Cloud Computing and Big Data

NoSQL databases

Oxford University

Software Engineering Programme

Nov 2015

Contents

- Why NoSQL?
- ReCAP
- BigTable and Dynamo
- A summary of a few NoSQL databases
  - MongoDB, Cassandra, Couchbase,

Why NoSQL?

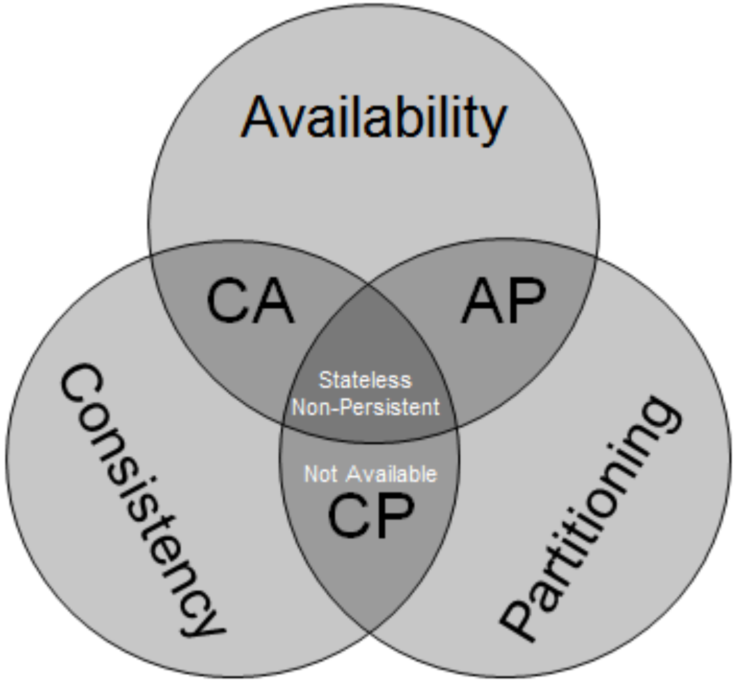
- Availability
  - Need better scaling capabilities
  - Elasticity
- Different schema approaches
  - Graphs, Key Values, Document, Sparse Columns, etc
- More appropriate balance in read/write performance
- Better integration with REST/SOA/Cloud

NoSQL history

- Not just a recent thing ☺
- IBM IMS (Information Management System)
  - Launched in 1968
  - Used to store the bill of materials for the Saturn V rocket
  - Hierarchical model
- Still in widespread use today

ReCAP

- You can have 2 out of three:
  - Consistent
    - ACID
  - Available
    - HA / Accessible 24x7
  - Partitioned
    - Able to split into different datacentres
    - Survive network down

