Last Class: Distributed Systems and RPCs

- Servers export procedures for some set of clients to call
- To use the server, the client does a procedure call
- OS manages the communication

Today: Distributed File Systems

- One of the most common uses of distributed systems
- **Basic idea:**
  - Given a set of disks attached to different nodes.
  - share disks between nodes as if all the disks were attached to every node.
- **Examples:**
  - **Edlab:** One server node with all the disks, and a bunch of diskless workstations on a LAN.
  - **AppleShare:** Every node is both a server with a disk and a client.

Distributed File Systems: Issues

- Naming and Transparency
- Remote file access
- Caching
- Server with state or without
- Replication

Naming and Transparency

- **Issues**
  - How are files named?
  - Do file names reveal their location?
  - Do file names change if the file moves?
  - Do file names change if the *user* moves?
- **Location transparency:** the name of the file does not reveal the physical storage location.
- **Location independence:** The name of the file need not change if the file's storage location changes.
- Most naming schemes used in practice do not have location independence, but many have location transparency.

Naming Strategies: Absolute Names

- **Absolute names:** <machine name: path name>
- Examples: AppleShare, Win NT
- **Advantages:**
  - Finding a fully specified file name is simple.
  - It is easy to add and delete new names.
  - No global state.
  - Scales easily.
- **Disadvantages:**
  - User must know the complete name and is aware of which files are local and which are remote.
  - File is location dependent, and thus cannot move.
  - Makes sharing harder.
  - Not fault tolerant.

Naming Strategies: Mount Points

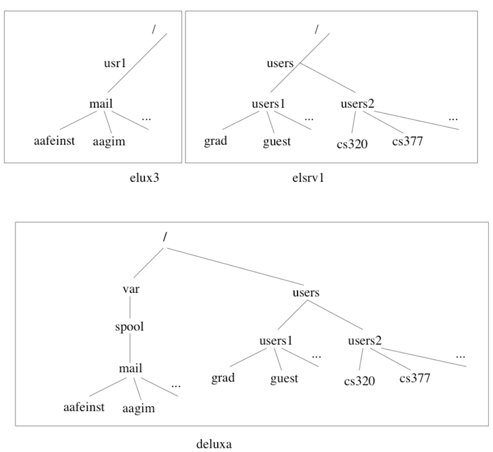
- Mount Points (NFS - Sun's Network File System)
  - Each host has a set of local names for remote locations.
  - Each host has a mount table (/etc/fstab) that specifies <remote path name @ machine name> and a <local path name>.
  - At boot time, the local name is bound to the remote name.
  - Users then refer to the <local path name> as if it were local, and the NFS takes care of the mapping
- **Advantages:** location transparent, remote name can change across reboots
- **Disadvantages:** single unified strategy hard to maintain, same file can have different names

NFS: Example

Partial contents of /etc/fstab for Edlab machines:

/usr1/mail@elux3.cs.umass.edu:/var/spool/mail
/users/users1@elsrv1:/users/users1
/users/users2@elsrv1:/users/users2
/users/users3@elsrv2:/users/users3
/users/users4@elsrv2:/users/users4
/courses/cs300@elsrv3:/courses/cs300
/rcf/mipsel/4.2/share@elsrv1:/exp/rcf/share
/rcf/common@elsrv1:/exp/rcf/common

NFS: Example



Naming Strategies: Global Name Space

- Single name space: CMU's Andrew and Berkeley's Sprite
  - No matter which node you are on, the file names are the same.
  - Set of workstation clients, and a set of dedicated file server machines.
  - When a client starts up, it gets its file name structure from a server.
  - As users access files, the server sends copies to the workstation and the workstation caches the files

Global Name Space

- **Advantages:**
  - Naming is consistent and easy to keep consistent.
  - The global name space insures all the files are the same regardless of where you login.
  - Since names are bound late, moving them is easier.
- **Disadvantages:**
  - It is difficult for the OS to keep file contents consistent due to caching.
  - Global name space may limit flexibility.
  - Performance problems.

