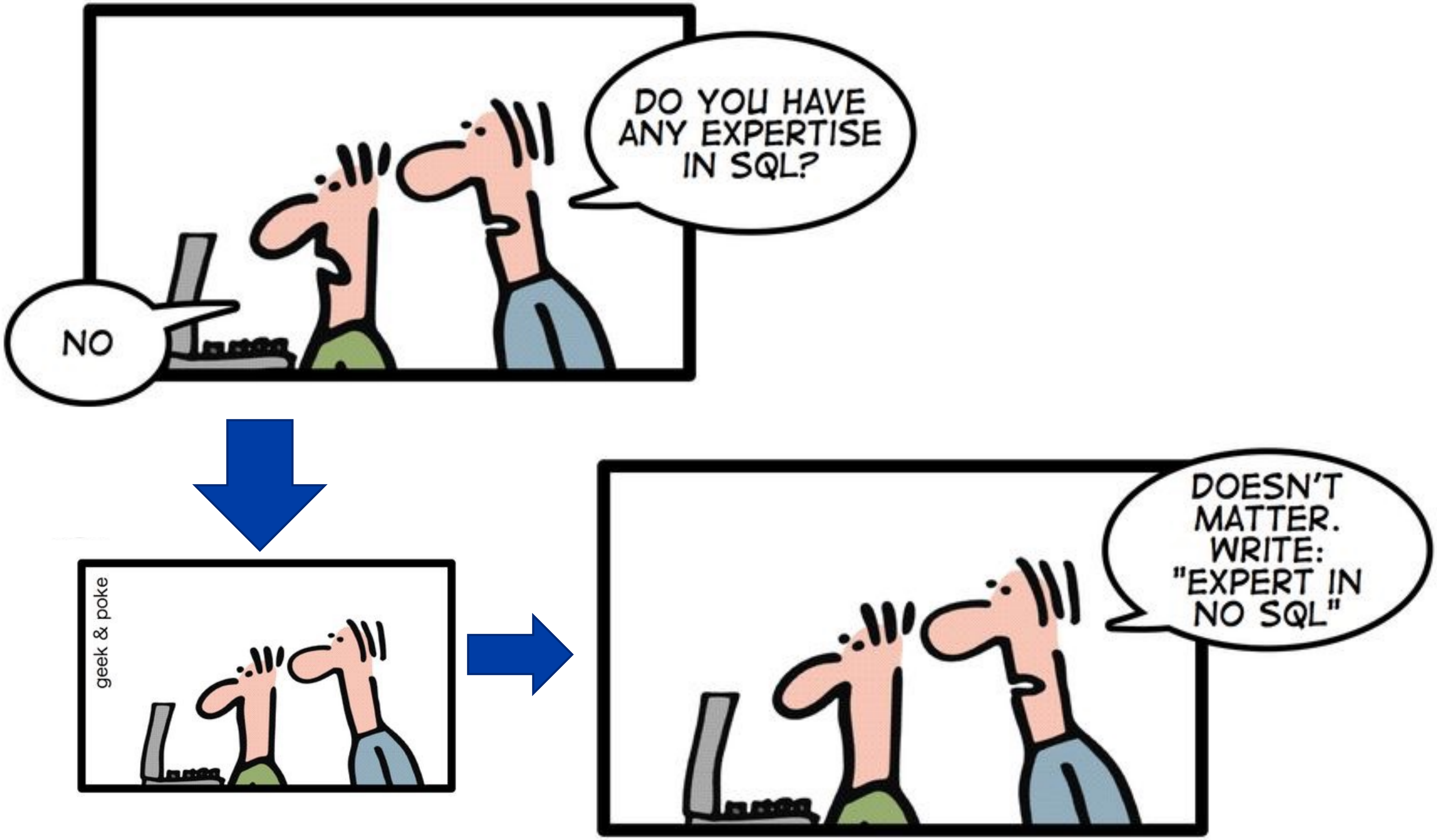
NoSQL and MongoDB

CELEBRATING 30 YEARS
Marlan and Rosemary Bourns College of Engineering

HOW TO WRITE A CV


DO YOU HAVE ANY EXPERTISE IN SQL?
NO
geek & poke
DOESN'T MATTER. WRITE: "EXPERT IN NO SQL"

Leverage the NoSQL boom

Introduction to NoSQL

Based on a presentation by Traversy Media

What is NoSQL?

