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Facebook Tao

Distributed Data Store for the Social Graph

Table of Contents

Introduction

What is TAO?

TAO is a geographically distribute store

- deployed at Facebook
- with efficient and timely access to social graph
- using a fixed set of query
- replacing memcache
- running on thousands of machines
- provide access to many PB of data
- process a billion reads ad millions of writes each second!

The social graph

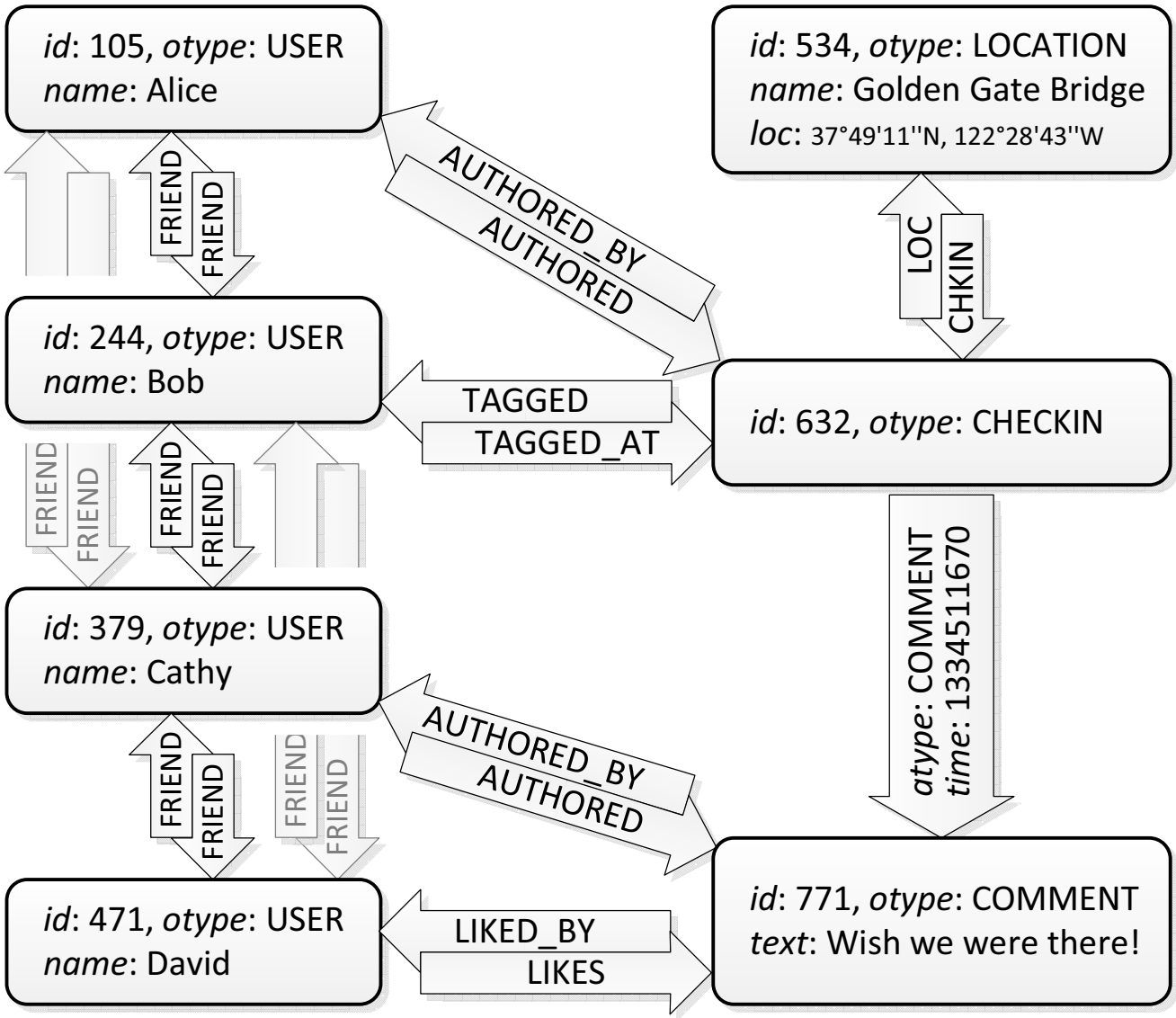
Facebook has more than 1 billion active user

- recording relationships,
- sharing interests,
- uploading pictures and …

The user experience of Fb comes from rapid, efficient and scalable access to the *social graph*

What's behind an entry in yours Fb page?

A single Fb page aggregate and filter hundreds of items from the social graph.


id: 105, otype: USER
name: Alice
id: 534, otype: LOCATION
name: Golden Gate Bridge
loc: 37°49'11''N, 122°28'43''W
FRIEND
FRIEND
AUTHORED_BY
AUTHORED
LOC
CHKIN
id: 244, otype: USER
name: Bob
TAGGED
TAGGED_AT
id: 632, otype: CHECKIN
FRIEND
FRIEND
FRIEND
FRIEND
atype: COMMENT
time: 1334511670
id: 379, otype: USER
name: Cathy
AUTHORED_BY
AUTHORED
FRIEND
FRIEND
FRIEND
FRIEND
id: 471, otype: USER
name: David
LIKED_BY
LIKES
id: 771, otype: COMMENT
text: Wish we were there!

