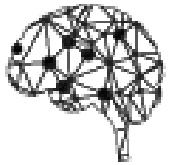
INFORMATION TECHNOLOGY UNIVERSITY



DATA SCIENCE LAB

# Introduction to NoSQL Databases

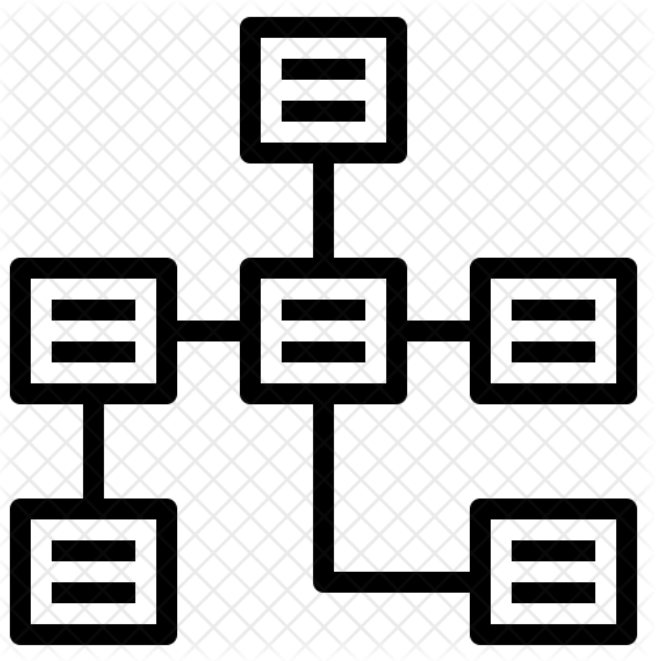
## CS 537- Big Data Analytics

Dr. Faisal Kamiran

March 22, 2021

# RELATIONAL DATABASES

**Benefits of Relational databases:**



- Designed for all purposes
- ACID
- Strong consistency, concurrency, recovery
- Mathematical background
- Standard Query language (SQL)
- Lots of tools to use with i.e: Reporting services, entity frameworks

# RELATIONAL DATABASES

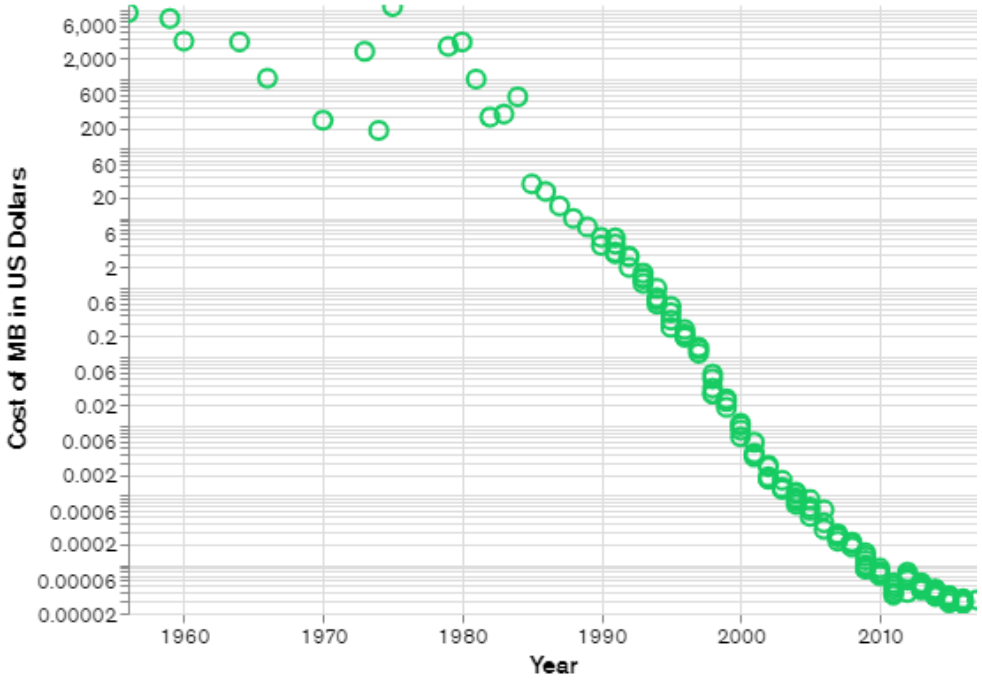
In general, RDBMS systems have been considered as the **one-size-fits-all** data retrieval and persistence solution for decades





# RELATIONAL DATABASES - CHALLENGES

- **Dramatic decrease in storage costs** - Exponential rise in data applications
- **Variations in Data**
- Continuously **evolving schema** with change in requirements
- Single **point of failure**