- Not only SQL
- SQL means
  - Relational model
  - Strong typing
  - ACID compliance
  - Normalization
  - …
- NoSQL means more freedom or flexibility

Relevance to Big Data

- Data gets bigger
- Traditional RDBMS cannot scale well
- RDBMS is tied to its data and query processing models
- NoSQL relaxes some of the restrictions of RDBMS to provide a better performance

Advantages of NoSQL

- Handles Big Data
- Data Models – No predefined schema
- Data Structure – NoSQL handles semi-structured data
- Cheaper to manage
- Scaling – Scale out / horizonal scaling

Advantages of RDBMS

- Better for relational data
- Data normalization
- Well-established query language (SQL)
- Data Integrity
- ACID Compliance

Types of NoSQL Databases

- Document Databases [MongoDB, CouchDB]
- Column Databases [Apache Cassandra]
- Key-Value Stores [Redis, Couchbase Server]
- Cache Systems [Redis, Memcached]
- Graph Databases [Neo4J]
- Streaming Systems [FlinkDB, Storm]

Structured/Semi-structured

ID	Name	Email	…
1	Jack	jack@example.com	
2	Jill	jill@example.net	
3	Alex	alex@example.org	

Document 1

{ “id”: 1, “name”:”Jack”, “email”: “jack@example.com”,
“address”: {“street”: “900 university ave”, “city”: “Riv
state: “CA”}, “friend_ids”: [3, 55, 123]}

Document 2

{ “id”: 2, “name”: “Jill”, “email”: “jill@example.net”, “hobbies”: [“hiking”, “cooking”]}

Document Database

MongoDB

Document Data Model

- Relational model (RDBMS)
  - Database
    - Relation (Table) : Schema
      - Record (Tuple) : Data
- Document Model
  - Database
    - Collection : No predefined schema
      - Document : Schema+data
- No need to define/update schema
- No need to create collections

Document 1

{ “id”: 1, “name”:”Jack”, “email”: “jack@example.com”,
“address”: {“street”: “900 university ave”, “city”: “Riverside”,
state: “CA”}, “friend_ids”: [3, 55, 123]}

Document Format

- MongoDB natively works with JSON documents
- For efficiency, documents are stored in a binary format called BSON (i.e., binary JSON)
- Like JSON, both schema and data are stored in each document

How to Use MongoDB

Install: Check the MongoDB website
https://docs.mongodb.com/manual/installation/

Create collection and insert a document

```
db.users.insert({name: “Jack”, email:
“jack@example.com”});
```

Retrieve all/some documents

```
db.users.find();
db.users.find({name: “Jack”});
```

Update

```
db.users.update({name: "Jack"}, {$set: {hobby:
"cooking"}});
updateOne, updateMany, replaceOne
```