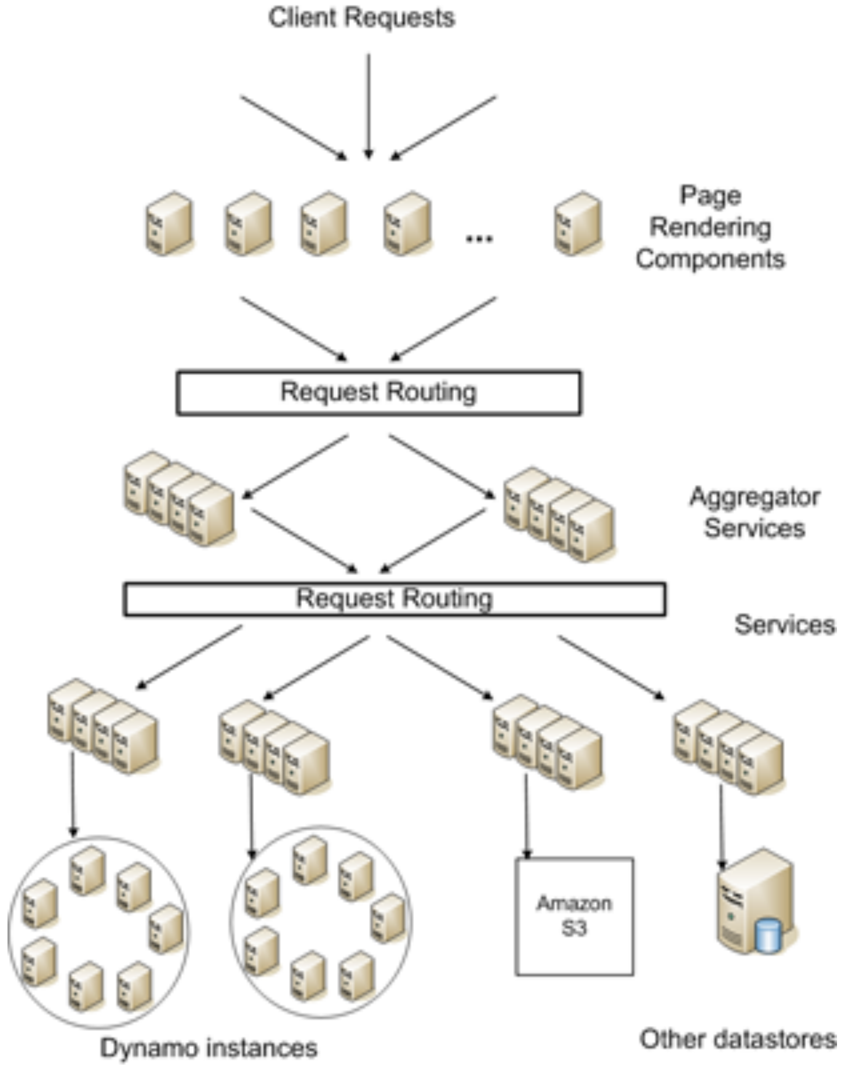


http://blog.mccrory.me/2010/11/03/cap-theorem-and-the-clouds/

NoSQL parents

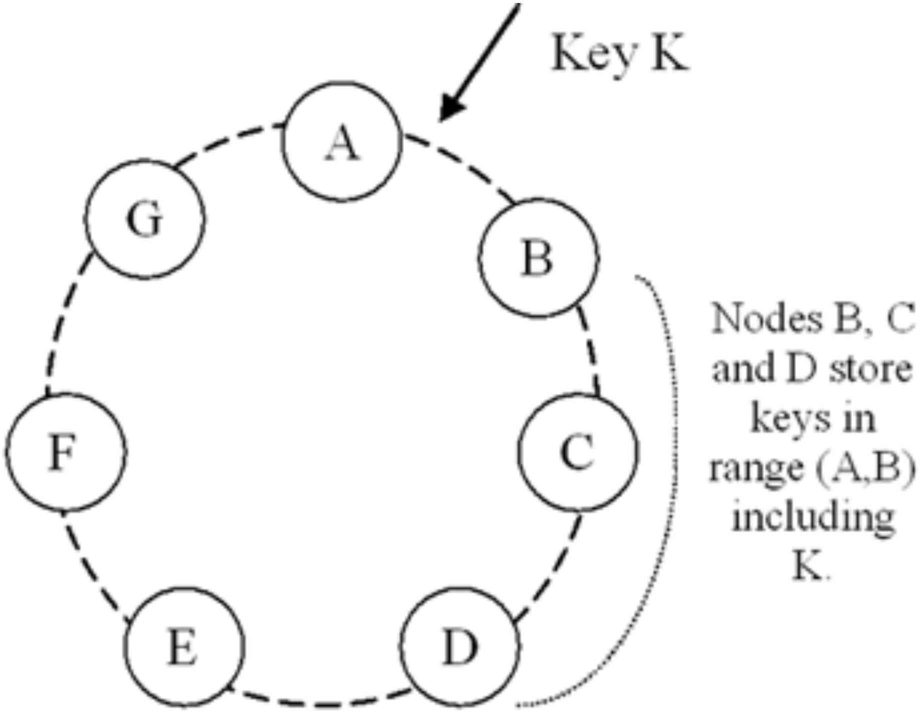
- Amazon Dynamo
  - Eventually consisten
- Google BigTable
  - Supporting very large rows
- LDM
  - Graph database

