File Systems

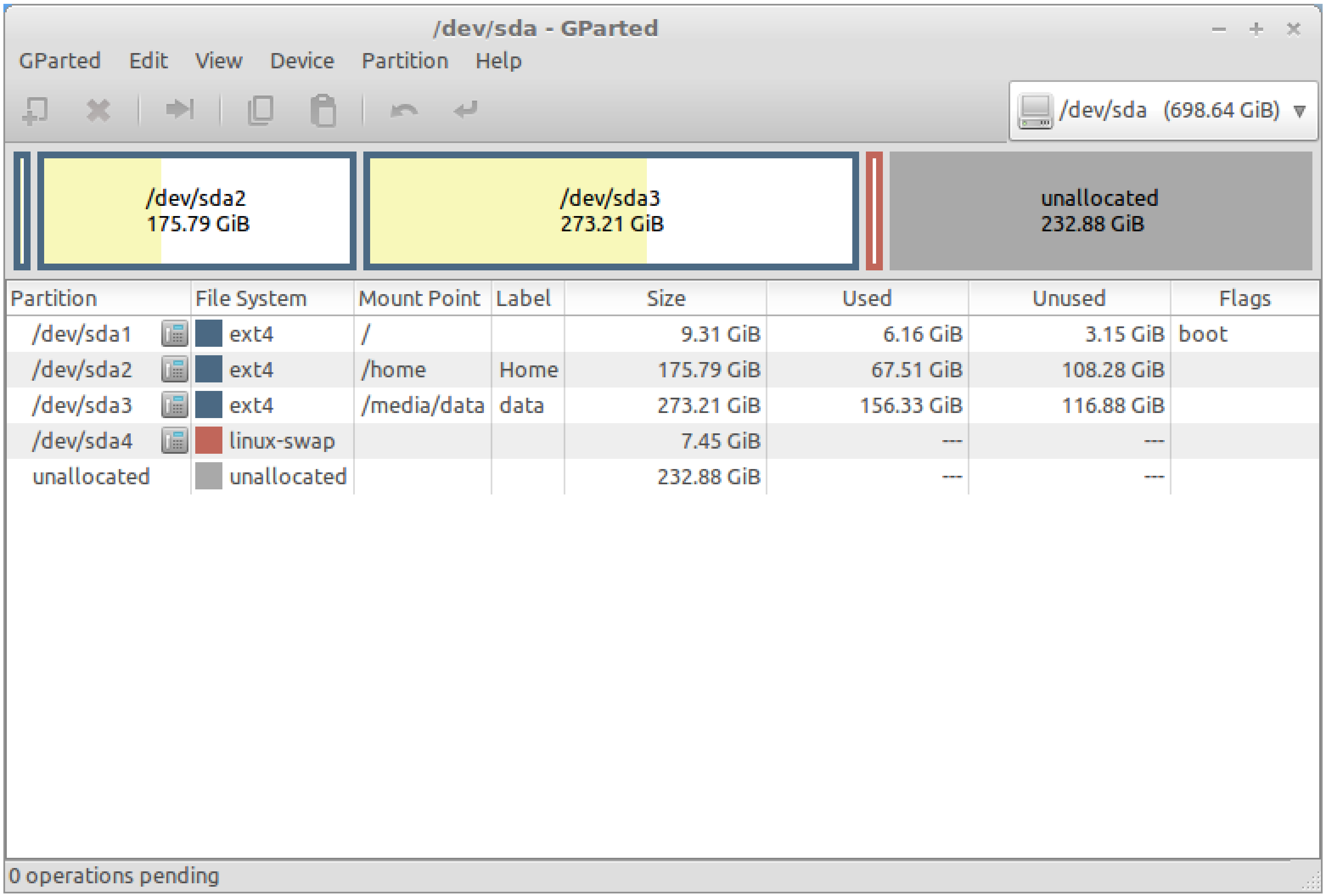
File System Layout

- Filesystem refer to an entire hierarchy of directories, or directory tree, that is used to organize files on a computer system.
- File systems usually are stored on disks
- Most disks can be divided up into partitions
  - Independent file systems on each partition
- Sector 0 of the disk is the Master Boot Record (MBR)
  - By the way a sector is a disk unit (more later)
- The end of the MBR contains the partition table
  - Gives the start and end of each partition
  - One of the partitions is marked as active

