File Systems - Part II

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2022

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- How to
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  - allocate disk space
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  - track the locations of data
  - interface other parts of the OS to secondary storage

File System Structure

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  - User interface to storage, mapping logical to physical
  - Efficient and convenient access to disk
- File structure
  - Logical storage unit
  - Collection of related information

File System Design Problems

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  - The operations allowed on a file
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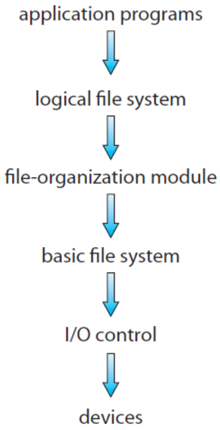
- Algorithms and data structures to map the logical file system onto the physical secondary-storage devices.

File System Layers (1/6)

- Different levels



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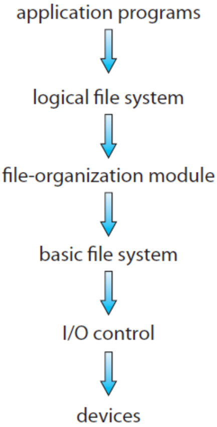
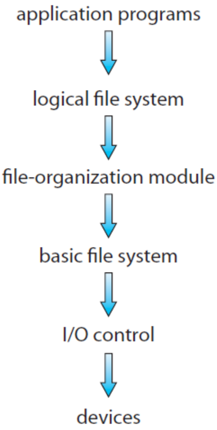


File System Layers (1/6)

- Different levels
- Each level uses the features of lower levels to create new features for use by higher levels.
- Reducing complexity and redundancy, but adds overhead and can decrease performance.



application programs

logical file system

file-organization module

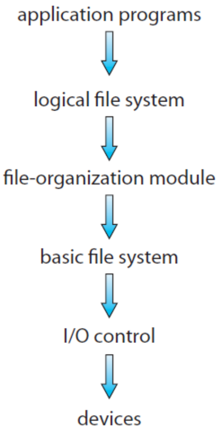
basic file system

I/O control

devices

File System Layers (2/6)

- Device drivers manage I/O devices at the I/O control layer.



File System Layers (2/6)

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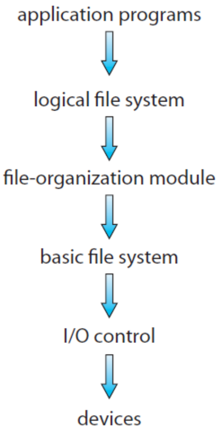
- Translates high-level commands to low-level hardware-specific instructions.



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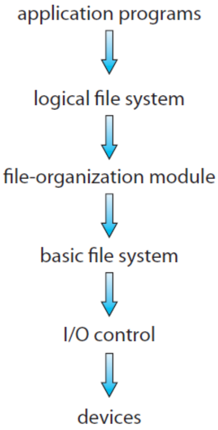

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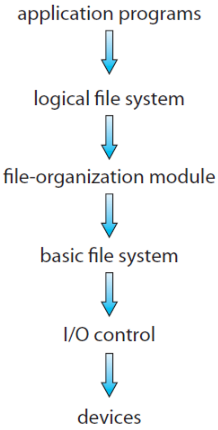

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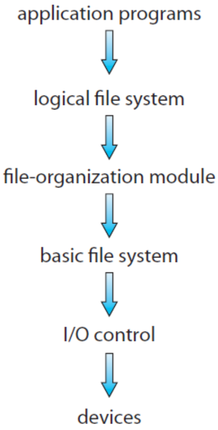

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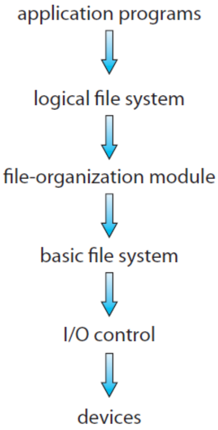

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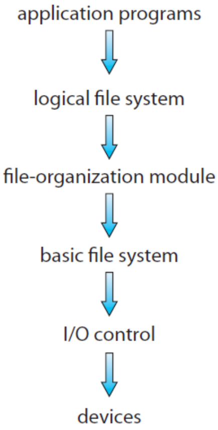

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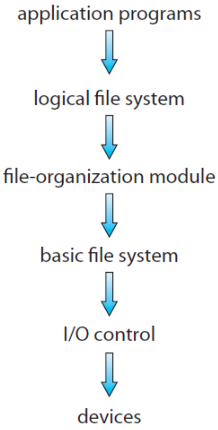

File System Layers (4/6)

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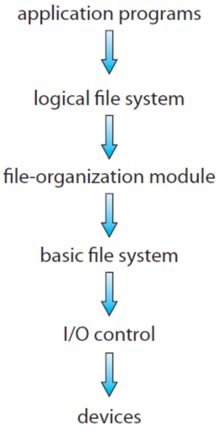
- Translates logical block number to physical block number.

