CSE 421/521 - Operating Systems
Fall 2011

LECTURE - XXV

DISTRIBUTED SYSTEMS - III

Tevfik Koşar

University at Buffalo

December 1st, 2011

What does Distributed File System Provide?

- Provide access to and manipulation of data stored at remote servers using ***file system interfaces***
- What are the file system interfaces?
  - Open a file, check status on a file, close a file;
  - Read data from a file;
  - Write data to a file;
  - Lock a file or part of a file;
  - List files in a directory, delete a directory;
  - Delete a file, rename a file, add a symlink to a file;
  - i.e. POSIX interface

Why is DFS Useful?

- Data sharing of multiple users
- User mobility
- Data location transparency
- Data location independence
- Replications and increased availability

- Not all DFS are the same:
  - Local-area vs Wide area DFS
  - Fully Distributed FS vs DFS requiring central coordinator

File System vs Block-Level Interface

- Data are organized in files, which in turn are organized in directories
- Compare these with disk-level access or "block" access interface: [Read/Write, LUN, block#]
- Key differences:
  - Implementation of the directory/file structure and semantics
  - Synchronization

Buzz Words: NAS vs SAN

	NAS	SAN
Access Methods	File access	Disk block access
Access Medium	Ethernet	Fiber Channel and Ethernet
Transport Protocol	Layer over TCP/IP	SCSI/FC and SCSI/IP
Efficiency	Less	More
Sharing and Access Control	Good	Poor
Integrity demands	Strong	Very strong
Clients	Workstations	Database servers

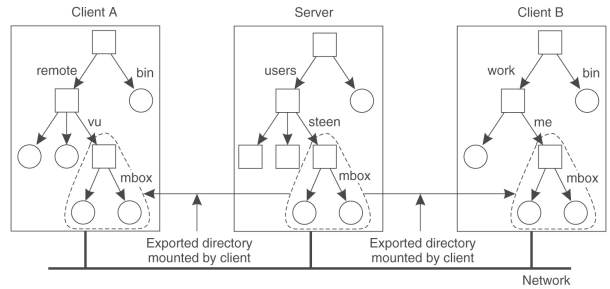
Naming of Distributed Files

- *Naming* – mapping between logical and physical objects.
- A *transparent* DFS hides the location where in the network the file is stored.
- **Location transparency** – file name does not reveal the file's physical storage location.
  - File name denotes a specific, hidden, set of physical disk blocks.
  - Convenient way to share data.
  - Could expose correspondence between component units and machines.
- **Location independence** – file name does not need to be changed when the file's physical storage location changes.
  - Better file abstraction.
  - Promotes sharing the storage space itself.
  - Separates the naming hierarchy from the storage-devices hierarchy.

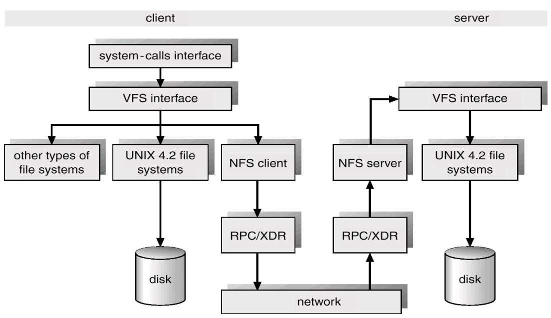
DFS - Three Naming Schemes

1. *Mount* remote directories to local directories, giving the appearance of a coherent local directory tree
   - *Mounted* remote directories can be accessed transparently.
   - Unix/Linux with NFS; Windows with mapped drives
2. Files named by combination of *host name* and *local name*;
   - Guarantees a unique system wide name
   - Windows *Network Places*, Apollo Domain
3. Total integration of component file systems.
   - A single global name structure spans all the files in the system.
   - If a server is unavailable, some arbitrary set of directories on different machines also becomes unavailable.
   - AFS

Mounting Remote Directories (NFS)



Mounting Remote Directories (NFS)



Mounting Remote Directories (NFS)

- Note:– *names* of files are not unique
  - As represented by *path names*
- E.g.,
  - Server A sees : */users/steen/mbox*
  - Client A sees: */remote/vu/mbox*
  - Client B sees: */work/me/mbox*
- Consequence:– Cannot pass file "names" around haphazardly

DFS - File Access Performance

- Reduce network traffic by retaining recently accessed disk blocks in local *cache*
- Repeated accesses to the same information can be handled locally.
  - All accesses are performed on the cached copy.
- If needed data not already cached, copy of data brought from the server to the local cache.
  - Copies of parts of file may be scattered in different caches.
- *Cache-consistency* problem – keeping the cached copies consistent with the master file.
  - Especially on write operations

DFS - File Caches

- In client memory
  - Performance speed up; faster access
  - Good when local usage is transient
  - Enables diskless workstations
- On client disk
  - Good when local usage dominates (e.g., AFS)
  - Caches larger files
  - Helps protect clients from server crashes

DFS - Cache Update Policies

- When does the client update the master file?
  - I.e. when is cached data written from the cache to the file?
- *Write-through* – write data through to disk ASAP
  - I.e., following *write*() or *put*(), same as on local disks.
  - Reliable, but poor performance.
- *Delayed-write* – cache and then write to the server later.
  - Write operations complete quickly; some data may be overwritten in cache, saving needless network I/O.
  - Poor reliability
    - unwritten data may be lost when client machine crashes
    - Inconsistent data
  - Variation – scan cache at regular intervals and flush *dirty* blocks.

