PNUTS: Yahoo!'s Hosted Data Serving Platform

Presented by: Gaurav Vaidya

Some of the slides in this presentation have been taken from
http://www.cse.iitb.ac.in/dbms/Data/Courses/CS632/Talks/pnuts-vldb08.ppt

INTRODUCTION

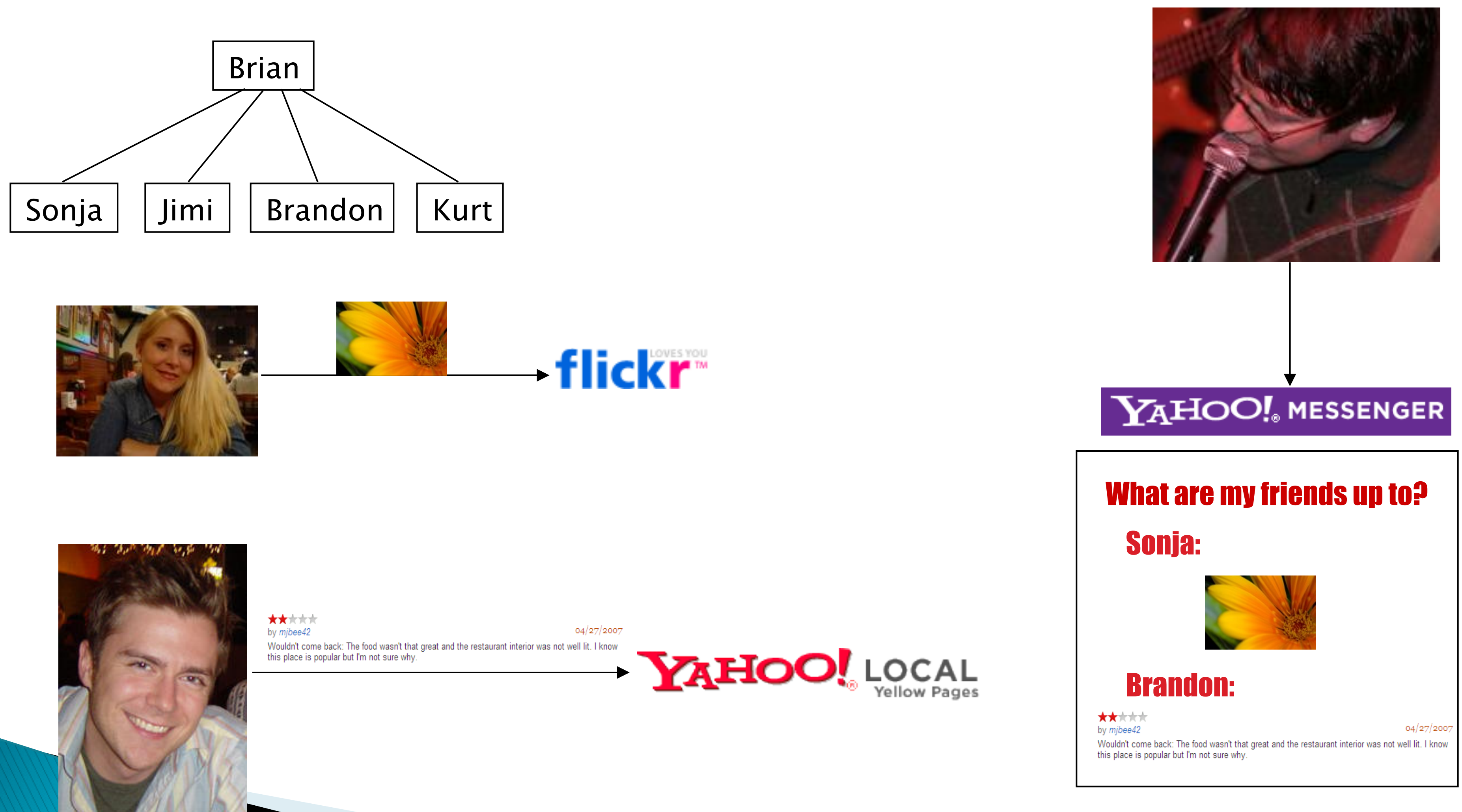
How do I build a cool new web app?

- Option 1: Code it up! Make it live!
  - Scale it later
  - It gets posted to slashdot
  - Scale it now!
  - Flickr, Twitter, MySpace, Facebook, …

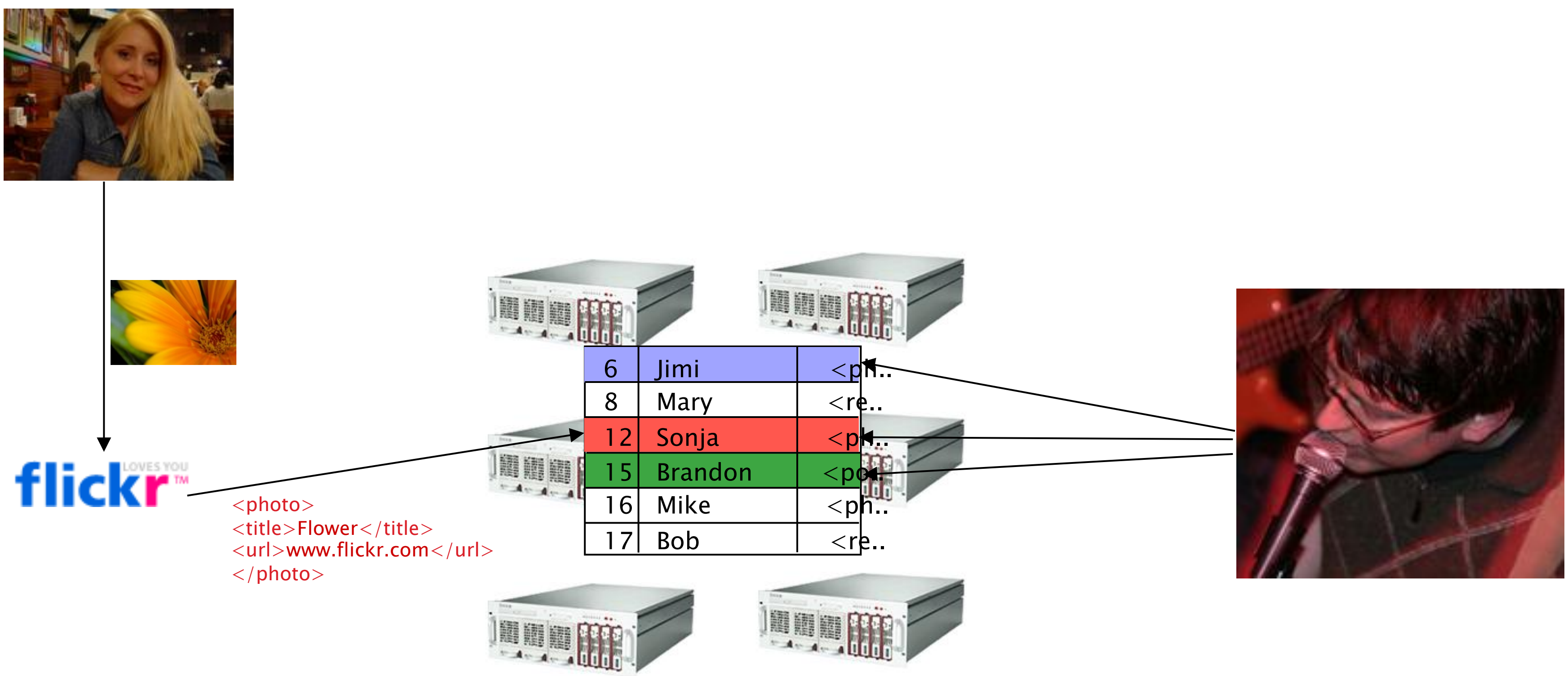
How do I build a cool new web app?