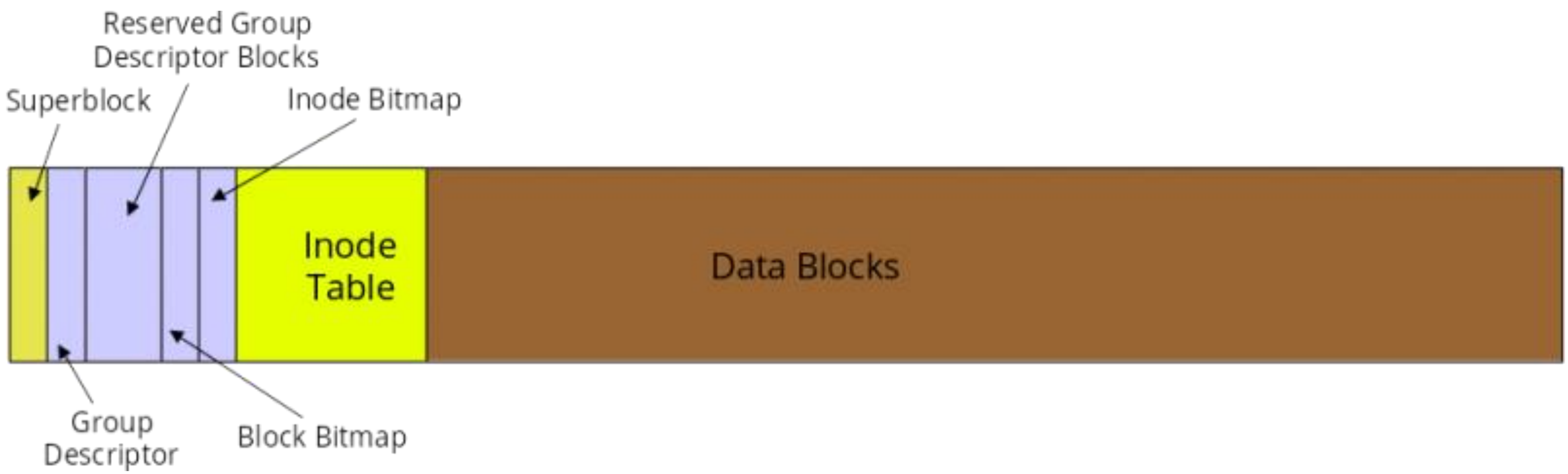
File System Layout

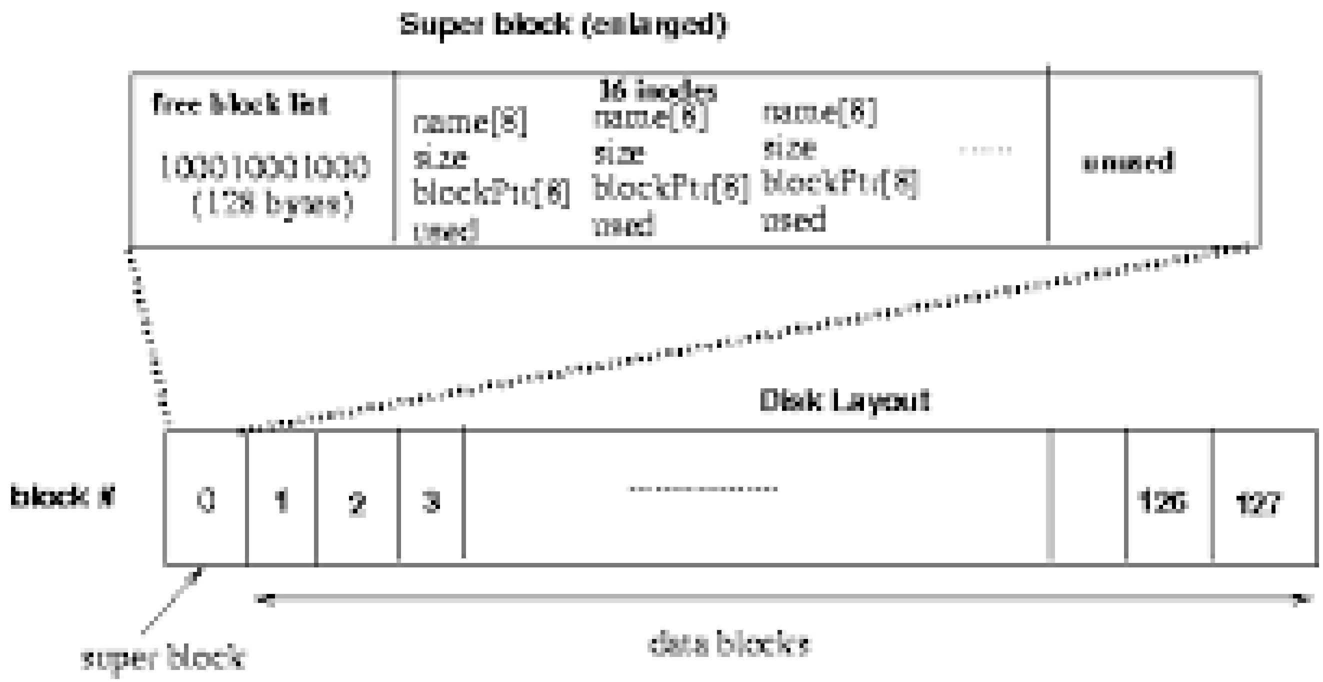
- The MBR program reads in and executes the code in the MBR
- This first thing that is determined is the active partition
  - The first block of the active partition is read in (boot block)
  - This program loads the OS contained in that partition

File System Layout-GParted

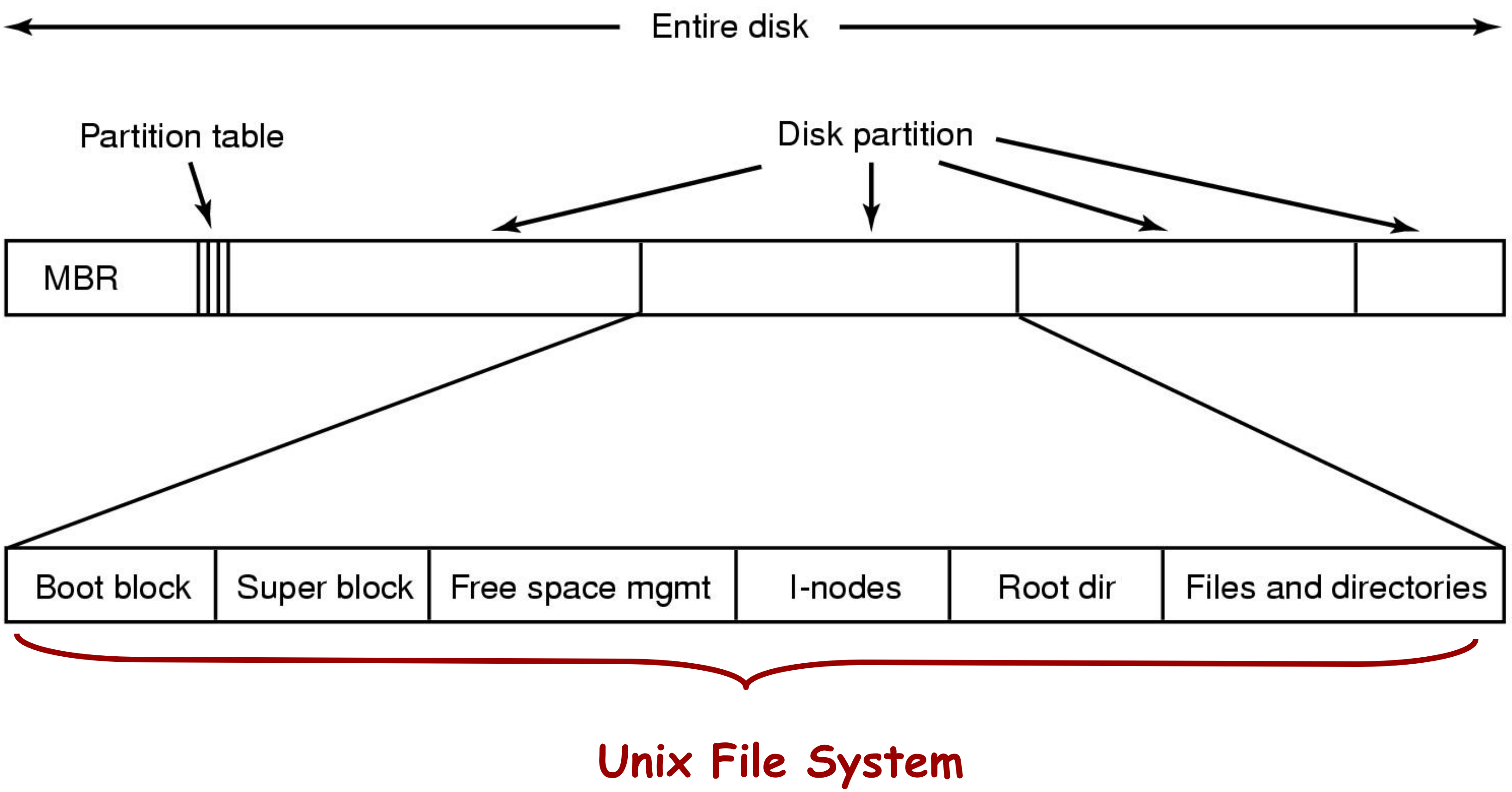


File System Layout





File System Layout



File Bytes vs Disk Sectors

- Files are sequences of bytes
  - Granularity of file I/O is byte
- Disks are arrays of sectors (512 bytes)
  - Granularity of disk I/O is sector
  - File data must be stored in sectors

File Bytes vs Disk Sectors

- File systems may also define a block size
  - Block size usually consists of a number of sectors
  - Contiguous sectors are allocated to a block
- File systems view the disk as an array of blocks
  - Must allocate blocks to file
  - Must manage free space on disk

