RainbowFS

Modular Consistency and Co-designed Massive File system

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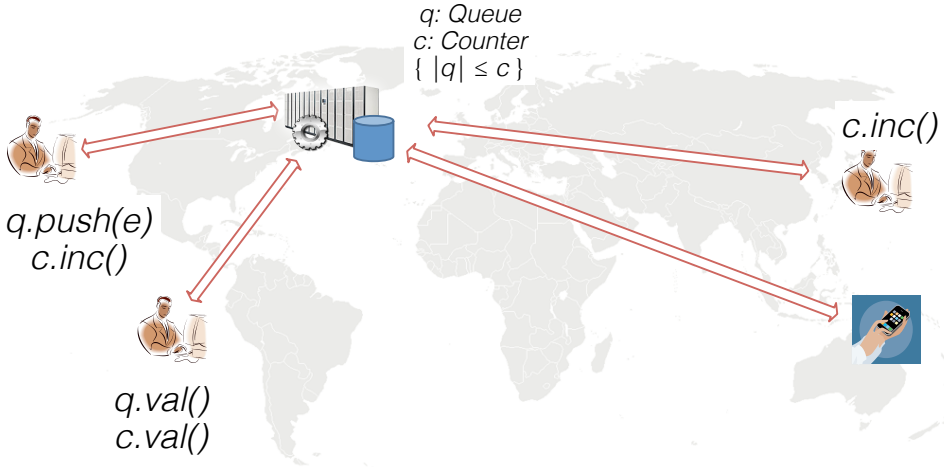
Background

Distributed application ⟹ shared data

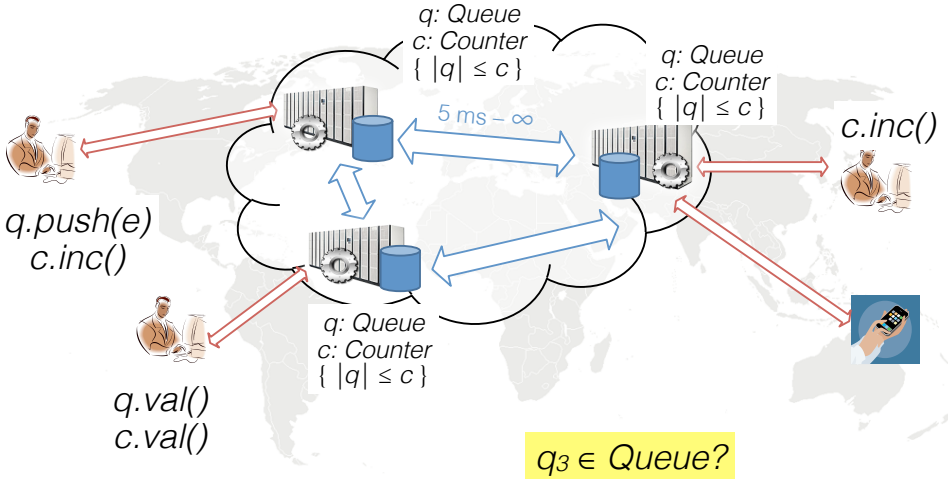
1. Large scale (cloud) ⟹ data replication ⟹ consistency issues
   - Strong : dependable, not available, inefficient.
   - Available : parallel, anomalies.
   - Pre-defined models
2. Complex : configuration, analysis, control, decomposition
3. System, data access API

