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NoSQL: HBase and Neo4j

A.A. 2024/25

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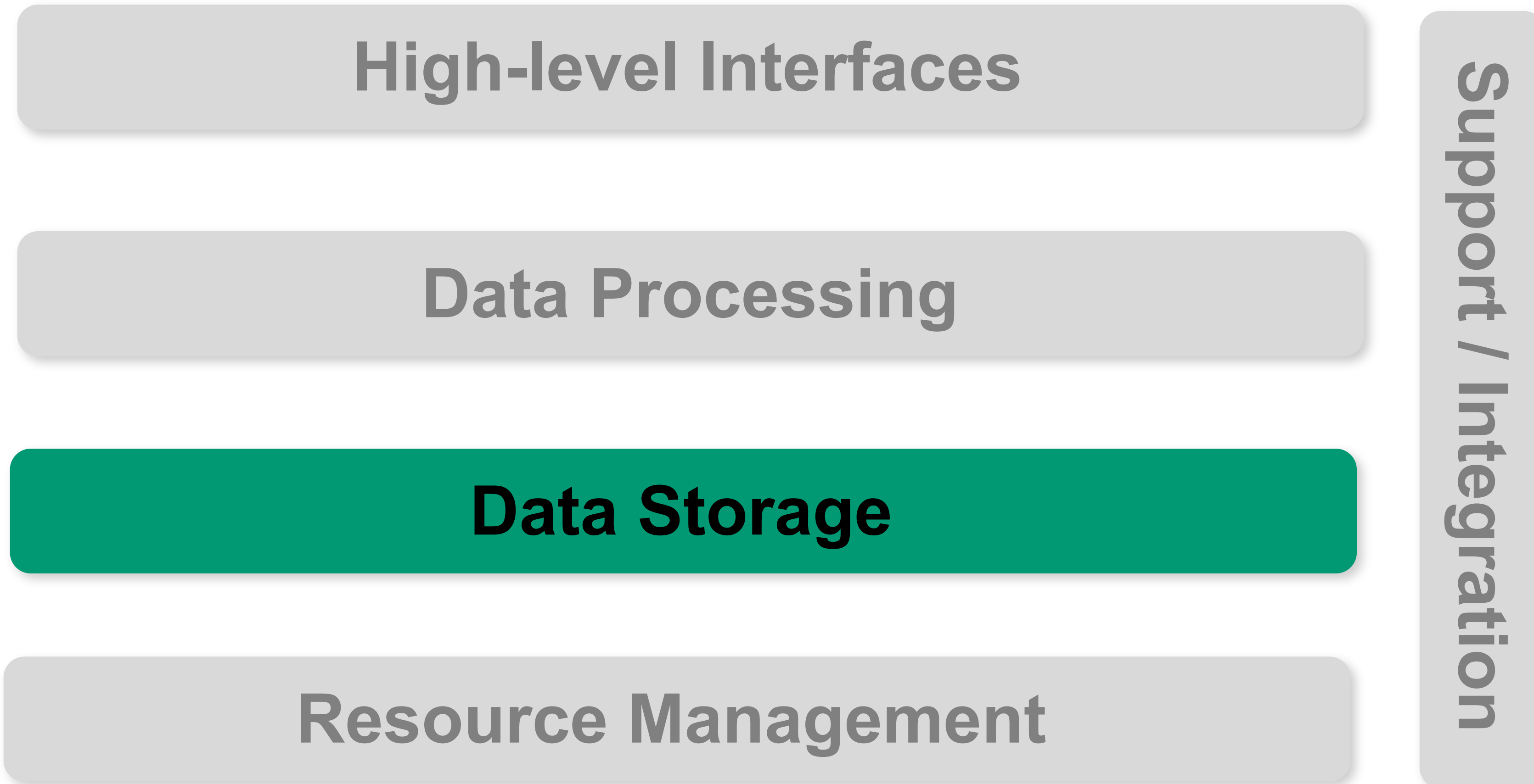
The reference Big Data stack



Column-family data model

- Strongly aggregate-oriented
  - Lots of aggregates
  - Each aggregate has a key
- Similar to a key/value store, but the value can have multiple attributes (*columns*)
- Data model: a two-level map structure:
  - A set of <row-key, aggregate> pairs
  - Each aggregate is a group of pairs <column-key, value>
  - Column: a set of data values of a particular type
- Structure of the aggregate visible
- Columns can be organized in families
  - Data usually accessed together

HBase

- Apache HBase:
  - open-source implementation providing Bigtable-like capabilities on top of Hadoop and HDFS
  - CP system (in the CAP space)
- Data Model
  - HBase is based on Google's Bigtable model
  - A table store rows, sorted in alphanumerical order
  - A row consists of a set of columns
  - Columns are grouped in column families
  - A table defines a priori its column families (but not the columns within the families)

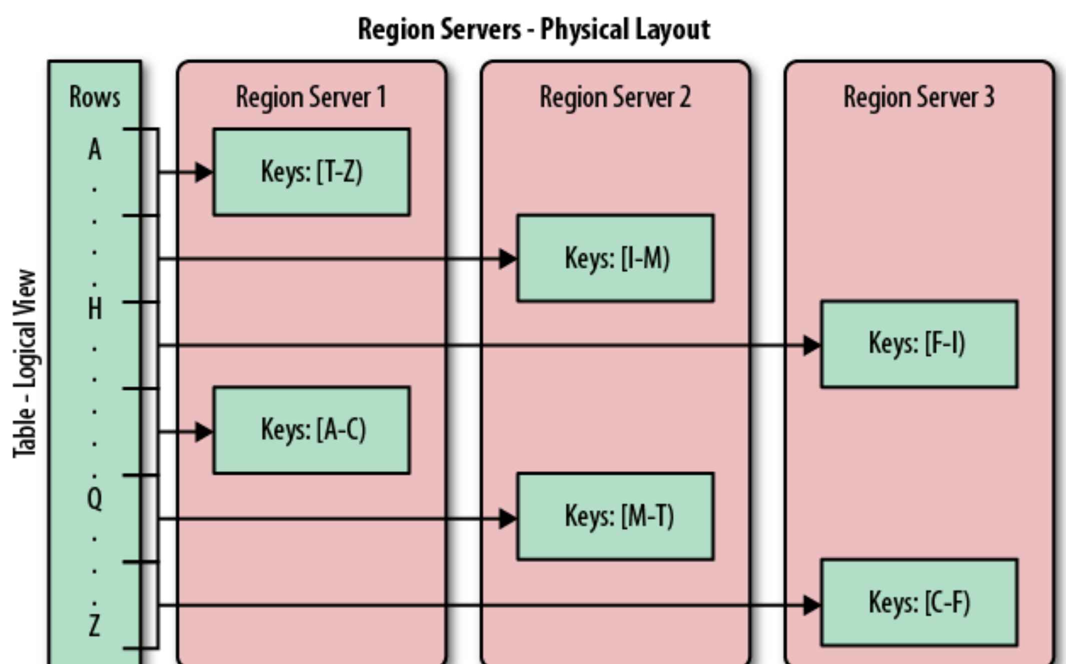
Row key	Column key	Timestamp	Cell value
cutting	info:state	1273516197868	IT
parser	role:Hadoop	1273616297466	g91m