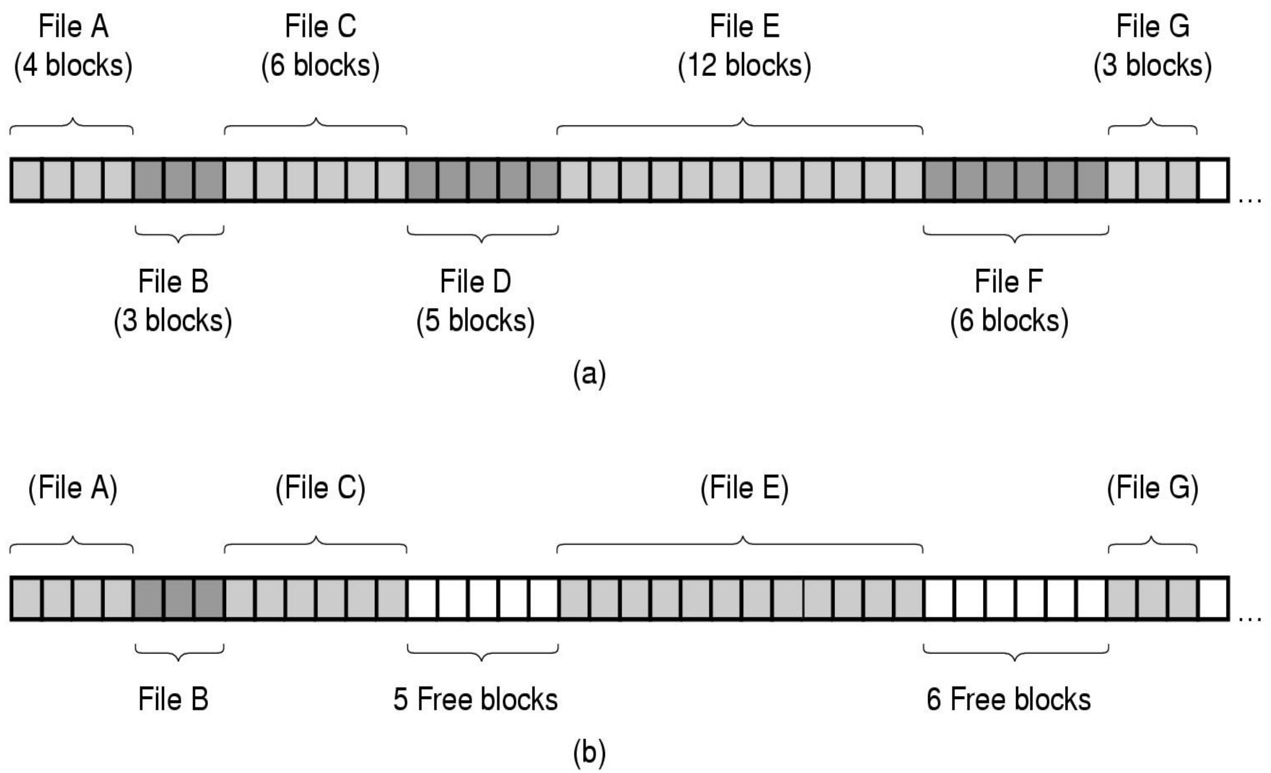
File System Implementation

- Approaches to allocating blocks to a file
  - Contiguous Allocation
  - Linked List Allocation
  - Linked List Allocation using Index
    - FAT used by WINDOWS
  - I-nodes
    - Used by UNIX

Contiguous Allocation

- Store each file as a contiguous run of disk blocks
- Assume a disk of 1-KB blocks
  - 50 KB file is allocated 50 consecutive blocks
- Advantages:
  - Easy to implement
    - Two numbers needed for each file: disk address of the first block and the number of blocks in the file
  - Read performance is excellent

Contiguous Allocation



(a) Contiguous allocation of disk space for 7 files

(b) State of the disk after files *D* and *E* have been removed

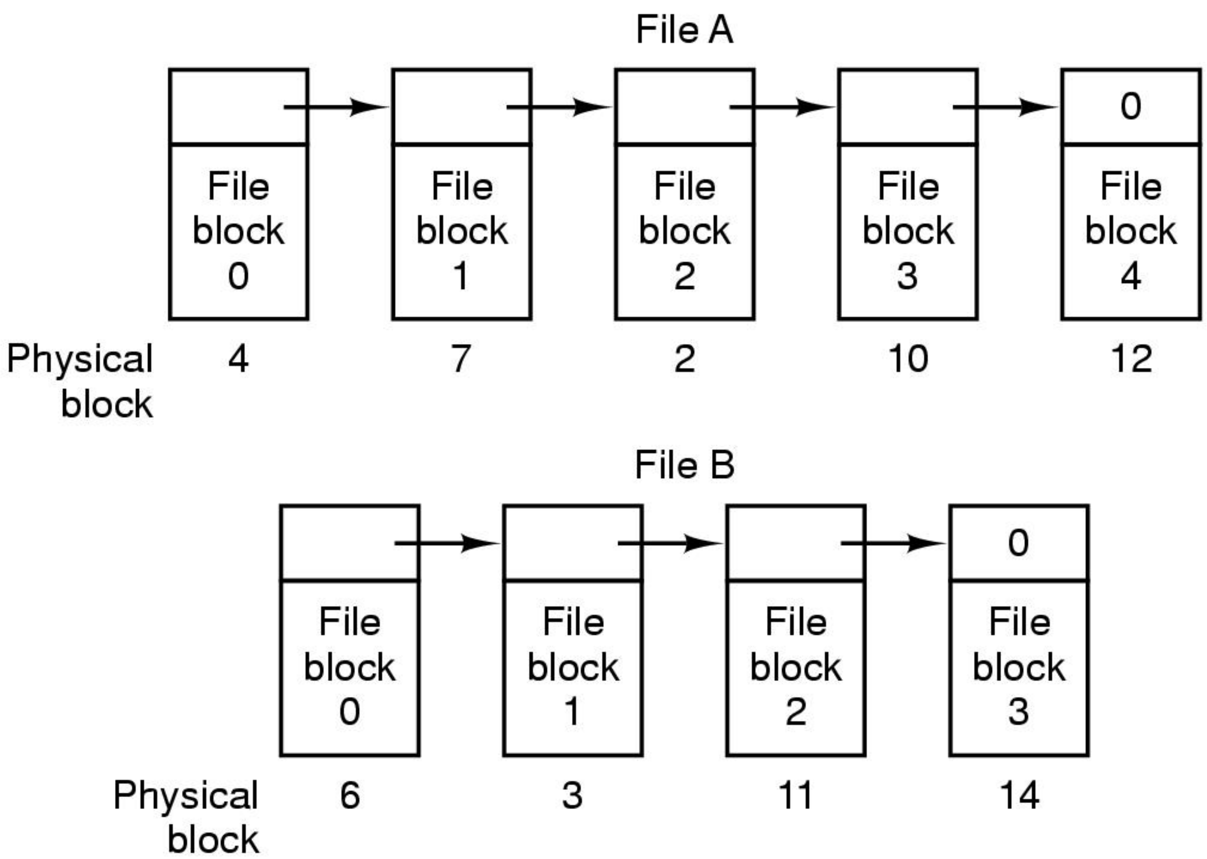
Contiguous Allocation

- Disadvantages
  - Fragmentation
  - Will need periodic compaction (time-consuming)
  - Will need to manage free lists
  - If new file is put at end of disk
    - No problem
  - If new file is put into a "hole"...
    - Have to know a file's maximum possible size ... at the time it is created!

Contiguous allocation

- Good for CD-ROMs, DVDs
  - All file sizes are known in advance
  - Files are never deleted

