A Replication Schema to Support Weak Connectivity in Mobile Information Systems

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Introduction

- Wireless Technology. Portable Computers.

- Access to databases.
  Replication for:
  - reliability
  - performance
  - cost

- Topic:
  A replication schema for mobile computing with emphasis on implementation issues and performance.

Introduction

Motivation

1. Wireless conections are slow, expensive and not widely available

   intermittent or partial connectivity

2. support for disconnected operation

3. variant connectivity

4. weak connectivity

A replication schema adapted to the above.

Outline of the Rest of the Talk

1. A Weak Consistency Model:
   Outline. Implementation. Correctness.

2. Protocols:
   Serializability.
   Bounded inconsistency.

3. Examples

4. Performance Evaluation:

   - The performance model

   - Performance parameters:
     (a) System throughput.
     (b) Communication cost.
     (c) Transaction response time

5. Related Work

6. Conclusions

A Weak Consistency Model

Outline of the Model

- *Clusters* as units of consistency.
- *Weak consistency:* intracluster consistency and bounded intercluster consistency.
  For replicated data: set a limit on the divergence among copies of data items.
- Reconciliation.
- Adaptability. Dynamic cluster configuration
- Weak reads and writes on local data.
- Weak transactions.
  data at the same cluster, visibility

A Weak Consistency Model

Implementation

- *core* and *quasi* copies
- Translation function h: operations on data items $\rightarrow$ operations on data copies
  - *strict read:* on core copies
  - *weak write:* on quasi copies
  - *weak read:* (a) Best-effort: most up-to-date
    (b) Conservative: quasi copies
  - *strict write:* (a) Eventual: only core copies
    (b) Immediate: also quasi copies at the cluster

Correctness

Given that d-degree is maintained, an intracluster schedule S is correct if its projection on strict transactions is equivalent to a serial one-copy (1C) schedule S_{1C}, and each of its projections on a cluster Cl_i is conflict-equivalent to a serial schedule S_{S_i} such that the order of transactions in S_{S_i} is consistent with the order of transactions in S_{1C}.

Protocols

Coherency: a quorum-based schema

Concurrency: Strict 2PL.
Weak release locks upon local commitment, strict upon global.
Lock compatibility for best-effort and eventual h:

	WR	WW	SR	SW
WR	X		X	
WW			X	X
SR	X	X	X	
SW		X		

Protocols

- **Definition**: *Up to d transactions can operate on inconsistent data*
  Protocol: Bound the number of weak transactions at each cluster

- **Definition:** *d the maximum number divergent versions per item*
  Protocol: h is defined such as a strict write modifies quasi copies at a cluster at least after every d updates. Applicable for voluntary disconnections

- **Definition:** *(data with arithmetic values) Each copy can take values from a range d*
  Protocol: Accept only those weak writes whose values are inside the range

- **Definition:** *Up to d data items can diverge*
  Protocol: Allow weak writes only on a set of d items

- **Definition:** *Up to d data copies per item can diverge*
  Protocol: Bound the number of weak writes at each cluster so that the total number of quasi copies that differ from core copies in all clusters is d

Examples

- Caching in a client/server setting.
  Cached data at mobile hosts are quasi data. Data at the fixed hosts are core data. Transactions invoked by mobile client are weak. Weak writes are accepted only if they do not conflict with strict.

- Cooperative enviroment.
  Groups of users. Clusters: data of a group. Data belong to the groups that access them frequently. At a group, core copies of data that belong to the group. Strict transactions for data that belong to the group. Weak writes are accepted only if they do not conflict.

- Location data.
  Quasi location copies. Bounded inconsistency.

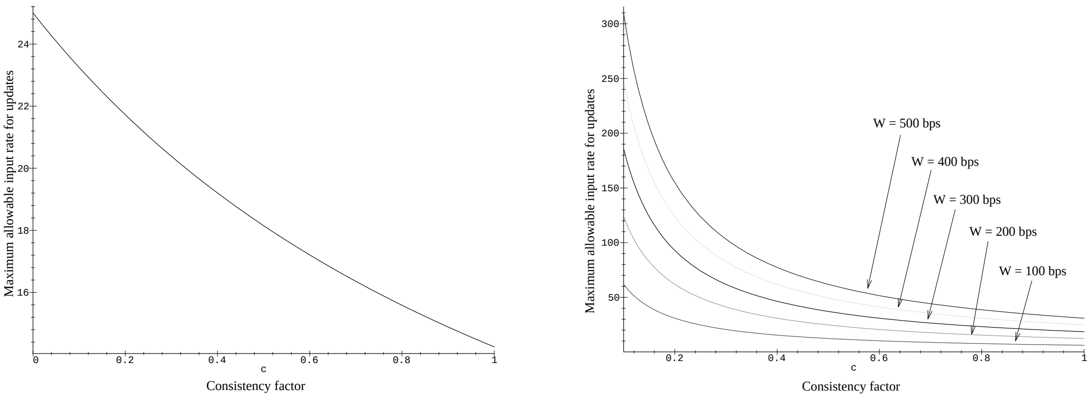
Performance

The model

- Analytical model, iteration-based methodology for coupling hardware resource and data contention, as in [Yu et. al., 1993]
- Consistency factor (c): fraction of strict operations
- Locality (o): roughly the fraction of transactions that access data from a hot set. Affects replication of core copies.
- Vacation system to model disconnections.
- Parameters: (a) System Throughput. (b) Communication Cost. (c) Response Time.

