# Weak Consistency and Disconnected Operation in git

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# Motivation

How can we support disconnected or weakly connected operation?

Applications

- File synchronization across users / devices (e.g. Dropbox)
- Source code control (e.g. git)
- Disconnected / intermittent connectivity (e.g. laptops, mobile, 3rd world)

# Consistency Recap

**Sequential consistency**:
everyone sees same read/write order (cache coherence, Paxos)

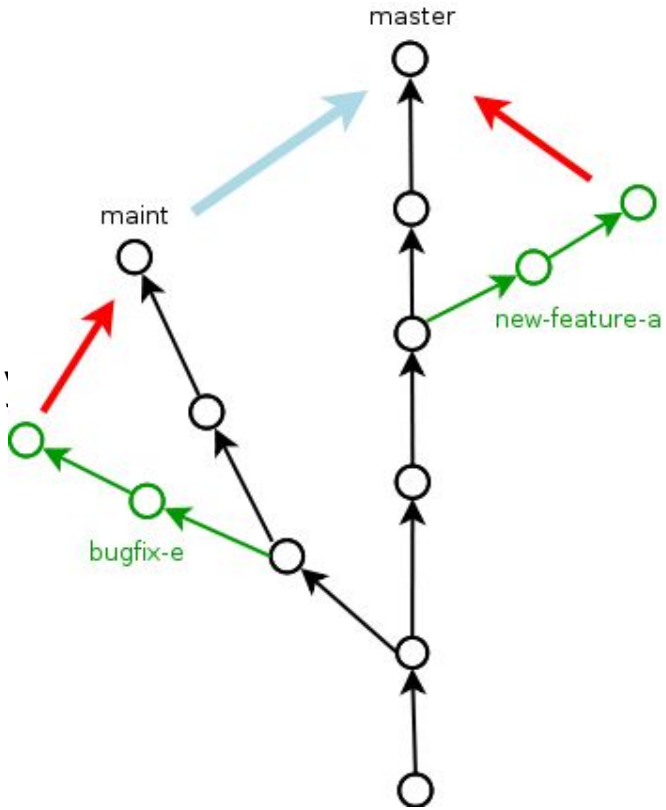
**Release consistency:**
everyone sees writes in unlock order (x86/ARM)
(more generally, reads/writes forced to complete at memory barriers)

Sequential/release consistency is slow:

- wait at memory barrier
- communication needed if recently modified by another node
  or if write and the local copy is not exclusive

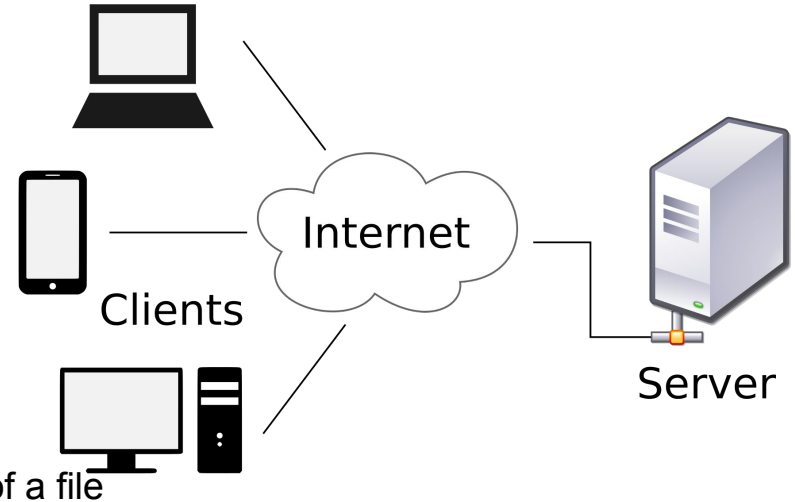
# Source Code Control

- Eventual Consistency
  - Okay to read/write cached copy (different versions)
  - Check if it's okay later, recover if necessary
- Track history (with metadata)
- Concurrent editing / Many contributors
- Working copy: Don't want files to change beneath
  - Push / Pull to server/peers
  - Contributors may be offline / disconnected
- Cheap Branches / Merging
- Centralized / Distributed