(info and role are column families)

HBase: Auto-sharding

Region:

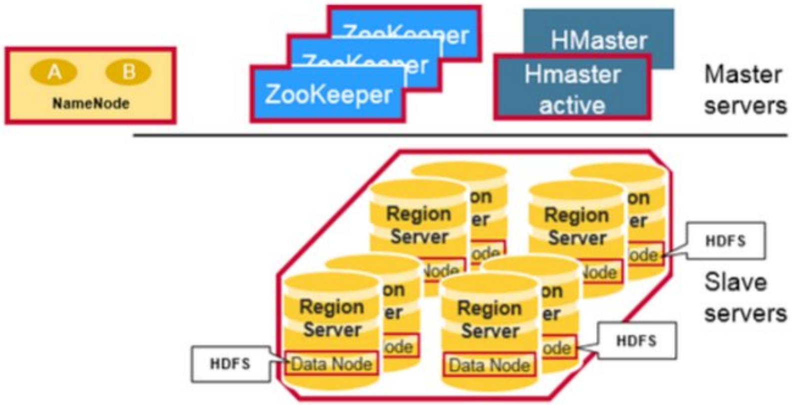
- the basic unit of scalability and load balancing
- similar to the tablet in Bigtable
- a contiguous range of rows stored together
- each region is served by exactly one region server
- they are dynamically split by the system when they become too large



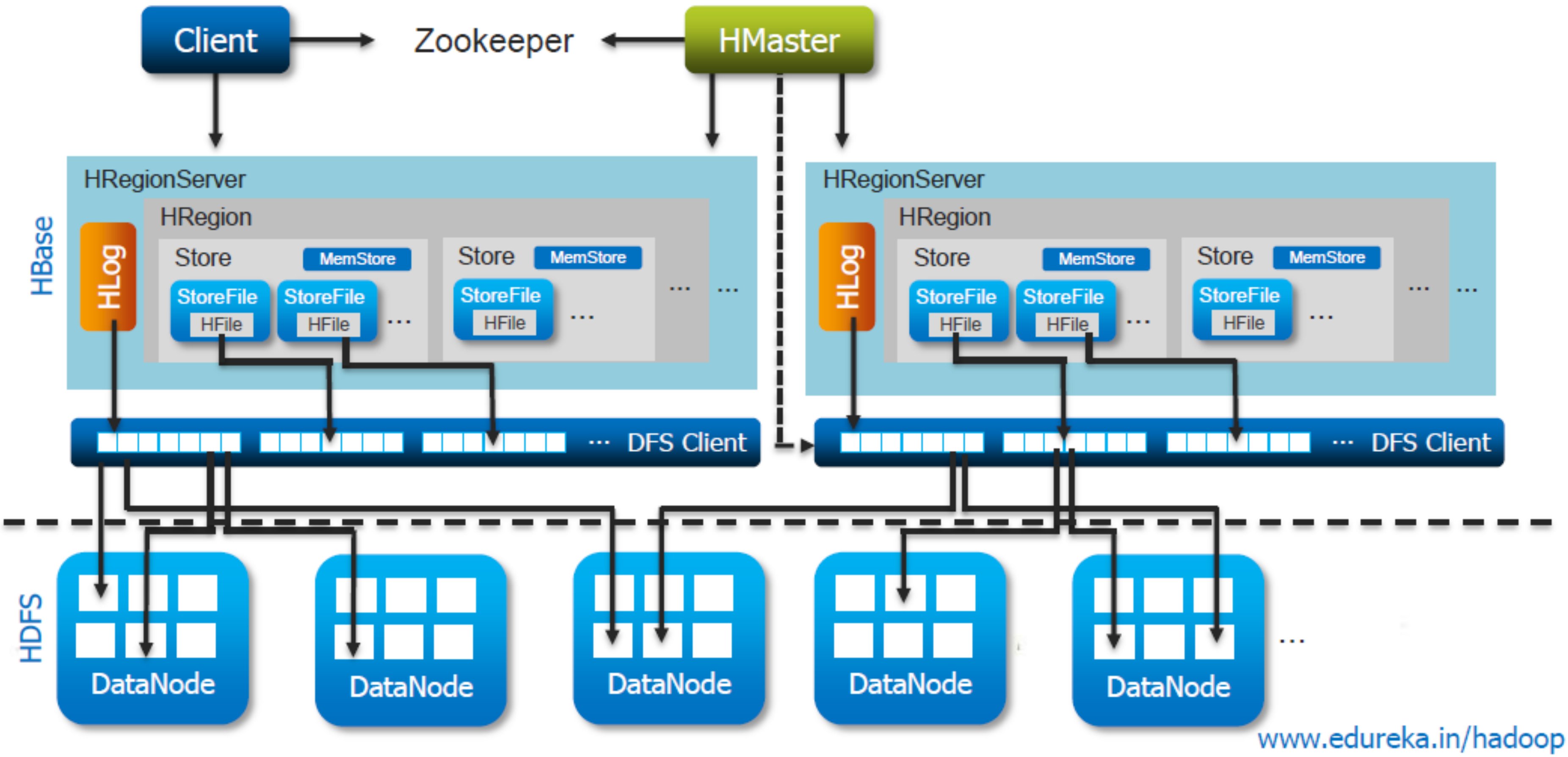
HBase: Architecture

Three major components:

