

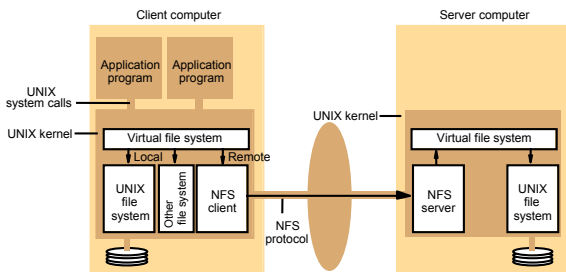
CS 5523 Lecture 24: Andrew versus NFS versus Laboratory 2

- Questions on Laboratories 3 and 4
- NFS architecture
- NFS implementation
- NFS scorecard
- Andrew architecture
- Andrew implementation
- Andrew scorecard
- How is Laboratory 2 related to NFS and Andrew?

NFS Overview (Sun OS implementation)

- NFS Protocol – set of remote procedure calls for clients to perform operations on remote files
- NFS server resides in kernel and responds to RPC requests
- Based on SUN RPC protocol
- Portmapper enables clients to bind to services in a given host by name
- Any process can send requests, but must provide valid user credentials

Figure 8.8
NFS architecture



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Figure 8.9
NFS server operations (simplified) – 1

<code>lookup(dirfh, name) -> fh, attr</code>	Returns file handle and attributes for the file <i>name</i> in the directory <i>dirfh</i> .
<code>create(dirfh, name, attr) -> newfh, attr</code>	Creates a new file <i>name</i> in directory <i>dirfh</i> with attributes <i>attr</i> and returns the new file handle and attributes.
<code>remove(dirfh, name) -> status</code>	Removes file <i>name</i> from directory <i>dirfh</i> .
<code>getattr(fh) -> attr</code>	Returns file attributes of file <i>fh</i> . (Similar to the UNIX <i>stat</i> system call.)
<code>setattr(fh, attr) -> attr</code>	Sets the attributes (mode, user id, group id, size, access time and modify time) of a file. Setting the size to 0 truncates the file.
<code>read(fh, offset, count) -> attr, data</code>	Returns up to <i>count</i> bytes of data from a file starting at <i>offset</i> . Also returns the latest attributes of the file.
<code>write(fh, offset, count, data) -> attr</code>	Writes <i>count</i> bytes of data to a file starting at <i>offset</i> . Returns the attributes of the file after the write has taken place.
<code>rename(dirfh, name, todirfh, toname) -> status</code>	Changes the name of file <i>name</i> in directory <i>dirfh</i> to <i>toname</i> in directory <i>todirfh</i> .
<code>link(newdirfh, newname, dirfh, name) -> status</code>	Creates an entry <i>newname</i> in the directory <i>newdirfh</i> which refers to file <i>name</i> in the directory <i>dirfh</i> .

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Figure 8.9
NFS server operations (simplified) – 2

<code>symlink(newdirfh, newname, string) -> status</code>	Creates an entry <i>newname</i> in the directory <i>newdirfh</i> of type symbolic link with the value <i>string</i> . The server does not interpret the <i>string</i> but makes a symbolic link file to hold it.
<code>readlink(fh) -> string</code>	Returns the string that is associated with the symbolic link file identified by <i>fh</i> .
<code>mkdir(dirfh, name, attr) -> newfh, attr</code>	Creates a new directory <i>name</i> with attributes <i>attr</i> and returns the new file handle and attributes.
<code>rmdir(dirfh, name) -> status</code>	Removes the empty directory <i>name</i> from the parent directory <i>dirfh</i> . Fails if the directory is not empty.
<code>readdir(dirfh, cookie, count) -> entries</code>	Returns up to <i>count</i> bytes of directory entries from the directory <i>dirfh</i> . Each entry contains a file name, a file handle, and an opaque pointer to the next directory entry, called a <i>cookie</i> . The <i>cookie</i> is used in subsequent <i>readdir</i> calls to start reading from the following entry. If the value of <i>cookie</i> is 0, reads from the first entry in the directory.
<code>statfs(fh) -> fsstats</code>	Returns file system information (such as block size, number of free blocks and so on) for the file system containing a file <i>fh</i> .

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Virtual file system

- part of Unix kernel
- makes access to local and remote files transparent
- translates between Unix file identifiers and NFS file handles
- keeps track of filesystems that are currently available both locally and remotely
- NFS file handles:
 - filesystem ID
 - i-node number
 - i-node generation number
- filesystems are mounted
- The VFS keeps a structure for each mounted file system

NFS Client Module

- part of Unix kernel
- allows user programs to access files via UNIX system calls without recompilation or reloading
- one module serves all user-level processes
- a shared cache holds recently used blocks
- the encryption key for authentication of user IDs is kept in the kernel

