

# Today: Distributed File Systems

- Overview of stand-alone (UNIX) file systems
- Issues in distributed file systems
- Next two classes: case studies of distributed file systems
  - NFS
  - Coda
  - xFS
  - Log-structured file systems (time permitting)
  - object storage systems



## File System Basics

- File: named collection of logically related data
  - Unix file: an uninterpreted sequence of bytes
- File system:
  - Provides a logical view of data and storage functions
  - User-friendly interface
  - Provides facility to create, modify, organize, and delete files
  - Provides sharing among users in a controlled manner
  - Provides protection



# Unix File System Review

- User file: linear array of bytes. No records, no file types
- Directory: special file not directly writable by user
- File structure: directed acyclic graph [directories may not be shared, files may be shared (*why?*) ]
- Directory entry for each file
  - File name
  - inode number
  - Major device number
  - Minor device number
- All inodes are stored at a special location on disk [super block]
  - Inodes store file attributes and a multi-level index that has a list of disk block locations for the file



## Inode Structure

- Fields
  - Mode
  - Owner\_ID, group\_id
  - Dir\_file
  - Protection bits
  - Last access time, last write time, last inode time
  - Size, no of blocks
  - Ref\_cnt
  - Address[0], ... address[14]
    - Multi-level index: 12 direct blocks, one single, double, and triple indirect blocks

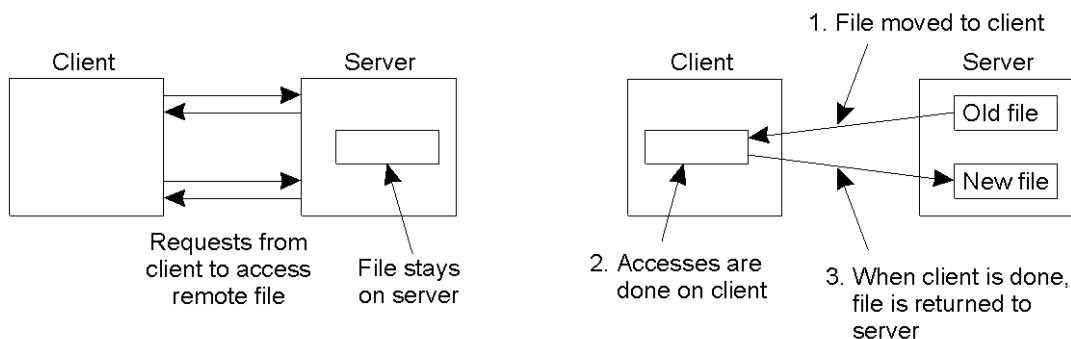


# Distributed File Systems

- *File service*: specification of what the file system offers
  - Client primitives, application programming interface (API)
- *File server*: process that implements file service
  - Can have several servers on one machine (UNIX, DOS,...)
- Components of interest
  - File service
  - Directory service



## File Service



- Remote access model
  - Work done at the server
- Stateful server (e.g., databases)
- Consistent sharing (+)
- Server may be a bottleneck (-)
- Need for communication (-)
- Upload/download mode
  - Work done at the client
- Stateless server
- Simple functionality (+)
- Moves files/blocks, need storage (-)