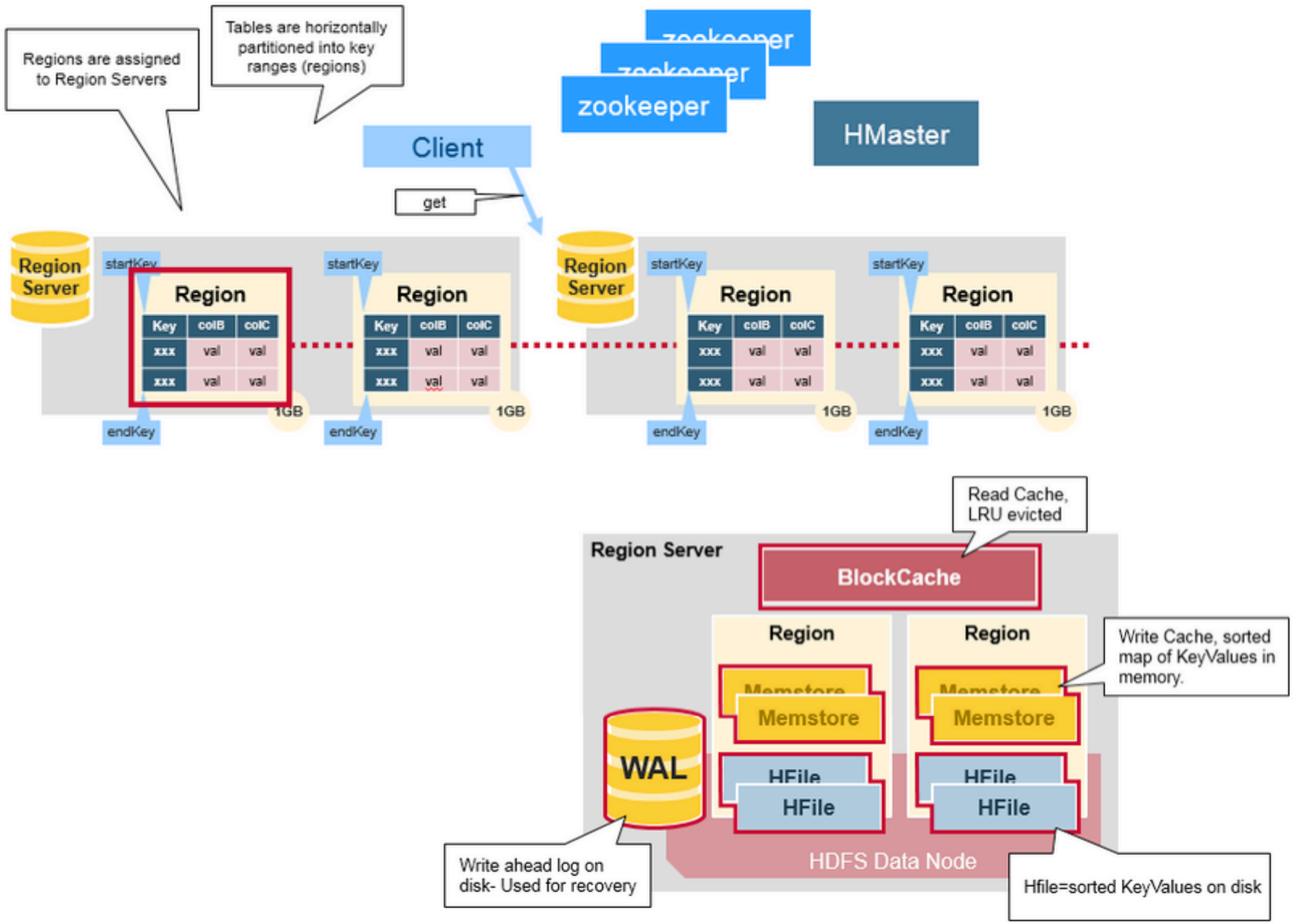
- the client library
- one master server
  - The master is responsible for assigning regions to region servers and uses Apache ZooKeeper to facilitate that task
- many region servers
  - manage the persistence of data
  - region servers can be added or removed while the system is up and running to accommodate changing workloads



