CS514: Intermediate Course in Computer Systems

Lecture 27: Nov. 26, 2003

"Challenges of Mobility"

Mobility is a huge topic

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- Breaks existing applications
  - Anything bandwidth intensive or synchronous
- Opportunities for new applications
  - Location-specific (nearest Starbucks)
  - Ubiquity (short messaging)
  - Ad hoc networks
- Can't possibly give it justice in one lecture

Focus on a couple systems-level attempts

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- What can the system do to support applications in mobile contexts, and how how effective is it?
- Coda (mobile file system)
  - CMU (AFS-based)
  - Application awareness
- Rover (mobility systems toolkit)
  - MIT
  - Application transparent

Characteristics of mobility

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Disconnection (long or short, predictable or sudden)	Caching, hoarding, prefetching, DB/file inconsistencies
Variable and asymmetric bandwidth	Above, plus compression, prioritization, clever use of downlink
Expensive ($$$) BW	Above, plus user control
Battery, battery, and battery	Minimize transmissions (and also processing)
Weakened security (physical and radio)	User auth, encryption

Rover goals

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- Philosophy is that applications know best how to deal with mobility
  - But there are general mechanisms that all applications can benefit from
- Provide a toolkit to applications
- Make it easier to write applications that deal with mobility issues
  - Reduce client/server communications requirements
  - Allow the user to effectively work offline

(Some slides care of Michael Ferguson)

Rover project

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- Build Rover toolkit
- Build range of applications using Rover toolkit
  - Email
  - Calendar
  - Browser
- Evaluate effectiveness of Rover for supporting these applications

Conclusion: Success!

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- Though Rover itself has not taken off…
- Applications easy to port
  - They say…
- Performs well
  - Compared to what?
- In my mind, they never really answer the question whether a toolkit/OS approach is better
  - This would be a hard question to answer…

Two basic mechanisms

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- Relocatable dynamic objects (RDO)
  - Code/data shipping, like simple agents or process migration
  - Allows dynamic control over processing versus communications tradeoff
- Queued remote procedure calls (QRPC)
  - Asynchronous RPCs
  - Allows offline operations without blocking

Rover operations

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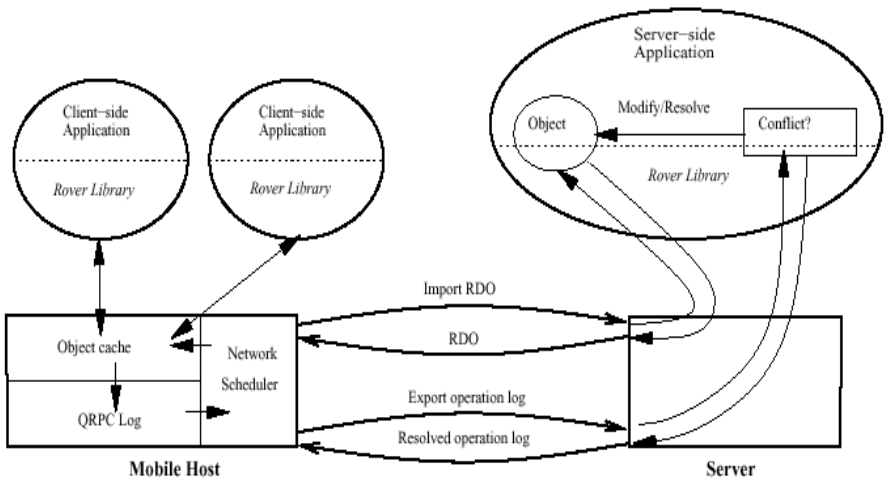
- *Import* objects onto client machine
  - RDO: contains data and operations on the data
- *Invoke* methods on those objects
- *Export* logs of method invocations to servers
  - Can also export RDOs
- Reconcile client data with server data

