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Operating Systems

Lecture 10 ： File system implementation

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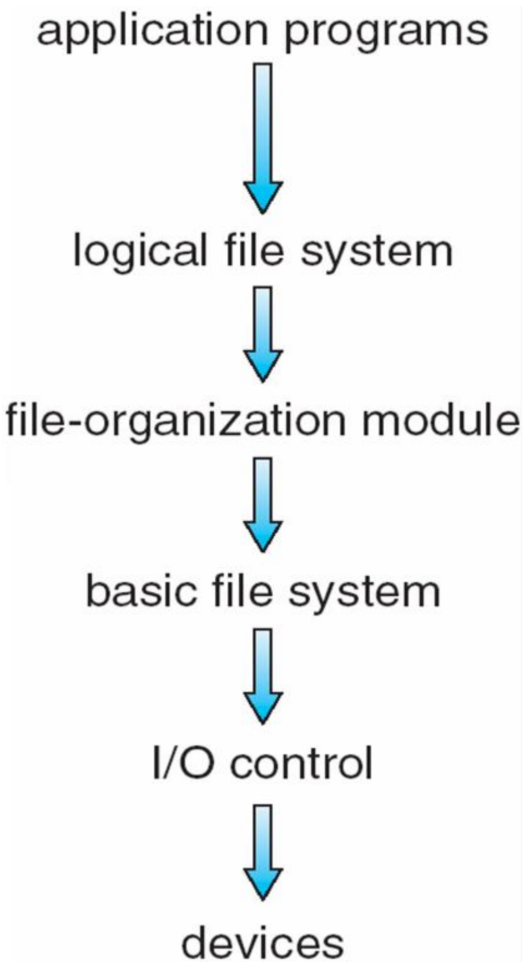
Catalog Description

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

File-System Structure

- File structure
  - Logical storage unit
  - Collection of related Information
- FS resides on secondary storage(disks)
  - Provides efficient and convenient access to disk by allowing data to be stored, located retrieved easily
- File system organized into layers
- File control block – storage structure consisting of information about a file

Layered File System



File name

Logical block address

Physical block address

Issue commands to I/O to retrieve physical block

Hardware-specific instructions

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FS Implementation

- Structures and operations used to implement file system operation, OS- & FS-dependent
  - On-disk structures
  - In-memory structures

FS Implementation

- On-disk structures
  - Boot control block: contains info needed by system to boot OS from that volume
    - ✓ To boot an OS from the partition (volume)
    - ✓ If empty, no OS is contained on the partition
  - Volume control block: contains volume details
  - Directory structure organizes the files
  - Per-file File Control Block (FCB) contains many details about the file