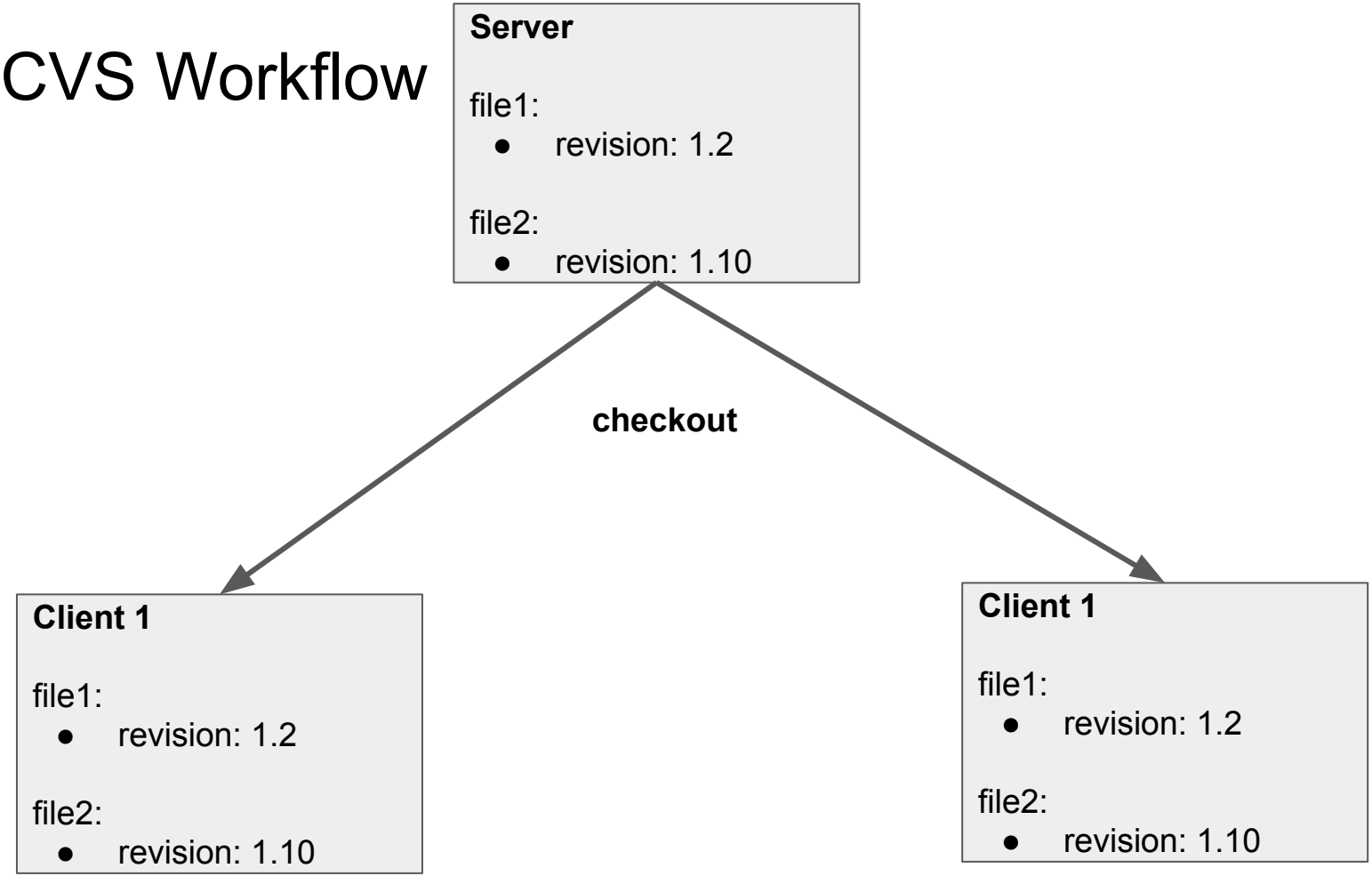


# CVS (1990)

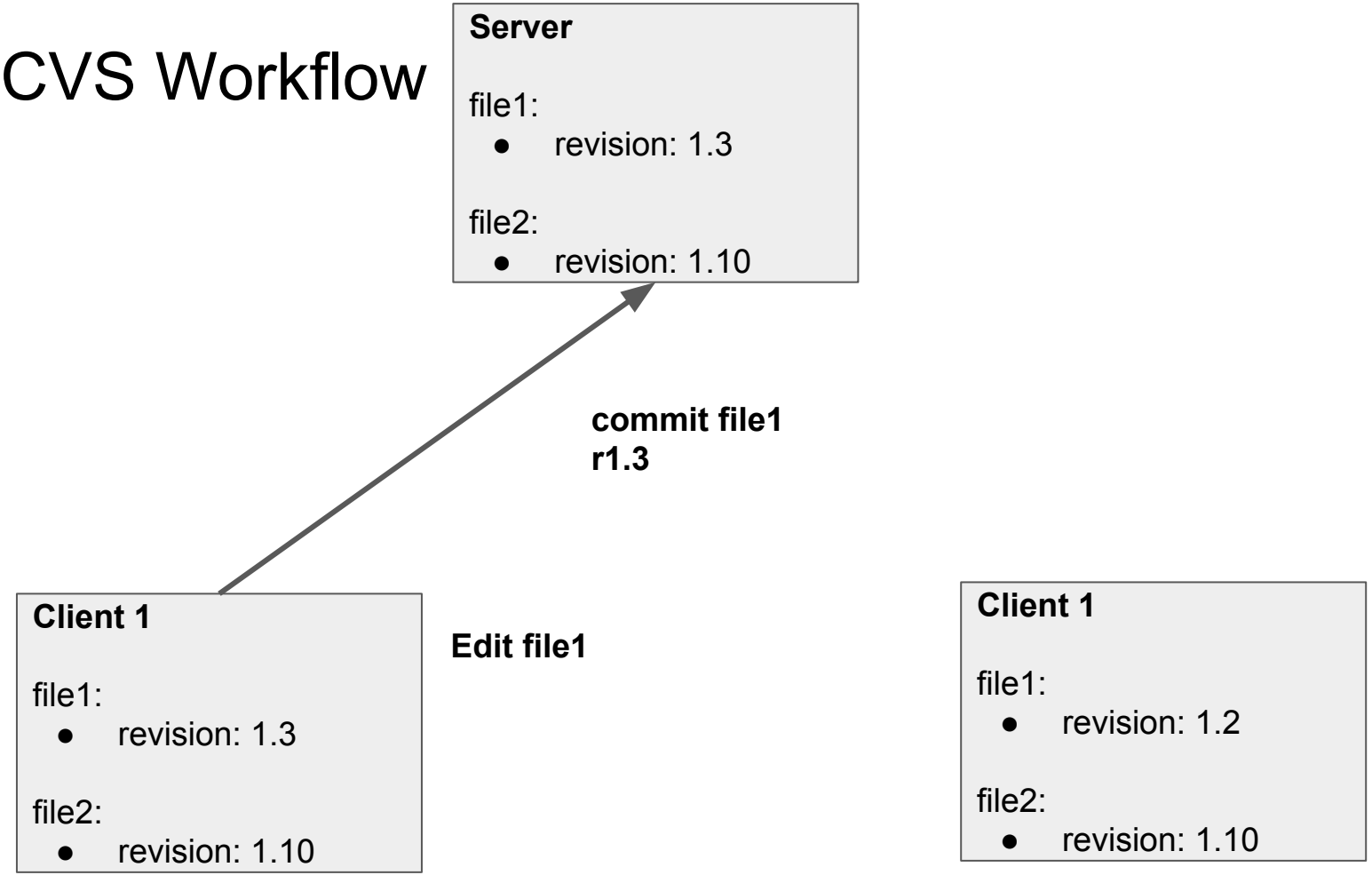
- Client-server architecture
  - Check out a working copy
  - Check in your changes
- Server arbitrates order of changes
  - Only accept changes to the most recent version of a file
  - Developers must always keep their files up to date