Theory of replication and consistency, tools

Shared data

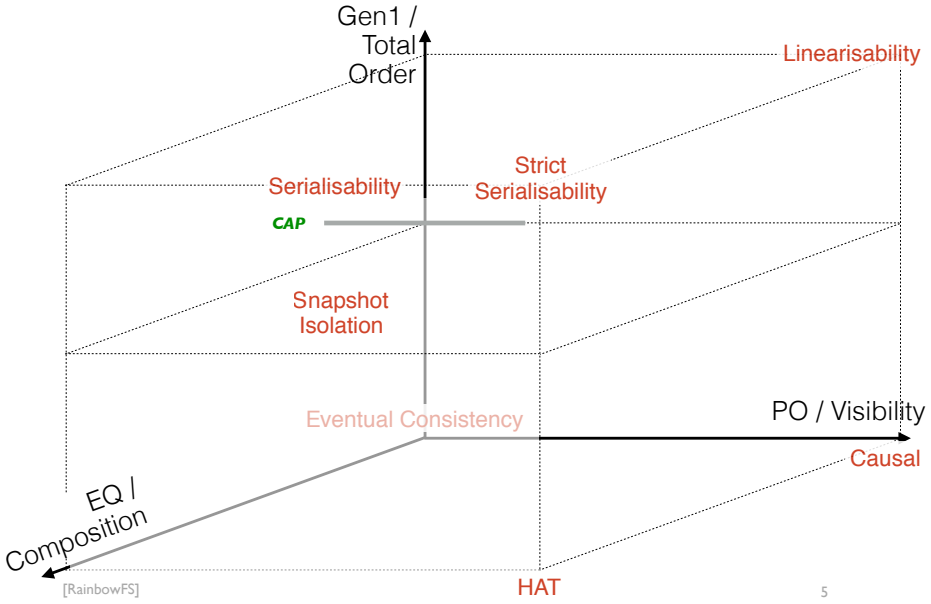


Geo-replicated sharing



$q_3 \in Queue?$
$q_1 = q_2$?
$|q_1| \leq c_4$?

Three dimensions



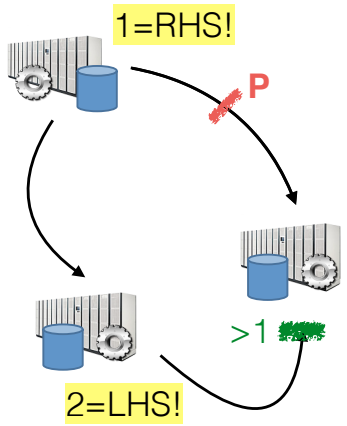
Relative order pattern

mkdir before *creat*

Relative-order invariant pattern:

- "Directory references valid file"
- *x* valid ∧ *x* points to *y* ⟹ *y* valid
- Pattern RHS!; LHS!
- Make visible in same order

AP-compatible: Causal Consistency



Joint update pattern

write updates content, metadata

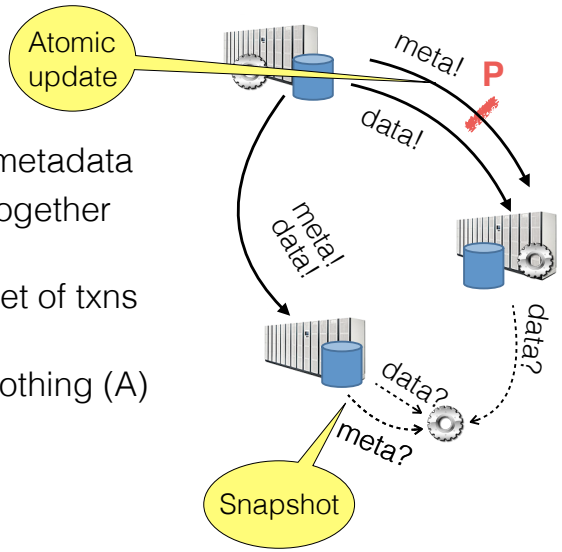
Transmit joint updates together

- write-atomic

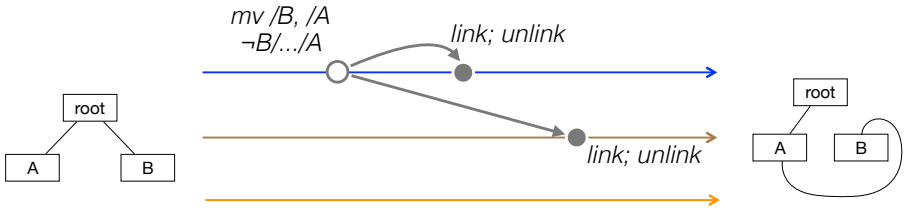
+ Read from common set of txns

- snapshot property

AP-compatible: All-or-Nothing (A)

