THE UNIVERSITY of EDINBURGH

Advanced Database Systems

Spring 2025

Lecture #19:

Locking

R&G: Chapters 16 & 17

1

Query Scheduler

How to guarantee only serializable schedules in DBMS?

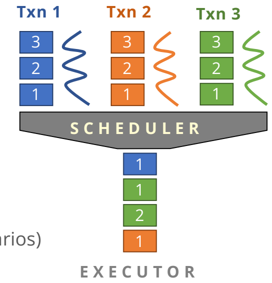
- Problem: user does not need to specify the full transaction at once
- Goal: build a query scheduler that always emits serializable schedules

Pessimistic (locking)

- Use locks to protect database objects
- Standard approach if conflicts are frequent

Optimistic (versioning)

- Record changes for each txn individually
- Validate and possibly rollback on commit
- Used if conflicts are rare (e.g., write-once-read-many scenarios)



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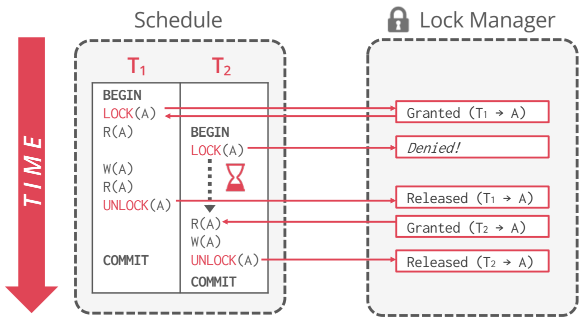
Executing with Locks



3

Executing with Locks

Basic lock types:

- **S-LOCK**: Shared locks for reads
- **X-LOCK**: Exclusive locks for writes

Compatibility Matrix

	Shared	Exclusive
Shared	✓	✕
Exclusive	✕	✕

Steps:

- Transactions request locks (or upgrades) before accessing objects
- Lock manager grants or blocks requests
- Transactions release locks
- Lock manager updates its internal lock-table

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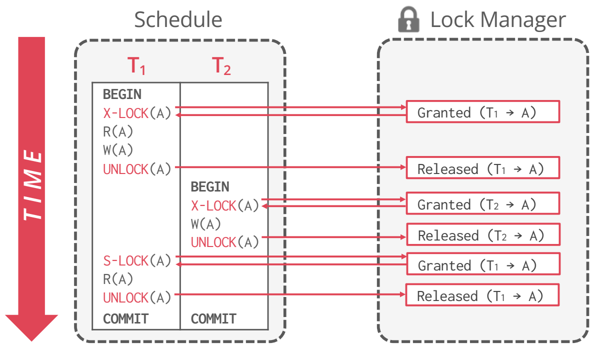
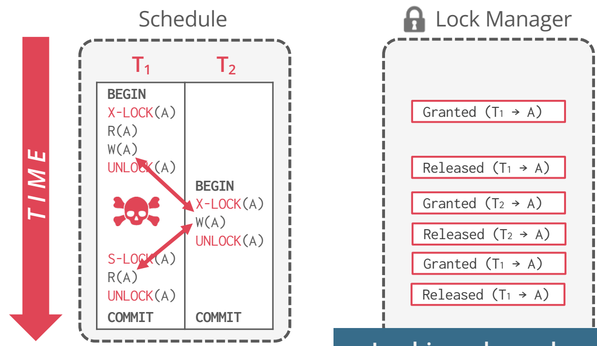
Executing with Locks



Executing with Locks



Not serializable

Locking alone does not enforce serializable schedules

Two-Phase Locking

Locks + concurrency control protocol

- Determines if a txn is allowed to access an object in the database on the fly
- Does not need to know all of the queries that a txn will execute ahead of time