- Manages free space and disk allocation.



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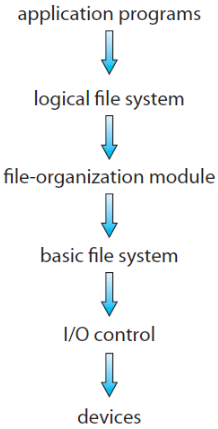

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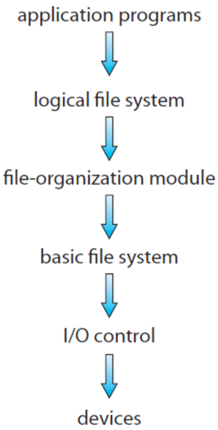

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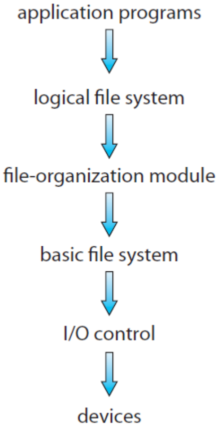
- Directory management and protection



File System Layers (6/6)

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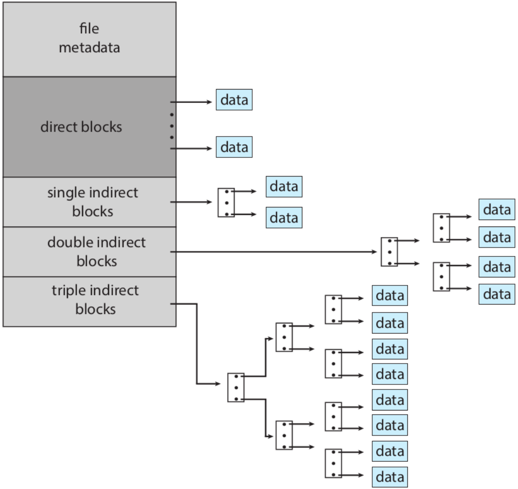
- Many file systems, sometimes many within an OS
- Each with its own format
  - CD-ROM: ISO 9660
  - Unix: UFS, FFS
  - Windows: FAT, FAT32, NTFS
  - Linux: more than 40 types, with extended file system (ext2, ext3, ext4)

File System Implementation

The Unix inode



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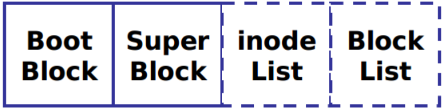
- In-memory
  - Mount table
  - Directory structure cache
  - The open-file table (system-wide and per process)
  - Buffers of the file-system blocks

On-Disk File System Structures (1/2)

- Boot control block contains information needed by system to boot OS from that volume.



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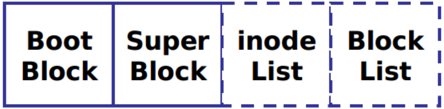

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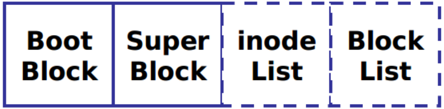

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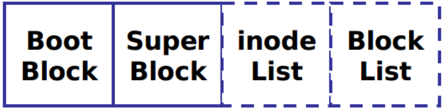
- Volume control block contains volume details.
  - Total num. of blocks, num. of free blocks, block size, free block pointers or array
  - In UFS, it is called super block, and in NTFS master file table.