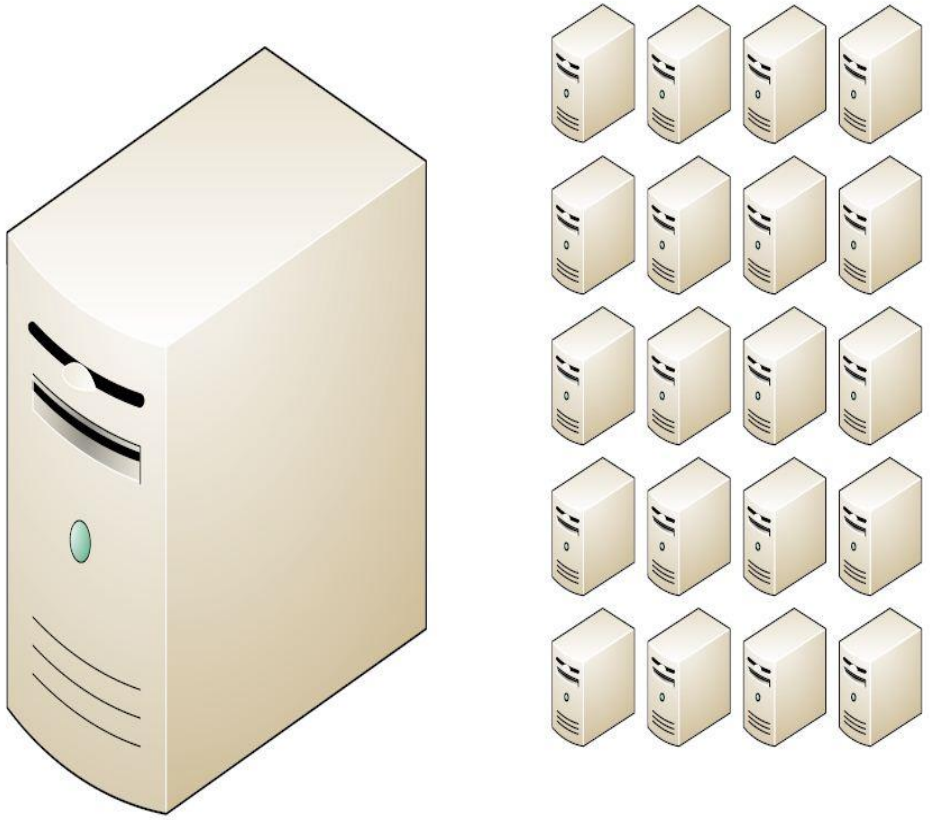


# RELATIONAL DATABASES - CHALLENGES

Relational databases were not built for **distributed applications.**

Because...

- Joins are expensive
- Hard to scale horizontally
- Expensive (product cost, hardware, maintenance)



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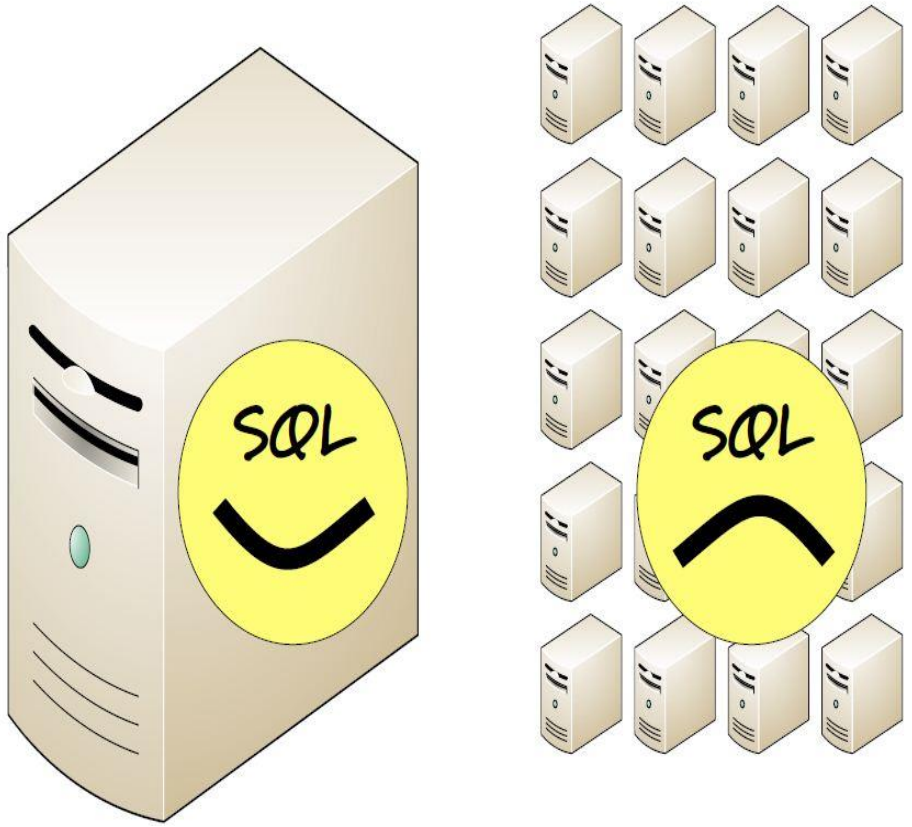
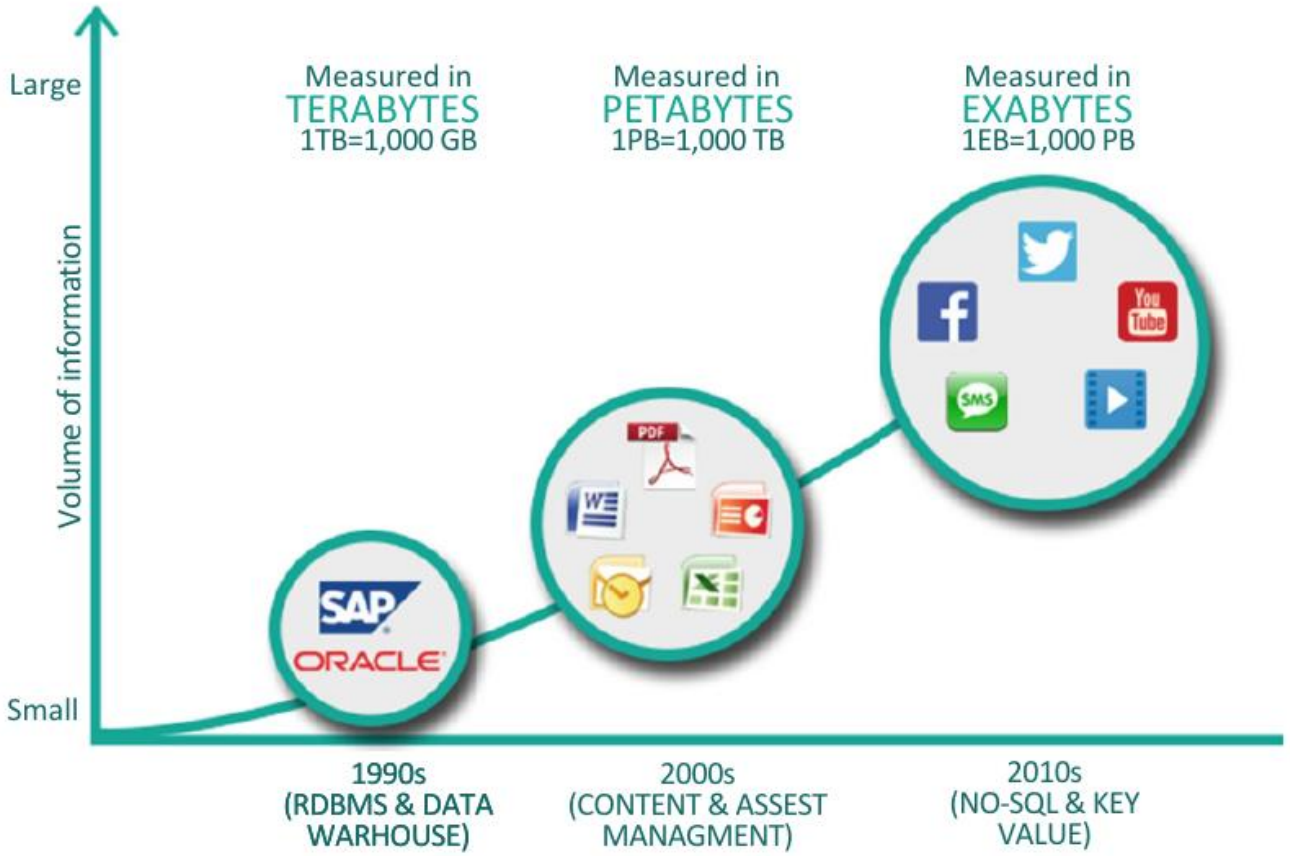


