

DATA BASE SYSTEMS ARCHITECTURE

Databases III

Author: Eng. Carlos Andrés Sierra, M.Sc.
cavirguezs@udistrital.edu.co

Full-time Adjunct Professor
Computer Engineering Program
School of Engineering
Universidad Distrital Francisco José de Caldas

2025-III



Outline

- 1 DataBases Infrastructure
- 2 DBMS Architecture
- 3 Database System Administration
- 4 Transactional System
- 5 Query Execution
- 6 Concurrency Control
- 7 Failure Recovery



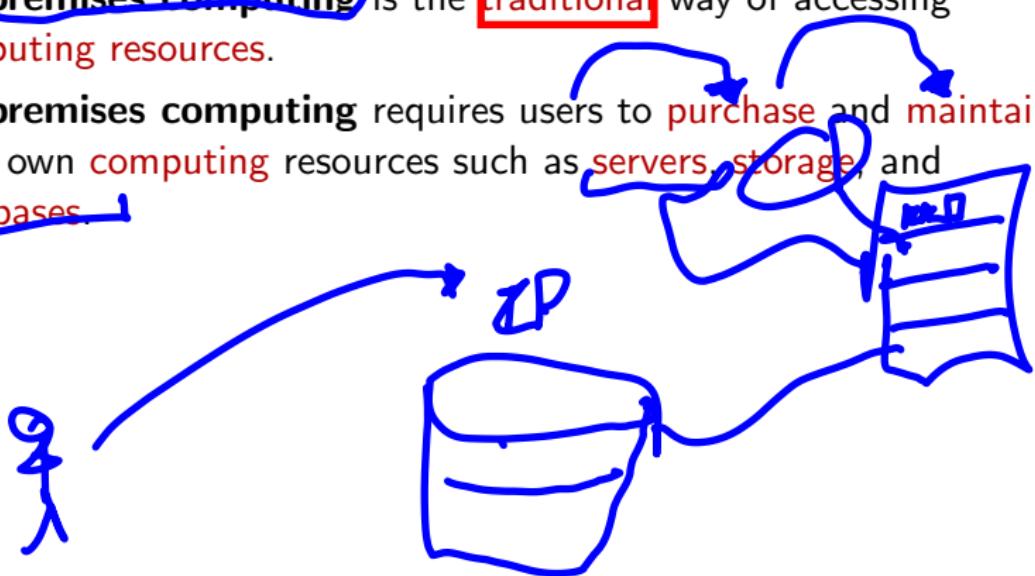
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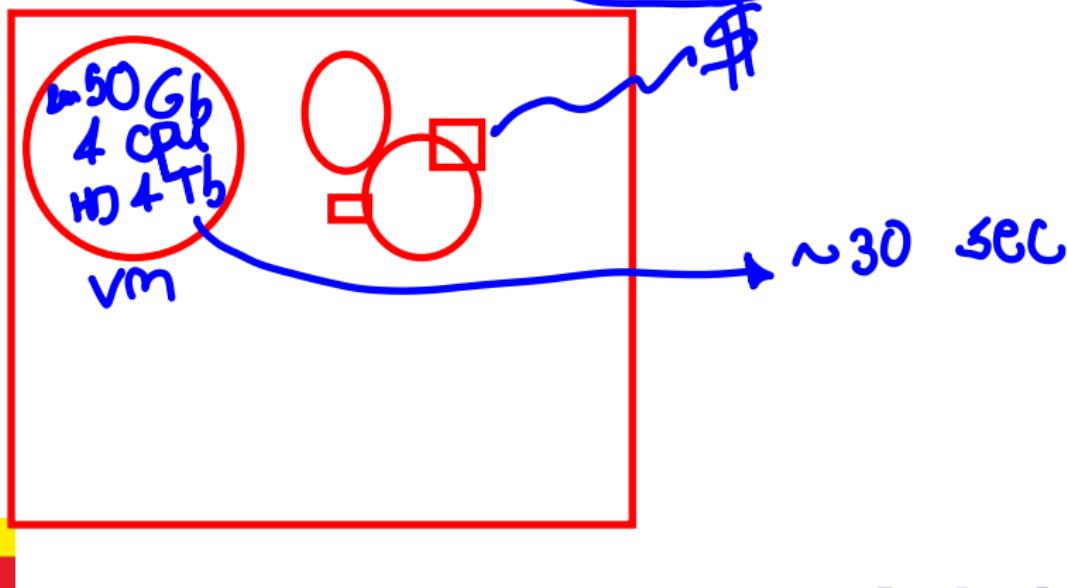
What is On-Premises Computing?

- **On-premises computing** is the **traditional** way of accessing computing resources.
- **On-premises computing** requires users to **purchase** and **maintain** their own **computing** resources such as **servers**, **storage**, and **databases**.



What is the Cloud Computing?

- **Cloud computing** is the delivery of **computing services** over the **internet**.
- **Cloud computing** allows users to **access computing resources** such as servers, storage, and databases **on demand**.

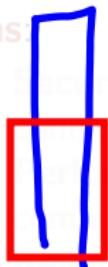


Pros & Cons of Cloud Computing

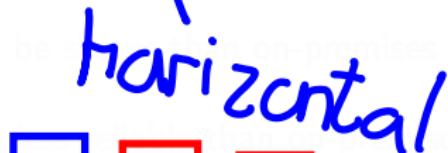
- Pros:

- **Cost-Effective:** Cloud computing is a **cost-effective** way to access computing resources.
- **Scalable:** Cloud computing is a **scalable** way to access computing resources.
- **Flexible:** Cloud computing is a **flexible** way to access computing resources.

- Cons:



vertical



horizontal



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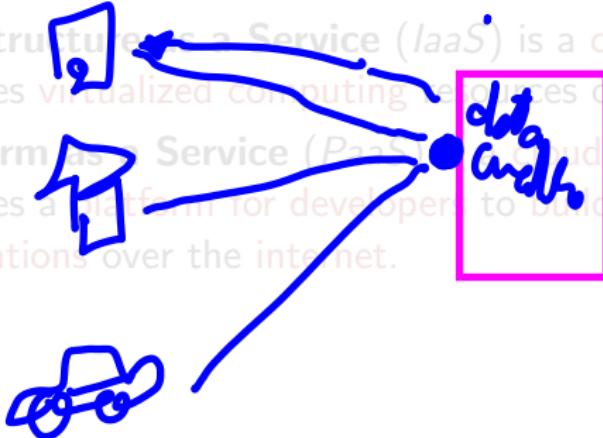
• Cons:

- **Security:** Cloud computing can be less secure than on-premises computing.
- **Performance:** Cloud computing can be slower than on-premises computing.
- **Reliability:** Cloud computing can be less reliable than on-premises computing.