Rover operation

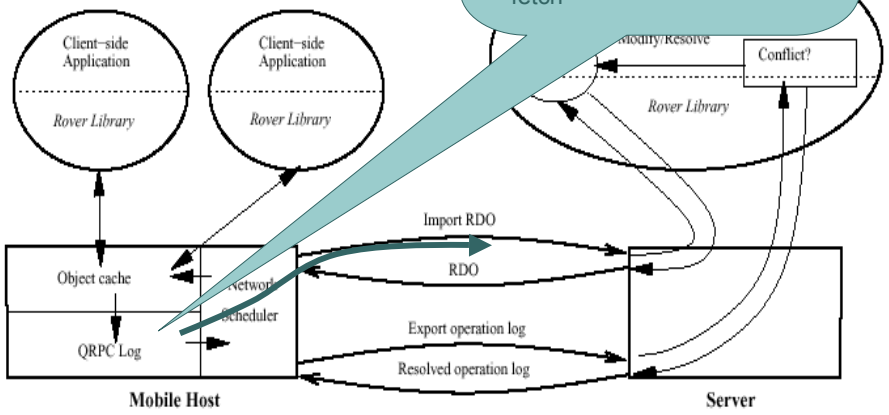


Import

Import call provides:
- Object ID (URN)
- Session ID
- callback routing
- arguments

Import call returns a “promise”

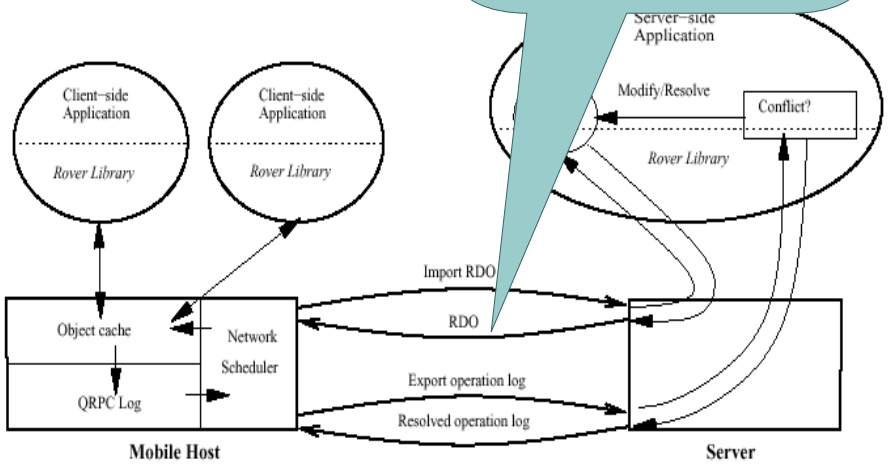
Call is queued (QRPC) for lazy fetch



Import

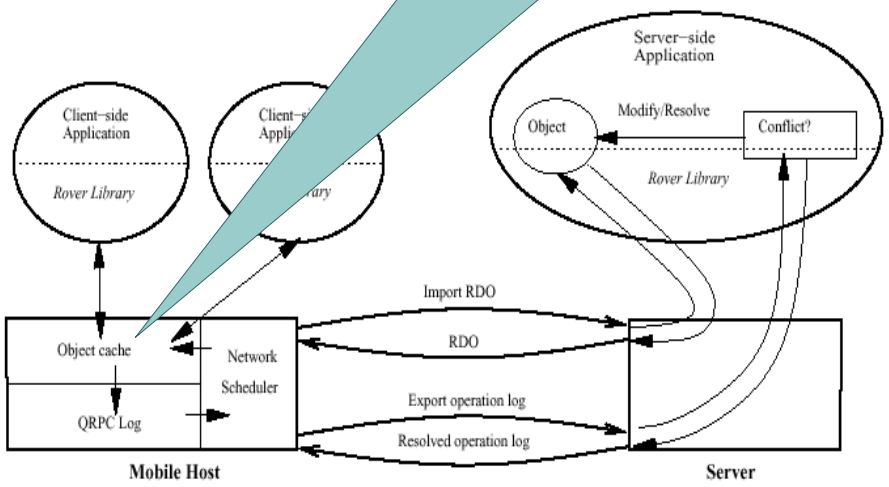
When imported object arrives:
- Callback routine is called
- Object is put into the cache
- RDO may invoke a thread