Before Tao

- Facebook was storing the social graph to MySql
  - Quering it from PHP
  - Storing result in memcache

Over time Fb deprecated direct access to MySQL in favor of a graph (associations, nodes) abstraction

Limits

- Operations on lists are inefficient in memcache (update whole list)
- Complexity on clients managing cache
- Hard to offer read-after-write consistency

Also they want to access social graph from non-PHP services

TAO's Goals

- Efficiency at Scale
- Low read latency
- Timeliness of writes
- High read availability

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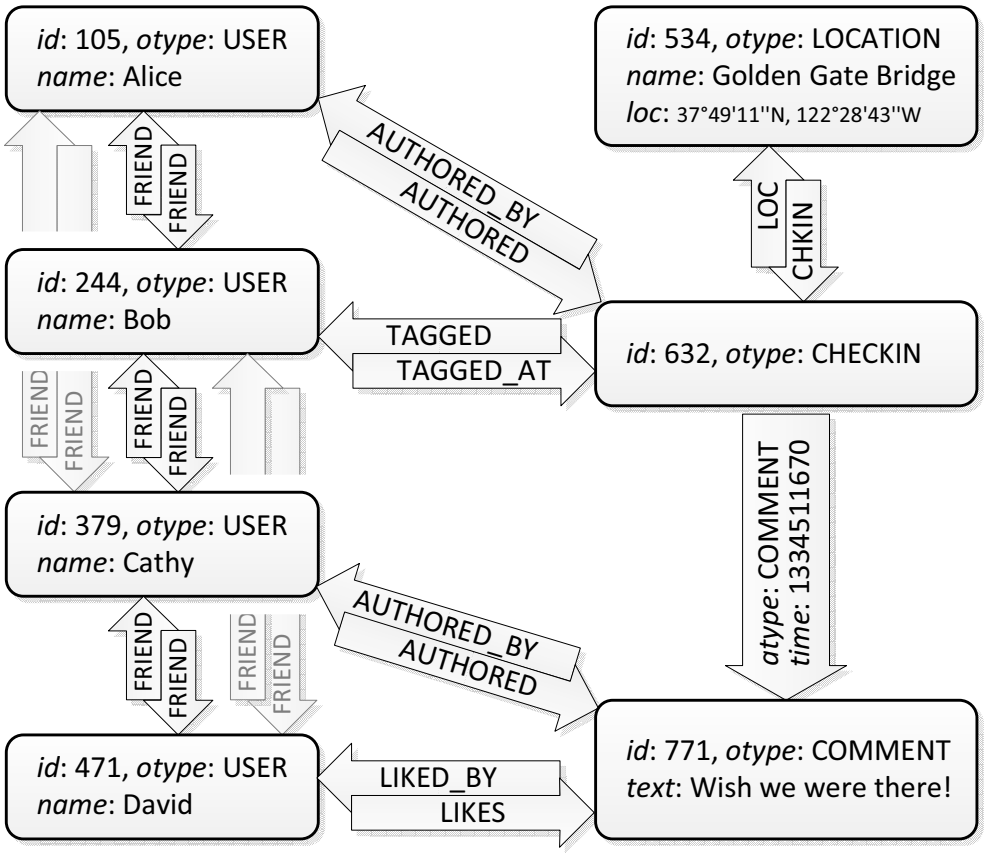
Tao Data Model

T.A.O. stands for “The Associations and Objects”



Objects

- Typed nodes (type is denoted by `otype`)
- Identified by 64-bit integers (unique)
- Contains data in the form of key-value pairs
- Models users and repeatable actions (e.g. comments)

API for objects:

- Allocate new object
- retrieve
- update
- delete

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Associations

- Typed directed edges between objects (type is denoted by `atype`)
- Identified by source object `id1`, `atype` and destination object `id2`
- Contains data in the form of key-value pairs.
- Contains a 32-bit `time` field.
- Models actions that happen at most once or records state transition (e.g. like)
- Often inverse association is also meaningful (eg like and liked by).

Associations API

- Add new
- Delete
- Change type

Also inverse association is created or modified automatically

Querying TAO

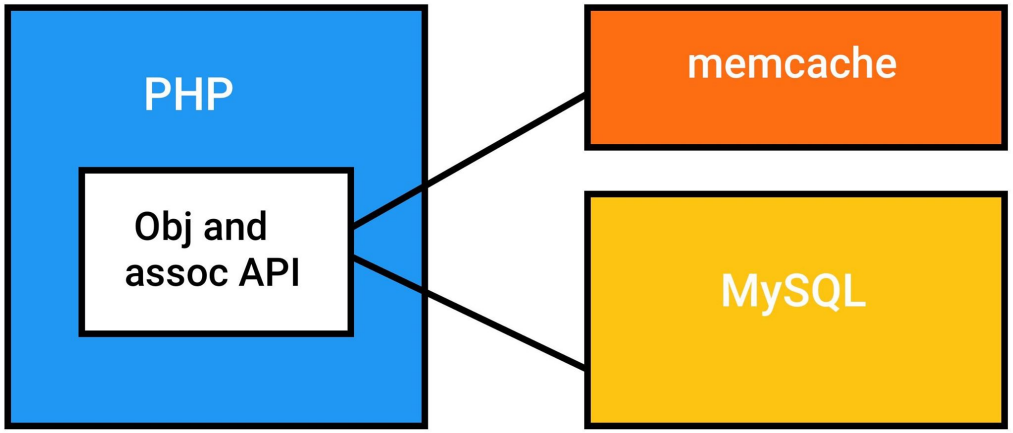
TAO's associations queries are organized around *associations list*