Delete

```
db.users.remove({name: "Alex"});
deleteOne, deleteMany
```

https://docs.mongodb.com/manual/crud/

Schema Validation

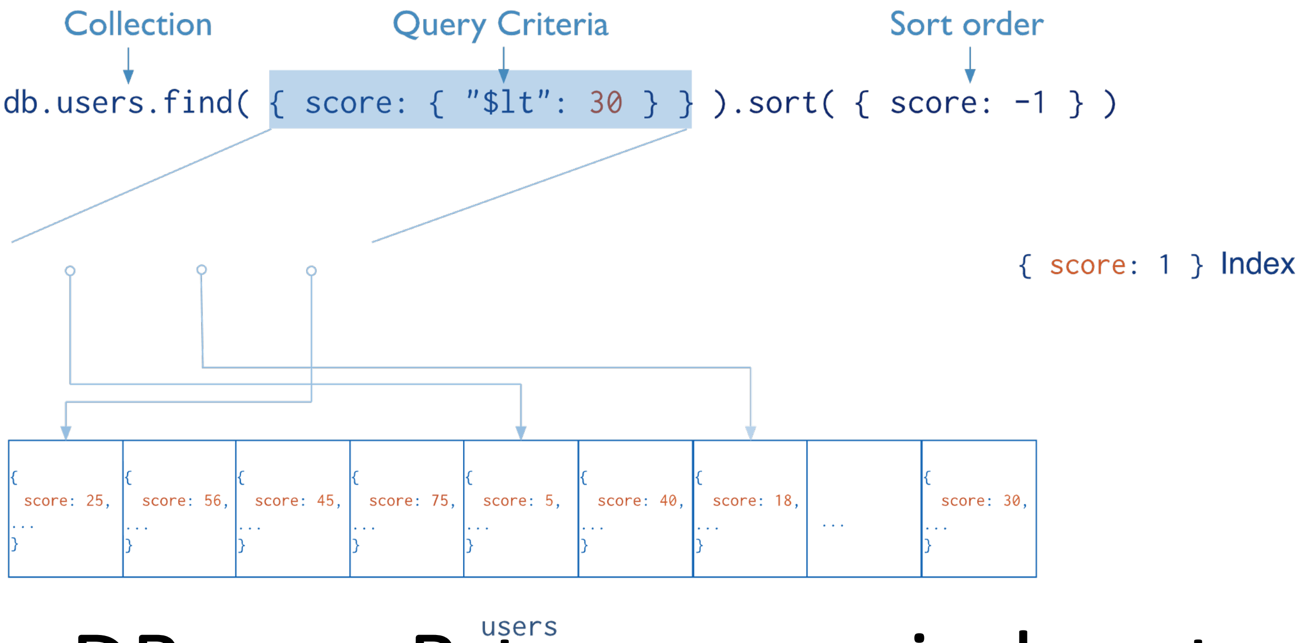
- You can still explicitly create collections and enforce schema validation

```
db.createCollection("students", {
  validator: { $jsonSchema: {
    bsonType: "object",
    required: [ "name", "year", "major", "address" ],
    properties: {
      name: {
        bsonType: "string",
        description: "must be a string and is required" },
    …
    }
  }}
}
```

https://docs.mongodb.com/manual/core/schema-validation/

Indexing

- Like RDBMS, document databases use indexes to speed up some queries



```
db.users.find( { score: { "$lt": 30 } } ).sort( { score: -1 } )
```