Object may be locked at server



Invoke

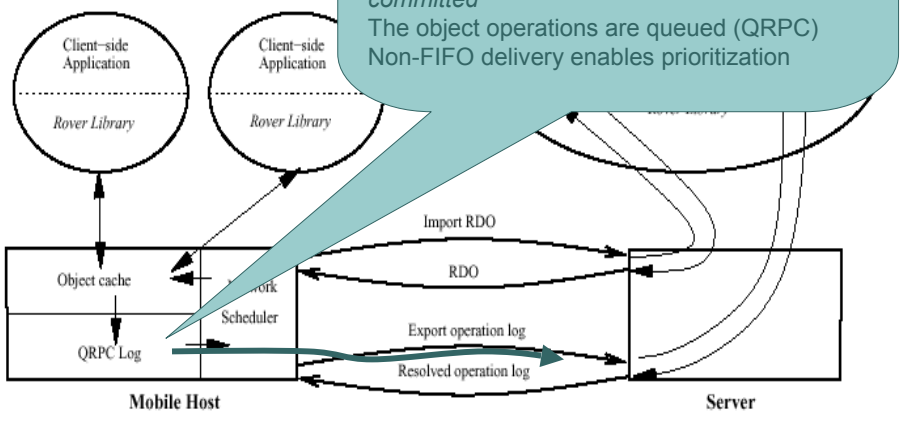
Application invokes methods on received object
- Each operation is stored
- Changes in object indicated by version vectors



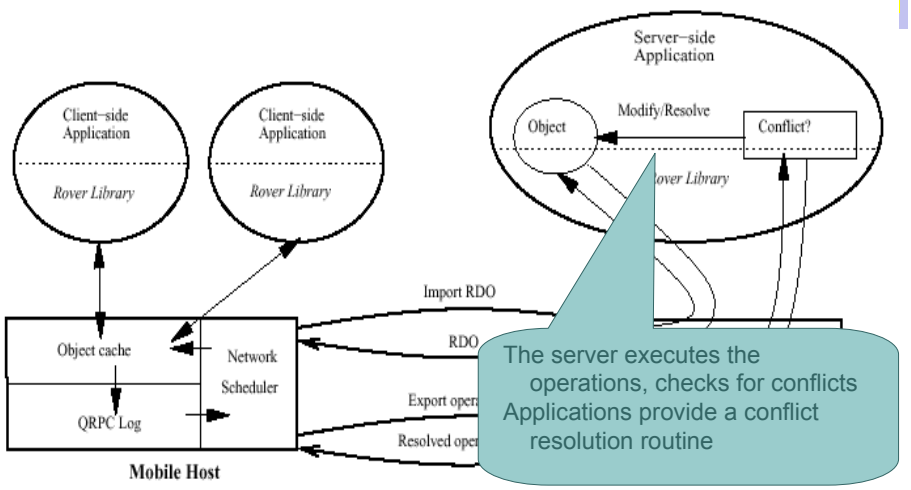
Export

Export call provides:
- Object ID (URN)
- Session ID
- callback routing
- arguments

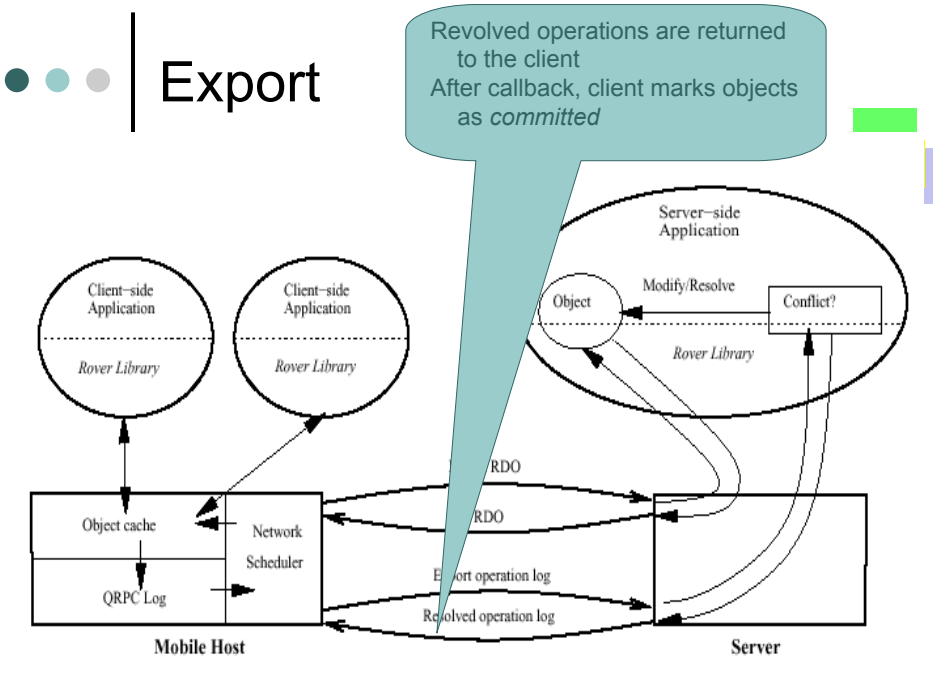
Export call returns a “promise”
Updates to object are labeled *tentatively committed*
The object operations are queued (QRPC)
Non-FIFO delivery enables prioritization



