PNUTS and Weighted Voting

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PNUTS

- Distributed database built by Yahoo
- Paper describes a production system
- Goals:
    - Scalability
    - Low latency, predictable latency
    - Must handle attacks: flash crowds, denial of service
    - High Availability
    - Eventual Consistency

PNUTS

- Data model: relational table
- Pub-Sub system: Yahoo Message Broker
- Each record has a master
- Uses a guaranteed message delivery service

Data and Query Model

- Relational tables
- Each row has a primary row
- Rows can have binary blobs
- Queries:
  - Point access
  - Range access

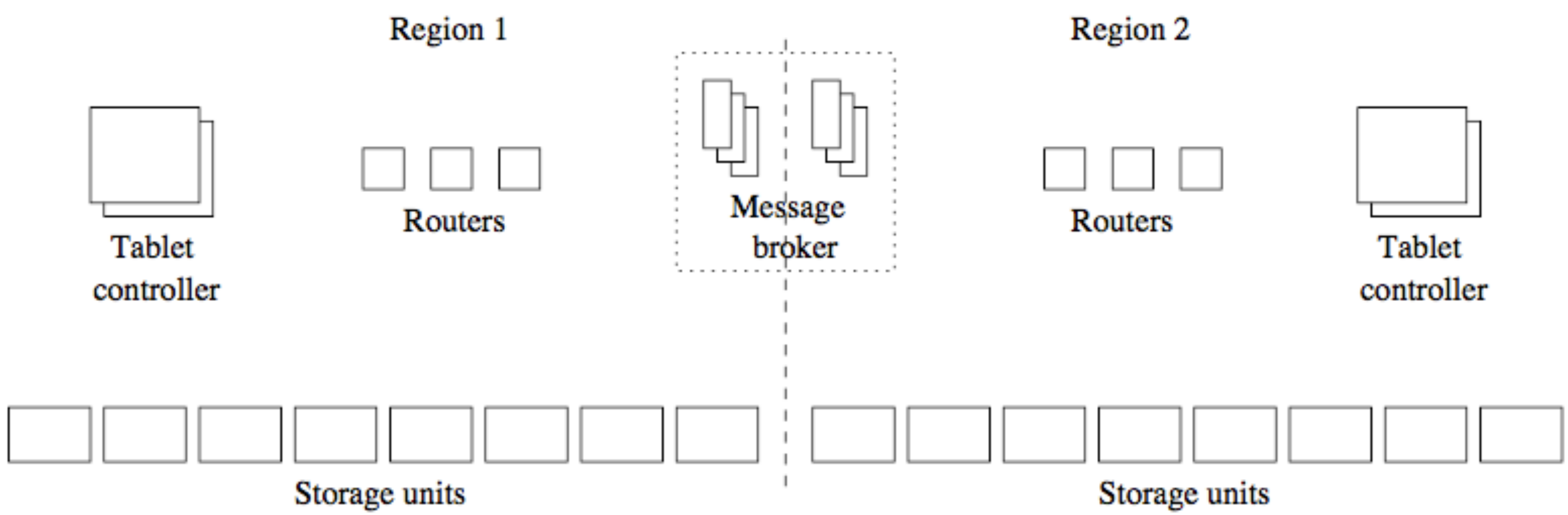
Consistency Model

- API
  - Read-any
  - Read-critical(version)
  - Read-latest
  - Write
  - Test-and-set-write(version)

Consistency Model

- Per-record “timeline” consistency
- No multi-record guarantee
- Per-record sequential consistency
- All record operations go to a master

Architecture



Data Storage and Retrieval

- Groups of records are called tablets
- Each server has 100s-1000s of tablet
- Each tablet is stored in a single server in a region
- Tablet size: 100s of MB or a few GBs

Data Storage

- Storage Unit: get(), scan(), set()
- Message broker is where the update is committed
- Router: identifies which tablet and server contain data
- Ordered data: key range sharded into tablets
- Unordered data: do the same with hash(key)
- Mapping information stored in memory
- True source of mapping info: tablet controller

Yahoo Message Broker (YMB)