- Option 2: Make it industrial strength!
  - Evaluate scalable database backends
  - Evaluate scalable indexing systems
  - Evaluate scalable caching systems
  - Architect data partitioning schemes
  - Architect data replication schemes
  - Architect monitoring and reporting infrastructure
  - *Write application*
  - Go live
  - Realize it doesn't scale as well as you hoped
  - Rearchitect around bottlenecks
  - 1 year later – ready to go!

Example: social network updates



Example: social network updates



Consistency Example

Photo Sharing List

- Mom
- John

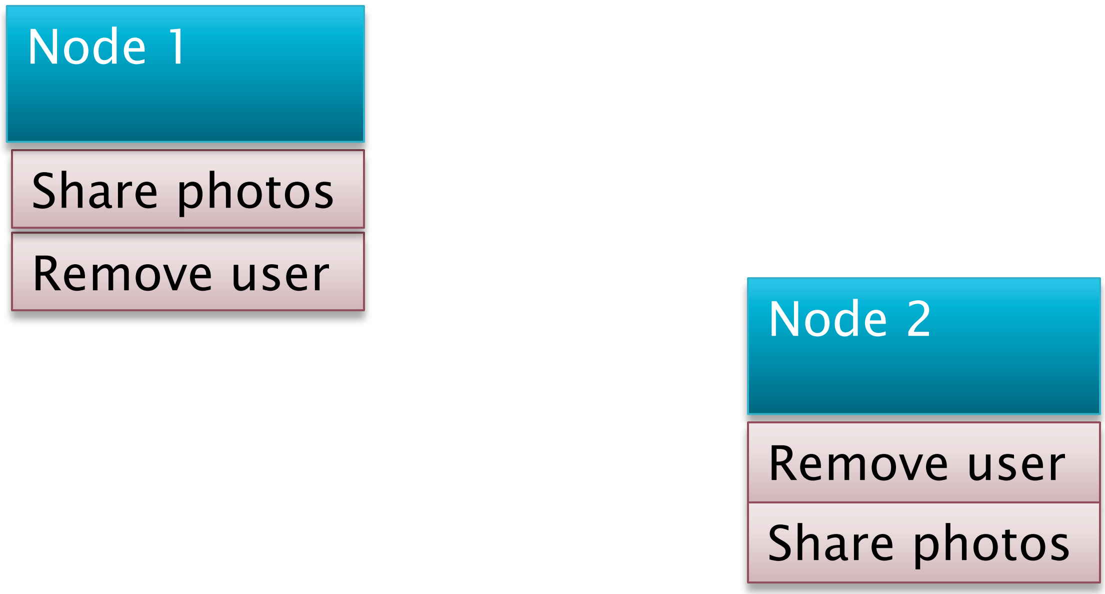
remove

remove

Photo Sharing

Album :
Spring Break Party

Timeline consistency



Features needed for web-apps

- Scalability
- Response Time and Geographic Scope
- High Availability and Fault Tolerance
- Relaxed Consistency Guarantees

PNUTS in a nutshell

It is a

- massively parallel
- geographically distributed
- database system for Yahoo!'s web applications.

It is a hosted & centrally managed service

PNUTS in a nutshell

- Data storage organized as hashed or ordered tables
- Low latency for large numbers of concurrent requests including updates and queries
- Per-record consistency guarantees

Contributions

- Record-level, asynchronous geographic replication
- A consistency model that offers applications transactional features but stops short of full serializability.
- A careful choice of features
  - include (e.g., hashed and ordered table organizations, flexible schemas) or
  - exclude (e.g., limits on ad hoc queries, no referential integrity or serializable transactions).
- Data management as a hosted service

FUNCTIONALITY

PNUTS Specifications

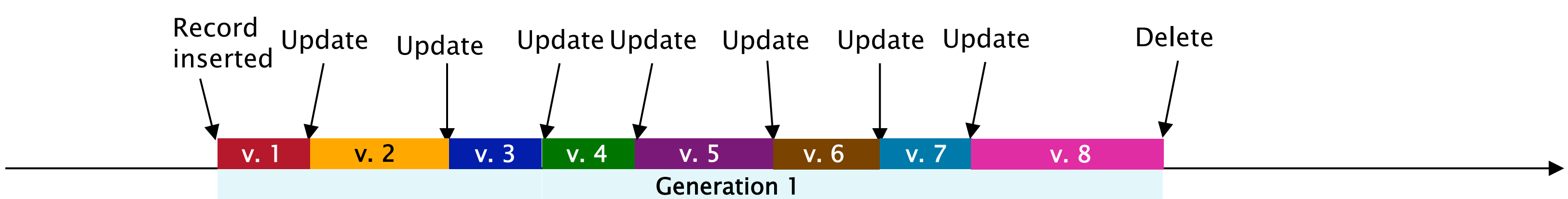
- Data Model and Features
  - Simple relational model
- Fault Tolerance
- Topic-based pub/sub system
  - Yahoo! Message Broker (YMB)
- Record-level Mastering
- Hosting

Data and Query Model

- Data is organized into tables of records with attributes
  - hashed / ordered tables
- The query language of PNUTS supports selection and projection from a single table.
- **point access**: A user may update her own record.
- **range access**: Another user may scan a set of friends in order by name.
- PNUTS also does not enforce constraints such as
  - referential integrity
  - complex ad hoc queries(joins, group-by, etc.).