Export



Export



Rover Architecture

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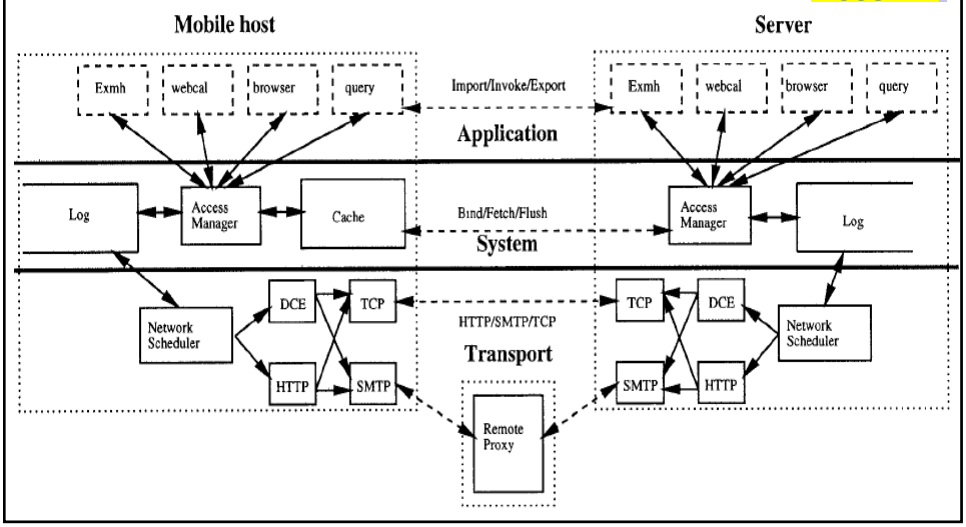

Rover Arc

All applications run over a single Rover process
Communicate via Local RPC
Allows prioritization across applications

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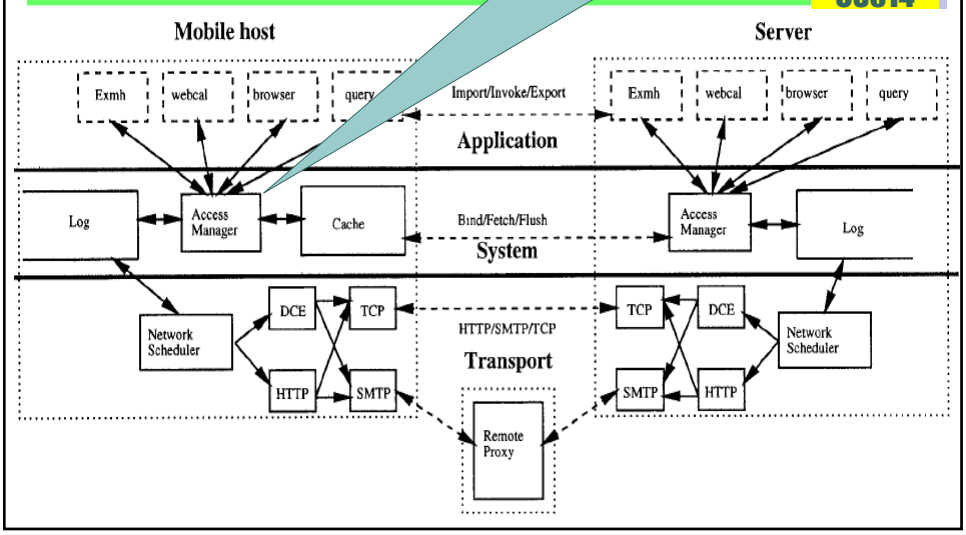

