Module 11: File-System Implementation

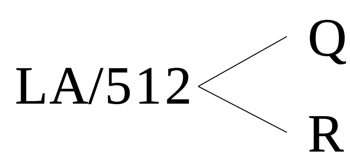
- File-System Structure
- Allocation Methods
- Free-Space Management
- Directory Implementation
- Efficiency and Performance
- Recovery

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.

Contiguous Allocation

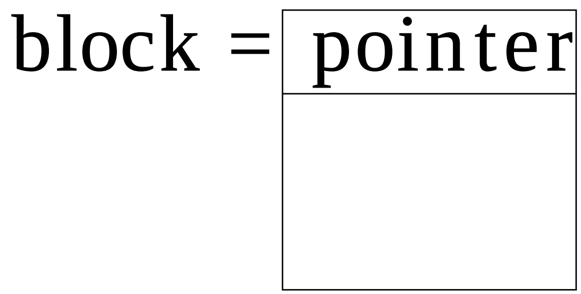
- Each file occupies a set of contiguous blocks on the disk.
- Simple – only starting location (block #) and length (number of blocks) are required.
- Random access.
- Wasteful of space (dynamic storage-allocation problem).
- Files cannot grow.
- Mapping from logical to physical.



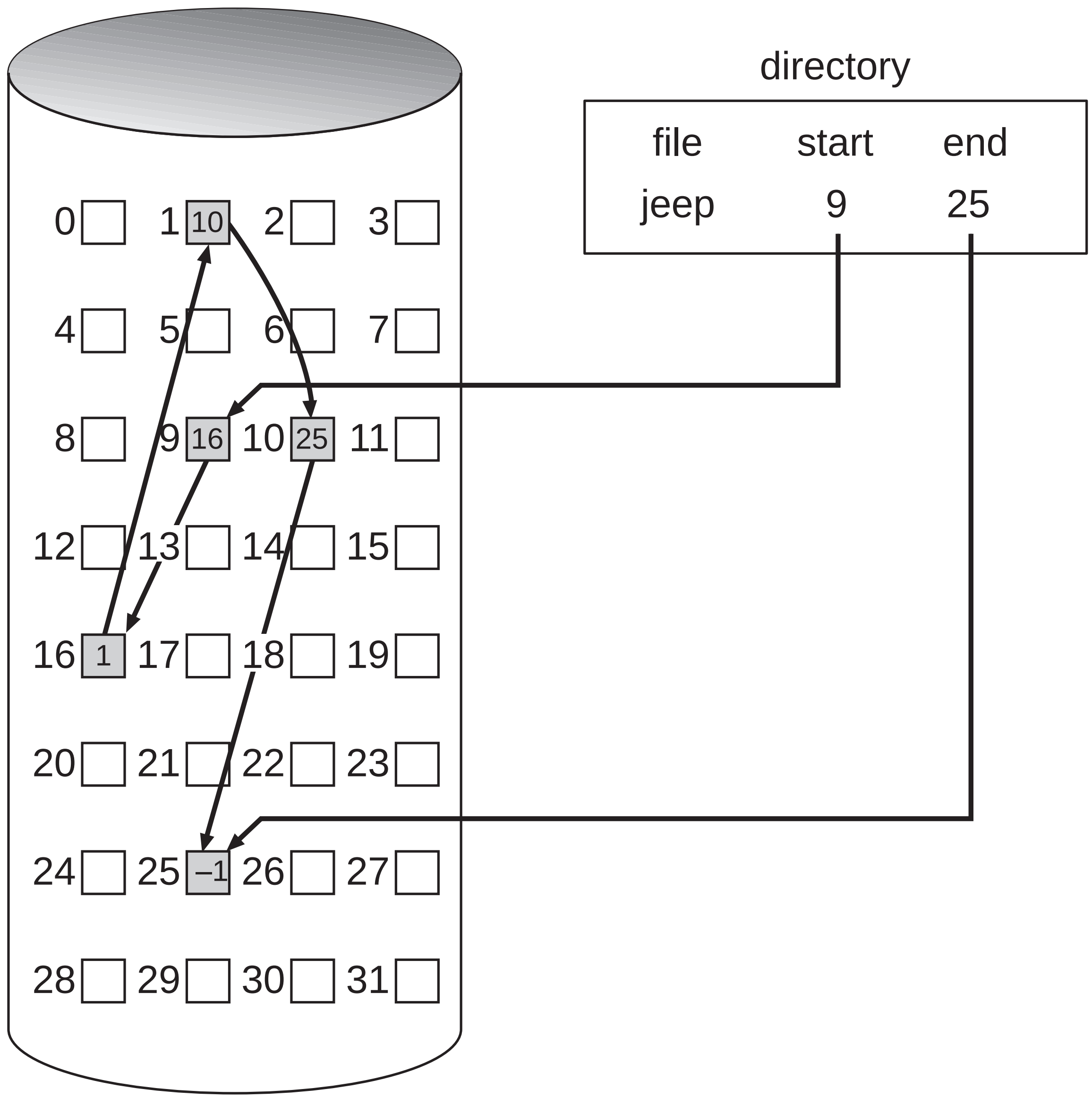
  - Block to be accessed = Q + starting address
  - Displacement into block = R