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

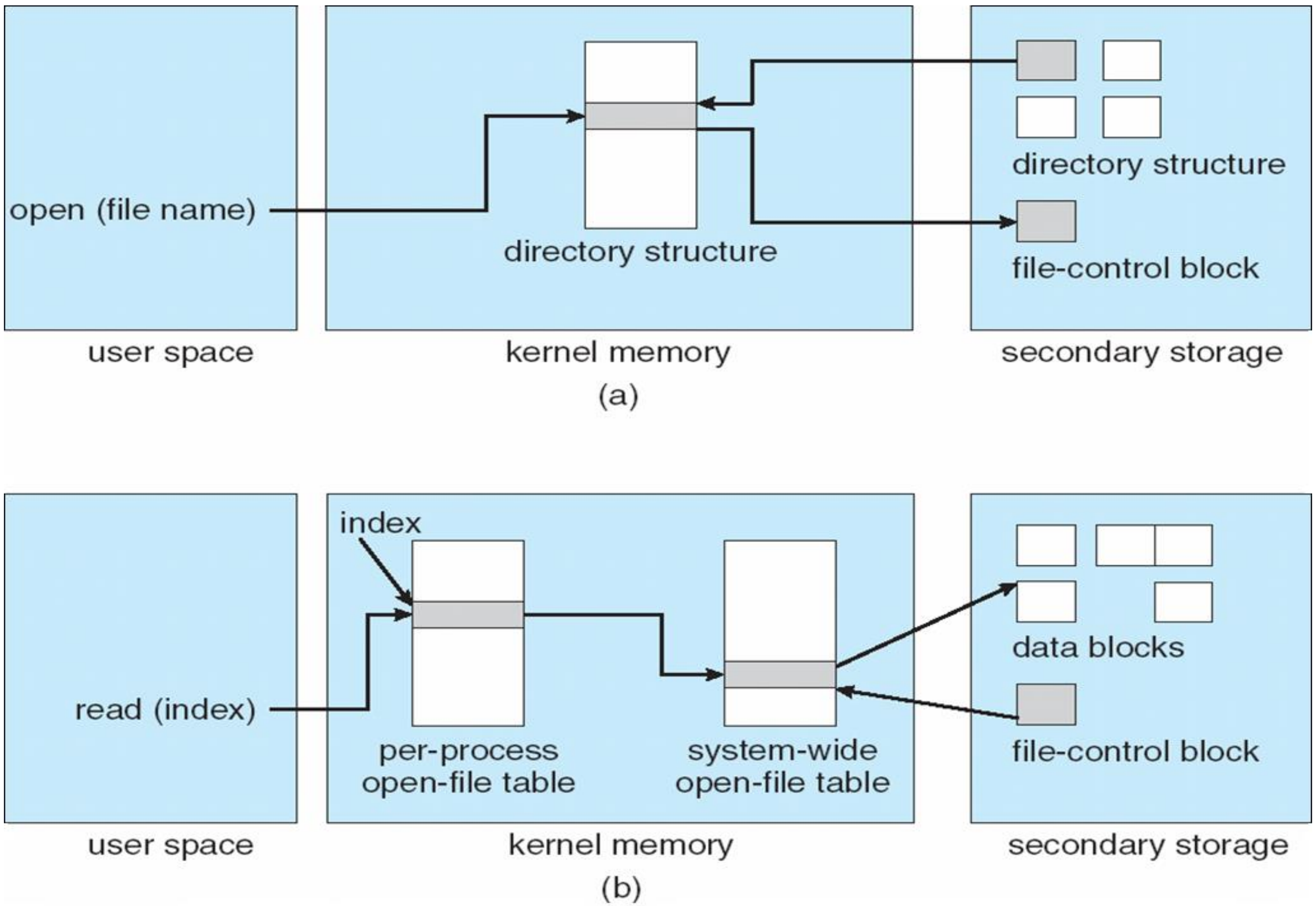
A typical file control block

FS Implementation

- In-memory structures: for both FS management and performance improvement via caching
  - Data are loaded at mount time and discarded at dismount
  - Structures include:
    - ✓ system-wide open-file table
    - ✓ per-process open-file table
    - ✓ …

- The following figure illustrates the necessary file system structures provided by the operating systems

In-Memory File System Structures



(a) refers to opening a file. (b) refers to reading a file.

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Directory Implementation

- 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

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Allocation Methods (分配方法)

- An allocation method refers to how disk blocks are allocated for files so that disk space is utilized effectively & files can be accessed quickly
  - Contiguous allocation (连续分配)
  - Linked allocation (链接分配)
  - Indexed allocation (索引分配)
  - Combined (组合方式)

Contiguous Allocation (连续分配)

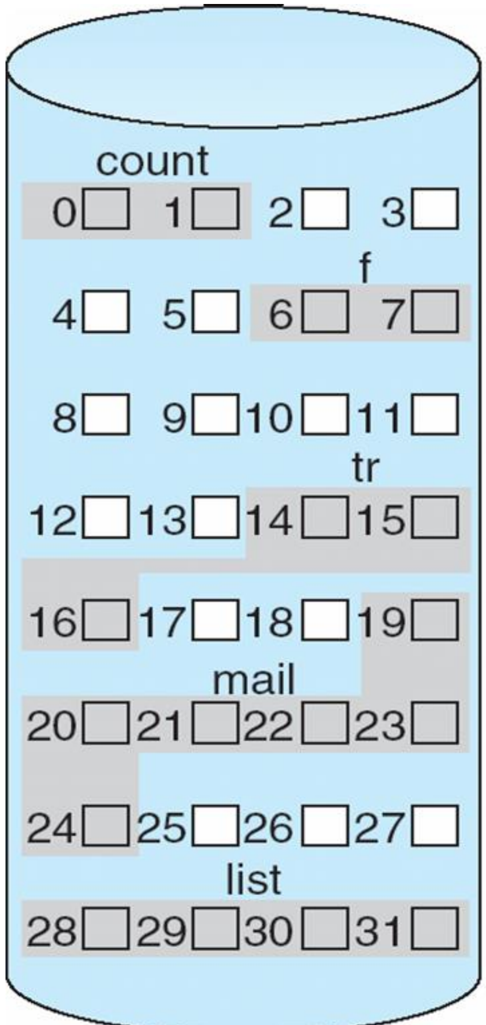
- Each file occupies a set of contiguous blocks on the disk
- Simple – directory entry only need
  - starting location (block #)
  - & length (number of blocks)
- Mapping from logical to physical