- MongoDB uses B-tree as an index structure

https://docs.mongodb.com/manual/indexes/

Index Types

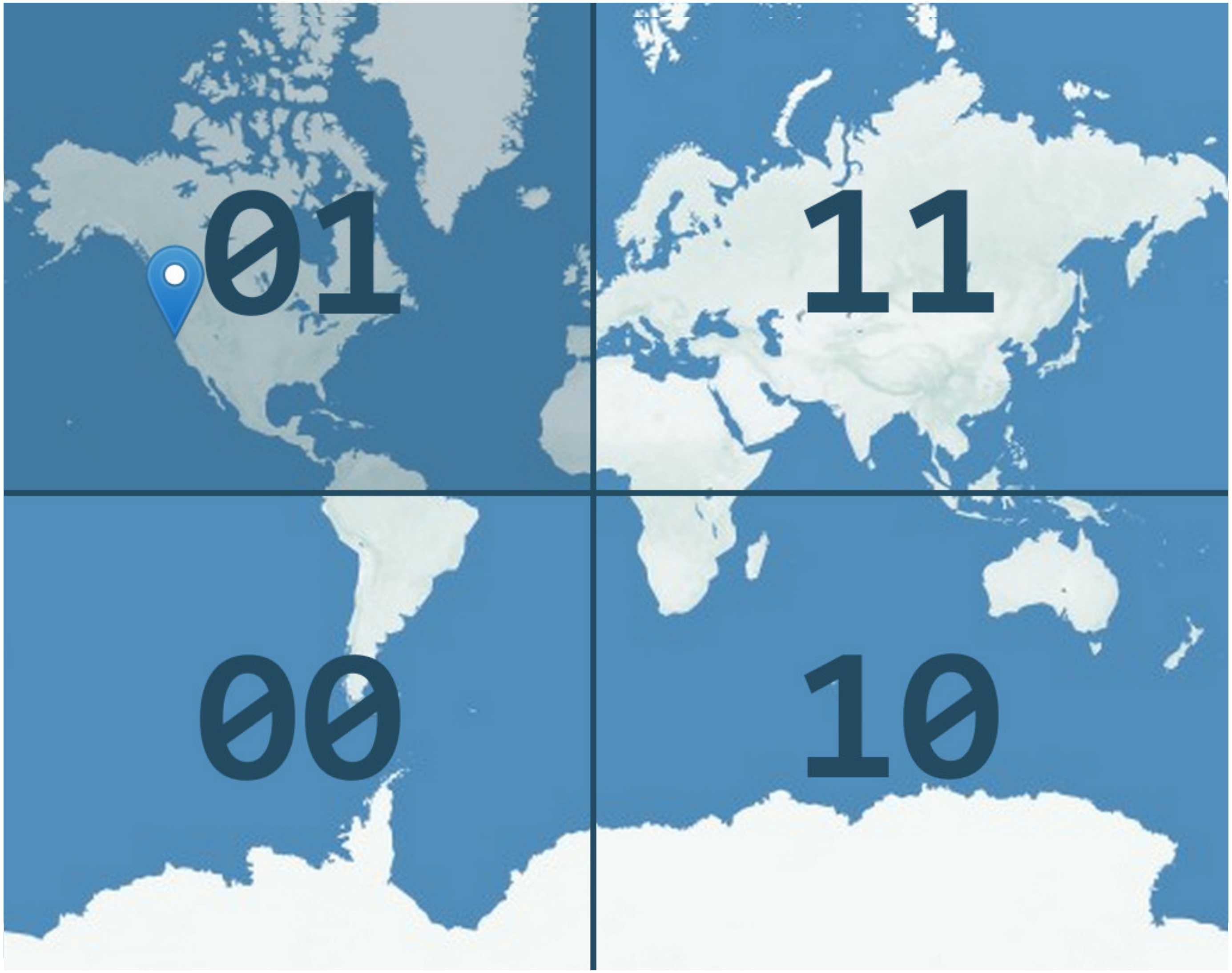
- Default unique _id index
- Single field index
  - db.collection.createIndex({name: -1});
- Compound index (multiple fields)
  - db.collection.createIndex({ name: 1, score: -1});
- Multikey indexes (for array fields)
  - Creates an index entry for each value

https://docs.mongodb.com/manual/indexes/

Index Types

- Geospatial index (for geospatial points)
  - Uses geohash to convert two dimensions to one dimension
  - 2d indexes: For Euclidean spaces
  - 2d sphere: spherical (earth) geometry
  - Works with multikey indexes for multiple locations (e.g., pickup and dropoff locations for taxis)
- Text Indexes (for string fields)
  - Automatically removes stop words
  - Stems the words to store the root only
- Hashed Indexes (for point lookups)

Geohashes



Additional Index Features

- Unique indexes: Rejects duplicate keys
- Sparse Indexes: Skips documents without the index field
  - In contrast, non-sparse indexes assume a null value if the index field does not exist
- Partial indexes: Indexes only a subset of records based on a filter.

```
db.restaurants.createIndex(
   { cuisine: 1, name: 1 },
   { partialFilterExpression: { rating: { $gt: 5 } } }
)
```

Comparison of data types

- Min key (internal type)
- Null
- Numbers (32-bit integer, 64-bit integer, double)
- Symbol, String
- Object
- Array
- Binary data
- Object ID
- Boolean
- Date, timestamp
- Regular expression
- Max key (internal type)

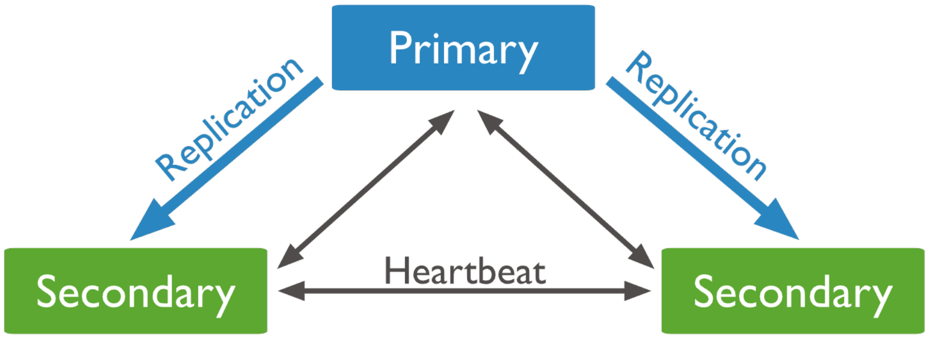
https://docs.mongodb.com/v3.6/reference/bson-type-comparison-order/