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.)

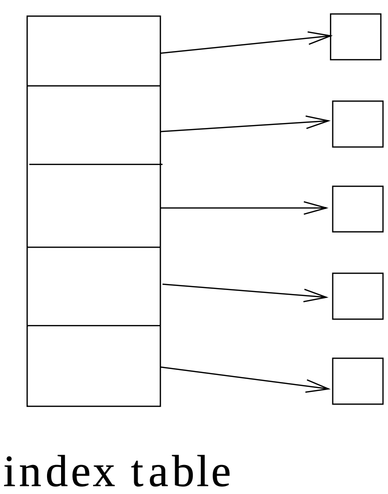
- Simple – need only starting address
- Free-space management system – no waste of space
- No random access
- Mapping

  LA/511 ⟨ Q, R

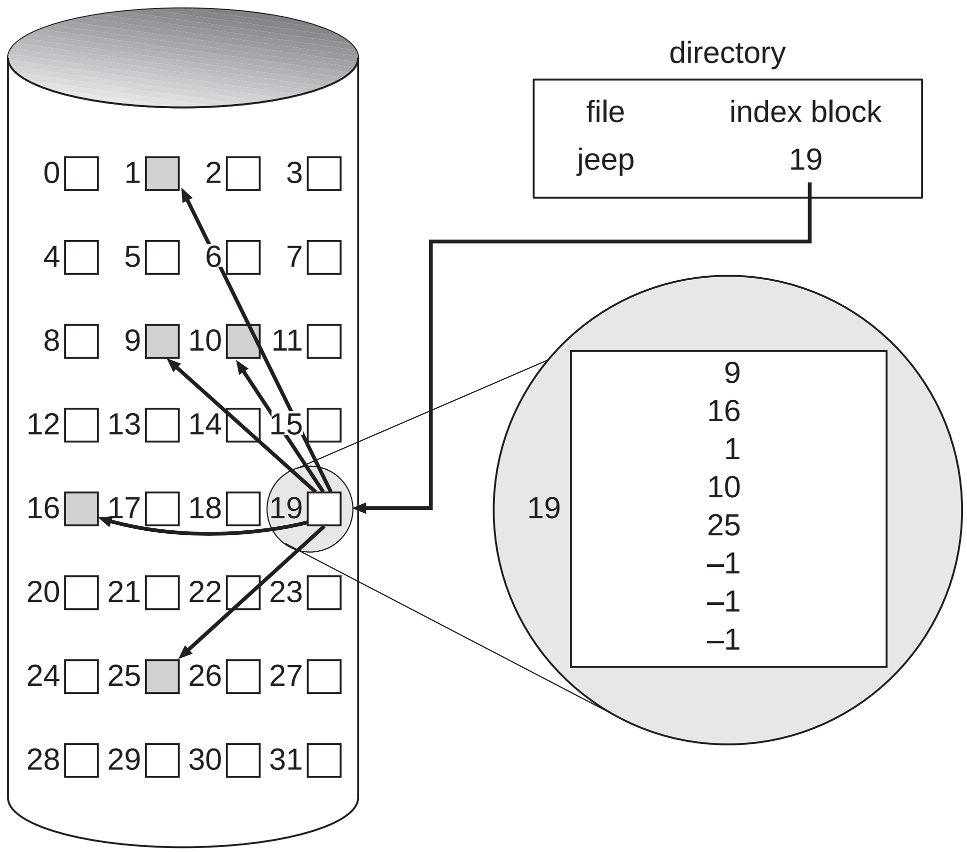
  - Block to be accessed is the Qth block in the linked chain of blocks representing the file.
  - Displacement into block = R + 1
- *File-allocation table (*FAT*)* – disk-space allocation used by MS-DOS and OS/2.