Phase 1: Growing

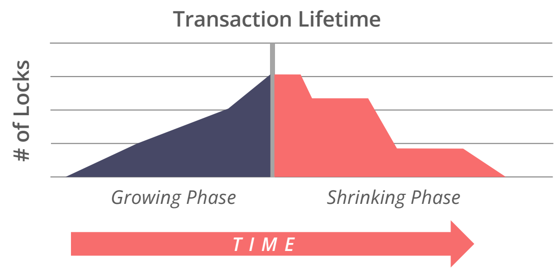
- Each txn requests the locks that it needs from the lock manager
- The lock manager grants/denies lock requests

Phase 2: Shrinking

- The txn is allowed to only release locks that it previously acquired
- It cannot acquire new locks

Two-Phase Locking

The transaction is not allowed to acquire/upgrade locks after the growing phase finishes



Two-Phase Locking

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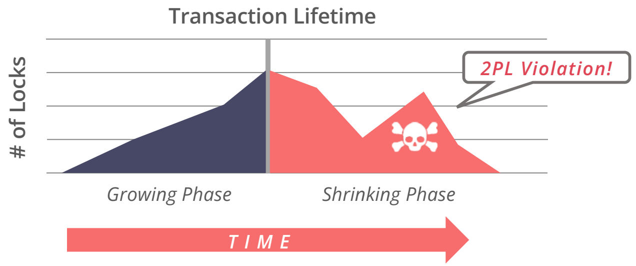
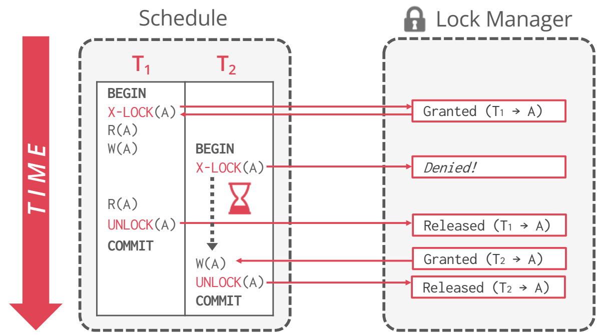


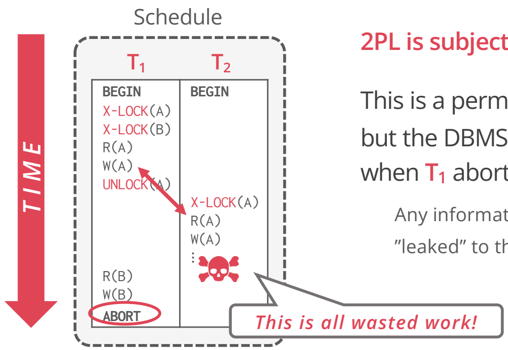
Executing with Locks



2PL is sufficient to guarantee conflict-serializability

(generates schedules whose precedence graph is acyclic)

2PL – Cascading Aborts



2PL is subject to cascading aborts

This is a permissible schedule in 2PL but the DBMS has to also abort T_2 when T_1 aborts

- Any information about T_1 cannot be "leaked" to the outside world

2PL Observations

There are schedules that are serializable but not be allowed by 2PL

- Locking limits concurrency

May require cascading aborts

- **Solution:** Strict 2PL

May still have "dirty reads"