- `assoc_get(id1,atype, id2set, high?, low?)`
- `assoc_count(id1,atype)`
- `assoc_range(id1, atype, pos, limit)`
- `assoc_time_range(id1,atype, high, low, limit)`

Query results are bounded to 6000 results

Architecture

Before Tao

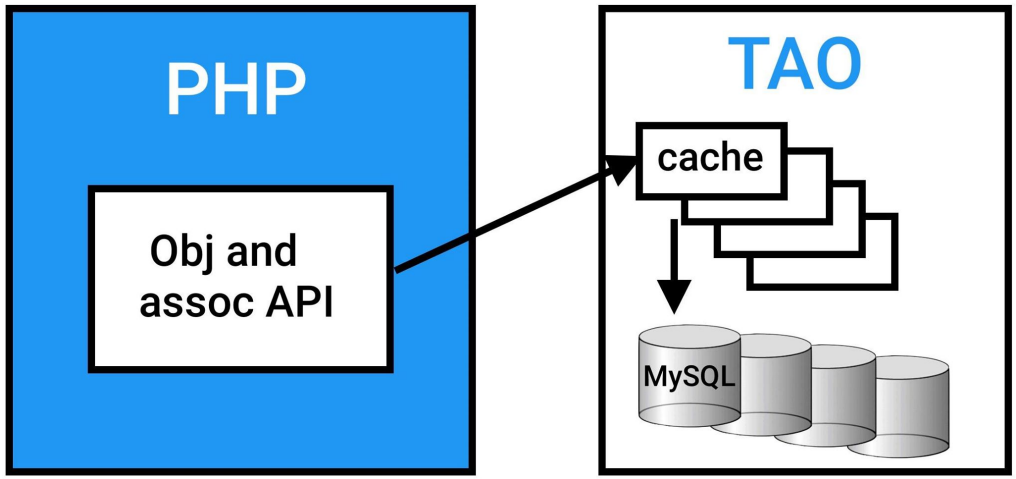


After Tao

Architecture

Before Tao

After Tao



Storage Layer

- Object and Associations are stored in MySql (before & with TAO)
- TAO API is mapped to a small set of SQL queries
- A single MySql server can't handle TAO volumes of data
  - We divide data into logical *shards*
  - *shards* are mapped to db
  - different servers are responsible for multiple shards
  - mapping is adjusted for load balancing
- Object are bounded to a *shard* for their entire lifetime
- Associations are stored in the *shard* of its `id1`

Cache Layer

TAO cache

- contains: Objects, Associations, Associations counts
- implement the complete API for clients
- handles all the communication with storage layer
- it's filled on demand end evict the least recently used items
- Understand the semantic of their contents

It consists of multiple servers forming a *tier*

- Request are forwarded to correct server by a *sharding* scheme as dbs
- For cache miss and write request, the server contacts other caches or db

Yet Another caching layer

Problem: A single caching layer divided into a *tier* is susceptible to *hot spot*