SaaS Vs. IaaS Vs. PaaS

- **Software as a Service (SaaS)** is a **software distribution** model in which a **third-party** provider **hosts applications** and makes them available to customers over the **internet**.
- **Infrastructure as a Service (IaaS)** is a **cloud computing** model that provides **virtualized computing resources** over the **internet**.
- **Platform as a Service (PaaS)** is a **cloud computing** model that provides a **platform** for developers to **build, deploy, and manage** applications over the **internet**.



SaaS Vs. IaaS Vs. PaaS

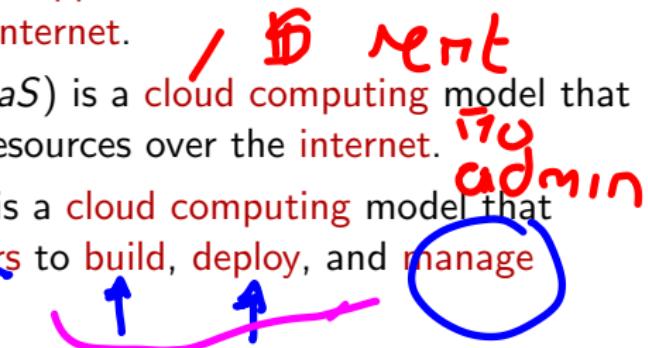
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IaC → terraform



SaaS Vs. IaaS Vs. PaaS

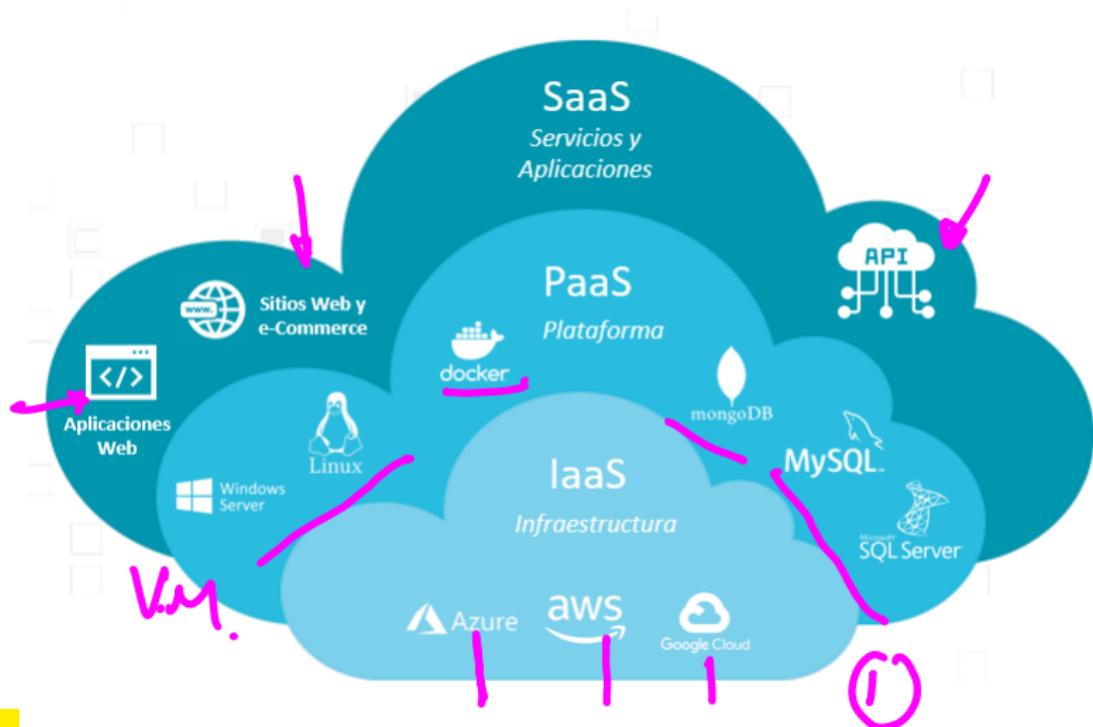
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Docker - K8s
Artifacts
ML/AI



Cloud Levels



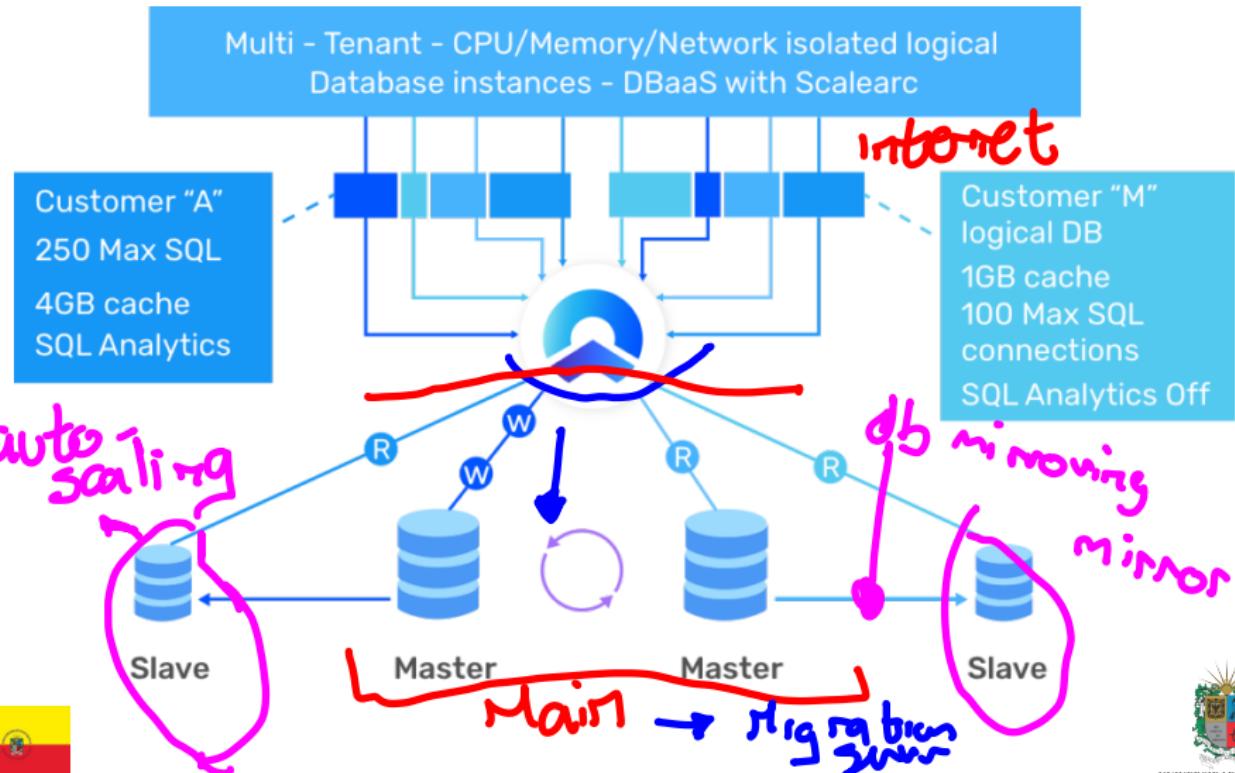
DataBases as a Service

Database as a Service (DBaaS) is a cloud computing model that provides database services over the internet.