- **Solution:** Strict 2PL

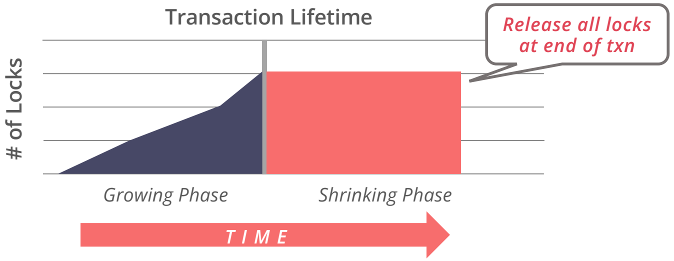
May lead to deadlocks

- **Solution:** Detection or Prevention

Strict Two-Phase Locking

The txn is not allowed to acquire/upgrade locks after the growing phase finishes

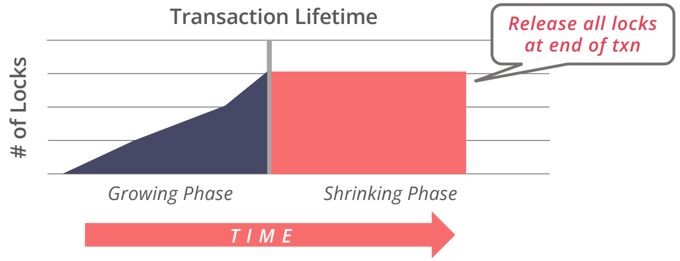
Allows only conflict-serializable schedules, but it is often stronger than needed for some applications



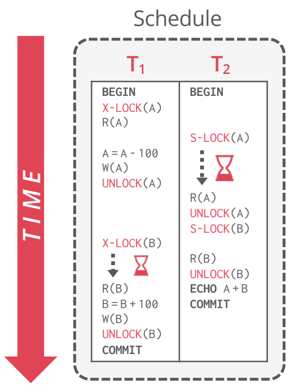
Strict Two-Phase Locking

Advantages:

- Does not incur cascading aborts
- Aborted txns can be undone by just restoring original values of modified tuples



Non-2PL Example



T_1 – move £100 from account A to account B

T_2 – compute the total amount in all accounts and return it to the application

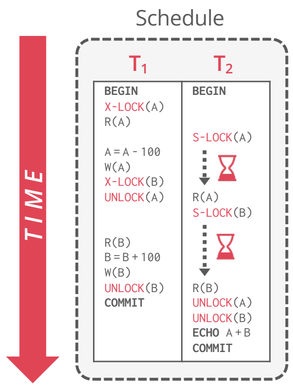
Initial Database State

A = 1000, B = 1000

T_2 Output

A + B = 1900

2PL Example



T_1 – move £100 from account A to account B

T_2 – compute the total amount in all accounts and return it to the application

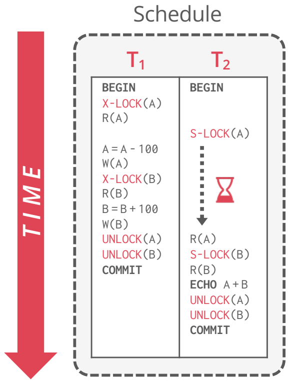
Initial Database State

A = 1000, B = 1000

T_2 Output

A + B = 2000

Strict 2PL Example



T_1 – move £100 from account A to account B

T_2 – compute the total amount in all accounts and return it to the application

Initial Database State

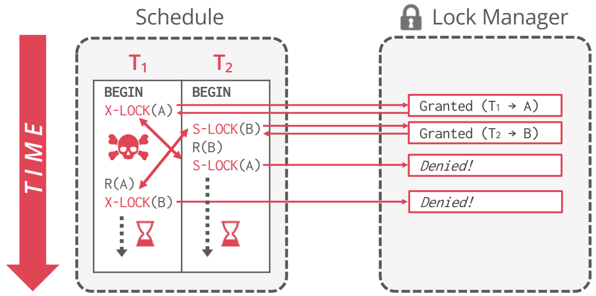
A = 1000, B = 1000

T_2 Output

A + B = 2000

Scheduling: Deadlocks

Two-phase locking has the risk of **deadlock situations**



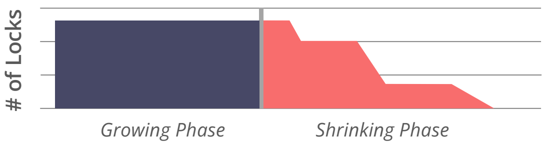
2PL Deadlocks

Deadlock = a cycle of txns waiting for locks to be released by each other

Two ways of dealing with deadlocks:

- Deadlock Detection
- Deadlock Prevention

Conservative (or "preclaiming") 2PL also prevents deadlocks. Why?