Solution: Split the caching layer in two levels

- A *Leader* tier
- Multiple *Followers* tiers

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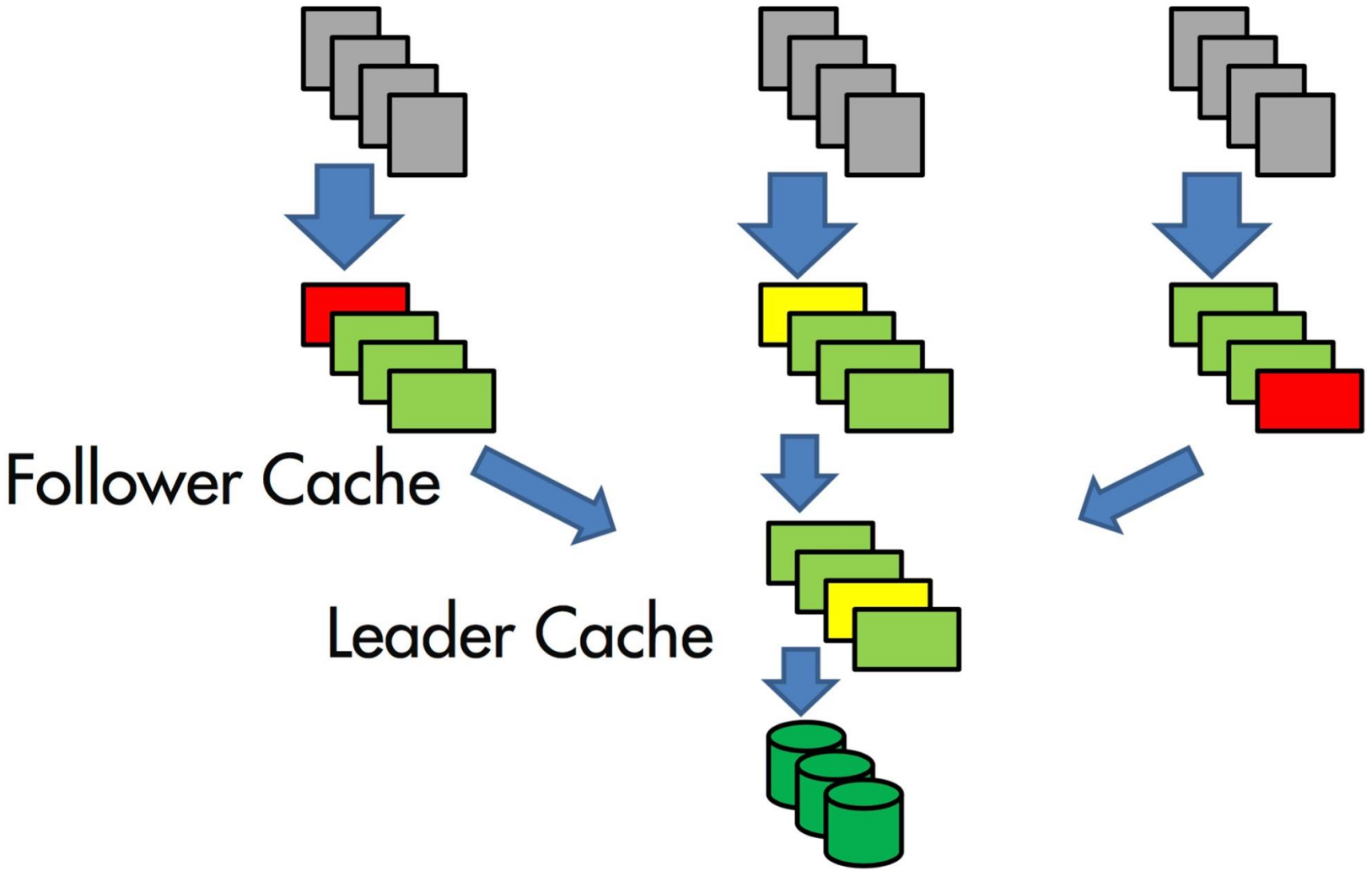
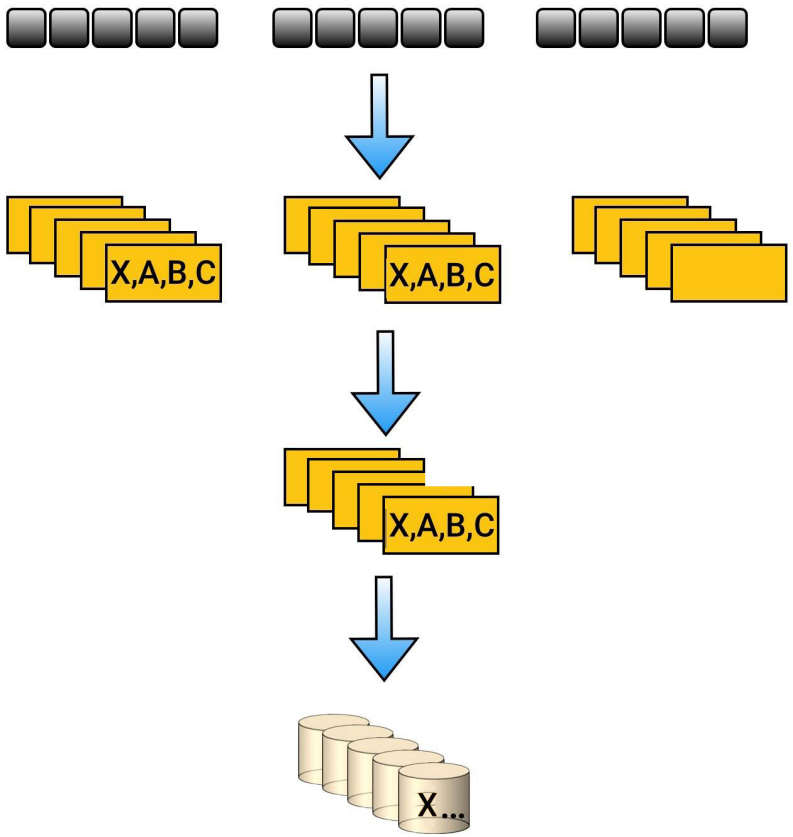
Leaders & Followers