Comparison of data types

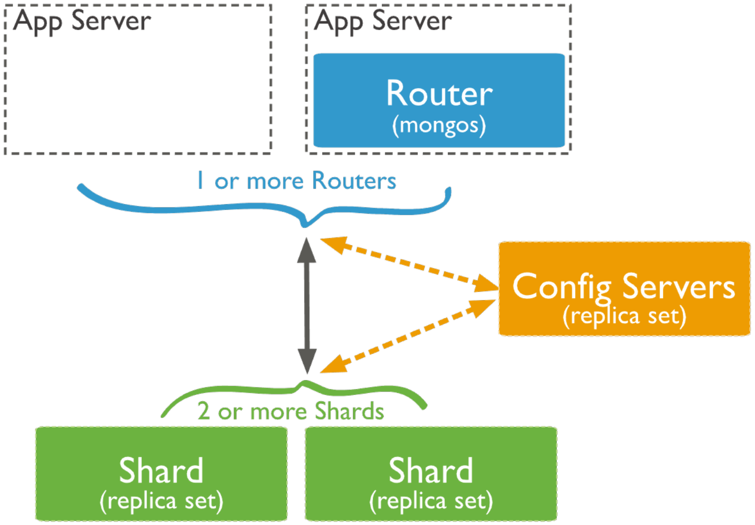
- Numbers: All converted to a common type
- Strings
    - Alphabetically (default)
    - Collation (i.e., locale and language)
- Arrays
    - <: Smallest value of the array
    - >: Largest value of the array
    - Empty arrays are treated as null
- Object
    - Compare fields in the order of appearance
    - Compare <name,value> for each field

Distributed Processing

- Two methods for distributed processing
  - Replication (Similar to MySQL)
  - Sharding (True horizontal scaling)