Deadlock Detection

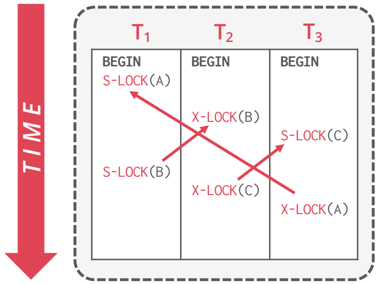
The DBMS creates a **waits-for** graph to keep track of what locks each transaction is waiting to acquire:

- Nodes are transactions
- Edge from T_i to T_j if T_i is waiting for T_j to release a lock

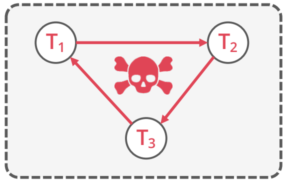
The system periodically checks for cycles in waits-for graph and then make a decision on how to break it

Deadlock Detection

Schedule



Waits-For Graph



Deadlock Handling

Upon detecting a deadlock, the DBMS selects a "**victim**" transaction to rollback to break the cycle

- Selecting a "victim" transaction might depend on:
  - age (lowest timestamp)
  - progress (least/most executed queries)
  - # of items already locked
  - # of txns that we have to rollback with it
  - # of previous restarts (to prevent starvation)

There is a trade-off between the frequency of checking for deadlocks and how long transactions have to wait before deadlocks are broken

Deadlock Prevention

When a transaction tries to acquire a lock that is held by another transaction, kill one of them to prevent a deadlock

No waits-for graph or detection algorithm

Assign **priorities** based on timestamps

- Older ⇒ higher priority (e.g., $T_1 > T_2$)

Two deadlock prevention policies:

- **Wait-Die** ("Old Waits for Young")
- **Wound-Wait** ("Young Waits for Old")

Deadlock Prevention

Wait-Die ("Old Waits for Young")

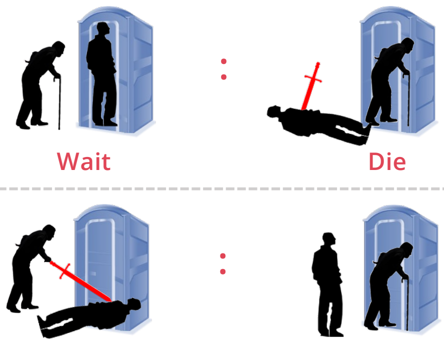
- If *requesting* txn has higher priority than *holding* txn
- Then *requesting* txn **waits** for *holding* txn
- Else *requesting* txn **aborts**

Wound-Wait ("Young Waits for Old")

- If *requesting* txn has higher priority than *holding* txn
- Then *holding* txn **aborts** and releases locks
- Else *requesting* txn **waits**

Deadlock Prevention

$T_{req} > T_{hold}$? Wait : Die



$T_{req} > T_{hold}$? Wound : Wait

Deadlock Prevention

T_1	T_2
BEGIN	
	BEGIN
	X-LOCK(A)
X-LOCK(A)	⋮
⋮	

Wait-Die: T_1 waits

Wound-Wait: T_2 aborts

T_1	T_2
BEGIN	
X-LOCK(A)	
⋮	
	BEGIN
	X-LOCK(A)
	⋮

Wait-Die: T_2 aborts

Wound-Wait: T_2 waits

Deadlock Prevention

Why do these schemes guarantee no deadlocks?

Only one "type" of direction allowed when waiting for a lock

When a transaction restarts, what is its (new) priority?

Its original timestamp. Why?

Summary

ACID Transactions

- **A**tomicity: All or nothing
- **C**onsistency: Only valid data
- **I**solation: No interference
- **D**urability: Committed data persists

Concurrency Control

- Prevent anomalous schedules
- Locks + protocol (2PL, Strict 2PL) guarantees conflict serializability
- Deadlock detection and deadlock prevention

Serializability

- Serializable schedules
- Conflict & view serializability
- Checking for conflict serializability