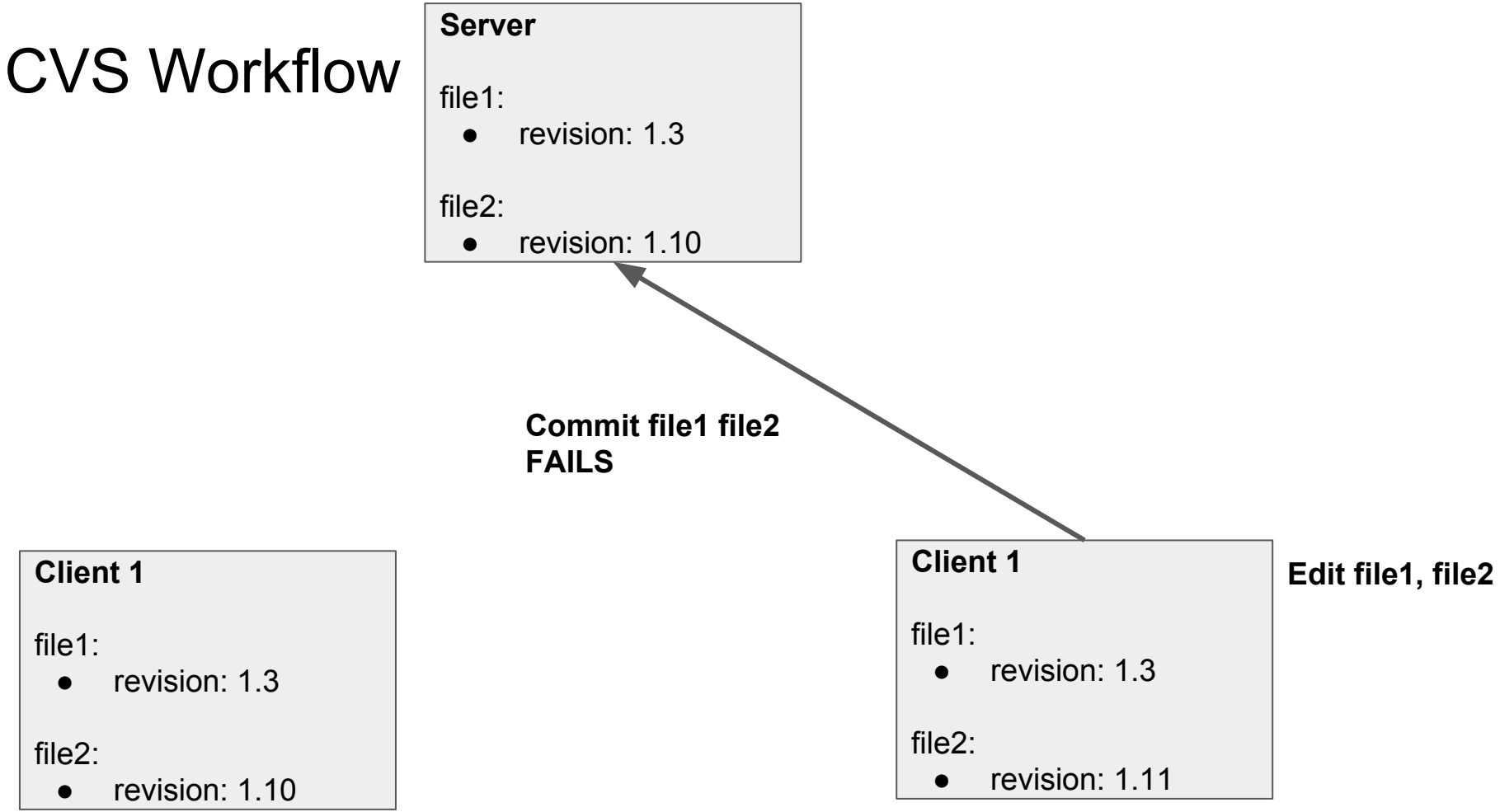
# CVS Workflow



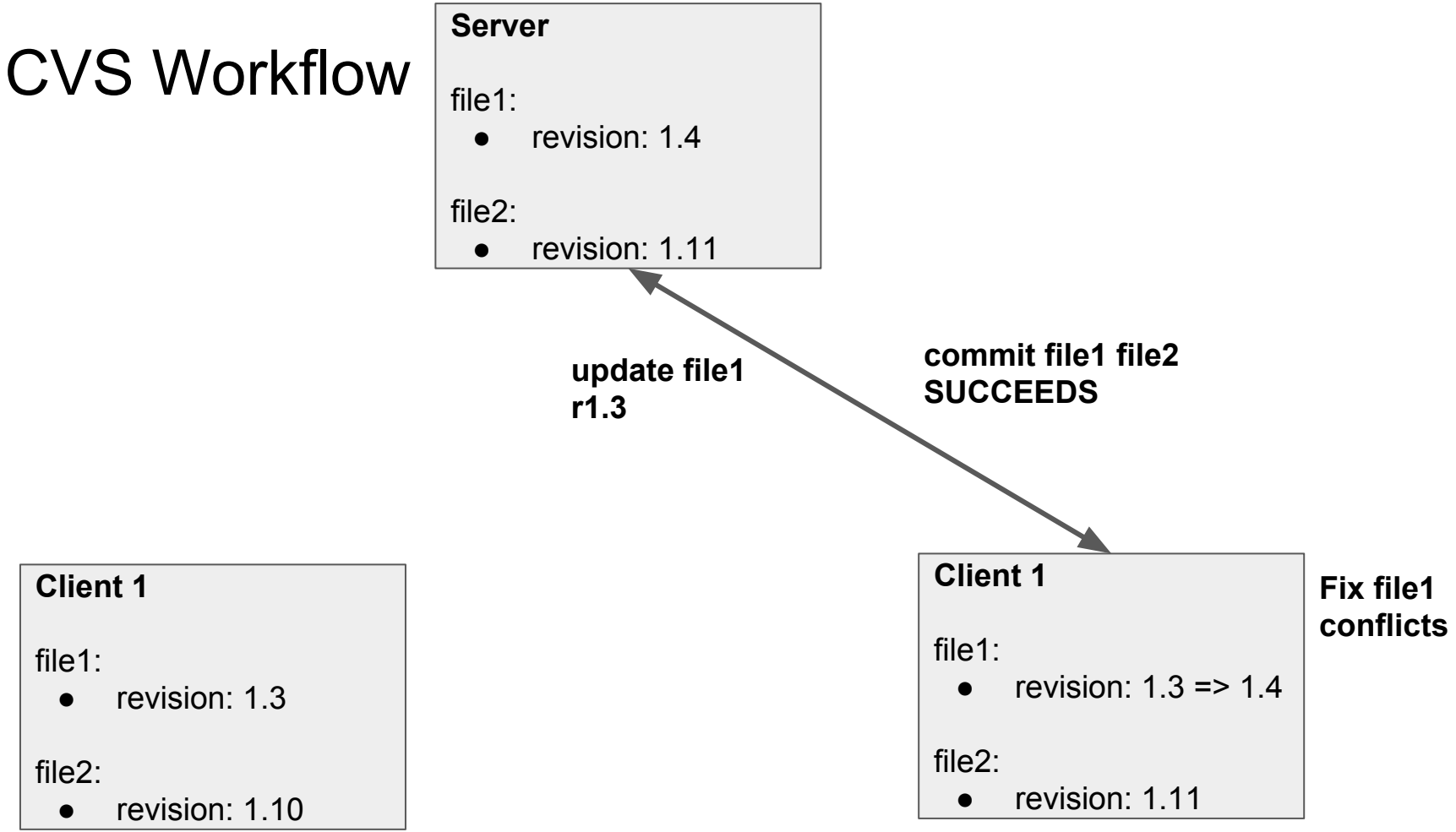
# CVS Workflow



# CVS Workflow



# CVS Workflow



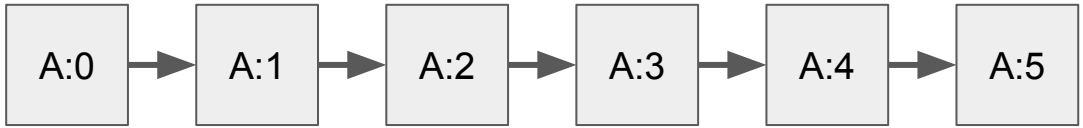
# CVS Limitations

- Everyone is editing the same repository
  - How do you implement a complex feature without constantly conflicting?
- No local version control
  - cvs commit ~ git commit && git push
- No log
  - How do I time travel?
- No versioning of moving / renaming files