- Received messages are logged and replicated
- When update has been applied to all replicas, log is pruned
- YMB servers are present in different regions
- Cross-region traffic is limited to YMB
- Messages are ordered within a YMB region
- Across regions, different ordering is possible

YMB Consistency

- Update considered “committed” once YMB acks it
- A committed update may not be visible to other replicas
- Master replica for a given record is stored inside that record
- Tablet master can be different from record master
- Tablet master serializes updates to record
- Record master is the “true” copy of the data
  - Update is considered “committed” once record master gets it

Recovery

- Request copy
- Checkpoint all inflight updates
- Apply copy

Query Processing

- Scatter-gather engine is used
- Server has the engine, not the client
  - Done to reduce network connections to the server
  - Allows optimization over the whole scatter-gather call
- Range queries are broken up
  - Clients keep a continuation object to continue the range query

Notifications

- User can subscribe to notifications
- Built on top of pub/sub architecture
- Accomplished by talking to the YMB broken
- Each tablet has a topic that user subscribe to
- Whenever tablet is updated or split, notifications can be sent out

PNUTS Applications

- User database
- Social Applications
- Metadata for file systems
- Listings Management
- Session Data

Weighted Voting for Replicas

Updating Replicas

- Goal: you want to replicate data, and read any of the replicas to get the data
- Problem: how do you update the replicas?
- Obvious solution: Write to all replicas
- Can we do better?
- Turns out we can

Quorum-based Reads and Writes

- All reads go to R replicas
- All writes go to W replicas
- As long as we have R+W>N, we have strong consistency
  - Why? Condition implies at least one overlapping server between R and W
- We need version numbers to detect which is the latest copy of the data

Weighted Voting

- Weighted Voting is similar to Quorums
- Each server gets N votes instead of 1
- Extra read-only copies get no votes at all
- Each file is assigned some number of votes K
  - If each server gets one vote, this is the number of replicas of the file
- To read, you need R votes.
- To write W votes. Condition: $R + W > K$
- Can tune R, W, K per file to meet performance requirements

Guarantees

- Every read will always see the latest write
- Tuning:
  - Condition: $R + W > K$
  - $R = 1$, reads are efficient, writes are slow
    - Every replica has to be updated
  - $W = 1$, writes are efficient, reads are slow
    - Every replica has to be read
  - Most systems are read-heavy, as a result R is set to between 1 and 3

Tuning

- Giving each server one vote: decentralized quorum system with high availability, low performance
- Giving one server all the votes: centralized system with high performance, low availability

Tuning

	Example 1	Example 2	Example 3
Latency (msec)			
Representative 1	75	75	75
Representative 2	65	100	750
Representative 3	65	750	750
Voting Configuration	<1, 0, 0>	<2, 1, 1>	<1, 1, 1>
r	1	2	1
w	1	3	3
Read			
Latency (msec)	65	75	75
Blocking Probability	1.0×10^{-2}	2.0×10^{-4}	1.0×10^{-6}
Write			
Latency (msec)	75	100	750
Blocking Probability	1.0×10^{-2}	1.0×10^{-2}	3.0×10^{-2}

Weak Representatives

- Possibly stale, read-only copies of the data
- If you read only a weak representative, no guarantees are given about the data
- In others words, it is a local cached copy

Atomicity of operations

- Each read or write is an atomic, isolated operation at each copy
- While the read is going on, there is no other writer at that copy (similarly for writes)

Transactional Isolation

- First lock all files the tx wants to read/write
- Perform reads/writes
- Unlock
- This guarantees serializable transactions
- Obtaining the locks has to be done with a total order, otherwise deadlock is possible
- A tx can hold locks for a max time period

Locks Used

Three locks:
read lock, intention-to-write lock, commit lock

	No Lock	Read	I-Write	Commit
No Lock	Yes	Yes	Yes	Yes
Read	Yes	Yes	Yes	No
I-Write	Yes	Yes	No	No
Commit	Yes	No	No	No

Violet

- All of this was implemented in the Violet distributed system
- Violet was used to sync personal and private calendars
- Think of it as a very primitive Google Calendar or Outlook Calendar