  LogicalAddress/512 = Q. . . . . . R

  Block to be accessed = Q + starting address

  Displacement into block = R

Contiguous Allocation of Disk Space



directory

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

Contiguous Allocation (连续分配)

- Advantages:
  - Support both random & sequential access
    - ✓ Start block: b;
      Logical block number: i
      ⇒physical block number: b + i
    - ✓ Fast access speed, because of short head movement
- Disadvantages:
  - External fragmentation
    - ✓ Wasteful of space (dynamic storage-allocation problem).
    - ✓ Files cannot grow,
      or File size must be known in advance.

Contiguous Allocation (连续分配)

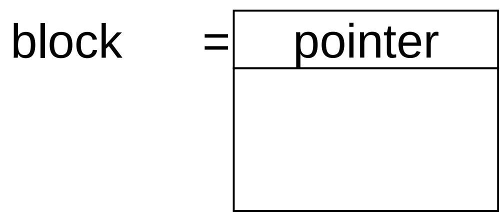
- Extent-Based Systems
  - Many newer file systems (I.e.Veritas File System) use a modified contiguous allocation scheme
  - Extent-based file systems allocate disk blocks in extents
  - An extent is a contiguous block of disks
    - ✓ Extents are allocated for file allocation
    - ✓ A file consists of one or more extents.

Linked Allocation（链接分配）

- Each file is a linked list of disk blocks: blocks may be scattered anywhere on the disk.
- Two types
  - Implicit (隐式链接)
  - Explicit (显式链接)

Linked Allocation（链接分配)

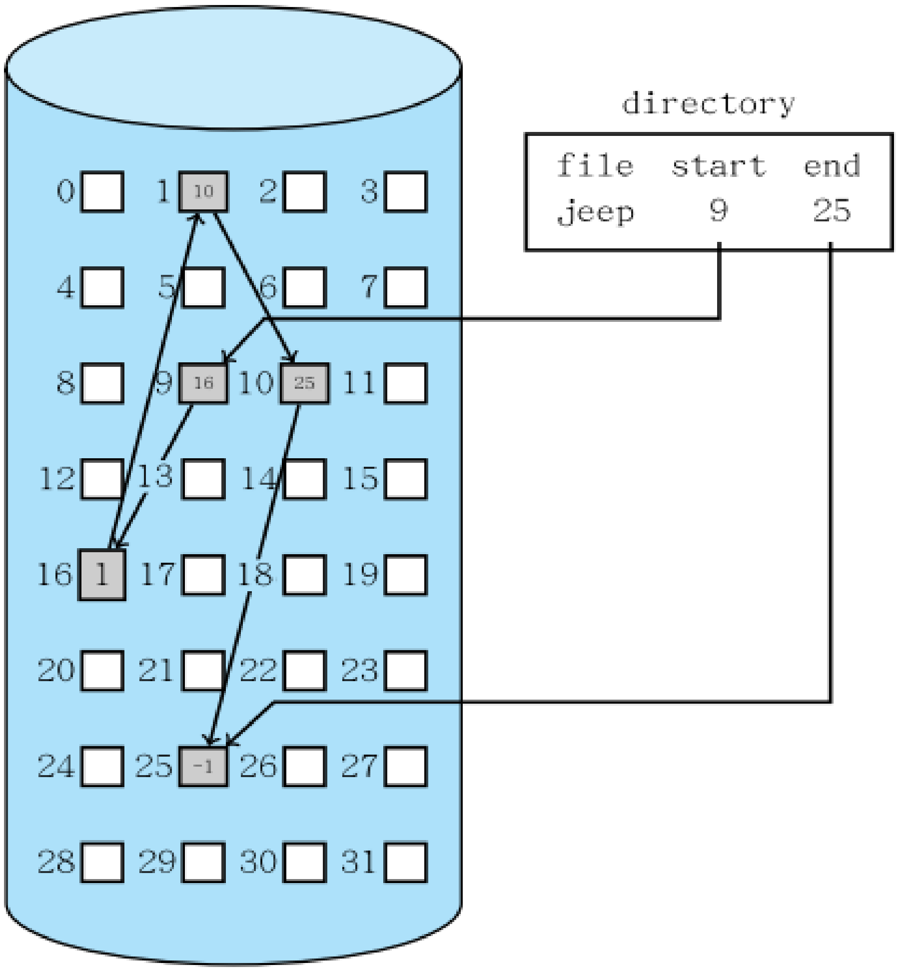
- Implicit (隐式链接)
  - Directory contains a pointer to the first
  - block & last block of the file.
  - Each block contains a pointer to the next block.



