File System Implementation (Part II)

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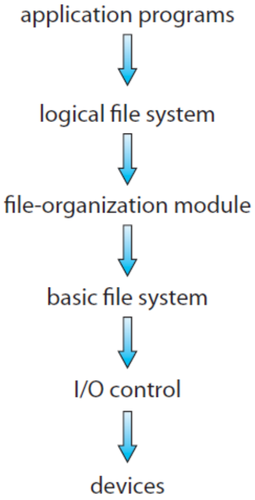
Reminder

File System Layers



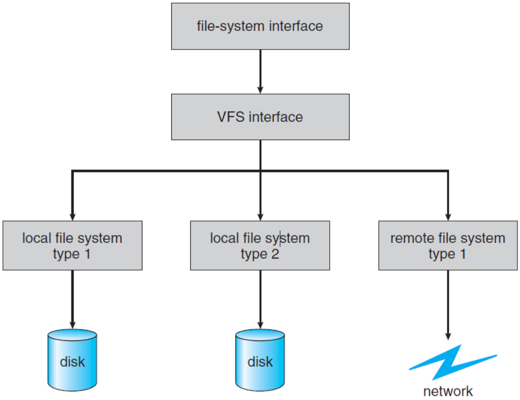
File-System Implementation

- Based on several on-disk and in-memory structures.

- On-disk
  - Boot control block (per volume)
  - Volume control block (per volume)
  - Directory structure (per file system)
  - File control block (per file)

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

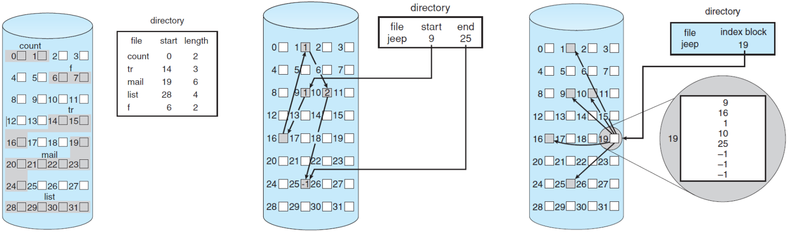
Virtual File Systems (VFS)



Directory Implementation

- Linear list
- Hash table

Allocation Methods



Free Space Management

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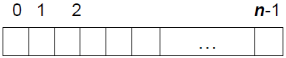
  - This space is then removed from the free-space list.
- When a file is deleted, its disk space is added to the free-space list.

Free-Space Management (2/2)

- Possible techniques:
  - Bit vector
  - Linked list
  - Grouping
  - Counting
  - Space maps

Bit Vector

- Bit vector or bit map (n blocks)



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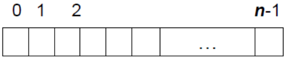

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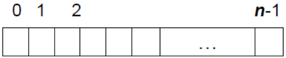

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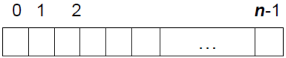

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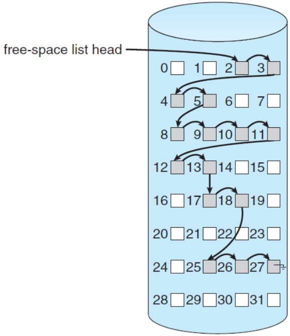
Linked List

- Linked list (free-list)
  - Cannot get contiguous space easily
  - No waste of space
  - No need to traverse the entire list



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- Free space list then has entries containing addresses and counts.

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- Rather than write counting structures to disk, it uses log-structured file-system techniques to record them.
- Metaslab activity → load space map into memory in balanced-tree structure

Efficiency and Performance

Efficiency and Performance

- Disks are the major bottleneck in system performance.
- A variety of techniques used to improve the efficiency and performance of secondary storage.

Efficiency (1/2)

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  - It improves the file system's performance, but consumes disk space.

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  - Make them dynamic.

Performance

- Techniques to improve the file system performance:
  - Unified buffer cache
  - Optimizing sequential access
  - Synchronous and asynchronous writes

Unified Buffer Cache (1/4)

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  - Cache file data as pages rather than as file-system blocks.
  - More efficient: accesses interface with virtual memory rather than the file system.

