File System Implementation

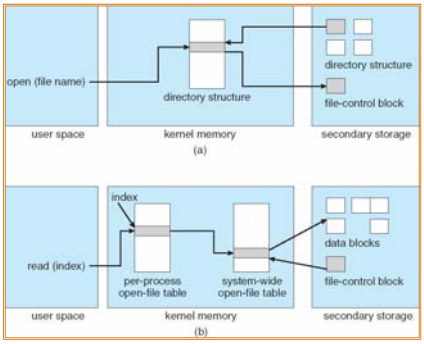
File-System Structure

- 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

A Typical File Control Block

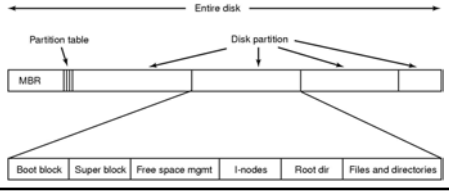
file permissions
file dates (create, access, write)
file owner, group, ACL
file size
file data blocks or pointers to file data blocks

In-Memory File System Structures



File System Layout

- File System is stored on disks
  - Disk is divided into 1 or more partitions
  - Sector 0 of disk called Master Boot Record
  - End of MBR has partition table (start & end address of partitions)
- First block of each partition has boot block
  - Loaded by MBR and executed on boot



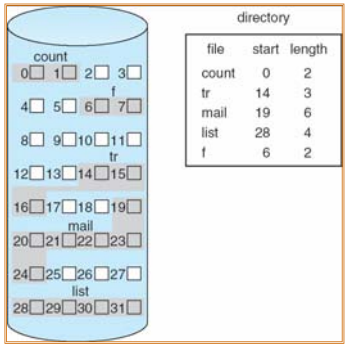
Allocation Methods

- An allocation method refers to how disk blocks are allocated for files:
- **Contiguous allocation**
- **Linked allocation**
- **Indexed allocation**

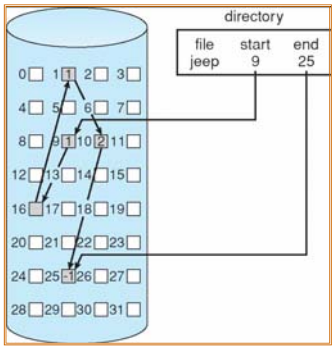
Contiguous Allocation

- 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

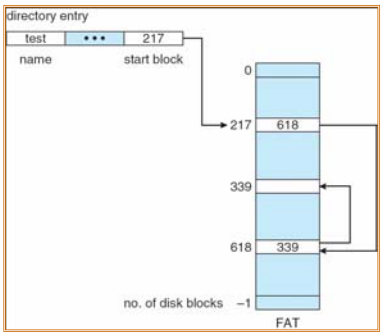
Contiguous Allocation of Disk Space



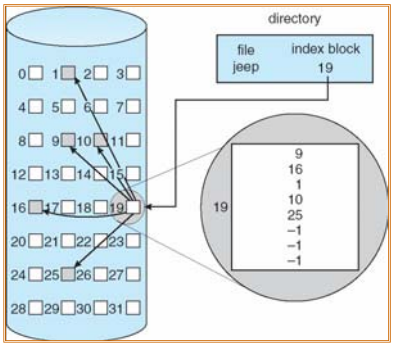
Linked Allocation



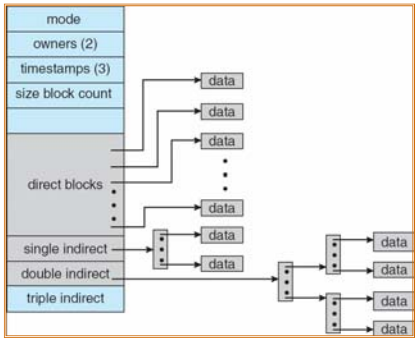
File-Allocation Table



Example of Indexed Allocation

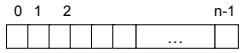


Combined Scheme: UNIX (4K bytes per block)



Free-Space Management

- Bit vector (*n* blocks)



bit[*i*] = { 0 ⇒ block[*i*] free
1 ⇒ block[*i*] occupied

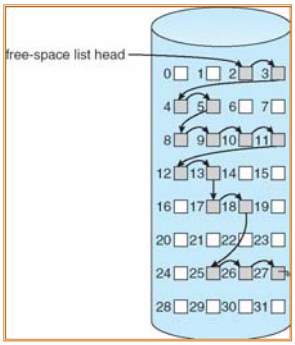
Block number calculation

(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
    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 (many links per block)
- Counting (aggregate continuous blocks)

Linked Free Space List on Disk



Directory Implementation

- Each directory is a file
- Linear list of file names with pointer to the data blocks
  - simple to program
  - time-consuming to execute
- Hash Table – linear list with hash data structure
  - decreases directory search time
  - **collisions** – situations where two file names hash to the same location
  - fixed size

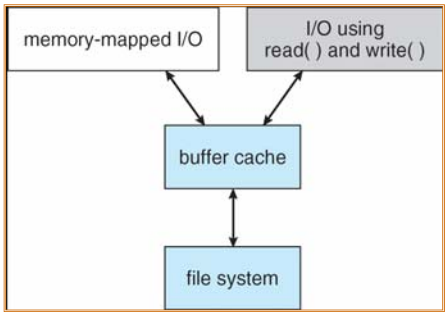
Efficiency and Performance

- Efficiency dependent on:
  - disk allocation and directory algorithms
  - types of data kept in file's directory entry
- Performance
  - disk cache – separate section of main memory for frequently used blocks
  - free-behind and read-ahead – techniques to optimize sequential access
  - improve PC performance by dedicating section of memory as virtual disk, or RAM disk

Page Cache

- A **page cache** caches pages rather than disk blocks using virtual memory techniques
- Memory-mapped I/O uses a page cache
- Routine I/O through the file system uses the buffer (disk) cache
- Sync, Async, flush

I/O Using a Unified Buffer Cache



Recovery

- Consistency checking – compares data in directory structure with data blocks on disk, and tries to fix inconsistencies
- Use system programs to **back up** data from disk to another storage device (floppy disk, magnetic tape, other magnetic disk, optical)
- Recover lost file or disk by **restoring** data from backup

Log Structured File Systems

- **Log structured** (or journaling) file systems record each update to the file system as a **transaction**
- All transactions are written to a **log**
  - A transaction is considered **committed** once it is written to the log
  - However, the file system may not yet be updated
- The transactions in the log are asynchronously written to the file system
  - When the file system is modified, the transaction is removed from the log
- If the file system crashes, all remaining transactions in the log must still be performed