CS848 Paper Presentation

Scalable Query Result Caching for Web Applications

Garrod, Manjhi, Ailamaki, Maggs,
Mowry, Olston, Tomasic

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Presented by Rehan Rauf

David R. Cheriton School of Computer Science
University of Waterloo

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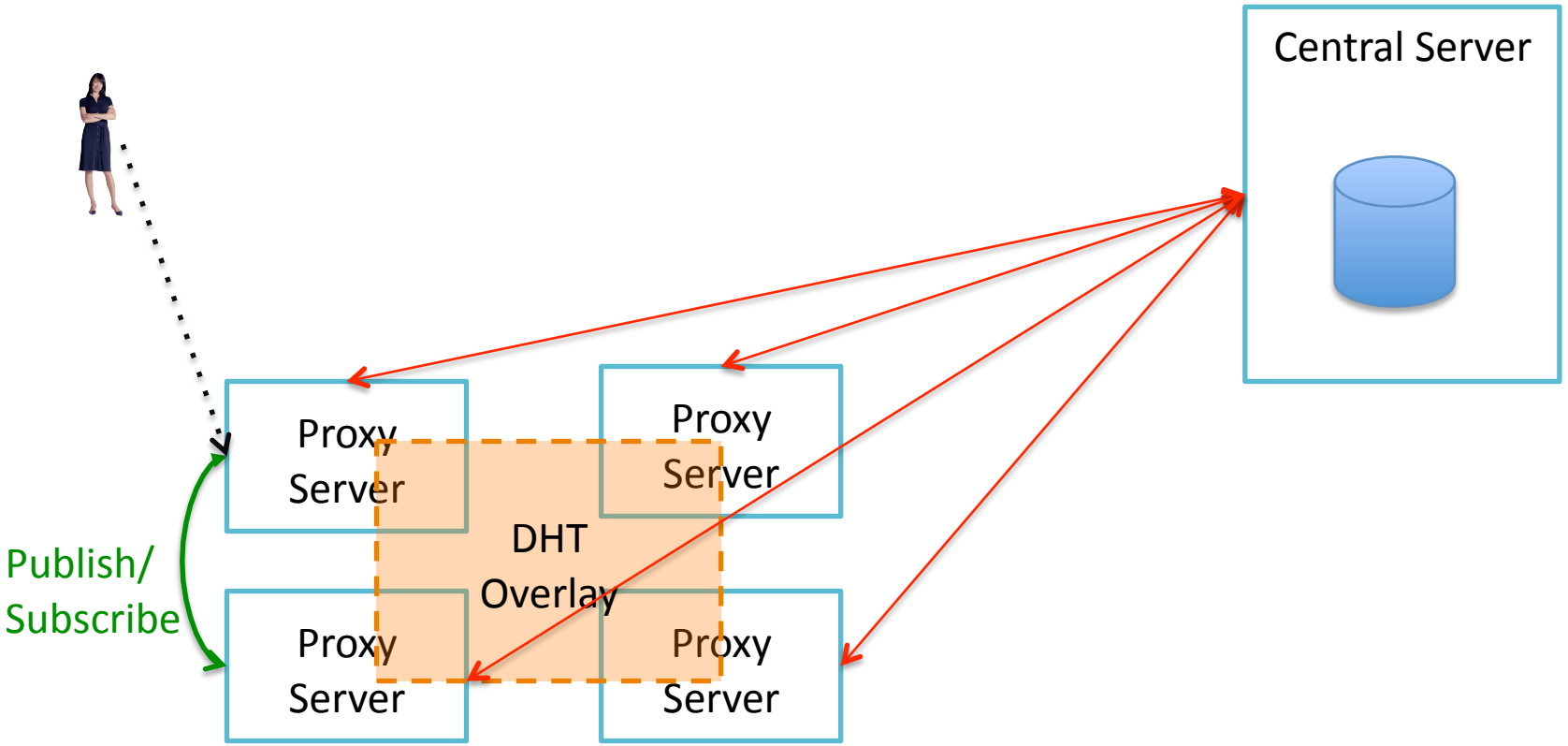
Problem

- Central database server becomes a bottle-neck in Content Distributed Networks

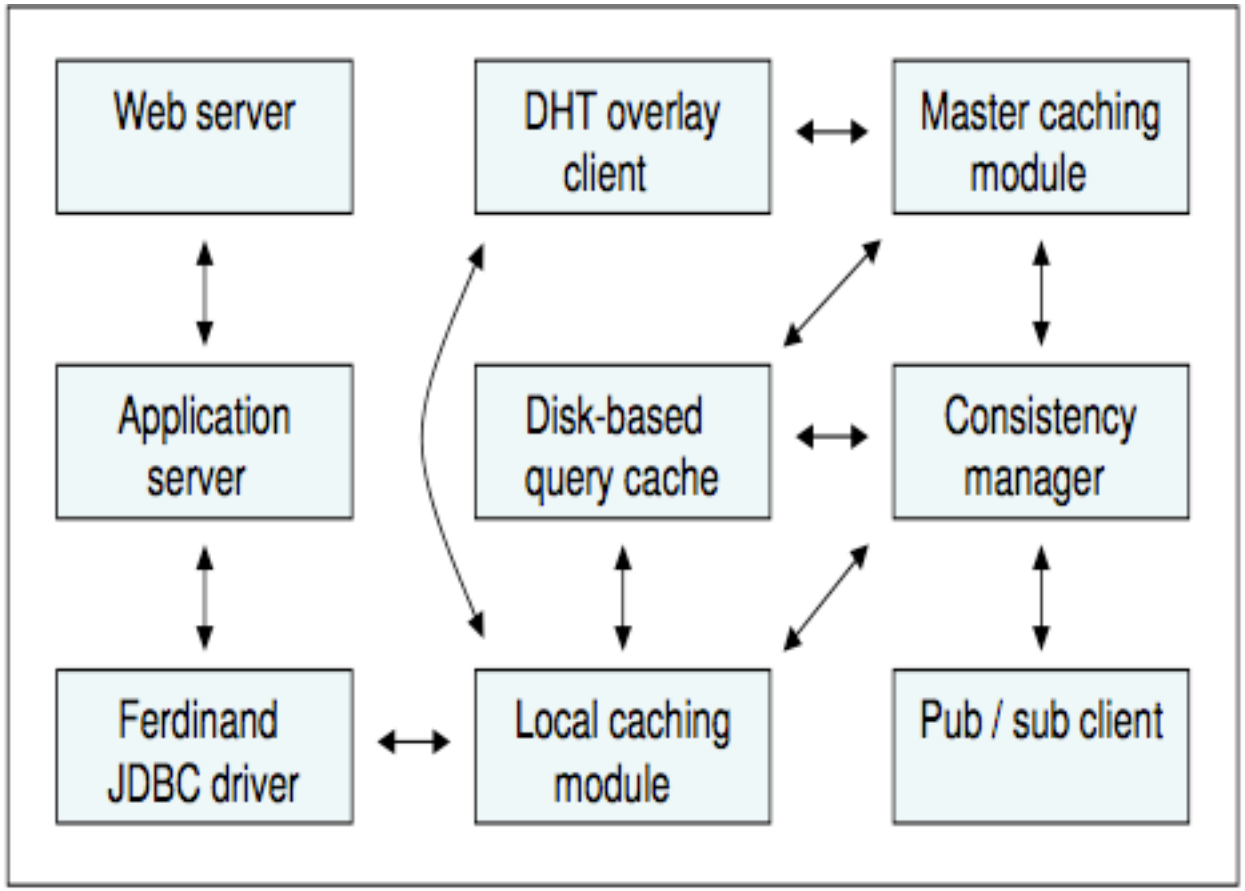
- Replication of database among multiple servers removes bottle-neck but …
    - requires low latency consistency which conflicts with low latency between user and server
    - does not scale linearly with cost.

