**A) What is NOSQL and Why No SQL**

* **Discussing what is SQL and data model used for SQL(RDBMS)**

Databases like RDBMS which supports SQL, stores data in tables divided into rows and columns. Here each row represents a data record which comprises of collection of various columns or attributes. A fixed schema governs the tables, which means a data type is associated with each column. In case of data type violations, while inserting data into the table, the insert operation fails and there is no flexibility in the data model to accommodate such discrepancies in data. A record is added successfully to a SQL table only when the type of all the individual data elements in the record is strictly adhering to the destination table’s schema . Because of such strict schema oriented regulations, SQL databases are used for storing and processing structured data. As discussed in previous modules, structured data can be easily stored using the relational databases because data is mostly in tabular format with well-defined columns. Most importantly, the data contained in individual columns will be of the uniform data type. Databases supporting SQL are used for storing transactional data which are mostly structured in nature such as bank transactions, hotel reservations etc.

* **Why popularity of SQL started to decline or for which use cases SQL databases were incompetent**

In the introduction module, you understood why traditional systems are considered unpopular when it comes to storing and processing big data. The 4 V's of Big data, i.e. volume, variety, velocity and veracity gave you a clarity regarding how storing and processing big data using traditional systems like RDBMS is challenging. With technological advancements such as ease in availability of internet at affordable prices, increased usage of IoT devices, usage of social networking websites, etc. the rate of generation of digital data grew at an alarming pace. Hence, traditional systems were not scalable to accommodate such massive volumes of data. Moreover, the digital data was not structured anymore, and organisations were not interested in discarding this data because nowadays non-structured data comprises almost 80% of the total generated data and 80% is a significant proportion of the total data. So to store and process humongous non-structured data, organisations started to migrate from traditional SQL supporting systems to other data processing tools which are scalable and fault tolerant.

* **Hadoop/HDFS solved some of the challenges faced in SQL. But introduced new challenges**

When organisations were trying to find out a way for storing and processing Big Data, Hadoop came to their rescue. Hadoop uses HDFS as its storage layer. As already discussed HDFS is used to store data in a distributed manner across a cluster of machines. HDFS is a robust file system which can store structured, unstructured and semi-structured data. Apart from this HDFS uses commodity hardware to store data and is horizontally scalable. So, with the advent of HDFS, the problem of storing massive non-structured data was solved, but at this point, the job is half done. The stored data is of no use if the data is not being churned or processed. So, Hadoop used Map-Reduce for processing the data stored in HDFS. But the biggest drawback of using Map Reduce for processing big data is it is not suited for all use cases. Map-reduce is well suited for batch processing, where the whole data set is accessed sequentially. In other words, irrespective of the task being performed entire data set is always scanned. So, there was a need for a way to access the data randomly.

* **What is a NoSQL database and how it solved the SQL and HDFS-related challenges**

We discussed that Hadoop solved the problem of storing huge volumes of data which could be structured or unstructured. But capabilities of map-reduce were only limited to performing batch processing on the data. Like it is not a preferable solution for quick random lookup of specific records from a vast data store. Hence, apart from Hadoop, there was a need for some other solutions which can service use cases such as random lookup. So this led to the inception of NoSQL datastores. Unlike SQL data stores, every NoSQL data stores are designed to solve a particular use case. Which means every data store has its own functionality and which may not be there in other NoSQL datastores. Irrespective of the use cases these NoSQL data stores serve, all NoSQL stores are fundamentally intended to run on a cluster of machines. The name NoSQL is misleading, i.e. NoSQL can be expanded as "Not Only SQL" which means there are other non SQL ways of managing data in the data store, but sometimes SQL can be used for querying data as well. So some of the reasons why there is an increasing popularity of NoSQL databases are firstly NoSQL datastores are efficient in storing and handling Big Data. Based on the targeted use cases, every NoSQL database has its data model for storing data. Secondly, NoSQL data stores provide scalability, i.e. in case of space crunch extra space can be easily created by just adding additional nodes to the cluster. Thirdly, NoSQL data stores are flexible. They do not restrict themselves to a fixed schema. Hence, NoSQL data stores can adapt to changes in the schema of data dynamically.

**B) CAP Theorem**

When the data volume increases, and it becomes sufficiently large to be stored and managed by a single machine, the data is partitioned and is distributed across a cluster of machines. The CAP theorem is a tool used to make system designers aware of the trade-offs while designing networked shared-data systems. In CAP, 'C' refers to consistency, 'A' refers to availability, and 'P' refers to partition tolerance. Consistency guarantees that every node in the distributed system returns the same, most successful, recent write. Availability refers to every request receives a response without the guarantee that it contains the most recent write and lastly partition tolerance refers to the system continues to function and upholds its consistency guarantees in spite of network partitions. Distributed systems guaranteeing partition tolerance can gracefully recover from partitions once the partition heals.