Consistency Model:

- **Hiding the Complexity of Replication**
- **per-record timeline consistency**: all replicas of a given record apply all updates to the record in the same order
- <u>The sequence number</u>
  - **generation** of the record (each new insert is a new generation)
  - **version** of the record (each update of an existing record creates a new version).
- Note that we (currently) keep only one version of a record at each replica



API calls

- Read-any
  - Stale versions
- Read-critical (required version)
- Read-latest
- Write
  - Single ACID operation
- Test-and-set-write (required version)
  - Concurrent writes

API Calls – Future Plans

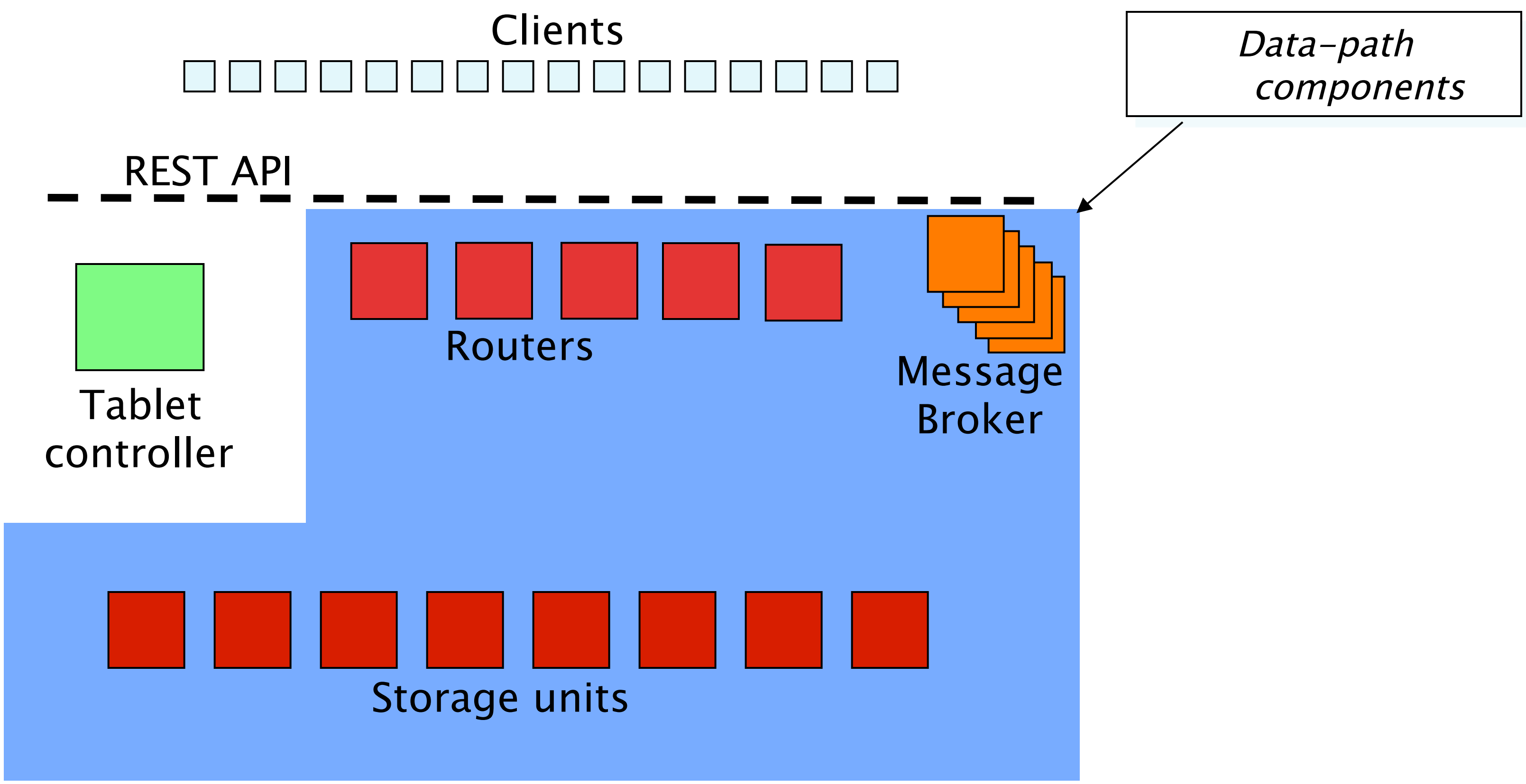
- **Bundled updates**
- **Relaxed consistency**: Allow applications to indicate, per-table, whether they want updates to continue in the presence of major outages, potentially branching the record timeline

Notifications

- Trigger-like notifications are important for applications e.g.: Ad - Serving
- allow the user to subscribe to the stream of updates on a table