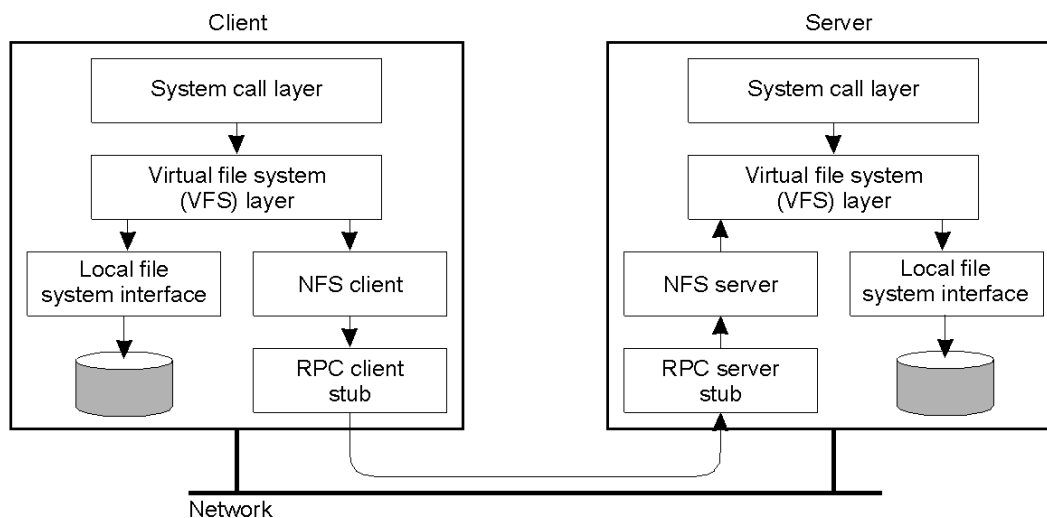
# System Structure: Server Type

- Stateless server
  - No information is kept at server between client requests
  - All information needed to service a requests must be provided by the client with each request (*what info?*)
  - More tolerant to server crashes
- Stateful server
  - Server maintains information about client accesses
  - Shorted request messages
  - Better performance
  - Idempotency easier
  - Consistency is easier to achieve



## NFS Architecture

- Sun's Network File System (NFS) – widely used distributed file system
- Uses the virtual file system layer to handle local and remote files

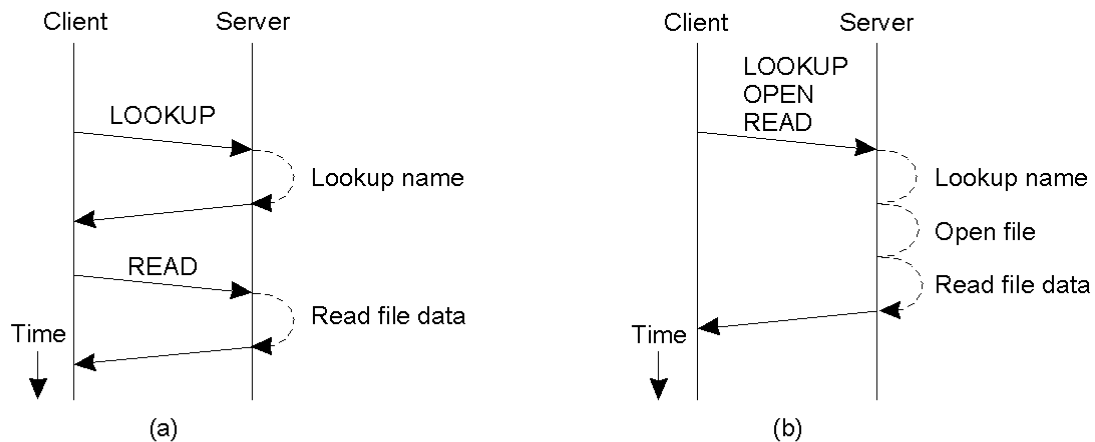


# NFS Operations

Operation	v3	v4	Description
Create	Yes	No	Create a regular file
Create	No	Yes	Create a nonregular file
Link	Yes	Yes	Create a hard link to a file
Symlink	Yes	No	Create a symbolic link to a file
Mkdir	Yes	No	Create a subdirectory in a given directory
Mknod	Yes	No	Create a special file
Rename	Yes	Yes	Change the name of a file
Rmdir	Yes	No	Remove an empty subdirectory from a directory
Open	No	Yes	Open a file
Close	No	Yes	Close a file
Lookup	Yes	Yes	Look up a file by means of a file name
Readdir	Yes	Yes	Read the entries in a directory
Readlink	Yes	Yes	Read the path name stored in a symbolic link
Getattr	Yes	Yes	Read the attribute values for a file
Setattr	Yes	Yes	Set one or more attribute values for a file
Read	Yes	Yes	Read the data contained in a file
Write	Yes	Yes	Write data to a file



## Communication



- a) Reading data from a file in NFS version 3.
- b) Reading data using a compound procedure in version 4.