The CAP theorem states that it is impossible for a distributed data store to simultaneously provide more than two out of the three guarantees mentioned. They are Consistency, Availability and Partition tolerance. Systems which guarantees consistency and availability are RDBMS systems which support SQL. As NoSQL systems store data in a distributed manner across a cluster of interconnected machines, they provide network partitioning. Hence, there are two flavours of NoSQL databases, one which guarantees consistency and partition tolerance and the second one guarantees availability and partition tolerance. The first flavour which guarantees consistency over availability will report an error or a time-out if particular information is not latest due to network partitioning. Let's say you are using a chat application and you sent an instant message to your friend. If during this process there is a network partition then ideally the message will not get delivered and there will be a time out. Once the system is up, the exact message which you sent will be delivered to your friend's message box. So, in a messaging application consistency was given preference over availability. Just to ensure instantaneous delivery of message the system should not deliver a garbage message.

When choosing availability over consistency, the system processes the query for sure and tries to return the most recent available version of the information, even if it the data is not latest due to network partitioning. Let's say you are using a travel portal like MakeMyTrip to check for available hotel rooms. So, due to network partition, if the portal is unable to fetch latest prices it’s perfectly fine because the customer may not be concerned about prices, he/she is concerned about other aspects like location of the hotel, amenities, etc. So, in such scenarios using a highly available data store is must because travel portals and e-commerce websites cannot afford website timeout for showing consistent results. A point to be noted over here is, in the absence of network failure both consistency and availability are satisfied by a distributed data store.

**C) Introduction to HBase**

* History of Hbase.
  + Who developed it
  + Like inspired by Google’s Big Table etc.

HBase is a distributed data store built on top of HDFS. Hence it holds a prominent position in Hadoop ecosystem. This means HBase can leverage all the benefits provided by Hadoop or HDFS. Some of the benefits which HBase has because of HDFS are distributed processing, horizontal scalability and fault tolerance because of replication. But beyond its Hadoop roots, HBase is a powerful database because of some features which are unique to HBase only. In short, HBase has the ability which allows a user to query for individual records as well as derive aggregate analytic reports across a massive amount of data.

In early 2000's as usage of internet increased drastically, the number of resources available on the web started to grow exponentially. So there was a daunting task in front of the search engine giant Google, i.e. How could it provide timely search results across the entire Internet? Already the number of resources available on the internet was huge but again the number is not static, it has the potential of increasing exponentially. So to solve this problem, Google defined the following technologies: Google File System, Big Table and Map Reduce. In 2007, Mike Cafarella released code for an open source BigTable implementation that he called HBase. The first HBase release was integrated with Hadoop 0.15.0 in October 2007. In May 2010, HBase became a top-level Apache project that runs on Facebook, Twitter, and Adobe, just to name a few.

* Features of Hbase

Let's discuss some features of HBase which differentiate it from Hadoop and some other relational or NoSQL data stores. Firstly, HBase is a key-value store which stores data internally as key, value pairs where the rowkey is the key and rest of the data is value. Secondly, the records in HBase are sorted by rowkey. Thirdly, the columns in an HBase do not have a specific data type. All data in HBase are stored in form of bytes. Lastly, HBase tables do not follow a strict schema which means any number of columns can be added dynamically.

**D) Data Model Used in Hbase**

Like SQL, HBase also stores data in tabular format with some modifications. In HBase tables, instead of columns, there are column families. A column family is a collection of related columns known as column qualifiers, and there can be any number of columns in a single column family. This feature ensures that the schema of an HBase table is flexible and the table can scale linearly. Every row in an HBase table is associated with a rowkey. Entire data in HBase table is sorted as per the row key. Records in an HBase table are fetched as per the rowkey. Also, each column can have a configurable number of versions and there is a provision for selecting data for a particular version. In HBase, each version is identified by a timestamp.

In this figure, you can see an individual row is reached through its row key and each row comprises of one or more column families. Each column family has one or more column qualifiers called columns and each column has one or more versions. To access an individual piece of data, you need to know its row key, column family, column qualifier, and version which makes it a four dimensional model.

So reiterating what we learnt, in HBase data is stored in tables which are nothing but a collection of rows. In an HBase table, a row is a collection of column families. Every entry in an HBase table is identified and indexed by a RowKey. A column family is a collection of columns, and for every row key, an unlimited number of columns can be stored.

**F) Common Operations performed on a HBase table (25% of student time on this section)**

HDFS along with Map Reduce follows write once and read many times paradigm. In other words, data in HDFS is written once, but it can be read an unlimited number of times. Even there is no provision for updating an existing data set or record in HDFS. Let's see how can we perform basic CRUD operations in HBase using HBase shell commands. Please note even if HBase uses HDFS to store data but HBase supports update operations by maintaining multiple versions of same data points.