SYSTEM ARCHITECTURE

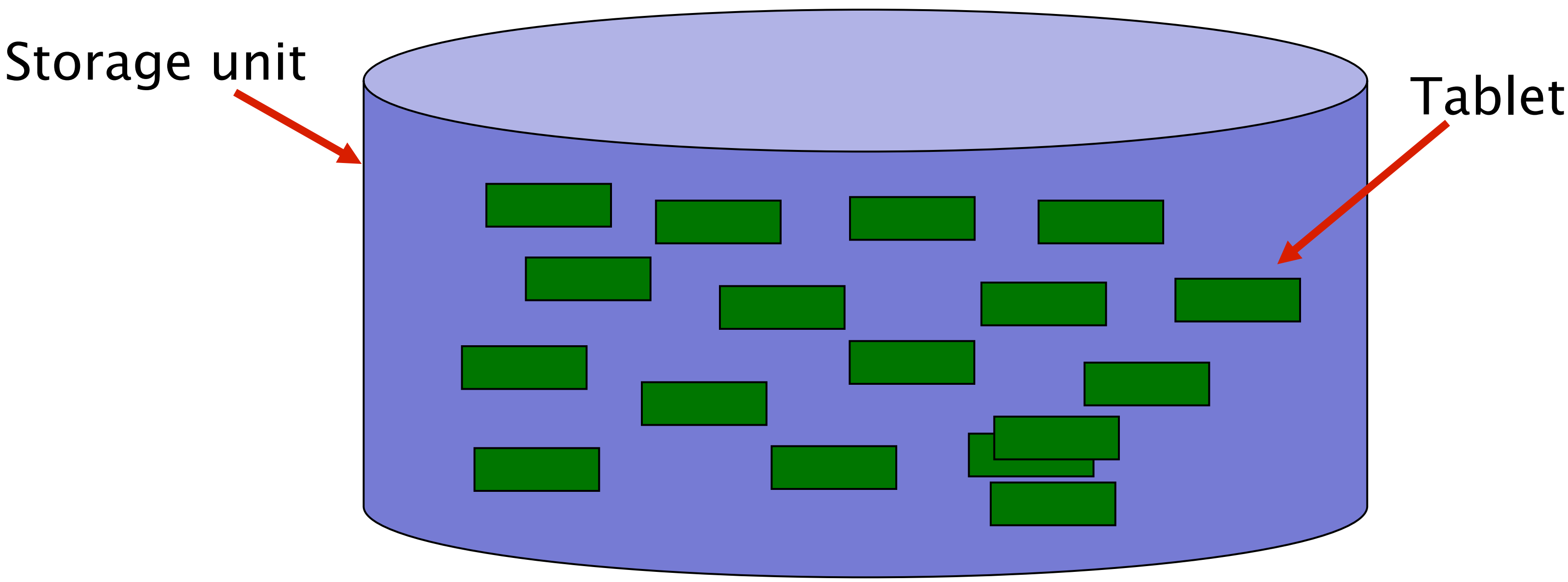
Architecture



Tablet splitting and balancing

Each storage unit has many tablets (horizontal partitions of the table)