Dynamo



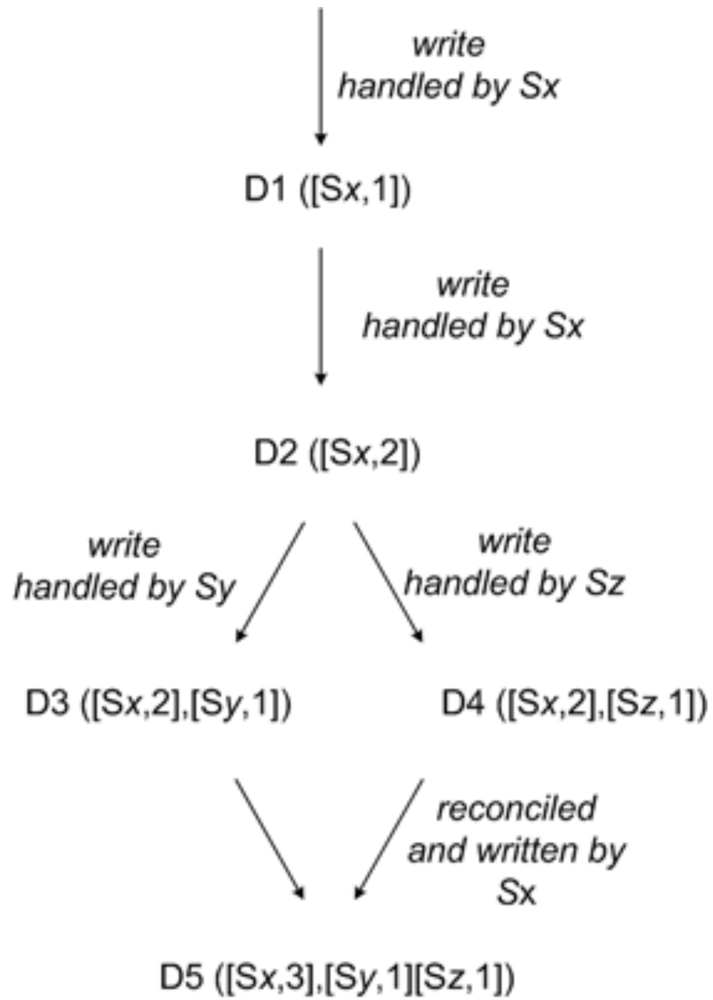
Client Requests
...
Page Rendering Components
Request Routing
Aggregator Services
Request Routing
Services
Amazon S3
Dynamo instances
Other datastores

Dynamo Model



http://www.allthingsdistributed.com/2007/10/amazons_dynamo.html

Reconciliation / Eventual Consistency



http://www.allthingsdistributed.com/2007/10/amazons_dynamo.html

Dynamo Techniques

Problem	Technique	Advantage
Partitioning	Consistent Hashing	Incremental Scalability
High Availability for writes	Vector clocks with reconciliation during reads	Version size is decoupled from update rates.
Handling temporary failures	Sloppy Quorum and hinted handoff	Provides high availability and durability guarantee when some of the replicas are not available.
Recovering from permanent failures	Anti-entropy using Merkle trees	Synchronizes divergent replicas in the background.
Membership and failure detection	Gossip-based membership protocol and failure detection.	Preserves symmetry and avoids having a centralized registry for storing membership and node liveness information.

Google BigTable

- Optimized to support very large data
  - Not just many rows, but rows that cannot fit into the memory of a single server
  - Column Families allow each row to live across servers
- This table dates back to 2005

Project name	Table size (TB)	Compression ratio	# Cells (billions)	# Column Families	# Locality Groups	% in memory	Latency-sensitive?
Crawl	800	11%	1000	16	8	0%	No
Crawl	50	33%	200	2	2	0%	No
Google Analytics	20	29%	10	1	1	0%	Yes
Google Analytics	200	14%	80	1	1	0%	Yes
Google Base	2	31%	10	29	3	15%	Yes
Google Earth	0.5	64%	8	7	2	33%	Yes
Google Earth	70	–	9	8	3	0%	No
Orkut	9	–	0.9	8	5	1%	Yes
Personalized Search	4	47%	6	93	11	5%	Yes

Current NoSQL Databases

- Too many to list!
- Popular databases include:
  - MongoDB
  - Couchbase
  - Apache Cassandra
  - Apache HBase
  - Voldemort
  - Redis
  - Riak
  - Etc, etc