HBase: Architecture

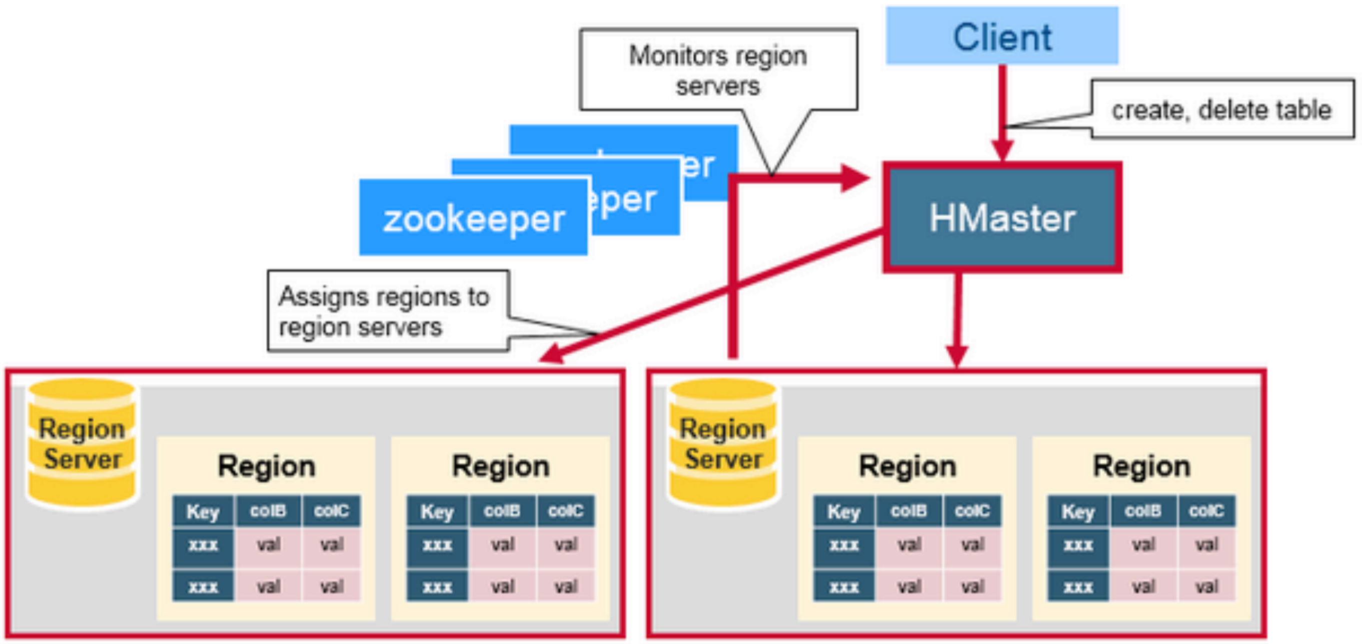


Regions

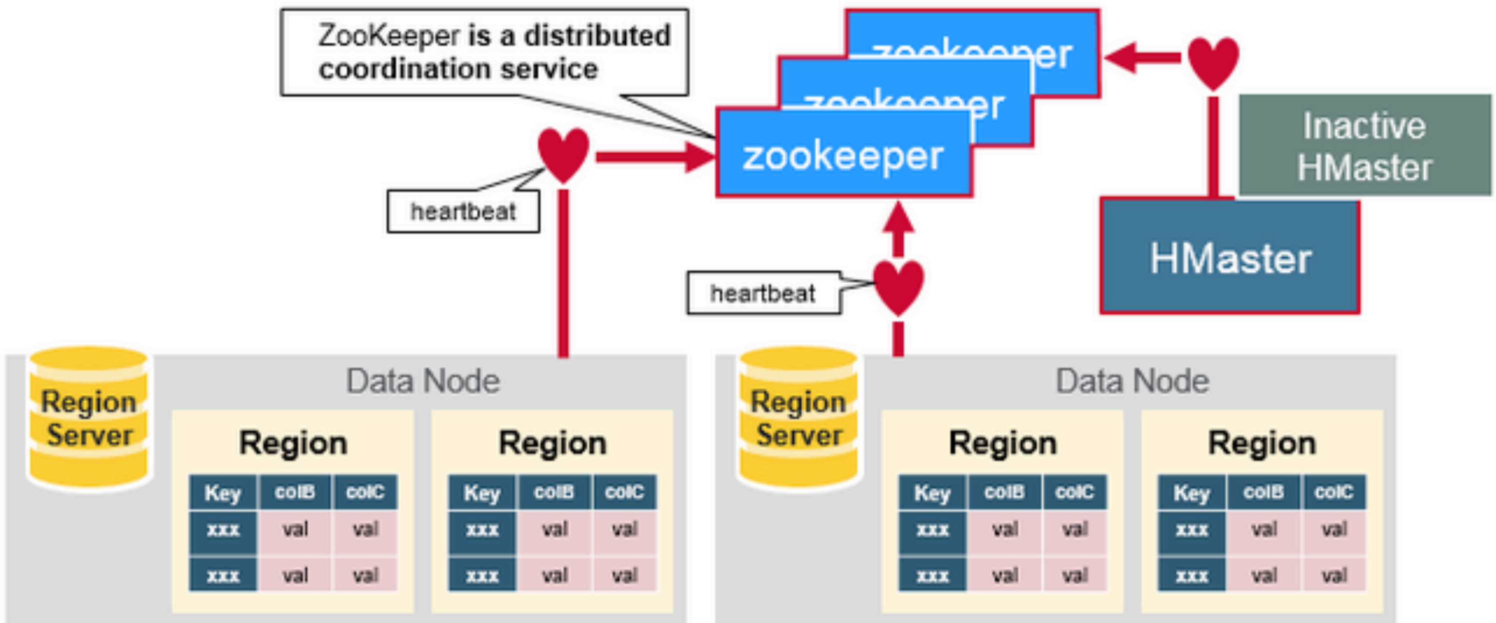


Regions are assigned to Region Servers
Tables are horizontally partitioned into key ranges (regions)
zookeeper
zookeeper
zookeeper
HMaster
Client
get
Region Server
startKey
Region
Key
colB
colC
xxx
val
val
xxx
val
val
1GB
endKey
Region Server
Read Cache, LRU evicted
BlockCache
Region
Region
Memstore
Memstore
Write Cache, sorted map of KeyValues in memory.
WAL
HFile
HFile
HDFS Data Node
Write ahead log on disk- Used for recovery
Hfile=sorted KeyValues on disk