# MODERN DATA REQUIREMENTS

- Explosion of **social media sites** (Facebook, Twitter) with large data needs
- Rise of **cloud-based solutions** such as Amazon S3 (simple storage solution)
- Constantly **changing requirements**
- High-Velocity Data requiring fast query processing
- Increasingly sparse and semi-structured data

# MODERN DATA REQUIREMENTS



# NOSQL DATABASES

NoSQL stands for:

- No Relational
- No RDBMS
- **Not Only SQL**
  - Allows SQL-like query languages to be used.


NoSQL is an umbrella term for all databases and data stores that do not follow the RDBMS principles

# NOSQL DATABASES

"Next Generation Database Management Systems mostly addressing some of the points: being **non-relational, distributed, open-source** and **horizontally scalable.**"

-- Nosql-database.org

The primary objective of a NoSQL Database is to have:

- Simplicity of design
- Horizontal scaling
- Finer control over availability

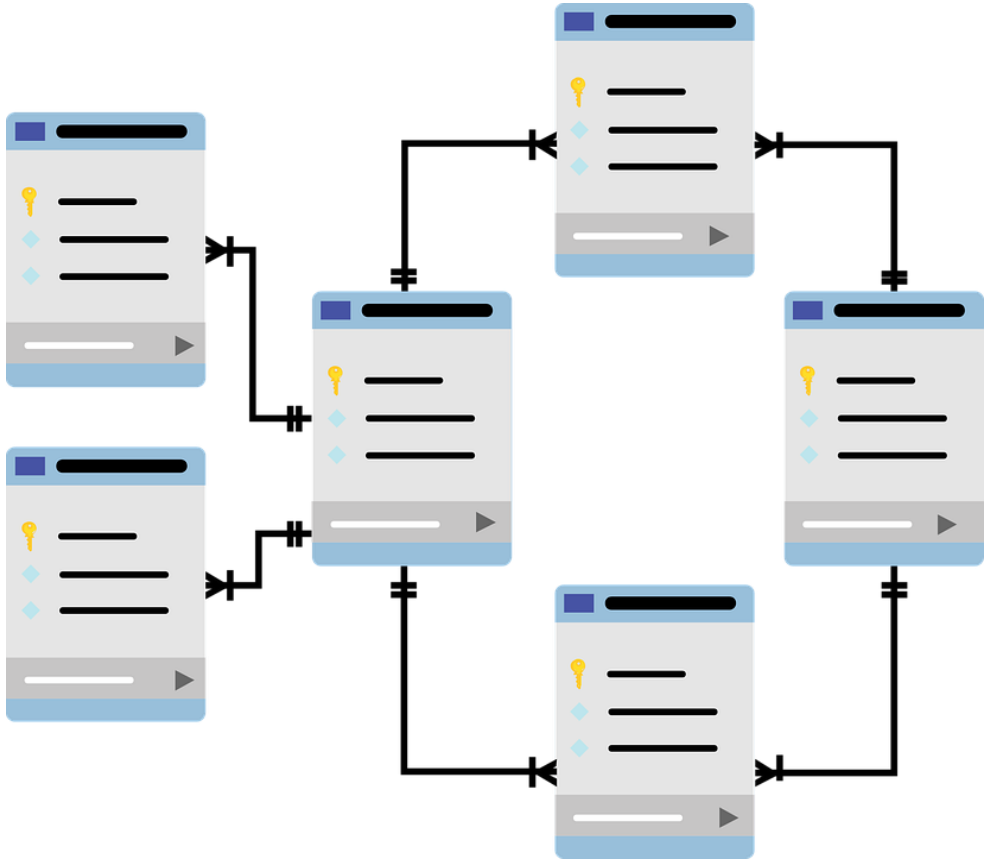
# CHARACTERISTICS OF NOSQL DATABASES

| THEY AVOID | THEY ALLOW |
|---|---|
| Overhead of ACID transactions | Easy and frequent changes to DB |
| Complexity of SQL query | Fast development |
| Burden of up-front schema design | Large data volume |
| DBA presence | Schema less |
| Transactions (It should be handled at application layer) | Distributed |