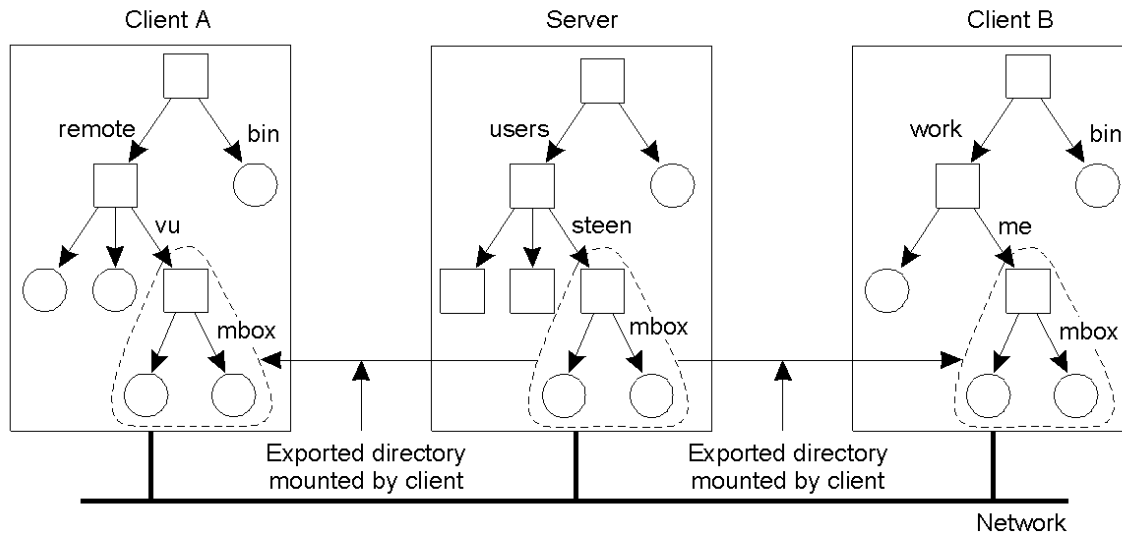
Both versions use Open Network Computing (ONC) RPCs

- One RPC per operation (NFS v3); multiple operations supported in v4.



