

Normal

ADVANCED DATABASES

Databases II

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2025-III



Outline

1 Object-Oriented Databases (OODB)

2 NoSQL Databases

3 Parallel Databases

4 Distributed Databases



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1 Object-Oriented Databases (OODB)

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What is an OODB?

~2000s

- Combines object-oriented programming and database principles.
- Stores **objects** with their methods and attributes.
- Supports complex data and inheritance.

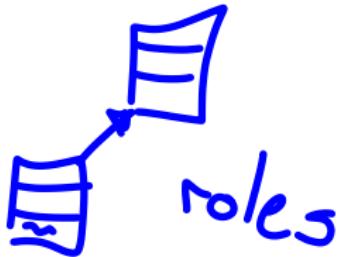
↓
calculations
queries



What is an OODB?

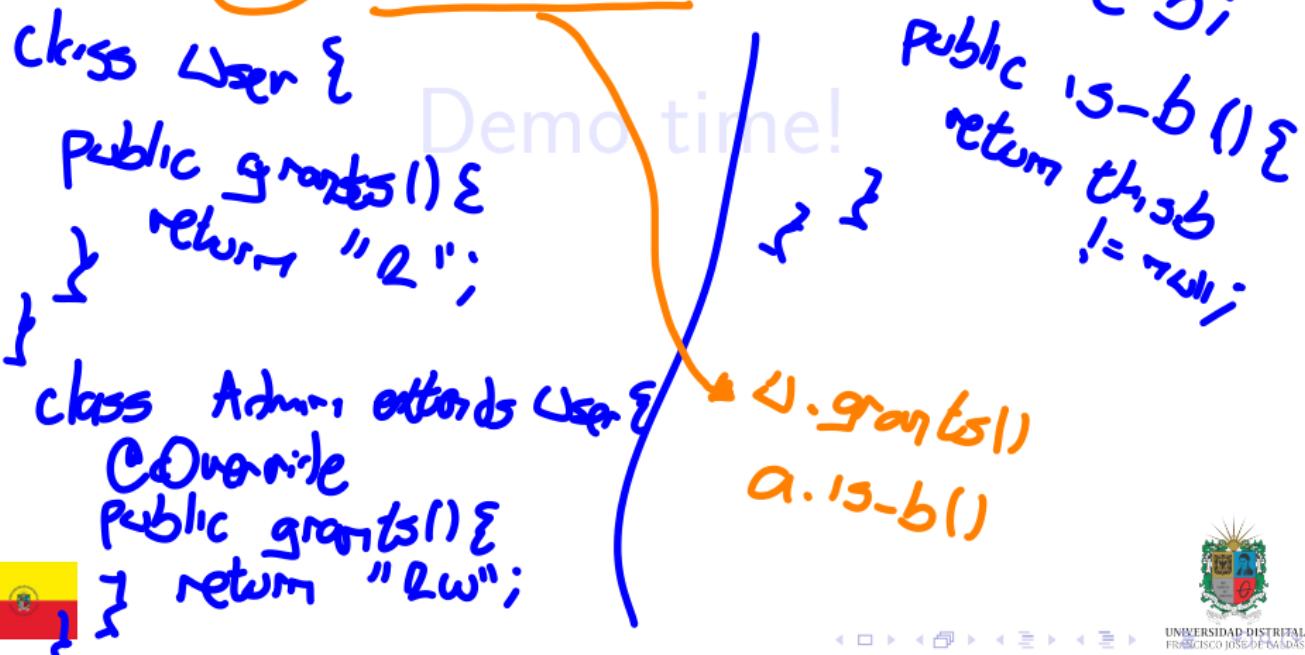
- Combines **object-oriented programming** and **database principles**.
- Stores **objects** with their **methods** and **attributes**.
- Supports **complex data** and **inheritance**.

trees
graphs



OODB Features

- Encapsulation, Inheritance, Polymorphism.
- Direct object storage and identity.
- Supports OQL (Object Query Language).



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Demo time!



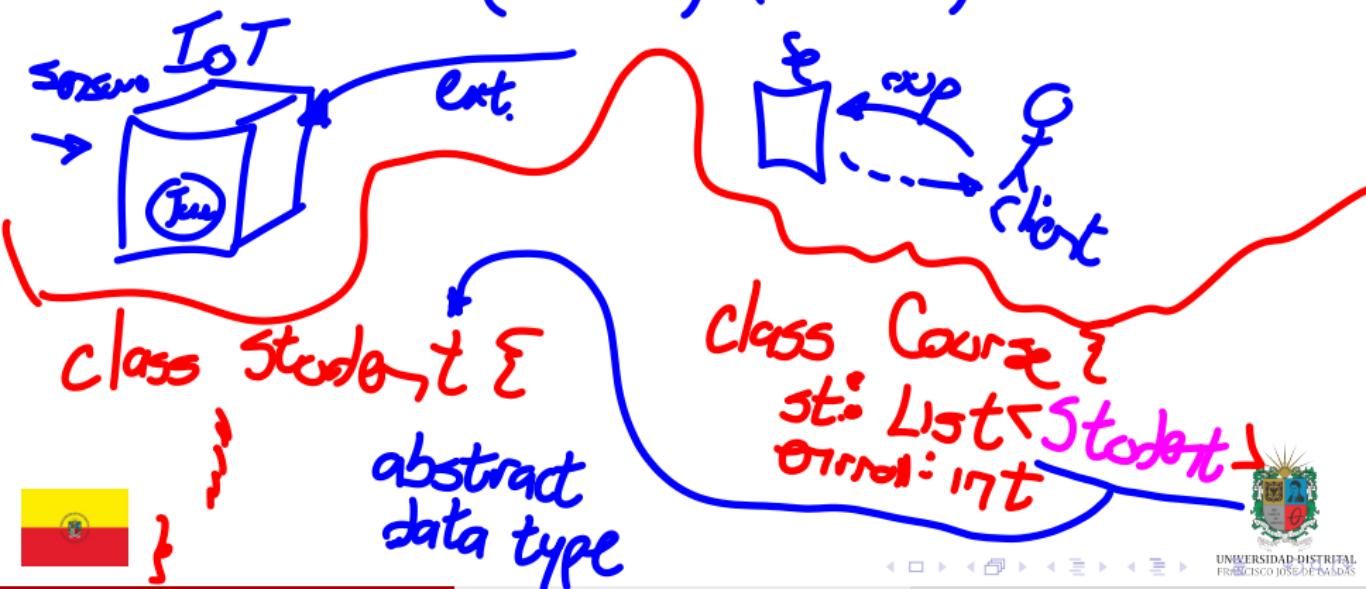
OODB Architecture

- Integrates:

JVM / MICSIL



- Common deployment (embedded) or client-server



Persistence Mechanisms

- By Reachability: Root object persistence.