Replication
https://docs.mongodb.com/manual/replication/



Sharding
https://docs.mongodb.com/manual/sharding/

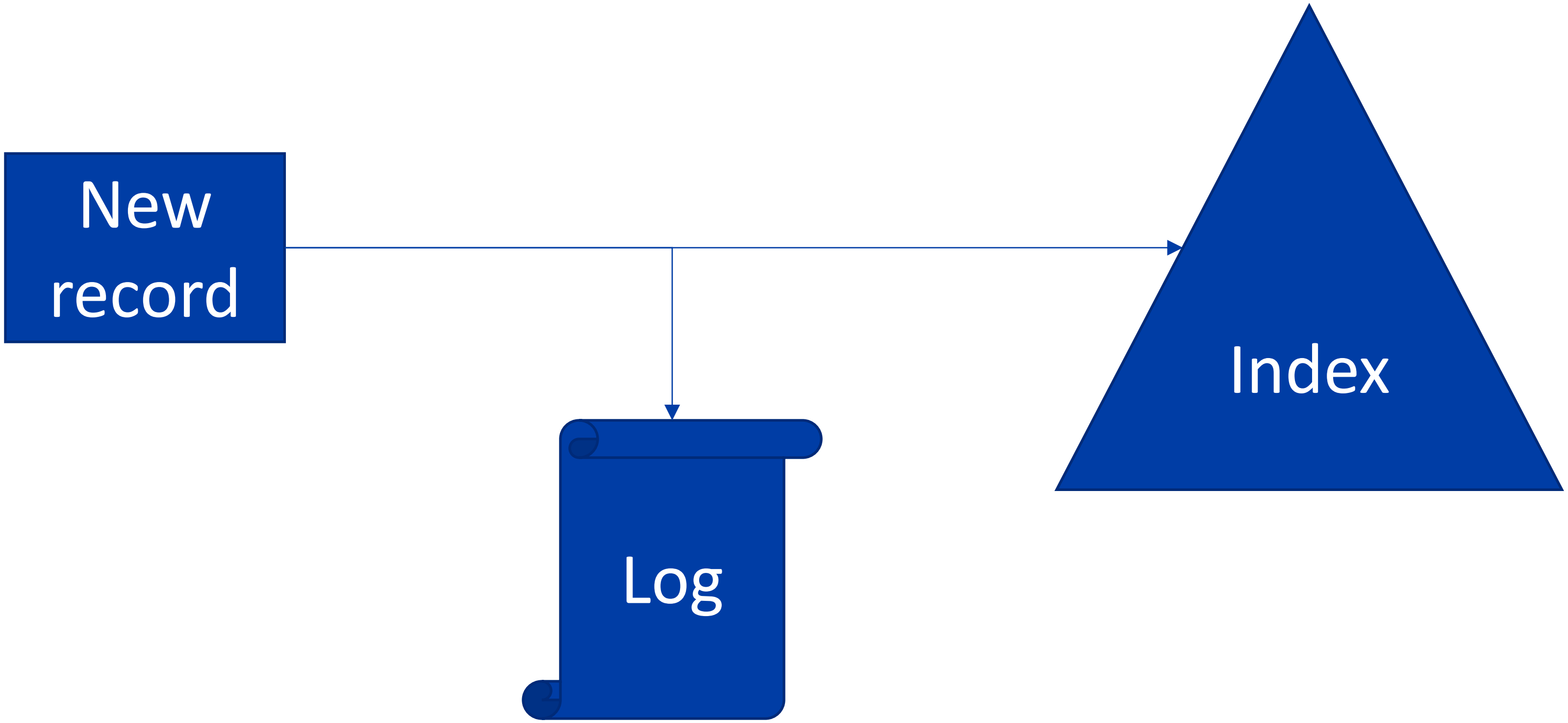
Distributed Index Structure

Log-structured Merge Tree (LSM)

