Distributed File Systems

Concepts & Overview

Goals and Criteria

- Goal: present to a user a coherent, efficient, and manageable system for long-term data storage in a distributed environment.

- Criteria:
  - Transparency: the degree to which the user is aware of the existence of the underlying distribution of data (naming schemes)
  - Performance: the difference in time between access to local vs. remote data (caching vs. remote operations)
  - Fault tolerance: the ability of the system to provide acceptable service in the presence of failures to clients, servers, and the network (stateful vs. stateless; replicas)
  - Scaleability: the ability of the system to exhibit sustained performance against increases in the number of users and the volume of data
  - Security: a guarantee that data access conforms to stated policies

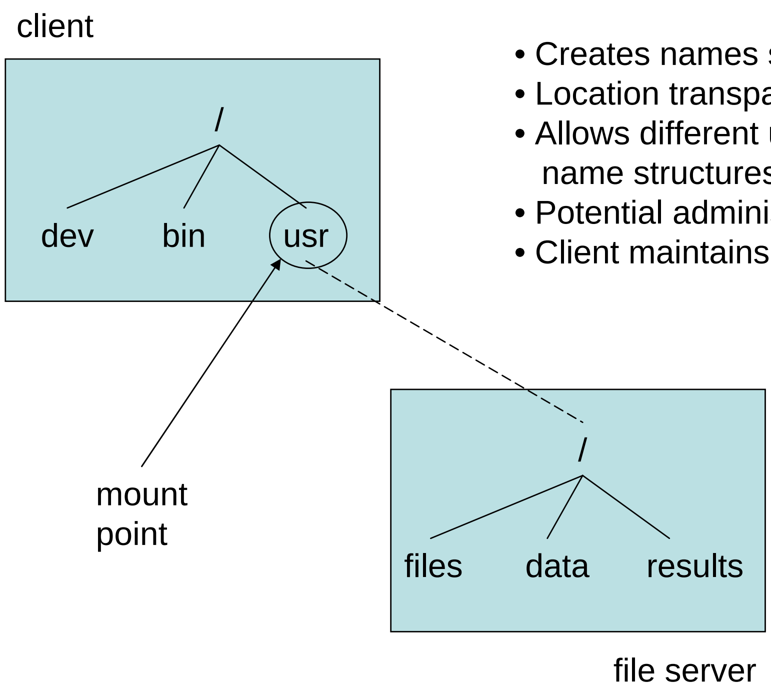
Transparency

- Network: the same interface is presented for access to local and non-local files
- Acess: the user has the same view of the file system regardless of the physical point of access
- Naming:
  - Location transparency (the name conveys no information about the location of the data)
  - Location independence (the name of a file need not be changed if/when the location of the file is changed)

Naming Schemes

- Location evident: *host-name::local-name*
- Mounting: assigning the root of a remote file system to an already accessible directory (e.g., NFS)
- Single image: all users see the same integrated name structure for all files (e.g., Sprite)

Mounting



- Creates names such as /usr/data
- Location transparent
- Allows different users to see different name structures
- Potential administrative costs
- Client maintains “mount table”

Semantics

- "Unix" semantics:
  - reflects familiar semantics of a non-distributed file system
  - Allows existing applications to be run without change
  - value read is the value stored by last write
  - writes to an open file are visible immediately to others that have this file opened concurrently
  - easy to implement if one server and no caching

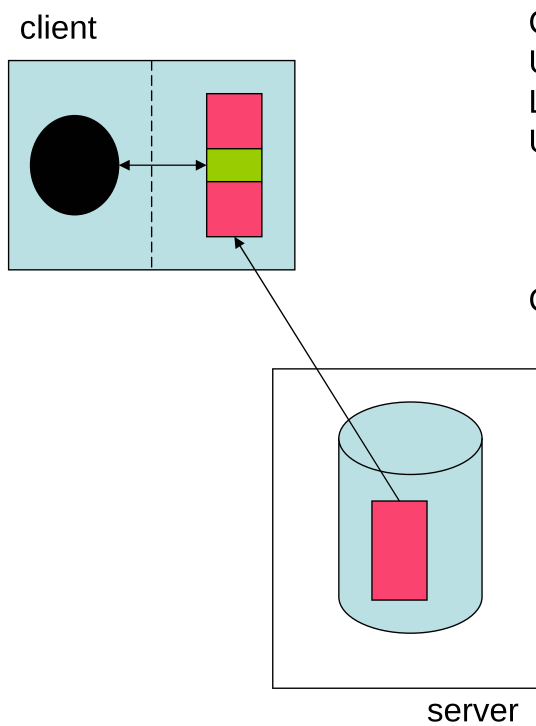
Semantics

- Session semantics
  - Acknowledges difficulty in reflecting changes immediately to other readers
  - Write to an open file are not immediately visible to remote readers (are visible to local readers)
  - Changes are visible to those readers who open the file after the file is closed by the writer (not visible to those reading concurrently with the writer)