Rule of Least Knowledge

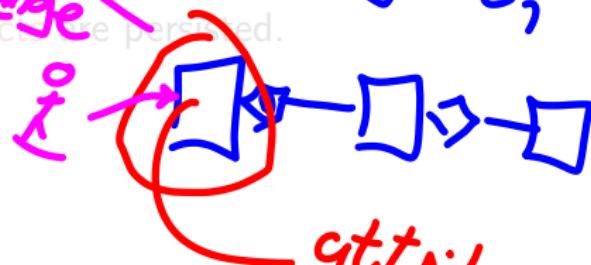
- By Depth Traversing: Annotate persistable objects.

- By Modification: Modified objects are persisted.

bad practice

`a.getB(); getc();`

Composite, aggregation,



attribute
abstract
type *data*



Persistence Mechanisms

- By Reachability: Root object persistence.
- By Explicit Marking. Annotate persistable objects.
- By Modification: Modified objects are persisted.

@Save
class A {
 b:B; *x*
 c:C; */*
}

class B {
};
{

@Save
class C {
};
{



Persistence Mechanisms

- **By Reachability:** Root object persistence.
- **By Explicit Marking:** Annotate persistable objects.
- **By Modification:** Modified objects are persisted.

att.: null
att2: "a"



OODB Query Example (OQL)

OOI

Student s = new Student()

```
SELECT s.name FROM Student s WHERE s.average() > 4.0
```

- Queries can follow object references.
- Better for nested, recursive, or complex types.

Class Student {

```
    public String name;
    private double[] grades;
    public double average()
        return Math.avg(grades);
}
```

Demo time!



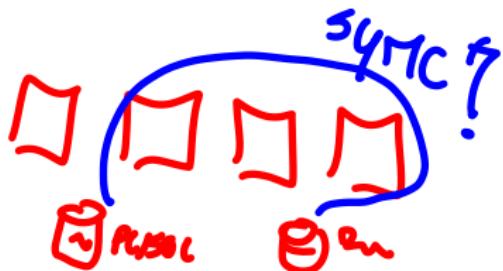
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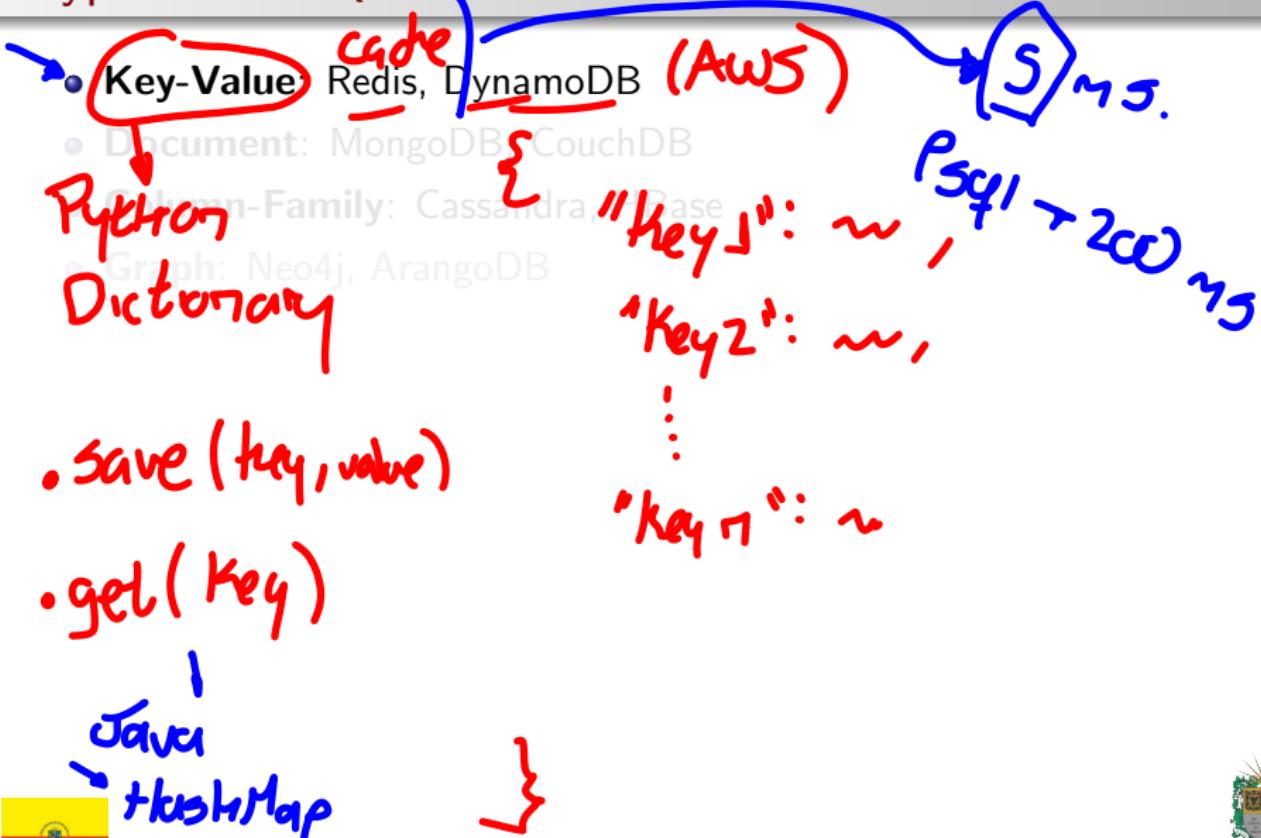
- 4 Distributed Databases