Storage unit may become a hotspot

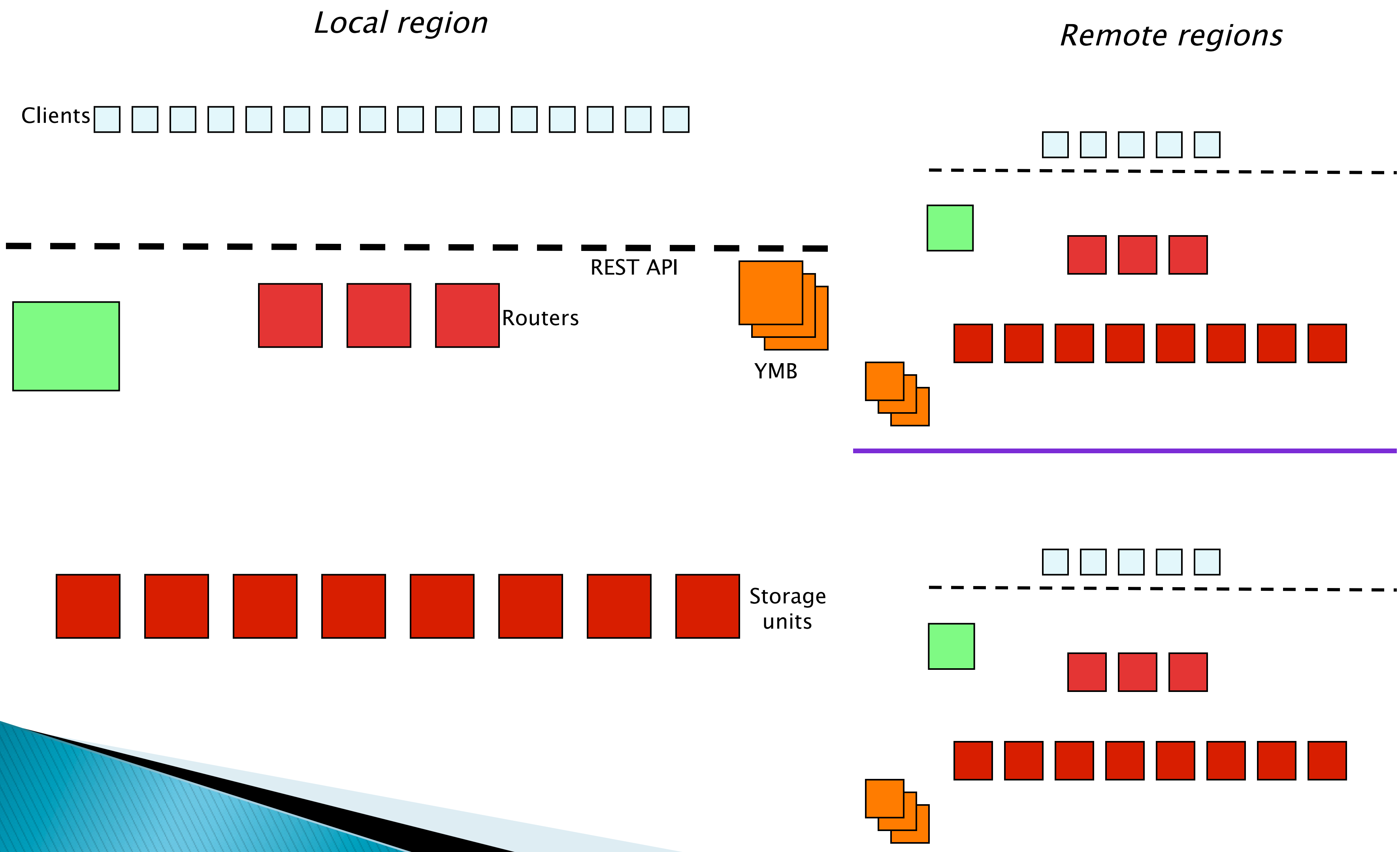


Overfull tablets split

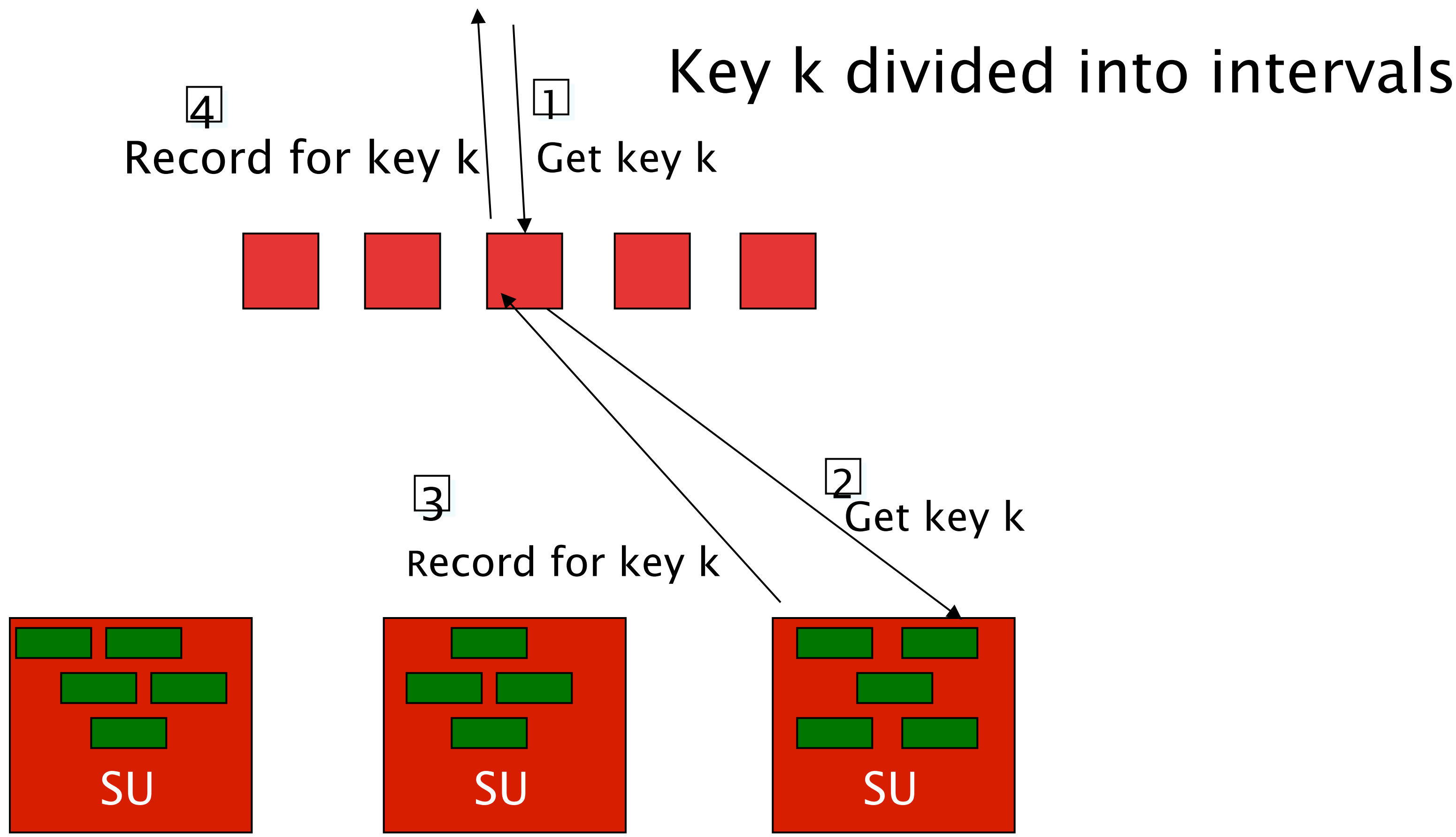
Tablets may grow over time

Shed load by moving tablets to other servers

Architecture



Accessing Data – Ordered tables

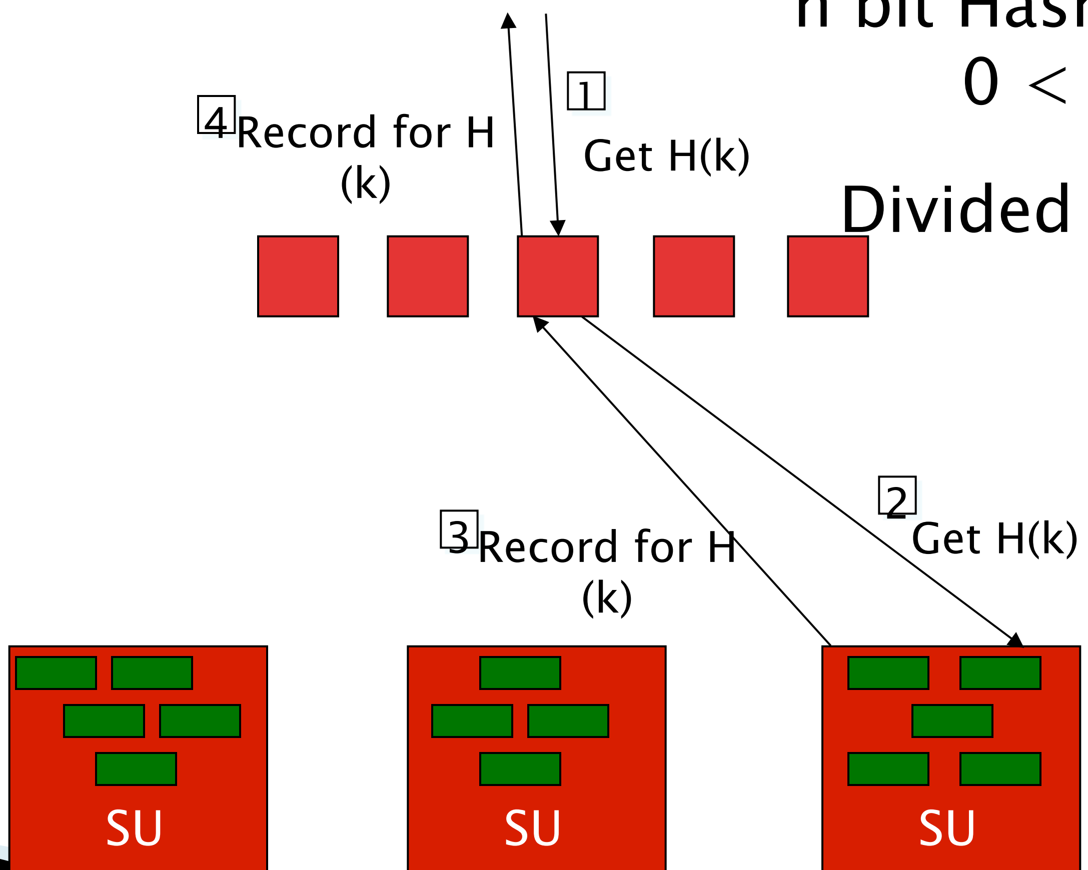


Accessing Data – Hash tables

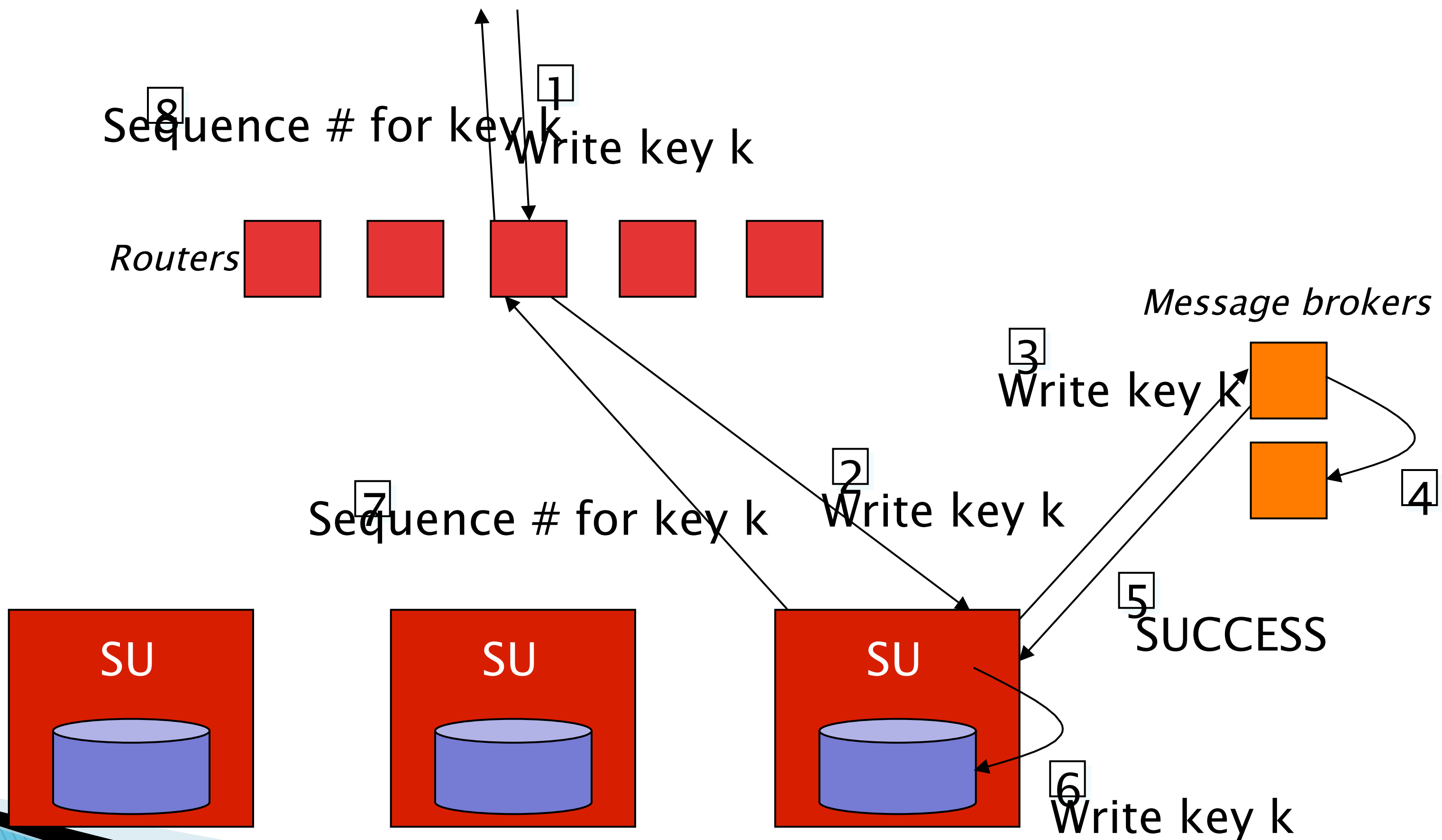
n bit Hash Function H(k)

$0 < H(k) < 2^n$

Divided into intervals



Updates



8
Sequence # for key k
1
Write key k
Routers
Message brokers
3
Write key k
4
2
Write key k
7
Sequence # for key k
5
SUCCESS
SU
SU
SU
6
Write key k

Replication and Consistency

Yahoo Message Broker

- Data updates are considered “committed” when they have been published to YMB
- YMB guarantees message delivery
- Logs the updates
- PNUTS clusters saved from dealing with update propagation
- Provides partial ordering

Record Level mastering

- One replica becomes a master copy
- 85% writes to a record originate from the same datacenter
- Master propagates updates to other replicas
- Mastership can be assigned to other replicas as needed
  - Eg: When a change in user's location is detected
- Every record has a hidden metadata field storing the identity of the master

Router Failure

- Routers contain only a cached copy of the interval mapping
- The mapping is owned by the tablet controller
- if a router fails, we simply start a new one

Recovery

- Involves copying lost tablets from another replica
- The tablet controller requests a copy from a particular remote replica
- "checkpoint message" is published to YMB, to ensure that any in-flight updates at the time the copy is initiated are applied to the source tablet.
- The source tablet is copied to the destination region

Other Database System Functionality

- Query Processing
  - Multi-record requests
  - Range Queries
- Notifications
  - Notifying external systems on updating certain records
  - Subscribe to the topic for specific tablet

