Scalable Web Architectures(SWA)

COMP 599 - Graduate Seminar, Fall 2018

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Roadmap

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- Availability
- Partial Tolerance
- Consistency
- scalability
- Maintenance

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Vertical & Horizontal scaling

Horizontal

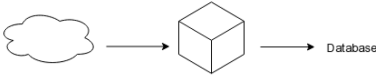
- ability to redirect request to another nodes (in short, resilency) *
- load balancing
- network calls RPC/REST
- data consistency issues
- system scales proportional to variable data sets *

Vertical

- has a single point of failure
- N/A
- inter-process communication (IPC) *
- consistent *
- hardware limit

Beyond single node deployment

Imagine a simple image upload service using a central server



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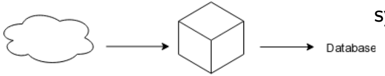

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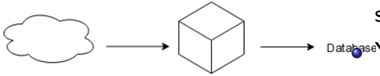

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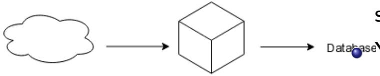

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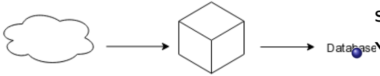

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- low-latency request-response

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2. Multi-leader replication

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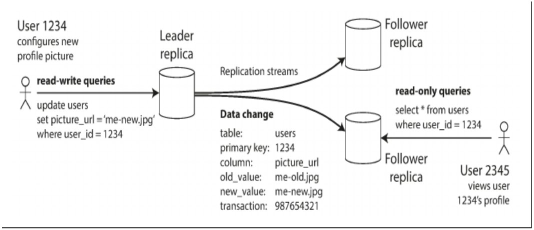
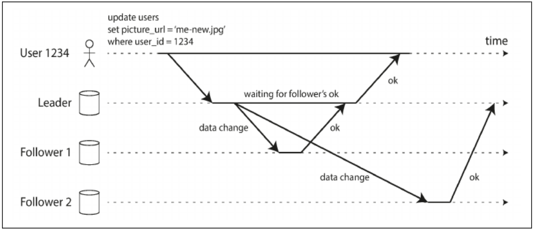
1. Single-leader based replication
2. Multi-leader replication
3. Leaderless replication

Single-Leader based replication



- Also called master-slave replication
- Considering synchronous/asynchronous config in databases.
- Using synchronous configuration is bad
- Async configuration is widely used in production deployments.

leader follower copying strategy



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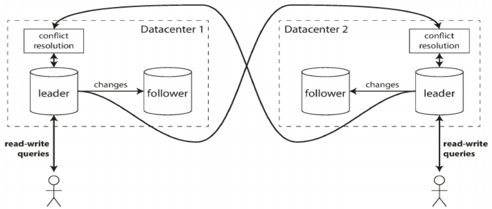
- Leader failure
  - one of its followers takes the leader
  - clients need to be reconfigured to send writes to new leader
  - other followers need to start consuming data changes from new leader.
  - old leader joins back as normal follower

Multi-leader based replication



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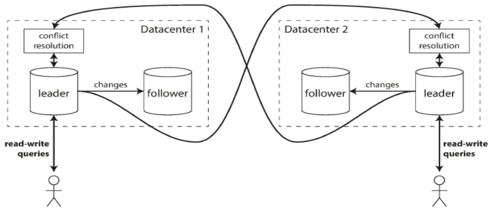

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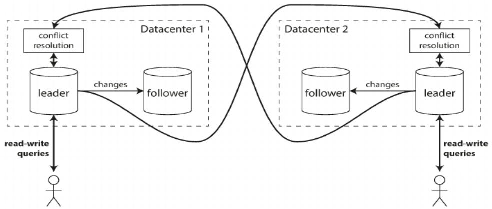

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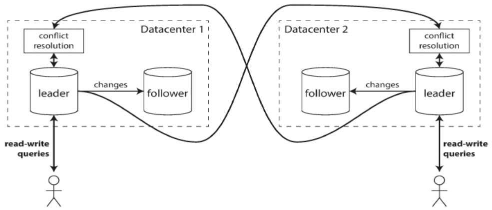