- Depends on live server to operate
  - Needs to be scaled / backed up / always up / reachable
- Branches were expensive
  - Manual locks are common
- No atomicity (e.g. network failure lead to inconsistency)

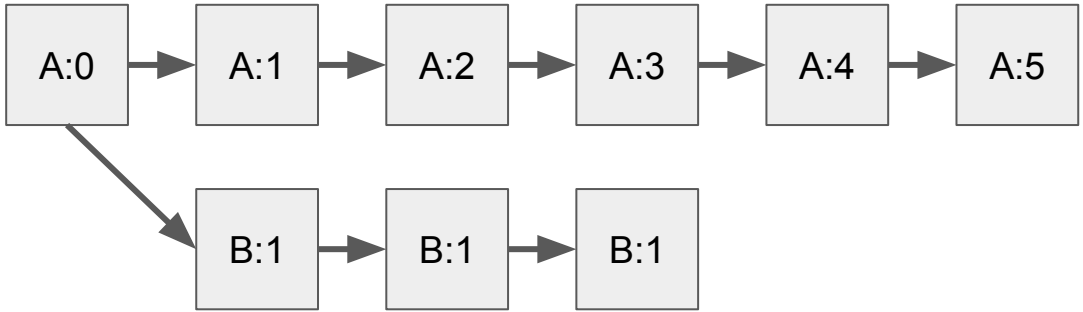
# Apache SVN (2000)


- “CVS done right”
- Improvements
  - Atomic commits
  - Renamed / moved / copied files retained version history
  - Versioning of directories and metadata
  - Cheap branches / tagging
- Centralized - server/client architecture