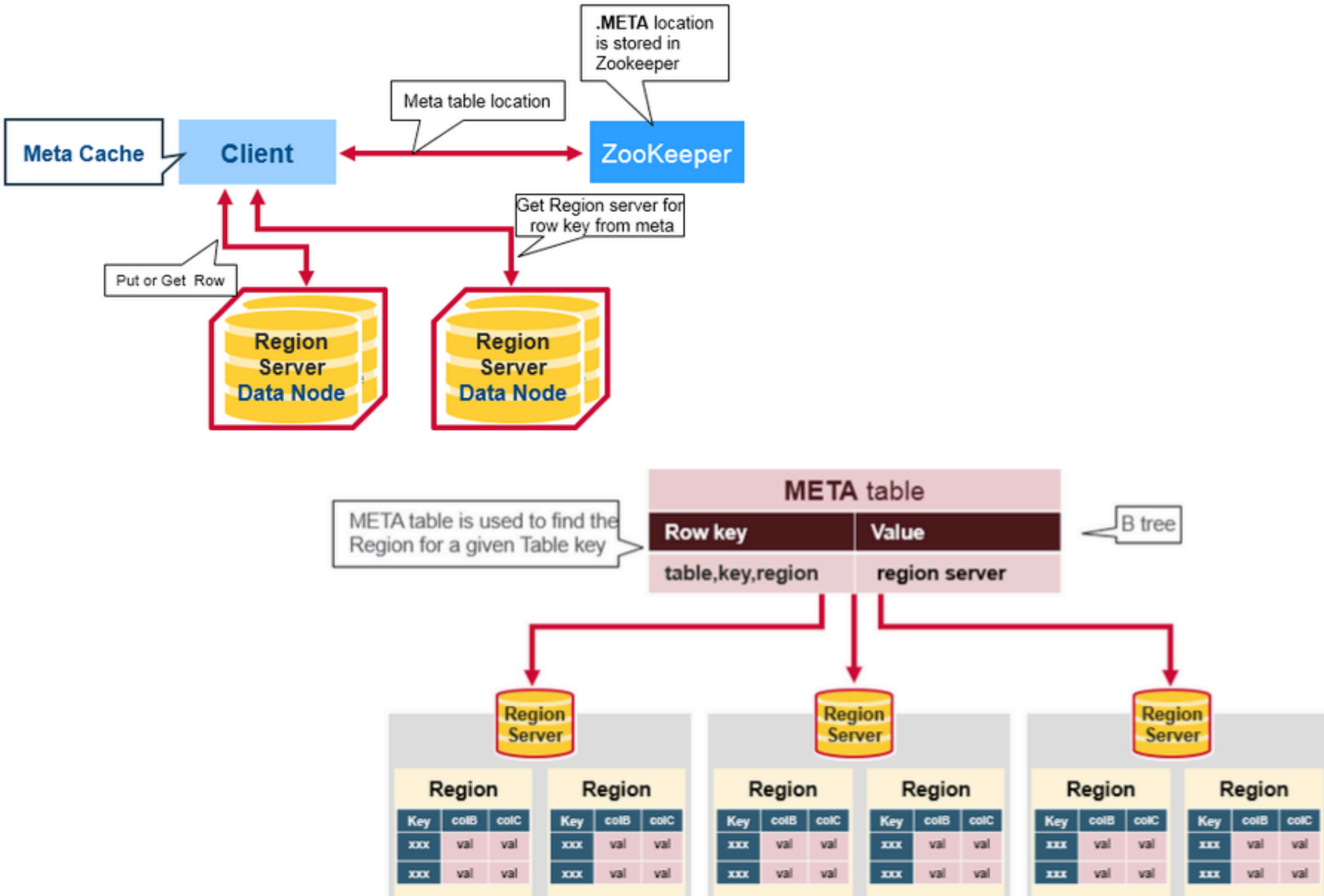
HBase HMaster



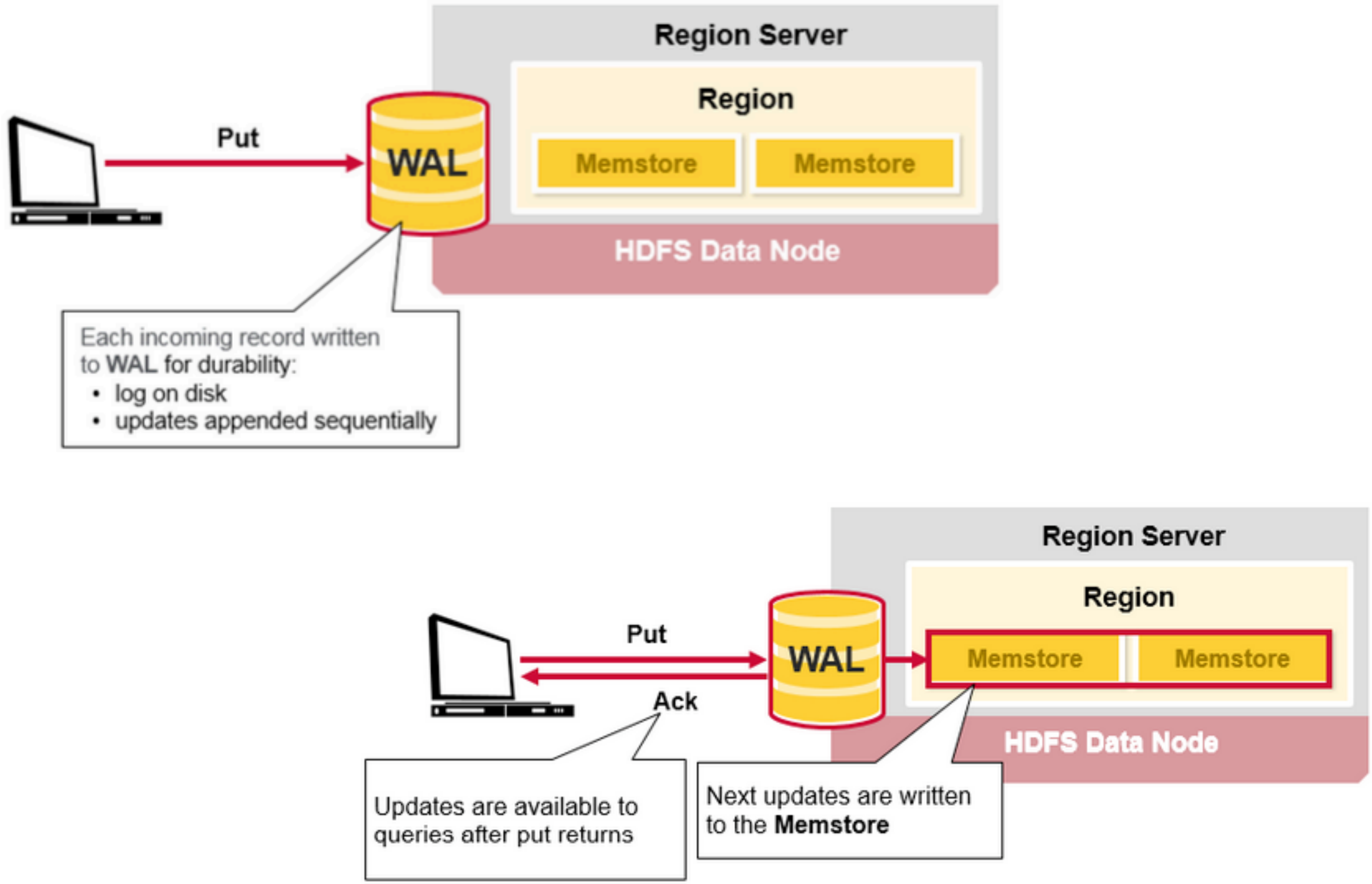
ZooKeeper: the Coordinator



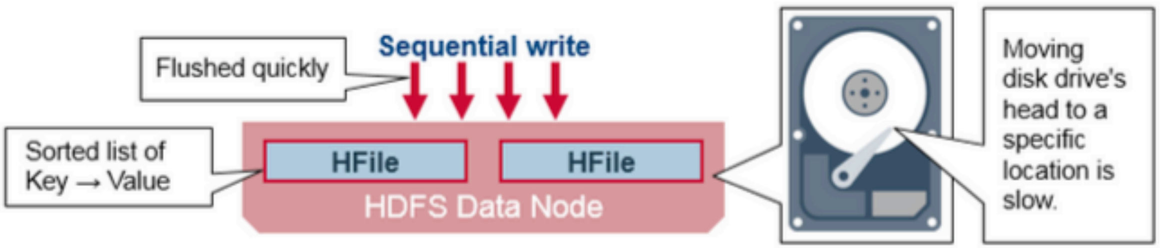
Meta Table Lookup



HBase Write Steps

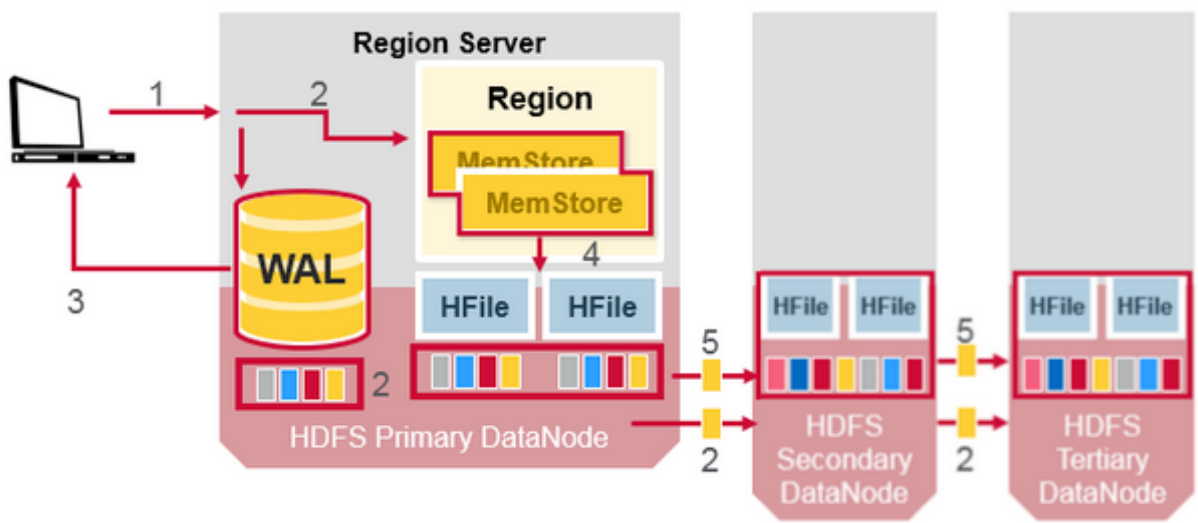


HBase HFiles



Key	CF1:Col	version	value
ra	cf1:ca	v1	1
rb	cf1:cb	v2	4
rb	cf1:cb	v1	3
rc	cf1:ca	v1	5

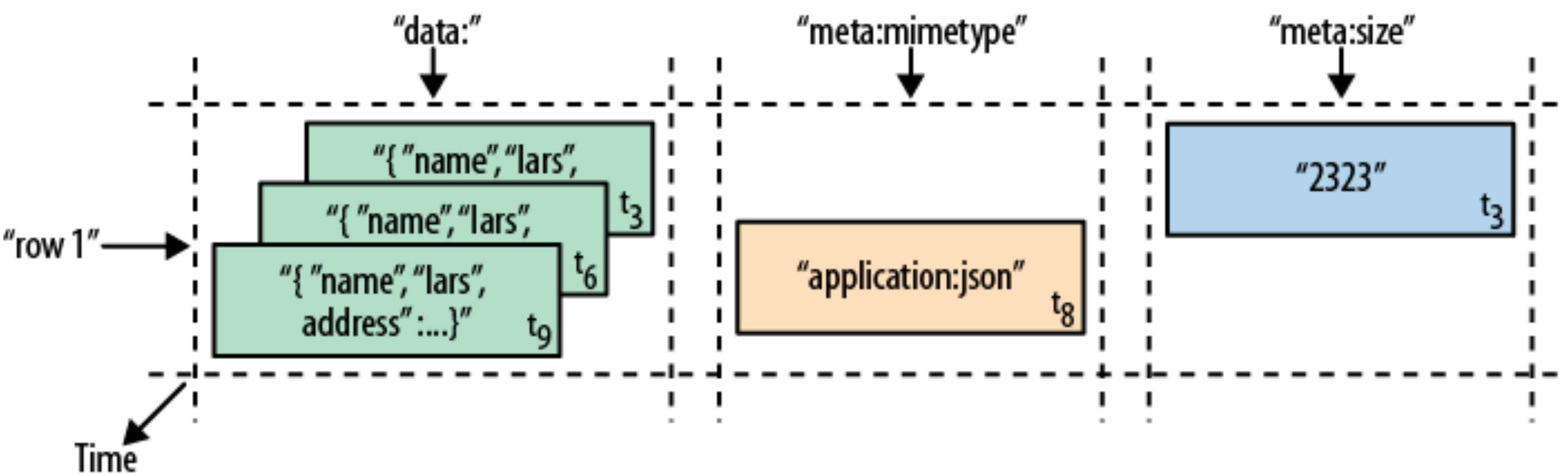
Key	CF2:Col	version	value
ra	cf2:ca	v1	2
rc	cf2:ca	v2	7
rc	cf2:ca	v1	6
rc	cf2:cd	v1	8



HBase: Versioning

- Cells may exist in multiple versions, and different columns have been written at different times.