- ① DBMS { NoSQL } ready to use
- ② Security : Firewall, Duty, Logs, Policies
- ③ Migration (Snowball → mobile)

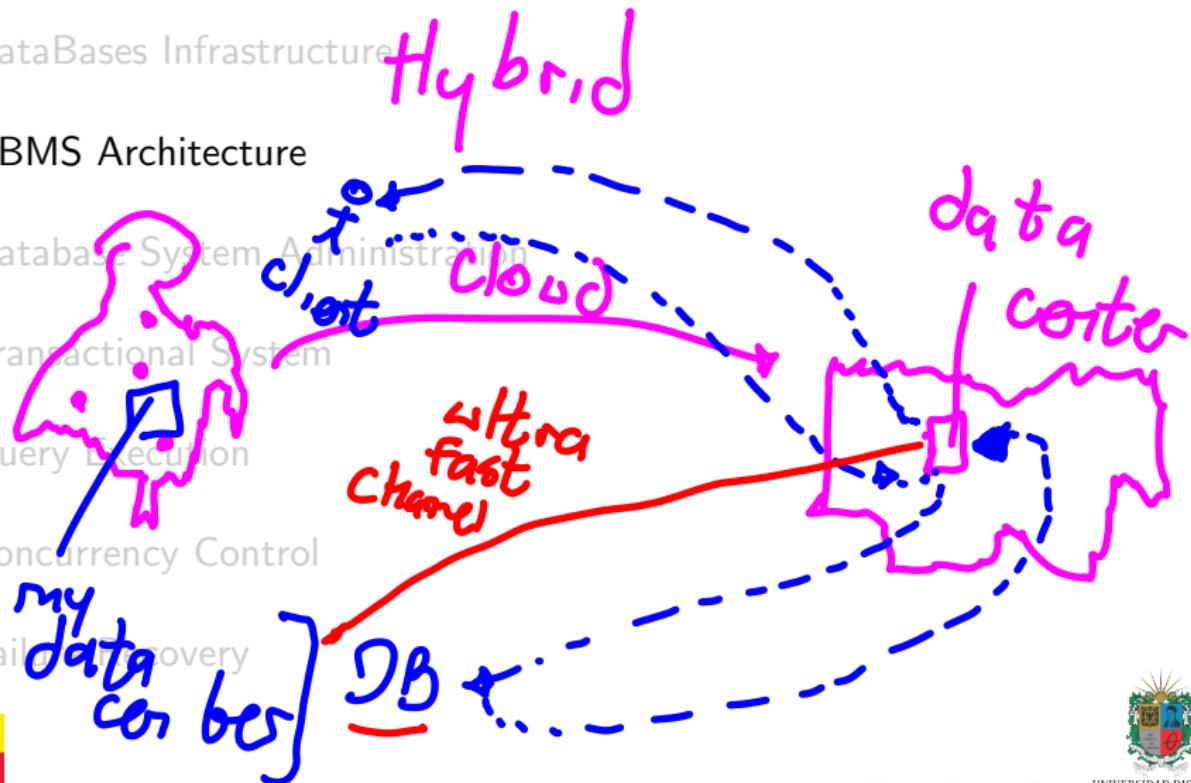


Case Study: DBaaS Custom for Clients



Outline

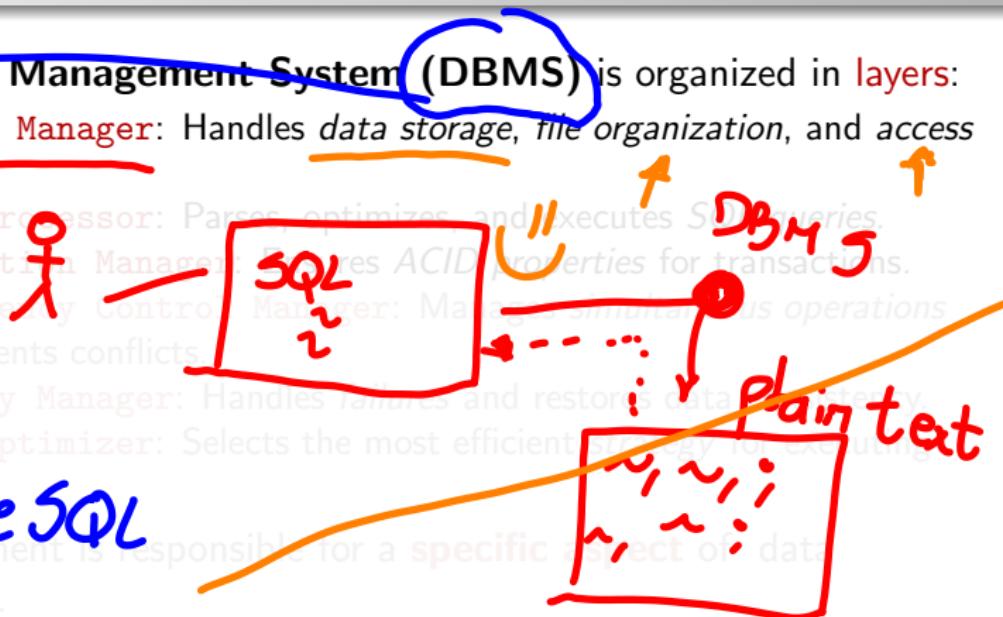
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DBMS Architecture Overview

- A Database Management System (DBMS) is organized in layers:
 - Storage Manager:** Handles data storage, file organization, and access methods.
 - Query Processor:** Parses, optimizes, and executes SQL queries.
 - Transaction Manager:** Ensures ACID properties for transactions.
 - Concurrency Control Manager:** Manages simultaneous operations and prevents conflicts.
 - Recovery Manager:** Handles failures and restores data integrity.
 - Optimizer:** Selects the most efficient query execution plan for executing queries.

