Distributed Systems
Principles and Paradigms

Maarten van Steen

VU Amsterdam, Dept. Computer Science
steen@cs.vu.nl

Chapter 11: Distributed File Systems

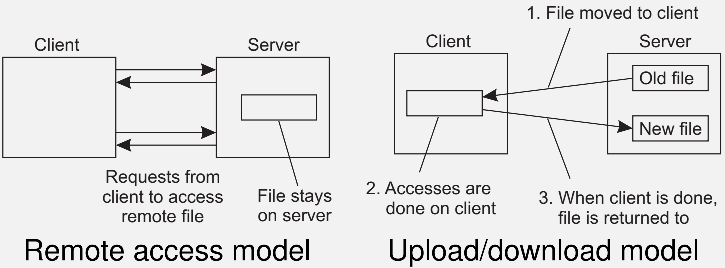
Version: December 10, 2012

vrije Universiteit amsterdam

Distributed File Systems

General goal

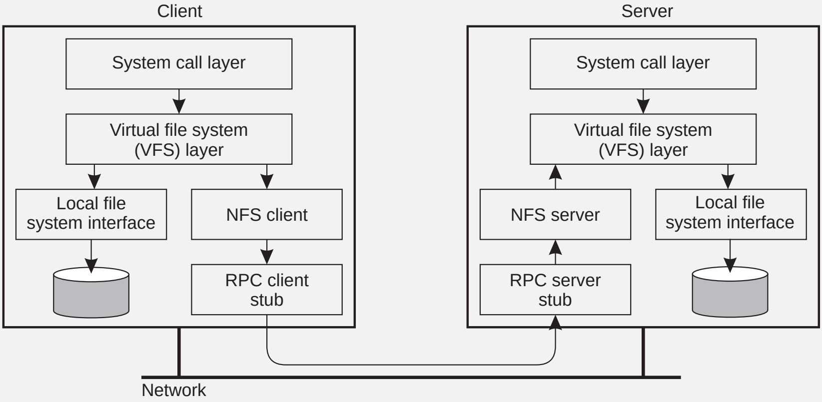
Try to make a file system transparently available to remote clients.



Example: NFS Architecture

NFS

NFS is implemented using the Virtual File System abstraction, which is now used for lots of different operating systems.



Example: NFS Architecture

Essence

VFS provides standard file system interface, and allows to hide difference between accessing local or remote file system.

Question

Is NFS actually a file system?

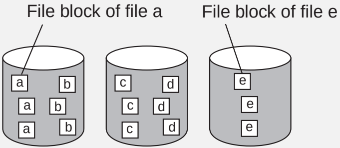
NFS File Operations

Oper.	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
Mknod	Yes	No	Create a special file
Rename	Yes	Yes	Change the name of a file
Remove	Yes	Yes	Remove a file from a file system
Rmdir	Yes	No	Remove an empty subdirectory
Open	No	Yes	Open a file
Close	No	Yes	Close a file
Lookup	Yes	Yes	Look up a file by means of a name
Readdir	Yes	Yes	Read the entries in a directory
Readlink	Yes	Yes	Read the path name in a symbolic link
Getattr	Yes	Yes	Get the attribute values for a file
Setattr	Yes	Yes	Set one or more file-attribute values
Read	Yes	Yes	Read the data contained in a file
Write	Yes	Yes	Write data to a file

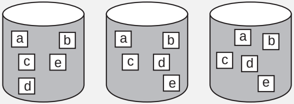
Cluster-Based File Systems

Observation

With very large data collections, following a simple client-server approach is not going to work ⇒ for speeding up file accesses, apply striping techniques by which files can be fetched in parallel.

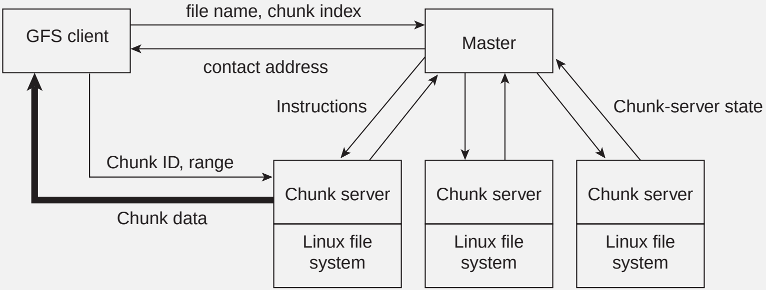


Whole-file distribution



File-striped system

Example: Google File System

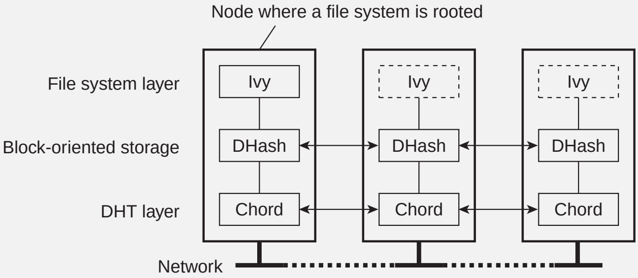


The Google solution

Divide files in large 64 MB chunks, and distribute/replicate chunks across many servers:

- The master maintains only a (file name, chunk server) table in main memory $\Rightarrow$ minimal I/O
- Files are replicated using a primary-backup scheme; the master is kept out of the loop