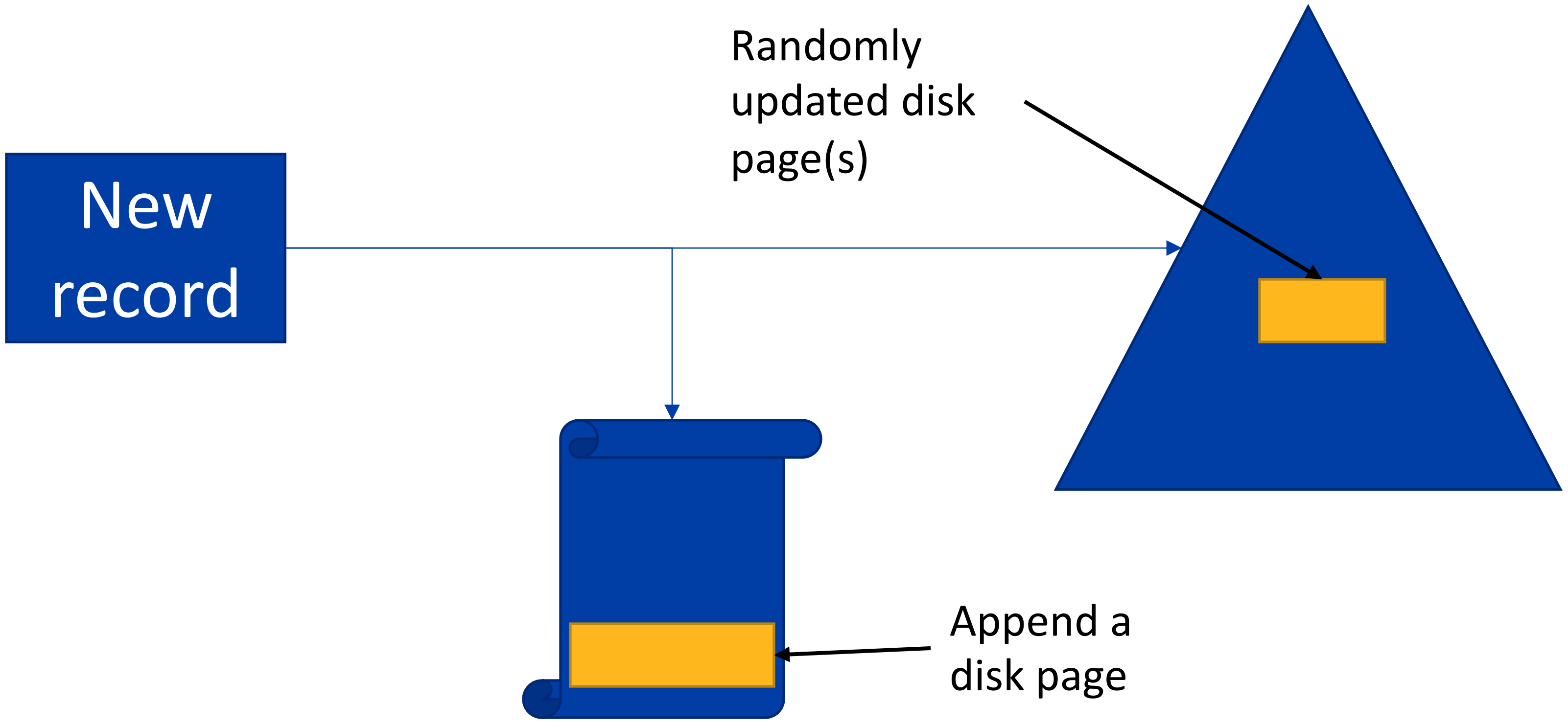
Big Data Indexing

- Hadoop and Spark are good in scanning large files
- We would like to speed up point and range queries on big data for some queries
- HDFS limitation: Random updates are not allowed
- Log-structured Merge Tree (LSM-Tree) is adopted to address this problem.

RDBMS Indexing



Index Update in RDBMS



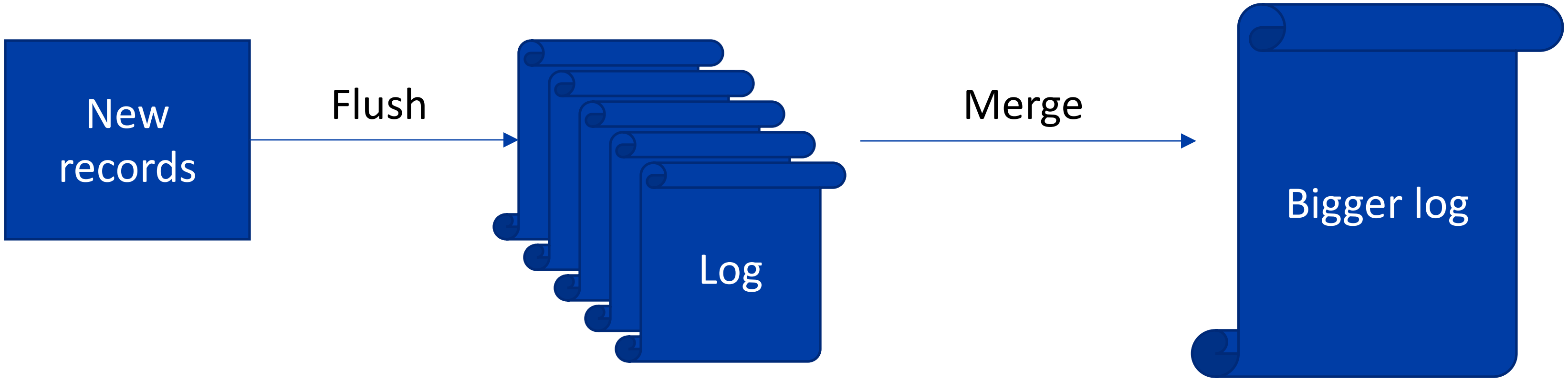
New record

Randomly updated disk page(s)