Semantics

- Immutable shared files
  - A shared file cannot be changed
  - File names cannot be reused
  - Simple to implement
- Transaction:
  - Operations conform to ACID properties
  - Requires greater system support

Caching



Caching vs. remote service
Units of caching: block or file
Local cache: disk or memory
Update policy:
- Write through
- Delayed write
- Write-on-close

Consistency
- Client initiated validity check
- Server-initiated callback
- Leases

Disk vs. Memory Caches

- Disk caches
  - More reliable (survive failures)
  - Avoids reloading on recovery
- Memory caches
  - Allow diskless workstations
  - Faster access on client machine
  - Since servers use memory caching, allows a single uniform mechanism

Update policy

- Write-through
  - reliable: little loss of information in the event of a client failures
  - slow: defeats purpose of cache
- Delayed-write
  - Optimizes network traffic for successive writes to same/nearby blocks
  - Avoids overhead for data that will be overwritten (20-30% of data is deleted within 30 seconds)
- Write-on-close
  - Works best for files open for a short period
  - Susceptible to loss of data for files in long use

Fault Tolerance:
Stateful vs. Stateless Servers

- Stateful
  - Server maintains information about a file opened by a client (e.g., file pointer, mode)
  - Mechanism: on open, the server provides a “handle” to the client to use on subsequent operations
- Stateless
  - Server maintains no information about client access to files
  - Mechanism: each client operation must provide context information for that operation

Comparison

- Failure recovery
  - Stateful server looses its state information
    - Recovery protocol needed to restablish synchronization with clients or abort client operations
    - Server needs to know of client failures so that it can discard state information
  - Stateless server
    - Server failure/recover transparent to client
    - Recovered server can respond to self-contained client request

Comparison

- Costs for stateless service
  - Longer messages (to carry state information)
  - Slower processing of requests (to recreate state)
- Stateless service not always possible
  - Incompatible with some caching policies (e.g., server initiated cache invalidation)
  - Some operations inherently stateful (e.g, Unix file offset style file operations)

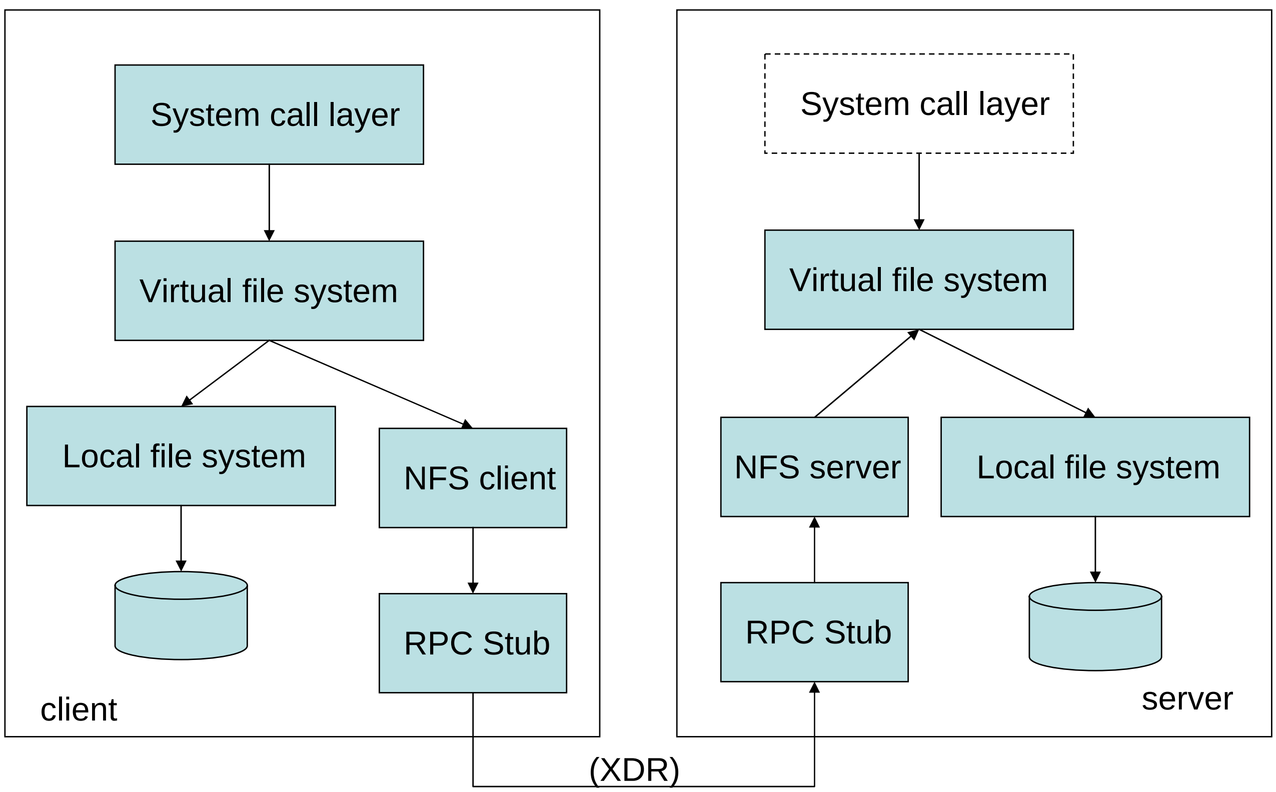
Fault Tolerance: Replication

- Purpose
  - Improve reliability/availability (one replica always available)
  - Allow load balancing among servers
- Issues
  - Replica transparency
    - replicas must be invisible to higher levels
    - replicas must be distinguishable at lower levels
  - Replica consistency
    - server failure or
    - network partition