Rover Arc

Network scheduler can select TCP or SMTP (mail) for transport
Latter for batching lower priority requests
(Interim solution)

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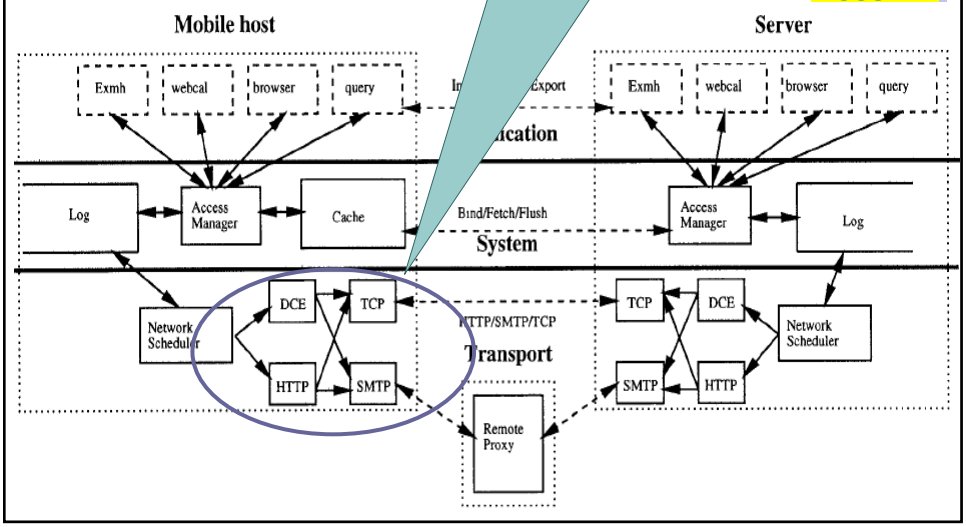

Implementation

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- RDOs are Tcl/tk objects
- Transported in HTTP
  - Using CERN's Web Common Library
  - Server uses CGI scripts

Applications

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- Mail reader (based on Exmh Tcl/Tk)
- Calendar (based on Ical Tcl/Tk calendar)
- Web browser proxy (new application)

Mail Reader

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- Parts of GUI and messages sent as RDOs
- RDOs used for prefetching and application-specific consistency (inconsistent folder changes)

Calendar

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- Each calendar item (appointment or notice) is an RDO
- Item imported, changed tentatively, and exported and committed
- Routines for conflict resolution
  - Error notice, or give some users priority

Web browser proxy

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- Implements “click ahead”
  - During disconnection, clicks are queued for later download
  - User has access to list of queued clicks
    - List is an RDO
- Does prefetching

Some thoughts on Rover

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- Rover is a nice proof-of-concept for how to deal with mobility
- But Rover itself of limited value
  - Tcl/Tk based RDOs probably overtaken by Java
  - Use of SMTP a bad choice (they know this)
  - Probably hard to automatically prioritize among disparate applications
    - User would prefer to control this based on immediate circumstances
    - Not clear there is much value to running Rover as a single, system service

Some thoughts on Rover

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- Email not the best proof-of-concept application
  - Already fundamentally asynchronous, so not much different with Rover
- Click-ahead sounds like a bad idea to me
  - I'd rather control when clicks happen…
- Calendar is a decent proof-of-concept application

Surprising conclusion

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- From the Rover paper:
  - "*The largest, most important, drawback of the Rover approach is that application designers must think carefully about how application functions should be divided between a client and a server*"
- Funny…this struck me as probably the main advantage of Rover!!!
  - Provides a nice model for how to think about disconnection, asynchrony, and consistency