- Traditional proxy-cache based solutions remove bottle-neck but …
    - inefficiently maintain consistency
    - scalability is limited by low cache hit-rate

High-level Architecture of Ferdinand

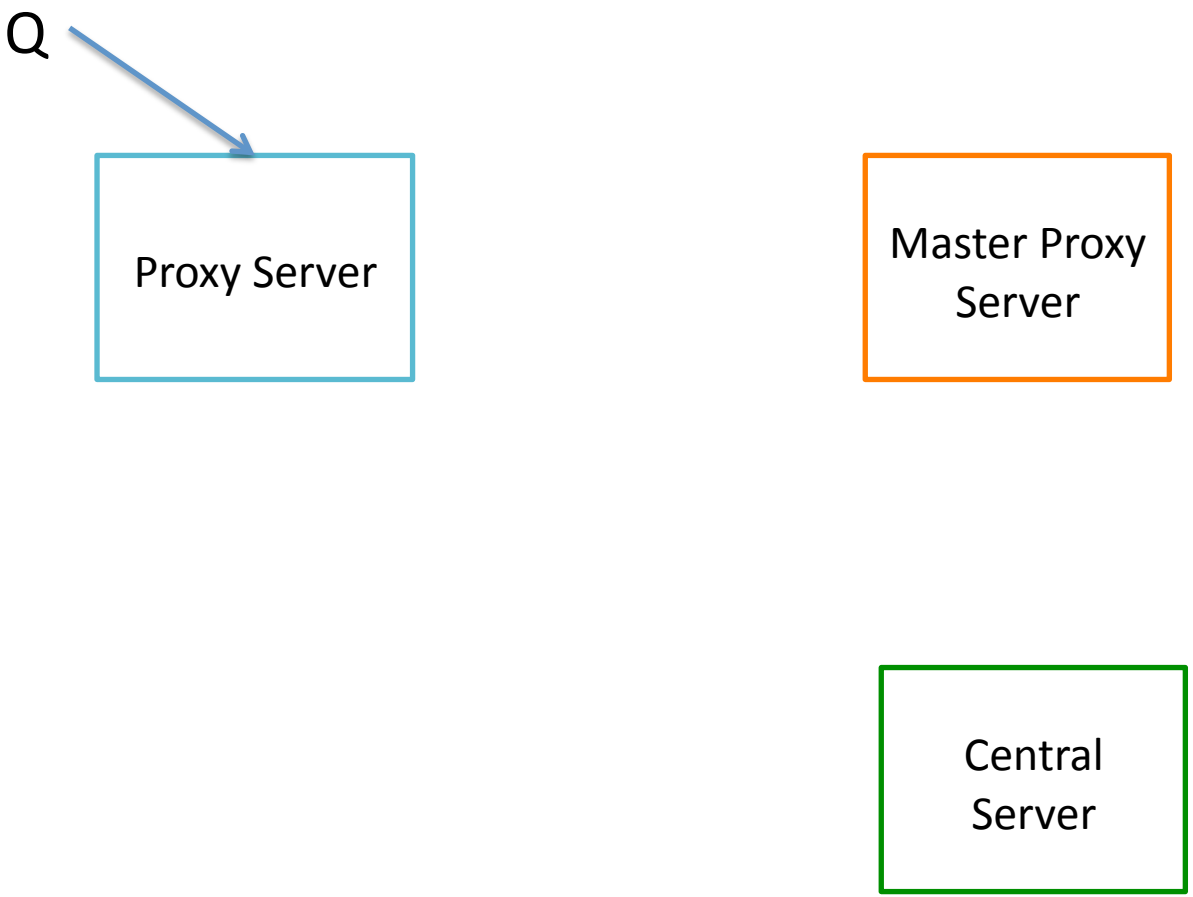


Ferdinand Proxy Server



Operations

Each query has a master proxy server



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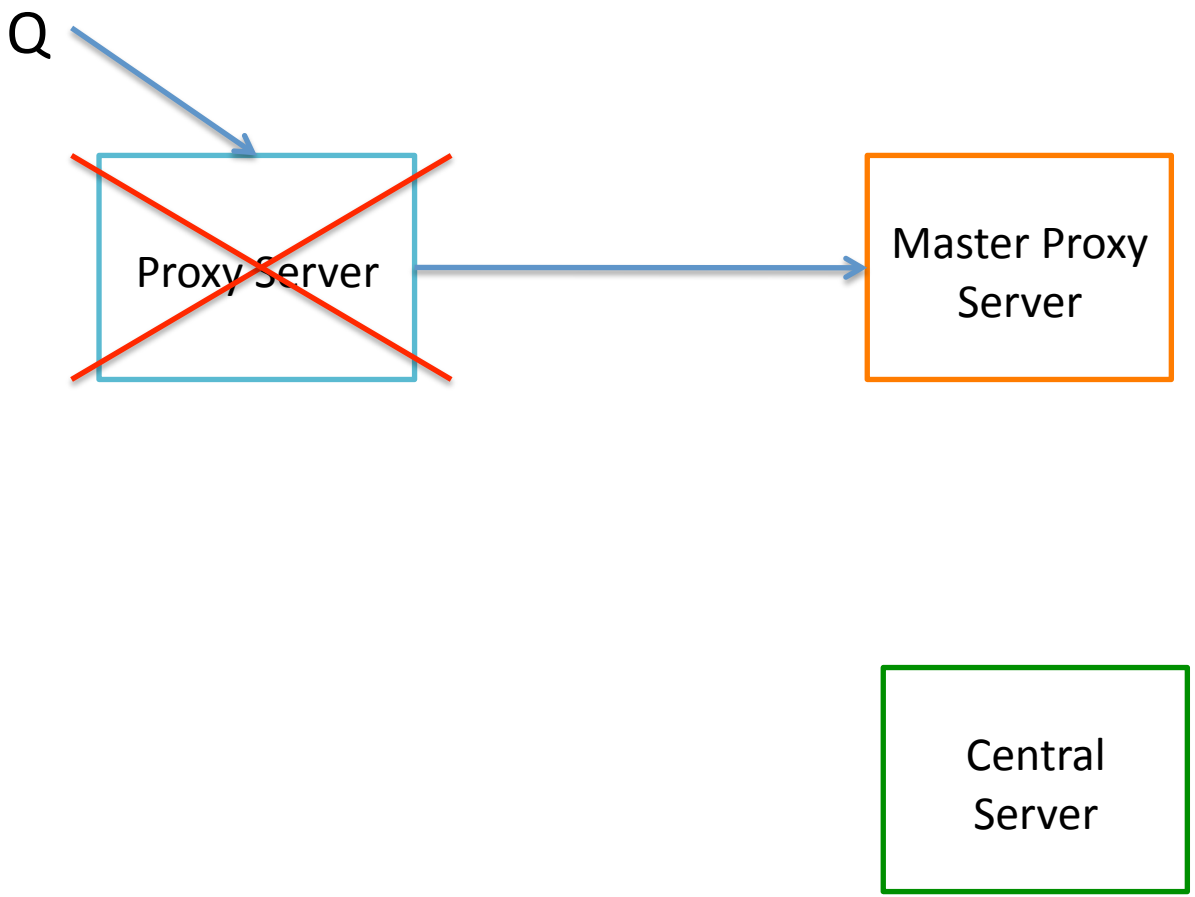

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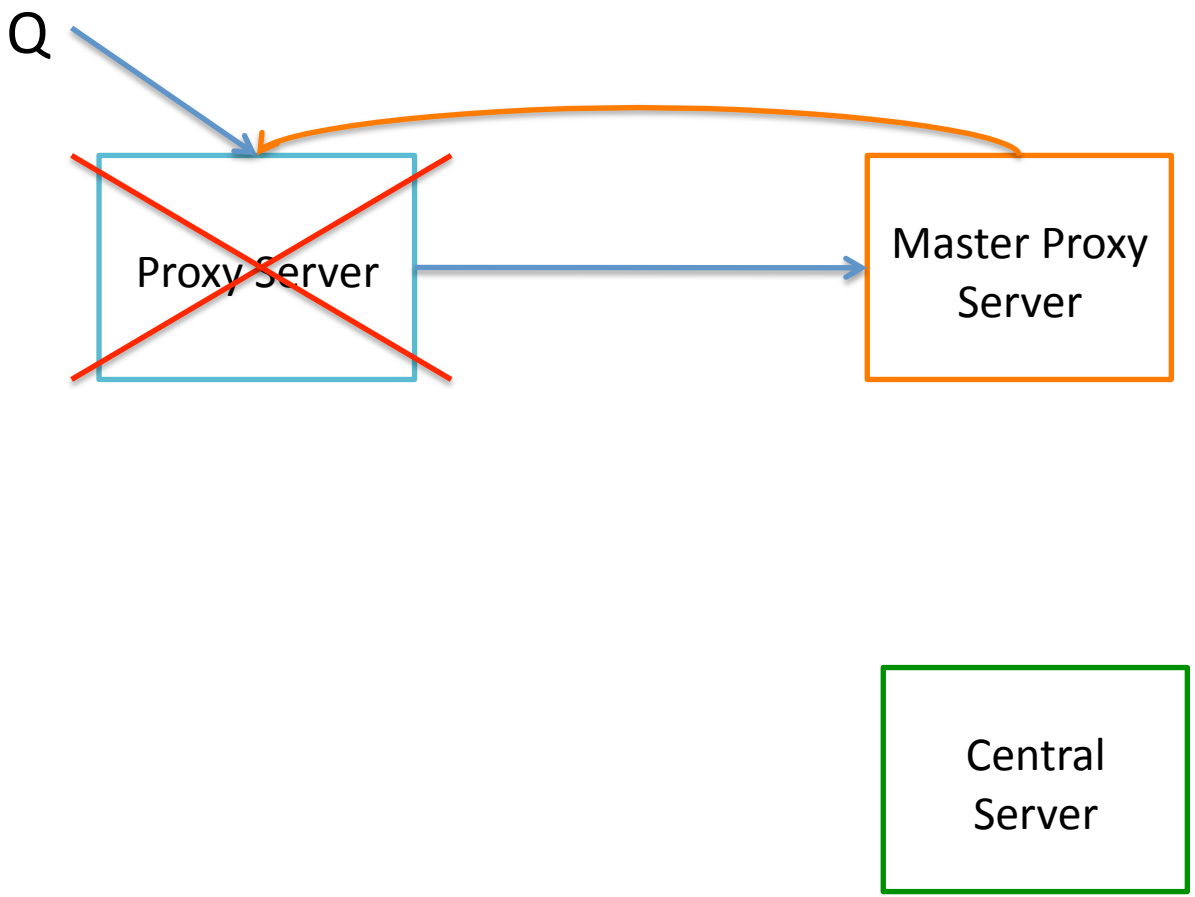