# SCHEMA BASED DATA MODELLING

- In RDBMS, a schema describes every functional element, including tables and rows

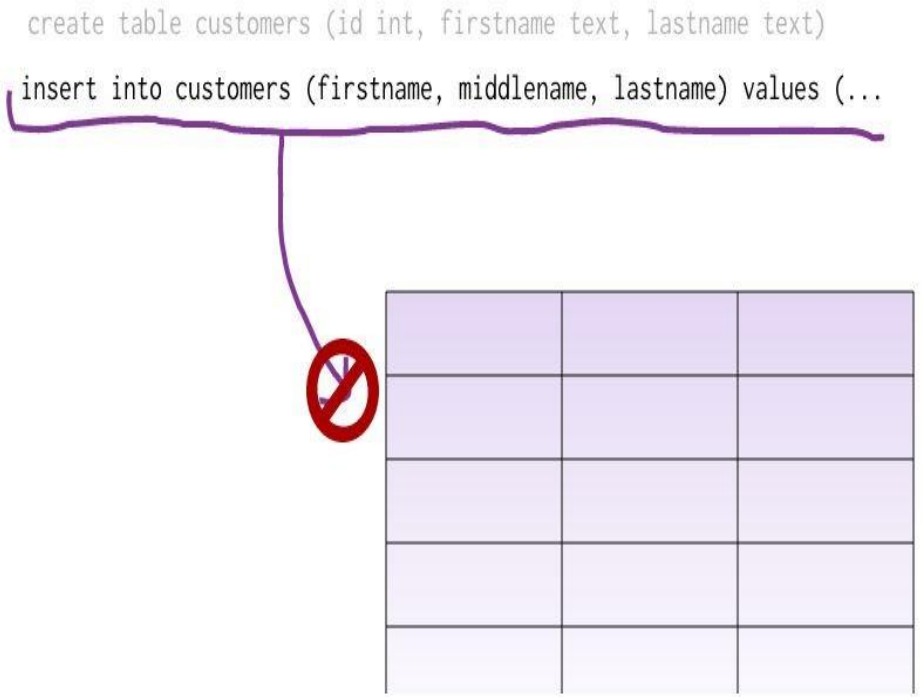
- Exerts a high degree of control and prevents capture of low-quality data



# SCHEMA BASED DATA MODELLING

**Problems**

- Cannot add a record which does not fit the schema
- Need to add NULLs to unused items in a row
- Need to consider the datatypes - cannot add a string to an integer field
- Cannot add multiple items in a field



# SCHEMALESS DATA MODEL

In NoSQL Databases:

- There is no schema to consider – No need to conform to a rigid schema
- There is no unused cell
- There are no datatype enforcements on columns
- Most of the considerations are done in the application layer
- Data can be rapidly transformed as requirements change
- Facilitates the storage of unstructured data as well as structured data

# SCHEMALESS DATA MODEL

Information stored in **JSON-style** documents which can have **varying sets of fields** with **different data types** for each field

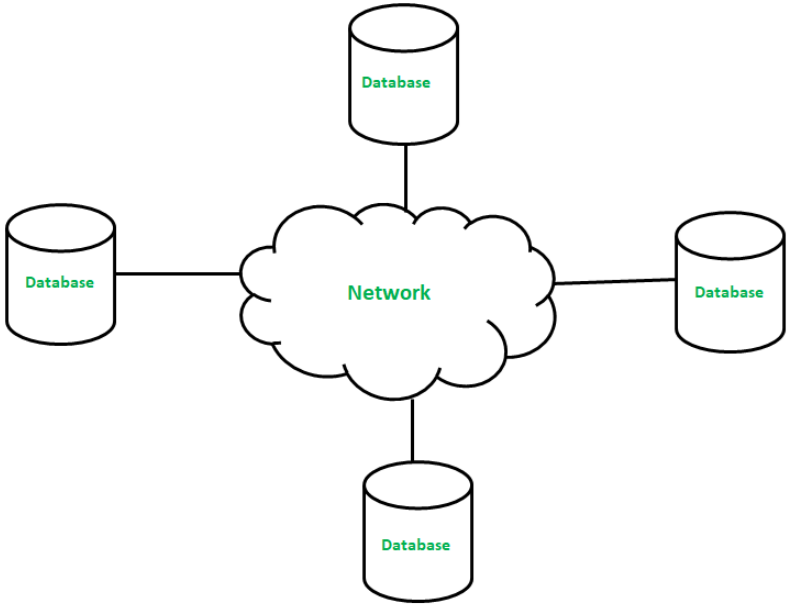
```
{
        "name":"Joe",
        "age":30,
        "interests":"football"
}
{
        "name":"Kate",
        "age":25
}
```

# SCHEMALESS DATA MODEL - ADVANTAGES

- No pre-defined database schemas
- No data truncation
- Suitable for real-time analytics
- On demand scalability to meet extreme Volumes, Velocity and Variety of data