Linked List Allocation



Storing a file as a linked list of disk blocks

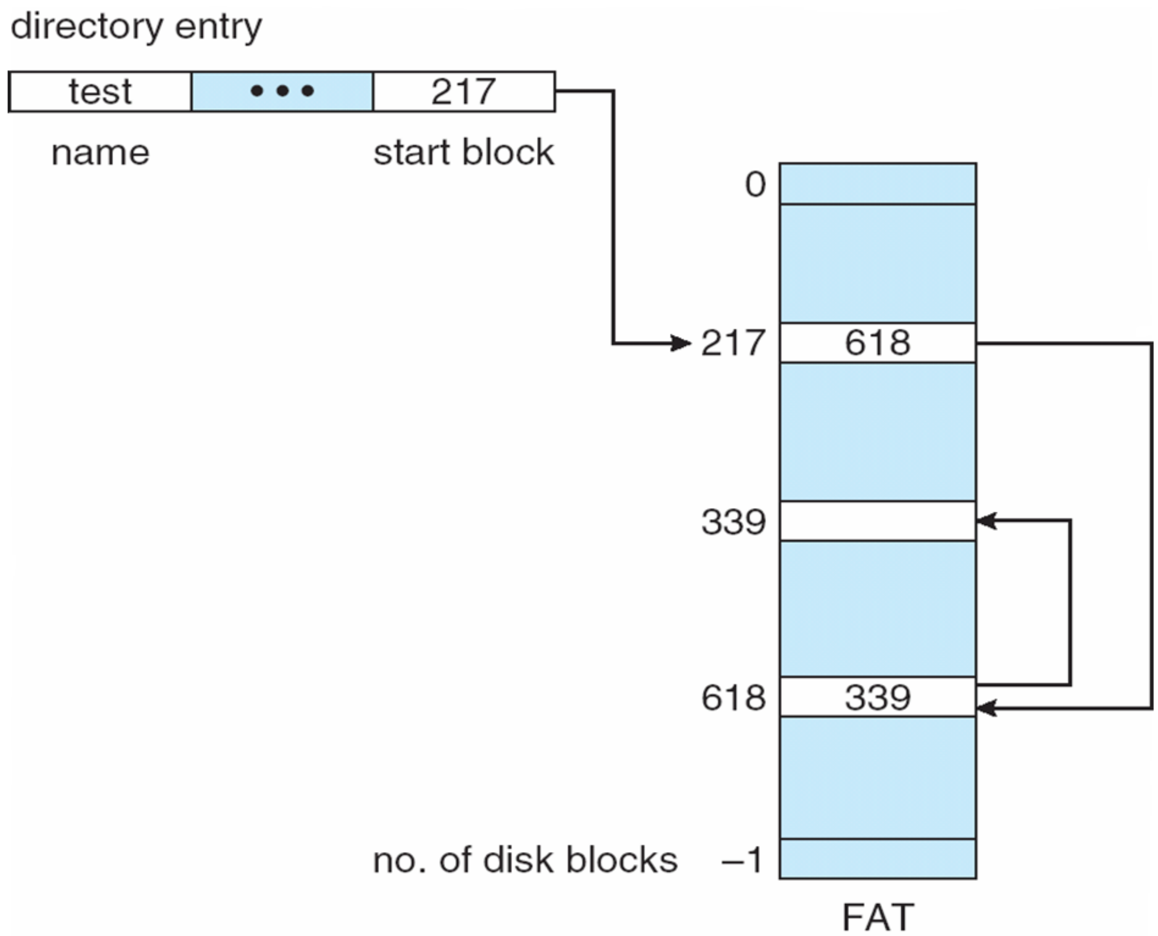
Linked List Allocation

- Advantage
  - No fragmentation (except internal fragmentation)
- Disadvantage
  - Random access is slow
    - To get to block n, the operating system has to start at the beginning and read the n-1 blocks prior to it

Linked List Allocation Using Index

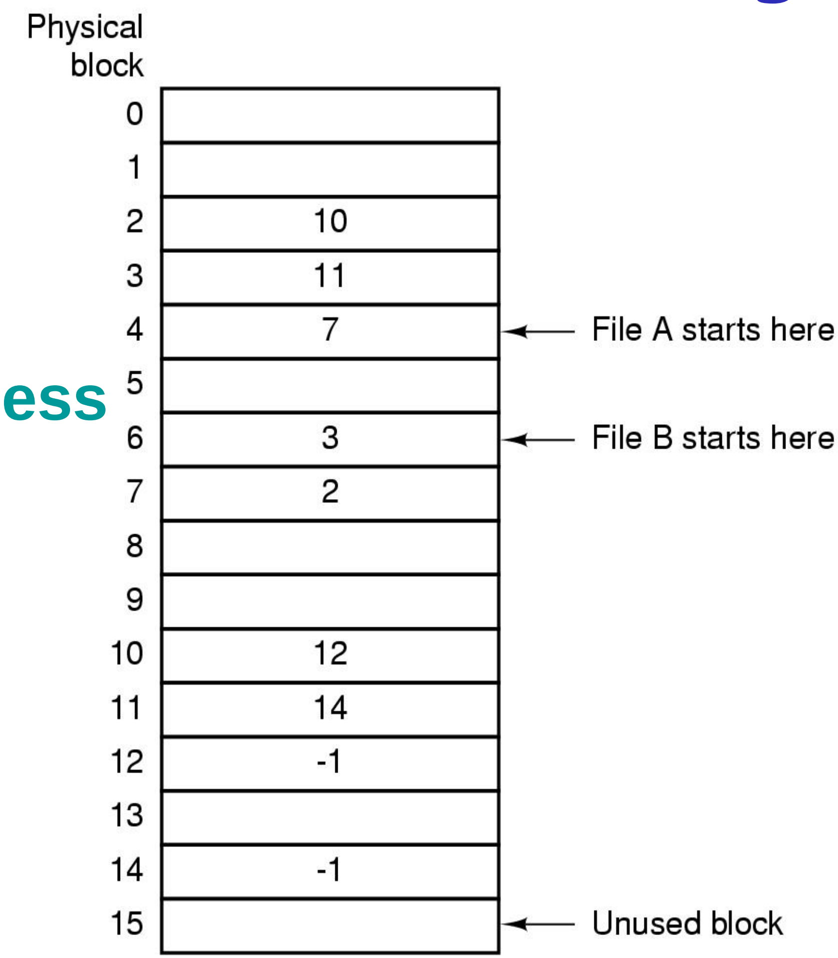
- Take the pointer word from each disk block and put it in a table in memory
- The figure on the next page is based on the previous figure
- The chains are terminated with a special marker (-1).
- The table in main memory is called a FAT (File Allocation Table)

File-Allocation Table



Linked List Allocation using Index

Fast Random Access

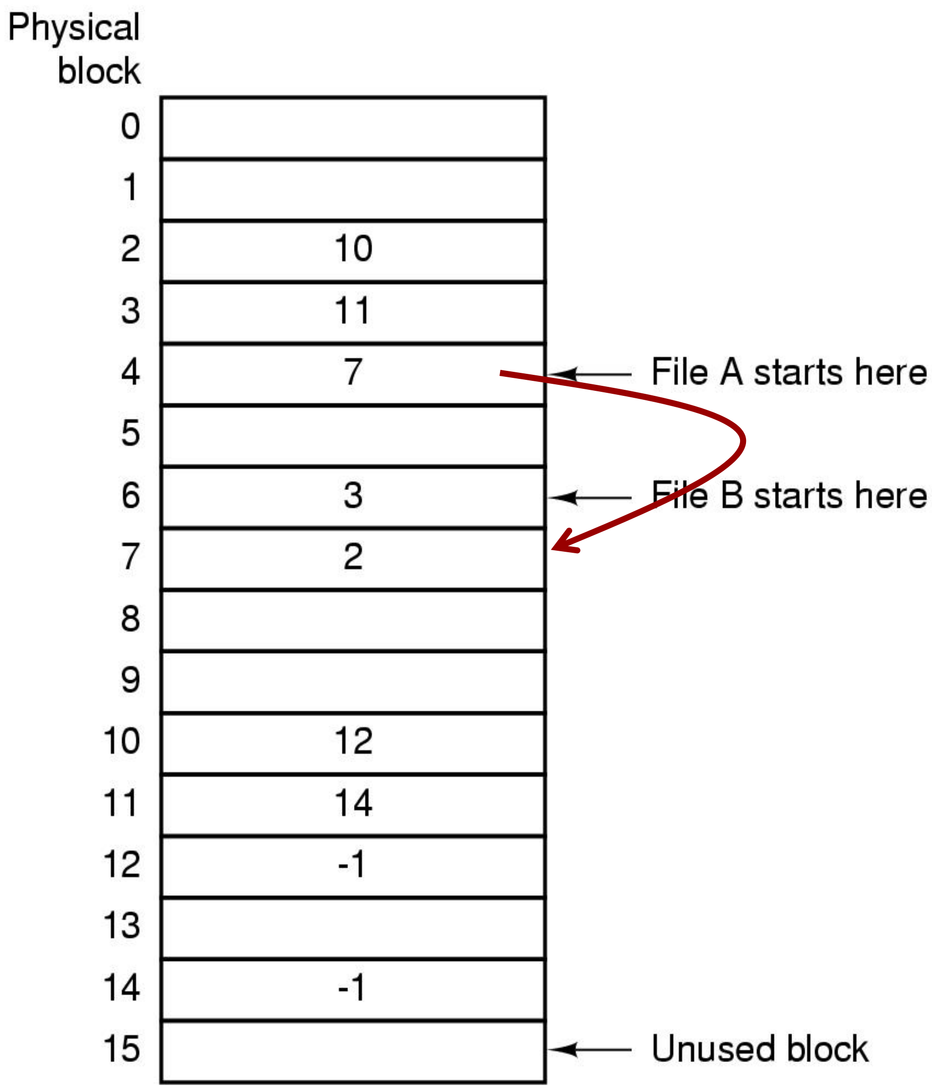


Linked list allocation using a file allocation table in RAM

File allocation table (FAT)

