Data sharding and replication

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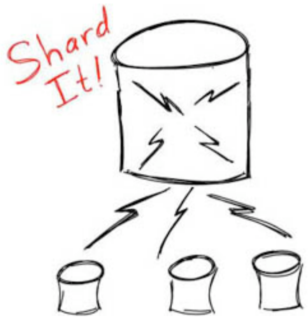
NoSql Stores: availability and performance

- Replication
  - Copy data across multiple servers (each bit of data can be found in multiple servers)
  - Increase data availability
  - Faster query evaluation
- Sharding
  - Distribute different data across multiple servers
  - Each server acts as the single source of a data subset
- Orthogonal techniques

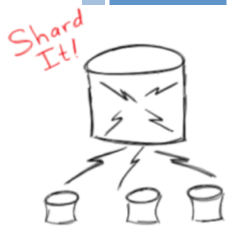


Replication: pros & cons

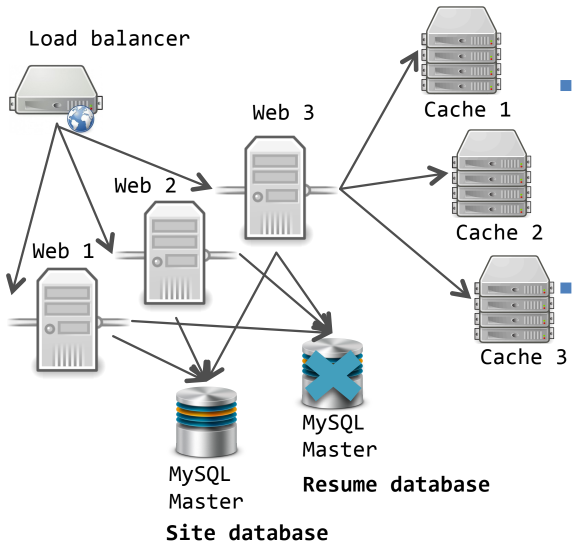
- Data is more available
  - Failure of a site containing E does not result in unavailability of E if replicas exist
- Performance
  - Parallelism: queries processed in parallel on several nodes
  - Reduce data transfer for local data

- Increased updates cost
  - Synchronisation: each replica must be updated
- Increased complexity of concurrency control
  - Concurrent updates to distinct replicas may lead to inconsistent data unless special concurrency control mechanisms are implemented

Sharding: why is it useful?



- Scaling applications by reducing data sets in any single databases
- Segregating data
- Sharing application data
- Securing sensitive data by isolating it



- Improve read and write performance
  - Smaller amount of data in each user group implies faster querying
  - Isolating data into smaller shards accessed data is more likely to stay on cache
  - More write bandwidth: writing can be done in parallel
  - Smaller data sets are easier to backup, restore and manage
- Massively work done
  - Parallel work: scale out across more nodes
  - Parallel backend: handling higher user loads
  - Share nothing: very few bottlenecks
- Decrease resilience improve availability
  - If a box goes down others still operate
  - But: Part of the data missing

Sharding and replication

- Sharding with no replication: unique copy, distributed data sets
  - (+) Better concurrency levels (shards are accessed independently)
  - (-) Cost of checking constraints, rebuilding aggregates
  - Ensure that queries and updates are distributed across shards
- Replication of shards
  - (+) Query performance (availability)
  - (-) Cost of updating, of checking constraints, complexity of concurrency control
- Partial replication (most of the times)
  - Only some shards are duplicated

Merci

Thanks

Gracias

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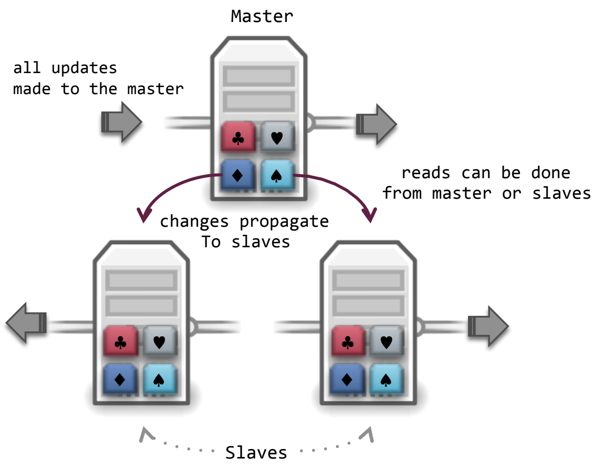
NOSQL STORES: AVAILABILITY AND PERFORMANCE