- Still active
  - All of Facebook’s source code was in a single SVN repository until 2014

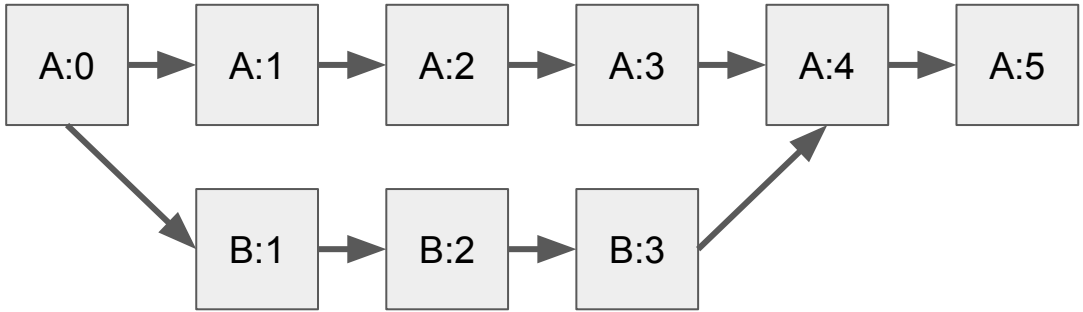
# Commit Log



# Branching



# Merging




**A:5 Ancestry Set**
{A: 0-4, B:1-3}

# Merging and Causal Ordering

Operations that potentially are causally related are seen by every node of the system in the same order

Example:

C1: f=1 -> C2

C2: f=2 -> C3

C3: f=3 -> C1

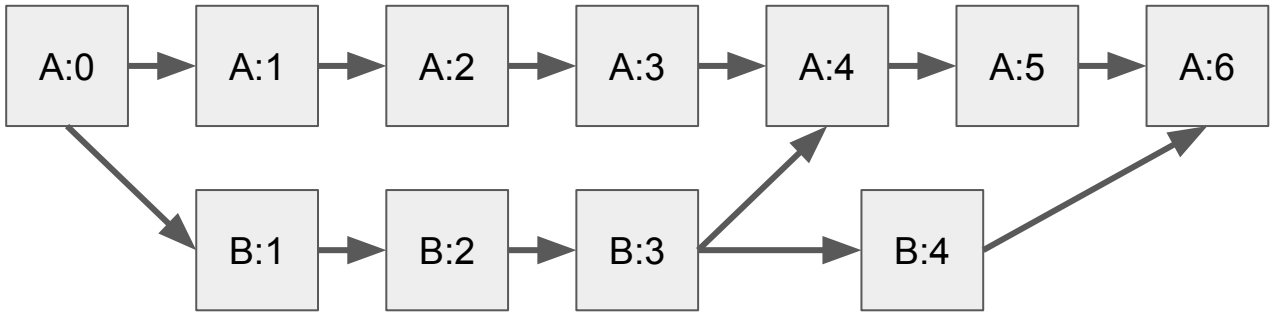
Example:

C1: a=1 -> C2

C2: b=2 -> C3

C3: c=3 -> C1

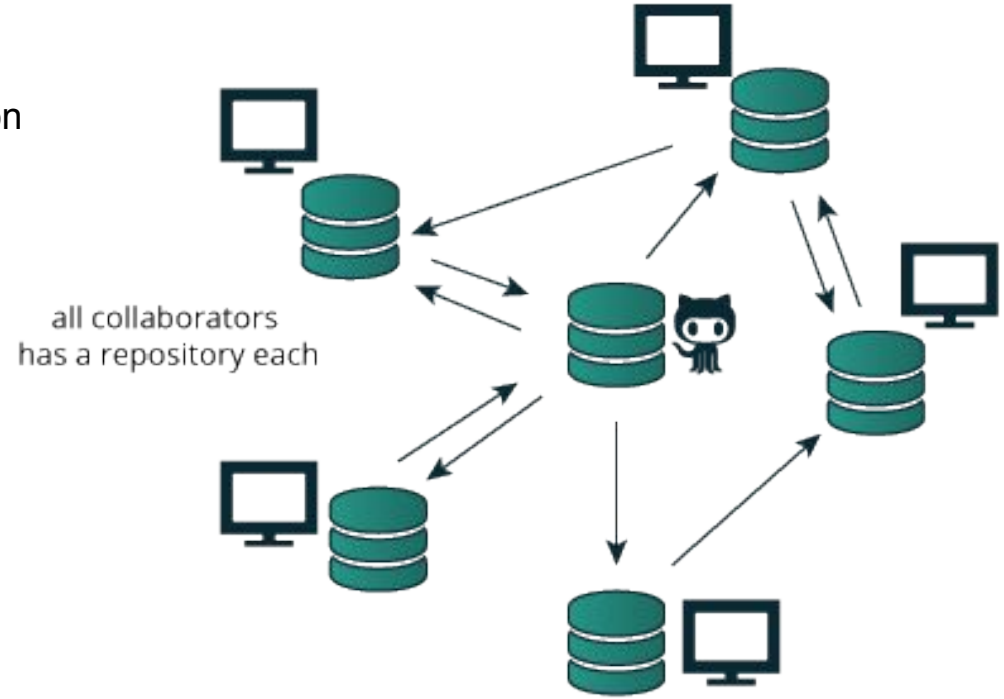
# Merging




**A:5 Ancestry Set**
{A: 0-5, B:1-4}

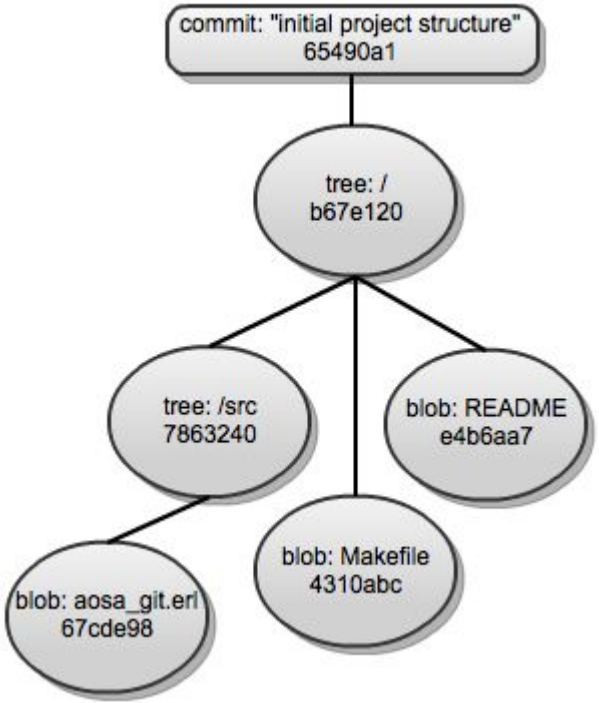
# git (2005)

- Distributed!
  - Everyone is a replica
- Consistency and performance
  - Protects from memory, disk corruption
- Cheap branches / merges
- .git/
  - Config
  - Content-addressable filesystem
  - Log of changes (commit history)