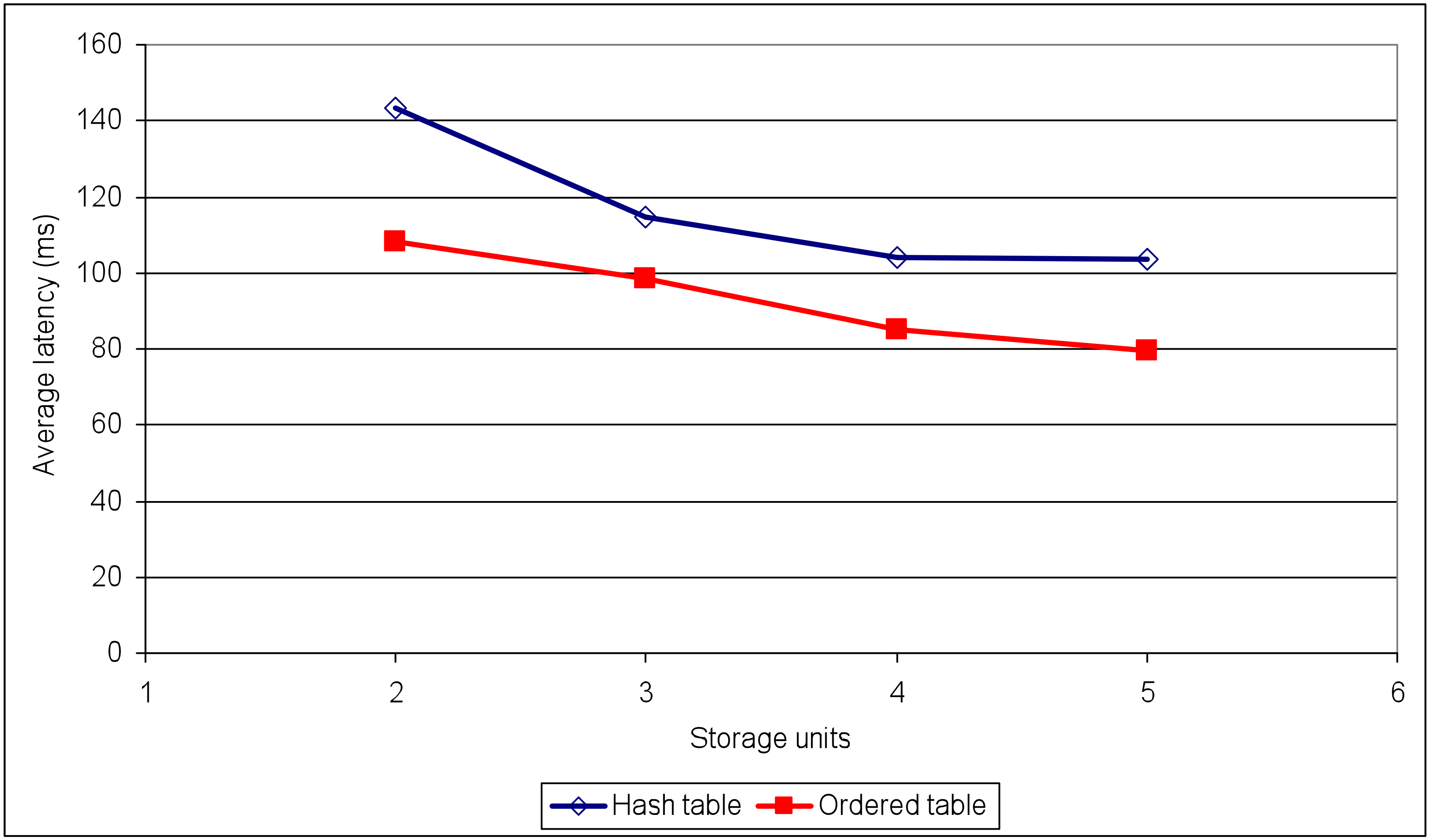
PNUTS APPLICATIONS

- User Database
- Social Applications
- Content Meta-Data
  - Eg: email attachments
- Listings Management
  - Eg: Comparison shopping
- Session Data