# DISTRIBUTED ARCHITECTURE

- Multiple NoSQL databases can be created in a distributed fashion
- Data is physically stored across different sites
- Reaches Eventual consistency
- Offers auto-scaling and fail-over capabilities



# BASE (NOT ACID)

Recall ACID for RDBMS desired properties of transactions

- Atomicity, Consistency, Isolation, and Durability

NoSQL systems provide BASE and do not provide ACID

- Basically Available
- Soft state
- Eventually consistent

# ACID VS. BASE

The idea is that by giving up ACID constraints, one can achieve much higher performance and scalability

The systems differ in how much they give up

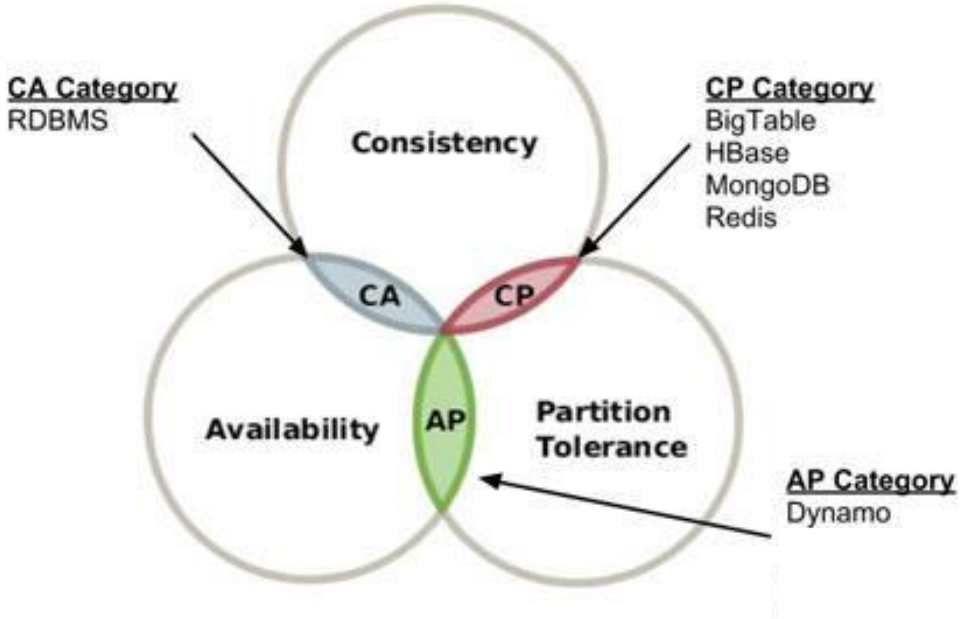
- e.g. most of the systems call themselves "**eventually consistent**", meaning that updates are eventually propagated to all nodes
- but many of them provide mechanisms for some degree of consistency, such as **multi-version concurrency control** (MVCC)

# CAP THEOREM

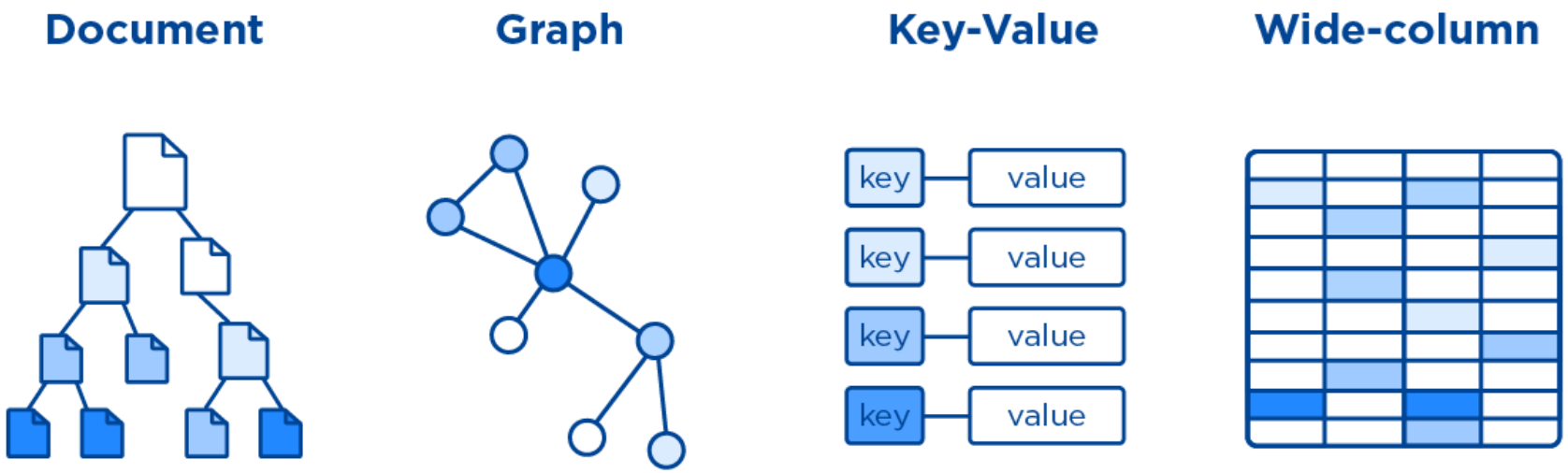
Often Eric Brewer's CAP theorem cited for NoSQL

A system can have only two out of three of the following properties:

- Consistency – Data is same across all sites even after updates and deletions
- Availability – Data is always immediately available
- Partition-Tolerance – System continues to work even in the presence of a partial network failure