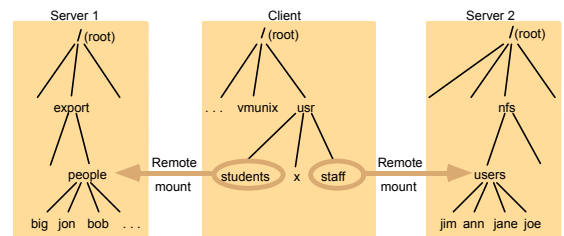
Access control and authentication

- The NFS server is stateless
- User identity is checked with each request
- Because the underlying RPC protocol uses a well-known port, any one can impersonate anyone else
- DES encryption of user security information can be used
- Kerberos has also been integrated recently

NFS mount service

- remote file systems can be mounted in directory trees of clients
- each system has an `/etc/exports` listing filesystems available for remote mounting with list of allowed hosts
- clients use modified mount protocol
- with hard-mounted filesystems, user process is suspended until request completes
- with soft-mounted filesystems, NFS returns a failure indication after a small number of retries

Figure 8.10
Local and remote file systems accessible on an NFS client



Note: The file system mounted at `/usr/students` in the client is actually the sub-tree located at `/export/people` in Server 1; the file system mounted at `/usr/staff` in the client is actually the sub-tree located at `/nfs/users` in Server 2.

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NFS path translation

- pathnames are translated in a step by step procedure by the client
- the file handle used for one step is used as a parameter at next lookup

What type of navigation does this correspond to?

Server caching

- Read-ahead – fetches the pages following those that have been recently read
- Delayed-write – doesn't write out disk blocks until the cache buffer is needed for something else
- The UNIX sync flushes altered pages to disk every 30 seconds
- NFS commit operation forces the blocks of a file to be written in delayed-write mode
- NFS also offers write-through caching – block is written to disk before the reply is sent back to client

What problems occur with delayed-write?

What problems occur with write-through?

Client caching (reads)

- Client caching can result in inconsistent files. Why?
- NFS uses timestamped validation of cache blocks:
 - ┆ T_c is time block last validated
 - ┆ T_m is time when block was last modified at the server
 - ┆ t is the freshness interval (set adaptively for individual files 3 to 30 secs)
 - ┆ T is current timeIf $(T - T_c < t)$ or $(T - T_c \geq t$ and $T_m \text{ client} = T_m \text{ server})$, file is okay
- Validation check is made a client with each access
- When a new value to T_m is received for a file, it is applied to all blocks
- Current attributes are piggy-backed on other requests

Client caching (writes)

- Modified pages are marked as dirty and flushed at next sync
- Bio-daemons (block input-output) perform read-ahead and delayed-write
 - ┆ notified when client reads a block to get next blocks
 - ┆ notified when client fills a block then writes it out

NFS optimizations

- Use UNIX BSD Fast File Systems with 8K blocks
- Use UDP with 8K blocks
- Allows clients and servers to negotiate larger block sizes

NFS scorecard?

- Transparency
 - ┆ access transparency
 - ┆ location transparency
 - ┆ mobility transparency
 - ┆ performance transparency
 - ┆ scaling transparency
- Concurrency control possibility with support for transactions
- Replication
- Fault tolerance
- Heterogeneity
- Security
- Consistency

Andrew

- Based on whole-file serving
 - Supports whole-file caching
 - Designed to support a large number of simultaneous users
 - Based on the following assumptions about access:
 - ┆ Most files are small (< 10 K)
 - ┆ Reads are more common than writes (6:1)
 - ┆ Sequential access is common
 - ┆ Most files are accessed by only one user
 - ┆ Files are referenced in bursts
- What are the implications of these characteristics for performance of whole-file serving and caching?
- What kinds of files do not have these characteristics?

Andrew scenario

- User process issues an open and there is not a current copy of the file in the client cache.
- The client sends a request to the server for the whole file and stores it as a local file in a local file system (client cache).
- An open is then performed on the local file
- Subsequent operations work on the local file
- When the client issues a close, the entire file is written back, but the copy is still kept on the client machine.

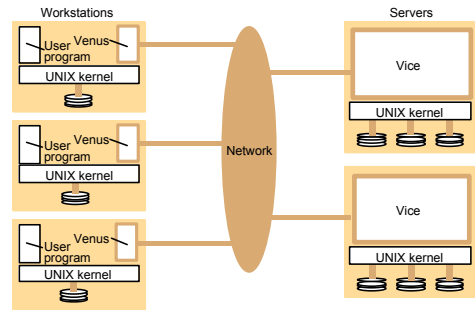
Andrew

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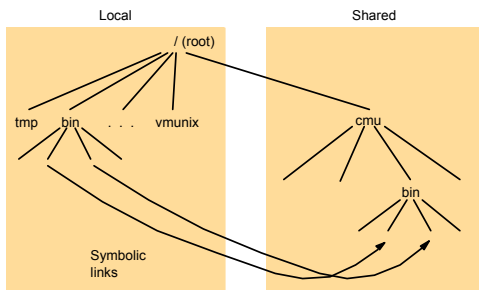
What kinds of files do not have these characteristics?