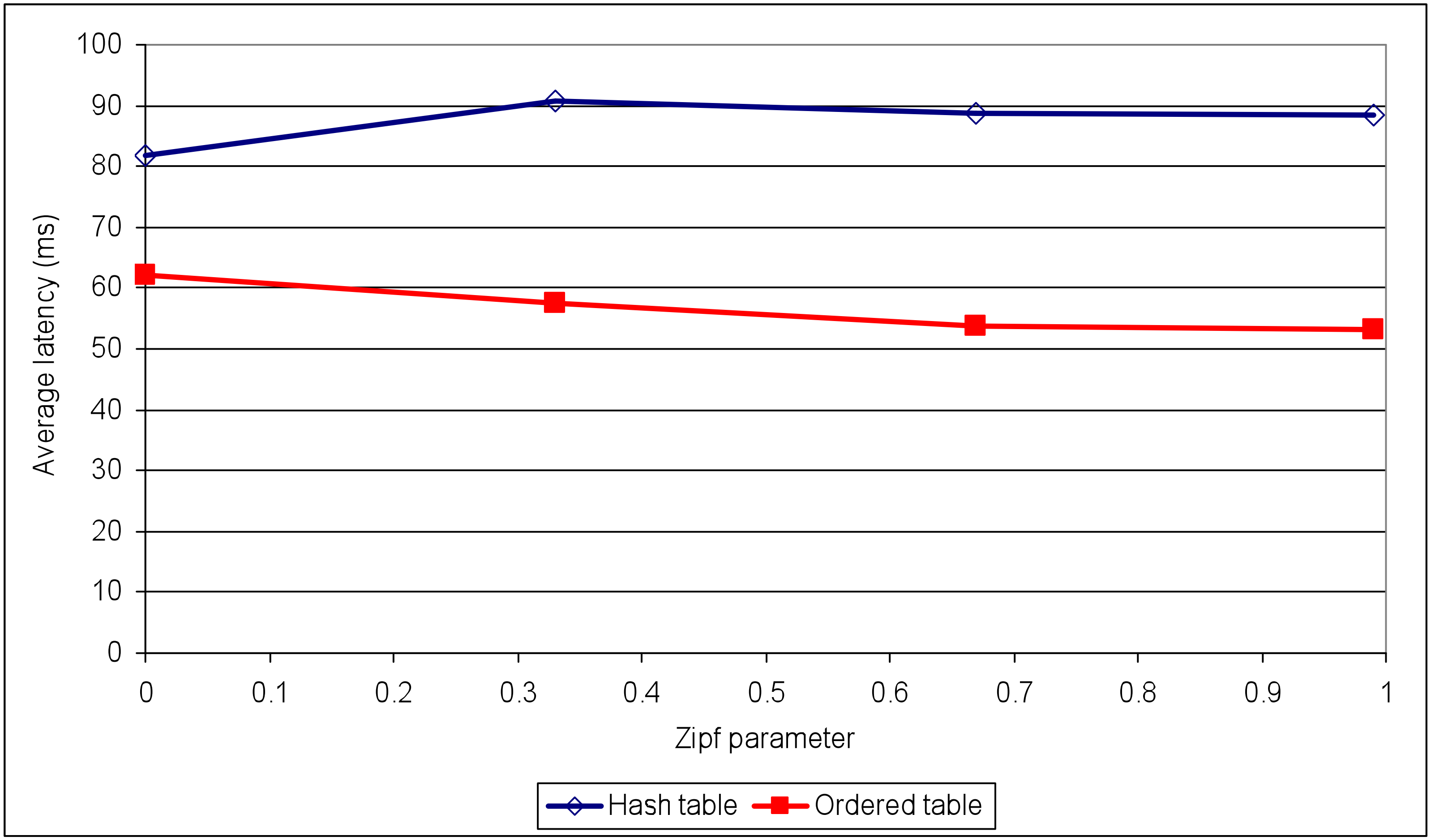
Experimental setup

- Production PNUTS code
  - Enhanced with ordered table type
- Three PNUTS regions
  - 2 west coast, 1 east coast
  - 5 storage units, 2 message brokers, 1 router
  - West: Dual 2.8 GHz Xeon, 4GB RAM, 6 disk RAID 5 array
  - East: Quad 2.13 GHz Xeon, 4GB RAM, 1 SATA disk
- Workload
  - 1200-3600 requests/second
  - 0-50% writes
  - 80% locality

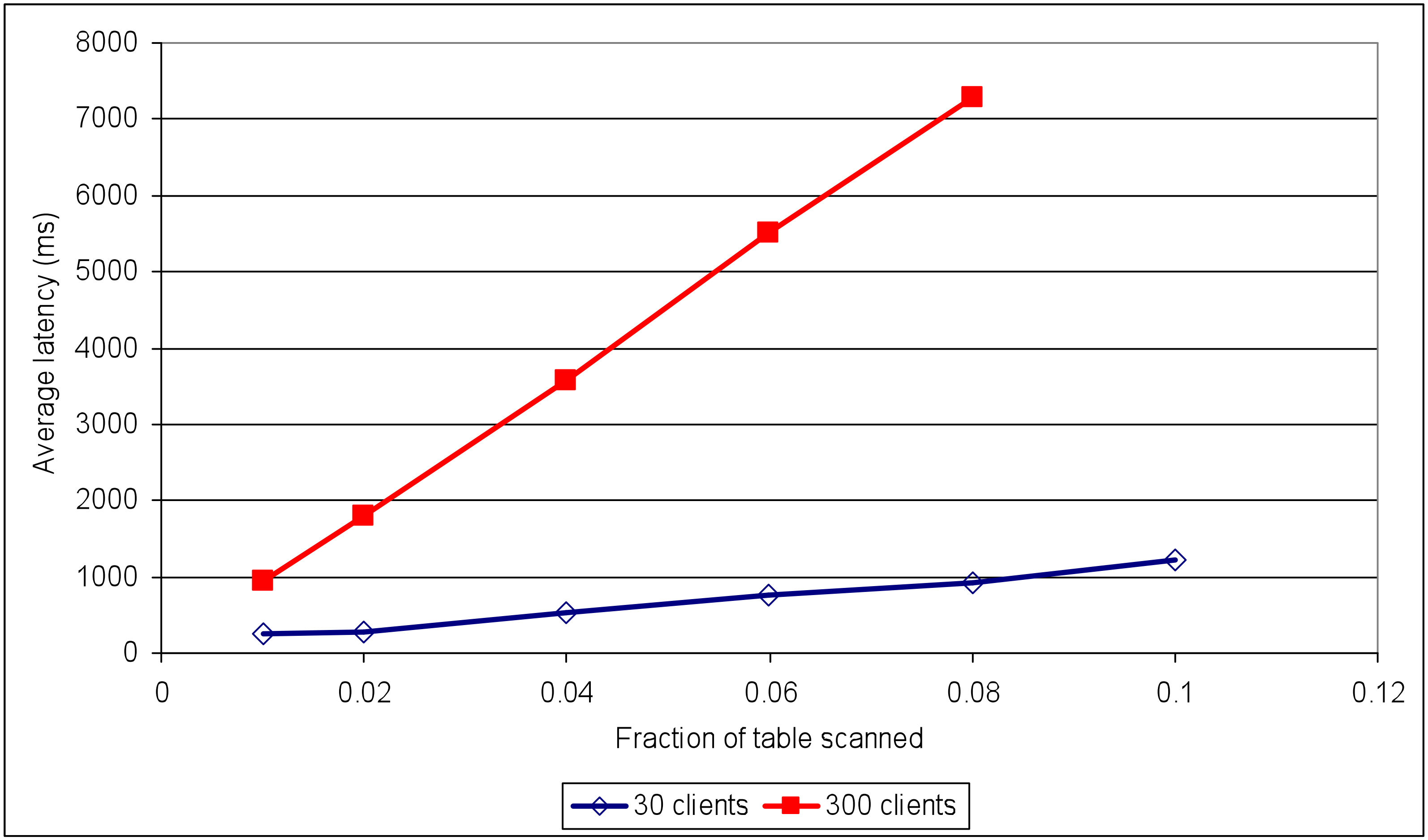
Scalability



Request skew



Size of range scans



Related work

- Distributed and parallel databases
  - Especially query processing and transactions
  - BigTable, Dynamo, S3, SimpleDB, SQL Server Data Services, Cassandra
- Distributed filesystems
  - Ceph, Boxwood, Sinfonia
- Distributed (P2P) hash tables
  - Chord, Pastry, …
- Database replication
  - Master-slave, epidemic/gossip, synchronous…

Conclusions and ongoing work

- PNUTS is an interesting research product
  - Research: consistency, performance, fault tolerance, rich functionality
  - Product: make it work, keep it (relatively) simple, learn from experience and real applications

- Ongoing work
  - Indexes and materialized views
  - Bundled updates
  - Batch query processing