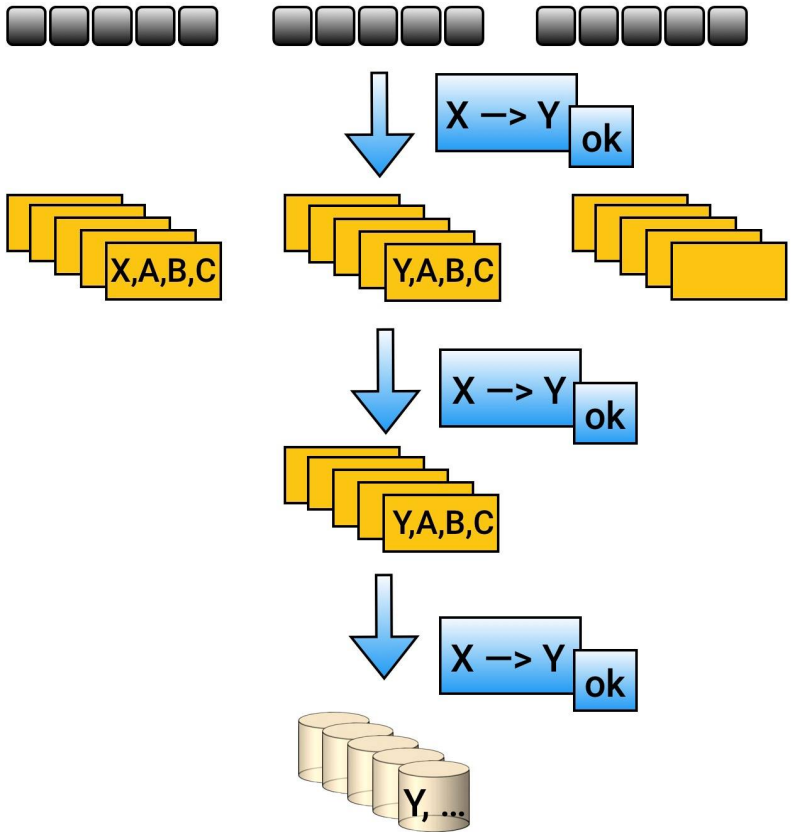
Leaders & Followers

- Followers forward all writes and read cache misses to the leader tier
- Leader sends async cache maintenance messages to follower tier
  - Eventually Consistent
- If a follower issues a write, the follower's cache is updated synchronously
- Each update message has a version number
- Leader serializes writes

Leaders & Followers



Leaders & Followers



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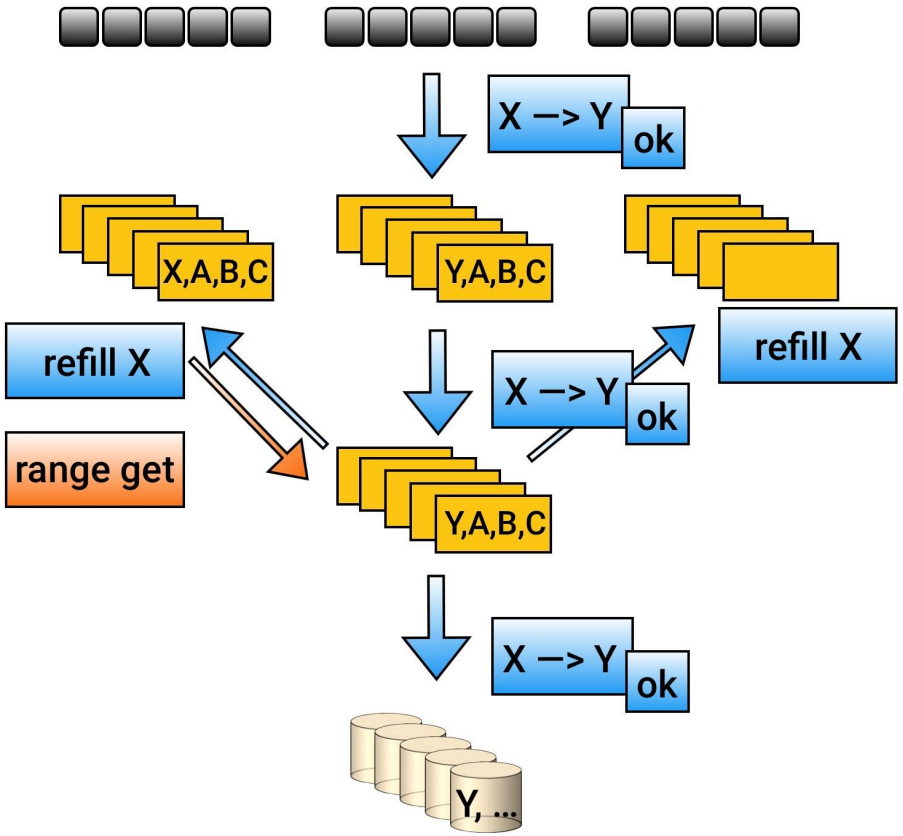