By default, the API provides a coherent view of all columns wherein it automatically picks the most current value of each cell.



HBase: Strengths

- The column-oriented architecture allows for huge, wide, sparse tables as storing NULLs is free.
- Highly scalable due to the flexible schema and row-level atomicity
- Since a row is served by exactly one server, HBase is strongly consistent, and using its multi-versioning can help you to avoid edit conflicts
- The storage format is ideal for reading adjacent key/value pairs
- Table scans run in linear time and row key lookups or mutations are performed in logarithmic order
- Bigtable has been in use for a variety of different use cases from batch-oriented processing to real-time data-serving

Hands-on HBase
(Docker image)

HBase with Dockers

- We use a lightweight container with a standalone HBase

```
$ docker pull harisekhon/hbase:2.1
```

- We can now create an instance of HBase; since we are interesting to use it from our local machine, we need to forward several HBase ports and update the hosts file;

```
$ docker run -ti --name=hbase-docker -h hbase-docker -p 2181:2181 -p
8080:8080 -p 8085:8085 -p 9090:9090 -p 9095:9095 -p 16000:16000 -p
16010:16010 -p 16201:16201 -p 16301:16301 harisekhon/hbase:1.4
```

```
# append the following line to /etc/hosts
127.0.0.1        hbase-docker
```

HBase Client

- We interact with HBase through its Java APIs
- Using Maven, include the hbase-client dependency:

```
<dependency>
        <groupId>org.apache.hbase</groupId>
        <artifactId>hbase-client</artifactId>
        <version>2.5.8</version>
</dependency>
```

HBase Client

```
public Connection getConnection() throws ... {

    Configuration conf = HBaseConfiguration.create();
    conf.set("hbase.zookeeper.quorum", ZOOKEEPER_HOST);
    conf.set("hbase.zookeeper.property.clientPort",

ZOOKEEPER_PORT);
    conf.set("hbase.master", HBASE_MASTER);

    /* Check configuration */
    HBaseAdmin.checkHBaseAvailable(conf);

    Connection connection =
                    connectionFactory.createConnection(conf);
    return connection;

}
```

This is only an excerpt, check the HBaseClient.java file

HBase Client: Create Table

```
public void createTable(String table,
                        String... columnFamilies) {

    Admin admin = ...
    HTableDescriptor tableDescriptor = ... table ...

    for (String columnFamily : columnFamilies) {
        tableDescriptor.addFamily(columnFamily);
    }

    admin.createTable(tableDescriptor);

}
```

This is only an excerpt, check the HBaseClient.java file

HBase Client: Drop Table

```
public void dropTable(String table) {

        Admin admin = ...
        TableName tableName = ... table ...

    // To delete a table or change its settings,
        // you need to first disable the table
    admin.disableTable(tableName);

        admin.deleteTable(tableName);

}
```

This is only an excerpt, check the HBaseClient.java file

HBase Client: Put Data

```
public void put(String table, String rowKey,
                String columnFamily,
                String column, String value) {

    Table hTable =
            getConnection().getTable( ... table ... );

    Put p = new Put(b(rowKey));
    p.addColumn(b(columnFamily), b(column), b(value));

    // Saving the put Instance to the HTable
    hTable.put(p);

    hTable.close();
}
```

This is only an excerpt, check the HBaseClient.java file

HBase Client: Get Data

```
public String get(String table, String rowKey,
                  String columnFamily,
                  String column) {

    Table hTable =
               getConnection().getTable( ... table ... );

    Get g = new Get(b(rowKey));
    g.addColumn(b(columnFamily), b(column));

    Result result = hTable.get(g);

    return Bytes.toString(result.getValue());

}
```

This is only an excerpt, check the HBaseClient.java file

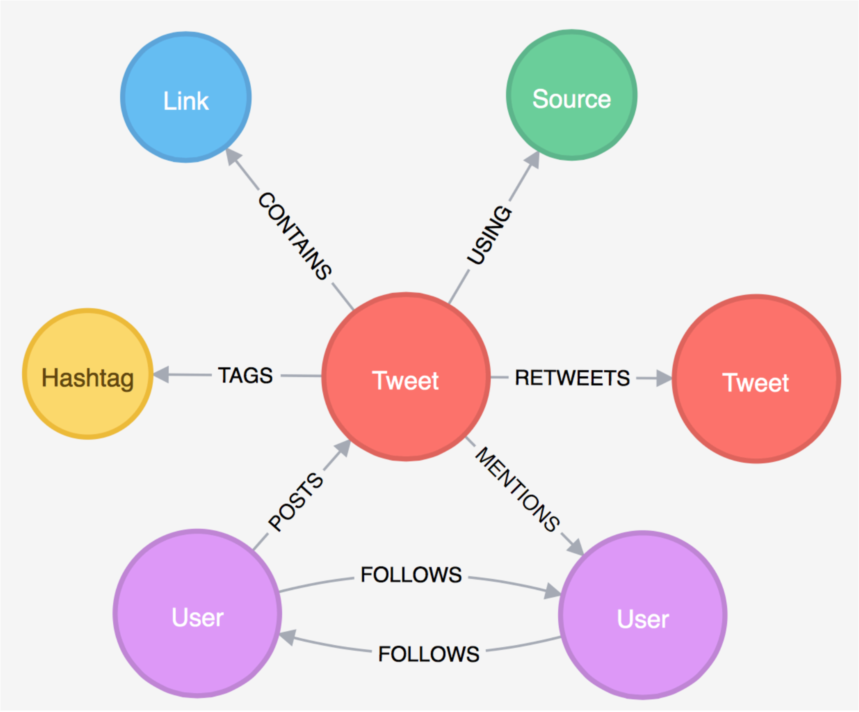
HBase Client: Delete Data

```
public void delete(String table, String rowKey) {

    Table hTable =
                getConnection().getTable( ... table ... );

    Delete delete = new Delete(b(rowKey));

    // deleting the data
    hTable.delete(delete);

    // closing the HTable object
    hTable.close();

}
```

