Year	System/ Paper	Scale to 1000s	Primary Index	Secondary Indexes	Transactions	Joins/ Analytics	Integrity Constraints	Views	Language/ Algebra	Data model	my label
1971	RDBMS	O	✔	✔	✔	✔	✔	✔	✔	tables	sql-like
2003	memcached	✔	✔	O	O	O	O	O	O	key-val	nosql
2004	MapReduce	✔	O	O	O	✔	O	O	O	key-val	batch
2005	CouchDB	✔	✔	✔	record	MR	O	✔	O	document	nosql
2006	BigTable (Hbase)	✔	✔	✔	record	compat. w/MR	/	O	O	ext. record	nosql
2007	MongoDB	✔	✔	✔	EC, record	O	O	O	O	document	nosql
2007	Dynamo	✔	✔	O	O	O	O	O	O	key-val	nosql
2008	Pig	✔	O	O	O	✔	/	O	✔	tables	sql-like
2008	HIVE	✔	O	O	O	✔	✔	O	✔	tables	sql-like
2008	Cassandra	✔	✔	✔	EC, record	O	✔	✔	O	key-val	nosql
2009	Voldemort	✔	✔	O	EC, record	O	O	O	O	key-val	nosql
2009	Riak	✔	✔	✔	EC, record	MR	O			key-val	nosql
2010	Dremel	✔	O	O	O	/	✔	O	✔	tables	sql-like
2011	Megastore	✔	✔	✔	entity groups	O	/	O	/	tables	nosql
2011	Tenzing	✔	O	O	O	O	✔	✔	✔	tables	sql-like
2011	Spark/Shark	✔	O	O	O	✔	✔	O	✔	tables	sql-like
2012	Spanner	✔	✔	✔	✔	?	✔	✔	✔	tables	sql-like
2012	Accumulo	✔	✔	✔	record	compat. w/MR	/	O	O	ext. record	nosql
2013	Impala	✔	O	O	O	✔	✔	O	✔	tables	sql-like

DynamoDB

Key features:

- Service Level Agreement (SLN): at the
- 99th percentile, and not on mean/median/variance (otherwise, one penalizes the heavy users)
- “Respond within 300ms for 99.9% of its requests”

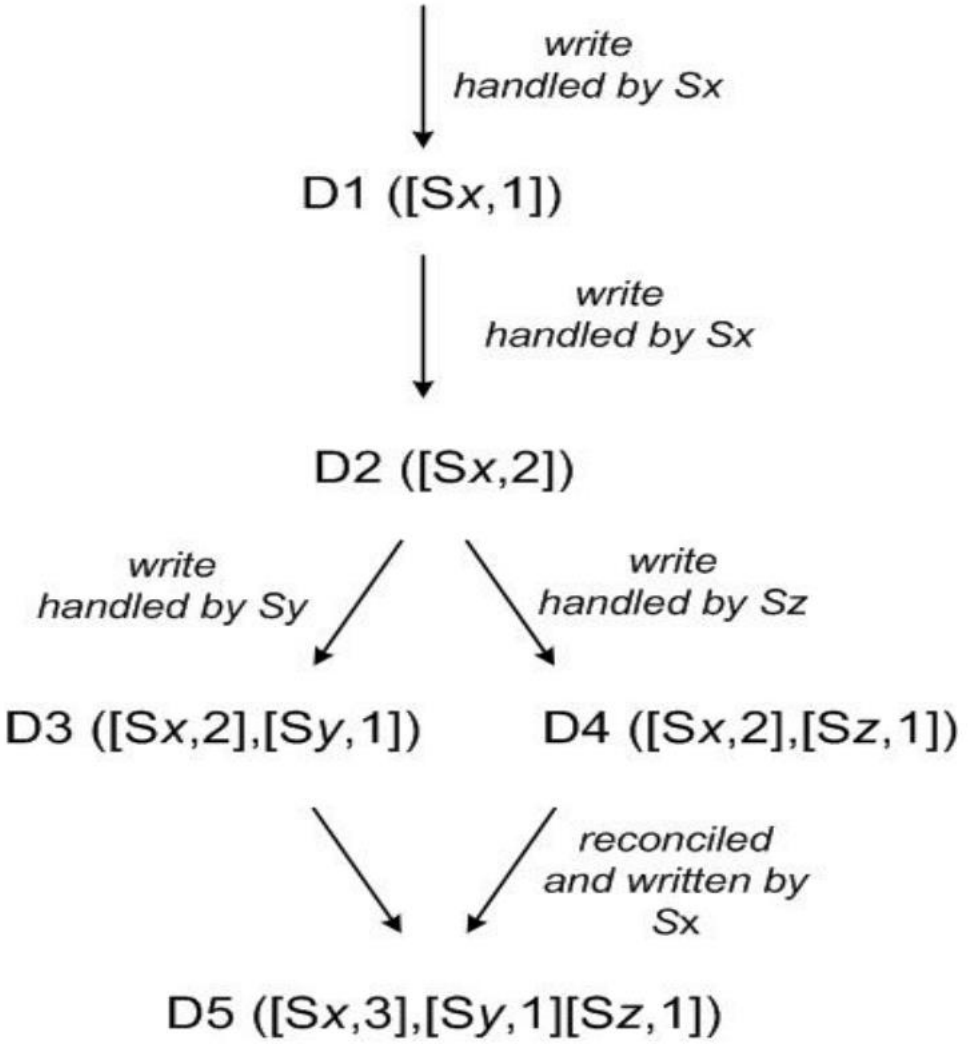
Dynamo (2)

Key features:

- DHT with replication:
  - Store value at k, k+1, …, k+N-1
  - Eventual consistency through vector clocks
- Reconciliation at read time:
  - Writes never fail (“poor customer experience”)
  - Conflict resolution: “last write wins” or application specific

Vector Clocks

Each data item associated with a list of (server, timestamp) pairs indicating its version history.



Vector Clocks Example

- A client writes D1 at server SX:
  D1 ([SX,1])
- Another client reads D1, writes back D2; also handled by SX:
  D2 ([SX,2]) (D1 garbage collected)
- Another client reads D2, writes back D3; handled by server SY:
  D3 ([SX,2], [SY,1])
- Another client reads D2, writes back D4; handled by server SZ:
  D4 ([SX,2], [SZ,1])
- Another client reads D3, D4: CONFLICT !

Data 1	Data 2	Conflict?
([SX,3],[SY,6])	([SX,3],[SZ,2])	
([SX,3])	([SX,5])	
([SX,3],[SY,6])	([SX,3],[SY,6],[SZ,2])	
([SX,3],[SY,10])	([SX,3],[SY,6],[SZ,2])	
([SX,3],[SY,10])	([SX,3],[SY,20],[SZ,2])	

Configurable Consistency

- R = Minumum number of nodes that participate in a successful read
- W = Minumum number of nodes that participate in a successful write
- N = Replication factor
- If R + W > N, you can claim consistency
- But R + W < N means lower latency.