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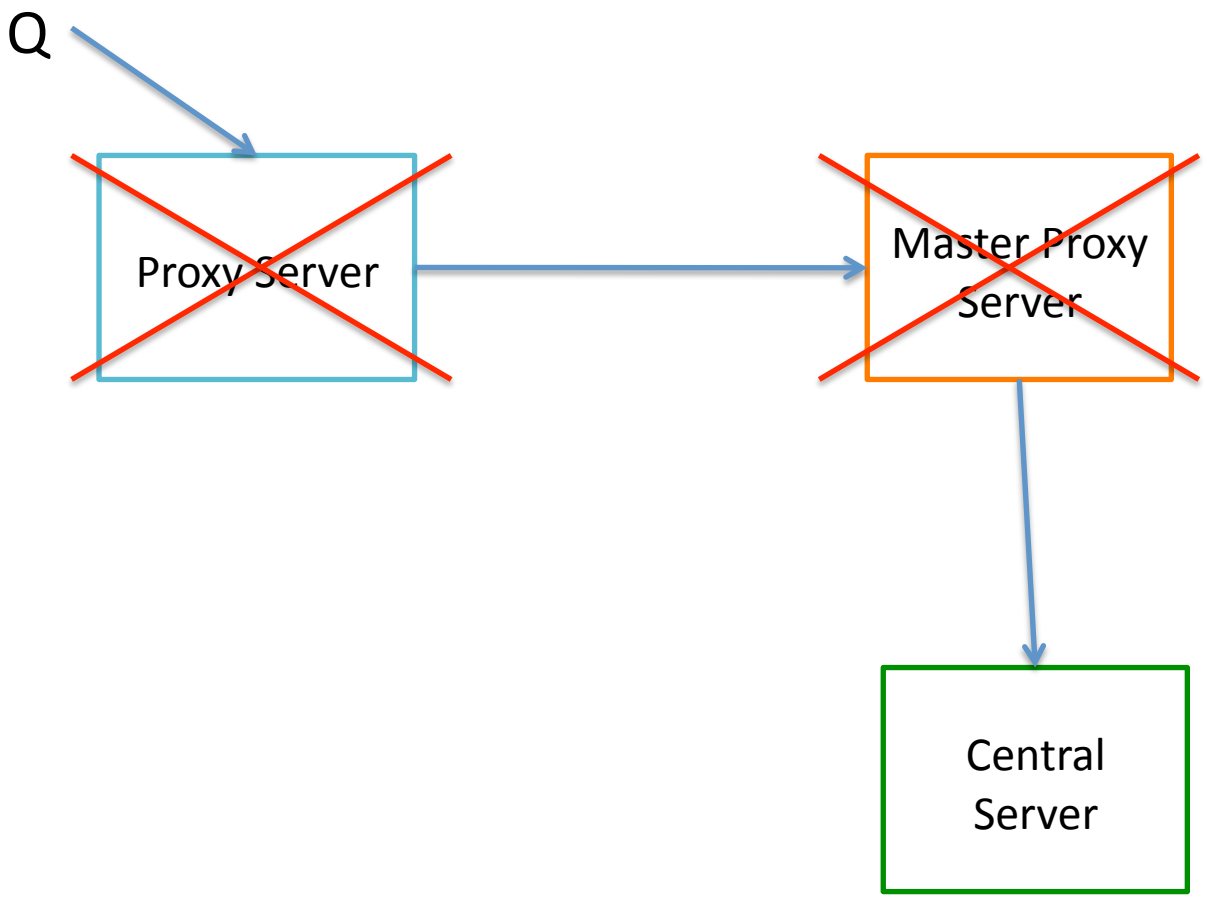

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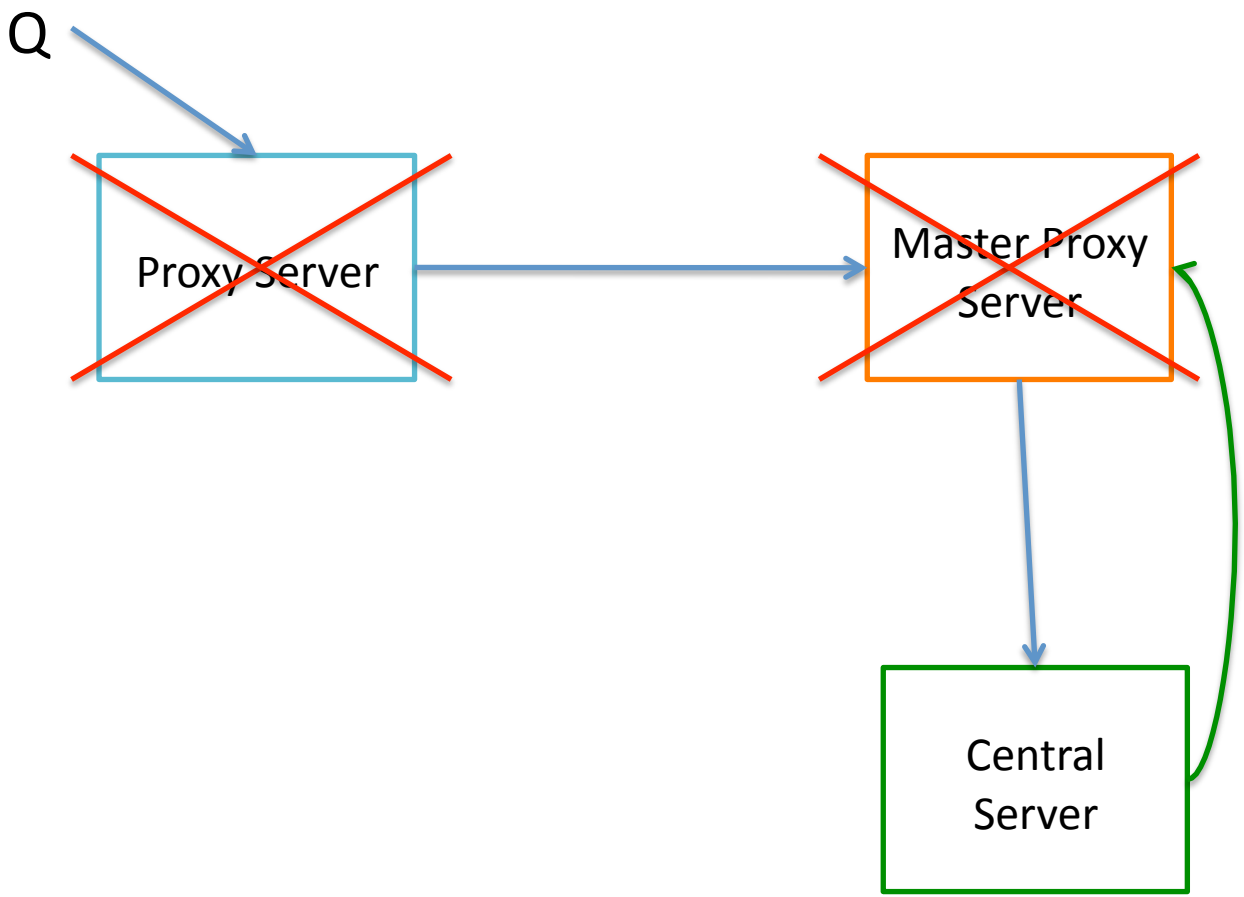
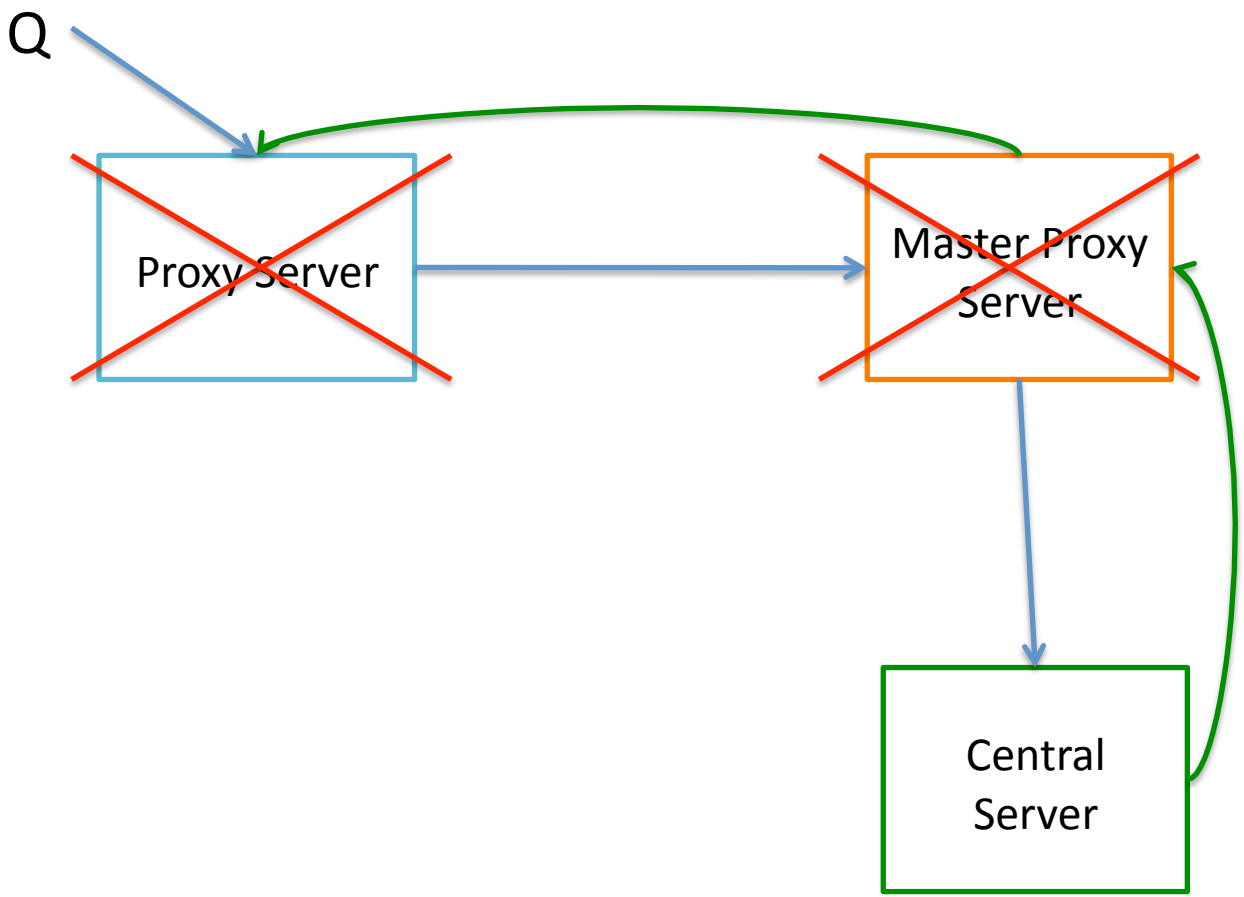