Replication master - slave



- Makes one node the authoritative copy/replica that handles writes while replica synchronize with the master and may handle reeds

- All replicas have the same weight
  - Replicas can all accept writes
  - The lose of one of them does not prevent access to the data store

- Helps with read scalability but does not help with write scalability

- Read resilience: should the master fail, slaves can still handle read requests

- Master failure eliminates the ability to handle writes until either the master is restored or a new master is appointed

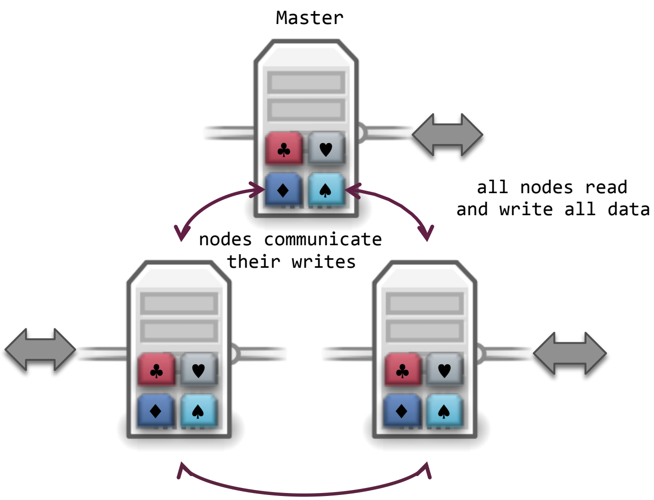
- Biggest complication is consistency
  - Possible write – write conflict
  - Attempt to update the same record at the same time from to different places

- Master is a bottle-neck and a point of failure

Master-slave replication management

- Masters can be appointed
  - Manually when configuring the nodes cluster
  - Automatically: when configuring a nodes cluster one of them elected as master. The master can appoint a new master when the master fails reducing downtime
- Read resilience
  - Read and write paths have to be managed separately to handle failure in the write path and still reads can occur
  - Reads and writes are put in different database connections if the database library accepts it
- Replication comes inevitably with a dark side: **inconsistency**
  - Different clients reading different slaves will see different values if changes have not been propagated to all slaves
  - In the worst case a client cannot read a write it just made
  - Even if master-slave is used for hot backups, if the master fails any updates on to the backup are lost

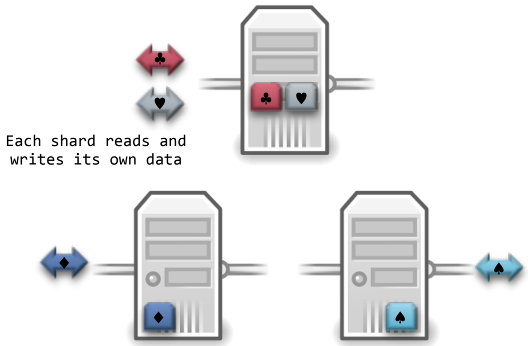
Replication: peer-To-Peer



- Allows writes to any node; the nodes coordinate to synchronize their copies
- The replicas have equal weight

- Deals with inconsistencies
  - Replicas coordinate to avoid conflict
  - Network traffic cost for coordinating writes
  - Unnecessary to make all replicas agree to write, only the majority
  - Survival to the loss of the minority of replicas nodes
  - Policy to merge inconsistent writes
  - Full performance on writing to any replica

Sharding



- Ability to distribute both data and load of simple operations over many servers, with no RAM or disk shared among servers
- A way to horizontally scale **writes**
- Improve **read** performance
- Application/data store support

- Puts different data on separate nodes
  - Each user only talks to one servicer so she gets rapid responses
  - The load should be balanced out nicely between servers

- Ensure that
  - data that is accessed together is clumped together on the same node
  - that clumps are arranged on the nodes to provide best data access

Sharding

Database laws	Principle

Database laws

- Small databases are fast
- Big databases are slow
- Keep databases small

Principle

- Start with a big monolithic database
  - Break into smaller databases
  - Across many clusters
  - Using a key value

Instead of having one million customers information on a single big machine ….