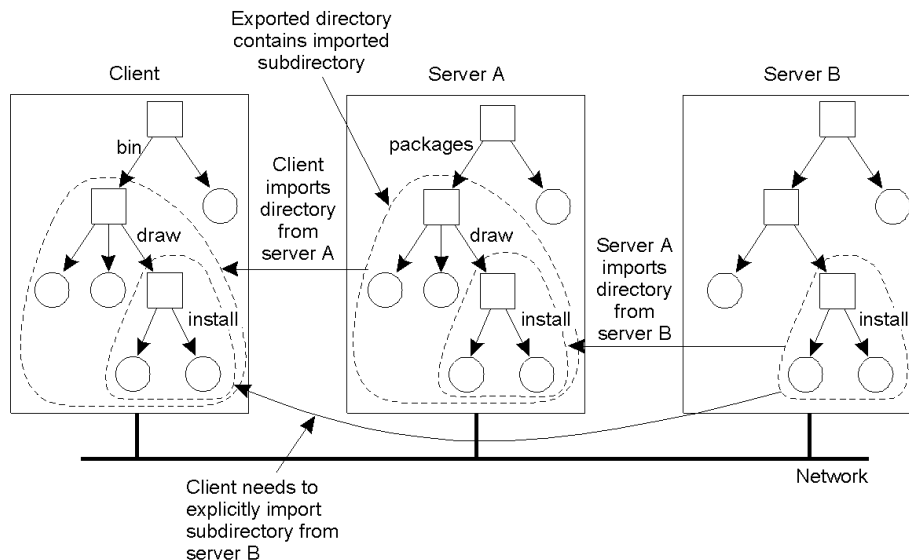
# Naming: Mount Protocol

- NFS uses the mount protocol to access remote files
  - Mount protocol establishes a local name for remote files
  - Users access remote files using local names; OS takes care of the mapping

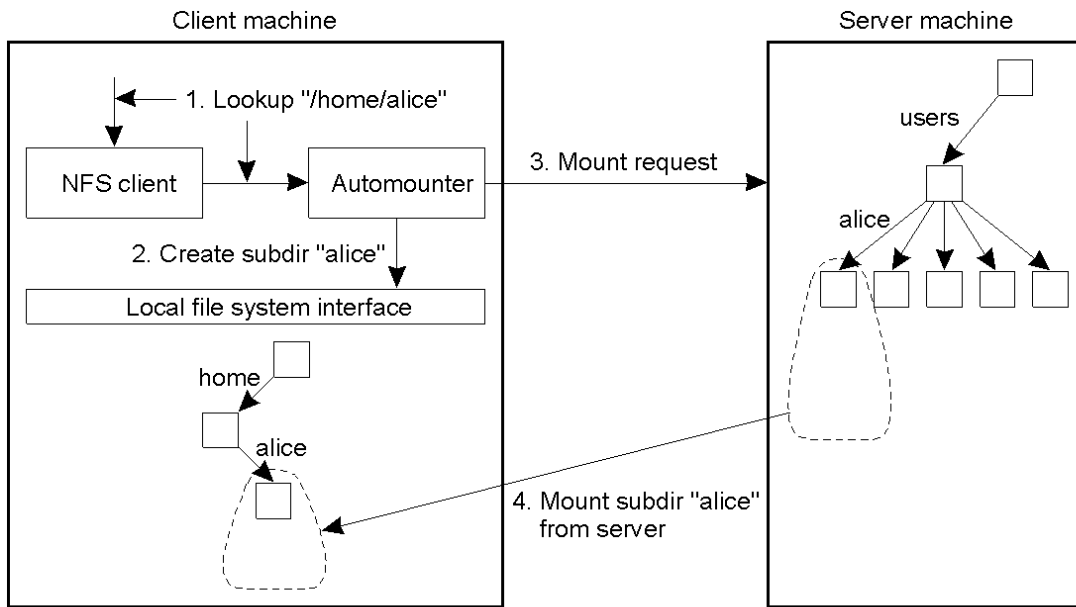


# Naming: Crossing Mount Points

- Mounting nested directories from multiple servers
- NFS v3 does not support transitive exports (for security reasons)
  - NFS v4 allows clients to detect crossing of mount points, supports recursive lookups



# Automounting



- Automounting: mount on demand



# File Attributes (1)

Attribute	Description
TYPE	The type of the file (regular, directory, symbolic link)
SIZE	The length of the file in bytes
CHANGE	Indicator for a client to see if and/or when the file has changed
FSID	Server-unique identifier of the file's file system

- Some general mandatory file attributes in NFS.
  - NFS modeled based on Unix-like file systems
    - Implementing NFS on other file systems (Windows) difficult
  - NFS v4 enhances compatibility by using mandatory and recommended attributes