Operations



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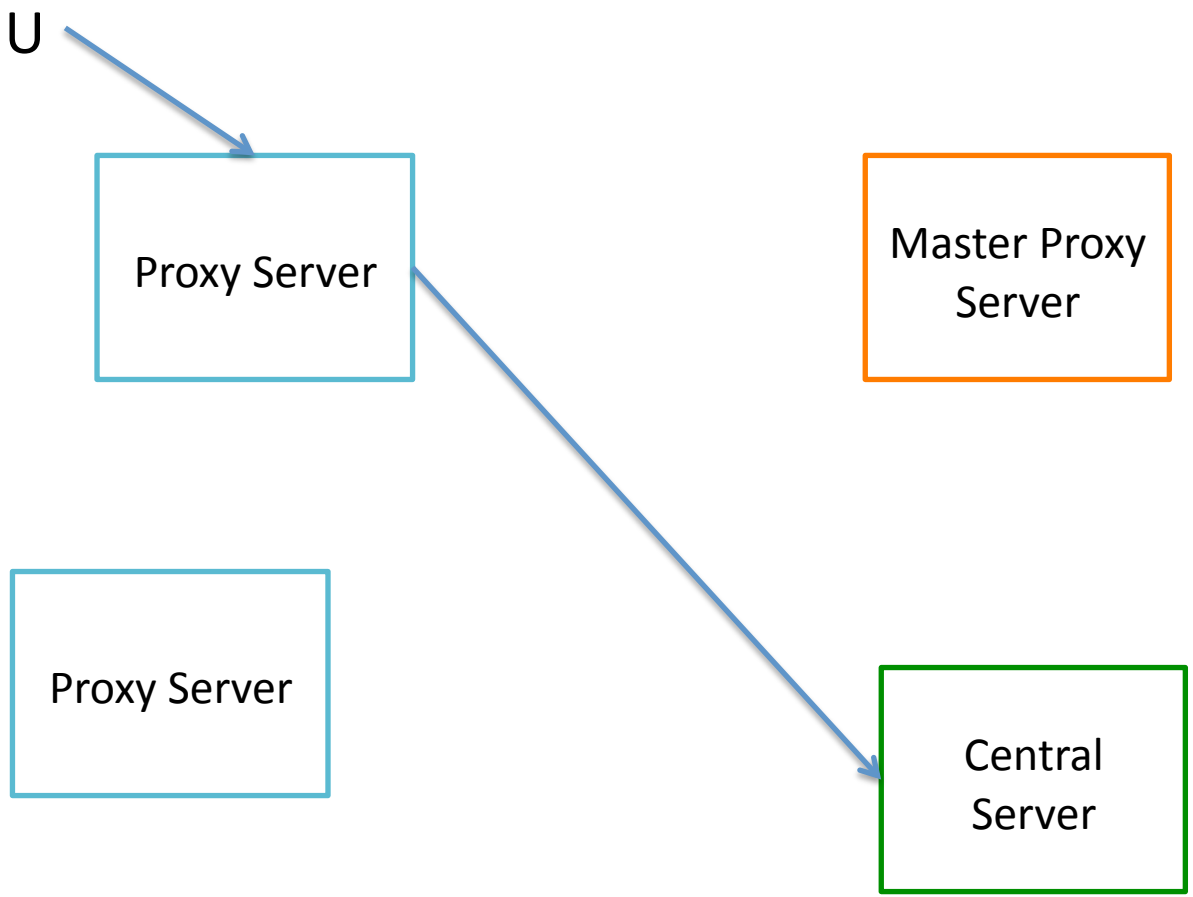
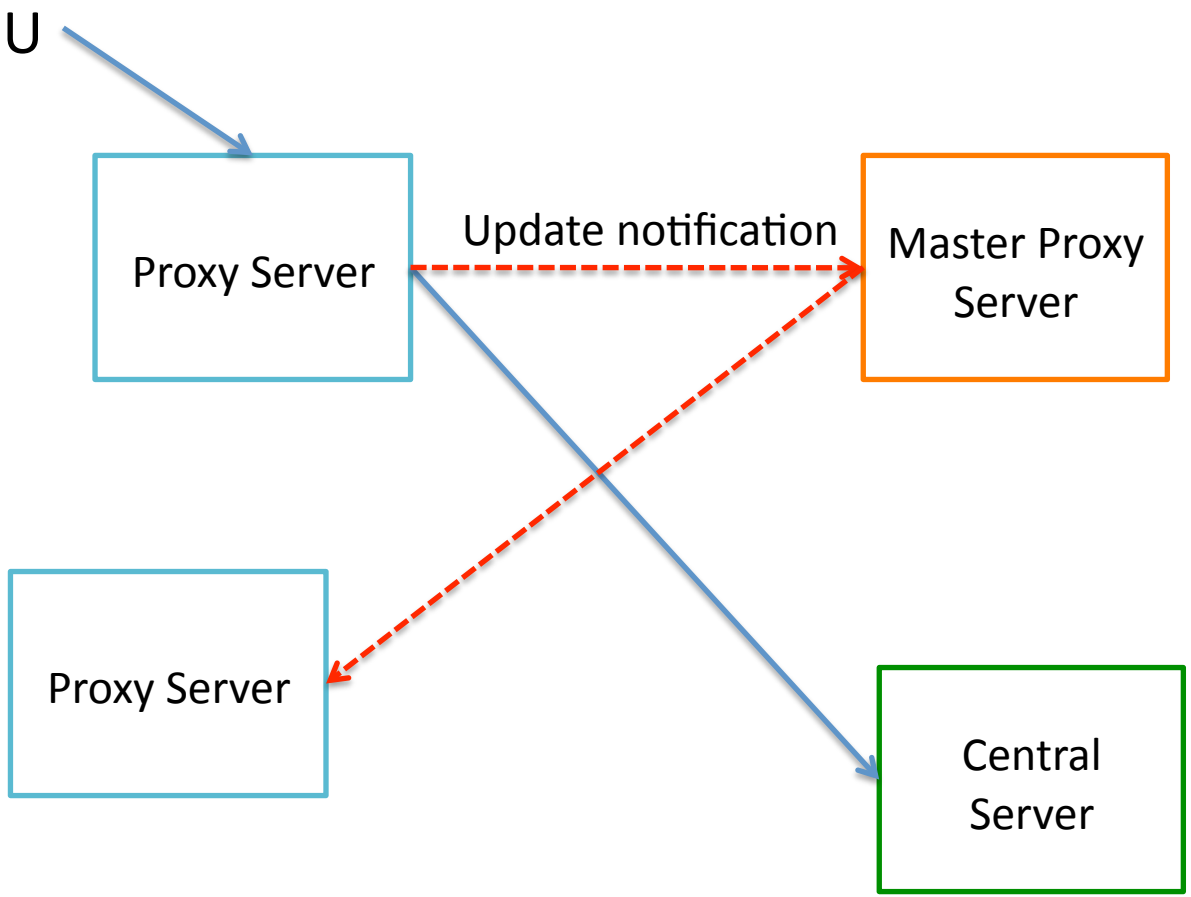

U
Proxy Server
Master Proxy Server
Proxy Server
Central Server

Operations


U
Proxy Server
Update notification
Master Proxy Server
Proxy Server
Central Server

Proxy Server Cache

• When proxy server receives update notification, the consistency module invalidates the query result.