MySQL
PostgreSQL
Oracle



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 - Query Optimizer: Selects the most efficient *strategy for executing queries.*
- Each component is responsible for a *specific aspect* of data management.

graph
Compiler
tree
language
to interact
with storage



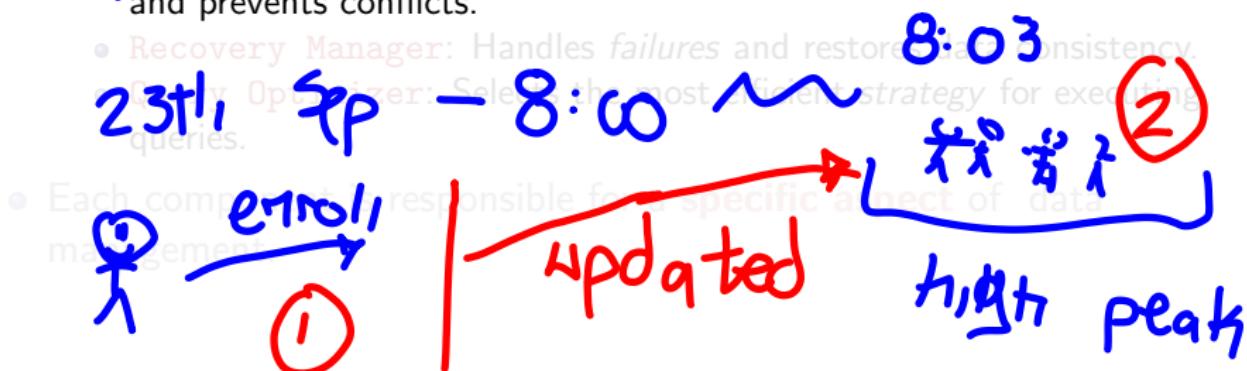
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- Each component is responsible for ~~specific aspect~~ *inherent* aspect of data management.

high level

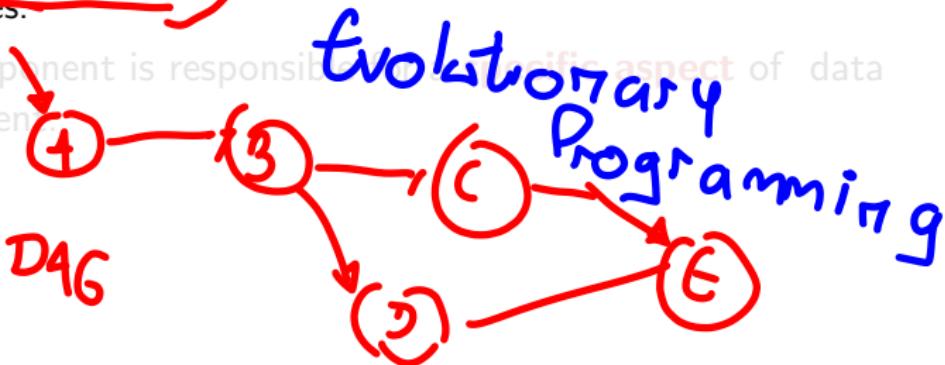
inherent

Backup



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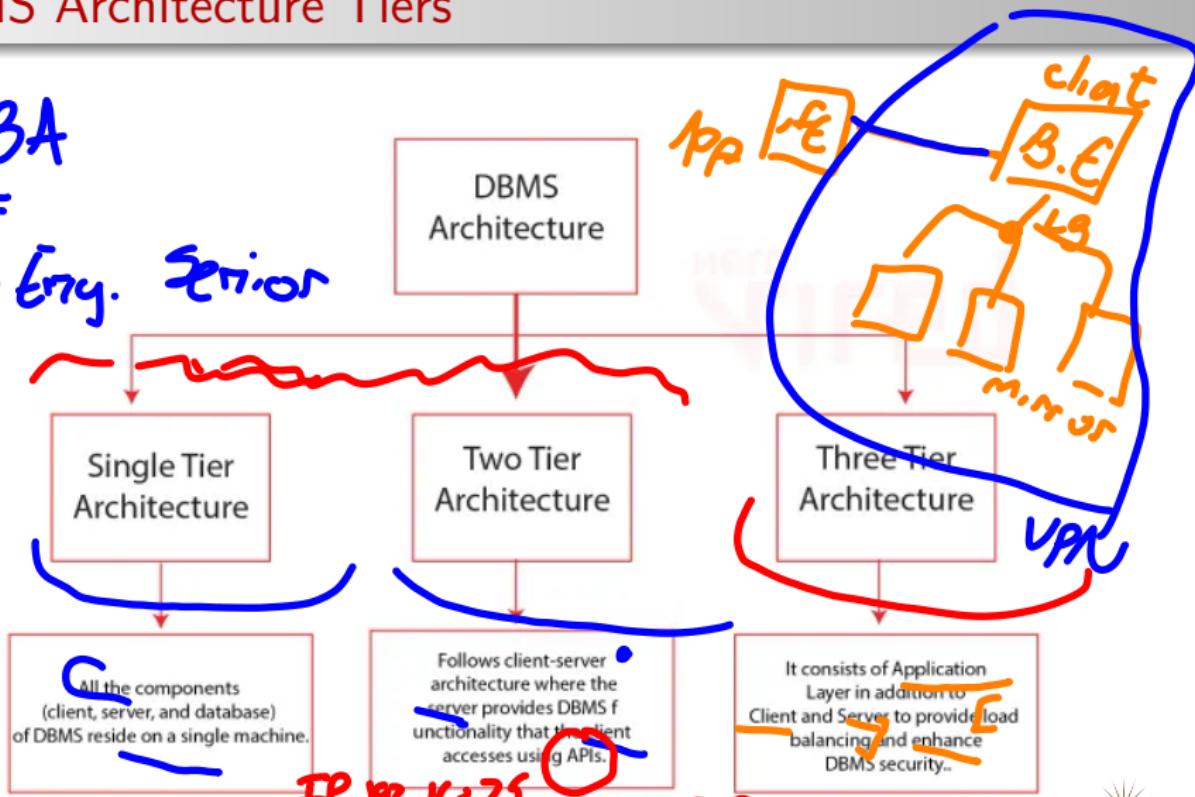
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all



DBMS Architecture Tiers

DBA
= Data Engr. Senior



DBMS Architecture N-Tier

DBMS Architecture



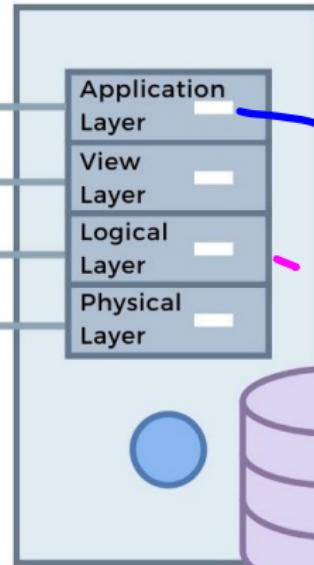
DatabaseTown.com

It is responsible for providing an interface for users.