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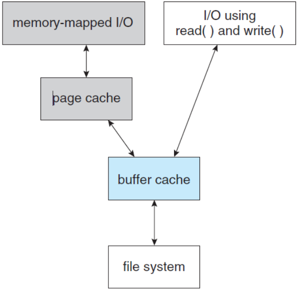

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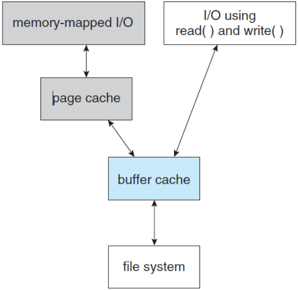

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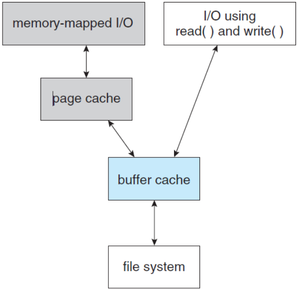

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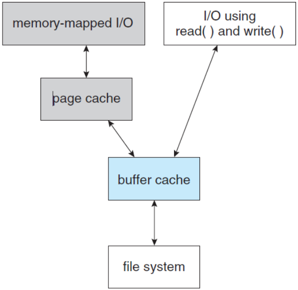
  - The memory-mapping call, requires using two caches: the page cache and the buffer cache.



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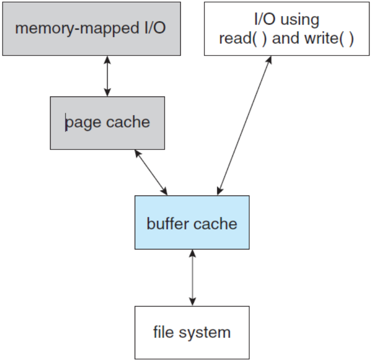

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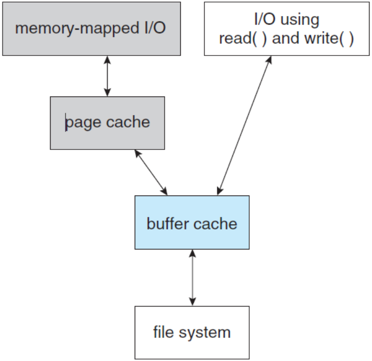

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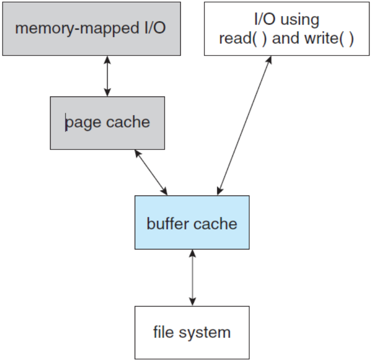

Unified Buffer Cache (3/4)

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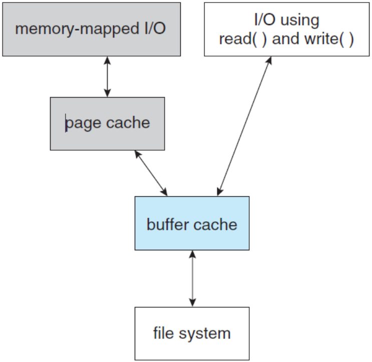
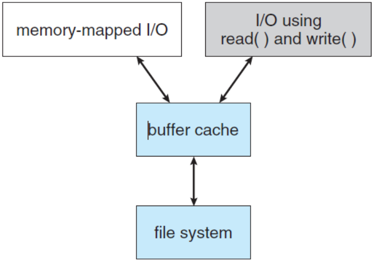
  - Waste of memory, CPU and I/O cycles
  - Inconsistency



Unified Buffer Cache (4/4)

- With unified buffer cache.
- Both memory mapping and the `read()` and `write()` use the same page cache.
- LRU for block or page replacement.



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- Read-ahead: a requested page and several subsequent pages are read and cached.
  - Retrieving these data from the disk in one transfer and caching them saves time.

Synchronous and Asynchronous Writes

- Synchronous writes sometimes requested by applications or needed by OS.
    - No buffering/caching: writes must hit disk before acknowledgement.

- Asynchronous writes more common, buffer-able, faster.

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- Methods to deal with corruption:
  - Consistency checking
  - Log-structured file systems
  - Backup and restore

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- Can be slow and sometimes fails.

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  - Sometimes to a separate device or section of disk.

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- Faster recovery from crash, removes chance of inconsistency of metadata.

Backup and Restore (1/2)

- Back up data from disk to another storage device, such as a magnetic tape or other hard disk.

- Recovery from the loss of an individual file, or of an entire disk, may then be a matter of restoring the data from backup.

Backup and Restore (2/2)

- A typical backup schedule:
  - Day 1. full backup: copy all files from the disk to a backup medium.
  - Day 2. incremental backup: copy all files changed since day 1 to another medium.
  - Day 3. incremental backup: copy all files changed since day 2 to another medium.
  - ...
  - Day N. incremental backup: copy all files changed since day N-1 to another medium. Then go back to day 1.