# TYPES OF NOSQL DATABASES

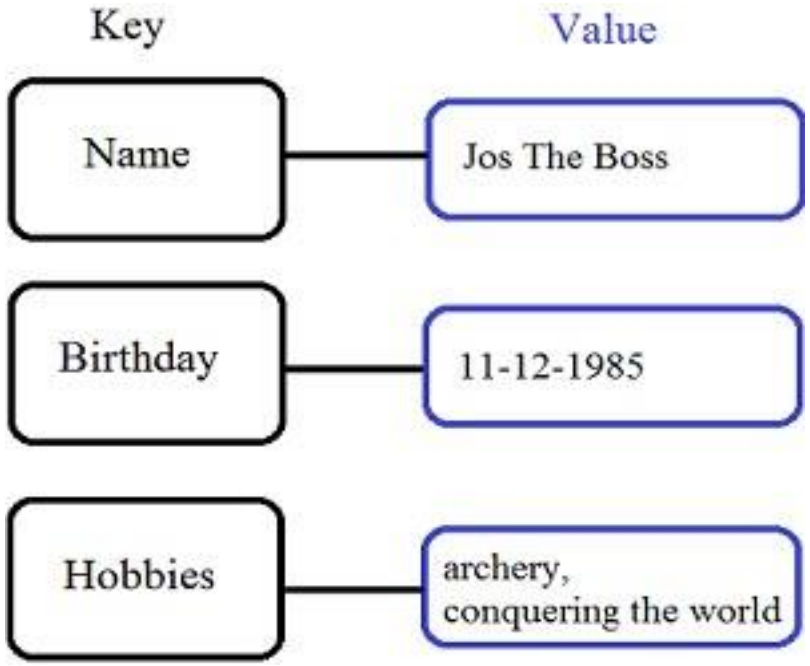


# KEY-VALUE STORE

Simplest NoSQL Database

Data is stored in the form of a key-value hash table

- Each key is unique
- Its corresponding value can be any data type (string, JSON, Blob e.t.c.)
- Values can also contain nested key-value pairs

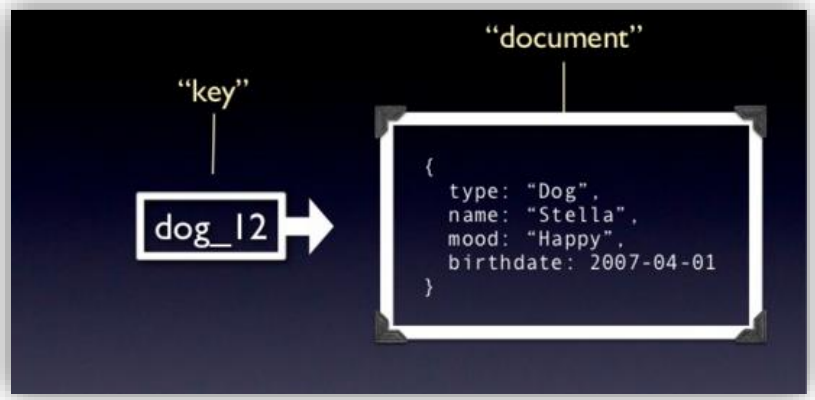


# DOCUMENT-ORIENTED

Subclass of key-value store

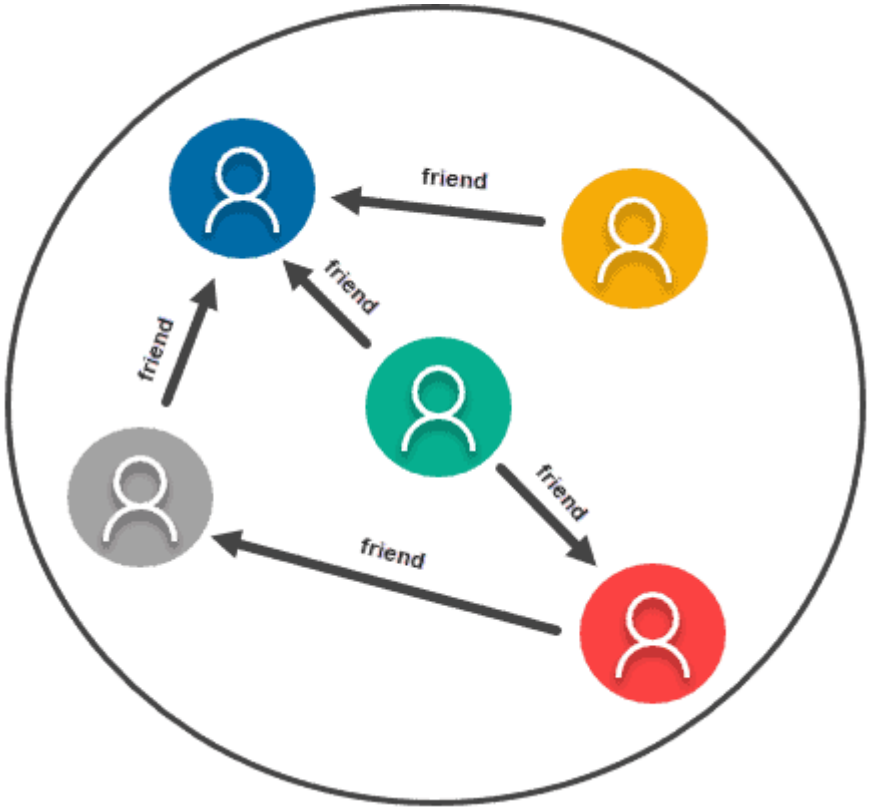
Assumes a certain internal document structure in the data

A query language  provides the ability to perform queries based on this internal structure