Physical block		
0		
1		
2	10	
3	11	
4	7	File A starts here
5		
6	3	File B starts here
7	2	
8		
9		
10	12	
11	14	
12	-1	
13		
14	-1	
15		Unused block

File allocation table (FAT)



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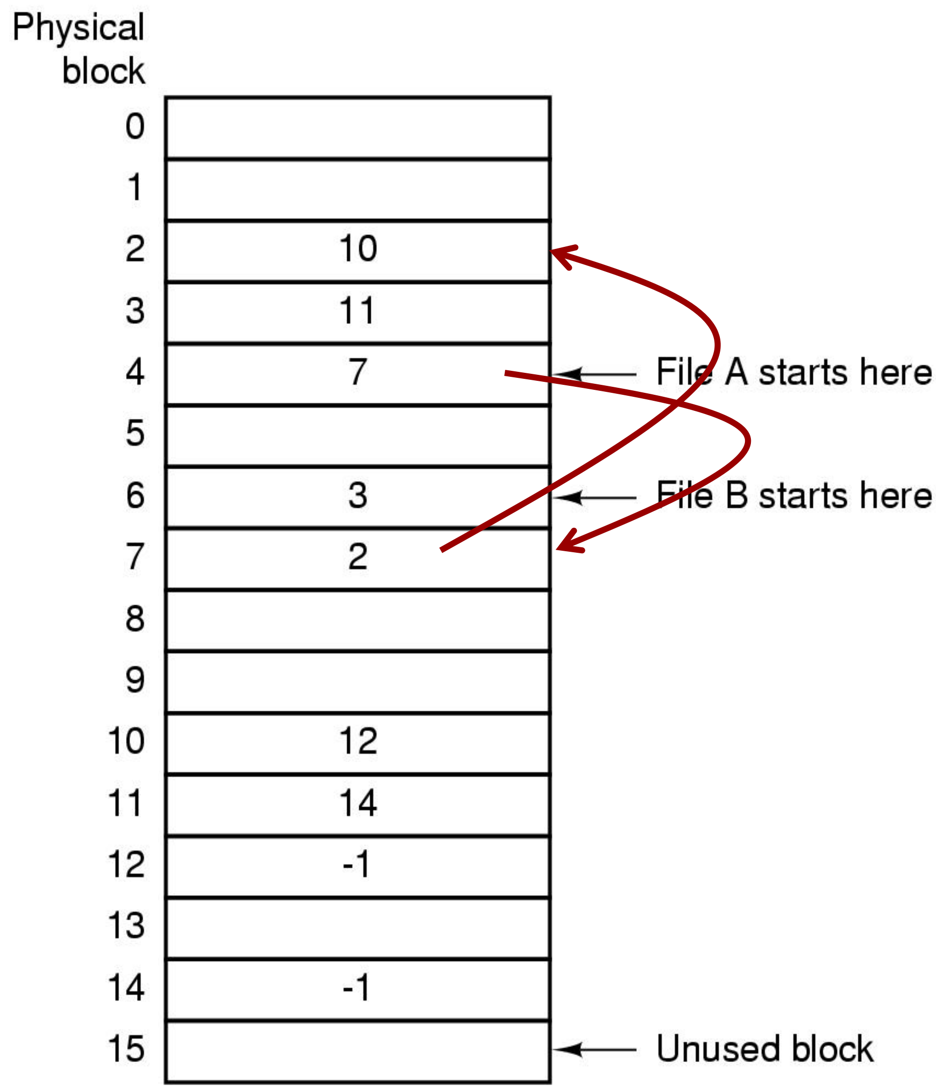

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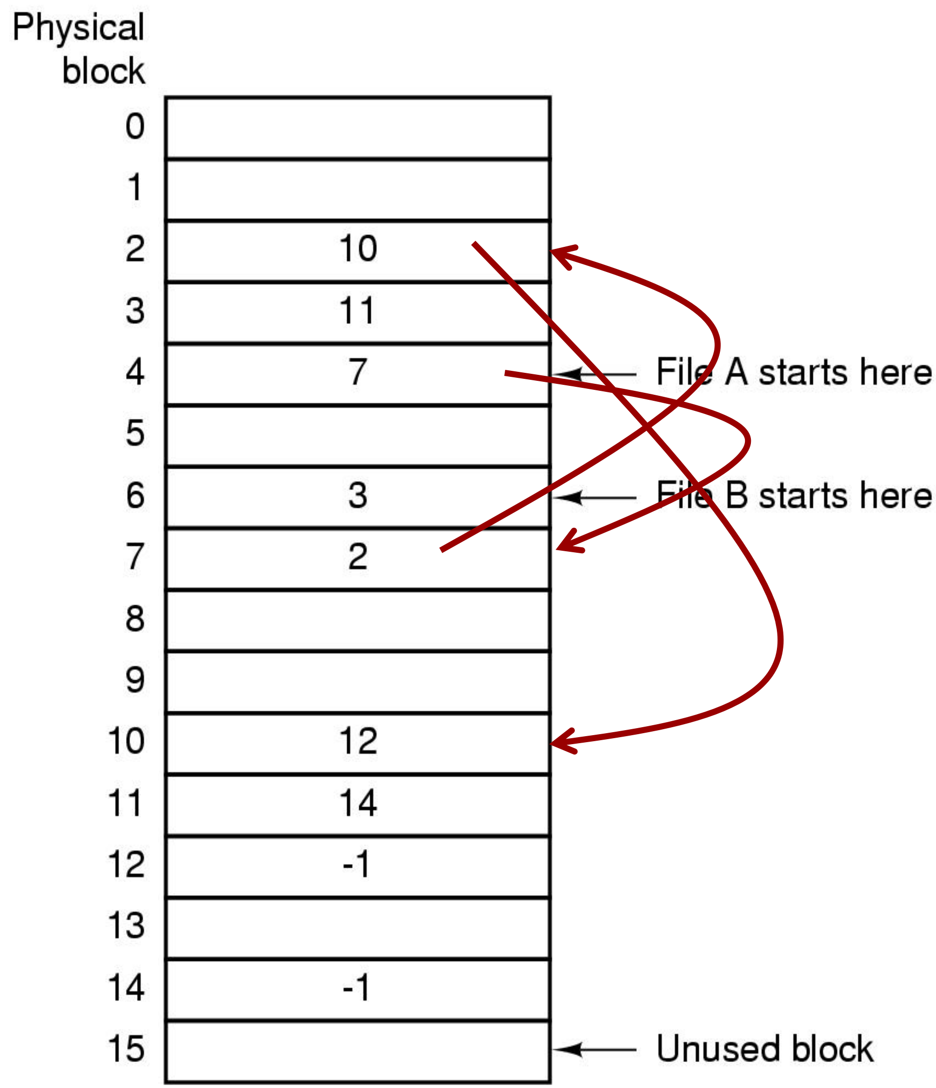