  - Allocate as needed, link together
    ✓ Simple -- need only starting address
    ✓ Free-space management system -- no waste of space

Linked Allocation（链接分配)

- Implicit (隐式链接)



Linked Allocation（链接分配)

- Implicit (隐式链接)
  - Disadvantage:
    - ✓ No random access
    - ✓ Link pointers need disk space

      E.g.: 512 per block, 4 per pointer ⇒0.78%

      Solution: clusters

      ⇒ disk throughput ↑

      But internal fragmentation↑

Linked Allocation（链接分配）

- Implicit (隐式链接)
  - Mapping:

    Suppose

    ✓ block size=512B,

    ✓ block pointer size=1B, using the first byte of a block

    ✓ Logical addr in the file to be accessed = A

    we have

    ✓ Data size for each block = 512 – 1 = 511

    ✓ A/511 = Q . . . . . . R

    then

    ✓ Block to be accessed is the Qth block in the linked chain of blocks representing the file.

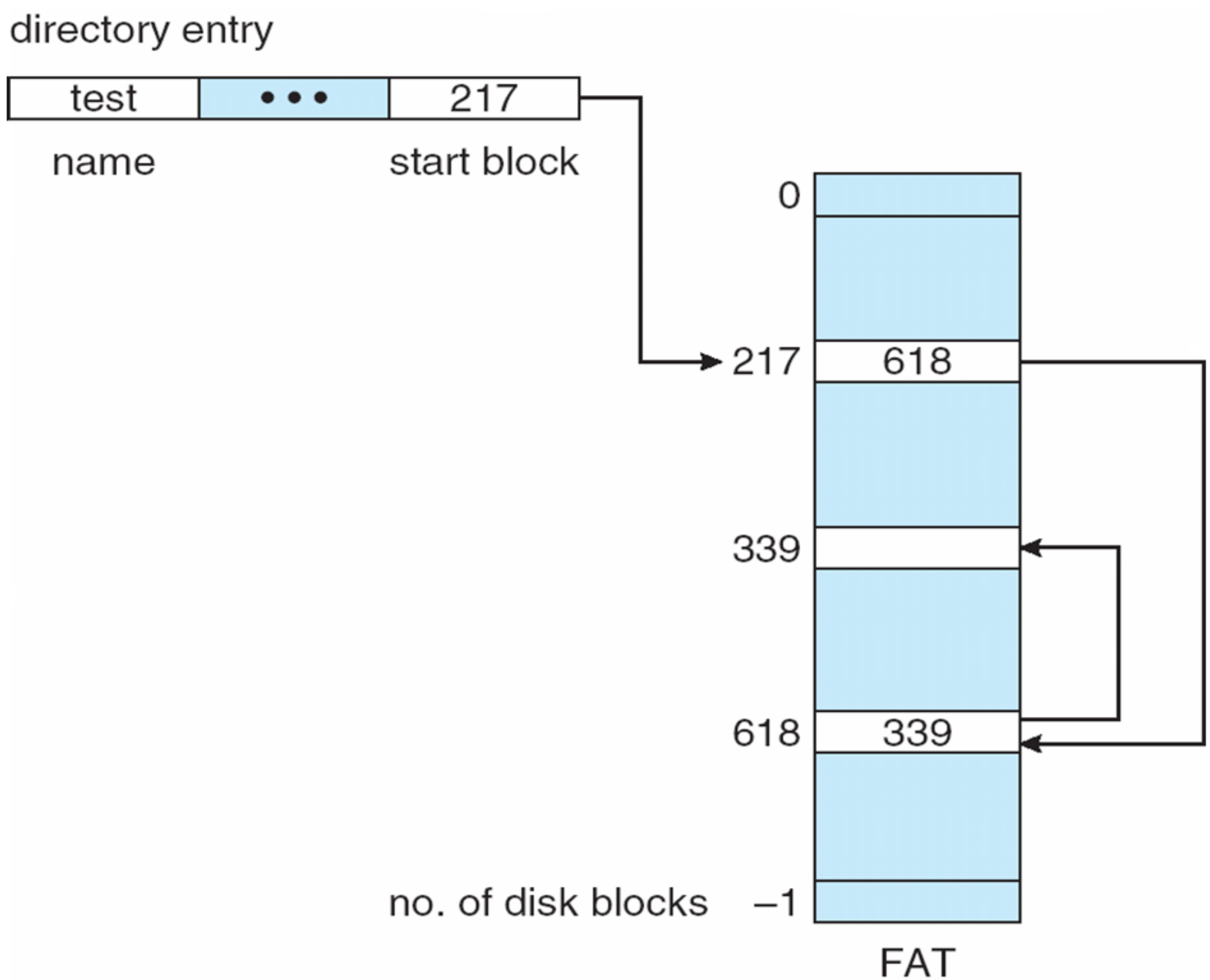
    ✓ Displacement into block = R + 1

Linked Allocation（链接分配)

- Explicit linked allocation:
  - File Allocation table, FAT
  - A section of disk at the beginning of each partition is set aside to contain the FAT
    - ✓ Each disk block one entry
    - ✓ The entry contains
      (1) the index of the next block in the file
      (2) end-of-file, for the last block entry
      (3) 0, for unused block
  - Directory entry contains the first block number

Linked Allocation（链接分配）

- File-Allocation Table



Linked Allocation（链接分配）

- Explicit linked allocation:
  - Now support random access, but still not very efficient
  - May result in a significant disk head seeks.
    Solution: Cached FAT
  - How to compute FAT size?
    Suppose
    ✓ Disk space = 80 GB, Block size = 4 KB
    Then

    Total block number $= 80 \times 2^{30} / 2^{12} = 5 \times 2^{22}$

    $4 \times 2^{22} = 2^{24} < 5 \times 2^{22} < 8 \times 2^{22} = 2^{25}$

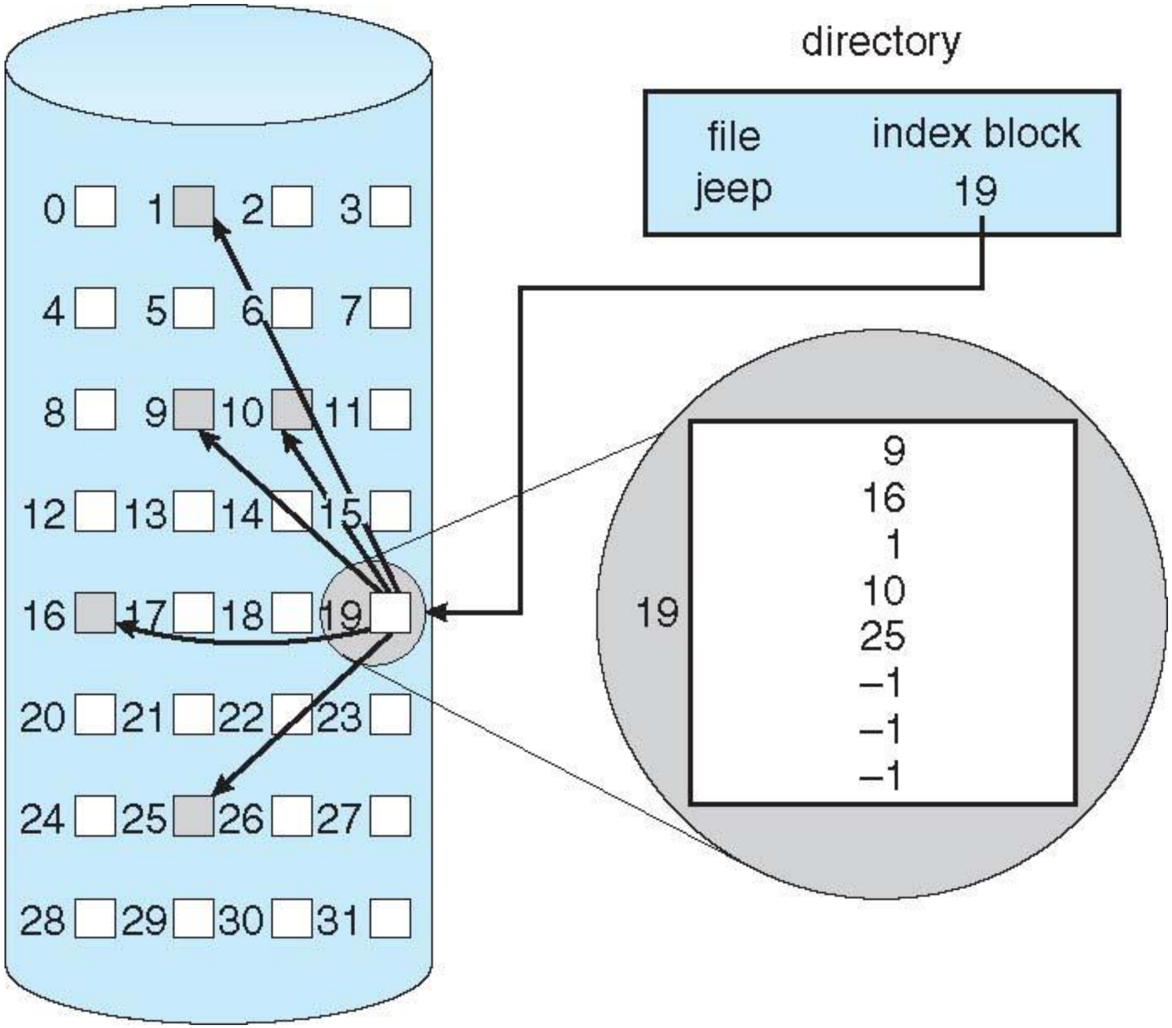
    ✓ Length of each FAT entry? (25bits? 28bits? 32bits?)
    ✓ Length of FAT?