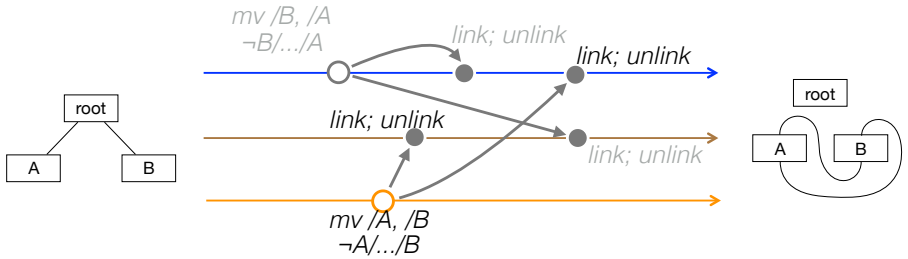


CAP-sensitive pattern



mv (node, ddir) { // tree
  if ¬ *ancestor (node, ddir)* // precond: at source
    link (ddir, node) // at every …
    unlink (sdir, node) // … replica
} // tree

CAP-sensitive pattern




```
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  if ¬ ancestor (node, ddir)    // precond: at source
    link (ddir, node)           // at every …
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} // tree
```
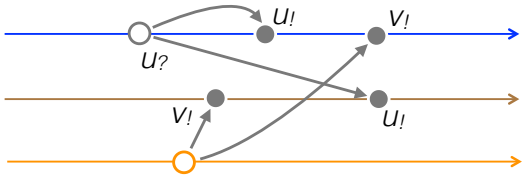

CISE Static Analysis

Precondition *not stable* w.r.t. concurrent *mv*

- Forbid concurrency? Synchro, CP.
- Or remove invariant? AP, degraded semantics

A data model for AP



Concurrent, asynchronous updates

- Standard register model: assignments ⟹ CP
- AP ⟹ concurrent updates merged

CRDT: register, counter, set, map, sequence

- Extends sequential type
- Encapsulates convergent merge

geoFS

Scality—UPMC

Tao Thanh Vinh

Posix-like replicated file system

- Available under Partition
- CRDTs: merge concurrent updates
- || *write* same file: merge or rename
- *delete* || *write*: file path survives
- *mv* || *mv* ⟶ copy; delete

mv || *mv* ⟹ unstable precondition

- Either CP or anomalous
- CP: minimal synch footprint

Mahsa Najafzadeh

RainbowFS

ANR project 2017–2021

UPMC + LIG + TSP + Scality + USMB

1. Application/system co-design
2. Modular replication
3. Multi-consistency file system

1. Application / consistency co-design

Just-Right Consistency:

- Most efficient consistency…
- …under which *my* application is correct

Static and dynamic verification

File system:

- Maintain tree invariant; others?
- Asynchronous: *mkdir, rmdir, creat, rm,* etc.
- Design options: *write* || *write, write* || *rm*
- Synchronised: *mv*

2. Modular geo-replication

From application skeleton to running system

Tools for large-scale deployment, monitoring, analysis, diagnosis

- Check correctness & efficiency
- Stress test
- Diagnose root cause

Protocol building blocks, compose for application

- 3D model, variants/strength
- Modular fault tolerance (Abstract)

3. Geo-replicated massive file system

Build a file system:

- Posix API
- Multi-consistency, tailor to application
- Scales to O(petabyte)
- Apply tools & methods from Tasks 1 & 2

Challenges:

- Geo-distributed, elastic
- Massive performance, partial replication
- Consistency, security, fault tolerance
- Layer above object store

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