So let's start by creating a simple HBase table. The command used for creating a table is 'create'. For creating a table you must name the table and define its schema. As a part of the schema, we only need to specify the column families, columns are defined while inserting records into the HBase table. So let's create a table named students with three column families they are Personal Details, Contact Details and Marks. The command for creating a student table in HBase is create table name which is students and list of column families they are Personal Detail, Contact Details, Marks.

We can check all the tables present in HBase using the list command. We see the table students is created successfully.

So we created a table named students successfully. Now we will insert some student records into this table. For populating the table cells, we make use of put command. To put a cell value into table ‘t1’ at row ‘r1’ under column ‘c1’ we use the command put ‘t1’, ‘r1’, ‘c1’, ‘value’. Using the same command let's insert information for a student into HBase table.

After we insert a data item into the table we can view the table contents using the scan command. scan table name will show all the data items present in the table.

Let's try to update the email id of student1 to sandeep@pqr.com using put command.

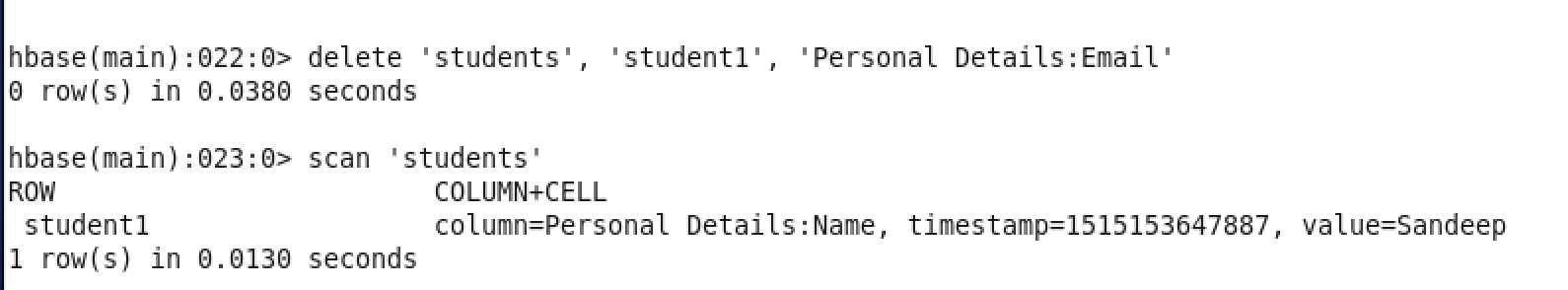
We see that the email id is updated to [sandeep@pqr.com](mailto:sandeep@pqr.com) from [sandeep@abc.com](mailto:sandeep@abc.com)

The command which is used to fetch data from HBase is 'get'. There are various ways by which we can use the get command. First of all, we will fetch entire row's data using the get table name and row key command.

If you want to fetch data for a given column family the command is get table name, row key, keyword COLUMN in the curly braces followed by implies operator and the column family name.

For fetching data for a particular cell, add column family name followed by column name. The column family and column name are separated by a colon(:)

For deleting a cell we will use the delete command. The syntax of delete command is delete, table name i.e students, rowkey i.e. students1, column family name i.e. Personal Details followed by colon and column name i.e. Email



Let’s execute the scan command and see if the data is removed or not.

**G) Java representation of all operations (25% of student time on this section)**

HBase like Hadoop is written in java. So we can also perform the operations discussed in the previous discussion using Java. Before going through the code, let me introduce some important classes along with their relevance. The first class is "HBaseConfiguration". This class is used to create a configuration object. The static method "create" defined in HBaseConfiguration class is used to return a configuration object. This configuration object will be used for creating tables. The configuration object points the code to that cluster where they are supposed to be executed.

The next class is HBaseAdmin. This class is used to administer or manage the HBase cluster. Table creation and deletion are taken care by HBaseAdmin class. The class HTable is used to operate on a table.

Objects of Put class are used for entering data into the HBase table. Each Put puts a single cell value in the Hbase table. A put object is created for a particular rowkey. Using the add method which takes the columnFamily, qualified and a value is added in the HBase table. Objects of the get class are used to fetch an entire row from the table. A get object is created for a rowkey.

First, let's see how we will be creating a table named User with column families as ID and Name.

Now as we have successfully created an HBase table we will put some values into the table using HTable and Put classes. Let's add the value AAA under column family ID and column qualifier col1. Similarly, lets add BBB under column family Name and column qualified col2.

Now as we have already inserted the data into the table we shall see how to fetch the data from a table. Typically, there are two ways of doing it. Firstly, we can use get method to retrieve row-wise data and secondly we can use a scanner to retrieve all the records in one go. A scanner is implemented using the ResultScanner class in java. Let's see how we are doing it programmatically in java.