It is responsible for managing the different views of the data in the database.

It is responsible for managing the logical organization of data in the database.

It is responsible for managing the physical storage of data on disk.



form (insert, update, delete)
GUI report
SQL query (SELECT)
component

Backend

Relational Algebra



Types of DBMS Architecture

There are several types of DBMS architectures:

- **Centralized DBMS:** All components are on a single server.
- Client-Server DBMS: Clients access the database through a server.
- Distributed DBMS: Data is distributed across multiple servers.
- Cloud DBMS: Database services are provided over the cloud.
- Hybrid DBMS: Combines features of centralized and distributed systems.
- Peer-to-Peer DBMS: Each node can act as a client and server.
- In memory DBMS: Data is stored in RAM for faster access.

1-tier
developers



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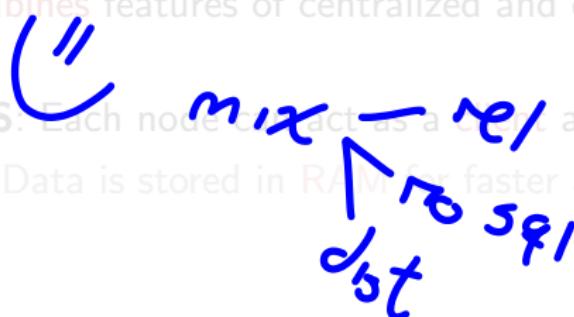
parallelism



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DB - 100-200ms

Cache - 5-10 ms

Cache
Lifetime (sec-min)

max 30
hours



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Database System Administration

- Database system administration is the discipline of managing, configuring, and maintaining database systems to ensure their reliability, performance, security, and availability.
- Key responsibilities include:
 - everything it works
 - memory processor time
 - profiling
 - grants
 - backups
 - accessible
 - scalability
- Database administrators (DBAs) are essential in modern organizations.



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- **Indexes**
- **Improve DB model**
- **Material Optimization**



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- Sync*
- replicas / only read*



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Plan

Backup and recovery

Security and access control

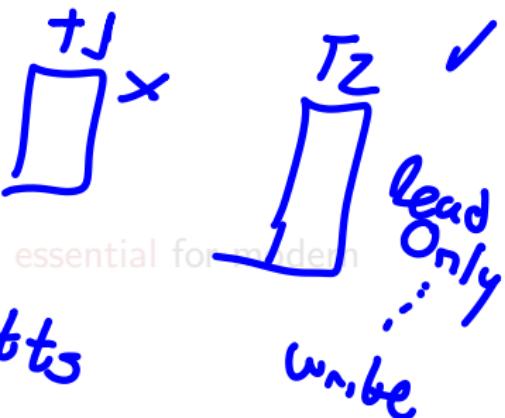
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today



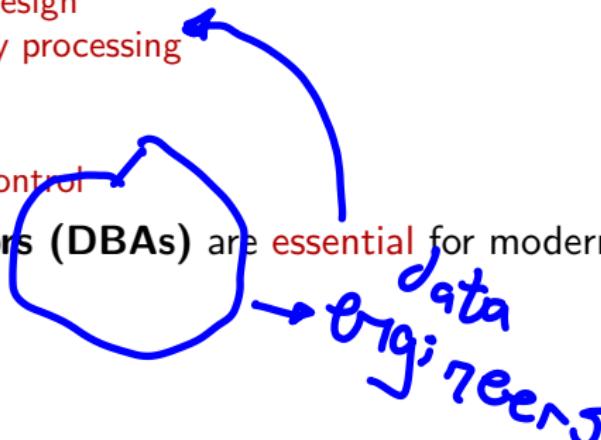
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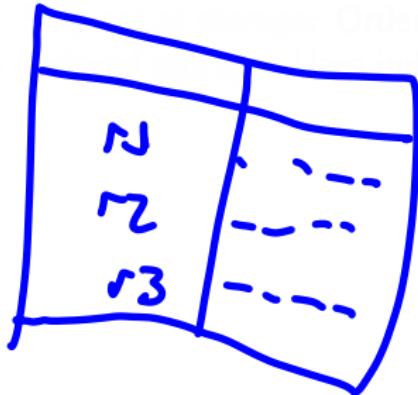
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Record Storage Concepts

- A **record** (or row/tuple) is the **basic unit** of data storage in a *database table*.
- Efficient record storage is crucial for fast data retrieval and update.
- Storage techniques

save variables



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 - Sequential storage: Ordered, fast range queries.
 - Hash indexes for fast lookups.



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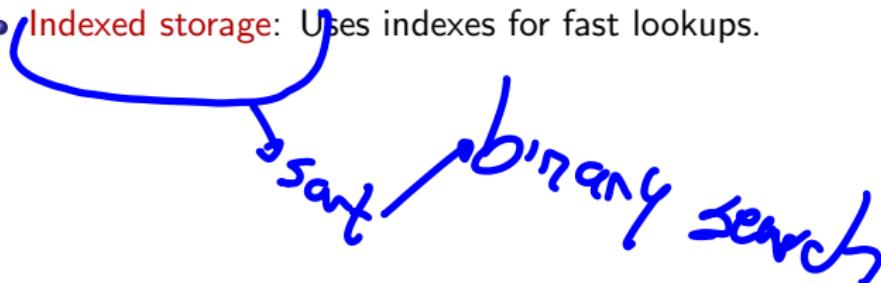
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say binary search



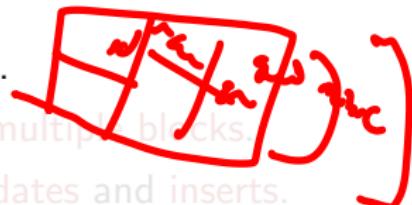
Block and Page Organization

- Data is stored in **blocks** (pages) on disk
- Block size and layout affect I/O performance.
- Records may be packed, slotted, or may span multiple blocks.
- Free space management is important for updates and inserts.
- Fragmentation management ensures efficient use of space.
- Data compression can also improve storage efficiency.