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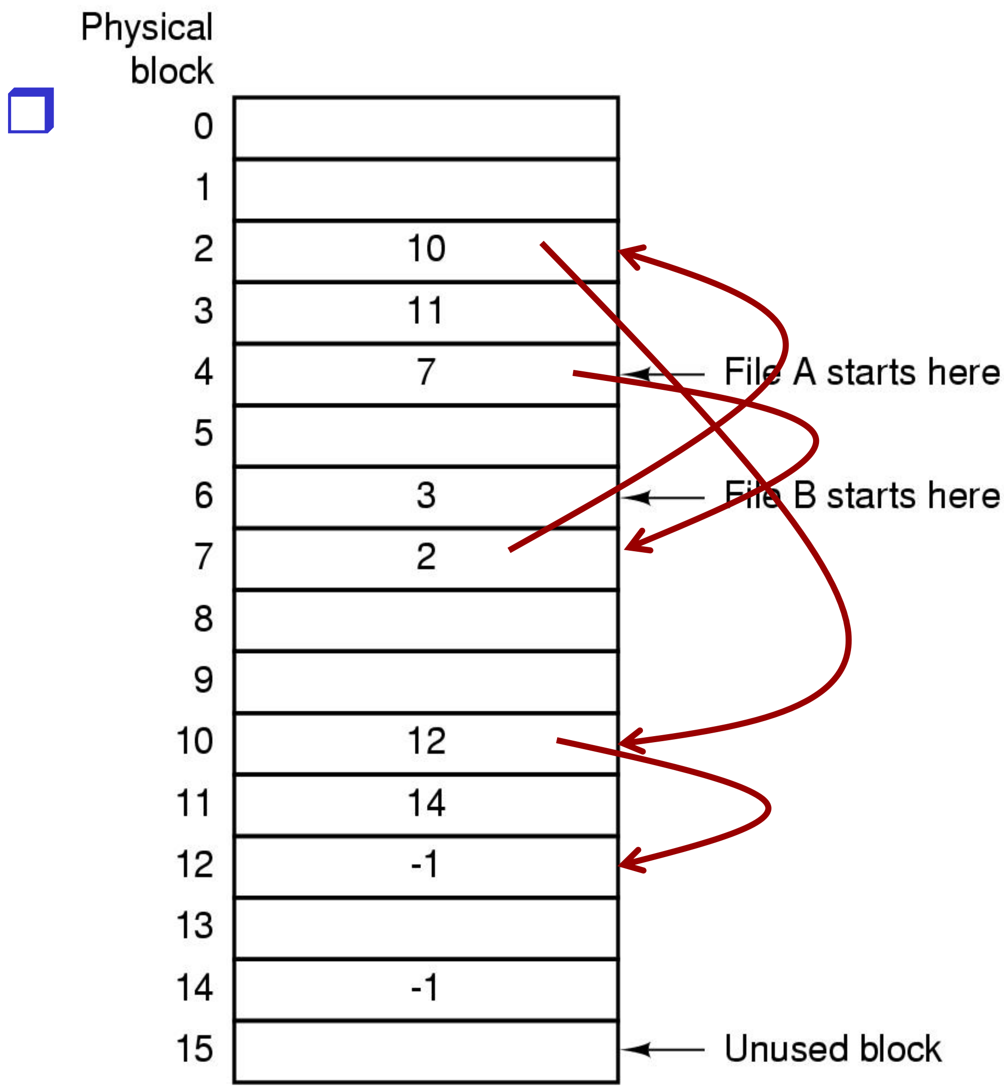

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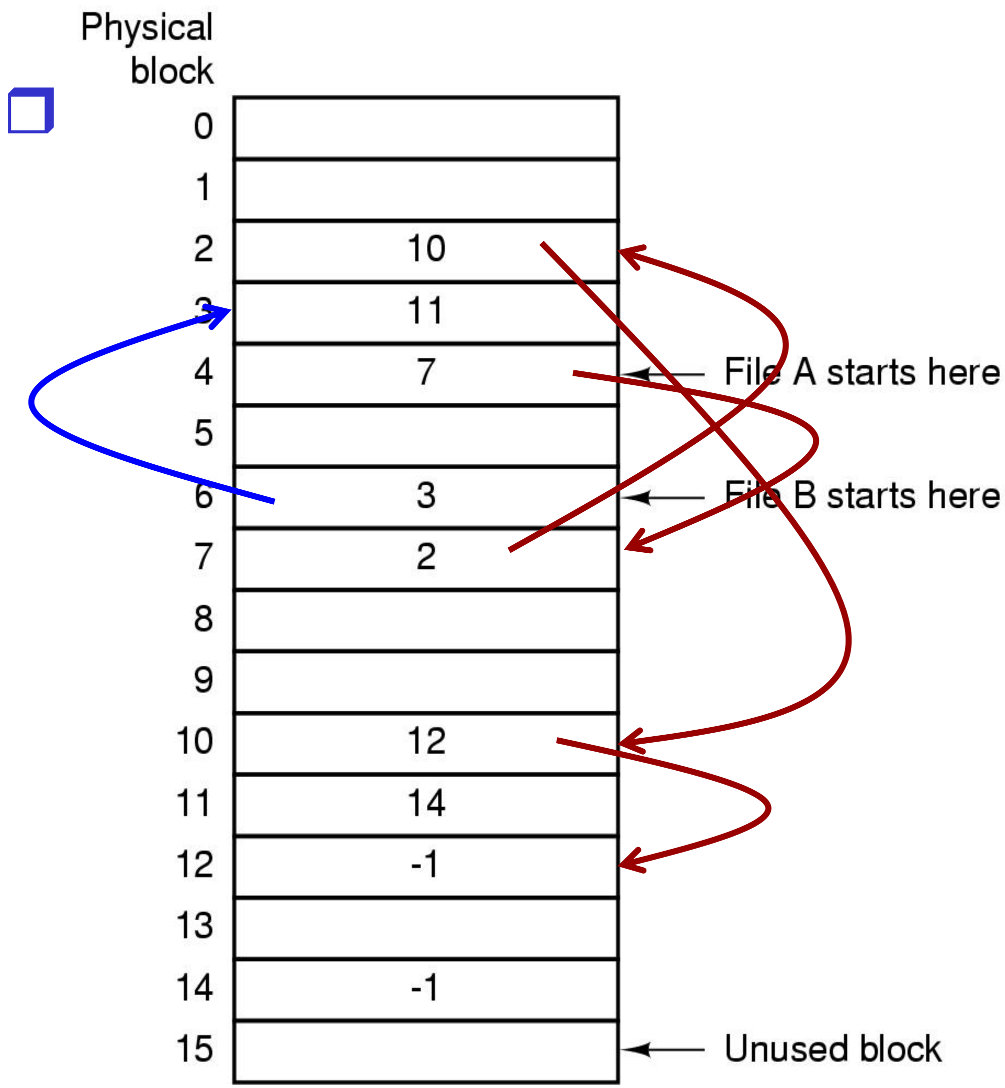

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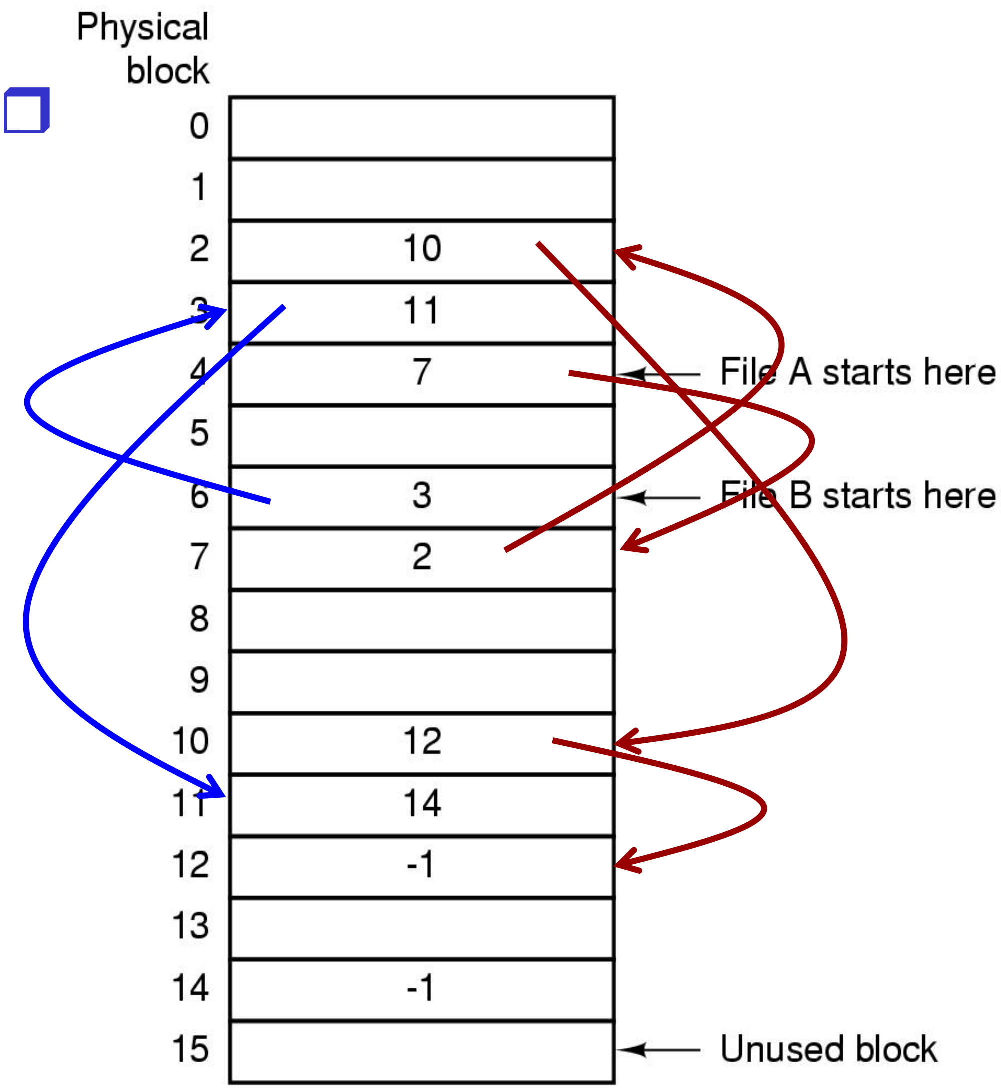