# GRAPH BASED

- Used to store fine-grained networks of inter-connected data
- Stores entities as well the relations amongst the entities
- Entity is stored as a node with the relationship as edges
- Traversing **persisted relationships** are faster



# COLUMN BASED

- Based on the BigTable paper by Google
- Variable-width tables
- Rows do not need to have the same columns
- Columns can be added to any row without having to add them to other rows

ColumnFamily: Authors

| Key | Value |
|---|---|
| "Eric Long" | Columns: {"email": "eric (at) long.com", "country": "United Kingdom", "registeredSince": "01/01/2002"} |
| "John Steward" | Columns: {"email": "john.steward (at) somedomain.com", "country": "Australia", "registeredSince": "01/01/2009"} |
| "Ronald Mathies" | Columns: {"email": "ronald (at) sodeso.nl", "country": "Netherlands, The", "registeredSince": "01/01/2010"} |

# WHEN TO USE A NOSQL DATABASE?

- Large amounts of data
  - Terabytes and Petabytes of data
- Need horizontal scalability
- Need high throughput – fast reads
- Need a flexible schema
  - No fixed number of columns
- Need high availability
- Need to be able to store different data type formats
- Users are distributed – low latency
- Need redundancy in case of failures

# WHEN NOT TO USE A NOSQL DATABASE?

- Need ACID Transactions
- Need ability to do JOINS
- Ability to do aggregations and analytics
- Have changing business requirements
- Queries are not available and need to have flexibility
- Have a small dataset

# APACHE CASSANDRA

"**Apache Cassandra** is a free and open-source, **distributed, wide-column store**, NoSQL database management system designed to handle large amounts of data across many commodity servers, providing **high availability with no single point of failure.**"

Apache Cassandra uses its own query language CQL

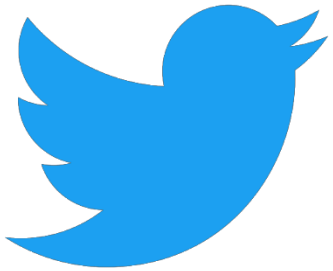
# FEATURES OF CASSANDRA

- **Elastic Scalability**
- **Always on architecture**
- **Fast linear scale performance**
- **Flexible data storage**
- **Fast writes**

# COMPANIES USING CASSANDRA

Netflix uses Apache Cassandra to serve all their videos to customers.

Uber uses Apache Cassandra for their entire backend.