No mandatory

Non-structured
semi-structured



Types of NoSQL Databases



Types of NoSQL Databases

- **Key-Value:** Redis, DynamoDB
- **Document:** MongoDB, CouchDB

- **Column-Family:** Cassandra, HBase
- **Graph:** Neo4j, ArangoDB

LIST OF Dictionaries
JSON

Collection

document

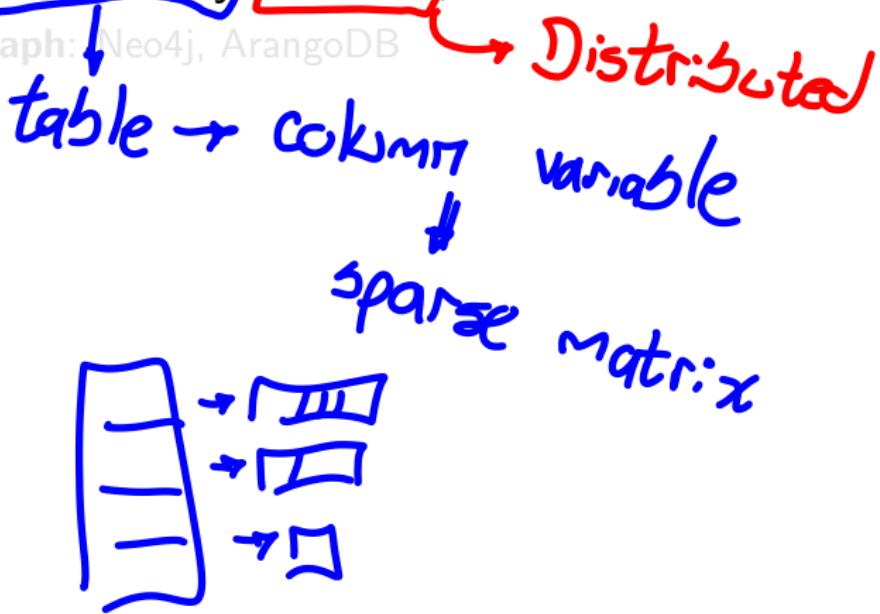
No same attributes in all documents

schema: common keys



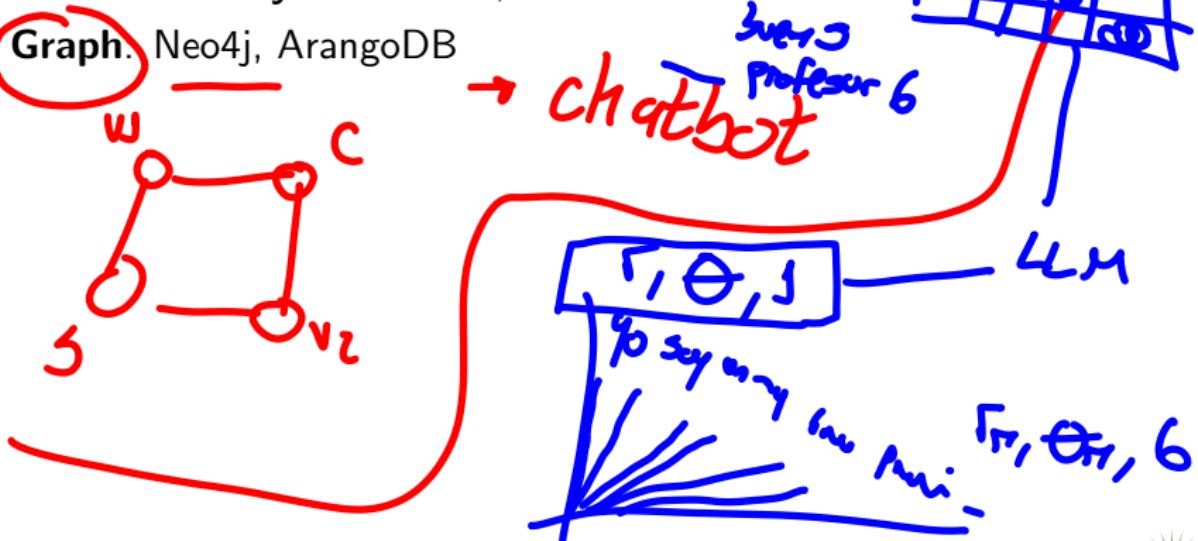
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CAP Theorem Deep Dive

C Consistency (C)

Latest write is visible to all reads.



A Availability (A)

System always responds.

→ no loss request

P Partition Tolerance (P)

Tolerates network splits

Only two can be guaranteed at the same time.



CAP: Practical Examples

Database	CAP Preference	Comment
MongoDB	A + P	Eventual Consistency
Cassandra	A + P	Tunable consistency
Spanner	C + P	Sacrifices availability

Google
DataLake

deadlines
by sync.

clusters
Atlas



NoSQL Architecture Patterns

- **Shared-nothing architecture** enables scalability.

- Sharding: Distributes data across partitions.

- Replication: Ensures fault-tolerance.

Routers coordinate requests across shards (e.g., mongos in MongoDB).

data

data

data

image
data

sync

no memory
no disk

no processing

→ Cost ↑

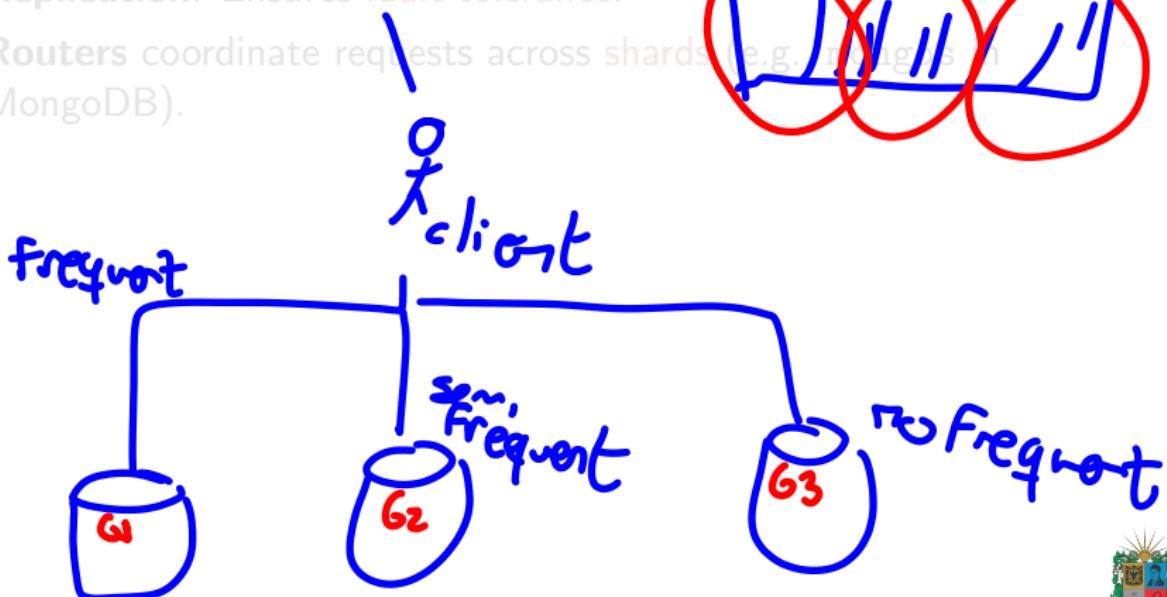
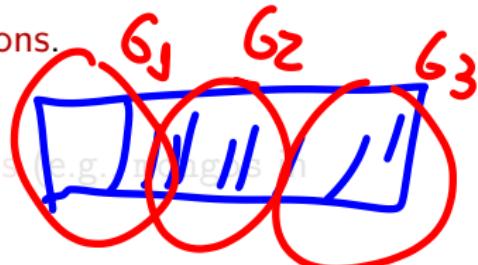