• Even if results can be processed using previously cached results, it is not done

Advantages/ Disadvantages

- Advantages
  - High cache hit rate.
  - More work offloaded from the backend server

- Disadvantage
  - Latency cost of an over all cache miss is greater

Consistency Management

• Any proxy caching a particular query must be notified when an update affects the result of that query.

• Query Update Multicast Association (QUMA) is used to ensure this requirement.

QUMA Solution

- Multicast groups are created.
    - Offline analysis of application's template database queries is performed.
    - Independence analysis is done to determine independence of query-update pairs.

- Goals
    - Any update notification published to a group should affect each query subscribed to that group
    - Related queries should be clustered into same multicast group to reduce number of notifications.

- Each cached query subscribes to appropriate multicast groups.
- Updates are published to these groups and hence reach the appropriate proxy server.

QUMA Example

Template U1:
```
INSERT INTO inv VALUES
  (id = ?, name = ?, qty = ?,
  entry_date = NOW())
```

Template U2:
```
UPDATE inv SET qty = ?
  WHERE id = ?
```

Template Q3:
```
SELECT qty FROM inv
  WHERE name = ?
```

Template Q4:
```
SELECT name FROM inv
  WHERE entry_date > ?
```

Template Q5:
```
SELECT * FROM inv
  WHERE qty < ?
```

QUMA Solution

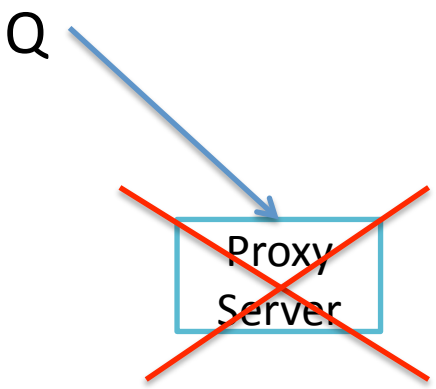
Template	Associated Multicast Groups
Template U1	{GROUPU1:NAME=?, GROUPU1}
Template U2	{GROUPU2}
Template Q3	{GROUPU1:NAME=?, GROUPU2}
Template Q4	{GROUPU1}
Template Q5	{GROUPU1, GROUPU2}

- Selection predicates are only practical when they are equality based.
- The process is not automated yet.

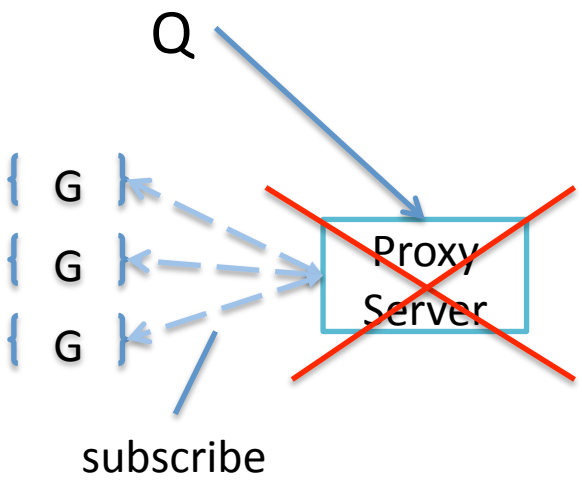
Consistency Management

- For each multicast group, there is a master multicast group.
    - used for communication with master proxies.