# File Attributes (2)

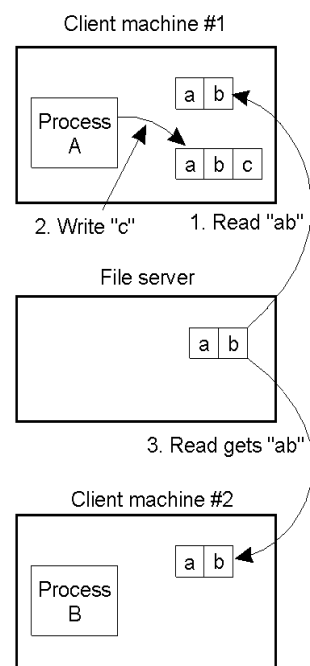
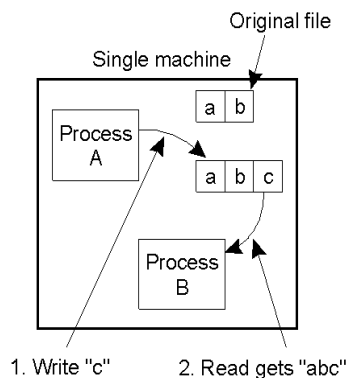
Attribute	Description
ACL	an access control list associated with the file
FILEHANDLE	The server-provided file handle of this file
FILEID	A file-system unique identifier for this file
FS_LOCATIONS	Locations in the network where this file system may be found
OWNER	The character-string name of the file's owner
TIME_ACCESS	Time when the file data were last accessed
TIME_MODIFY	Time when the file data were last modified
TIME_CREATE	Time when the file was created

- Some general recommended file attributes.



## Semantics of File Sharing

- On a single processor, when a *read* follows a *write*, the value returned by the *read* is the value just written.
- In a distributed system with caching, obsolete values may be returned.





# Semantics of File Sharing

Method	Comment
UNIX semantics	Every operation on a file is instantly visible to all processes
Session semantics	No changes are visible to other processes until the file is closed
Immutable files	No updates are possible; simplifies sharing and replication
Transaction	All changes occur atomically

- Four ways of dealing with the shared files in a distributed system.
  - NFS implements session semantics
    - Can use remote/access model for providing UNIX semantics (expensive)
    - Most implementations use local caches for performance and provide session semantics



## File Locking in NFS

Operation	Description
Lock	Creates a lock for a range of bytes (non-blocking_
Lockt	Test whether a conflicting lock has been granted
Locku	Remove a lock from a range of bytes
Renew	Renew the lease on a specified lock

- NFS supports file locking
  - Applications can use locks to ensure consistency
  - Locking was not part of NFS until version 3
  - NFS v4 supports locking as part of the protocol (see above table)



# File Locking: Share Reservations

**Current file denial state**

	NONE	READ	WRITE	BOTH
Request access	Succeed	Fail	Succeed	Fail
WRITE	Succeed	Succeed	Fail	Fail
BOTH	Succeed	Fail	Fail	Fail

(a)

**Requested file denial state**

	NONE	READ	WRITE	BOTH
Current access state	Succeed	Fail	Succeed	Fail
WRITE	Succeed	Succeed	Fail	Fail
BOTH	Succeed	Fail	Fail	Fail

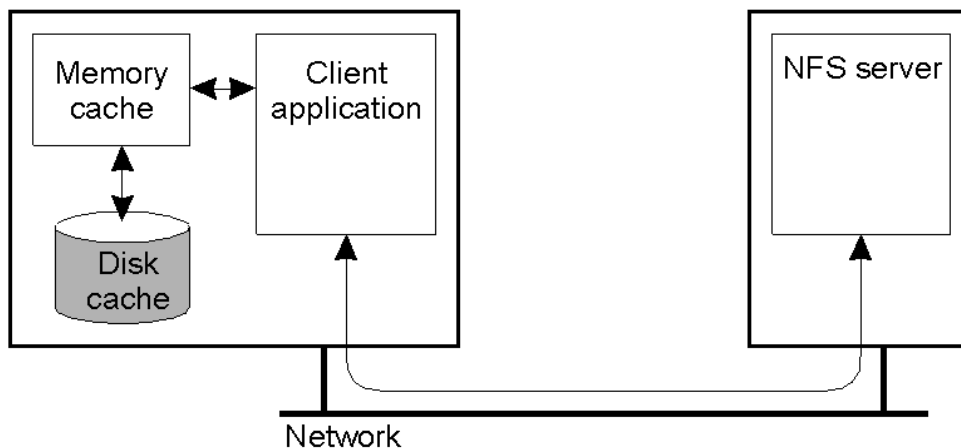
(b)

- The result of an *open* operation with share reservations in NFS.
- a) When the client requests shared access given the current denial state.
- b) When the client requests a denial state given the current file access state.