Coda File System

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- Unlike Rover, makes disconnection issues transparent to the application (and, to some extent, the user)
  - Coda transparently propagates file modifications and handles conflicts

Disconnected operation states on client (Venus)

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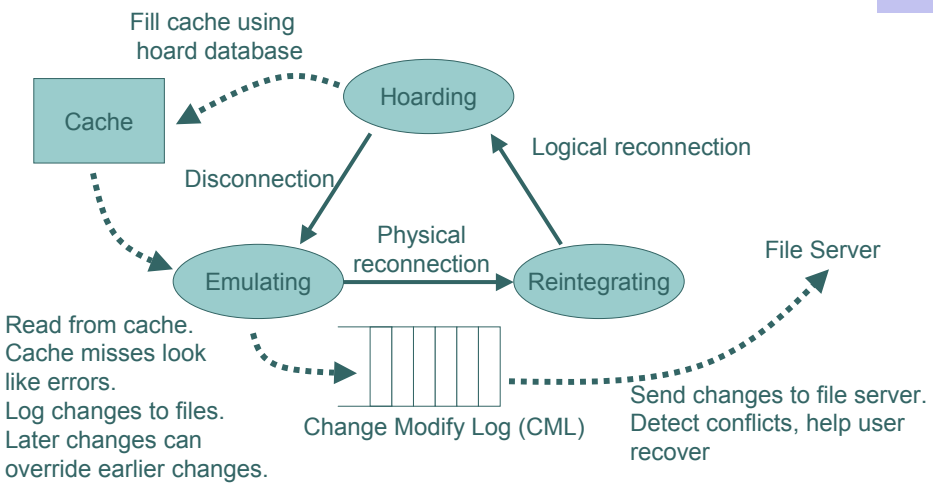

Conflict resolution

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- Code resolves most directory conflicts
- For files, requires application-specific resolvers
- Unresolvable files are presented to user in a manual repair tool
  - User sees an “explosion” of inconsistent files in a directory tree
  - Use diff and grep to resolve

Problem with disconnected states approach

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- Reintegration would consume bandwidth resources…users couldn't do anything useful immediately upon reconnect
- Solutions:
  - New states for weak connectivity
  - Rapid cache validation (version stamps for directories, not just files)
    - Cached by clients
  - "User patience threshold"…model to predict if a user would rather wait for a large file not in the cache, or be given an error

Weak connectivity operation states on Venus

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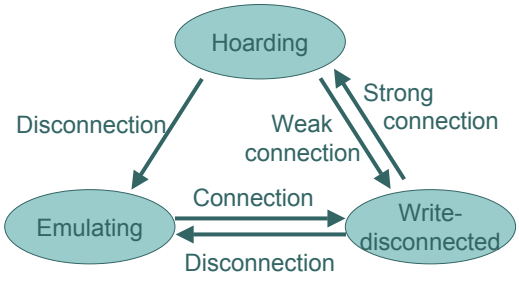
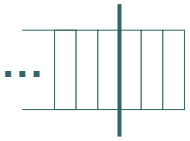


Changes older than some time (10 min) cannot be over-ridden. These are "trickled" out to the file server during weak connectivity.



Reintegration Barrier

Isolation-Only Transactions

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- Coda emulation of UNIX file system has benefit of backwards compatibility
- UNIX lacks notion of read-write file conflicts
  - Where an application is using a file as input, and that file is modified
    - Windows, on the other hand, locks the file
- This limitation is exacerbated by disconnected operation
- Coda deals with this by checking for possible read-write inconsistencies after reconnection