This is only an excerpt, check the HBaseClient.java file

Graph data model

- Uses graph structures
  - Nodes are the entities and have a set of attributes
  - Edges are the relationships between the entities
    - E.g.: an author writes a book
  - Edges can be directed or undirected
  - Nodes and edges also have individual properties consisting of key-value pairs



Graph data model

- Powerful data model
  - Differently from other types of NoSQL stores, it concerns itself with relationships
  - Focus on visual representation of information (more human-friendly than other NoSQL stores)
  - Other types of NoSQL stores are poor for interconnected data

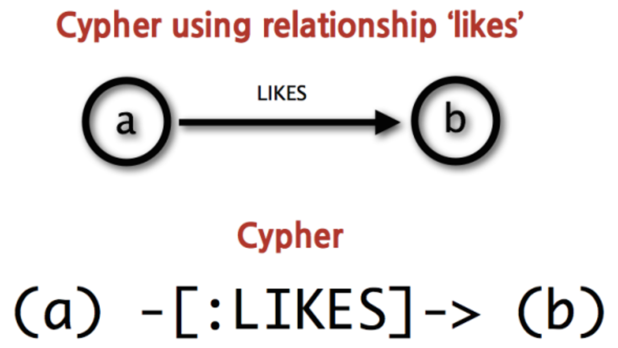
- Cons:
  - Sharding: data partitioning is difficult
  - Horizontal scalability
    - When related nodes are stored on different servers, traversing multiple servers is not performance-efficient
  - Requires rewiring your brain

Suitable use cases for graph databases

- Good for applications where you need to model entities and relationships between them
  - Social networking applications
  - Pattern recognition
  - Dependency analysis
  - Recommendation systems
  - Solving path finding problems raised in navigation systems
  - …
- Good for applications in which the focus is on querying for relationships between entities and analyzing relationships
  - Computing relationships and querying related entities is simpler and faster than in RDBMS

Neo4j: data model

- A graph records data in nodes and relationships
- Nodes are often used to represent entities
  - A node can have properties, relationships, and can also be labeled with one or more labels
  - Note that a node can have relationships to itself
- Relationships organize nodes by connecting them
  - A relationship connects two nodes; a start node and an end node
  - A relationship can have properties



Neo4j: data model

- Properties (both nodes and relationships) can be of different type:
  - Numeric values
  - String values
  - Boolean values
  - Lists of any other type of value
- Labels assign roles or types to nodes
  - A label is a named graph construct that is used to group nodes into sets
  - All nodes labeled with the same label belong to the same set
  - Labels can be added and removed at runtime
  - A node can have multiple labels

Neo4j: Cypher

- A traversal navigates through a graph to find paths;
  - starts from starting nodes to related nodes, finding answers to questions
- Cypher provides a declarative way to query the graph powered by traversals and other techniques
- A path is one or more nodes with connecting relationships, typically retrieved as a query or traversal result

- Cypher: is a textual declarative query language
  - It uses a form of ASCII art to represent graph-related patterns

Cypher

```
(a) -[:LIKES]-> (b)
```

Hands-on Neo4j
(Docker image)

Neo4j with Dockers

- We use the official neo4j container

```
$ docker pull neo4j:5.6.0
```

- Create a container with Neo4j and forward its ports

```
$ docker run
        --publish=7474:7474
        --publish=7687:7687
        --volume=$HOME/neo4j/data:/data
        neo4j:5.6.0
```

- We will interact with Neo4j using its webUI

```
http://localhost:7474
```

Cypher syntax

- Cypher uses a pair of parentheses (usually containing a text string) to represent a node

```
(varname:Label { p_name: p_value, ... } )
```

  - () represents a node
  - varname (optional) assigns a name to the node that can be used elsewhere within a single statement.
  - the Label (prefixed with a colon ":") declares the node's type (or label).
  - the node's properties are represented as a list of key/value pairs, enclosed within a pair of braces

Cypher syntax

- Cypher uses a pair of dashes (--) to represent an undirected relationship. Directed relationships have an arrowhead at one end (<--, -->).
  - It is possible to create only directed relationship, although they can be queried as undirected

```
-[role:ACTED_IN {roles: ["Neo"]}]->
```

Bracketed expressions ([...]) are used to add details:

- a variable (e.g., role) can be defined, to be used elsewhere in the statement.
- the relationship's type (e.g., :ACTED_IN) is analogous to the node's label. A relationship can have at most one type.
- the properties (e.g., roles) are entirely equivalent to node properties.

Cypher syntax

Variables:

To increase modularity and reduce repetition, Cypher allows patterns to be assigned to variables

```
acted_in = (:Person)-[:ACTED_IN]->(:Movie)
```

https://neo4j.com/developer/cypher-query-language/

Cypher syntax: Create

Create a node with label Person and property name with value "you":

```
CREATE (you:Person {name:"You"})
RETURN you
```

Create a more complex structure: add a new node and a new relationship with the existing one

```
MATCH  (you:Person {name:"You"})
CREATE (you)-[like:LIKE]->(neo:Database {name:"Neo4j"})
RETURN you, like, neo
```

Cypher syntax: Find, Update and Remove

Find a node (basic syntax)

```
MATCH (you {name:"You"})-[:FRIEND]->(yourFriends)
RETURN you, yourFriends
```

Update an existing node (similarly, to update a relationship)

```
MATCH (n {property:value})
SET n :NewLabel
RETURN n
```

Remove a property (or a Label) from a node (or relationship)

```
MATCH (b {name: "Bruce Springsteen"})
REMOVE b.nickname RETURN b
```

Cypher syntax: Delete

Delete a node:

```
MATCH (a:ToDel)
DELETE a
```

Note that a node cannot be deleted if it participates in a relationship. To remove also relationships, we need to detach the node, delete it and its relationships:

```
MATCH (b {name: "Bruce Springsteen"})
DETACH DELETE b;
```

Cypher syntax: Read Clauses

These clauses read data from the data store:

- MATCH Specify the patterns to search for in the database
- OPTIONAL MATCH Specify the patterns to search for in the database while using nulls for missing parts of the pattern
- WHERE Adds constraints to the patterns in a MATCH or OPTIONAL MATCH clause or filter the results of a WITH clause
- START Find starting points through legacy indexes

Read more: http://neo4j.com/docs/developer-manual/current/cypher/clauses/

Cypher syntax: Write Clauses

These clauses write data to the data store:

- CREATE Create nodes and relationships
- MERGE Ensures that a pattern exists in the graph. Either the pattern already exists, or it needs to be created.
- ON CREATE (used with MERGE) it specifies the actions to take if the pattern needs to be created.
- SET Update labels on nodes and properties on nodes and relationships.
- DELETE Delete graph elements (nodes, relationships or paths).
- REMOVE Remove properties and labels from nodes and relationships.

Cypher syntax: General Clauses

These comprise general clauses that work in conjunction with other clauses:

- RETURN Defines what to include in the query result set.
- ORDER BY A sub-clause following RETURN or WITH, specifying that the output should be sorted in particular way.
- LIMIT Constrains the number of rows in the output.
- SKIP Defines from which row to start including the rows in the output
- WITH Allows query parts to be chained together, piping the results from one to be used as starting points or criteria in the next.
- UNION Combines the result of multiple queries.

