

Caching: File Systems

Outline

- File Usage Patterns
- Concurrent Write Sharing
- Availability

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Distributed File Systems

- Most Commonly used Distributed Program
- Issues
 - naming
 - caching
 - availability
 - security
- Examples
 - NSF: Sun's Network File System
 - AFS: Andrew File System
 - Sprite: Berkeley research project; stressed caching
 - Coda: CMU research project; stressed availability

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Questions

- Semantics
 - How much does it behave like Unix on a single system?
- Performance
 - How close is its perform to Unix on a single system?
- Scale
 - How big can it grow?

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Unix File Usage

- Most files are small (<10k)
- Reads outnumber writes 6:1
- Sequential access is common; random is rare
- Files open short periods (75% < .5s, 90% < 10s)
- Most files accessed by only one user
- Most shared files written by only one user
- Temporal locality: recently accessed files are most likely to be accessed again

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NSF Structure

- Can mount an NFS file system into the name space of a Unix machine
 - hard mount: RPC failures block client
 - soft mount: RPC failures return error to client
- One NFS client module on each machine
 - in kernel for efficiency
- One NFS server module on each server
 - in kernel for efficiency

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Stateless Server

- Idea: server doesn't store any state except
 - contents of files
 - hints to help performance (but not correctness)
- Consequence: server can crash and recover easily
- All client RPC ops must be idempotent
- Server doesn't maintain lists of who has files open
 - always name file and check permission

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Stateless Server (cont)

- `fhandle, attr = lookup(fhandle, name)`
 - `uid, gid, size...`
 - `opaque`
 - `token from pathname`
- `attr, data = read(fhandle, offset, count)`
 - `current file pointer`
 - `client defines block size`
- `attr = write(fhandle, offset, data)`
 - `when returns, guaranteed to have written data to disk`

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Server Caching

- Server caches recent reads, writes, directory-ops
 - server typically has lots of memory
- Server cache is write-through
 - all modifications immediately written to disk
- Pro:
 - stateless, no data lost on server crash
- Con:
 - slow, client must wait for disk write

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Client Caching

- Clients cache results of reads, writes, and directory-ops in memory
- Raises cache consistency problem
- Half-Solution
 - server keeps last-modification time per file
 - client remembers time it got file data
 - on file open or new block access, client checks its timestamp against server's (checks every 3 seconds)
 - good enough?

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Performance Problems

- Write-through on server
 - put crash-proof cache in front of disk (e.g., battery-backed RAM, flash RAM)
- Frequent timestamp checking
- Pathname lookup done one component at a time
 - required by Unix semantics

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Andrew File System

- Originally a research project at CMU
- Now a commercial product from Transarc
- Goal: a single, world-wide file system

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AFS Features

- Files identified by 96-bit Ids
 - 32-bit VolumeId, 32-bit VnodeId, 32-bit UserId
- Directory info stored in flat file system
 - software provides hierarchical view to users
- Files cached on client's disk
- Whole-file transfers/cached
- Designed so files will migrate to desktop of people that use them; assumes sharing is rare

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Callback Promise

- Server commits to warn client about obsolete files
 - granted to client when client gets a copy of file
 - client accesses file only if it has a callback promise
 - once exercised by server, callback promise vanishes
- Fault-Tolerance
 - on client reboot, client discards all callback promises
 - server must remember promises made, even if it reboots

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Cache Consistency

- Client checks for callback promise only when file is opened
- When writing, new version of file made visible to the world only on file close
- Result: concurrent read sharing semantics
 - opening file gets current snapshot
 - closing file creates new snapshot
 - concurrent write sharing leads to unexpected results

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AFS Performance

- Only known file system that scales to thousands of machines
- Whole-file caching works well
- Callbacks more efficient than the repeated consistency checks of NFS

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Sprite File System

- Research project at UC Berkeley
- Supports concurrent write sharing
- Block-based
 - fixed sized (4KB)
 - unique block number (not physical address)
 - client can create new blocks w/out contacting server
- Stateful servers
 - server notified when file opened/closed
 - all interactions are client-to-server; no client-to-client

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Algorithm

- Write policy: write back all dirty blocks every 30s
 - client-to-server
 - server-to-disk
- When server detects concurrent write sharing
 - notifies clients to write back all dirty blocks
 - caching disabled
- Server serializes access to its cache

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Algorithm (cont)

- When client opens, may have out-of-date cache
 - server keeps version number for all files
 - increment each time file opened for writing
 - client keeps version number of all cached files
 - compare version numbers on open; flush if old
- Server keeps track of last writer (at most one)
 - when someone opens, server asks last writer to flush any dirty blocks
 - block open until done

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Coda File System

- Observation: AFS client often goes a long time without communicating with servers
- Coda use AFS-like implementation when disconnected from the network
 - on an airplane
 - at home
 - during network failure

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Disconnected Operation

- Problem: how to get the right files onto the client before disconnecting
- Solution
 - AFS does a decent job already
 - let user make a list of files to keep around
 - have system learn which files user tends to use

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Consistency

- Problem: how to keep disconnected versions consistent
 - what if two disconnected users write the same file at the same time?
 - what if a writer makes a disconnected version obsolete?
- Can't use callback promise since communication is impossible

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Consistency (cont)

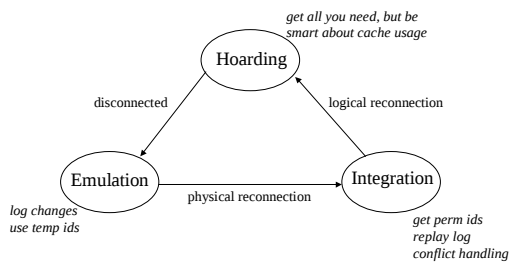
- Strategy
 - hope it doesn't happen
 - if it happens, hope it doesn't matter
- If it does happen, try to patch things up automatically
 - example: creating two files in the same directory
- If all else fails, ask the user what to do

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Implementation



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Experience

- Unfixable conflicts almost never happen
 - typical user can go months without seeing one
 - but are workloads changing?
- Can Coda experience be applied to AFS?
 - exercise callback promises lazily
 - keep working despite network failures

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Web Caching

- Who
 - client
 - classical proxy
 - transparent proxy
- HTTP Support
 - server sets **Expires** header line
 - after page expires, client uses...
 - **HEAD** operation, or
 - **GET** operation with **If-Modified-Since** header line

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