Performance

System Throughput.

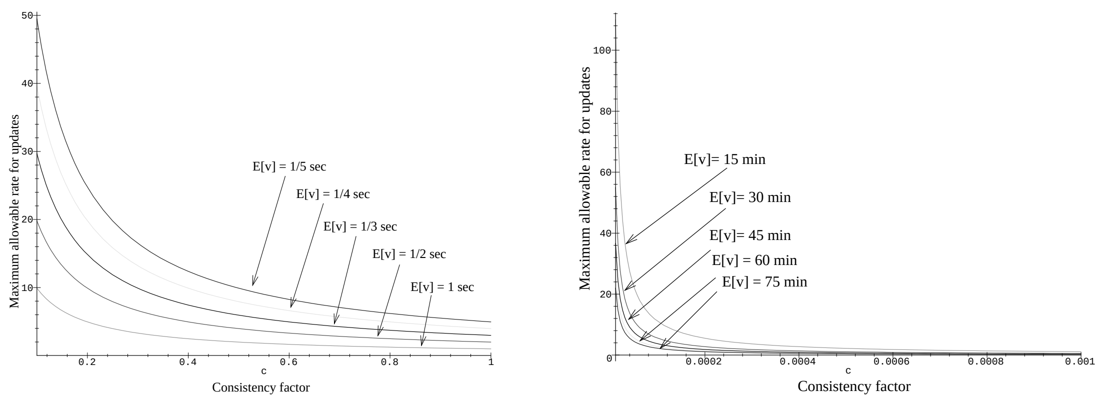


(Left) Limits by the processing rate at each cluster. Rate when $c = 0$ almost double that of $c = 1$.

(Right) Limits by bandwidth restrictions. Can be used to tune the consistency factor. Example: to get the same throughput as with 500bps and $c = 1$, when 100bps must set c below 0.1

Performance

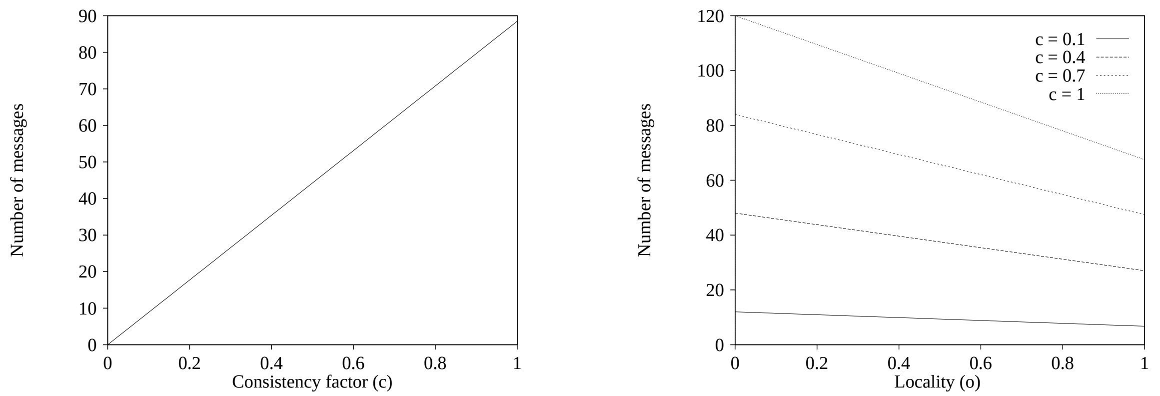
System Throughput.



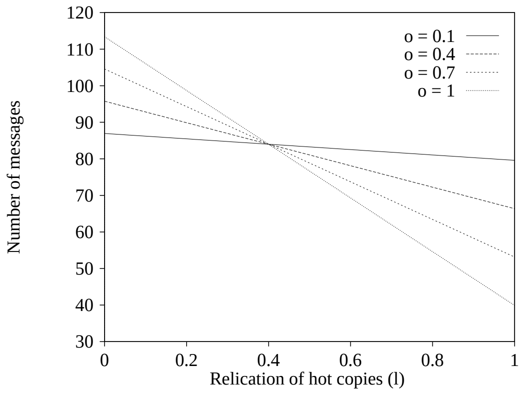
Limits imposed by disconnections. (Left) seconds, e.g., hand-offs. (Right) min, e.g., voluntary disconnections. Comparable throughput, drop c three orders of magnitude.