Indexed Allocation

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

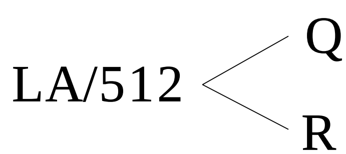


Example of Indexed Allocation



Indexed Allocation (Cont.)

- Need index table
- Random access
- Dynamic access without external fragmentation, but have overhead of index block.
- Mapping from logical to physical in a file of maximum size of 256K words and block size of 512 words. We need only 1 block for index table.



  - *Q* = displacement into index table
  - *R* = displacement into block

Indexed Allocation – Mapping (Cont.)

- Mapping from logical to physical in a file of unbounded length (block size of 512 words).
- Linked scheme – Link blocks of index tables (no limit on size).

$$LA/(512 \times 511) \rightarrow Q_1, \; R_1$$

  - Q_1 = block of index table
  - R_1 is used as follows:

$$R_1/512 \rightarrow Q_2, \; R_2$$

  - Q_2 = displacement into block of index table
  - R_2 = displacement into block of file

Indexed Allocation – Mapping (Cont.)

- Two-level index (maximum file size is 512^3)

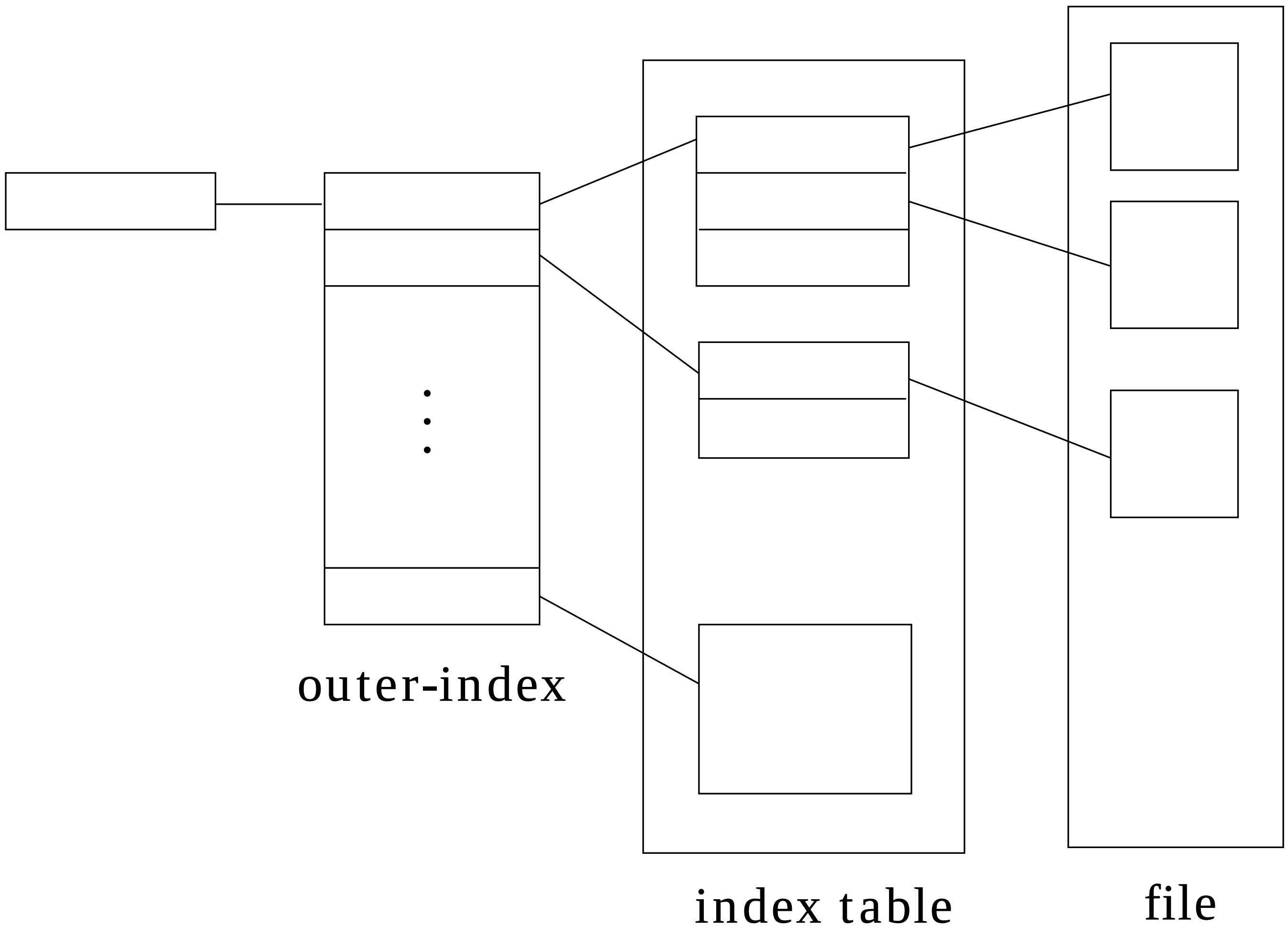
$$LA/(512 \times 512) \left\langle \begin{array}{l} Q_1 \\ R_1 \end{array} \right.$$