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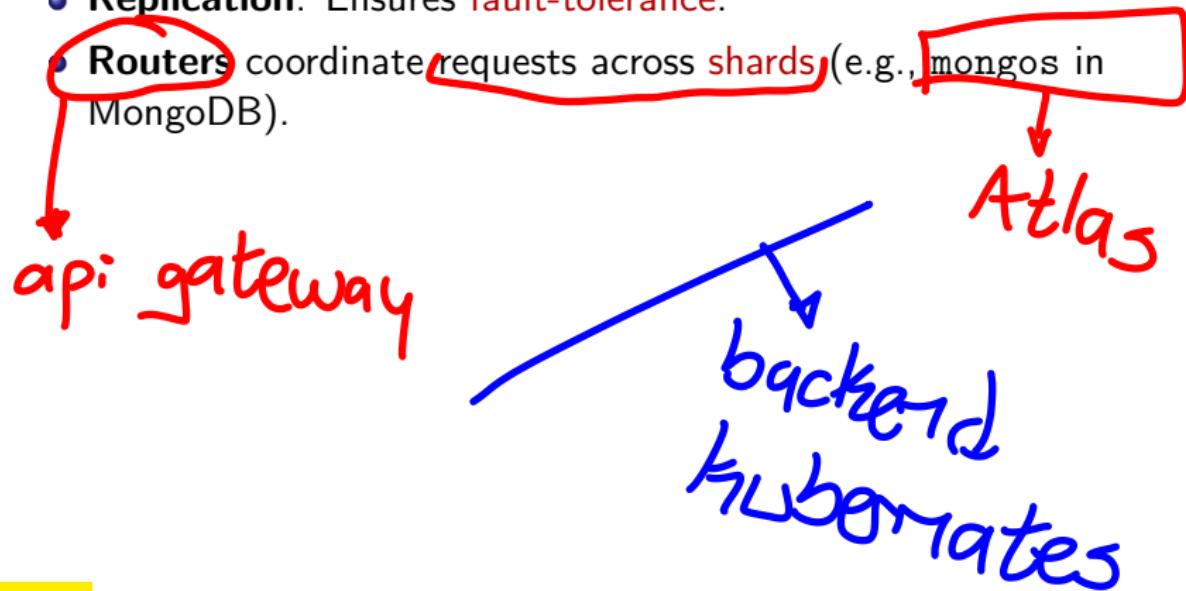
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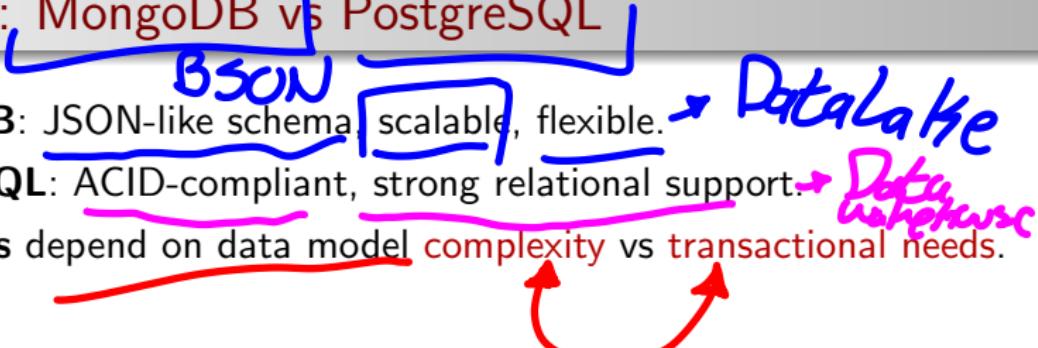


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Case Study: MongoDB vs PostgreSQL

- **MongoDB:** JSON-like schema, scalable, flexible.
 - **PostgreSQL:** ACID-compliant, strong relational support.
 - **Trade-offs** depend on data model complexity vs transactional needs.
- 

Demo time!



