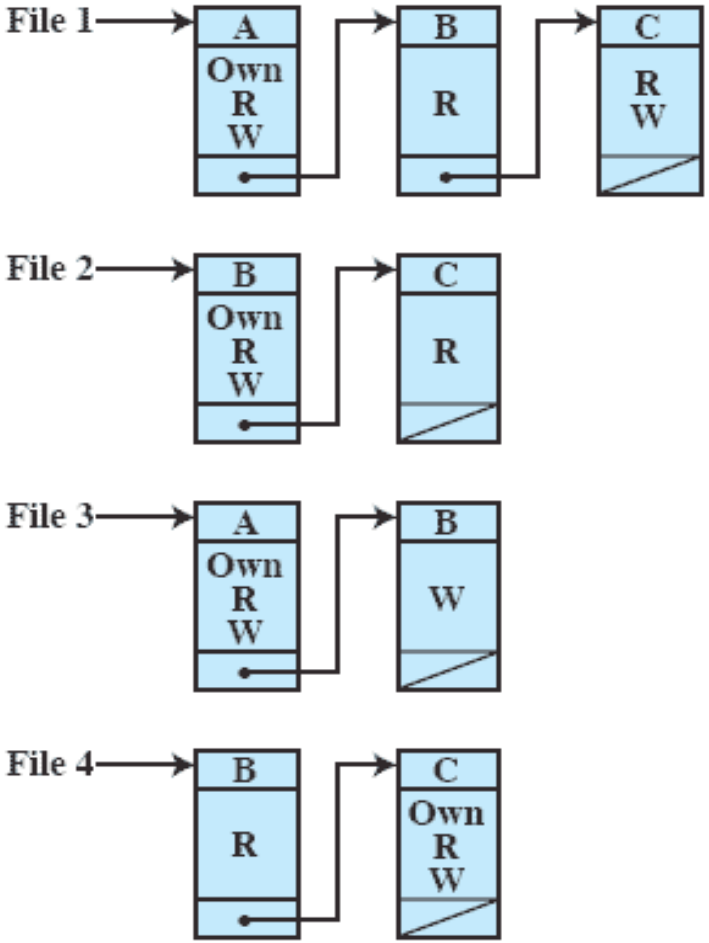
Access Matrix

	File 1	File 2	File 3	File 4	Account 1	Account 2
User A	Own R W		Own R W		Inquiry Credit	
User B	R	Own R W	W	R	Inquiry Debit	Inquiry Credit
User C	R W	R		Own R W		Inquiry Debit

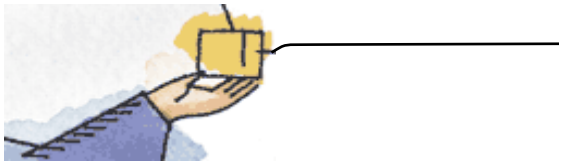
(a) Access matrix

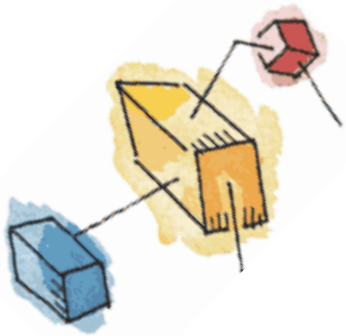


Access Control List

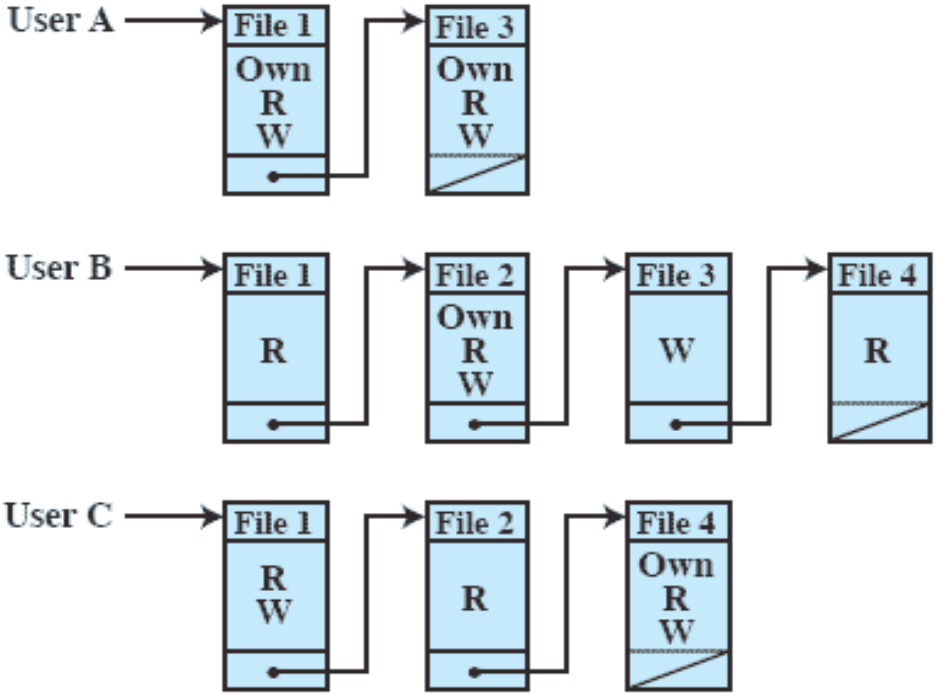


(b) Access control lists for files of part (a)





Capability Lists



(c) Capability lists for files of part (a)