DFS - File Consistency

- Is locally cached copy of the data consistent with the master copy?
- *Client*-initiated approach
  - Client initiates a validity check with server.
  - Server verifies local data with the master copy
    - E.g., time stamps, etc.
- *Server*-initiated approach
  - Server records (parts of) files cached in each client.
  - When server detects a potential inconsistency, it reacts

DFS - Remote Service vs Caching

- *Remote Service* – all file actions implemented by server.
  - RPC functions
  - Use for small memory diskless machines
  - Particularly applicable if large amount of write activity
- *Cached System*
  - Many "remote" accesses handled efficiently by the local cache
    - Most served as fast as local ones.
  - Servers contacted only occasionally
    - Reduces server load and network traffic.
    - Enhances potential for scalability.
  - Reduces total network overhead

DFS - File Server Semantics

- *Stateful* Service
- Client *opens* a file (as in Unix & Windows).
- Server fetches information about file from disk, stores in server memory,
  - Returns to client a *connection identifier* unique to client and open file.
  - Identifier used for subsequent accesses until session ends.
- Server must reclaim space used by no longer active clients.
- Increased performance; fewer disk accesses.
- Server retains knowledge about file
  - E.g., read ahead next blocks for sequential access
  - E.g., file locking for managing writes
    - Windows

DFS - File Server Semantics

- *Stateless* Service
  - Avoids *state* information in server by making each request self-contained.
  - Each request identifies the file and position in the file.
  - No need to establish and terminate a connection by open and close operations.
  - Poor support for locking or synchronization among concurrent accesses

DFS - Server Semantics Comparison

- Failure Recovery: S*tateful server* loses all volatile state in a crash.
  - Restore state by recovery protocol based on a dialog with clients.
  - Server needs to be aware of crashed client processes
    - orphan detection and elimination.
- Failure Recovery: *Stateless server* failure and recovery are almost unnoticeable.
  - Newly restarted server responds to self-contained requests without difficulty.

DFS - Server Semantics Comparison

- Penalties for using the robust stateless service: –
  - longer request messages
  - slower request processing
- Some environments require stateful service.
  - Server-initiated cache validation cannot provide stateless service.
  - File locking (one writer, many readers).

DFS - Replication

- *Replicas* of the same file reside on failure-independent machines.
- Improves availability and can shorten service time.
- Naming scheme maps a replicated file name to a particular replica.
  - Existence of replicas should be invisible to higher levels.
  - Replicas must be distinguished from one another by different lower-level names.
- Updates
  - Replicas of a file denote the same logical entity
  - Update to any replica *must* be reflected on all other replicas.

Two Popular DFS

- NFS: Network File System (from SUN)
- AFS: the Andrew File System

AFS - NFS Quick Comparison

- NFS: per-client linkage
  - Server: export /root/fs1/
  - Client: mount server:/root/fs1 /fs1 → fhandle
- AFS: global name space
  - Name space is organized into Volumes
    - Global directory /afs;
    - /afs/cs.wisc.edu/vol1/…; /afs/cs.stanfod.edu/vol1/…
  - Each file is identified as <vol_id, vnode#, vnode_gen>
  - All AFS servers keep a copy of "volume location database", which is a table of vol_id→ server_ip mappings

AFS - NFS Quick Comparison

- NFS: no transparency
- – If a directory is moved from one server to another, client must remount
- AFS: transparency
- – If a volume is moved from one server to another, only the volume location database on the servers needs to be updated
- – Implementation of volume migration
- – File lookup efficiency
- Are there other ways to provide location transparency?

More on NFS

- NFS is a **stateless** service
- Server retains no knowledge of client
  - Server crashes invisible to client
- All hard work done on client side
- Every operation provides *file handle*
- Server caching
  - Performance only
  - Based on recent usage
- Client caching
  - Client checks validity of caches files
  - Client responsible for writing out caches

More on NFS

- No locking! No synchronization!
- *Unix file semantics* not guaranteed
  - E.g., *read* after *write*
- *Session semantics* not even guaranteed
  - E.g., *open* after *close*
- Solution: *global lock manager*
  - Separate from NFS

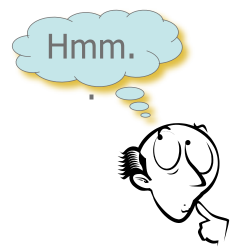
NSF Failure Recovery

- Server crashes are transparent to client
  - Each client request contains all information
  - Server can re-fetch from disk if not in its caches
  - Client retransmits request if interrupted by crash
    - (i.e., no response)
- Client crashes are transparent to server
  - Server maintains no record of which client(s) have cached files.

DFS Summary

- *Performance* is always an issue
  - Tradeoff between performance and the semantics of file operations (especially for shared files).
- *Caching* of file blocks is crucial in any file system, distributed or otherwise.
  - As memories get larger, most read requests can be serviced out of file buffer cache (local memory).
  - Maintaining coherency of those caches is a crucial design issue.
- Current research addressing disconnected file operation for mobile computers.

Any Questions?



Acknowledgements

- "Operating Systems Concepts" book and supplementary material by A. Silberschatz, P. Galvin and G. Gagne
- "Operating Systems: Internals and Design Principles" book and supplementary material by W. Stallings
- "Modern Operating Systems" book and supplementary material by A. Tanenbaum
- R. Doursat and M. Yuksel from UNR