Cypher syntax: Operators

Within clauses, we often rely on operators to combine and compare nodes/relationships or access to their properties

General operators:

DISTINCT, . for property access,

[] for dynamic property access

Mathematical operators:

+, -, *, /, %, ^

Comparison operators:

=, <>, <, >, <=, >=, IS NULL, IS NOT NULL

Cypher syntax: Operators

String-specific comparison operators:

STARTS WITH, ENDS WITH, CONTAINS

Boolean operators

AND, OR, XOR, NOT

String operators

+ for concatenation, =~ for regex matching

List operators

+ for concatenation,

IN to check existence of an element in a list,

[] for accessing element(s)

Cypher syntax: Relationship pattern length

Relationship pattern length:

```
(a)-[*2]->(b)
```

It is possible to specify a length (2 in the example) in the relationship description of a pattern.

It can be a variable length:

- *3..5 (between 3 and 5),
- *3.. (greater than 3),
- *..5 (less than 5),
- * (any length)

Read more: http://neo4j.com/docs/developer-manual/current/cypher/functions/

Cypher syntax: Relationship pattern

Relationship pattern:

- nodes and relationship expressions are the building blocks for more complex patterns;
- patterns can be written continuously or separated with commas

Examples:

- friend-of-a-friend:

```
(user)-[:KNOWS]-(friend)-[:KNOWS]-(foaf)
```

- shortest path:

```
path = shortestPath( (user)-[:KNOWS*..5]-(other) )
```

http://neo4j.com/docs/developer-manual/current/cypher/clauses/match/

Neo4j's Native Graph Processing

- Neo4j utilizes index-free adjacency:
  - Each node maintains direct references to its adjacent nodes.
  - Each node acts as a micro-index of other nearby nodes
    - This is much cheaper than using global indexes
    - Also, query times are independent of the total size of the graph, but are proportional to the amount of the graph searched!
  - In contrast, non-native graph databases use (global) indexes to link nodes together.

https://neo4j.com/developer/kb/understanding-data-on-disk/

Neo4j's Data on Disk

- Database files are persisted for long term durability;
  - data/databases/neo4j/neostore*
  - data stored as linked lists of fixed size records;
  - follow offsets to know how to fetch data;

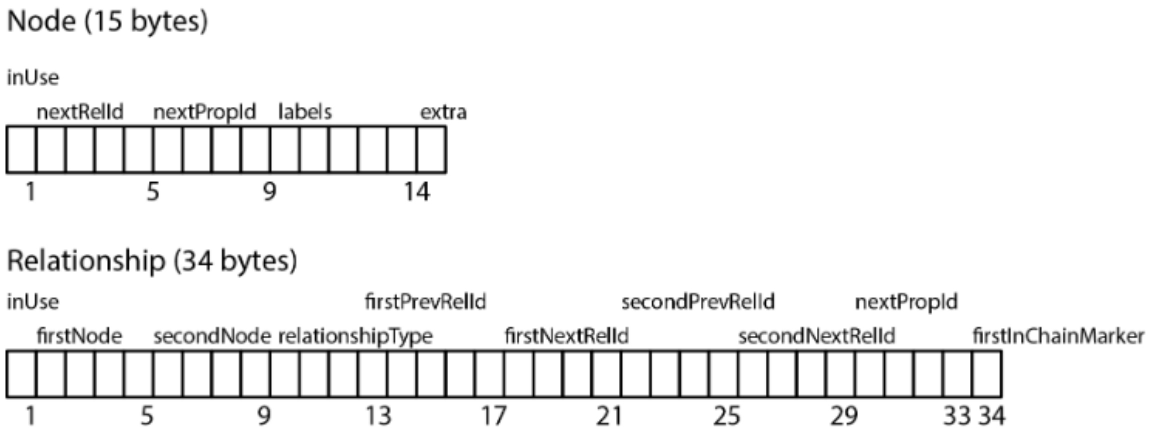
```
Store File                         | Record size    | Contents
----------------------------------------------------------------------------------------------------------------------------------
neostore.nodestore.db              | 15 B           | Nodes
neostore.relationshipstore.db      | 34 B           | Relationships
neostore.propertystore.db          | 41 B           | Properties for nodes and relationships
neostore.propertystore.db.strings  | 128 B          | Values of string properties
neostore.propertystore.db.arrays   | 128 B          | Values of array properties
Indexed Property                   | 1/3 * AVG(X)   | Each index entry is approximately 1/3 of the average property value size
```

- Properties: linked list holding a key and value and pointing to the next property.
- Each node and relationship references its first property record;
- Nodes also reference the first relationship in its relationship chain;
- Each Relationship references its start and end node and the previous and next relationship record for the start and end node.

https://neo4j.com/developer/kb/understanding-data-on-disk/

Neo4j's Data on Disk

- Details of node and relationship records:

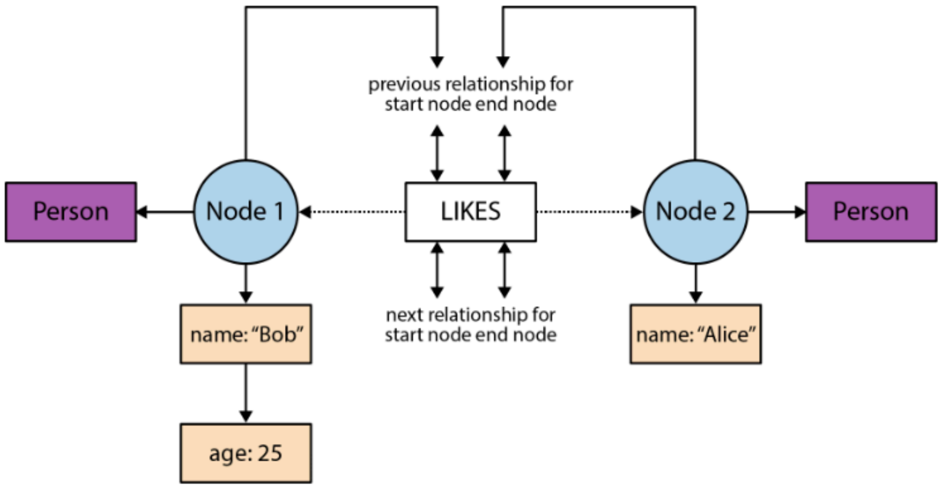


- Fixed-size records enable fast lookups for nodes in the store file.
  - If we have a node with id 100, then we know its record begins 900 bytes into the file.
  - Based on this format, the database can directly compute a record's location, at cost O(1), rather than performing a search, which would be cost O(log n).

https://neo4j.com/developer/kb/understanding-data-on-disk/

Neo4j’s Data on Disk

- How data is retrieved?
  - Each node record contains a pointer to its first property and relationship;
  - To read a node’s properties, we follow the singly linked list structure beginning with the pointer to the first property.
  - To find a relationship for a node, we follow the node’s relationship pointer to its first relationship.
    - From here, we follow the doubly linked list of relationships for that particular node until we find the relationship we’re interested in.
  - We can read the relationship properties using the singly linked list structure (also used for node properties).



Store files:

- nodestore.db
- relationshipstore.db
- propertystore.db