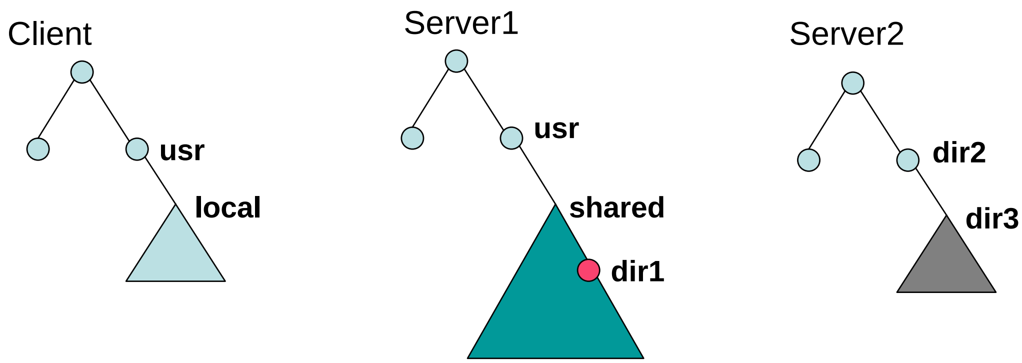
Sun NFS

- File system sharing among networked workstations in a client-server model
- Each workstation may be both a client and a server (no dedicated role)
- Services defined for implementation on heterogeneous architectures and file systems using machine-independent protocol
- Key protocols:
  - Mount (define hierarchical structure)
  - NFS (read/write operations)
- Employs stateless operations (until V4)

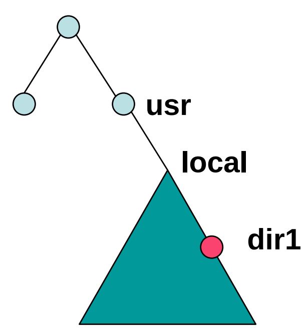
NFS Architecture



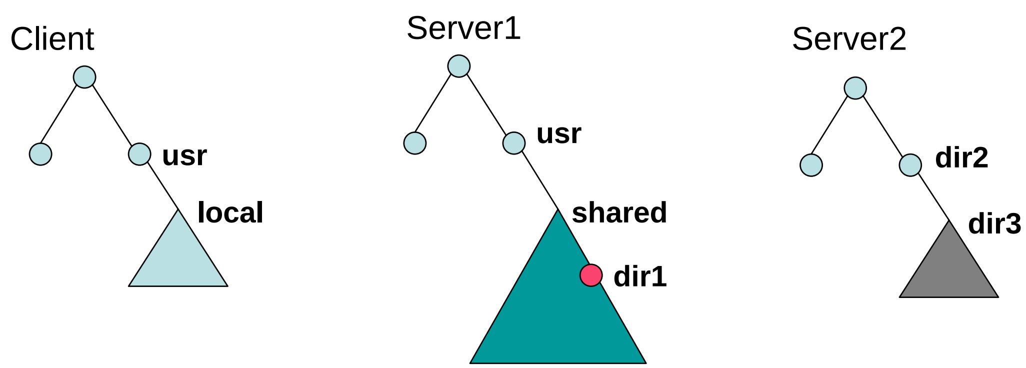
Mounting



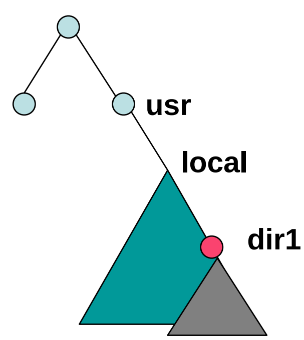
Mount Server1:/usr/shared on client:/usr/local



Mounting



Mount Server2:/dir2/dir3 on client:/usr/local/dir1



Mount Protocol

- Mount operation specifies remote file system and local directory mount point
  - Request translated to RPC and forwarded to server
  - Server maintains export list: local file systems it will allow to be mounted and clients that can mount them
- Server returns file handle that uniquely identifies the exported file system to the server.
- Mount operation does not change server's view of the file system – only the clients view is changed.

NFS Protcol

- Provides a set of RPCs for name translation and file manipulation (reading and writing)
- Path-name translation:
  - Separate NFS lookup performed on each component of path name
  - Client side cache used to speed-up lookup operation
- Uses remote service paradigm