Performance

Communication Cost



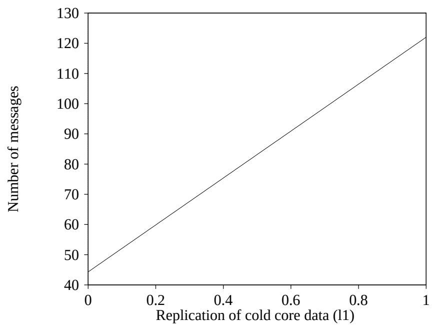
(Left) For various values of c. (Right) With locality.



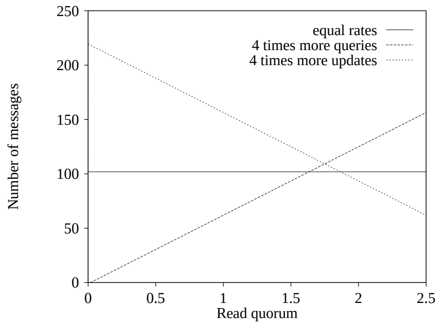
For different replication of hot core copies (ROWA). More rapid increase with locality

Performance

Communication Cost



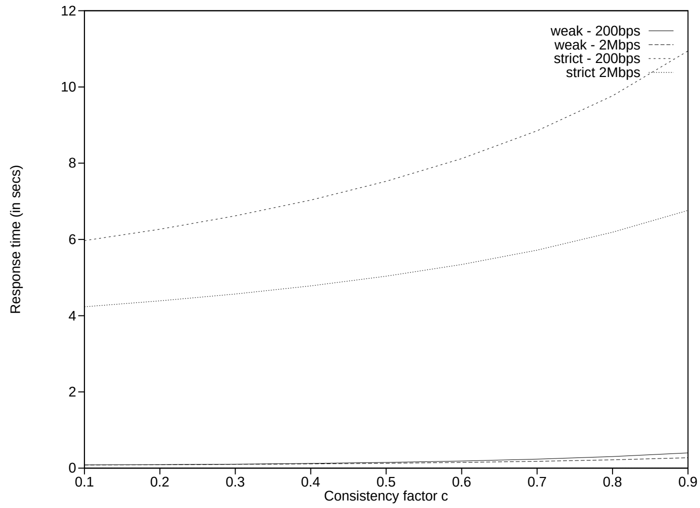
For different replication of hot core copies.



For different values of the read quorum.

Performance

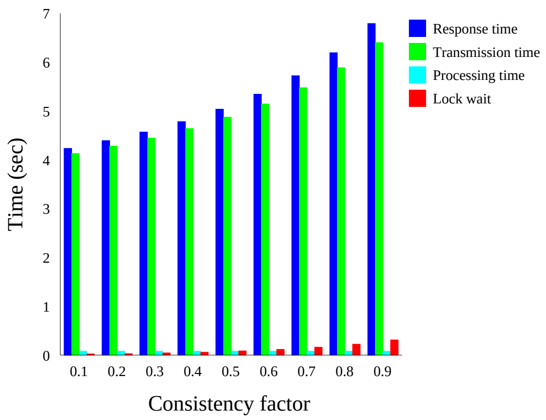
Response Time

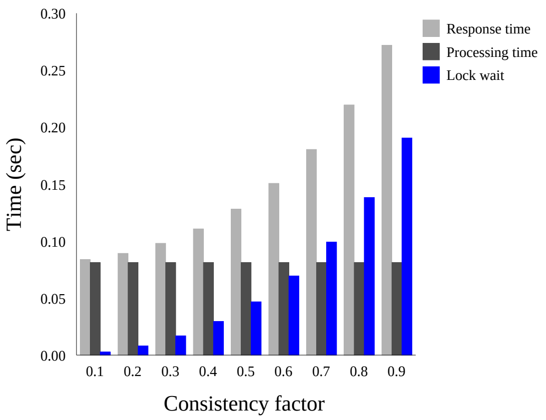


Comparison of the response times for weak and strict transactions for various values of c.

Performance

Response Time





Response time distribution (Left) for strict transactions. (Right) for weak transactions.

Related Work

- Network Partition
  – electively done
  – physically connected
  – hybrid (optimistic - pessimistic)

- Bayou
  – tentative and committed data
  – correctness based on session guarantees

- Coda
  – disconnections as partitions
  – optimistic

- Isolation-only Transactions
  – only isolation
  – not failure atomicity
  – conditionally permanence

- File Service Interface
  – add a weak read to a file system interface

Summary

- Mobile clients switch between connected and disconnected modes of operation
  Propose an appropriate replication schema

- Utilize bandwidth (tune the percentage of weak transactions)
  Support disconnections
  Provide for adaptability (various degrees of inconsistency and percentages of weak transactions)

- Application-aware adaptation
  Weak transactions as middleware

- Analytical model to study the performance under various networking conditions and percentages of weak and strict transactions