Case Study: MongoDB vs PostgreSQL

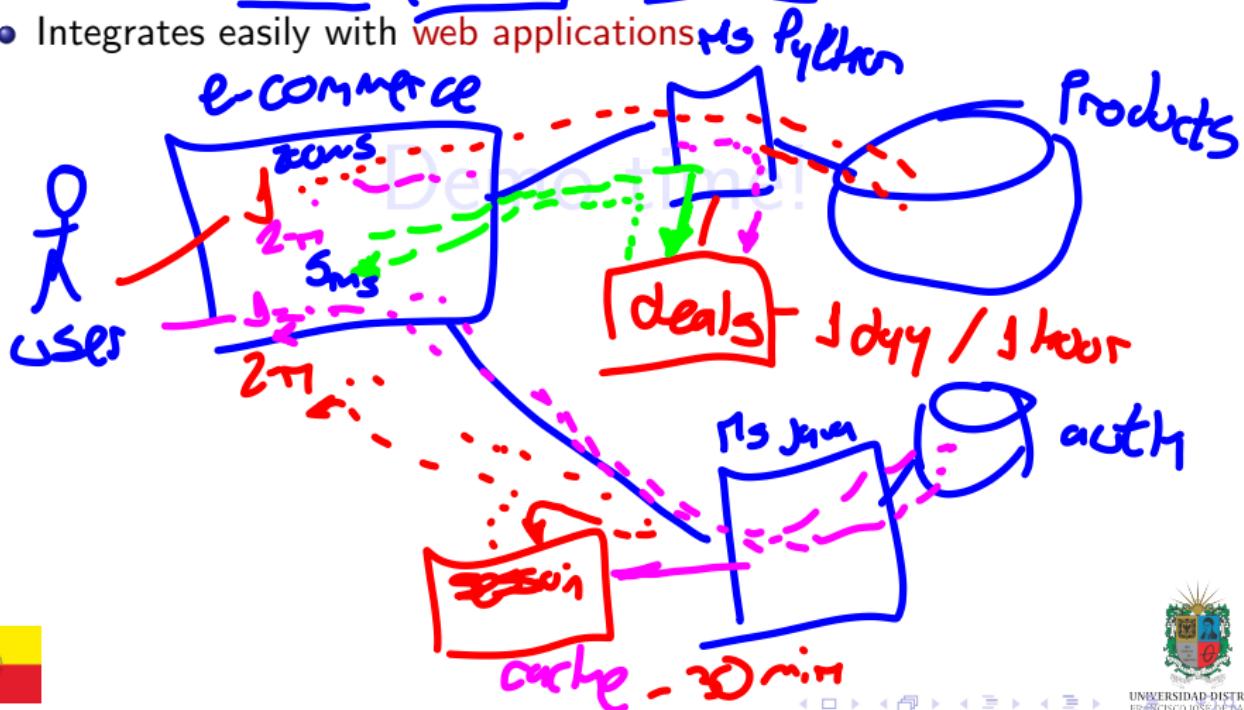
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- In-memory key-value store
- Excellent for caching, sessions, and real-time analytics.
- Integrates easily with web applications MS Python



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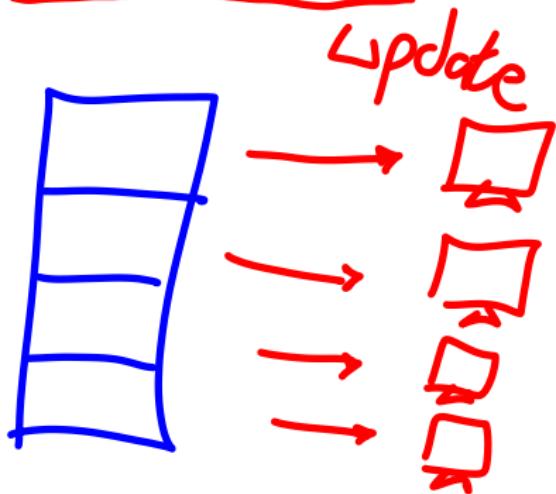
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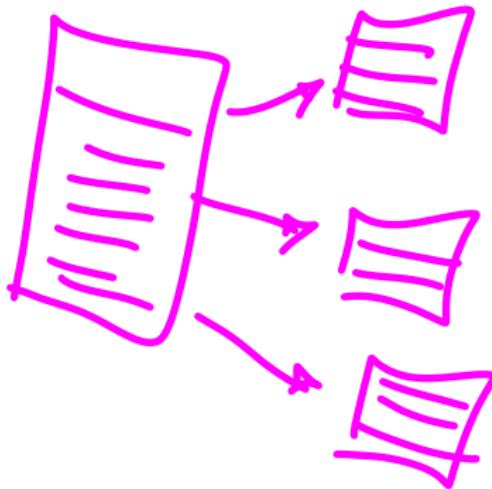
Parallel DB Concepts

- Uses multiple processors to speed up query execution.
- Exploits parallelism in data access and computation.
- Reduces query response time for big datasets.



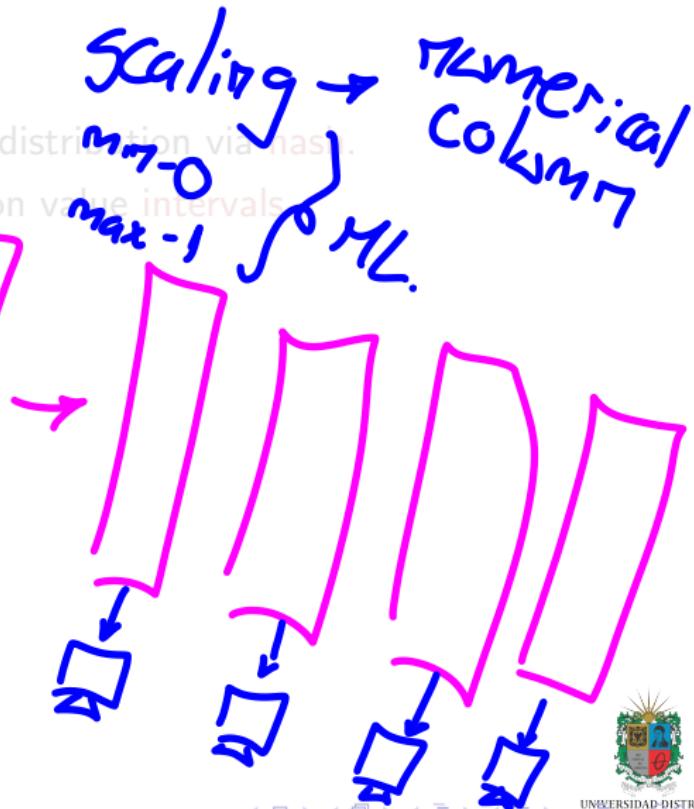
Partitioning Strategies

- **Horizontal:** Distributes **rows**.
- Vertical: Splits **columns**.
- Hash Partitioning: Uniform distribution via hash.
- Range Partitioning: Based on value intervals.