Figure 8.11
Distribution of processes in the Andrew File System



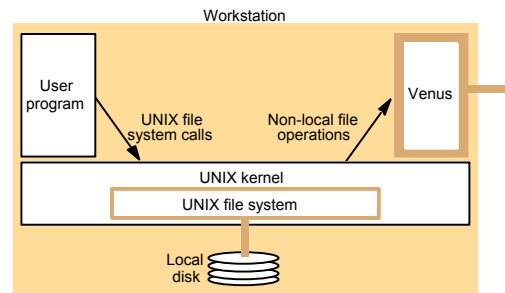
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Figure 8.12
File name space seen by clients of AFS



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Figure 8.13
System call interception in AFS



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Venus and Vice

- Venus – a user-level process that runs on each client
- Venus manages the cache (using a LRU strategy)
- Vice runs on the server and translates client requests into a flat file system
- UFIDs uniquely identify the file:
 - volume number
 - file handle
 - uniquifier
- Venus translates pathnames into UFIDs.

Figure 8.14
Implementation of file system calls in AFS

User process	UNIX kernel	Venus	Ver	Vice
<code>open(FileName, mode)</code>	If <code>FileName</code> refers to a file in shared file space, pass the request to Venus.	Check list of files in local cache. If not present or there is no valid <i>callback promise</i> , send a request for the file to the Vice server that is custodian of the volume containing the file.		Transfer a copy of the file and a <i>callback promise</i> to the workstation. Log the <i>callback promise</i> .
	Open the local file and return the file descriptor to the <code>subprocess</code> .	Place the copy of the file in the local file system, enter its local name in the local cache list and return the local name to UNIX.		
<code>read(FileDescriptor, Buffer, length)</code>	Perform a normal UNIX read operation on the local copy.			
<code>write(FileDescriptor, Buffer, length)</code>	Perform a normal UNIX write operation on the local copy.			
<code>close(FileDescriptor)</code>	Close the local copy and notify Venus that the file has been closed.	If the local copy has been changed, send a copy to the Vice server that is the custodian of the file.		Replace the file contents and send a <i>callback</i> to all other clients holding <i>callback promises</i> on the file.

Figure 8.15
The main components of the Vice service interface

<i>Fetch(fid) -> attr, data</i>	Returns the attributes (status) and, optionally, the contents of file identified by the <i>fid</i> and records a callback promise on it.
<i>Store(fid, attr, data)</i>	Updates the attributes and (optionally) the contents of a specified file.
<i>Create() -> fid</i>	Creates a new file and records a callback promise on it.
<i>Remove(fid)</i>	Deletes the specified file.
<i>SetLock(fid, mode)</i>	Sets a lock on the specified file or directory. The mode of the lock may be shared or exclusive. Locks that are not removed expire after 30 minutes.
<i>ReleaseLock(fid)</i>	Unlocks the specified file or directory.
<i>RemoveCallback(fid)</i>	Informs server that a Venus process has flushed a file from its cache.
<i>BreakCallback(fid)</i>	This call is made by a Vice server to a Venus process. It cancels the callback promise on the relevant file.

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Cache consistency

- Vice provides a callback promise with the file
- Callback promises a guarantees that server will notify client if someone else modifies the file
- Callbacks are either valid or cancelled
- When a file is modified, Vice makes a callback to each client cancelling the callback
- Venus checks the callback token whenever it opens a file
- If the callback token is cancelled, Venus must refetch the file.
- If a workstation crashes (or disconnects) must revalidate callback promises on reconnect.
- Callbacks must be renewed if a long time has elapsed since last communication with server.

AFS-1 semantics

- After successful open - latest(F, S)
- After failed open – failure(S)
- After successful close – updated (F,S)
- After failed close – failed (S)

F = file on client, S = server

AFS-2 semantics

AFS-2 requires Vice to maintain state on behalf of Venus clients. The lists of Venus clients are maintained over server failures and updated using atomic operations:

- After successful open - latest(F, S)
- After failed open – failure(S)
- After successful close – updated (F,S)
- After failed close – failed (S)

F = file on client, S = server

AFS cache consistency

- Cache consistency checks between workstations only done on open and close
- Callbacks don't provide true consistency in a genuinely concurrent environment (why?)
- Consistency is maintained among processes on same workstation (why?)

Andrew scorecard?

- Transparency
 - ┆ access transparency
 - ┆ location transparency
 - ┆ mobility transparency
 - ┆ performance transparency
 - ┆ scaling transparency
- Concurrency control possibility with support for transactions
- Replication
- Fault tolerance
- Heterogeneity
- Security
- Consistency

For next time:

- *Read CDK 8.5*
- *Be prepared to discuss CDK questions 8.1, 8.4, 8.5, 8.6, 8.7, 8.14, 8.15, 8.16*
- *Read the Sigmetrics 2000 paper on Microsoft's Farsite*