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Teacher

```

SELECT s.name career AS career, s.grade
FROM student AS s
JOIN career AS c
ON s.career_fk = c.id
ORDER BY s.grade DESC
OFFSET (n-1)*10
LIMIT 10;
    
```

Diagram illustrating the execution plan for the query:

The query is shown in pink ink. A red bracket on the right side groups the first two lines. An arrow points from this bracket to a red box containing a small table icon. Another arrow points from the word "grade" in the second line to a red box containing a small table icon with the numbers 1, 2, 3, ..., n.



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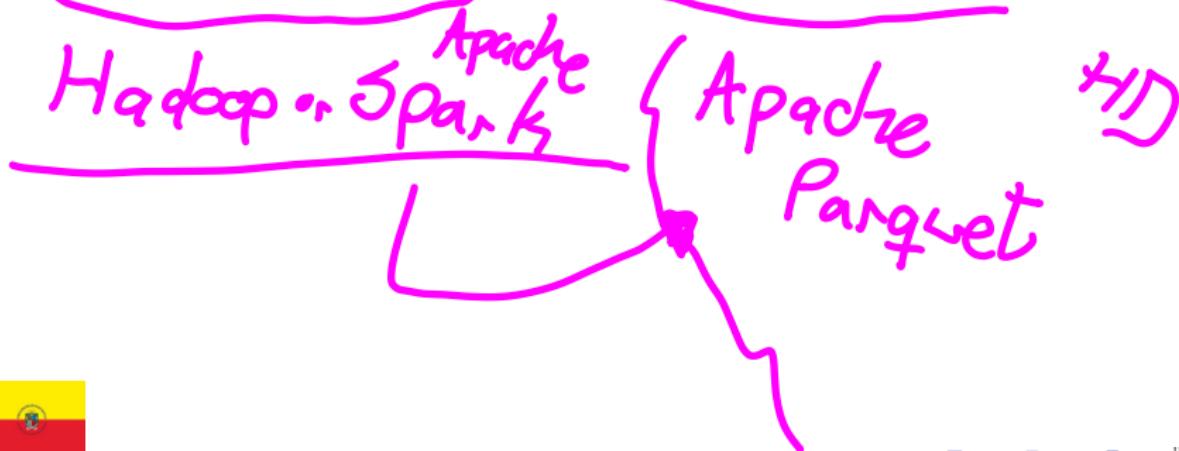
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Distrubuted
Data Sysem



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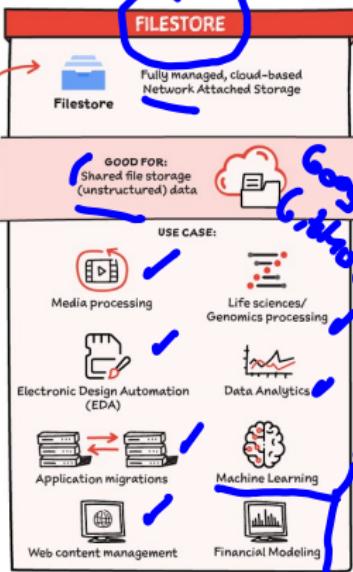
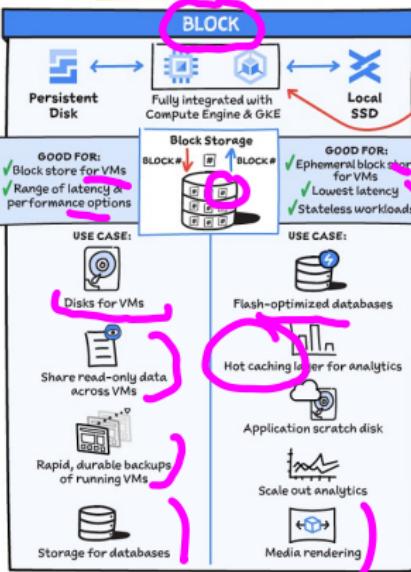
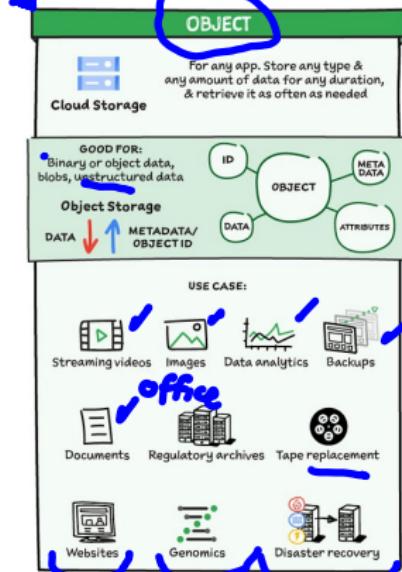


Record Storage: Use Cases

#GAPSketchnote
 @PVERGADIA
 THECLOUDGIRL.DEV
 04.23.2021



Which Storage Should I Use?



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Transactional System Concepts

- A **transaction** is a sequence of operations performed as a single logical unit of work.
- Transactions must satisfy the **ACID** properties:
 - **Atomicity**: All or nothing.
 - **Consistency**: Preserves database integrity.
 - **Isolation**: Transactions do not interfere.
 - **Durability**: Results persist after completion.

C
E
V
D

queue

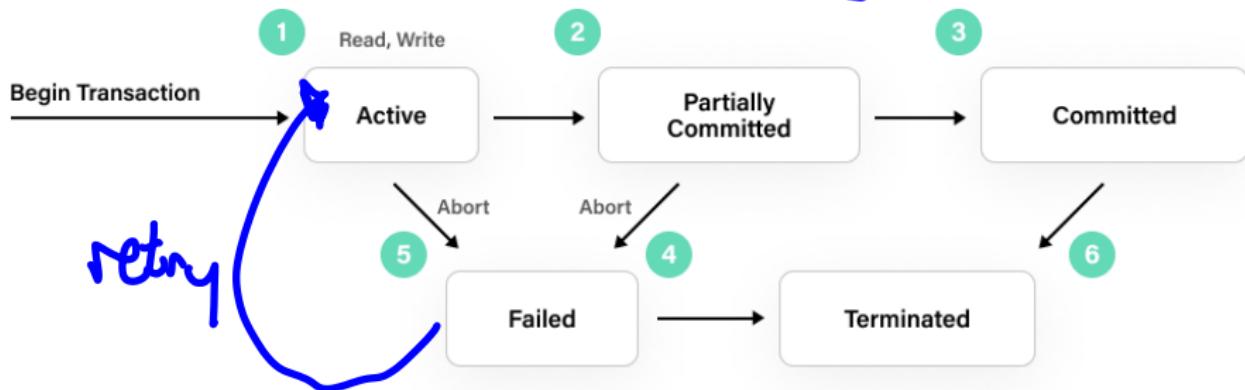
queries

concurrency



Transaction Lifecycle

- **Begin**: Transaction starts. → enter
- **Read/Write**: Operations are performed. → memory
- **Commit**: Changes are made permanent.
- **Rollback**: Changes are undone if an error occurs.
- **Savepoints** can be used for partial rollbacks.