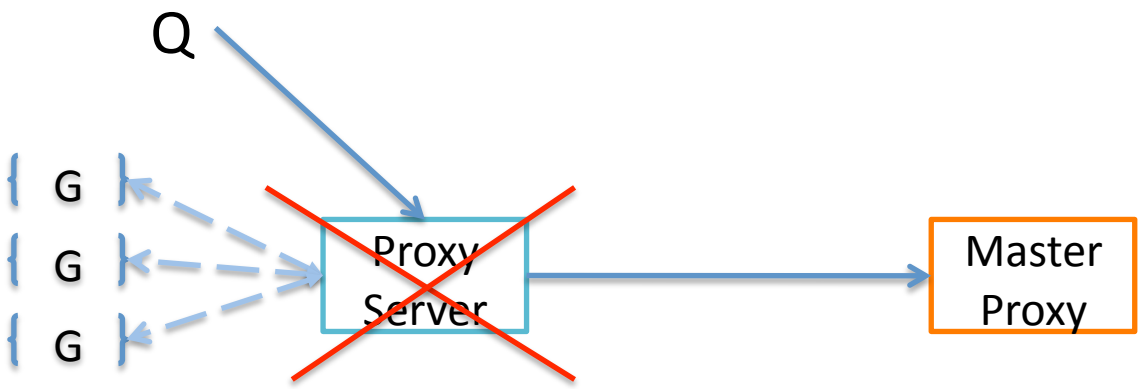
Cache Miss



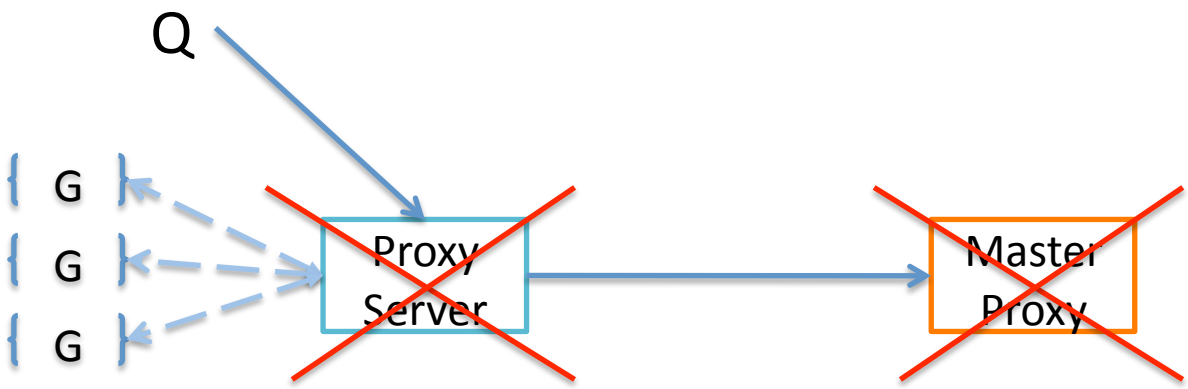
Cache Miss



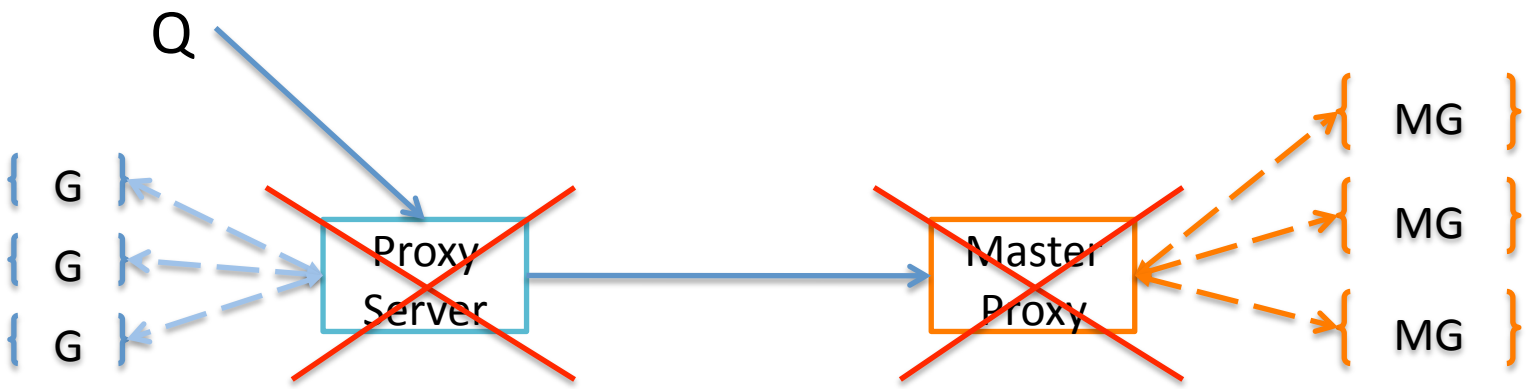
Cache Miss



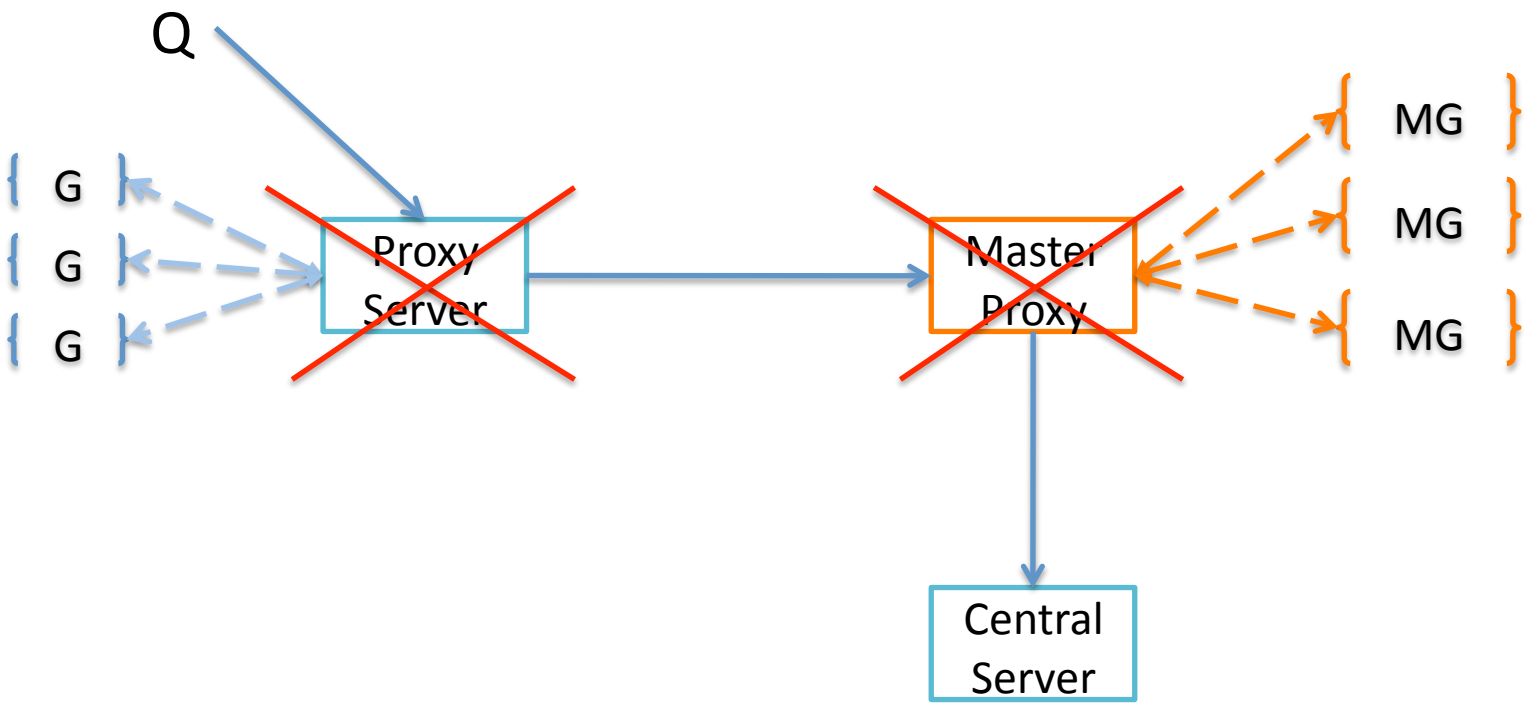
Cache Miss



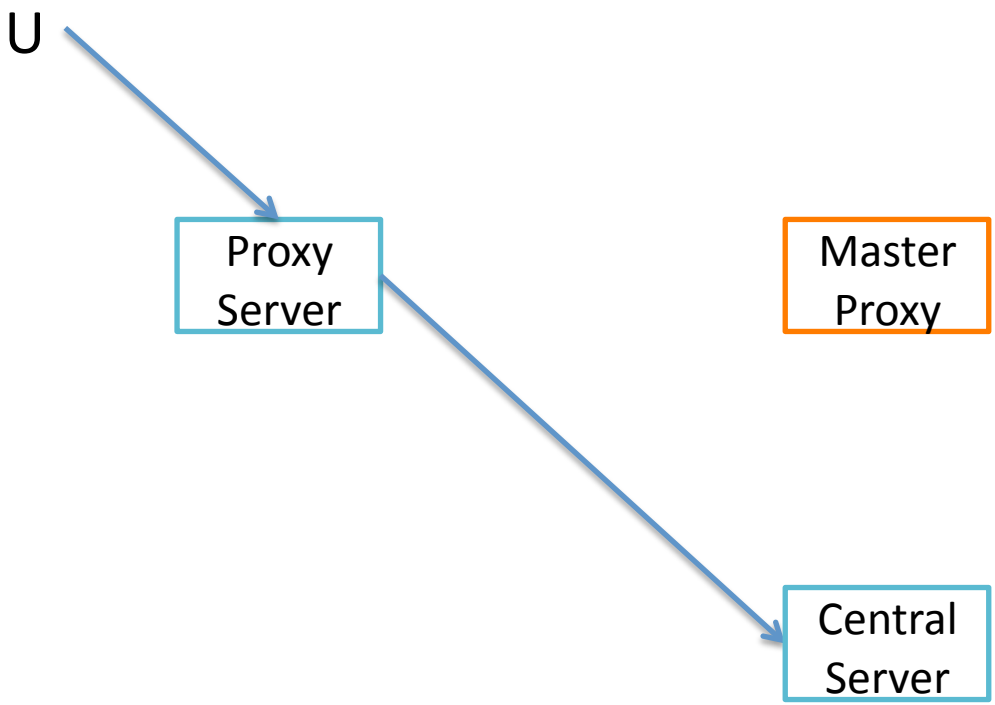
Cache Miss



Cache Miss



Update



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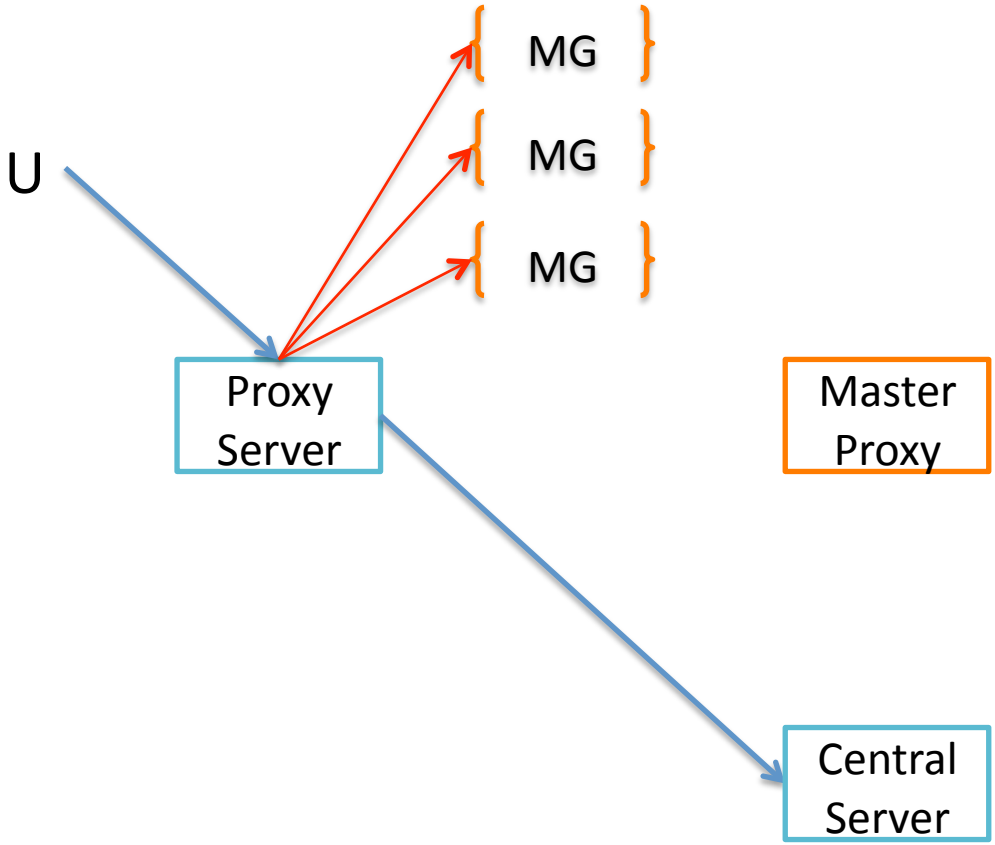

