Concurrency Control Without Locking

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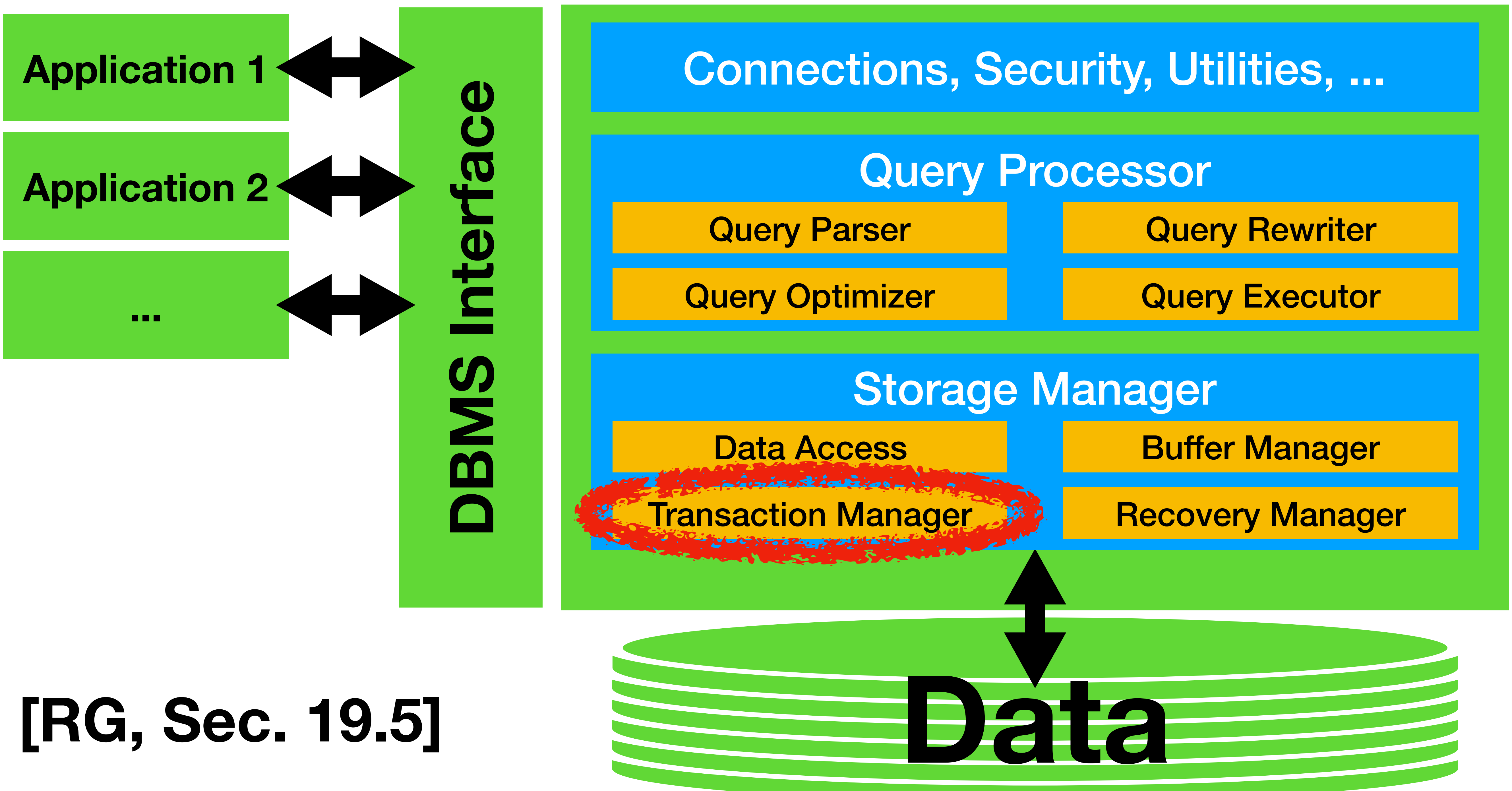
Database Management Systems (DBMS)



[RG, Sec. 19.5]

Outlook

- **Optimistic** concurrency control
- **Timestamp** concurrency control
- **Multi-version** concurrency control
- **Snapshot** isolation

Optimistic CC Motivation

- Locking itself leads to **overheads**
  - E.g., overheads due to **lock management**
  - Possibly overheads due to **deadlocks**
- Locking prevents conflicts **proactively**
  - **Pessimistic** assumption: conflicts are likely
- **Optimistic** concurrency control
  - Conflicts are **rare**, no need to avoid proactively

Optimistic CC Bookkeeping

- Need to keep read set and write set for each transaction
  - **Read set**: objects that the transaction read
  - **Write set**: objects that the transaction wrote

