Distributed Transactions

Presented By:

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What is a Transaction?

- An execution of a program that accesses a shared database.
- Consists of an *ordered* set of operations that must be executed in sequence.
- Has to be executed atomically:
  - Each transaction accesses shared data without interfering with other transactions.
  - If a transaction terminates normally, then all of its effects are made permanent; otherwise it has no effect at all.

The Problem

- Due to their being non-atomic by nature, concurrent execution of transactions can cause *interference*.
- Interference can lead to *inconsistency*, rendering the DBMS unreliable for data storage!
- Solution: Concurrency control.
  - The activity of coordinating the actions of processes that operate in parallel, access shared data, and therefore potentially interfere with each other.

The Goal of Concurrency Control

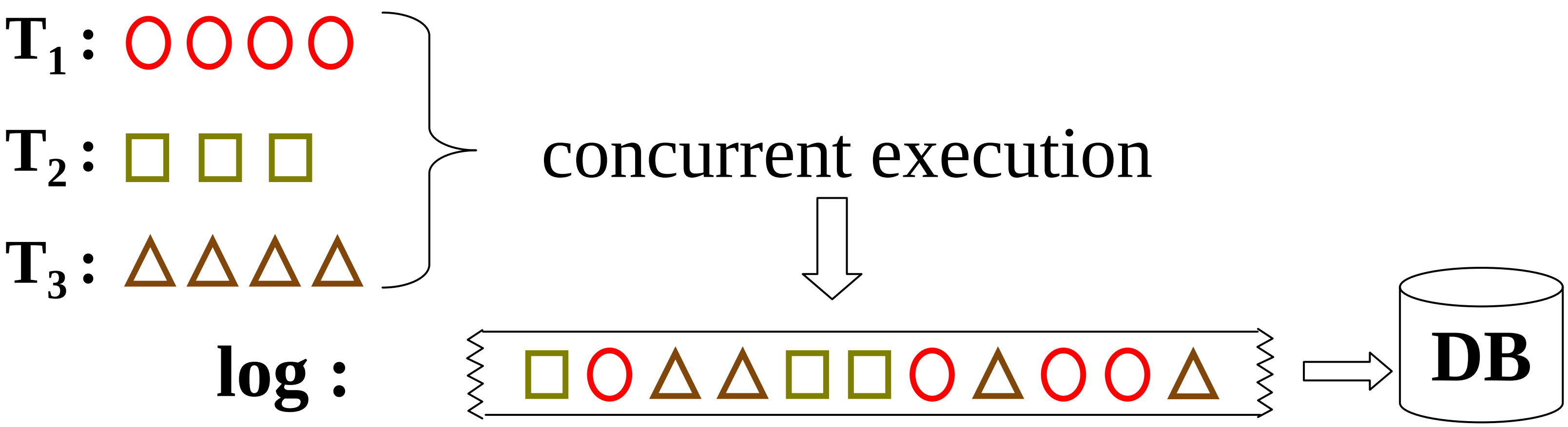
Maximizing throughput without compromising consistency.

- Unsupervised concurrency achieves high throughput, but also causes high contention → Consistency is lost.
- Absence of concurrency achieves consistency, but also eliminates sharing → Worst throughput.
- We need to find a point in-between where we can achieve:
  - Concurrent execution.
  - Final effect same as *some* sequential execution.

Serializability

- The DBMS interleaves the execution of operations from different transactions.
- It doesn't (and needn't) make any promises about the order in which different transactions will execute relative to each other.
- We can broaden the class of allowable executions to include executions that have the same effect as a serial ones.
- Such executions are called *serializable*.
- Since they have the same effect as serial executions, serializable executions are correct.

Serializability



DB is consistent if it is guaranteed to have resulted from any one of:

T_1	T_2	T_3
T_2	T_1	T_3
T_2	T_3	T_1
T_1	T_3	T_2
T_3	T_1	T_2
T_3	T_2	T_1

Serializability

Consider these two transactions:

T_1: $R_1(Z)\ W_1(Y)\ W_1(X)$ T2: $W_2(Y)\ W_2(Z)\ R_2(X)$

Is this execution log serializable?