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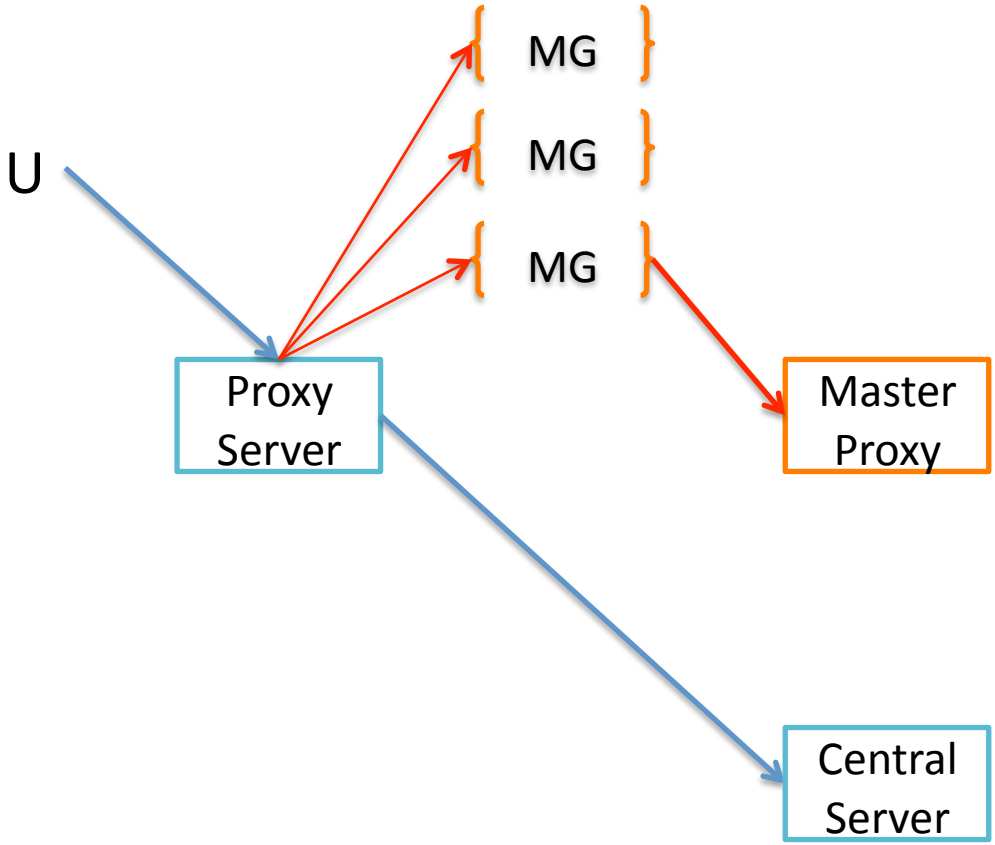

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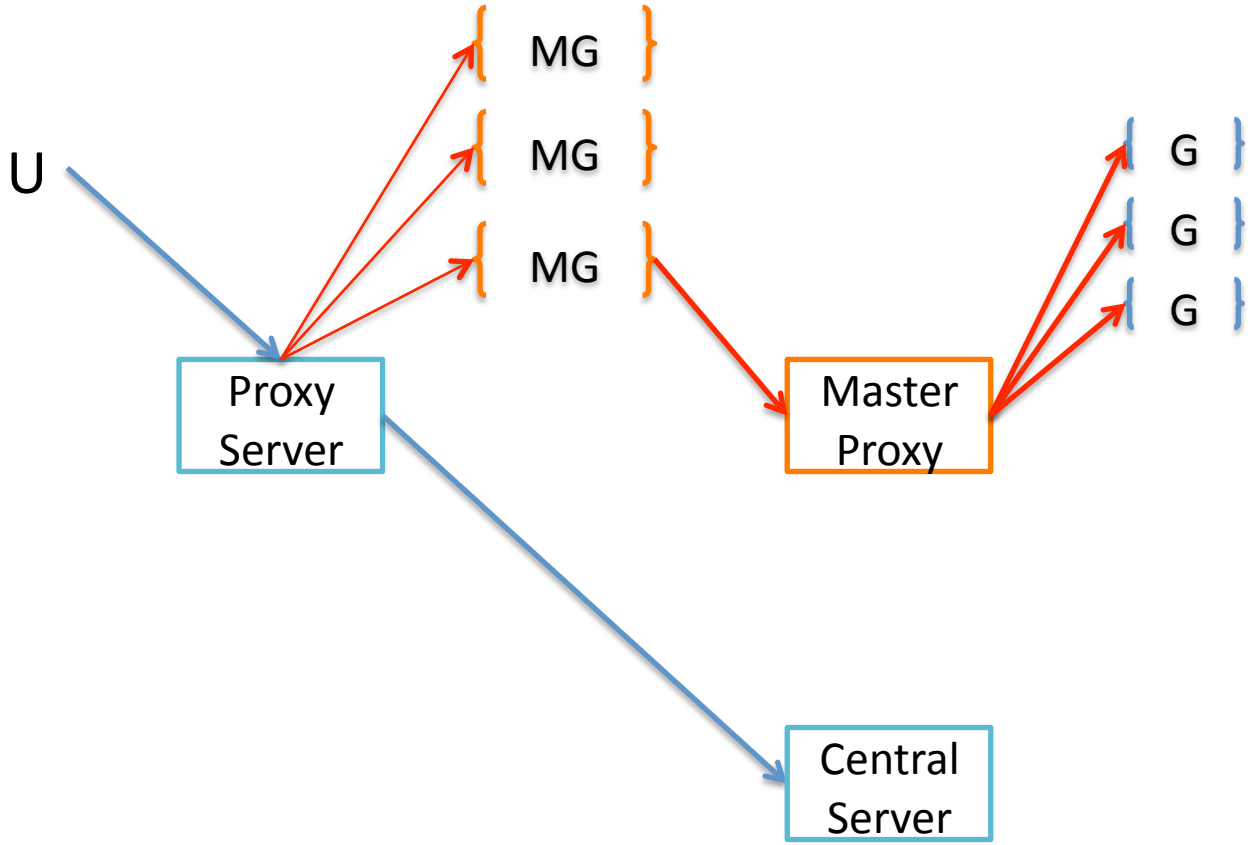
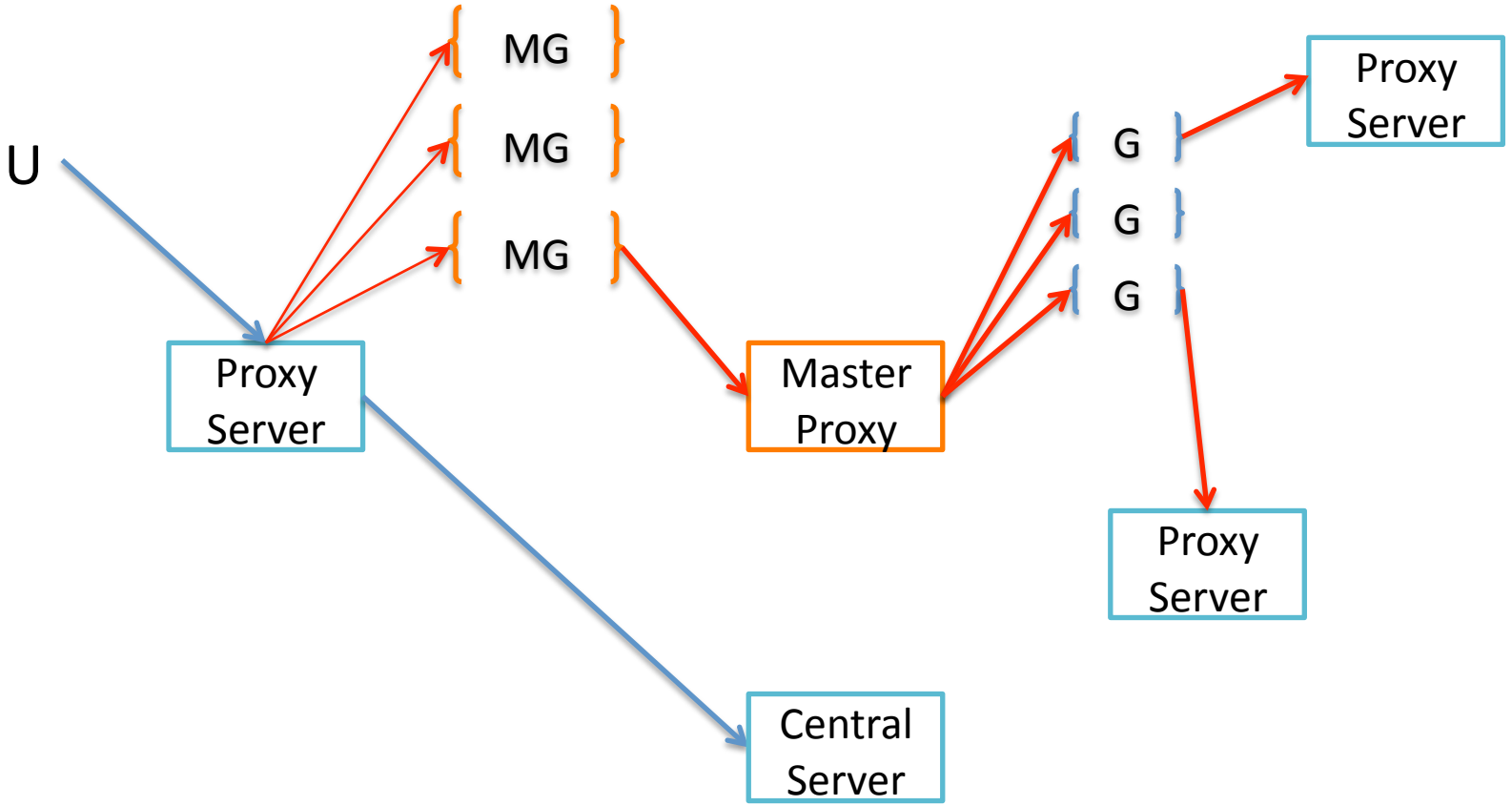


Update


U
MG
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Proxy Server
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Central Server

Consistency Management

- Ensures that query cache remains coherent with the central DB but..
  - Guarantees full consistency only for single statement transactions.
- Requires a reliable publish/subscribe system.
- Requires serializability guarantees from central database

Implementation

- JDBC Driver
- Proxy runs Apache tomcat as static cache
- Pastry overlay as DHT (is based on PRR tree)
- Scribe for publish scribe
    - does not guarantee reliable delivery.
- Ferdinand cache map is stored in MySQL4
- Backend database is MYSQL4

Evaluation

- Performance comparison with several alternative approaches.