  - Q_1 = displacement into outer-index
  - R_1 is used as follows:

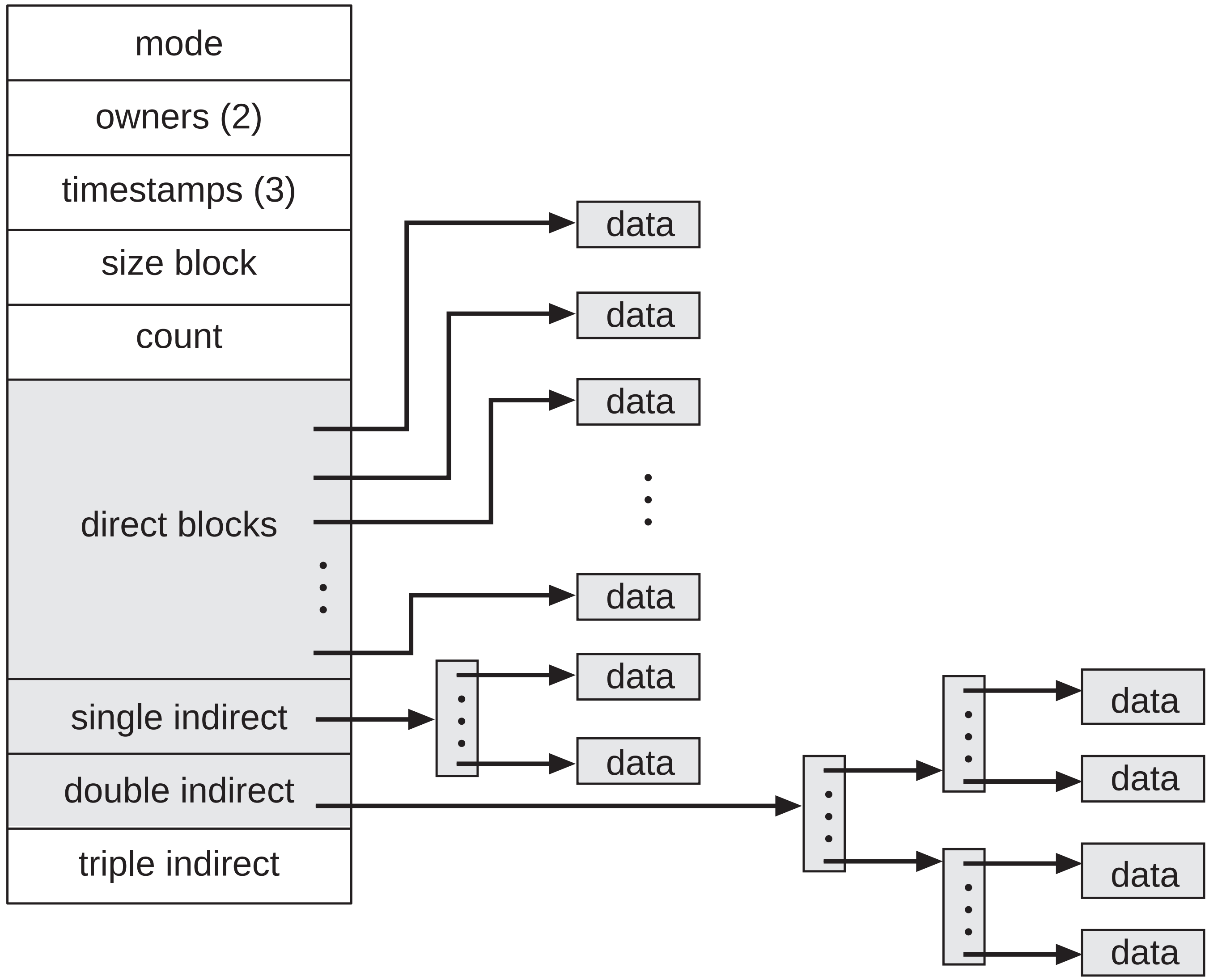
$$R_1/512 \left\langle \begin{array}{l} Q_2 \\ R_2 \end{array} \right.$$

  - Q_2 = displacement into block of index table
  - R_2 = displacement into block of file

Indexed Allocation – Mapping (Cont.)