# Logs (Commit Histories)

- Complete log of changes (needed for time travel with source code control)
  - Directed acyclic graphs (DAG)
- commit
  - parents
  - deltas (changes to content)
  - hash - for consistency
  - metadata



```
* 686995a jab (9 days ago): improve cloud invite confirm message  (HEAD -> dev, tag: v0.8.32, origin/release-candidate, origin/release, ori
*   764f8e5 dborkan (9 days ago): Merge pull request #2180 from uProxy/dborkan-quiver-reconnect
|\
| * dfd26a2 Daniel Borkan (9 days ago): replace == with ===
| * 9218ea9 Daniel Borkan (9 days ago): Fix Quiver disconnect and automatic reconnect
* |   f64ec8c Jonathan Pevarnek (12 days ago): Merge pull request #2172 from jpevarnek/switch-to-lib-rule
|\ \
| * | a66e18d Jonathan Pevarnek (5 weeks ago): Switch to using buildAndRunTest from uproxy-lib
* | |   1987beb Jonathan Pevarnek (12 days ago): Merge pull request #2171 from jpevarnek/separate-model
|\ \ \
| |/ /
|/| |
| * | 0db725e Jonathan Pevarnek (5 weeks ago): Separate the model from the user_interface file
|/ /
* |   d50d2fa Jonathan Pevarnek (13 days ago): Merge pull request #2147 from jpevarnek/update-ts
|\ \
| * \   d7d411d Jonathan Pevarnek (13 days ago): Merge branch 'dev' into update-ts
| |\ \
| * | | a26fe6a Jonathan Pevarnek (5 weeks ago): Update grunt-ts to the latest version
* | | |   a991855 dborkan (13 days ago): Merge pull request #2170 from uProxy/version-0.8.32
|\ \ \ \
| |_|/ /
|/| | |
| * | | b777228 Daniel Borkan (13 days ago): Bump versions
|/ / /
* | |   0266021 dborkan (13 days ago): Merge pull request #2169 from uProxy/trevj-uproxy-lib-update  (tag: v0.8.31)
|\ \ \
| |_|/
|/| |
| * | babbd50 Trevor Johnston (13 days ago): upgrade uproxy-lib for new cloud invite fixes and additions  (origin/trevj-uproxy-lib-update)