"NewSQL"

- ACID databases that aim to provide HA and Partition safety
  - VoltDB
  - NuoDB
  - Google Spanner
  - MemSQL
  - SAP HANA
- Also there are some backend engines for MySQL that aim to provide this:
  - MySQL Cluster
  - TokuDB

In Memory Databases

- Memory is relatively much cheaper than it used to be
- Uses snapshots or transaction logs to ensure durability
- *Some NoSQL, some NewSQL*
  - SAP Hana
  - Redis
  - VoltDB
  - MemSQL
  - Apache Geode

Top ten databases

283 systems in ranking, November 2015

Rank			DBMS	Database Model	Score		
Nov 2015	Oct 2015	Nov 2014			Nov 2015	Oct 2015	Nov 2014
1.	1.	1.	Oracle	Relational DBMS	1480.95	+13.99	+28.82
2.	2.	2.	MySQL	Relational DBMS	1286.84	+7.88	+7.77
3.	3.	3.	Microsoft SQL Server	Relational DBMS	1122.33	-0.90	-97.87
4.	4.	↑ 5.	MongoDB	Document store	304.61	+11.34	+59.87
5.	5.	↓ 4.	PostgreSQL	Relational DBMS	285.69	+3.56	+28.33
6.	6.	6.	DB2	Relational DBMS	202.52	-4.28	-3.71
7.	7.	7.	Microsoft Access	Relational DBMS	140.96	-0.87	+2.12
8.	8.	↑ 9.	Cassandra	Wide column store	132.92	+3.91	+40.93
9.	9.	↓ 8.	SQLite	Relational DBMS	103.45	+0.78	+8.17
10.	10.	↑ 11.	Redis	Key-value store	102.41	+3.61	+20.06

