Structured Data Stores

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Structured vs. Unstructured Data

- What is unstructured data?
  - General byte stream in a file
- Structured data
  - Specific, regular data organization that contains semantics to enable powerful/flexible search and update
- Most prominent example: relational database
  - Data is organized into tables, views, keys (references), indexes etc. that allow SQL queries and updates with potential multiple table joins
  - Data consistency (structural consistency) over failures is supported by transactions (implemented through REDO/UNDO logging-based atomic I/O)

Example SQL Statement (TPC-H Q2)

```
select
        s_acctbal, s_name, n_name, p_partkey, p_mfgr, s_address, s_phone, s_comment
from
        part, supplier, partsupp, nation, region
where
        p_partkey = ps_partkey and s_suppkey = ps_suppkey and p_size = 22
        and p_type like '%COPPER' and s_nationkey = n_nationkey
        and n_regionkey = r_regionkey and r_name = 'AFRICA'
        and ps_supplycost = (
                select min(ps_supplycost)
                from partsupp, supplier, nation, region
                where p_partkey = ps_partkey and s_suppkey = ps_suppkey
                        and s_nationkey = n_nationkey and n_regionkey = r_regionkey
                        and r_name = 'AFRICA'
        )
```


Relational Databases

- The ones that you know?
- They typically run one machine, right?
- How do they scale in the big data era?
  - Data partitioning makes distributed query complex and expensive
  - Data replication makes it challenging to maintain data consistency in updates
  - Transactions are already complex (much more complex if transactions commit in a distributed fashion)

Key-value/Nosql Store

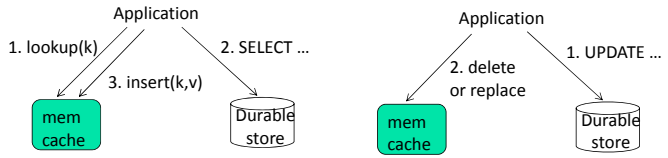
- There is space between no-structure (plain file system) and strongly-structured data (relational DBs supporting SQL)
- Key-value or hash table store
  - Data is organized into sets of key-value pairs
  - Support lookup(key), insert(key,value), delete(key), and replace(key,new_value)
  - Can also support transactions using REDO/UNDO logs
- What data fits the key-value model?
  - Webtable: key is the URL, value is the web page content
  - What else?
- Nosql data stores

Specific Key-value Stores

- Before the times of relational databases
  - dbm, developed by Ken Thompson (AT&T), 1970s
- After the wide uses of relational databases
  - TokyoCabinet/KyotoCabinet, 2000s
  - LevelDB, 2010s
  - … …

memcache

- In-memory key-value store, not durable
- Limited memory space, older things are evicted (following LRU order) when space runs out, effectively a cache
- Typically work together with a durable store [Nishtala et al. 2013]



- What is good about it?

Key-value Stores vs. Relational DBs

- Data semantics isn't as flexible
  - What if your data semantics does fit into one single table; semantic linking/joining of multiple tables are needed to answer queries or support updates?
- But leaner and faster
  - Really? Some argue SQLite is lean, fast, AND supporting SQL.
- Easier to scale up
  - Operations are uniformly simple, each operating on a single data item (no whole table scans or cross-table joins, data partitioning won't cause distributed operations)

Scalable Structured Store: Bigtable

- Developed at Google [Chang et al. 2006]
- Data model
  - Enhanced key-value model
  - (row:strong, column:string, time:int64) → string
  - Two-dimensional key allows multiple attributes for each key: in Webtable, a web page has content, incoming references, other labels (spam, …)
  - Timestamp allows version management (earlier versions may be useful; related to garbage collection)

Bigtable: Data Locality

- Data ordering
  - Data in lexicographic order by row key
  - Applications should devise the row key in a way such that rows often referenced together have lexicographically nearby keys
    - Reversing URL hostname components for row keys in Webtable "www.google.com/index.html" → "com.google.www/index.html"
- Processing near data
  - Data processing scripts can be supplied to run at data server

Bigtable: Distributed Organization

- Centralized or decentralized management?
  - A master server and many tablet servers
  - A special METADATA table that records the location of user tables
- Scalability and robustness in centralized management
  - Relieve the master from common tasks → won't become the scaling bottleneck
  - Fast recovery in case of master failure

Bigtable: Distributed Consistency

- Maintain consistency in distributed system
  - Ensure that everyone agrees with one master at a time
  - Ensure that everyone agrees with the root METADATA table
  - ⇨ Distributed consensus
- Paxos distributed consensus
  - Google's implementation: Chubby lock service

Bigtable: Performance

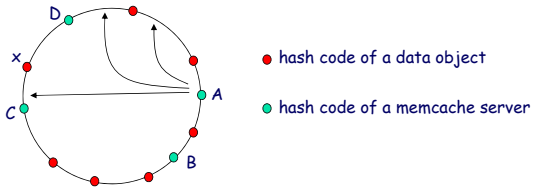
- Figure 6 of the paper

Distributed memcache

- Key idea:
  - Decouple the performance/scalability from I/O and durability, if the workload is read-mostly
- A two-layer data management system: distributed memcache and durable data store (relational databases or …)
  - Both layers handle writes
  - Distributed memcache handles reads alone (mostly)
  - If the workload is read-mostly, only the distributed memcache layer needs to be scalable and fast
  - Can work with legacy databases that don't scale well
- Used in many places including Facebook

Distributed memcache: Scalabilty

- Since memcache isn't concerned with durability or I/O, its scalability is easier to accomplish:
  - A balanced data partition to many memcache servers
  - A scalable, robust, distributed algorithm to tell which memcache server has your data



Bigtable vs. Distributed memcache

- Performance / scalability?
- Ease of construction?
- Distributed memcache is poor man's Bigtable (in a smart way)

Megastore

- A recent Google system [Baker et al. 2011] that is a step closer to relational databases
  - Support relational DB-like data model but do not support operations that hinder scalability (e.g., SQL table joins)
  - SQL table joins can be implemented by applications after initial lookups on the based tables with indexes
- A new point in the flexibility vs. scalability design space:
  - Bridge to the SQL world, but require applications to explicitly support expensive operations

Summary

- A variety of data management systems
  - Unstructured file system
  - Relational databases with SQL support (MySQL, SQLite, Oracle, Microsoft SQL Server, …)
  - Single machine key-value stores (KyotoCabinet, LevelDB, …)
  - Bigtable
  - Distributed memcache
  - Megastore
  - … …
- What is right for my big data application?
  - Data model and data access semantics
  - Scalability / performance requirements
  - Ease of development and ease of use