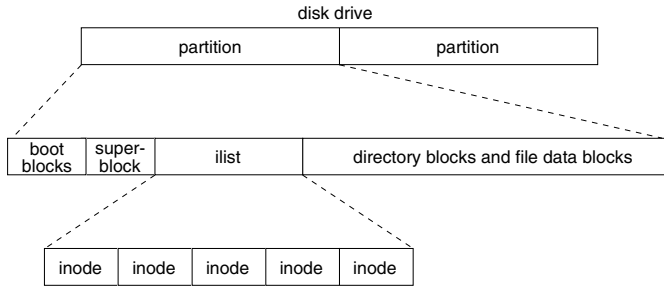


# UNIX File System (Review)

## High-level view:



## Low-level view:

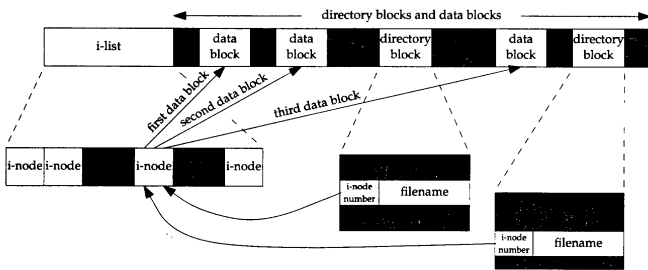


Diagram from *Advanced Programming in the UNIX Environment*, W. Richard Stevens, Addison Wesley, 1992.

# Working with Directories in UNIX

(Think about how this compares to Windows or to the Macintosh OS)

- UNIX keeps track of the inode number of current working directory for each process; directory searches begin there
- However, a file can also be specified as the full pathname from the “root”
  - If filename begins with “ / ”, start at root of the file system tree (inode 2)
- Other characters have special meaning:
  - If filename begins with “ ~ ”, start at the user’s home directory
  - If filename begins with “ . ”, start at the current working directory
  - If filename begins with “ .. ”, start at the parent directory

# Working with Directories (Lookup)

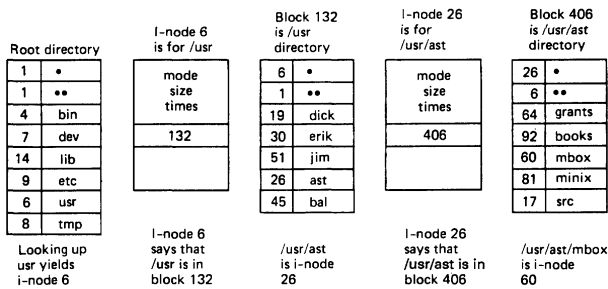


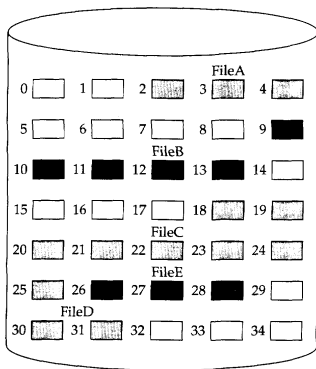
Fig. 4-16. The steps in looking up /usr/ast/mbox.

- A directory is a table of entries:
  - 2 bytes — inumber
  - 14 bytes — file name (improved in BSD 4.2 and later)
- Search to find the file begins with either root, or the current working directory
  - Inode 2 points to the root directory (“ / ”)
  - Example above shows lookup of /usr/ast/mbox

# Working with Directories (Links) in UNIX

- UNIX supports “links” — two directories containing the same file
  - Think of “shortcuts” in Windows, or “aliases” in the Macintosh OS
- Hard links (“ In *target\_file directory*”)
  - Specified directory refers to the target file
    - Both directories point to same inode
- Soft / symbolic links (“ In *-s target\_file directory*”)
  - Adds a pointer to the target file (or target directory) from the specified directory
    - Special bit is set in inode, and the file just contains the name of the file it’s linked to
    - View symbolic links with “ls -F” and “ls -l”
  - Can link across disk drives
  - Similar to linking in Windows / Mac OS

## Organization of Files (Contiguous Allocation)



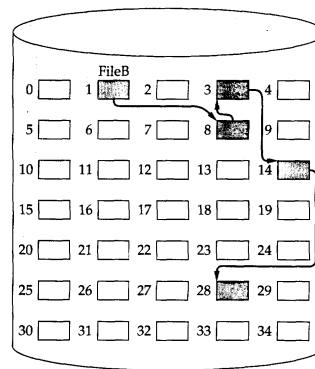
File Name	Start Block	Length
FileA	2	3
FileB	9	5
FileC	18	8
FileD	30	2
FileE	26	3

FIGURE 11.7 Contiguous file allocation

Diagram from *Operating Systems*, William Stallings, Prentice Hall, 1995.