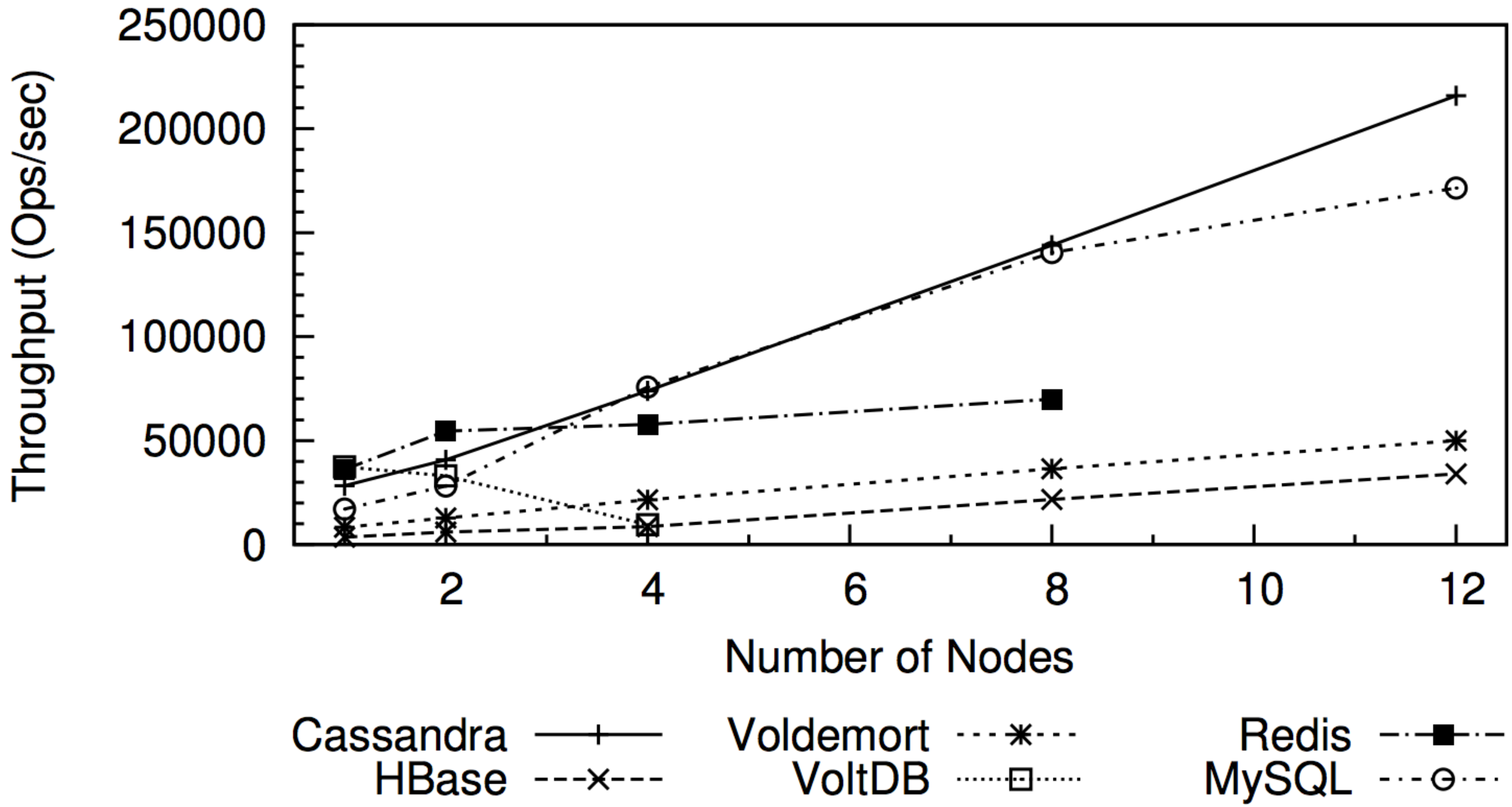
http://db-engines.com/en/ranking

Next 20

11.	11.	10.	SAP Adaptive Server	Relational DBMS	83.71	-1.93	-0.91
12.	12.	12.	Solr	Search engine	79.77	+0.71	+2.96
13.	13.	13.	Teradata	Relational DBMS	77.08	+3.64	+9.85
14.	14.	16.	Elasticsearch	Search engine	74.77	+4.55	+31.71
15.	15.	15.	HBase	Wide column store	56.46	-0.78	+9.49
16.	16.	17.	Hive	Relational DBMS	54.91	+1.35	+18.30
17.	17.	14.	FileMaker	Relational DBMS	51.73	+1.95	+0.39
18.	18.	20.	Splunk	Search engine	44.61	+1.11	+12.44
19.	19.	21.	SAP HANA	Relational DBMS	39.62	+0.52	+11.26
20.	20.	18.	Informix	Relational DBMS	38.46	+0.12	+2.88
21.	21.	23.	Neo4j	Graph DBMS	34.04	+0.63	+9.39
22.	22.	19.	Memcached	Key-value store	32.39	+0.82	-0.20
23.	25.	27.	MariaDB	Relational DBMS	26.64	+2.01	+9.35
24.	23.	22.	CouchDB	Document store	26.37	-0.49	+0.57
25.	24.	24.	Couchbase	Document store	25.82	-0.37	+4.33
26.	26.	26.	Firebird	Relational DBMS	22.56	-0.33	+4.95
27.	28.	25.	Netezza	Relational DBMS	21.84	+0.60	+3.76
28.	27.	31.	Amazon DynamoDB	Multi-model	21.75	+0.42	+9.43
29.	30.	28.	Microsoft Azure SQL Database	Relational DBMS	19.46	+0.62	+4.85
30.	29.	29.	Vertica	Relational DBMS	19.41	+0.45	+5.46

Performance (2012)