NFS

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- NFS views a set of interconnected workstations as a set of independent machines with independent file systems.
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- Sharing is based on a client-server relationship: either TCP or UDP/IP.

The Network File System (2/2)

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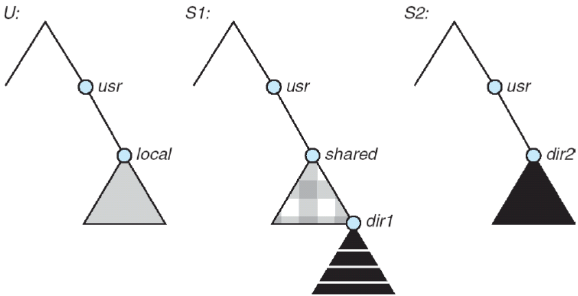
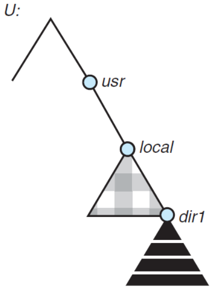
  - Files in the remote directory can then be accessed in a transparent manner.

NFS Mount (1/3)



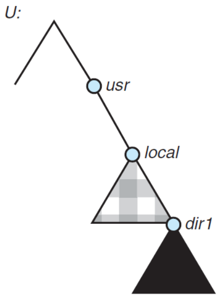
- Three independent file systems of machines named U, S1, and S2.

NFS Mount (2/3)



- Mounting S1:/usr/shared over U:/usr/local.
  `mount -t nfs S1:/usr/shared /usr/local`
- U can access any file within the dir1 using /usr/local/dir1.

NFS Mount (3/3)



- Cascading: mount a file system over another file system that is remotely mounted.
- Mounting `S2:/usr/dir2` over `U:/usr/local/dir1`, which is already remotely mounted from `S1`.
  `mount -t nfs S2:/usr/dir2 /usr/local/dir1`

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- Mount operation includes name of remote directory to be mounted and name of server machine storing it.
- Mount request is mapped to corresponding RPC and forwarded to mount server.
- Export list: specifies local file systems that server exports for mounting, along with names of machines that are permitted to mount them.

NFS Mount Protocol (2/2)

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- The mount operation changes only the user's view and does not affect the server side.

NFS Protocol (1/2)

- Provides a set of RPCs for remote file operations.
- The procedures support the following operations:
  - Searching for a file within a directory
  - Reading a set of directory entries
  - Manipulating links and directories
  - Accessing file attributes
  - Reading and writing files

NFS Protocol (2/2)

- NFS servers are stateless; each request has to provide a full set of arguments.
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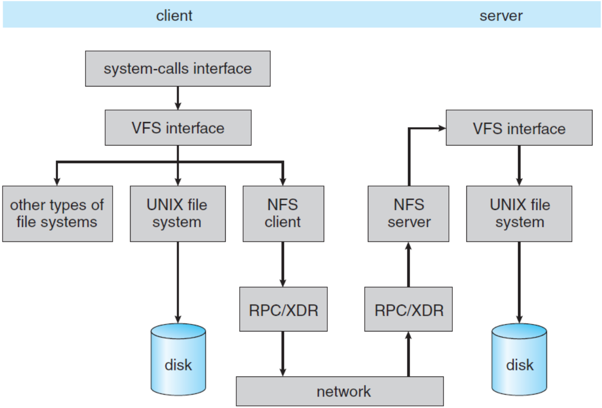
- The NFS protocol does not provide concurrency-control mechanisms.

Schematic View of NFS Architecture



- NFS is integrated into the OS via a VFS.

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- NFS service layer
  - Implements the NFS protocol.

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- Performs a separate NFS lookup call for every pair of component name and directory vnode.
- To make lookup faster, a directory-name-lookup cache on the client's side holds the vnodes for remote directory names.

NFS Remote Operations (1/2)

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- NFS adheres to the remote-service paradigm, but employs buffering and caching techniques for the sake of performance.

NFS Remote Operations (2/2)

- File-attribute cache: the attribute cache is updated whenever new attributes arrive from the server.
  - When a file is opened, the kernel checks with the remote server whether to fetch or revalidate the cached attributes.
  - By default, discarded after 60 seconds.

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- Clients do not free delayed-write blocks until the server confirms that the data have been written to disk

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- NFS: mount protocol, path-name translation, remote operation

Questions?

Acknowledgements

Some slides were derived from Avi Silberschatz slides.