State machine for IOT

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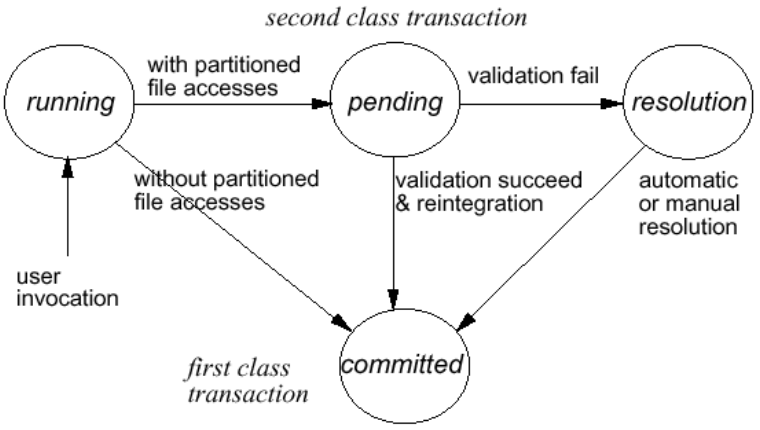

Pending validation

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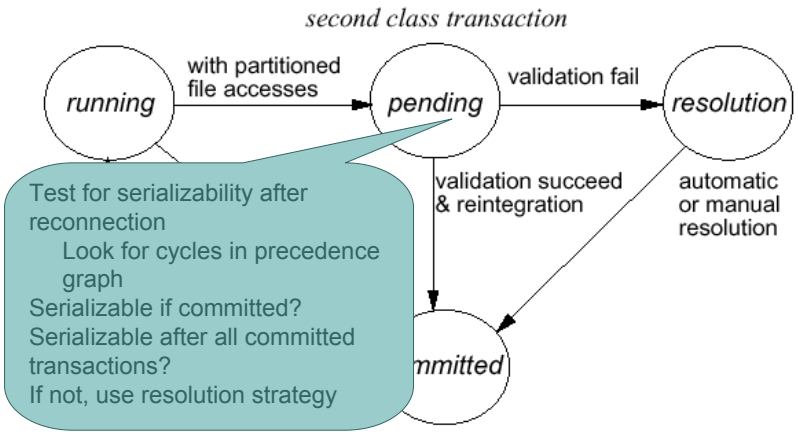

Resolution Strategies

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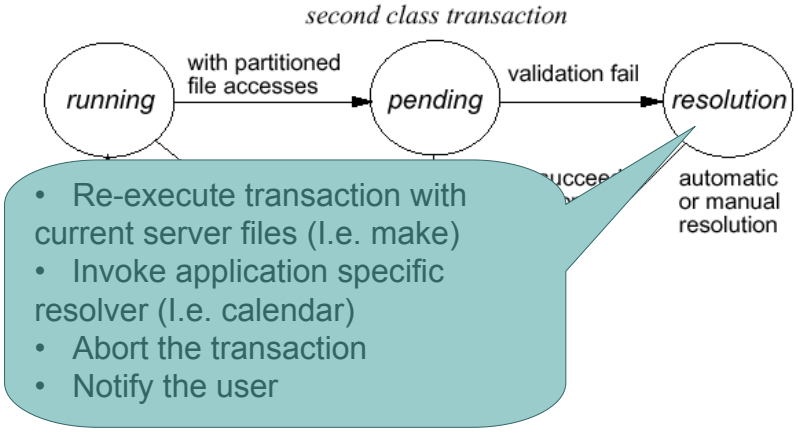

Some thoughts on Coda

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- File system is the wrong level of abstraction for many applications
  - Calendar, database
  - I agree with Rover on this
- As a user, I think Coda running "under the hood" would be confusing, sometimes annoying
  - If file is shared, I'd rather deal with resolution explicitly (version control, etc.)
  - If file is not shared, I'd rather control when "synchronization" takes place

Other interesting work

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- Bayou (Xerox Parc)
- "Peer-to-peer" ad hoc network write conflict resolution
  - Group document editing, calendar, etc.
- Basic idea, "anti-entropy": peers do pairwise comparison of writes, try to revolve conflicts
  - Determine conflict by trying the write on neighbors version, conflict exists if result is different
  - Eventually all peers reach an agreed state

Other interesting work

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- Broadcast disks
- Based on fact that radio reception much less expensive than radio transmission
  - Acharya et. al., SIGMOD95
- Continuous broadcast of “disks”, clients keep the ones they want
  - Broadcast index at set times so that clients know when to receive
- Variations to support caching, consistency
  - Broadcast version changes