50%/50% reads/writes

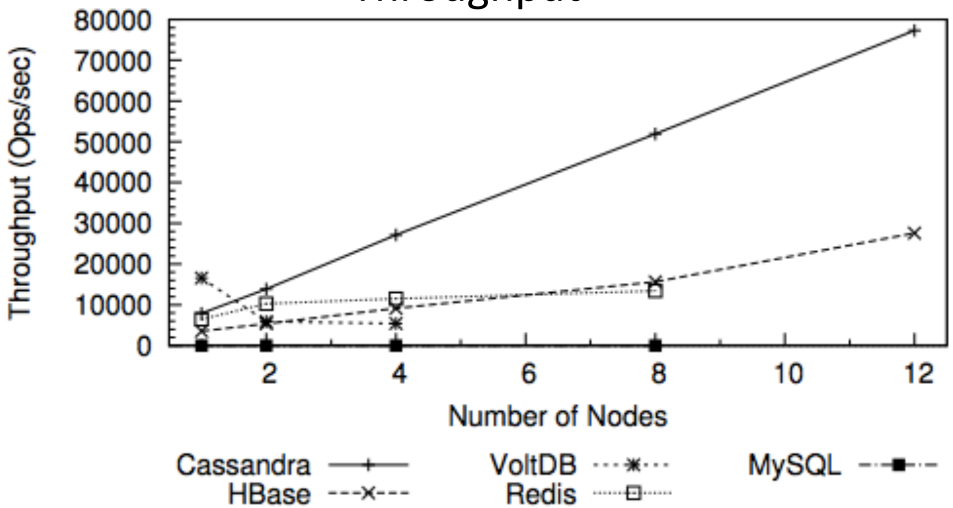


Rabl, Tilmann, et al. "Solving big data challenges for enterprise application performance management." Proceedings of the VLDB Endowment 5.12 (2012): 1724-1735.

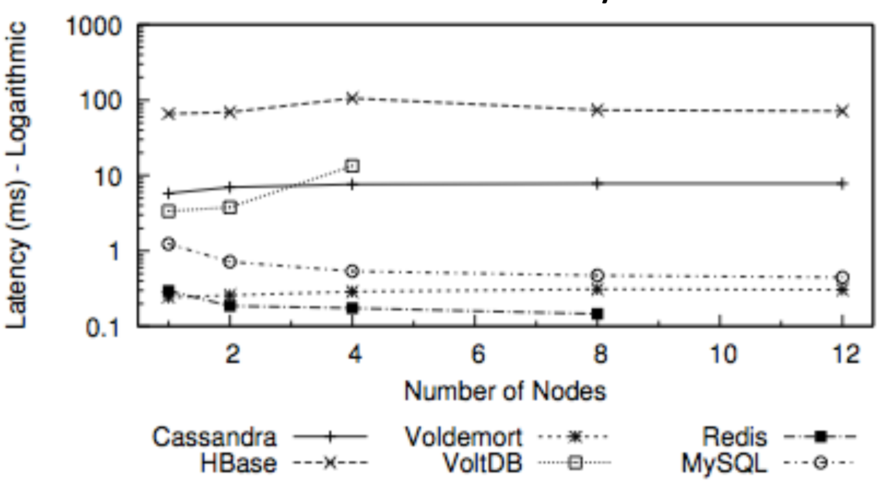
More performance (2012)