Boot Block | Super Block | inode List | Block List

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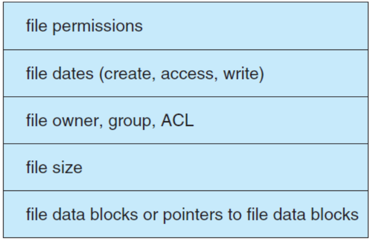
- File Control Block (FCB) contains many details about the file.
  - In UFS, inode number, permissions, size, dates.
  - In NFTS stores into in master file table.



file permissions

file dates (create, access, write)

file owner, group, ACL

file size

file data blocks or pointers to file data blocks

File Control Block (FCB)

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- Buffers hold file-system blocks when they are being read from disk or written to disk.

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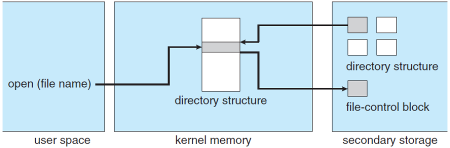
- The system, then, reads the appropriate directory into memory, updates it with the new file name and FCB, and writes it back to the disk.

Open a File

- The `open()` passes a file name to the logical file system.



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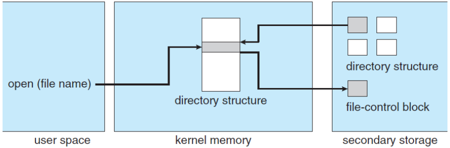

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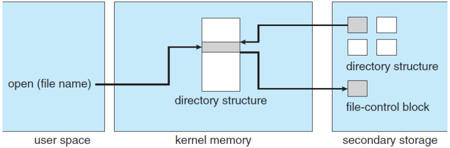

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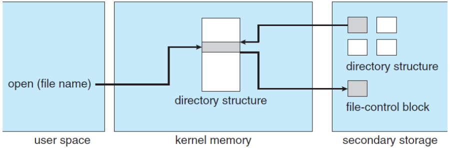

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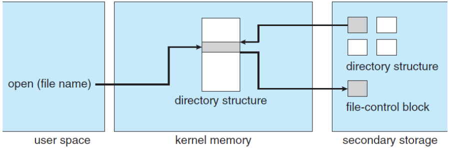
- This table stores the FCB as well as the number of processes that have the file open.



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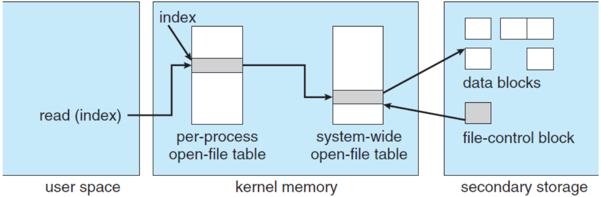

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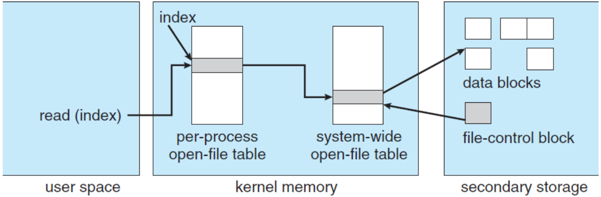

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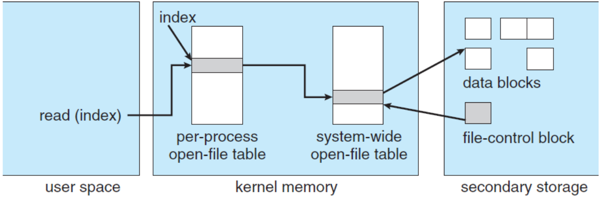
- This pointer is called file descriptor in Unix and file handle in Windows.



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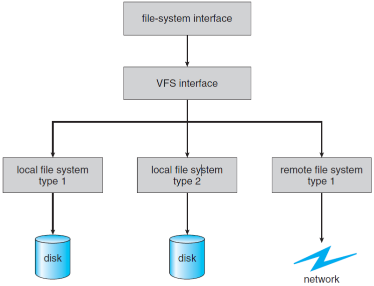
- When all users that have opened the file close it, any updated metadata is copied back to the disk-based directory structure, and the system-wide open-file table entry is removed.

Virtual File Systems

Virtual File Systems (1/2)

- Virtual File Systems (VFS) on Unix provide an object-oriented way of implementing file systems.



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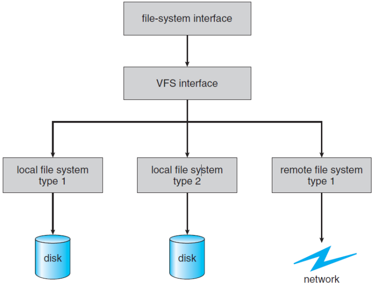
- VFS allows the same system call interface (the API) to be used for different types of file systems.