    $(5 \times 2^{22} \times 4\text{B} = 80\text{MB} = 80\text{GB}/2^{10})$

Indexed Allocation（索引分配)

- Indexed Allocation (索引分配):Brings all pointers together into one location -- the index block.
- Advantage:
  - Random access
  - Dynamic access without external fragmentation
- Disadvantage:
  - have overhead of index block.
  - File size limitation, since one index block can contains limited pointers

Example of Indexed Allocation



Indexed Allocation（索引分配）

- Mapping from logical to physical
- Suppose

  (1) Block size = 1KB

  (2) Index size = 4B

  Then for logical address LA, we have LA/1K = Q…R

  (3) Q = the index of the pointer

  (4) R = displacement into block

  We also have Max file size = $2^{10}/4 \times 1KB = 256KB$

Indexed Allocation（索引分配）

- How to support a file of unbounded length?
  - multi-level index scheme

Indexed Allocation（索引分配）

- multi-level index scheme
  - Link blocks of index table (no limit on size).
  - Mapping

    Suppose

    (1) Block size=1KB

    (2) Index or link pointer size = 4B
  - Example: Two-level index (maximum file size is?)

    We have

    $$LA / (1K \times 1K/4) = Q1 \ldots R1$$

    (1) Q1 = index into outer-index

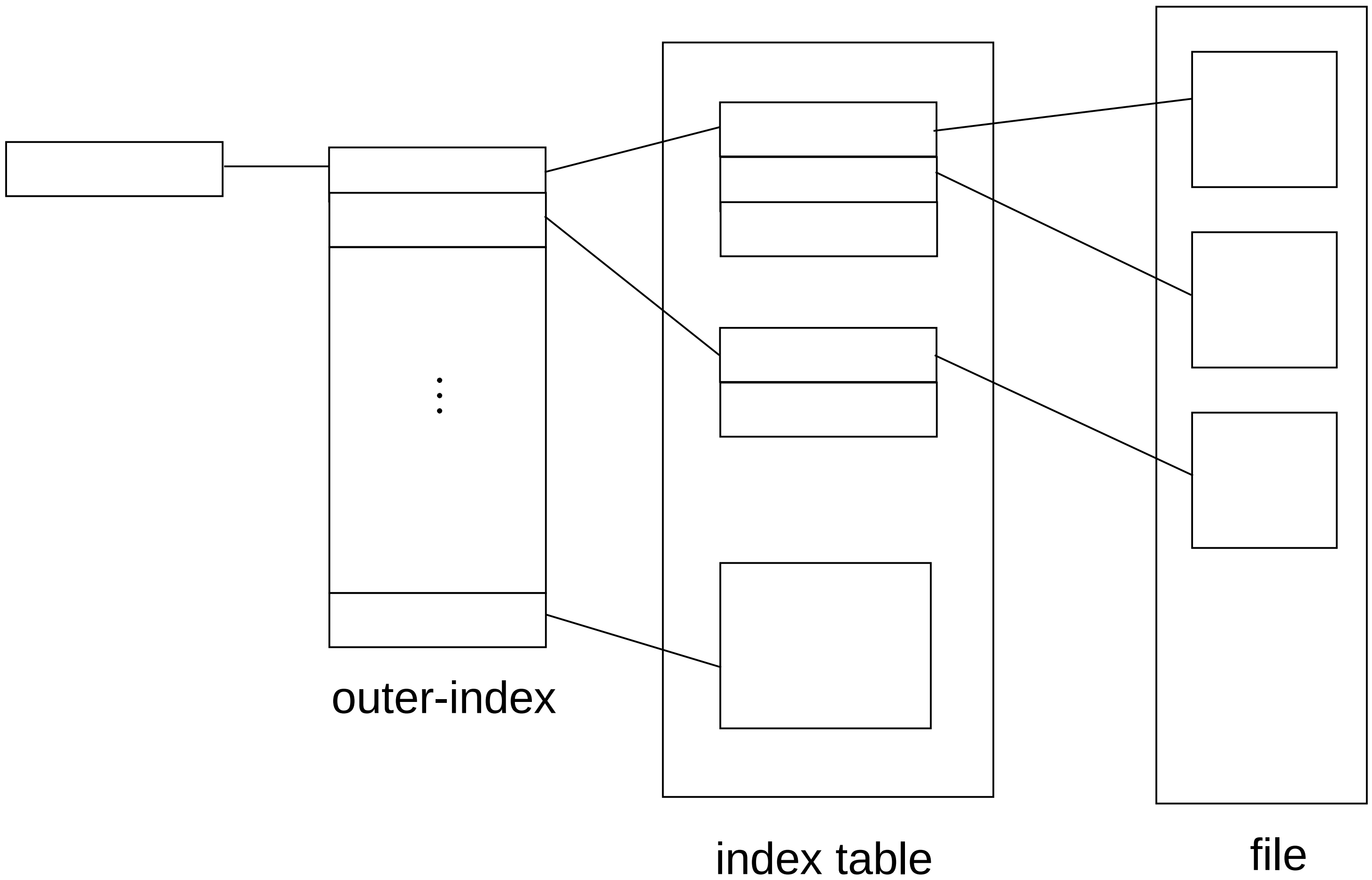
    (2) R1 is used as follows:

    $$R1 / 1KB = Q2 \ldots R2$$

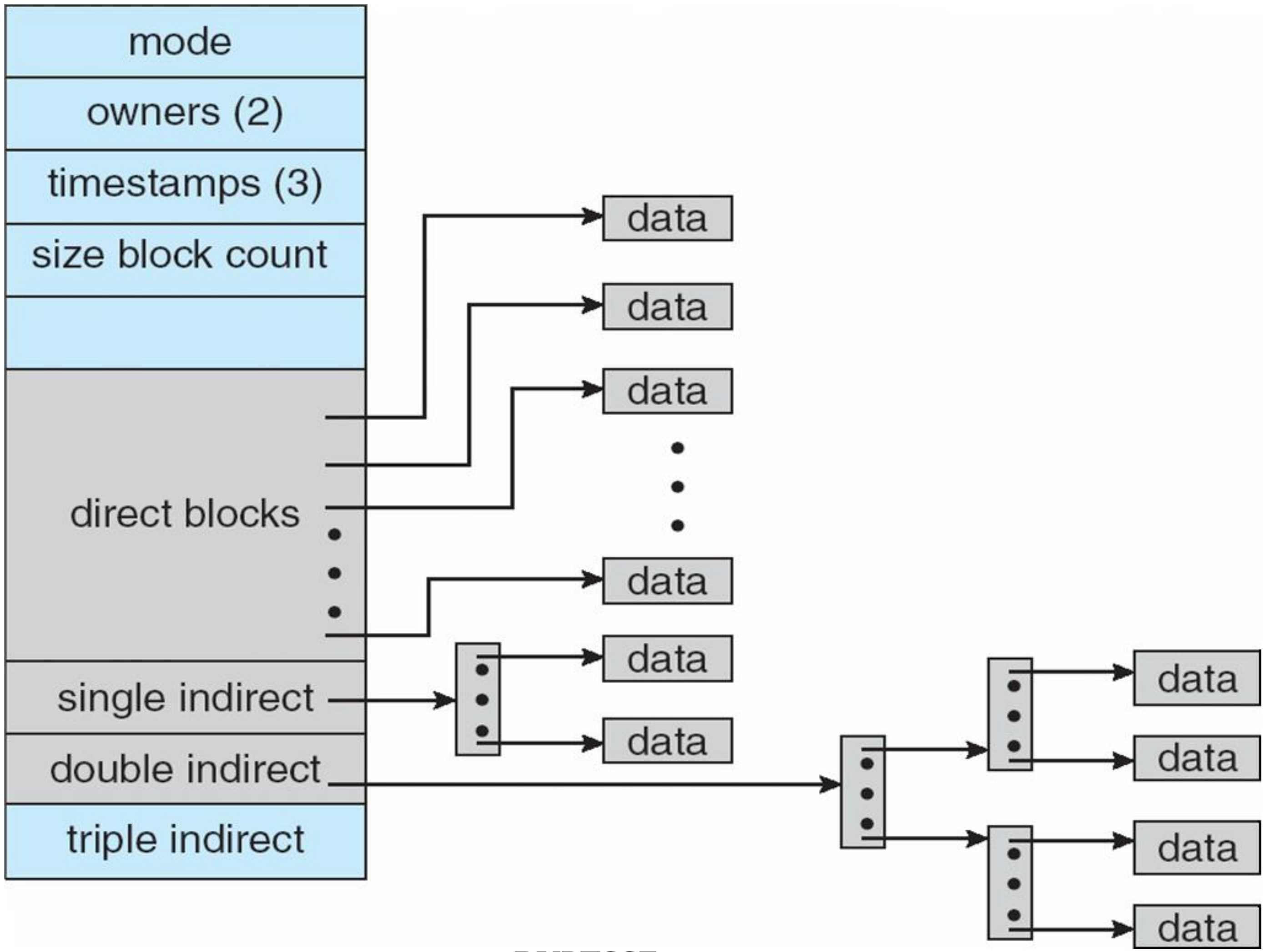
    (3) Q2 = displacement into block of index table