Read/Scan/Write workload

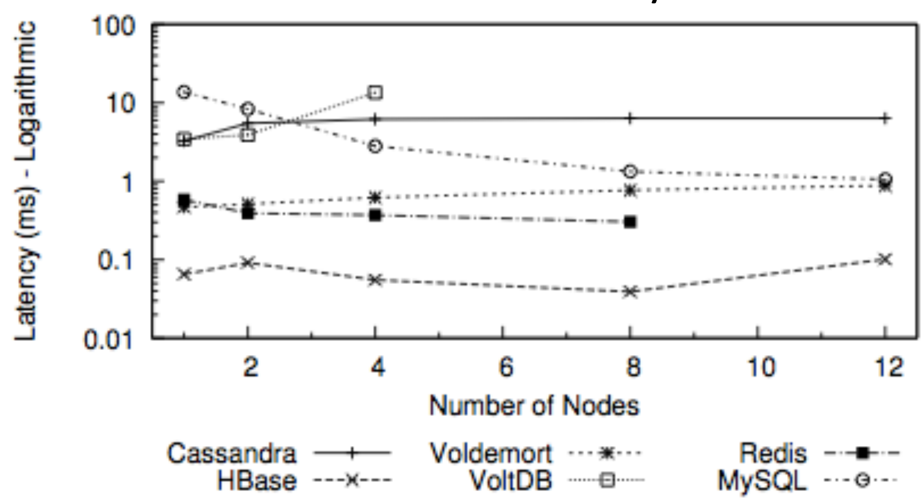
Throughput



Read Latency



Write Latency



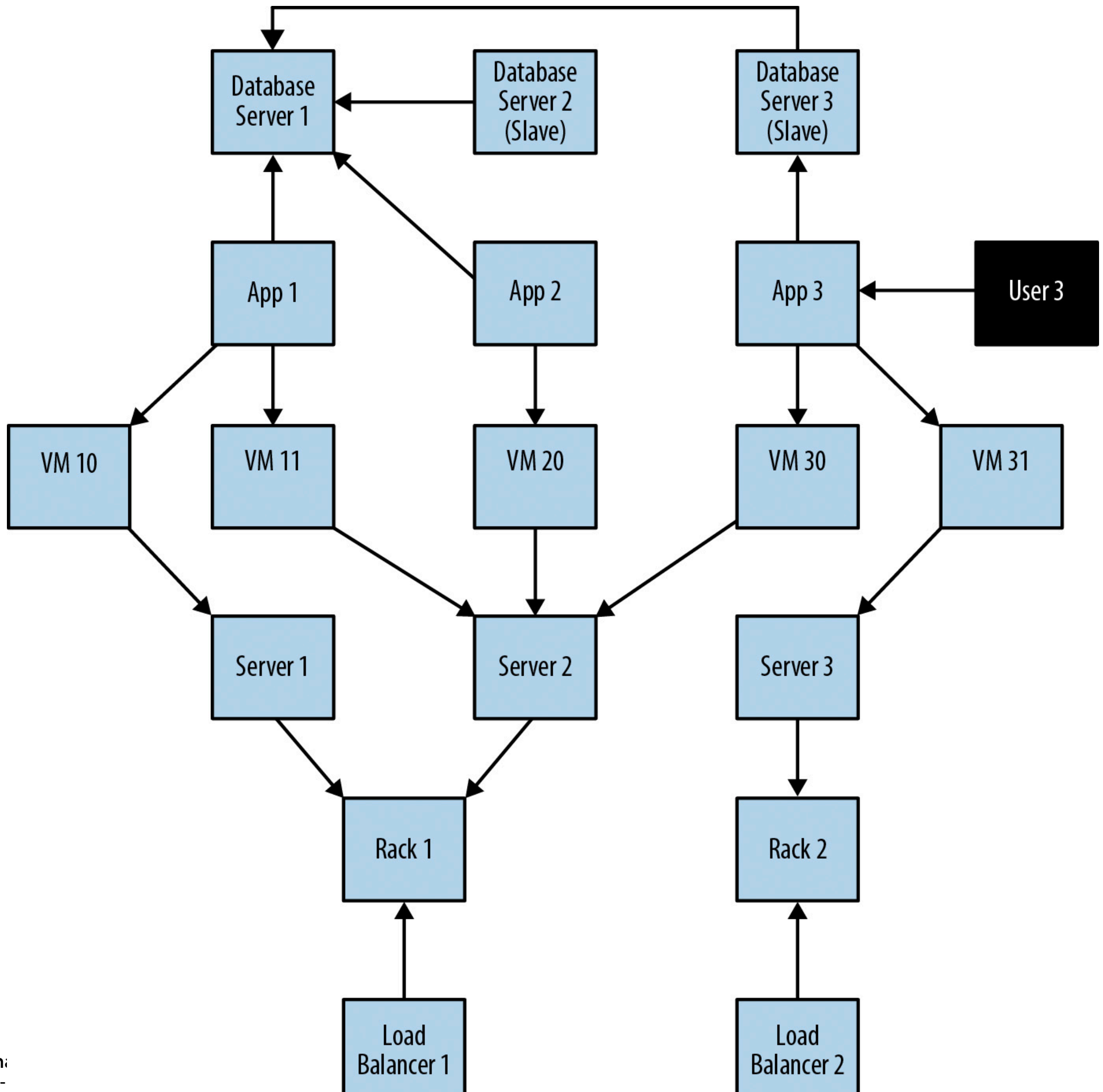
Summary of Performance benchmark (2012)

- **Cassandra** had the best throughput but high latency
- **Voldemort** had the best and most stable latency but lower throughput
- **HBase** had low performance per node but scaled well
  - Low write latency
- **Redis, MySQL and VoltDB** did not scale as well in multi-node setups