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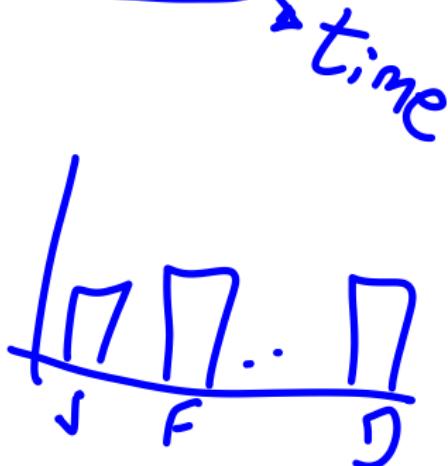
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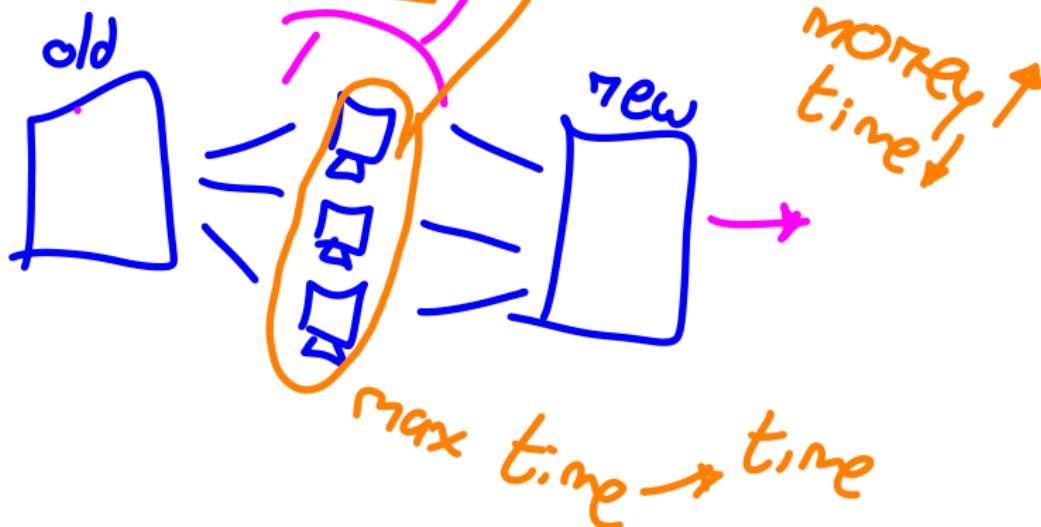
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January #
February #
:
December #



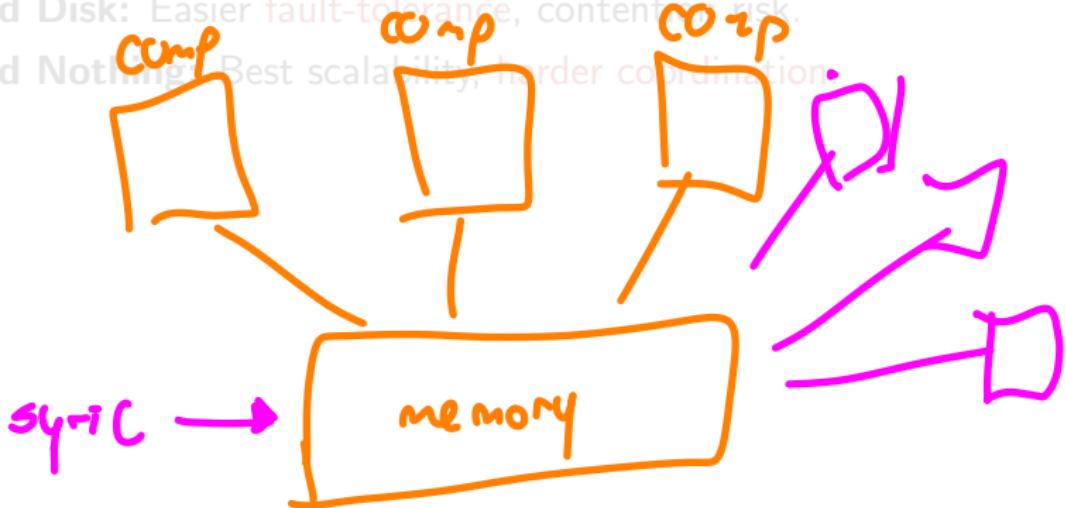
Parallel Query Cost Model

- **Startup cost (S)**: Fixed overhead.
- **Communication cost (C)**: Inter-node data transfer.
- **Computation cost (T)**: Local processing time.
- Total: $T_{total} = S + C + T$



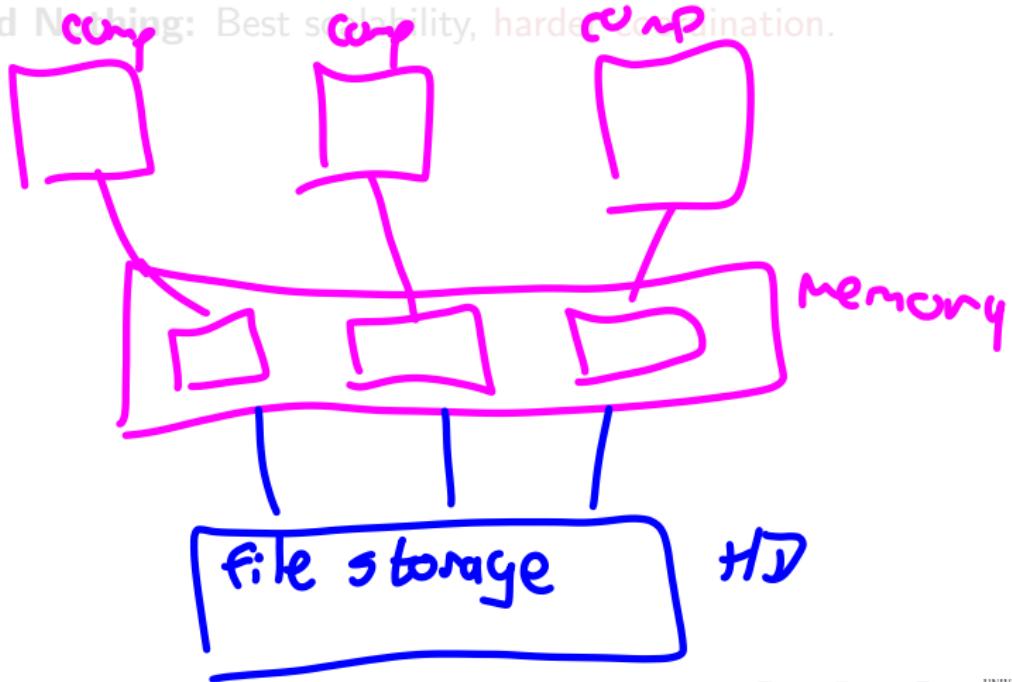
Parallel DB Architectures

- **Shared Memory:** Easy communication, **poor scalability.**
- Shared Disk: Easier fault-tolerance, contention risk.
- Shared Nothing: Best scalability, harder coordination.