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- each leader simultaneously acts as follower to each leader
- mostly used in multi-data center operations

Conflict resolution problem

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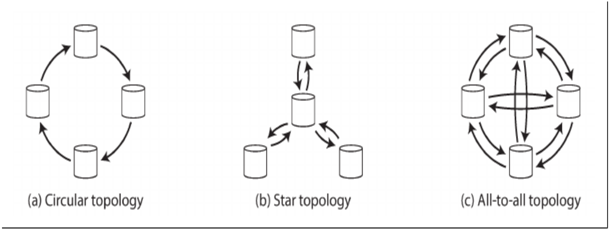
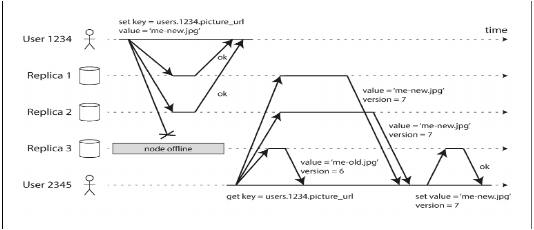
- In worst case, you have to deal with concurrent writes
- There is some research on conflict resolving
  - Conflict-free replicated data types
  - Mergeable persistent data structures
  - Operation transformation

Multi-leader topologies



Leaderless replication



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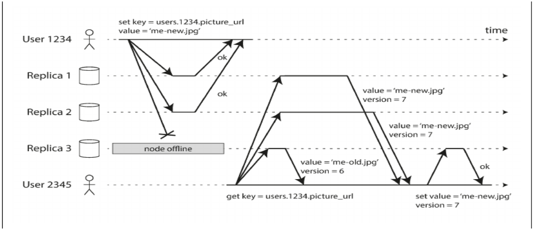

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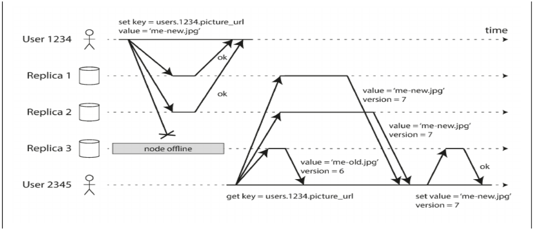

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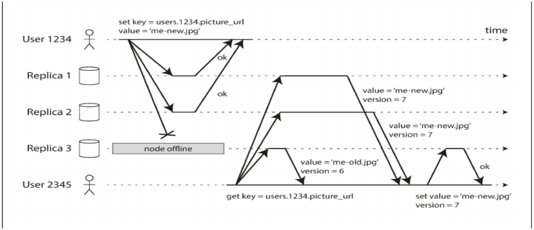

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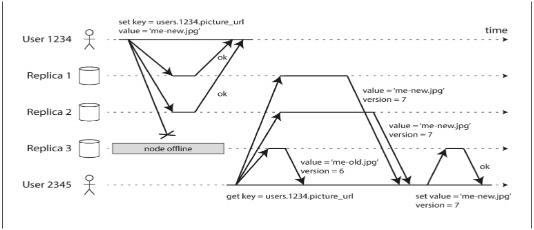

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- Amazon's DynamoDB is built using this concept
- examples include Cassandra, Riak

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- **Read Repair**
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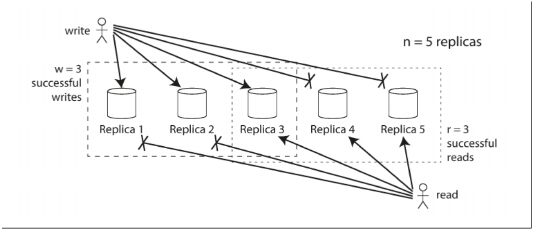
- **Anti-entropy process**
  - does reconcilation in background process
  - writes are copied in unordered way

Quorums for reading and writing

Write processed on 2 out of 3 replicas. What if only 1 of 3 replicas accepted write ? How far can we push ?