Key Value databases

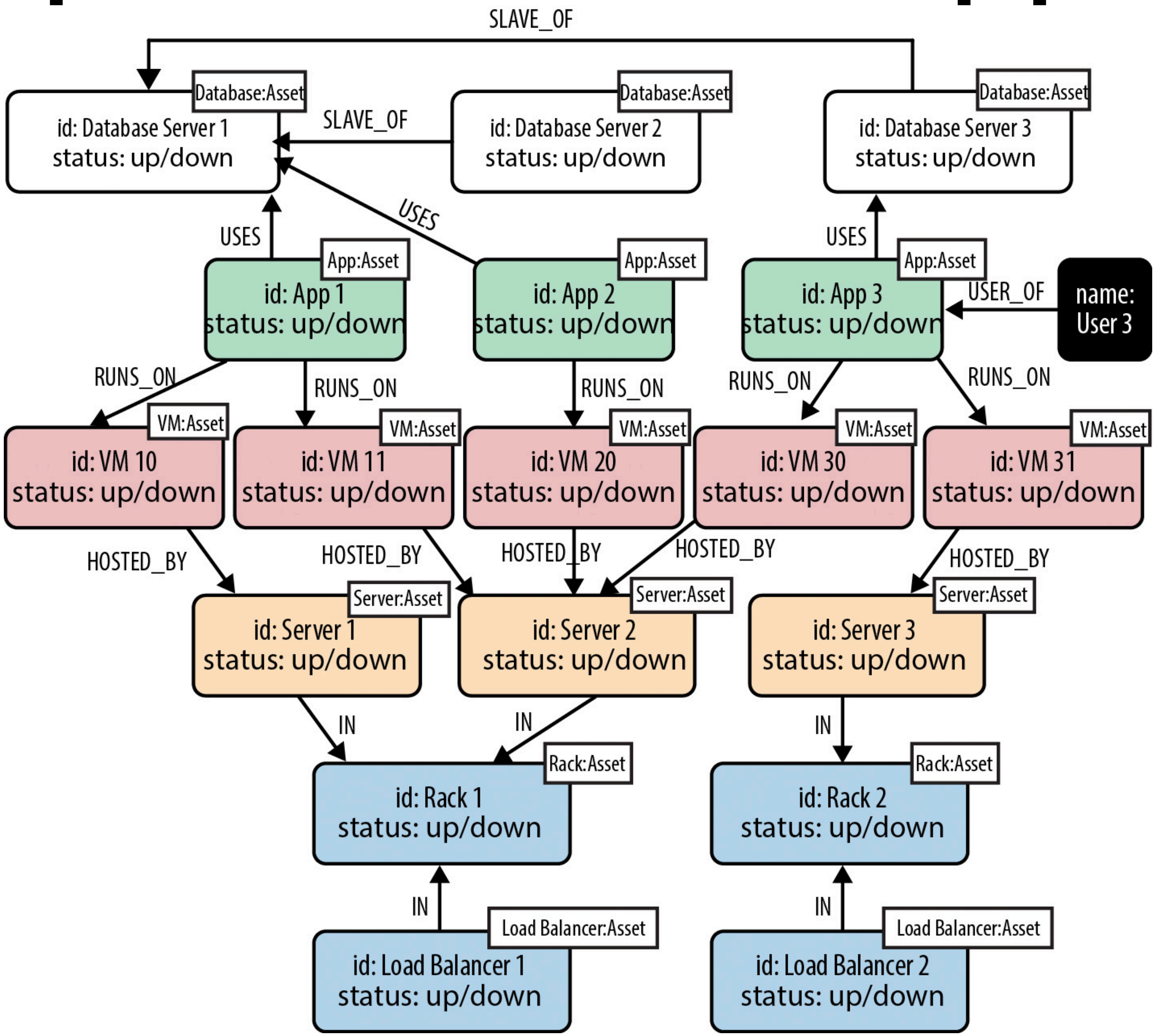
- A persistent associative array or dictionary
- Simple access and fits well with programming models (especially MR)
- Indexing on other data is not often possible and can be slow

Graph Databases



Source: neo4j

Graph Database mapping



Source: neo4j

Questions?