- OS keeps an ordered list of free blocks
  - Allocates contiguous groups of blocks when it creates a file
  - File descriptor must store start block and length of file
- Used in IBM 370, some write-only disks

## Organization of Files (Linked / Chained Allocation)



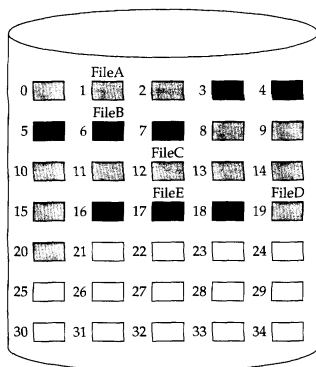
File Name	Start Block	Length
...	...	...
FileB	1	5
...	...	...

FIGURE 11.9 Chained allocation

Diagram from *Operating Systems*, William Stallings, Prentice Hall, 1995.

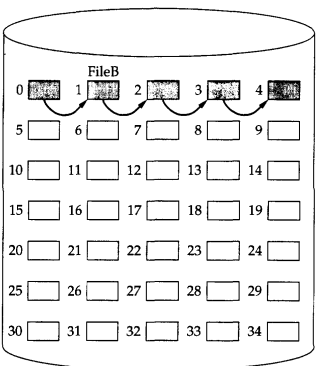
- OS keeps an ordered list of free blocks
  - File descriptor stores pointer to first block
  - Each block stores pointer to next block
- Used in DEC TOPS-10, Xerox Alto

## Organization of Files (Compaction for Contiguous and Linked Allocation)



File Name	Start Block	Length
FileA	0	3
FileB	3	5
FileC	8	8
FileD	19	2
FileE	16	3

FIGURE 11.8 Contiguous file allocation (after compaction)

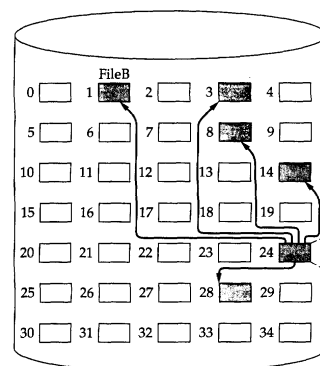


File Name	Start Block	Length
...	...	...
FileB	0	5
...	...	...

FIGURE 11.10 Chained allocation (after consolidation)

Diagrams from *Operating Systems*, William Stallings, Prentice Hall, 1995.

## Organization of Files (Indexed Allocation)



File Name	Index Block
...	...
FileB	24
...	...

FIGURE 11.11 Indexed allocation with block portions

Diagram from *Operating Systems*, William Stallings, Prentice Hall, 1995.

- OS keeps a list of free blocks
  - OS allocates an array (called the index block) to hold pointers to all the blocks used by the file
  - Allocates blocks only on demand
  - File descriptor points to this array
- Used in DEC VMS, Nachos

## Organization of Files (Multilevel Indexed Allocation)

- Used in UNIX (numbers below are for traditional UNIX, BSD UNIX 4.1)
- Each inode (file descriptor) contains 13 *block pointers*
  - First 10 pointers point to data blocks (each 512 bytes long) of a file
    - If the file is bigger than 10 blocks (5,120 bytes), the 11th pointer points to a *single indirect block*, which contains 128 pointers to 128 more data blocks (can support files up to 70,656 bytes)
      - If the file is bigger than that, the 12th pointer points to a *double indirect block*, which contains 128 pointers to 128 more single indirect blocks (can support files up to 8,459,264 bytes)
        - » If the file is bigger than that, the 13th pointer points to a *triple indirect block*, which contains 128 pointers to 128 more double indirect blocks
  - Max file size is 1,082,201,087 bytes

## Organization of Files (Multilevel Indexed Allocation) (cont.)

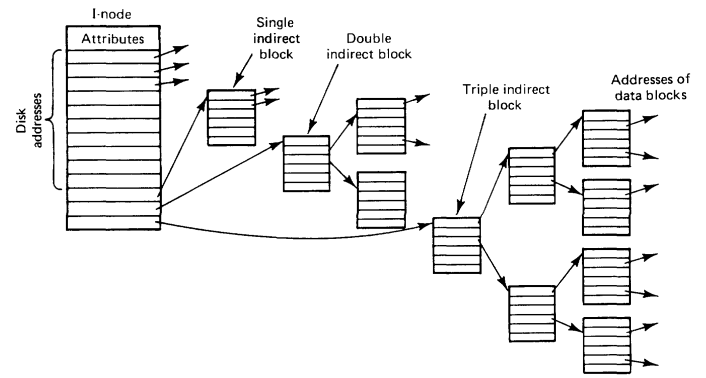


Diagram from *Modern Operating Systems*, Andrew Tanenbaum, Prentice Hall, 1992.

- BSD UNIX 4.2, 4.3:
  - Maximum block size is 4096 bytes
  - Inode contains 14 block pointers
    - 12 to data
    - 13 to single indirect block containing 1024 pointers, 14 to double indirect block...
  - Max file size is  $2^{32}$  bytes