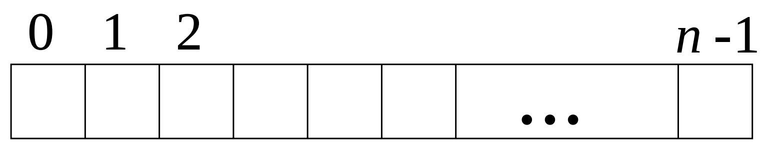


Combined Scheme: UNIX (4K bytes per block)



Free-Space Management

- Bit vector (*n* blocks)



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

- 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
  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

Free-Space Management (Cont.)

- Need to protect:
  - Pointer to free list
  - Bit map
    - ∗ Must be kept on disk.
    - ∗ Copy in memory and disk may differ.
    - ∗ Cannot allow for block[*i*] to have a situation where bit[*i*] = 1 in memory and bit[*i*] = 0 on disk.
  - Solution:
    - ∗ Set bit[*i*] = 1 in disk.
    - ∗ Allocate block[*i*].
    - ∗ Set bit[*i*] = 1 in memory.

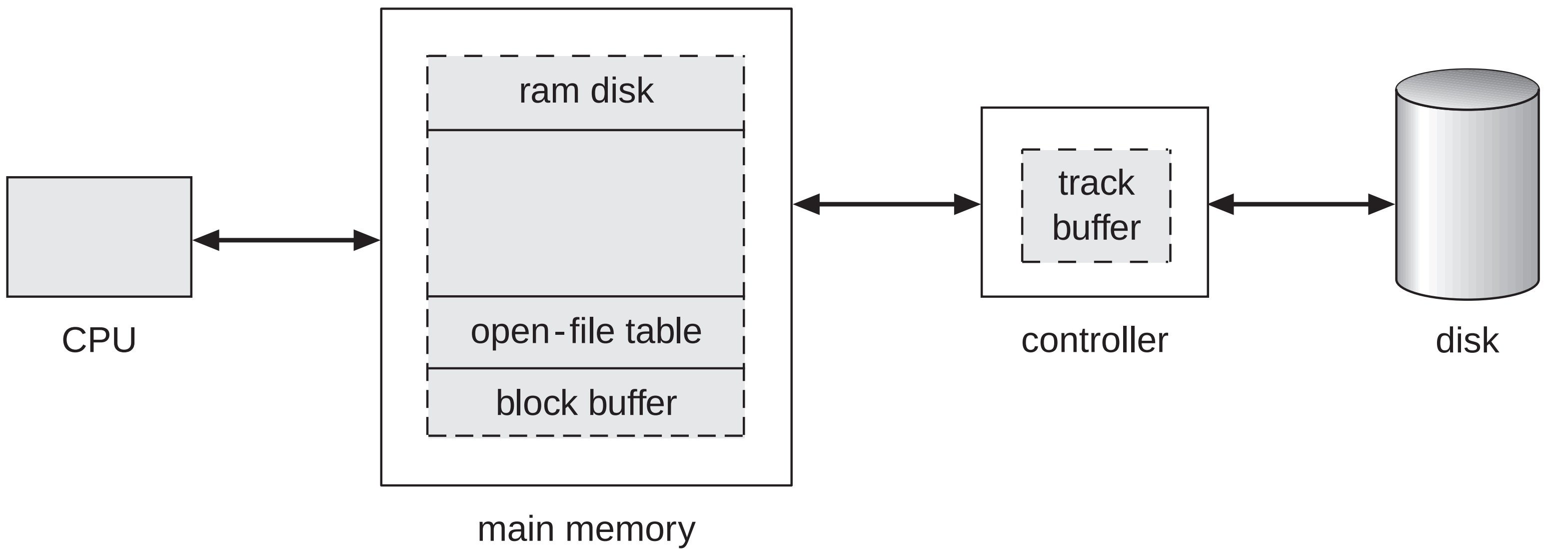
Directory Implementation

- Linear list of file names with pointers 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*

Various Disk-Caching Locations



Recovery

- Consistency checker – 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).
- Recover lost file or disk by *restoring* data from backup.