*100 000 customers on **smaller** and **different** machines*

Sharding criteria

- Partitioning
  - Relational: handled by the DBMS (homogeneous DBMS)
  - NoSQL: based on ranging of the k-value
- Federation
  - Relational
    - Combine tables stored in different physical databases
    - Easier with denormalized data
  - NoSQL:
    - Store together data that are accessed together
    - Aggregates unit of distribution

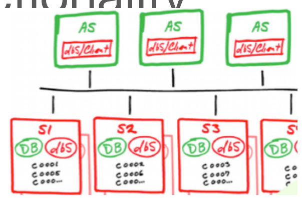
Sharding

Architecture

- Each application server (AS) is running DBS/client
- Each shard server is running
  - a database server
  - replication agents and query agents for supporting parallel query functionality

Process

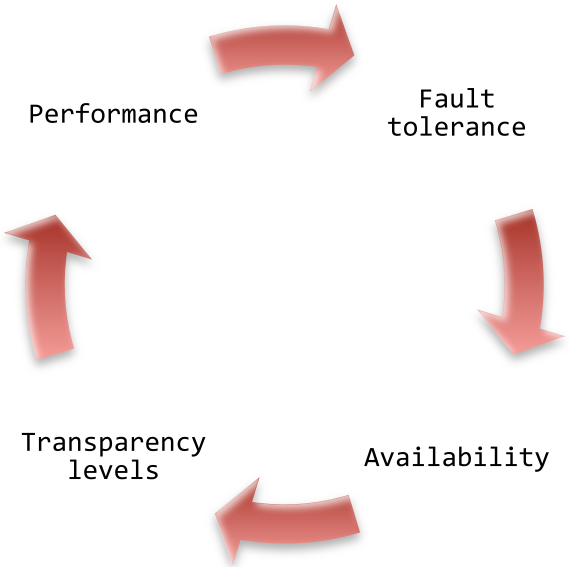
- Pick a dimension that helps sharding easily (customers, countries, addresses)
- Pick strategies that will last a long time as repartition/re-sharding of data is operationally difficult
- This is done according to two different principles
  - **Partitioning**: a partition is a structure that divides a space into tow parts
  - **Federation**: a set of things that together compose a centralized unit but each individually maintains some aspect of autonomy



Customers data is partitioned by ID in shards using an algorithm d to determine which shard a customer ID belongs to

Replication: aspects to consider

- Conditioning



- Important elements to consider
  - Data to duplicate
  - Copies location
  - Duplication model (master – slave / P2P)
  - Consistency model (global – copies)

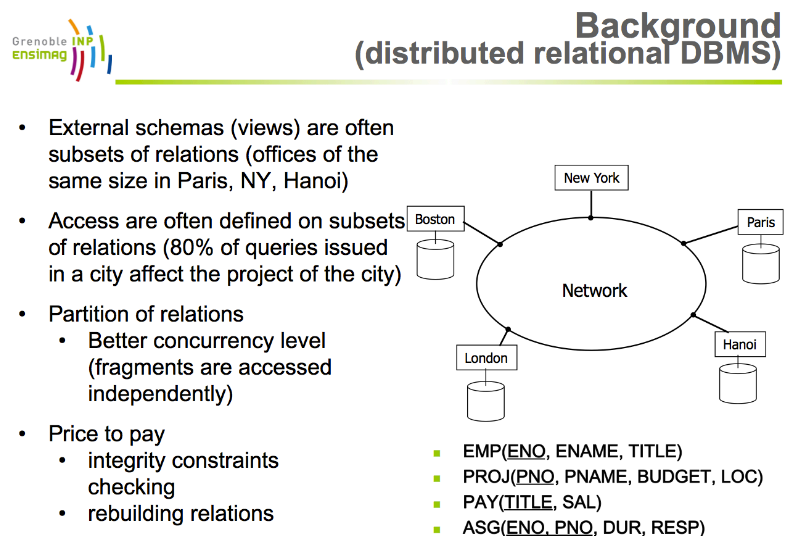
→ **Find a compromise !**

PARTITIONING

A PARTITION IS A STRUCTURE THAT DIVIDES A SPACE INTO TOW PARTS

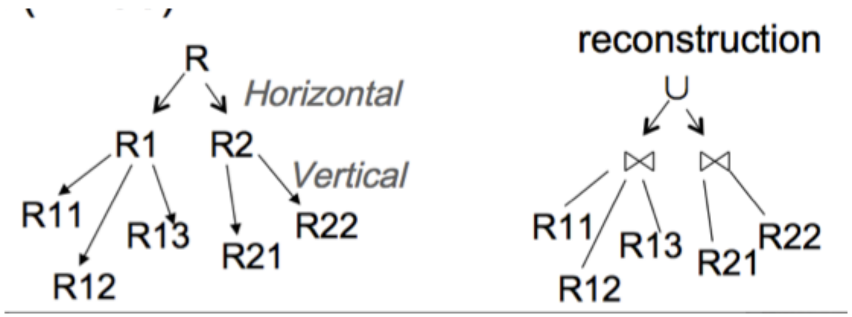
Background: distributed relational databases