Remote File Access and Caching

Once the user specifies a remote file, the OS can do the access either

1. remotely, on the server machine and then return the results using RPC (called *remote service*), or
2. can transfer the file (or part of the file) to the requesting host, and perform local accesses (called *caching*)

Caching Issues:

- Where and when are file blocks cached?
- When are modifications propagated back to the remote file?
- What happens if multiple clients cache the same file?

Remote File Access and Caching

Location

- Local disk
  - **Advantages:**
    - Access time reduced.
    - Safer if node fails.
  - **Disadvantages:**
    - Difficult to keep local copy consistent with remote copy.
    - Slower than just keeping it in local memory.
    - Requires client to have a disk.

Remote File Access and Caching

Location

- Local memory
  - **Advantages:** Quick access time.
  - **Disadvantages:**
    - Difficult to keep local copy consistent with remote copy.
    - Does not tolerate node failure well.
    - Limited cache size.
    - Works with diskless workstations.

Cache Update Policies

When to write local changes to the server has a central role in determining distributed file system performance.

- **Write through:** yields the most reliable results since every write hits the remote disk before the process continues, but it has the poorest performance.
  - Caching with write through is equivalent to using remote service for all writes, and exploits caching only for reads.
- **Write back:** yields the quickest response time since the write need only hit cache before the process continues.
  - It reduces network traffic and the number of writes to the disk for repeated writes to the same disk block, since only one of the writes will go across the network.
  - If a user machine crashes, the unwritten data is lost.
  - Write-back when file is closed, a block is evicted from cache, or every 30sec.

Cache Consistency

- **Client-initiated consistency:** Client contacts the server and asks if its copy is consistent with the server's copy.
  - Can check every access.
  - Can check at a given interval.
  - Can check only upon opening a file.
- **Server-initiated consistency:** Server detects potential conflicts and invalidates caches
  - Server needs to know:
    - which clients have cached which parts of which files.
    - which clients are readers and which are writers.

Server State and Replication

- Stateful versus stateless server
  - Web analogy
  - Tradeoff between performance and tolerence to crash faults
- Replication
  - Server data is replicated across machines
  - Need to ensure consistency of files when a file is updated on one server

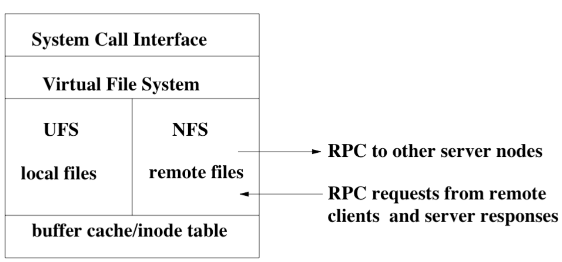
Case Study: Sun's Network File System

- NFS is the standard for distributed UNIX file access.
- NFS is designed to run on LANs (but works on WANs)
- Nodes are both servers and clients.
- Servers have no state (NFS v3 only; NFS v4 is stateful)
- Uses a mount protocol to make a global name local
  - /etc/exports lists the local names the server is willing to export.
  - /etc/fstab lists the global names that the local nodes import. A corresponding global name must be in /etc/exports on the server.

NFS Implementation

- NFS defines a set of RPC operations for remote file access:
  1. directory search, reading directory entries
  2. manipulating links and directories
  3. accessing file attributes
  4. reading/writing files
- Does not rely on node homogeneity - heterogeneous nodes must simply support the NFS mount and remote access protocols using RPC.
- Users may need to know different names depending upon the node to which they logon.

NFS Implementation



NFS Implementation

- NFS defines new layers in the Unix file system
- The virtual file system provides a standard interface, using vnodes as file handles. A vnode describes either a local file or a remote file.
- The ``buffer cache'' caches remote file blocks and attributes.
- On an *open*, the client asks the server whether its cached blocks are up to date.
- Once a file is open, different clients can write to it and get inconsistent data.
- Modified data is flushed back to the server every 30s.
- What file contents do new clients see?
  - Effects of last flush. Writers might have made changes but not updated remote file yet.
- What file contents do existing clients see?
  - For cached blocks, they see out of date info. For new blocks, same as new client

Summary

- Naming
  - Desire name independence, but it is difficult to attain
  - Location dependent names are most prevalent
- Speed up remote file access with caching
- Need to write changes back to disk