NoSQL

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What are NoSQL databases?

- hard to say
- more a theme than a well defined thing

Usually some or all of the following:

- no SQL interface
- no relational model / no schema
- no joins, emphasize on key/value pairs
- scale out to many machines
- weak or no consistency guarantees

Why not relational databases?

Some commonly stated reasons:

- RDBMS are hard to use
- do not scale to ”web-scale”
- relational model is too restrictive
- NoSQL is faster, scales better

Some of this is true (as we will see), but most likely will not affect you!

Illustrational Web Video

MongoDB is web scale
http://www.xtranormal.com/watch/6995033

The Performance Argument

Voter benchmark: People call to vote for American Idol

- at most 12 votes are counted per caller-id
- very simple transaction model

On a 8 core Intel Xeon X5570 with 64GB main memory:

- MongoDB: ca. 10,000 transactions per second
- relational main-memory database: ca. 1,000,000 transactions per second

Do not blindly follow a hype, do the math!

Sucess stories from the net

- Why we chose MongoDB [...] Very easy to install. [...] Very easy replication
- [...] We cut down the names to 2-3 characters. This is a little more confusing in the code but the disk storage savings are worth it [...] a massive saving.
- [...] Was it the right move? Yes. MongoDB has been an excellent choice [...] MongoDB is going to be very cool!

- MongoDB works fine, but the same query is 25 times faster in PostgreSQL
- [...] MongoDB will win once I have 26 machines

Technical Arguments in favor of NoSQL

CAP-Theorem: In a distributed system you can only have two of the following

- Consistency
  - all nodes see the same data at the same time
- Availability
  - node failures do not prevent survivors from continuing to operate
- Partition Tolerance
  - he system continues to operate despite arbitrary message loss

Basis for the claim the RDBMS are not "web-scale"

Scalability

How to scale to thousands of nodes?

- traditional RDBMS usually scale to less than 100 node
- transaction semantic requires a lot of coordination
- two phase commit is expensive
- $O(n^2)$ network connections
- does not scale to thousands of nodes

Partitioning helps, but usually requires human interaction.

Key/Value - Stores

Life would be much simpler if we only stored key/value pairs

- only (or mostly) point-access
- transactions operate on a single item
- allows for simple partitioning
- by spreading keys over nodes we distribute the data
- usually scales perfectly

Life is much simpler if you only care about individual values...

Distributed Hash Tables

Basis for many distributed storage schemes:

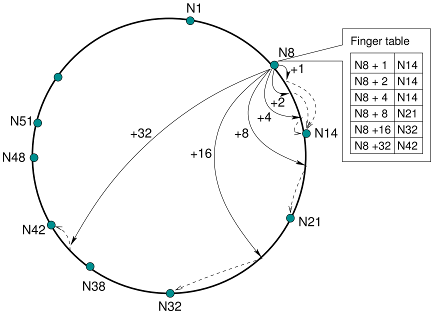
- spread a hash table over a large number of nodes
- nodes can enter and leave (more or less) at will
- nodes know only a few other nodes
- offers scalable distributed storage

Many algorithms exists: Chord, Pastry, P-Grid, etc.

- usual idea: hash nodes into hash domain
- nodes responsible to for hash values near to them

Distributed Hash Tables - Chord

Both items and nodes are hashed into ring structure



Finger tables similar to skip lists

Expressiveness

- DHTs are one giant Key$\rightarrow$Value table
- only three operations: lookup, insert, delete
- each operations is limited to a single data item
- range queries not supported efficiently

This is a severe limitation. Scalability is obtained by eliminating functionality

What about Consistency?

We want our database to be consistent

- as long as transactions operate on single items (note: **strong restriction**) life is relatively simple
- one node is responsible for the data item
- as long as all changes are atomic or idempotent everything is fine

But: nodes will be replicated for availability

- ensuring consistency adds the same costs as in standard distributed RDBMSs
- most systems aim at "eventual consistency"
- after waiting long enough (without updates in between), all replicas will have the same value

This is usually unacceptable if the data is valuable (e.g., involves money)!

What about Multi-Item Transactions?

Short answer: not supported

Long answer: not supported very well

- one can ignore the issue and run multi single-level transactions
- completely messes up consistency
- some systems offer explicit locking
- some problems as in distributed RDBMSs

How to Query the Data

Data is spread over thousands of nodes

- point query are supported by DHTs
- range queries are not
- aggregation queries are very important

Requires some very heavy machinery inside the NoSQL database

- query response time usually multiple seconds, even minutes
- not really suited for interactive queries
- data will change during query execution
- usually queries inconsistent data

Map/Reduce

Programming paradigm that allows for easy parallelization. Sequence of two operations:

1. Map: $(k_1, v_1) \rightarrow list(k_2, v_2)$
   - constructs key-value pairs from input pair
   - can be computed in parallel, no interaction
2. Reduce: $(k_2, list(v_2)) \rightarrow list(k_3, v_3)$
   - reduces all k_2 pairs into one (or more) value
   - different k_2s can be parallelized

Simple, scalable scheme, but involves massive movement of data

Map/Reduce - Canonical Example

Word count is the classical example:

1. map(*documentId*,*document*)
   for each word w in *document*
   emit (w,1)
2. reduce(*word*,*counts*)
   $count = 0$
   for each c in *counts*
   $count += c$
   emit(*word*,*count*)

Computes the frequency of each word

Map/Reduce - Database Queries

Can also be used to query distributed key/value stores:

1. map(*customerId*,*customerData*)
   emit (*customerId*,*customerData*.*amount*)
2. reduce(*customerId*,*revenues*)
   $sum = 0$
   for each r in *revenues*
   $\quad sum+ = r$
   emit(*customerId*,r)
3. reduce(*customerId*,*revenue*)
   if $revenue > 10000$
   $\quad$ emit (*customerId*,*revenue*)

- executed across all nodes
- very heavy operation

Systems

There is a huge number of NoSQL systems around

- BigTable
  - key/value store used inside Google, row/column/time dimensions, slicing
- Casandra
  - key/value store with tunable consistency
- MongoDB
  - document centric, JavaScript driven, relatively rich queries
- CouchDB
  - document centric, JavaScript driven, MVCC
- Dynamo, Project Voldemort, Hbase, ...

Unfortunately all incompatible, all different in some aspects

Who needs this ultra-scalability?

Going fully "web-scale" makes sense in a few cases:

- the data amount is huge
  - petabytes of data
- consistency is not important
  - click streams, not payment data
- access is mostly single-item
  - more complicated queries are expensive

But: very few companies have these characteristics

The real reason why (some) people use NoSQL: Money

A 1TB main-memory machine costs ca. 60K

- most people do not have large amounts of data anyway
- or if they have, the data is not that important
- enterprise database systems are expensive
- NoSQL products tend to be free or cheap
- startups do not have money

But is this really an argument for NoSQL?

Conclusion

NoSQL is a fuzzy term, but usually

- stores non-relational data
- aims at scalability to thousands of nodes
- sacrifices consistency
- support mainly simple queries efficiently

Mainly makes sense if

- data is really huge
- and not very valuable

Otherwise, use a RDBMS!