- External schemas (views) are often subsets of relations (contacts in Europe and America)
- Access defined on subsets of relations: 80% of the queries issued in a region have to do with contacts of that region
- Relations partition
  - Better concurrency level
  - Fragments accessed independently
- Implications
  - Check integrity constraints
  - Rebuild relations



Fragmentation

- Horizontal
  - Groups of tuples of the same relation
  - Budget < 300 000 or >= 150 000
  - Not disjoint are more difficult to manage
- Vertical
  - Groups attributes of the same relation
  - Separate budget from loc and pname of the relation project
- Hybrid



Fragmentation: rules

Vertical

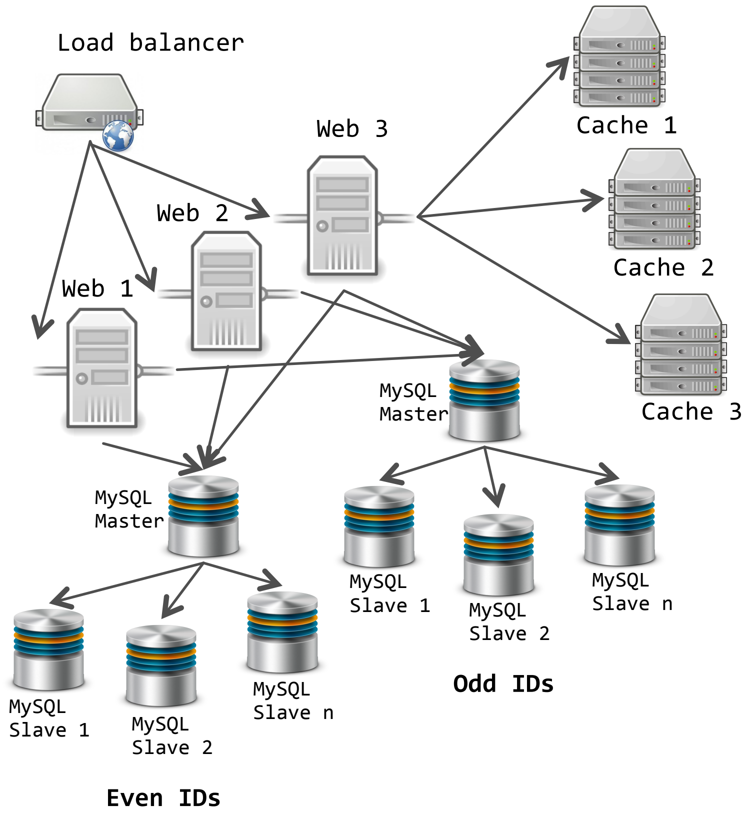
- Clustering
  - Grouping elementary fragments
  - Budget and location information in two relations
- Splitting
  - Decomposing a relation according to affinity relationships among attributes

Horizontal

- Tuples of the same fragment must be statistically homogeneous
  - If t1 and t2 are tuples of the same fragment then t1 and t2 have the same probability of being selected by a query
- Keep important conditions
  - Complete
    - Every tuple (attribute) belongs to a fragment (without information loss)
    - If tuples where budget >= 150 000 are more likely to be selected then it is a good candidate
  - Minimum
    - If no application distinguishes between budget >= 150 000 and budget < 150 000 then these conditions are unnecessary

Sharding: horizontal partitioning

- The entities of a database are split into two or more sets (by row)
- In relational: same schema several physical bases/servers
  - Partition contacts in Europe and America shards where they zip code indicates where the will be found
  - Efficient if there exists some robust and implicit way to identify in which partition to find a particular entity
- Last resort shard
  - Needs to find a sharding function: modulo, round robin, hash – partition, range - partition