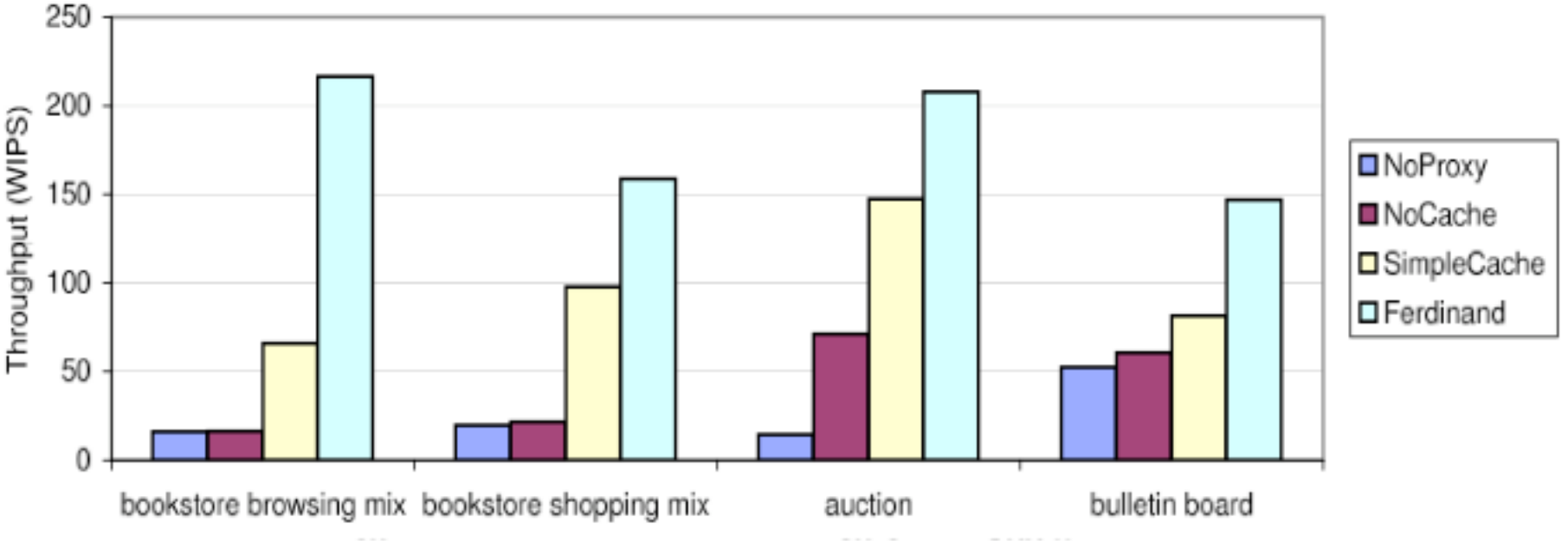
- Performance of DHT based cooperative caching in varying network latency scenarios.

- Publish/subscribe vs simple broadcast-based system

Evaluation

- Emulab testbed
- Proxy ran on 3 GHz Intel Pentium Xeon, 1GB ram, 10,000 RPM SCSI disk.
- Benchmark clients on 850 MHz client servers.
- Benchmark
    - TPC-W bookstore
    - RUBiS auction
    - RUBBos bulletin board
        - Conforms to TPC-W model of emulated browsers

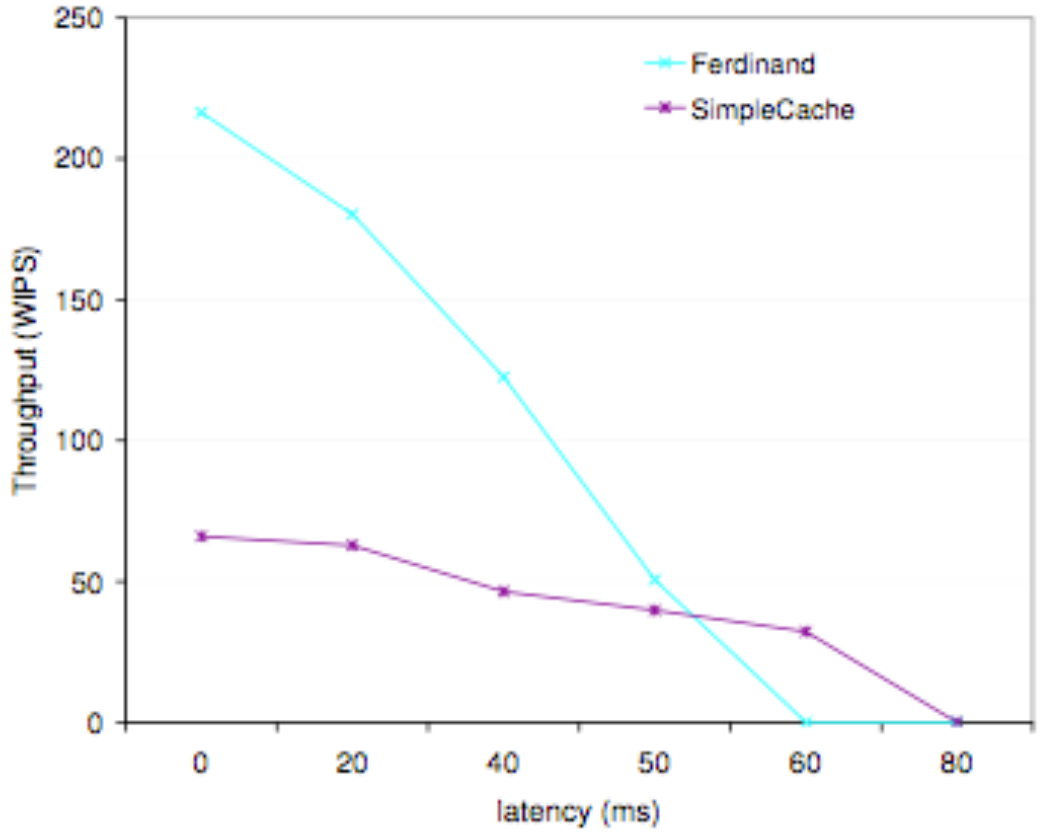
Evaluation: Comparison to other approaches



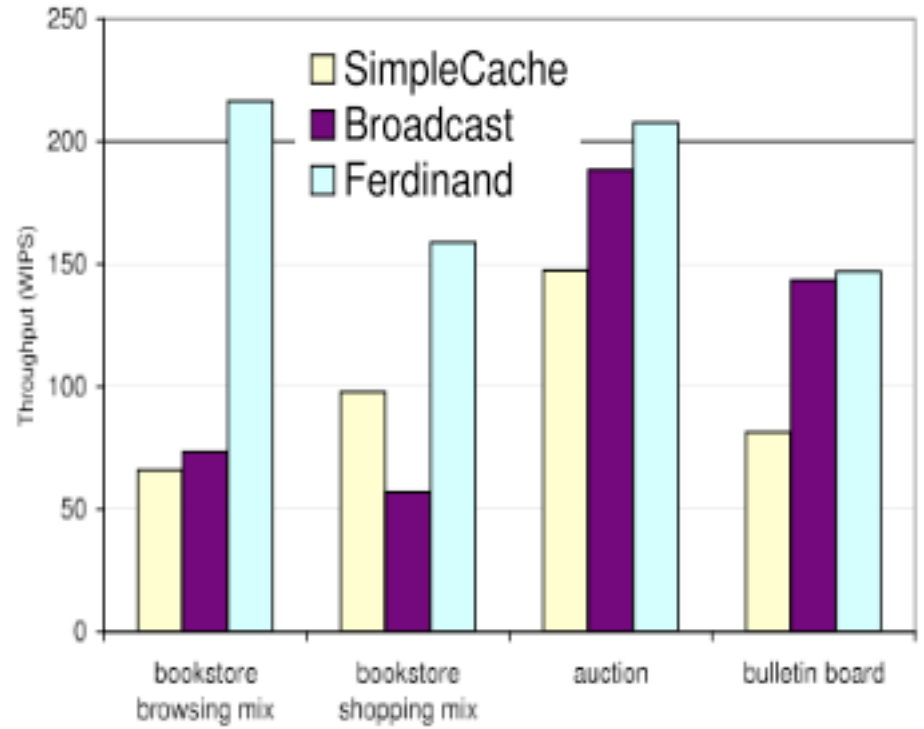
Evaluation: Cache Miss Rate

	SimpleCache	Ferdinand
bookstore browsing mix	17%	7%
bookstore shopping mix	22%	14%
auction	40%	17%
bulletin board	20%	11%

Evaluation: Throughput as a function of latency



Evaluation: Throughput compared to broadcast-based consistency



Closing Observations

- No Scalability evaluation shown.
- Not suitable for update intensive application.
- Requires offline analysis of database requests.
- Failure Scenarios need to be deal with.
- No consistency for multi statement transactions.