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Query Execution Process

- **Query execution** is the process of **interpreting** and **running** database queries.
- Steps:
 - **Parsing:** Analyzing query **syntax**.
 - **Optimization:** Choosing the best execution plan.
 - **Execution:** Retrieving and processing data.
- **Efficient execution** is critical for **performance**.

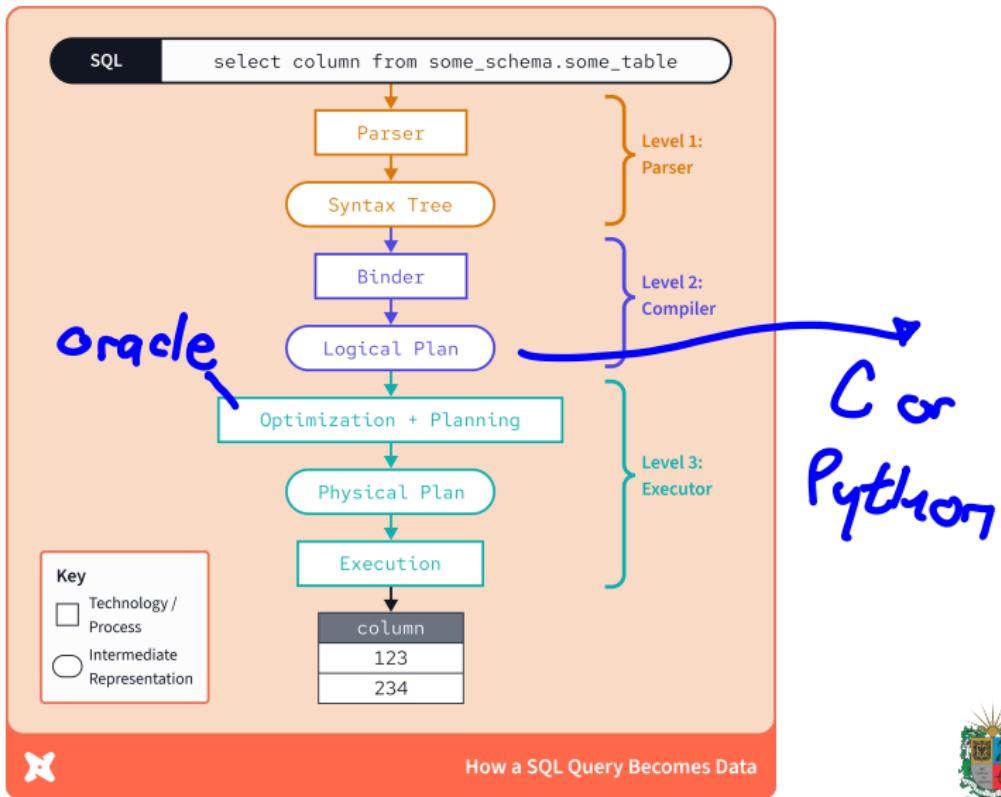
Snowflake

Compiler

SQL
functions
declarative



Query Execution Flow: Full Transaction



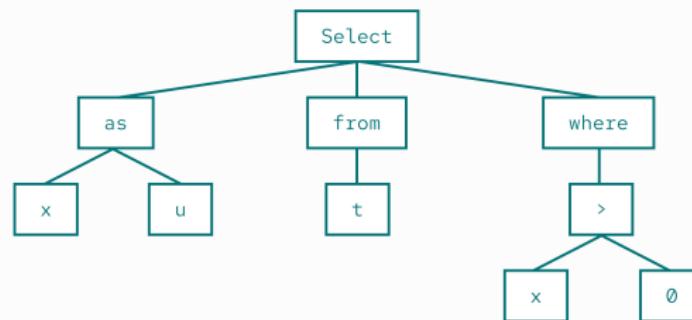
Query Execution Flow: Syntax Tree

SQL

select x as u from t where x > 0

Parser

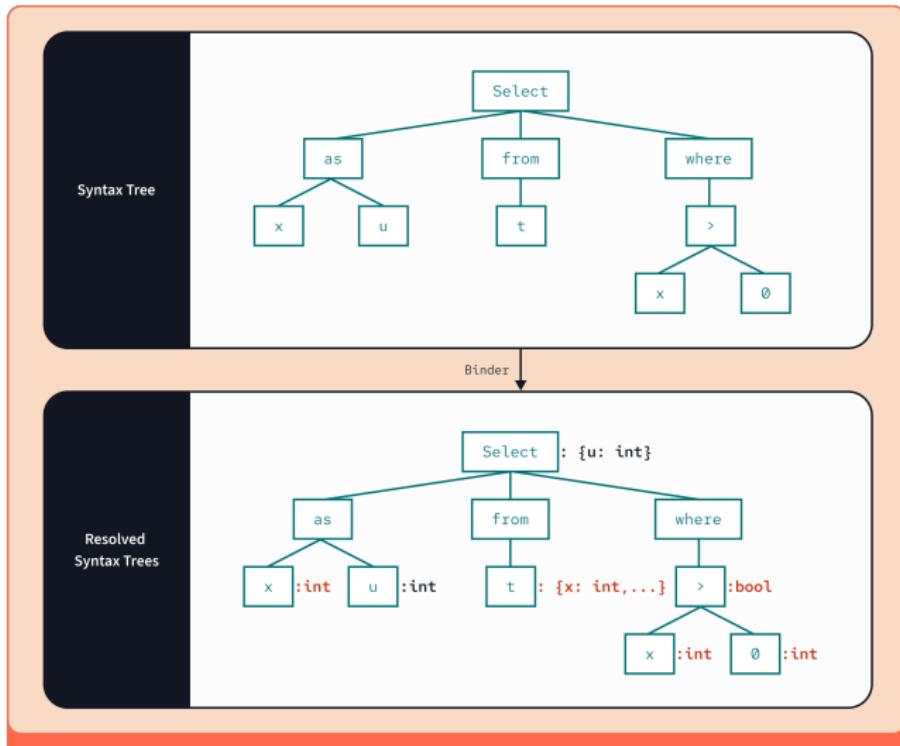
Syntax Tree



Parsers Recognize the Structure of the Query



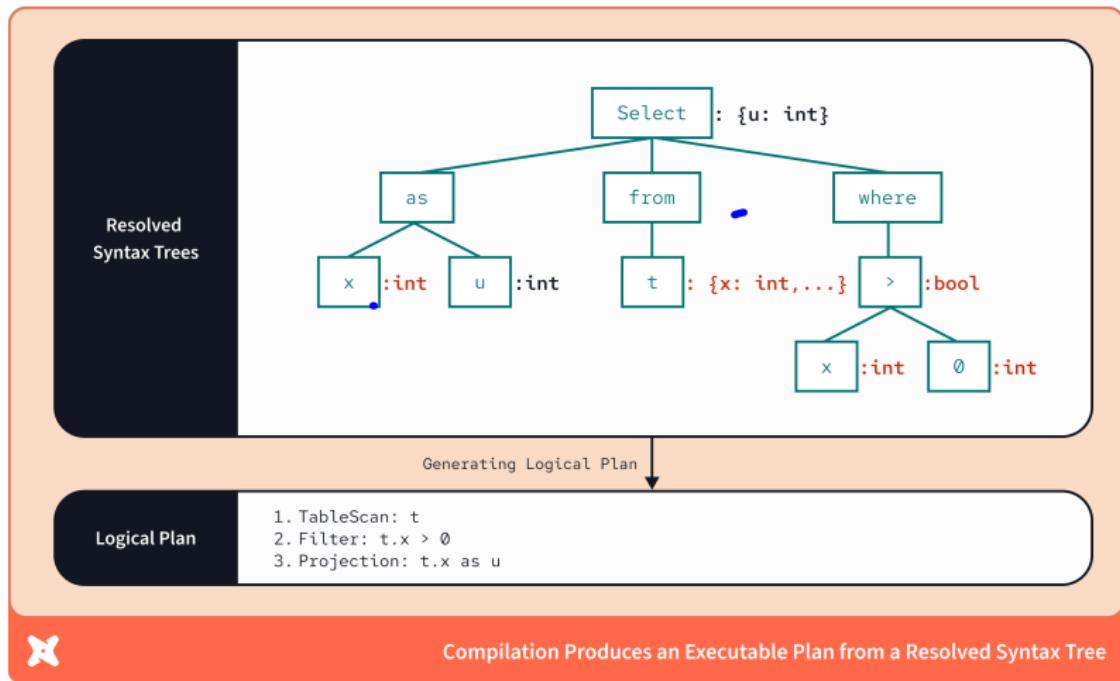
Query Execution Flow: Compilation



Binders Resolve Names and Check Types



Query Execution Flow: Logical Plan



Query Optimization

- The **query optimizer** selects the most efficient strategy for executing a query.
- Considers indexes, join methods, and data distribution.
- May rewrite queries for better performance.
- Cost-based and rule-based optimization approaches.



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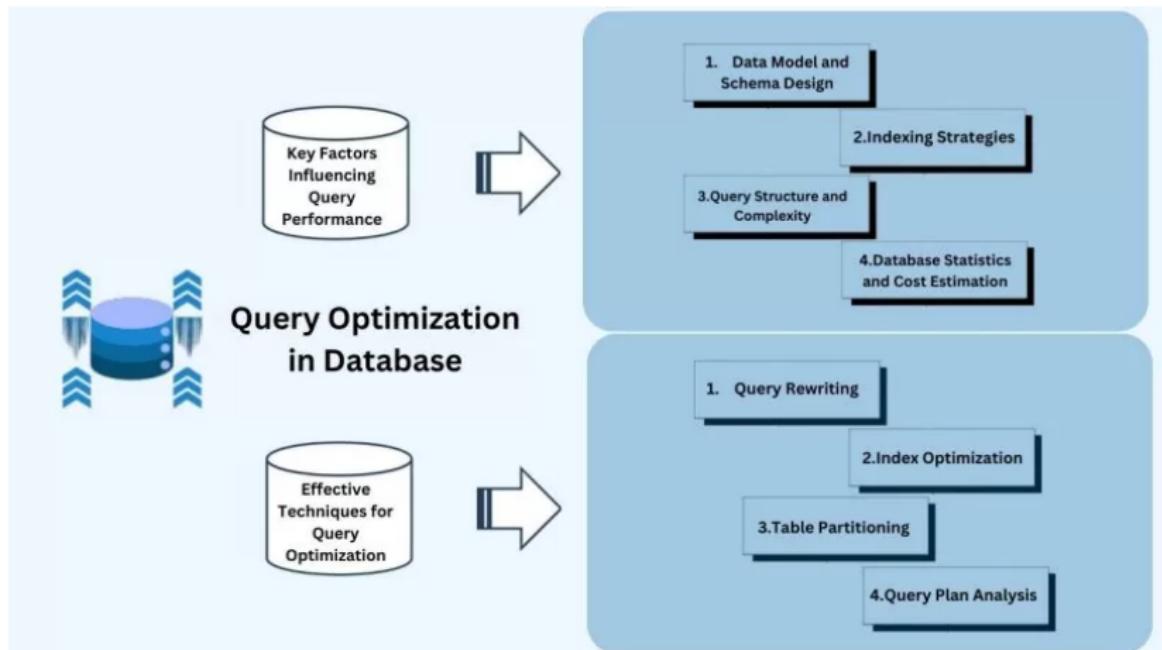


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Query Optimization Factors



Outline

- 1 DataBases Infrastructure
- 2 DBMS Architecture
- 3 Database System Administration
- 4 Transactional System
- 5 Query Execution
- 6 Concurrency Control
- 7 Failure Recovery



Concurrency Control Concepts

- **Concurrency control** ensures correct results when **multiple transactions** execute **simultaneously**.
- Prevents problems like **lost updates**, **dirty reads**, and **deadlocks**.
- Techniques:
 - Locking protocols: Use locks to control access (e.g., two-phase locking).
 - Timestamp ordering: Assigns timestamps to transactions.
 - Optimistic concurrency control: Assumes no conflicts.
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Locking and Deadlocks

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- Deadlocks occur when transactions **wait indefinitely** for each other.
- DBMS uses deadlock detection and **resolution strategies**.
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Failure Recovery Concepts

- **Failure recovery** restores the database to a **consistent state** after a failure.
- Types of failures:
 - Transaction failure: Only one transaction fails.
 - System crash: All active transactions are lost.
 - Media failure: Disk or storage device fails.
- Recovery techniques:
 - Write-ahead logging (WAL):
 - Log all changes made by transactions.
 - Log all changes made by the system.
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Thanks!

Questions?



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