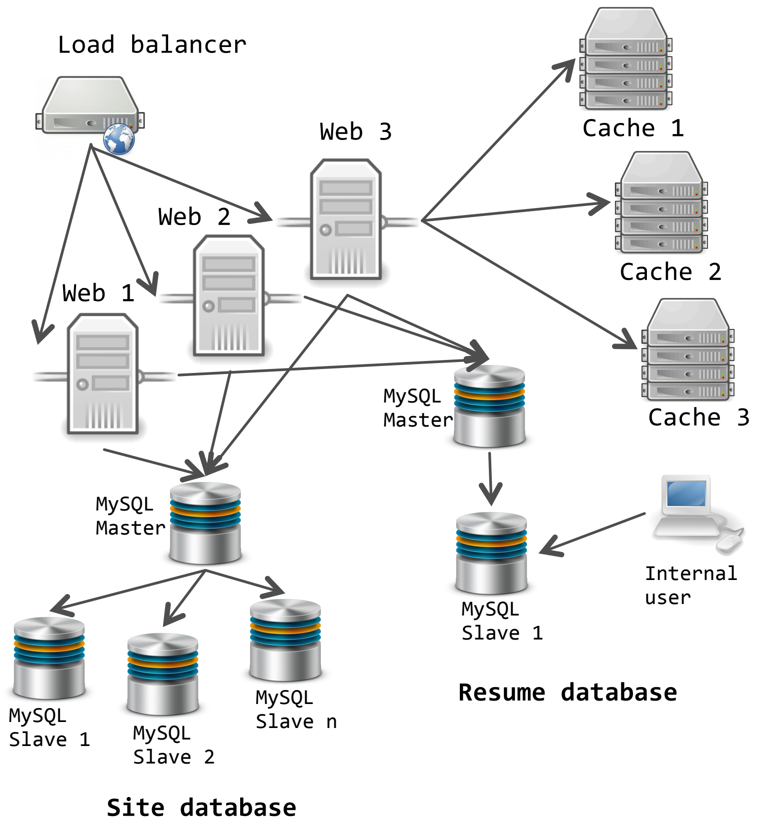


FEDERATION

A FEDERATION IS A SET OF THINGS THAT TOGETHER COMPOSE A CENTRALIZED UNIT BUT EACH INDIVIDUALLY MAINTAINS SOME ASPECT OF AUTONOMY

FEDERATION: vertical SHARDING

- Principle
  - Partition data according to their logical affiliation
  - Put together data that are commonly accessed
- The search load for the large partitioned entity can be split across multiple servers (logical and physical) and not only according to multiple indexes in the same logical server
- Different schemas, systems, and physical bases/ servers
- Shards the components of a site and not only data



NOSQL STORES: PERSISTENCY MANAGEMENT

«*memcached*»

- «*memcached*» is a memory management protocol based on a cache:
  - Uses the key-value notion
  - Information is completly stored in RAM
- «*memcached*» protocol for:
  - Creating, retrieving, updating, and deleting information from the database
  - Applications with their own «*memcached*» manager (Google, Facebook, YouTube, FarmVille, Twitter, Wikipedia)

Storage on disc (1)

- For efficiency reasons, information is stored using the RAM:
  - Work information is in RAM in order to answer to low latency requests
  - Yet, this is not always possible and desirable

➢ **The process of moving data from RAM to disc is called "*eviction*"; this process is configured automatically for every bucket**

Storage on disc (2)

- NoSQL servers support the storage of key-value pairs on disc:
  - **Persistency**–can be executed by loading data, closing and reinitializing it without having to load data from another source
  - **Hot backups**– loaded data are sotred on disc so that it can be reinitialized in case of failures
  - **Storage on disc**– the disc is used when the quantity of data is higher thant the physical size of the RAM, frequently used information is maintained in RAM and the rest es stored on disc

Storage on disc (3)

- Strategies for ensuring:
  - Each node maintains in RAM information on the key-value pairs it stores. Keys:
    - may not be found, or
    - they can be stored in memory or on disc
  - The process of moving information from RAM to disc is asynchronous:
    - The server can continue processing new requests
    - A queue manages requests to disc
- **In periods with a lot of writing requests, clients can be notified that the server is termporaly out of memory until information is evicted**

NOSQL STORES: CONCURRENCY CONTROL

Multi version concurrency control (MVCC)

- ***Objective***: Provide concurrent access to the database and in programming languages to implement transactional memory
- ***Problem***: If someone is reading from a database at the same time as someone else is writing to it, the reader could see a half-written or inconsistent piece of data.
- Lock: readers wait until the writer is done
- MVCC:
  - Each user connected to the database sees a snapshot of the database at a particular instant in time
  - Any changes made by a writer will not be seen by other users until the changes have been completed (until the transaction has been committed
  - When an MVCC database needs to update an item of data it marks the old data as obsolete and adds the newer version elsewhere → multiple versions stored, but only one is the latest
  - Writes can be isolated by virtue of the old versions being maintained
  - Requires (generally) the system to periodically sweep through and delete the old, obsolete data objects