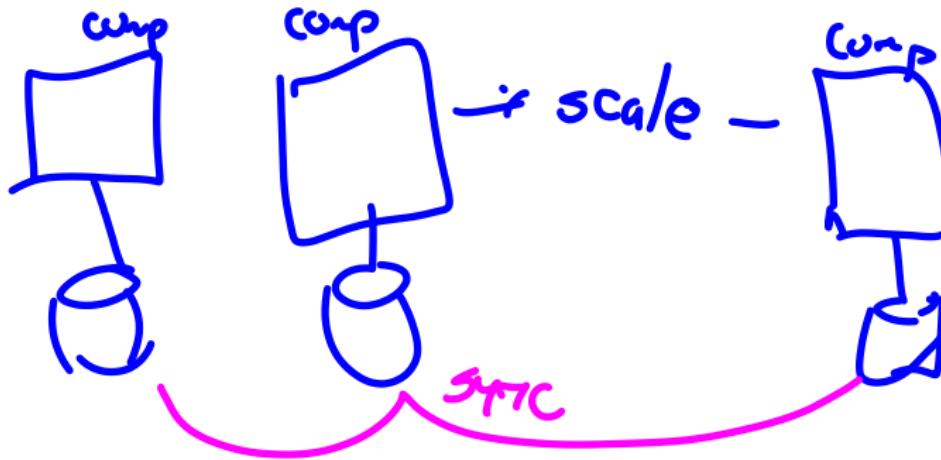
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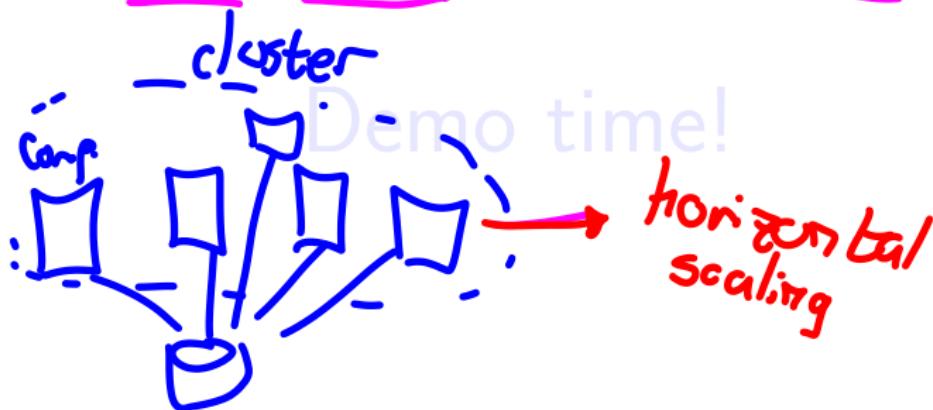
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Case Study: PostgreSQL + Citus

extension

- Open-source extension for **PostgreSQL** enabling parallel, distributed queries.
- **MPP architecture** (massively parallel processing) for scaling out across nodes
- Good for **real-time analytics**, multi-tenant SaaS, and large OLAP workloads.
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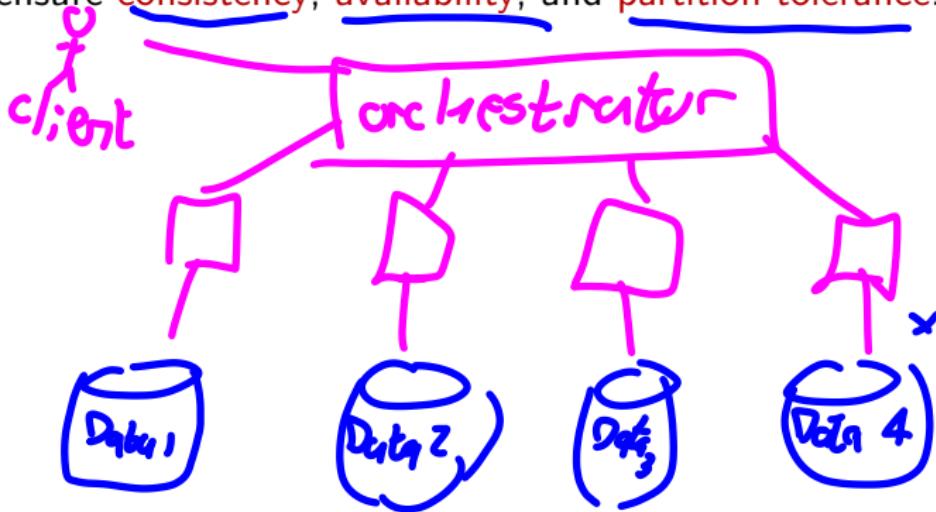
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What is a Distributed DB?

- **Data stored** across multiple **physical nodes**.
- Appears as a **single logical database**.
- Must ensure **consistency**, **availability**, and **partition tolerance**.

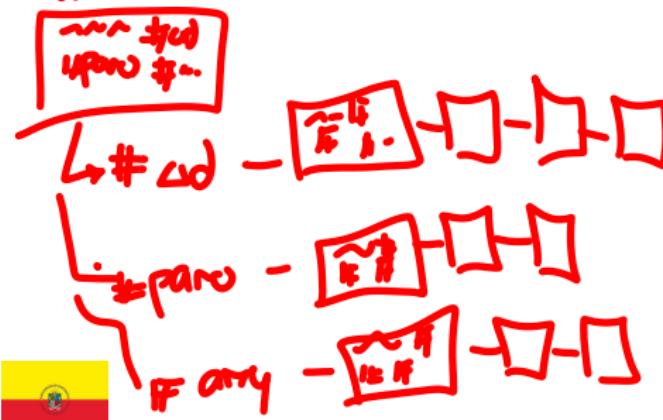


Transparency Goals

- **Location:** Hide physical location of data.
- **Replication:** Hide duplication.
- **Fragmentation:** Hide data partitioning.