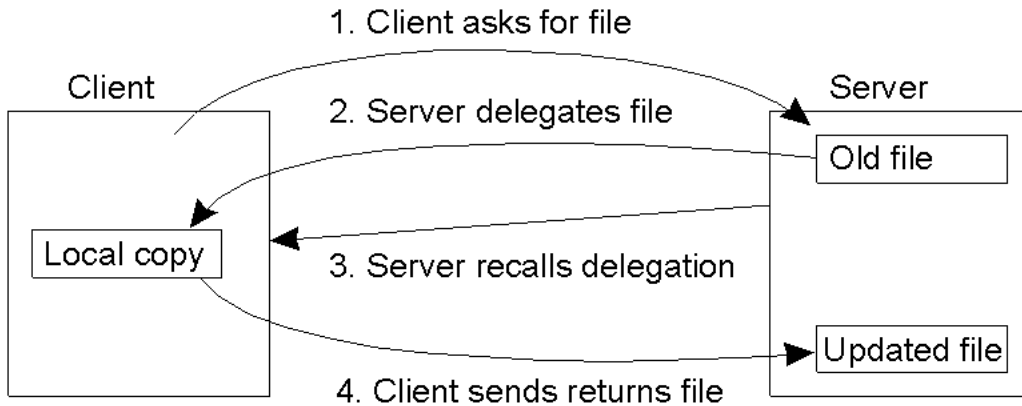
## Client Caching

- Client-side caching is left to the implementation (NFS does not prohibit it)
  - Different implementation use different caching policies
    - Sun: allow cache data to be stale for up to 30 seconds

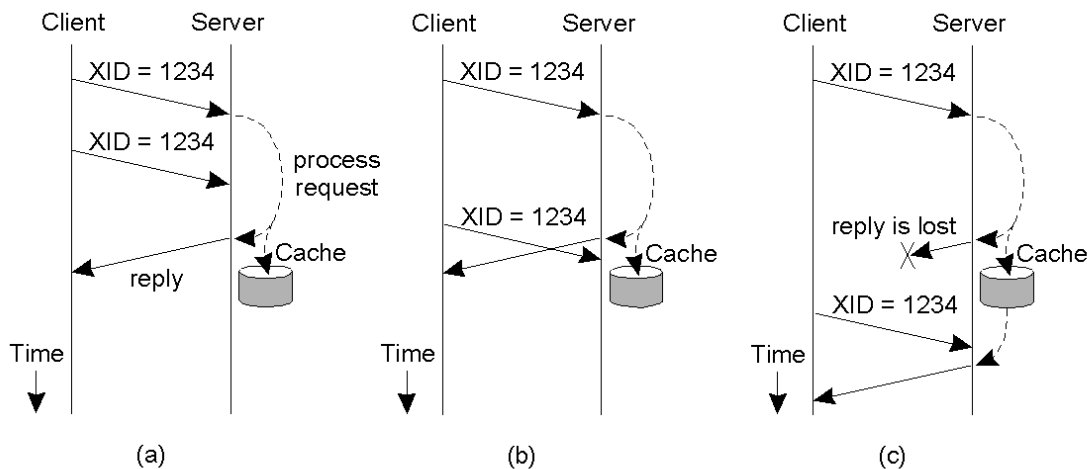


# Client Caching: Delegation

- NFS V4 supports open delegation
  - Server delegates local open and close requests to the NFS client
  - Uses a callback mechanism to recall file delegation.