    (4) R2 = displacement into block of file

Indexed Allocation – Mapping



Combined Scheme (组合方式): UNIX (4K bytes per block)



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Free-Space Management

- Disk Space: limited
- Free space management: To keep track of free disk space
- Algorithms
  - Bit vector
  - Linked list
  - Counting

Free-Space Management

- Bit vector
  - Free-space list is implemented as a bit map or bit vector
    - ✓ 1 bit for each block

      1=free;

      0=allocated
    - ✓ Example:

a disk where blocks 2,3,4,5,8,9,10,11,12,13,17,18,25,26,27 are free and the rest blocks are allocated. The bitmap would be

0011 1100 1111 1100 0110 0000 0111 0000 0…

✓ Bit map length.

For n blocks, if the base unit is word, and the size of word is 16 bits, then bit map length = (n + 15)/16

U16 bitMap[bitMaptLength];

Free-Space Management

- Bit vector
  - How to find the first free block or n consecutive free blocks on the disk?
    - ✓ To find the first free block:

      Suppose: base unit = word (16 bits) or other

      (1) find the first non-0 word

      (2) find the first 1 bit in the first non-0 word
    - ✓ If first K words is 0, & (K + 1)th word > 0, the first (K + 1)th word's first 1 bit has offset L, then

      first free block number $N = K \times 16 + L$

Free-Space Management

- Bit vector
  - Simple
  - Must be kept on disk

    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

Free-Space Management

- Bit vector
  - Efficient to get the first free block or n consecutive free blocks, if we can always store the vector in memory.
    - ✓ But copy in memory and disk may differ.
      E.g. bit[i] = 1 in memory & bit[i] = 0 on disk
    - ✓ Solution:
      Set bit[i] = 1 in memory.
      Allocate block[i]
      Set bit[i] = 1 in disk

Free-Space Management

- Linked Free Space List on Disk
  - Link together all the free disk blocks
    - ✓ First free block
    - ✓ Next pointer
  - Cannot get contiguous space easily
  - No waste of space

Free-Space Management

- Counting
  - Assume:

    Several contiguous blocks may be allocated or freed simultaneously
  - Each = first free block number & a counter (number of free blocks)
  - Shorter than linked list at most time, generally counter ＞ 1

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Efficiency (空间)

- Efficiency in usage of disk space dependent on:
  - Disk allocation and directory algorithms
  - Various approaches
    - ✓ Variable cluster size
    - ✓ Types of data kept in file's directory entry
    - ✓ Large pointers provides larger file length, but cost more disk space

Performance (时间)

- Performance: other ways
  - disk cache – on disk controllers, large enough to store entire tracks at a time.
  - buffer 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

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Recovery

- Consistency checking (一致性检查)
  - compares data in directory structure with data blocks on disk, and tries to fix inconsistencies
  - UNIX: fsck
  - MS-DOS: chkdsk
- Backup & restore
  - 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
  - A typical backup schedule may be:

    Day1: full backup;

    Day2: incremental backup;

    ...

    DayN: incremental backup. Then go back to Day1.