Scaling Geographically

Problem: Network latencies are not low in a multi Data Centers environment

Considering that read misses are more common than writes in the follower tier

Solution: Handles read cache miss locally

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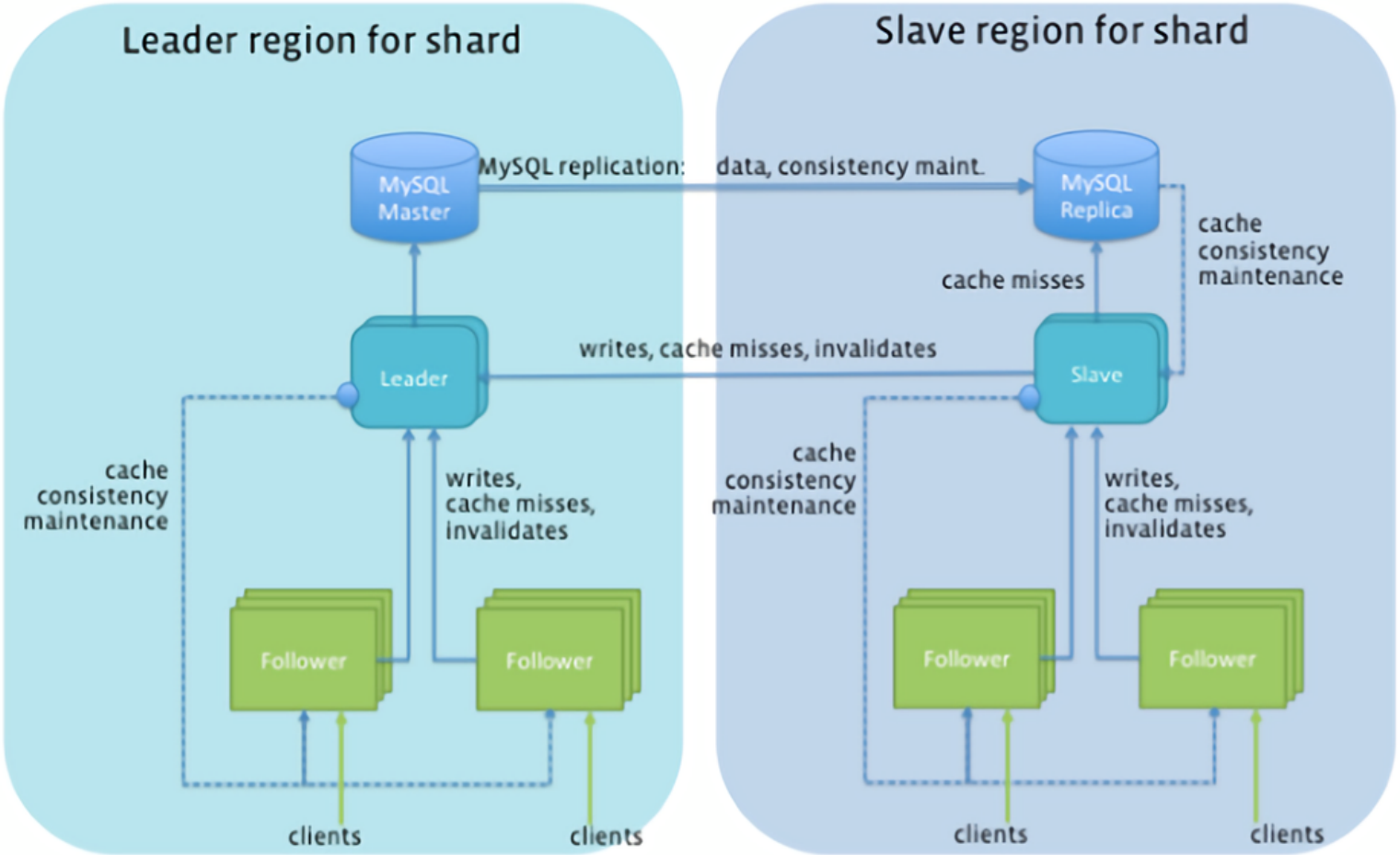
Master & Slave Regions

Fb cluster together DC in regions (with low intra region latency)

- Each region have a full copy of the social graph
- Region are defined master or slave for each shard
- Followers send read misses and write requests to the local leader
- Local leaders service read misses locally
- Slave leaders forward writes to the master shard
- Cache invalidation message are embedded into db replication stream
- Slave leader will update it’s cache as soon as write are forwarded to master

Overall Architecture



Implementation

To achieve performance and storage efficiency Fb have implemented some optimizations to servers and DBMS's.

Caching Servers

- Memory is partitioned into arenas by association type
  - This mitigates the issues of poorly behaved association types
  - They can also change the lifetime for important associations
- Small items with fixed size have a lot of pointer overhead
  - They use a directly mapped 8-way LRU cache
  - Used for association counts

MySql Mapping

We divided the space of objects and associations into *shards*. Each *shard*:

- is assigned to a logical DB
- there is a table for objects and a table for associations
- all field of object are serialized in a single `data` column
- object of different size can be stored in the same column

Exceptions:

- Some object can benefit from being stored in a different table
- Associations counts are stored in a separate table

Cache Sharding

Shards are mapped to chache server using consistent hashing (like dynamo)

This can lead to *imbalances*, so TAO use shard cloning to rebalance the load

There are also *popular object* that can be queried a lot more often than others.

TAO says to the clients to cache them these objects

High-Degree Objects

Some object have a lot of associations (remember there were a limit of 6000?)