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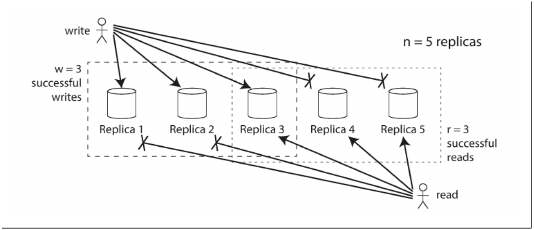

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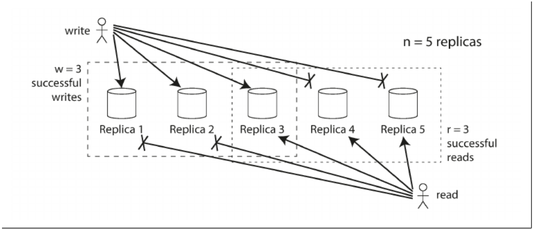

Corollary

$w + r > n$

- If w $<$ n, we can still process writes if a node is missing
- If r $<$ n, we can still process reads if a node is missing
- n $=$ 3, w $=$ 2, r $=$ 2, we can tolerate 1 unavailable node
- n $=$ 5, w $=$ 3, r $=$ 3, we can tolerate 2 unavailable nodes

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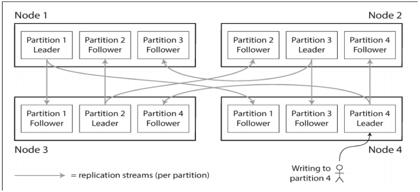
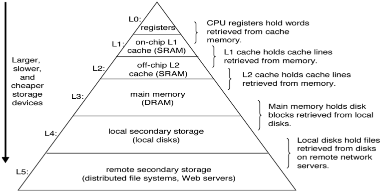
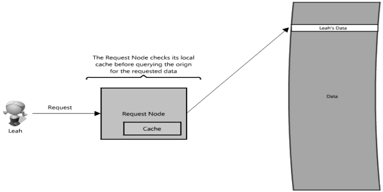


Using Caches





- any serious app will deploy a cache server
- usually placed in front of original data source
- algorithms like LRU(online algorithms) are widely used
- problem - If your system design uses load balancer, you will need to overcome high cache misses

Overcoming cache misses

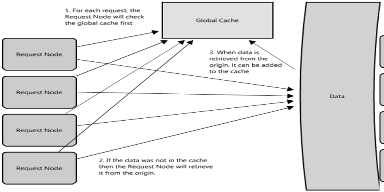


figure 2

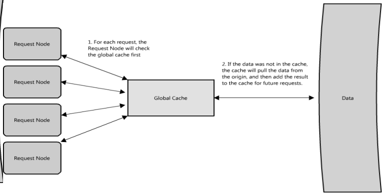


figure 1

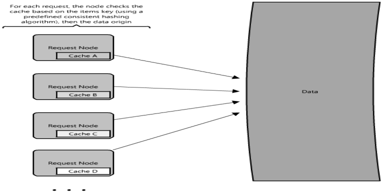


figure 3

- **1st figure** handles eviction and data retrieval on its own
- **2nd figure** application handles eviction
- **3rd figure** each cache holds a portion of cached data
- **3rd figure** uses consistent hashing to lookup data across nodes

Proxies

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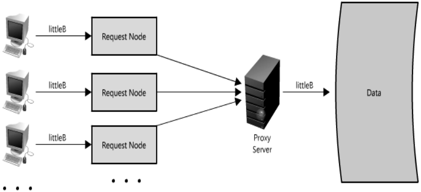