Append a disk page

LSM Tree

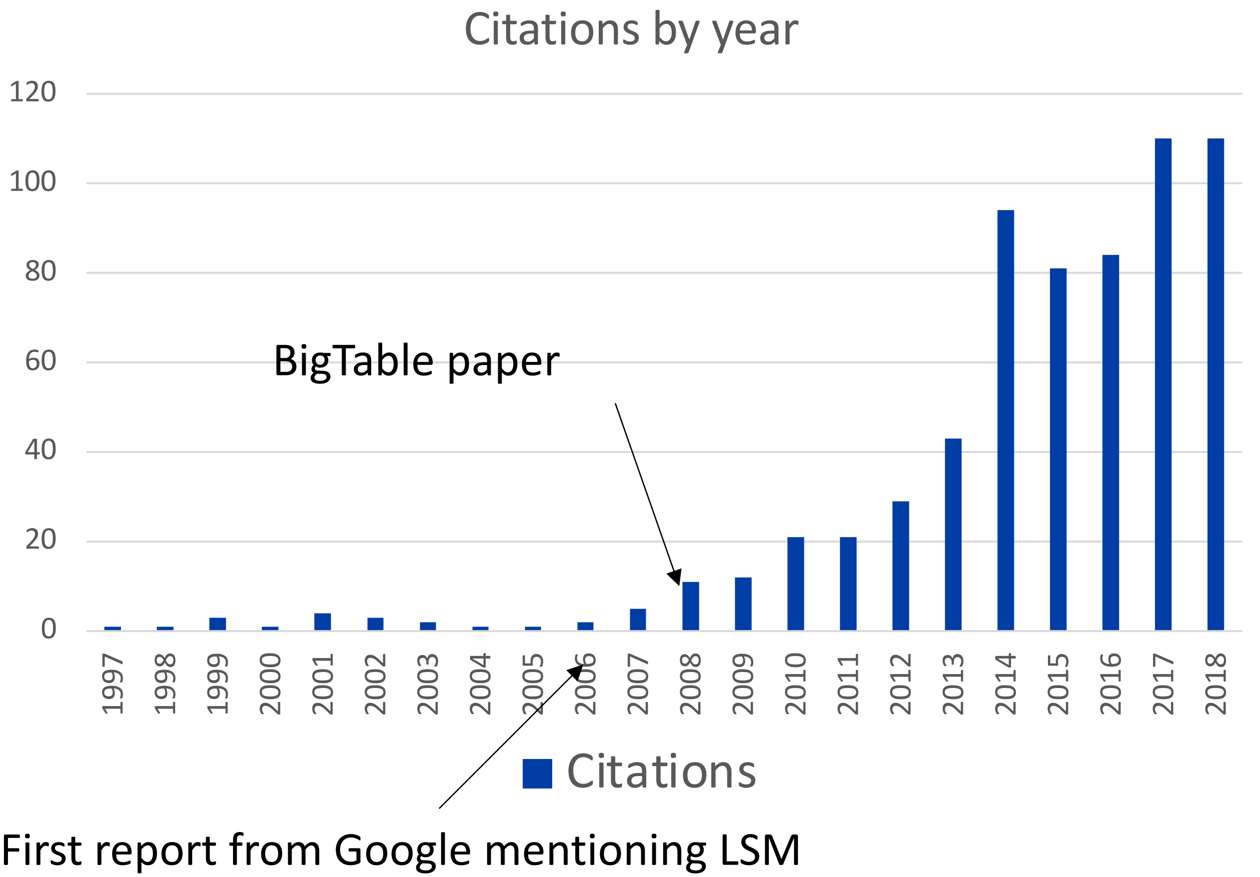
- Key idea: Use the log as the index
- Regularly: Merge the logs to consolidate the index (i.e., remove redundant entries)



O’Neil, Patrick, Edward Cheng, Dieter Gawlick, and Elizabeth O’Neil. "The log-structured merge-tree (LSM-tree)." Acta Informatica 33, no. 4 (1996): 351-385.

LSM in Big Data

- First major application: BigTable (Google)



BigTable paper

First report from Google mentioning LSM

LSM in Big Data

- Buffer data in memory (memory component)
- Flush records to disk into an LSM as a disk component (sequential write)
- Disk components are sorted by key
- Compact (merge) disk components in the background (sequential read/write)

Conclusion

- MongoDB is a document database that is geared towards high update rates and transactional queries
- It adopts JSON as a data model
- It provides the flexibility to insert any kind of data without schema definition
- LSM Tree is used for indexing
- Weak types are handled using a special comparison method for all types