- TAO can't cache all associations list
- Requests will always end to Db

so

- For `assoc_count`, the edge direction is chosen using the lower degree between source and destination object
- For `assoc_get` query, only associations whose time > object's creation time

Consistency

Under normal operation, TAO is *eventually consistent*

Replication lag usually < 1”

Race conditions are resolved by using version numbers

In special “*critical*” situation a read can be forwarded to database to ensure to read from a consistent source of truth. (Useful for auth procedures)

Detecting Failures

Each TAO server stores per-destination time-outs

- if several time-outs occurs, hosts are marked as down
- subsequent requests are aborted
- Tao reacts trying to route around failures (favouring availability over consistency)
- Down hosts are actively probed to check if recover

Handling Failures

Database Fail Db can crash or be off-line for maintenance.

- If master db is down, a slave is promoted to new master
- If a slave db is down, cache miss are redirected to TAO leaders in master region

Leader Fail Followers re-route requests around it

- Read miss goes directly to db
- Write are routed to a random member of the leader tier

Handling Failures (2)

Invalidation Fail Leader can't contact a follower during a cache invalidation message

- Leader queues message
- If Leader also crash message are lost so new leader send bulk invalidation

Follower Fail Followers in others tiers share the responsibility of it's shard

- Tao client have a primary tier and a backup tier

Workload

read requests	**99.8 %**	**write requests**	**0.2 %**
assoc_get	15.7 %	assoc_add	52.5 %
assoc_range	40.9 %	assoc_del	8.3 %
assoc_time_range	2.8 %	assoc_change_type	0.9 %
assoc_count	11.7 %	obj_add	16.5 %
obj_get	28.9 %	obj_update	20.7 %
		obj_delete	2.0 %

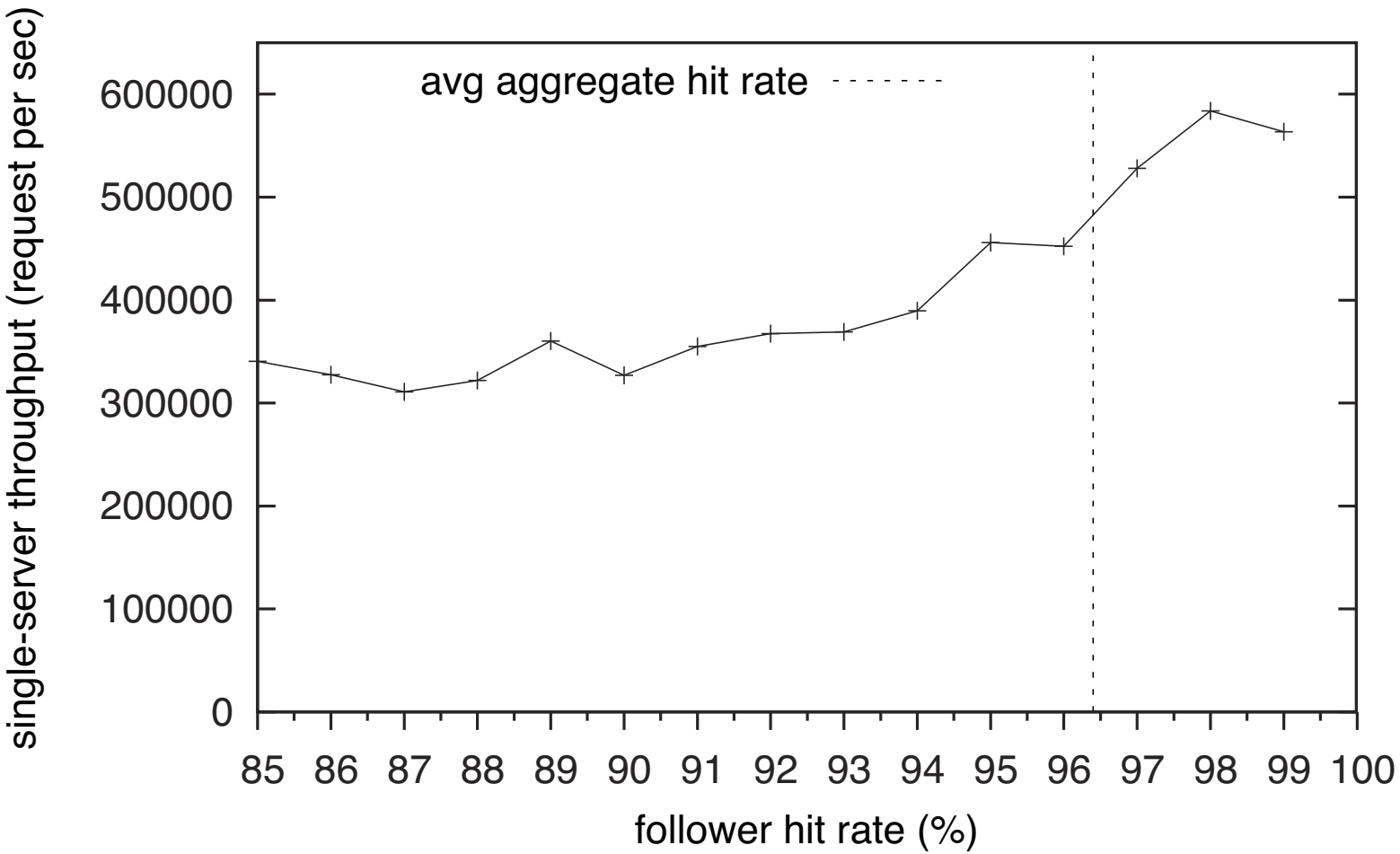
Frequencies for client request

Availability

Under real workload, over a period of 90 days, the **fraction of failed TAO queries** is:

$$4.9 \times 10^{-6}$$

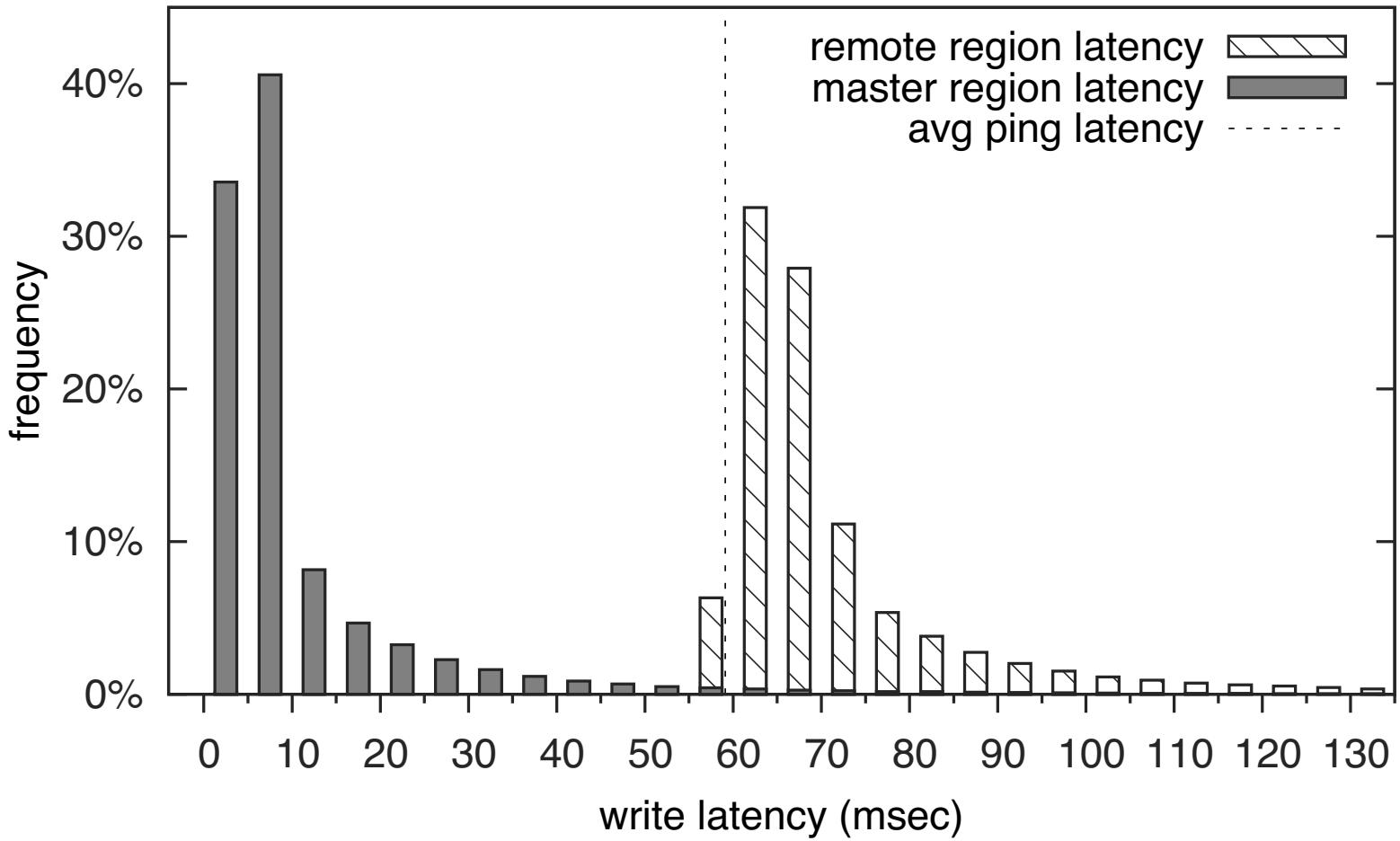
Followers Capacity



Hit Rates and latency

	hit lat. (msec)			*miss lat. (msec)*		
operation	*50%*	*avg*	*99%*	*50%*	*avg*	*99%*
assoc_count	1.1	2.5	28.9	5.0	26.2	186.8
assoc_get	1.0	2.4	25.9	5.8	14.5	143.1
assoc_range	1.1	2.3	24.8	5.4	11.2	93.6
assoc_time_range	1.3	3.2	32.8	5.8	11.9	47.2
obj_get	1.0	2.4	27.0	8.2	75.3	186.4

Write Latency



Summarizing

Read latency

- Separate cache from database
- Graph aware cache

Efficiency at scale

- Subdividing Data Centers

Write timeliness

- Write trough cache
- Async replication

Read availability

- Multiple data sources

Thank You