|/ /
* |   e9b5c6c lucyhe (2 weeks ago): Merge pull request #2159 from uProxy/lucyhe-cloudinvite
|\ \
| * | 17f6057 Lucy He (2 weeks ago): Update getInviteUrl API to take optional parameter too  (origin/lucyhe-cloudinvite)
| * |   90b988e Lucy He (2 weeks ago): Merge branch 'dev' of https://github.com/uProxy/uproxy into lucyhe-cloudinvite
| |\ \
| |/ /
|/| |
* | |   6456e95 Laura Rokita (2 weeks ago): Merge pull request #2165 from uProxy/gitlaura-build-for-ios
|\ \ \
| * | | fa6ca2b lrokita (2 weeks ago): Update gruntfile and index.html to build uProxy on ios  (origin/gitlaura-build-for-ios)
|/ / /
| * | d2cb231 Lucy He (2 weeks ago): Add Cloud descriptions to Share tab.
| * | eee3f4d Lucy He (2 weeks ago): Use showDialog instead of fireSignal to show invite URL.
| * | b4515ba Lucy He (2 weeks ago): Make userId optional for getInviteUrl
| * | ffa5391 Lucy He (3 weeks ago): Fix enum equality bug
| * |   c7c30d9 Lucy He (3 weeks ago): Merge with dev
| |\ \
| |/ /
|/| |
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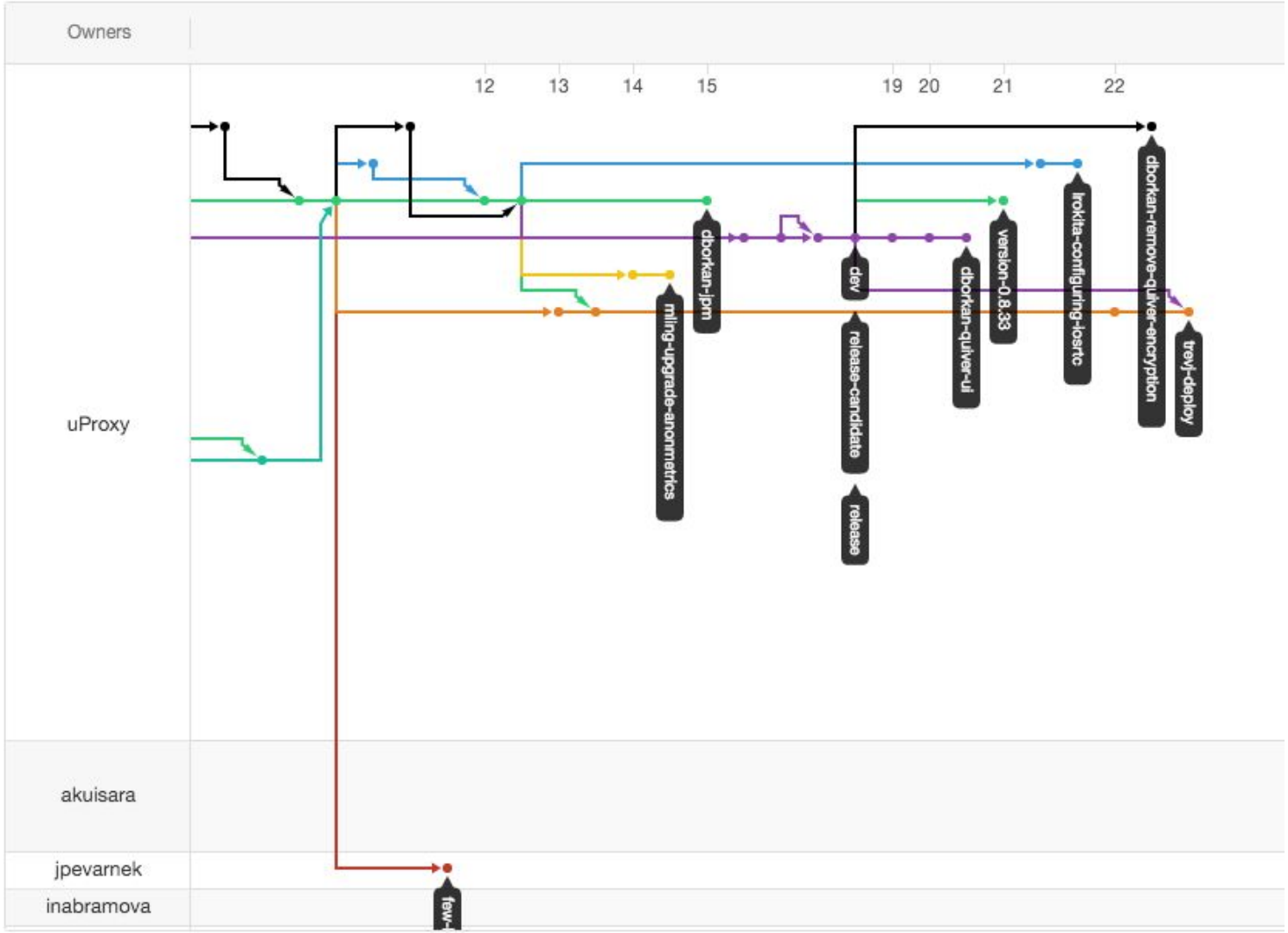
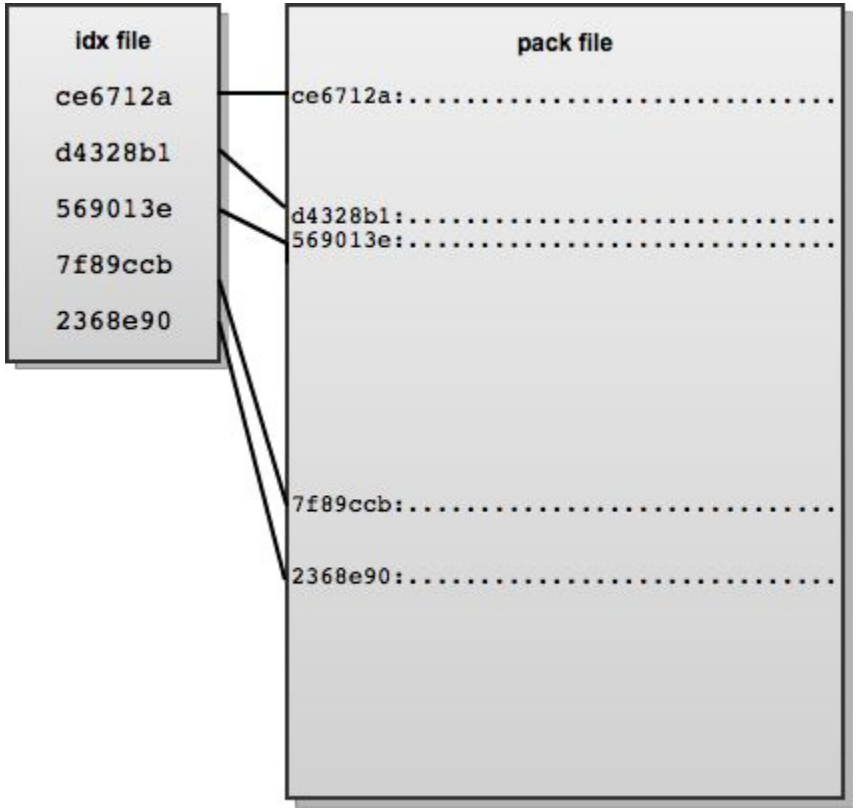

Owners
12
13
14
15
19
20
21
22
uProxy
dborkan-jpm
dev
version-0.8.33
trokita-configuring-losrtc
dborkan-remove-quiver-encryption
trevj-deploy
mling-upgrade-anonmetrics
release-candidate
dborkan-quiver-ui
release
akuisara
jpevarnek
inabramova

# Content Addressable Filesystem

.git/objects



# Reconciling Conflicts

- Last writer wins (AFS, NFS)
- User-specified conflict handler
- Manual reconciliation (git, svn)
- Conflict-free replicated data types (CRDT)
  - Data types such that conflicts are impossible
  - Operation-based CRDT (e.g. commutative replicated data types)

# Operational Transforms