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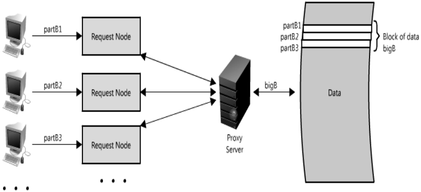

figure 2

1st figure — collapse similar requests into a single request

2nd figure — collapse requests for data that is spatially close together

Indexes

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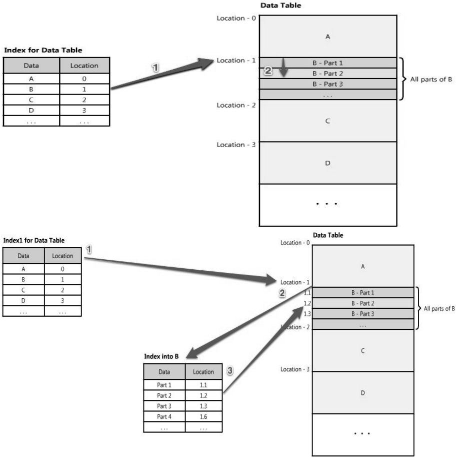

- the trick is to index your database based on users data access patterns
- In return for faster data access they do add write overhead and requiring updating indexes on each write

Load Balancers

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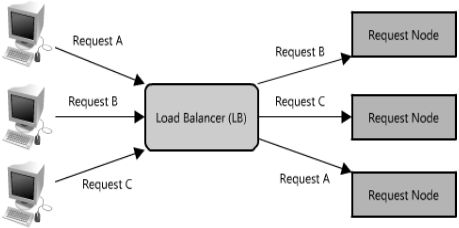

Algorithms used -

- round robin
- just pick a random node
- selecting a node on a criteria - CPU, memory

Queues

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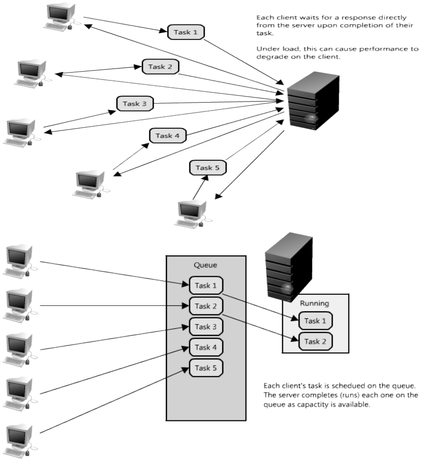
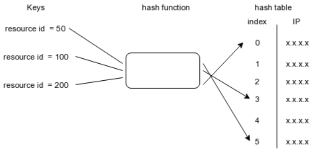


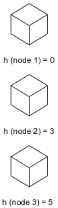
- work in async manner
- client is given acknowledgement that request is served
- tasks range from as simple as write to a data store to as complex as extracting pdf from text

Naive Hashing



hashing.png

General hashing

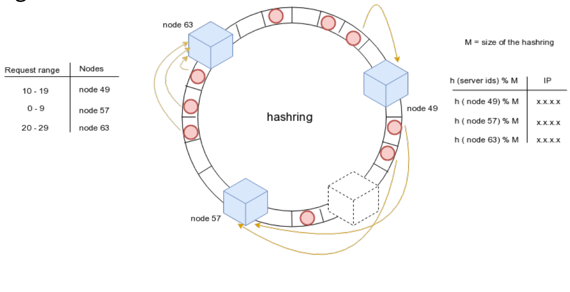


some assumptions -

- no. of nodes serving request never change
- repeated request can be served using cache
- requires rehashing every single key, caches get obselete.

Consistent Hashing

Incoming requests and serving nodes are placed onto a virtual ring structure called *hashring*



Consistent Hashing

Graphic By: Rihan Pereira

- placement of server nodes is not fixed on the ring, instead are placed at random locations
- each server owns a range of hashring
- No worries on adding new servers or server disruptions
- only rehashing of affected portion of requests is required

- Martin Kleppmann,
  Designing Data Intensive applications, **2017**
- James Hamilton,
  On Designing and Deploying Internet-Scale Services, **2007**.
- Twitter,
  Automatic Management of Partitioned, Replicated Search Services, **2011**.
- http://blog.acolyer.org/,
  The morning Paper.
- http://aosabook.org,
  The architecture of open source applications.
- http://book.mixu.net/distsys,
  Distributed Systems: fun and profit.

Thank you! Questions ?