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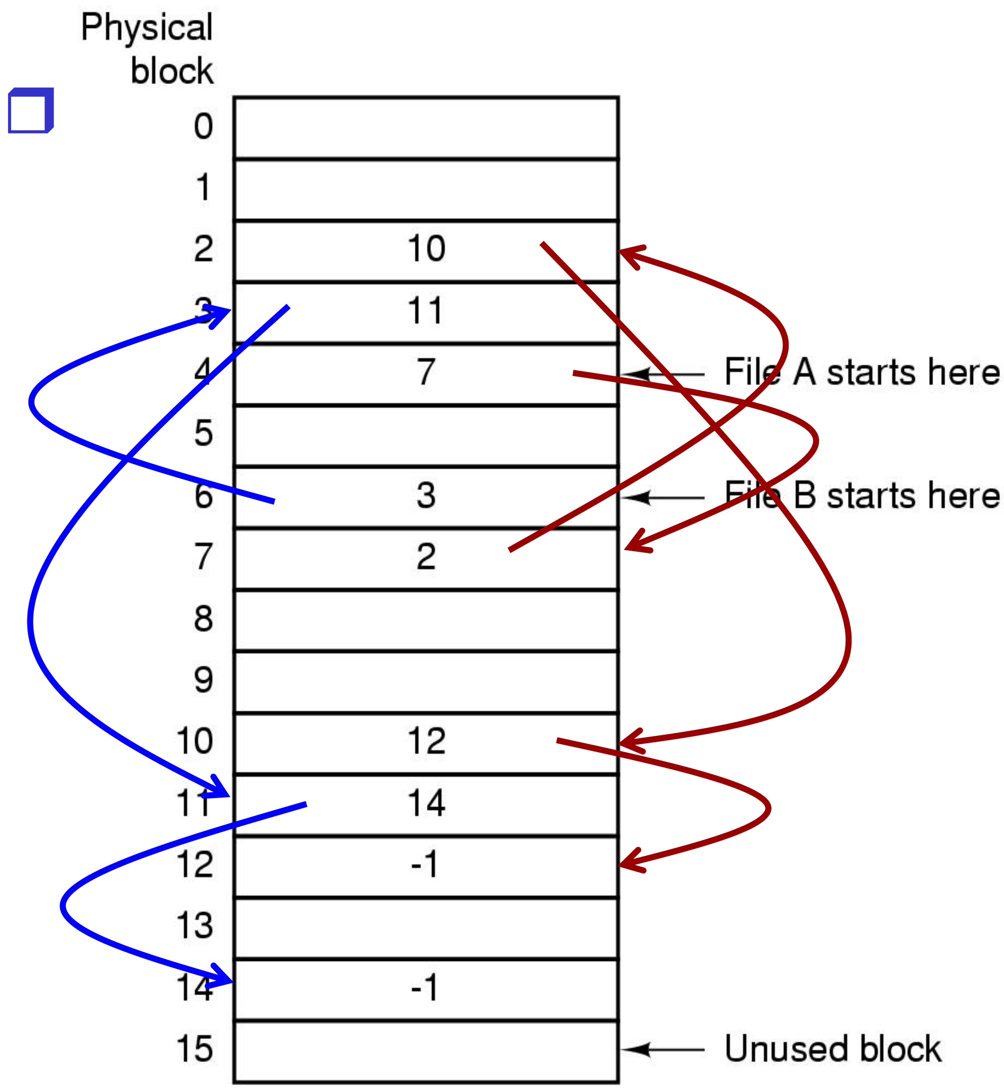


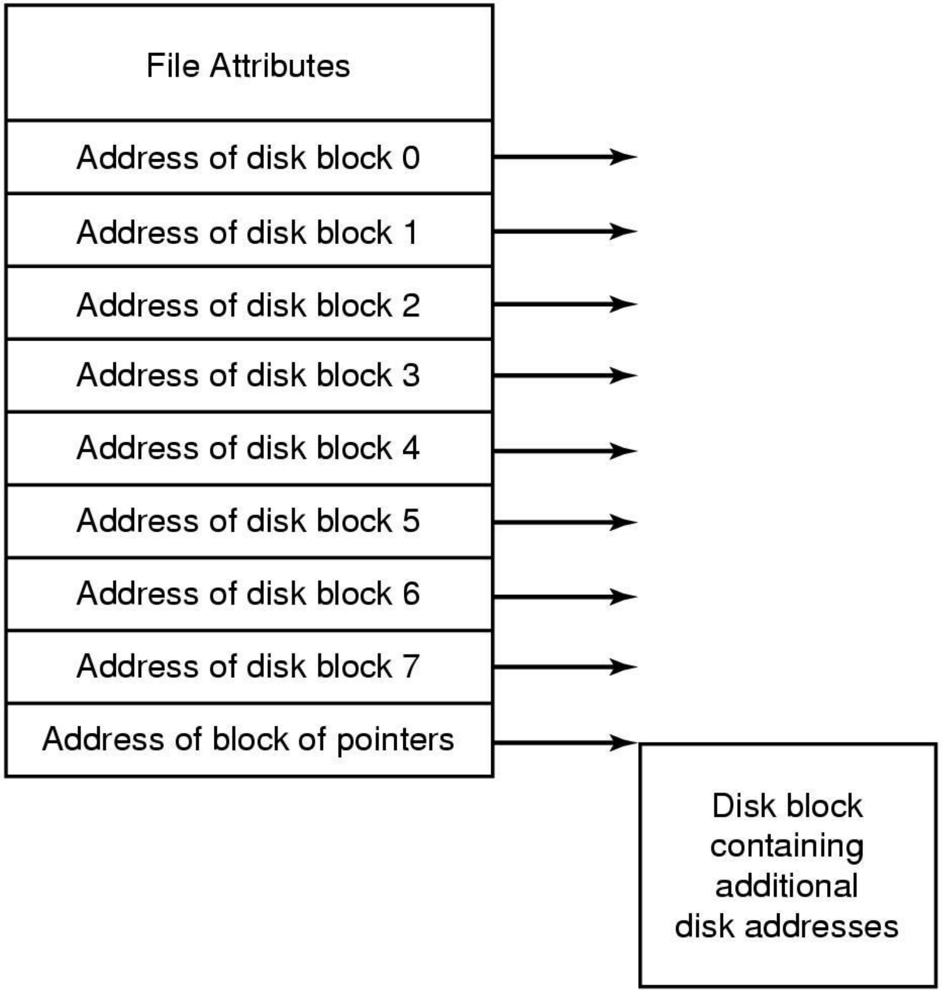
Linked List Allocation Using Index

- Advantage
  - Chain must still be followed to find a given offset within the file, but the chain is entirely in memory
    - No disk references are needed
- Disadvantage
  - Entire table must be in memory all the time
  - What if you have a 20-GB disk and a 1-KB block size?
    - The table needs 20 million entries, one for each of the 20 million disk block
    - Each entry is a minimum of 3 bytes which means 60 MB of memory
- This technique was used in MS-DOS and Windows-98