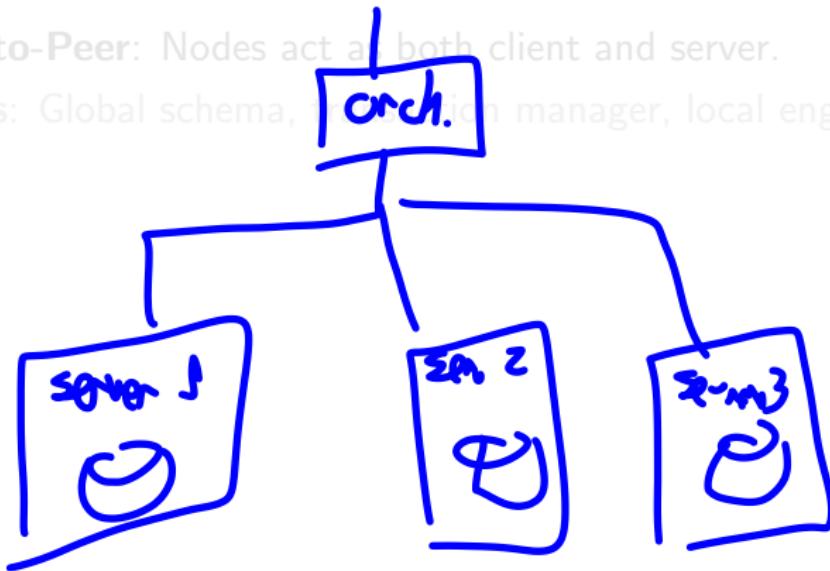
USI → data 1
EU → data 1
Latam → data 2
Asia → data 3

NoSQL



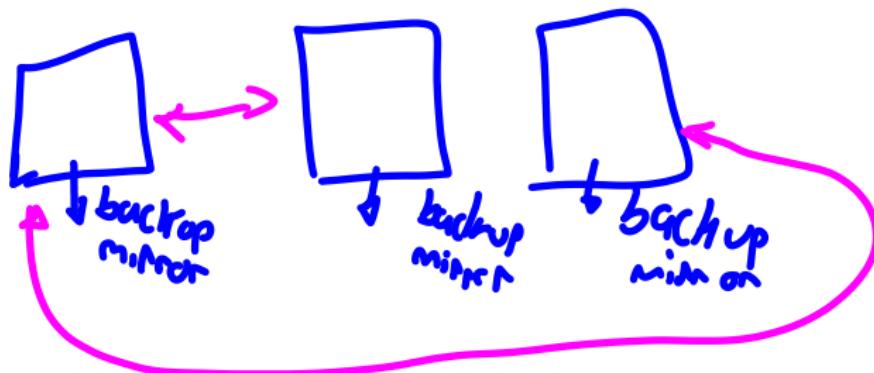
Distributed DBMS Architecture

- **Client-Server Model:** Clients query; servers store data.
- Federated Model: Semi-autonomous DBs collaborate.
- Peer-to-Peer: Nodes act as both client and server.
- Layers: Global schema, distributed transaction manager, local engines.



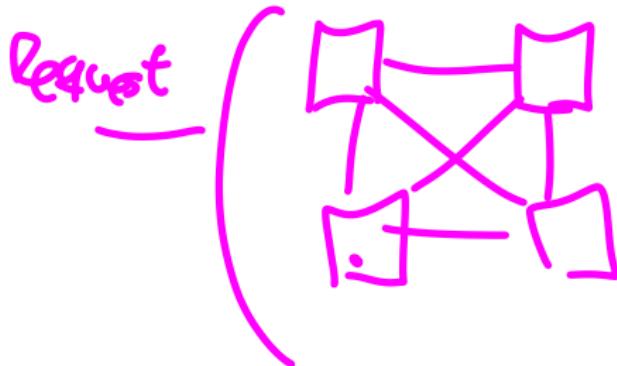
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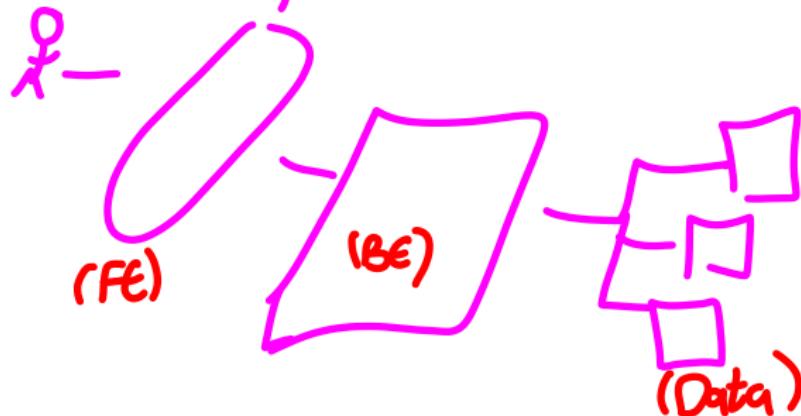
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Two-Phase Commit Protocol (2PC)

- ① **Prepare Phase:** Coordinator asks all participants to prepare.
- ② **Commit Phase:** If all vote yes, coordinator commits.

Issue: Blocking if coordinator crashes during commit.

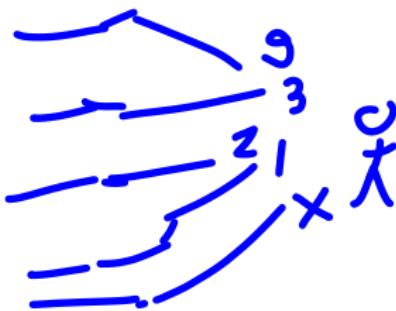
req/ desig → write

- Atomicity
 - No partial commits
 - Consistent
- Events - message queues → streaming
- Slow → communication / coordination



Paxos (Simplified Consensus)

- Needed for agreement in distributed systems.
- Roles:
 - Proposer: Suggests a value. → roles
 - Acceptor: Votes.
 - Learner: Learns chosen value. → trust
- Ensures consistency even if nodes fail.



Case Study: Apache Cassandra

FOSS

- Highly available and scalable NoSQL database.
- Designed for big data applications. → M-B data
- Supports multi-data center replication.
- Offers a rich query language (CQL).

Demo time!



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Conclusion

internet
↓

data - str
l - ser,
host
↑

- Data systems have evolved for scalability and complexity.
- Choosing the right DB model depends on the workload requirements.
- Understanding design trade-offs is key for architects.



Thanks!

Questions?



Repo: <https://github.com/EngAndres/ud-public/tree/main/courses/databases-ii>