# BASICS OF CASSANDRA

**Keyspace**

- Collection of Tables

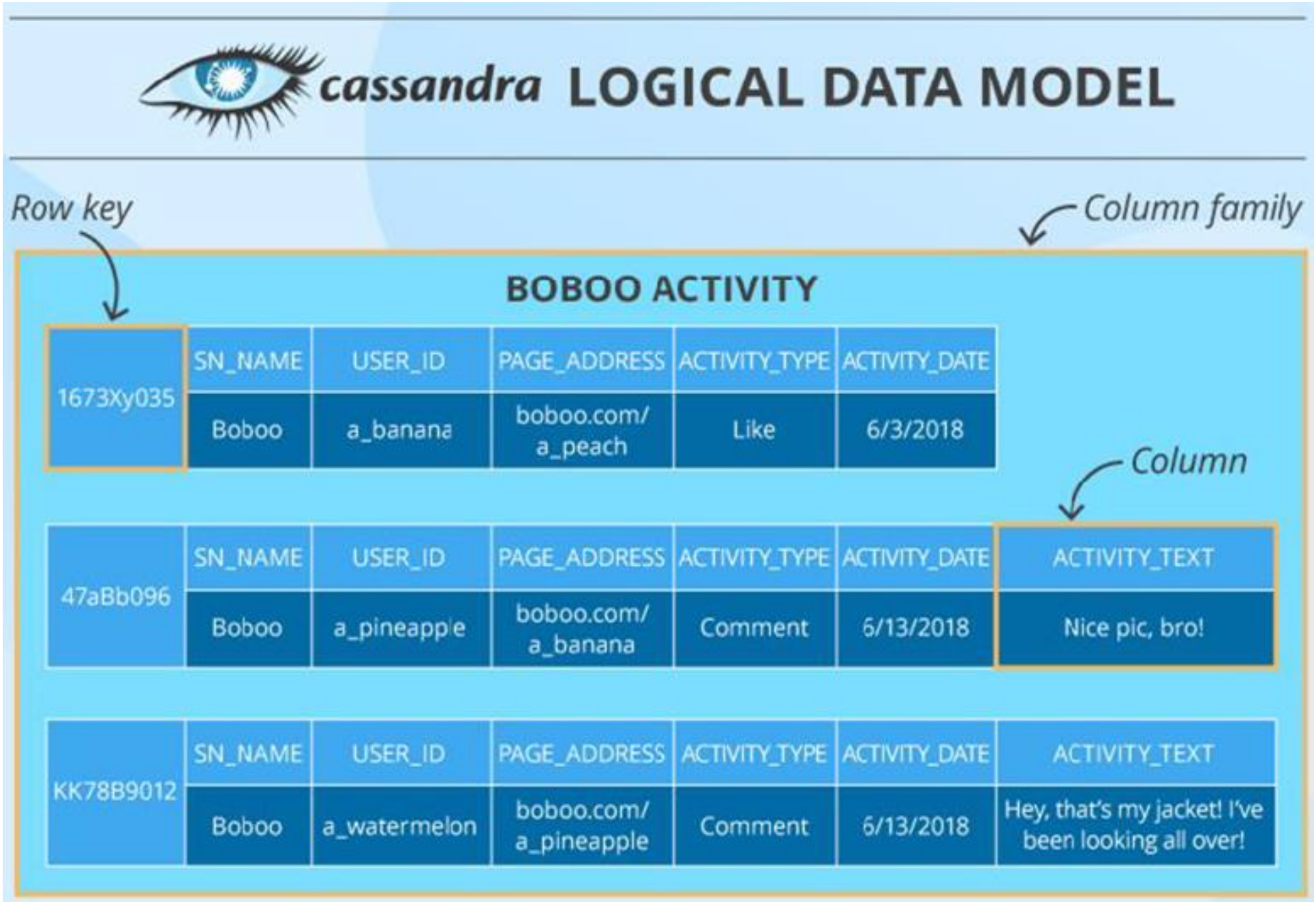
**Table**

- A group of partitions

**Rows**

- A single item

| Last Name | First Name | Address | Email |
|---|---|---|---|
| Flintstone | Dino | 3 Stone St | dino@gmail.com |
| Flintstone | Fred | 3 Stone St | fred@gmail.com |
| Flintstone | Wilma | 3 Stone St | wilm@gmail.com |
| Rubble | Barney | 4 Rock Cir | brub@gmail.com |


cassandra
LOGICAL DATA MODEL
Row key
Column family
BOBOO ACTIVITY
1673Xy035
SN_NAME
USER_ID
PAGE_ADDRESS
ACTIVITY_TYPE
ACTIVITY_DATE
Boboo
a_banana
boboo.com/
a_peach
Like
6/3/2018
Column
47aBb096
SN_NAME
USER_ID
PAGE_ADDRESS
ACTIVITY_TYPE
ACTIVITY_DATE
ACTIVITY_TEXT
Boboo
a_pineapple
boboo.com/
a_banana
Comment
6/13/2018
Nice pic, bro!
KK78B9012
SN_NAME
USER_ID
PAGE_ADDRESS
ACTIVITY_TYPE
ACTIVITY_DATE
ACTIVITY_TEXT
Boboo
a_watermelon
boboo.com/
a_pineapple
Comment
6/13/2018
Hey, that's my jacket! I've
been looking all over!

# THE BASICS OF APACHE CASSANDRA

## Partition

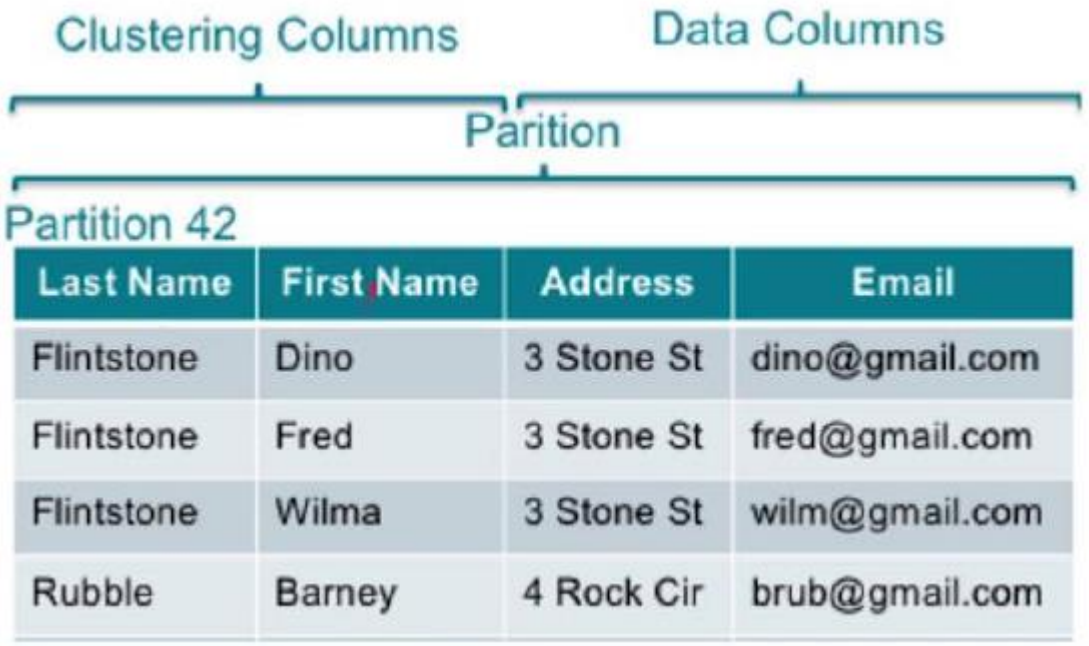
- Fundamental unit of access
- Collection of row(s)
- How data is distributed

## Primary Key

- Primary key is made up of a partition key and clustering columns

## Columns

- Clustering and Data
- Labeled element




| Last Name | First Name | Address | Email |
|---|---|---|---|
| Flintstone | Dino | 3 Stone St | dino@gmail.com |
| Flintstone | Fred | 3 Stone St | fred@gmail.com |
| Flintstone | Wilma | 3 Stone St | wilm@gmail.com |
| Rubble | Barney | 4 Rock Cir | brub@gmail.com |

# Summary

## SQL Databases

- Relational database (RDBMS)
- Table based with rows and columns and clearly defined schema
- Scales vertically by increasing server and hardware horsepower
- Well suited for high transactional based applications
- Common SQL DBs: MS SQL, MySQL, Oracle, PostgreSQL, DB2
- More mature application and support

## NoSQL Databases

- Non-relational or distributed database
- Document based, key value pairs, graph or wide-column stores with dynamic schema
- Scales horizontally by adding more servers to the pool or resources
- Well suited for Big Data and large unstructured data sets
- Common NoSQL DBs: MondoDB, CouchDB, Google BigTable
- New offerings with less mature support

# DEMO