I-node

- Associate with each file a data structure called an i-node which maintains this information:
  - File attributes
  - Disk addresses of the file's blocks
- Given an i-node it is possible to find all the blocks of the file
- Fixed size
- Unix systems use i-nodes

I-node

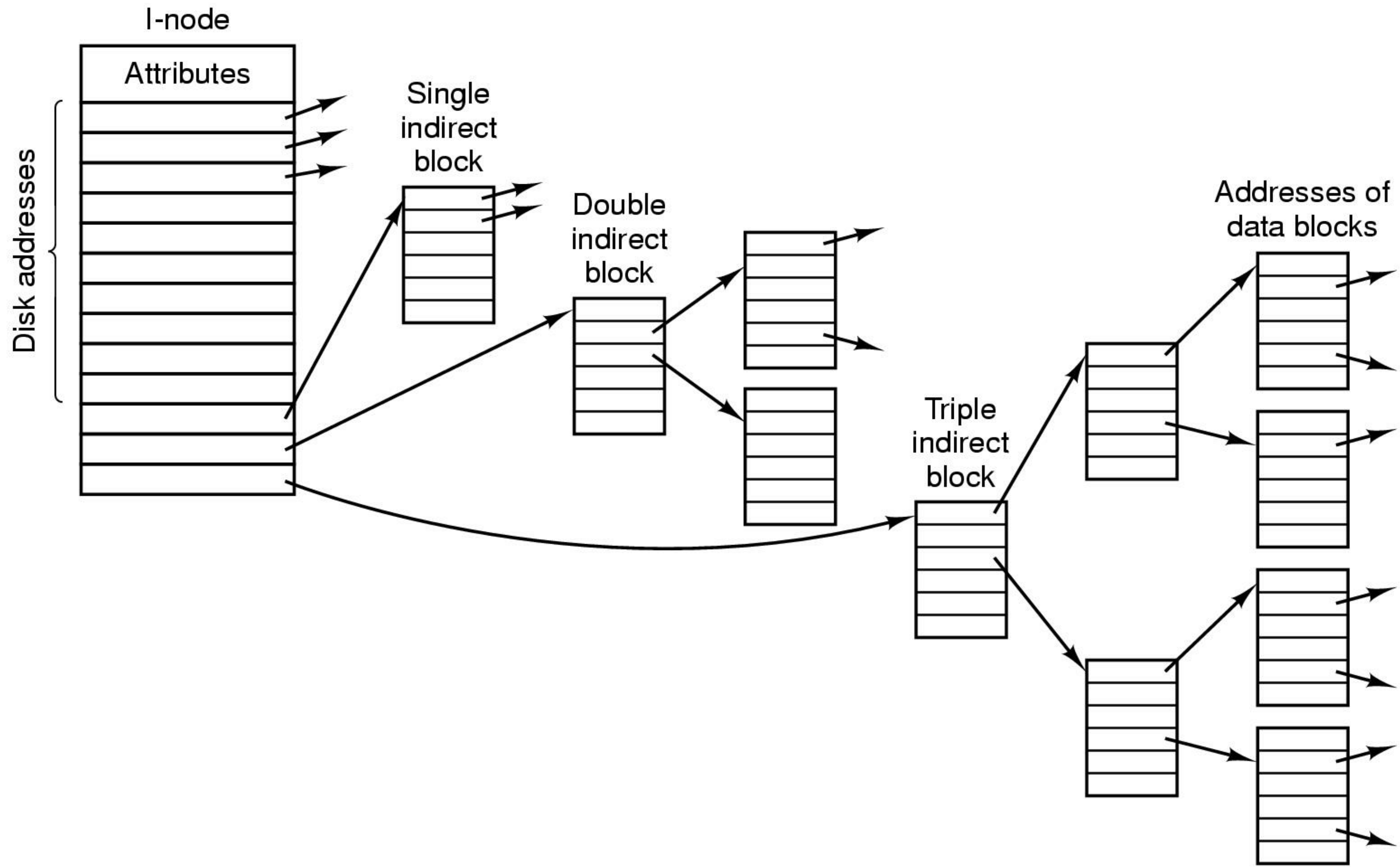


An example i-node

I-node

- What happens when a file needs more blocks?
  - Reserve the last disk address for the address of a block containing more disk block addresses

I-node



A UNIX i-node

The UNIX I-node entries

Field	Bytes	Description
Mode	2	File type, protection bits, setuid, setgid bits
Nlinks	2	Number of directory entries pointing to this i-node
Uid	2	UID of the file owner
Gid	2	GID of the file owner
Size	4	File size in bytes
Addr	39	Address of first 10 disk blocks, then 3 indirect blocks
Gen	1	Generation number (incremented every time i-node is reused)
Atime	4	Time the file was last accessed
Mtime	4	Time the file was last modified
Ctime	4	Time the i-node was last changed (except the other times)

Structure of an I-Node: Attributes and addresses of disk blocks

I-node

- Advantage
  - Only the i-node needs to be in memory when the corresponding file is open
- Disadvantage
  - Updating the structure is more complex

Implementing Directories

- Same as files but containing an array of 16-byte directory entries where each entry consists of the following: file name, inode number
  - The file name can refer to another directory

Implementing Directories

- Opening a file requires that the OS needs the pathname
- The OS uses the pathname supplied by the user to locate the directory entry
- How can we locate the root directory (the start of all paths)?

Implementing Directories

- In Unix systems
  - *Superblock* is a record of the characteristics of a filesystem, including its size, the *block* size, the empty and the filled blocks and their respective counts. It is file system metadata.
  - The superblock (among other things) has the location of the i-node which represents the root directory.
- Once the root directory is located a search through the directory tree finds the desired directory entry
- The directory entry provides the information needed to find the disk blocks for the requested file

Entry Lookup

- When a file is opened, the file system must take the file name supplied and locate its disk blocks
- Let's see how this is done for the path name */usr/ast/mbox*

Entry Lookup

- First the system locates the root directory
  - There is information for each file and directory within the root directory
  - A directory entry consists of the file name and i-node number
- The file system looks up the first component of the path, *usr*, to find the i-node for */usr* which is i-node 6
- From this i-node the system locates the directory for */usr/* which is in block 132

Entry Lookup

- The system then searches for *ast* within the */usr* directory which is block 132
- The entry gives the i-node for */usr/ast/*
- From this i-node the system can find the directory itself and lookup *mbox*
  - The i-node for this file is then read into memory and kept there until the file is closed

Looking up for an entry

Root directory

1	.
1	..
4	bin
7	dev
14	lib
9	etc
6	usr
8	tmp

Looking up usr yields i-node 6

I-node 6 is for /usr

Mode size times
132

I-node 6 says that /usr is in block 132

Block 132 is /usr directory

6	•
1	••
19	dick
30	erik
51	jim
26	ast
45	bal

/usr/ast is i-node 26

I-node 26 is for /usr/ast

Mode size times
406

I-node 26 says that /usr/ast is in block 406

Block 406 is /usr/ast directory

26	•
6	••
64	grants
92	books
60	mbox
81	minix
17	src

/usr/ast/mbox is i-node 60

The steps in looking up /usr/ast/mbox

Summary

- We have examined how files are implemented and how one particular implementation is used to support some of the file operations.