# RPC Failures



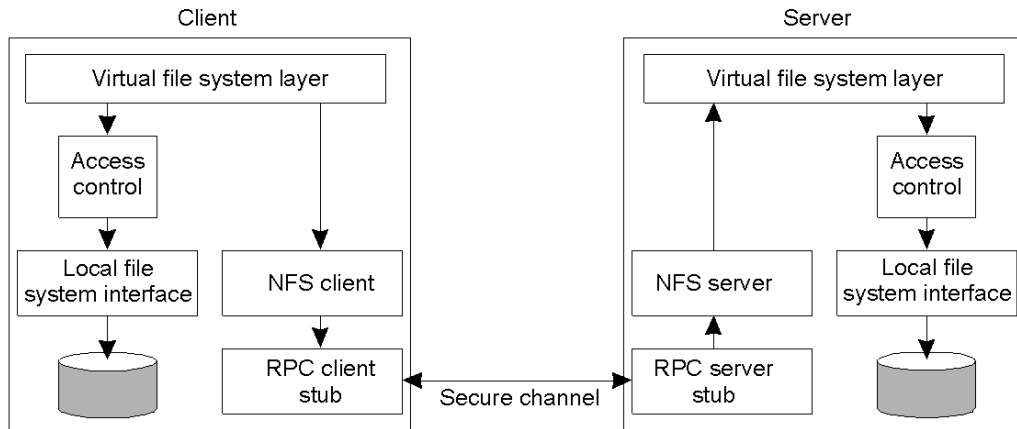
- Three situations for handling retransmissions: use a duplicate request cache
  - The request is still in progress
  - The reply has just been returned
  - The reply has been some time ago, but was lost.

**Use a duplicate-request cache: transaction Ids on RPCs, results cached**

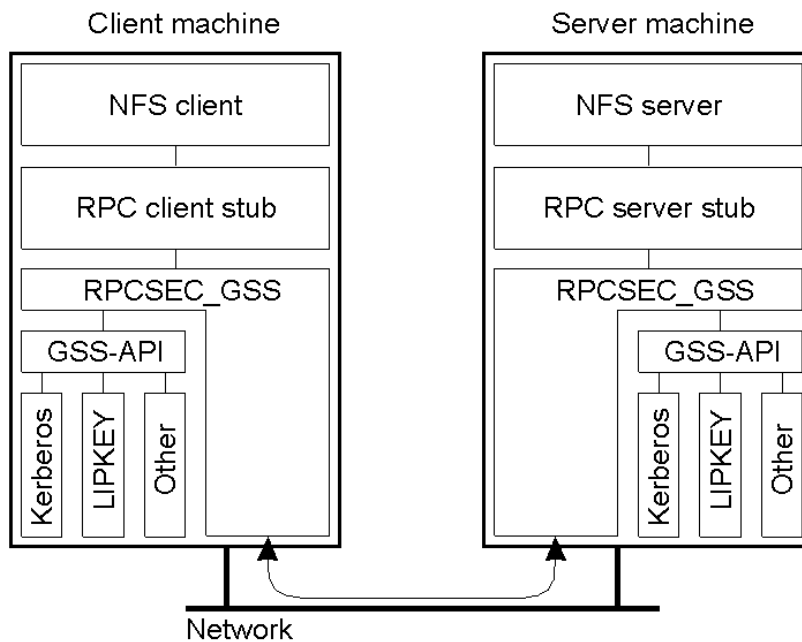


# Security

- The NFS security architecture.
  - Simplest case: user ID, group ID authentication only



# Secure RPCs



- Secure RPC in NFS version 4.



# Replica Servers

- NFS ver 4 supports replications
- Entire file systems must be replicated
- FS\_LOCATION attribute for each file
- Replicated servers: implementation specific