Execution Phases

- **Read**
  - **Read** relevant data from database
  - **Execute** transaction on private copy
- **Validate**
  - **Check** for conflicts with other transactions
- **Write**
  - **Publish** local changes if no conflicts

Validation Phase

- Assign transactions to unique **timestamps** at validation
  - Will try to **serialize** transactions in timestamp order
- Two transactions **cannot** have conflicted if
  - T1 completes **before** T2
  - T1 completes before T2 starts **writing**, Writes(T1) **disjunct** with Reads(T2)
  - T1 completes reads before T2 completes **reads**, Writes(T1) **disjunct** with Reads(T2) and Writes(T2)

Simplification: Combine Validation and Write Phase

- Only one transaction can be in **validation+write** phase
- Only need to consider conflict **cases 1 and 2**
  - Write phases **cannot** overlap

Optimistic CC Overheads

- Must **record** read and write sets
- Transaction **restarts** if validation fails
- **Critical** section during validation/writes

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Good if probability of conflicts is low

Timestamp CC Overview

- We associate transactions with **timestamps**
- Want to **serialize** transactions in timestamp order
- Also, we associate each **object** with timestamps
    - **Read timestamp**: time of last read
    - **Write timestamp**: time of last write

Timestamp CC Rules

- **TS(T)** is timestamp of transaction T
- **RTS(A)**, **WTS(A)**: read & write timestamp of object A
- Transaction T wants to **read** database object A
  - Abort & restart if **TS(T) < WTS(A)**
- Transaction T wants to **write** database object A
  - Abort & restart if **TS(T) < RTS(A)**
  - ***What if TS(T) < WTS(A) ... ?***

Thomas Write Rule

- Transaction T wants to **write A** but TS(T) < WTS(A)
- **Conflicts** with serialization order, could abort
- **Thomas Write Rule** ignores outdated writes instead
    - E.g., consider **R1(A) W2(A) C2 W1(A) C1**
    - Not conflict serializable but view-serializable
    - Simplifies to **R1(A) C2 W1(A) C1**

Timestamp CC Overheads

- **Restarting** overheads for aborted transactions
- Need to keep track of **object timestamps**
  - Means **space** consumption increases
  - Overheads for **updating timestamps**
    - **Requires write** for each operation

Multi-version CC (MVCC) Overview

- Idea: keep **multiple versions** of database objects
- Doing so **helps** for instance in the following situation
  - R1(A) W1(A) R2(A) **W2(B)** **R1(B)** W1(C)
  - Not conflict-serializable as written
  - Could fix by moving **R1(B)** before **W2(B)**
  - Making **R1(B)** read old version of B has same effect

MVCC Protocol

- Each transaction receives **timestamp** when entering
  - Will try to **serialize** transactions in this order
- Each **write** creates a new version of an object
  - Perform **write check** and abort if not valid
  - Version has **timestamp** of writing transaction
- **Read** mapped to last version before transaction timestamp
  - Transaction with timestamp i reads version with **largest timestamp k such that k<i**

Write Check

- Want to be **consistent** with transaction timestamps
- Can transaction with timestamp I **write object A**?
  - Assume transaction with **timestamp > I**
  - Cannot read **earlier** version of A than I
  - Must **abort** if this has already happened
    - Track **read timestamps** for versions!

Abort-Related Behavior

- Aforementioned protocol guarantees **serializability**
- Need additional mechanisms for **abort** properties
- E.g., delay commits for **recoverability**

Snapshot Isolation Overview

- Each transaction operates on database **snapshot**
- This snapshot is taken once transaction **starts**
  - Uses last **committed** value for each object
- Maintains multiple object **versions** internally
  - Different from MVCC: **no uncommitted** values

Handling Writes

- Check before commit for **overlapping writes**
- Everything OK if target objects **unchanged**
- Otherwise **abort** & restart transaction

Example with SI

- Consider **tables A and B** with one integer column each
- Consider **two transactions** that execute one update each
  - T1: **Insert into B select count(*) from a;**
  - T2: **Insert into A select count(*) from b;**
- ***What happens if both transaction start at same time?***
  - *Is the result equivalent to a serial execution?*

Write Skew

T1: Insert into B select count(*) from A;
T2: Insert into A select count(*) from B;

Execution	Content of A	Content of B
T1; T2	1	0
T2; T1	0	1
Snapshot Isolation	0	0

Serializability vs. SQL Definition

- SQL-92 standard defines isolation via **anomalies**
- The write skew anomaly is missing, drawing **criticism**
- Careful, may get SI when choosing serializable isolation