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  - The kernel maintains one vnode structure for each active node.

Allocation Methods

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- How disk blocks are allocated to files?

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- Methods:
  - Contiguous allocation
  - Linked allocation
  - Indexed allocation

Contiguous Allocation

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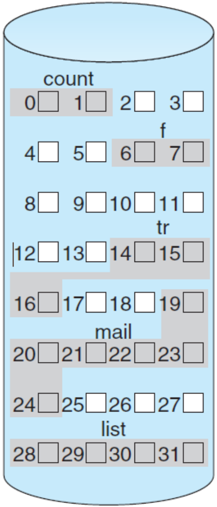
- Allocation strategies like contiguous memory allocation:
  - First fit
  - Best fit
  - Worst fit

Contiguous Allocation (2/2)



directory

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

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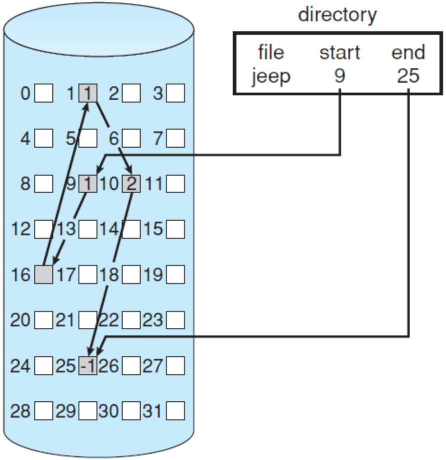

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- Reliability can be a problem.
- The space required for the pointers.
    - Efficiency can be improved by clustering blocks into groups but increases internal fragmentation.

Indexed Allocation

Indexed Allocation (1/2)

- Indexed allocation: each file has its own index block(s) of pointers to its data blocks.

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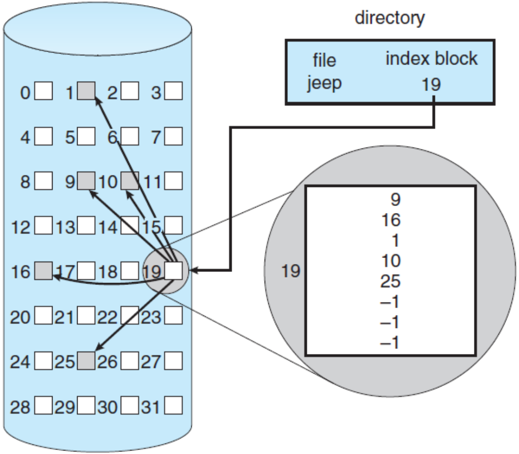
- Need index table
- Random access
- Dynamic access without external fragmentation, but have overhead of index block

Indexed Allocation (2/2)



Indexed Allocation Problems

- Wasted space: overhead of the index blocks.
- For example, even with a file of only one or two blocks, we need an an entire index block.

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- Mechanisms for this purpose include the following:
  - Linked scheme
  - Multi-level index
  - Combined scheme

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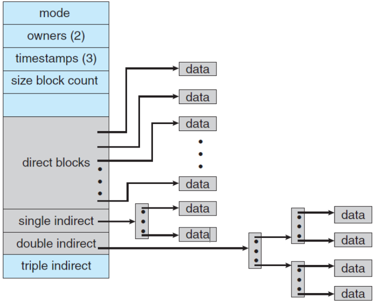
- For example, an index block might contain a small header giving the name of the file and a set of the first 100 disk-block addresses.
- The next address is null or is a pointer to another index block.

Multi-Level Index

- Two-level index
- A first-level index block to point to a set of second-level index blocks, which in turn point to the file blocks.
- Could be continued to a third or fourth level.

Combined Scheme

- Combine scheme: used in Unix/Linux FS
- The first 12 pointers point to direct blocks
  - The data for small files do not need a separate index block.
- The next 3 pointers point to indirect blocks.
  - Single indirect
  - Double indirect
  - Triple indirect



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- Virtual file system (VFS)

- Allocation methods: contiguous allocation, linked allocation, and indexed allocation

Questions?

Acknowledgements

Some slides were derived from Avi Silberschatz slides.