P2P-based File Systems



Basic idea

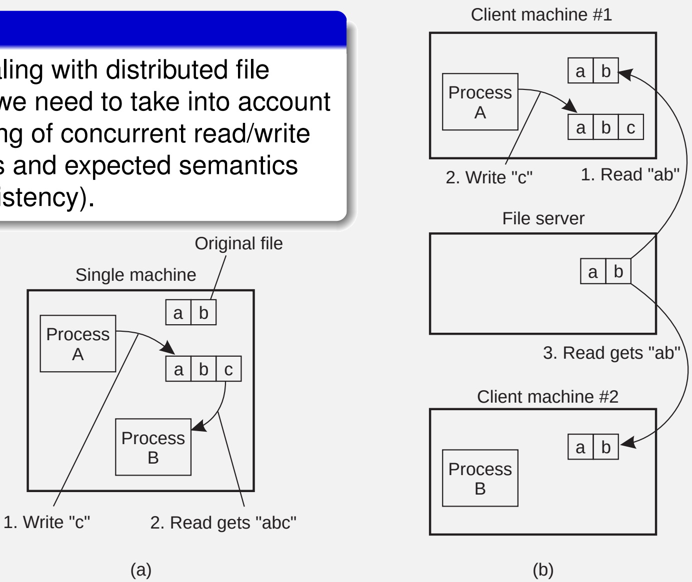
Store data blocks in the underlying P2P system:

- Every data block with content D is stored on a node with hash $h(D)$. Allows for integrity check.
- Public-key blocks are signed with associated private key and looked up with public key.
- A local log of file operations to keep track of $\langle blockID, h(D) \rangle$ pairs.

File sharing semantics

Problem

When dealing with distributed file systems, we need to take into account the ordering of concurrent read/write operations and expected semantics (i.e., consistency).



File sharing semantics

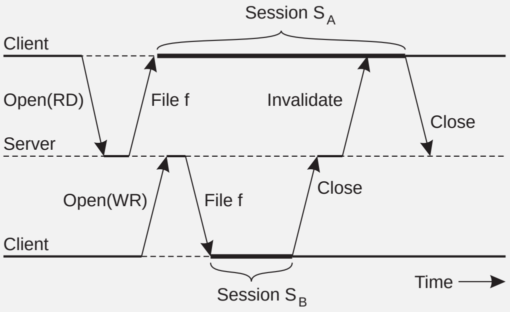
Semantics

- UNIX semantics: a *read* operation returns the effect of the last *write* operation $\Rightarrow$ can only be implemented for remote access models in which there is only a single copy of the file
- Transaction semantics: the file system supports transactions on a *single* file $\Rightarrow$ issue is how to allow concurrent access to a physically distributed file
- Session semantics: the effects of *read* and *write* operations are seen only by the client that has opened (a local copy) of the file $\Rightarrow$ what happens when a file is closed (only one client may actually win)

Example: File sharing in Coda

Essence

Coda assumes transactional semantics, but without the full-fledged capabilities of real transactions. Note: Transactional issues reappear in the form of "this ordering could have taken place."



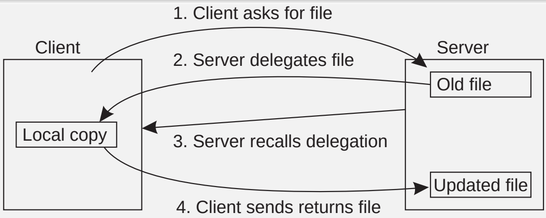
Consistency and replication

Observation

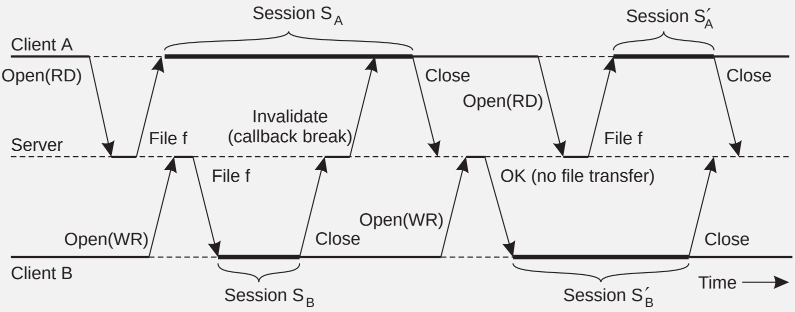
In modern distributed file systems, client-side caching is the preferred technique for attaining performance; server-side replication is done for fault tolerance.

Observation

Clients are allowed to keep (large parts of) a file, and will be notified when control is withdrawn $\Rightarrow$ servers are now generally stateful



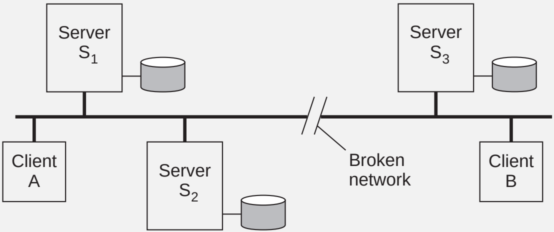
Example: Client-side caching in Coda



Note

By making use of transactional semantics, it becomes possible to further improve performance.

Example: Server-side replication in Coda



Main issue

Ensure that concurrent updates are detected:

- Each client has an Accessible Volume Storage Group (AVSG): is a subset of the actual VSG.
- Version vector $CVV_i(f)[j] = k \Rightarrow S_i$ knows that S_j has seen version k of f.
- Example: A updates $f \Rightarrow S_1 = S_2 = [+1, +1, +0]$; B updates $f \Rightarrow S_3 = [+0, +0, +1]$.