L: $R_1(Z)\ W_1(Y)\ W_2(Y)\ W_2(Z)\ R_2(X)\ W_1(X)$

Serializability

S_1: $R_1(Z)\ W_1(Y)\ W_1(X)\ W_2(Y)\ W_2(Z)\ R_2(X)$

read source conflict

L: $\mathbf{R_1(Z)\ W_1(Y)\ W_2(Y)\ W_2(Z)\ R_2(X)\ W_1(X)}$

last write conflict

S_2: $W_2(Y)\ W_2(Z)\ R_2(X)\ R_1(Z)\ W_1(Y)\ W_1(X)$

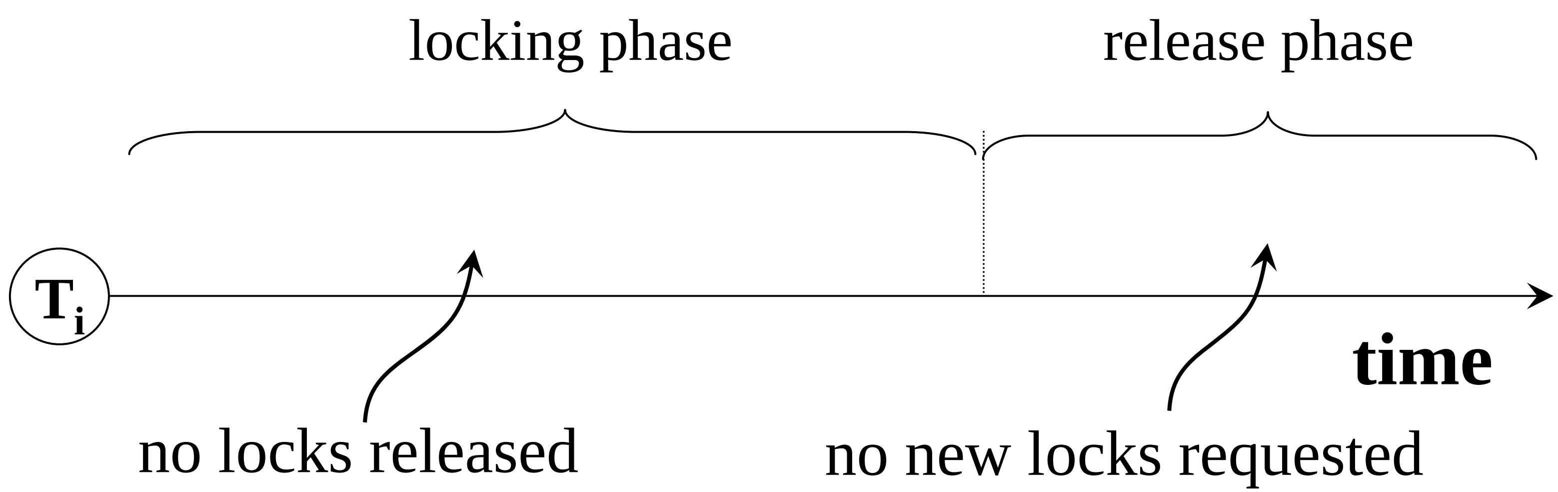
Scheduling

- The DBMS's scheduler restricts the order in which transactional operations are executed.
- The goal is to order these operations so that the resulting execution is serializable.
- Each data item has a *lock* associated with it.
- The scheduler utilizes a protocol for executing, rejecting, or delaying an operation according to lock states.

	Current lock state		
Lock Request	Not locked	READ locked	WRITE locked
READ	OK	OK	DENY (=defer)
WRITE	OK	DENY (=defer)	DENY (=defer)

Two Phase Locking (2PL)

- 2PL is a locking protocol that guarantees serializability.
- Consists of three rules:
  - On receiving a conflicting operation, delay the requesting transaction until the requested lock is released then assign the lock to it.
  - A lock is never released until its associated operation is processed.
  - Once the scheduler has released a lock for a transaction, it may not subsequently obtain any more locks for that transaction (on any data item).

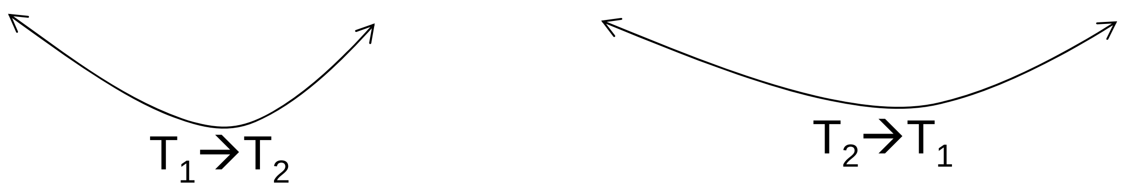


Two Phase Locking (2PL)

- Rule (1) prevents two transactions from concurrently accessing a data item in conflicting modes.
- Rule (2) ensures that the DM processes operations on a data item in the order that the scheduler submits them.
- Rule (3) guarantees that all pairs of conflicting operations of two transactions are scheduled in the same order.

$$T_1: r_1[x] \rightarrow w_1[y] \rightarrow c_1 \qquad T_2: w_2[x] \rightarrow w_2[y] \rightarrow c_2$$

$$L_1: rl_1[x]\ r_1[x]\ ru_1[x]\ wl_2[x]\ w_2[x]\ wl_2[y]\ w_2[y]\ wu_2[x]\ wu_2[y]\ c_2\ wl_1[y]\ w_1[y]\ wu_1[y]\ c_1$$



$$L_2: rl_1[x]\ r_1[x]\ wl_1[y]\ w_1[y]\ c_1\ ru_1[x]\ wu_1[y]\ wl_2[x]\ w_2[x]\ wl_2[y]\ w_2[y]\ c_2\ wu_2[x]\ wu_2[y]$$

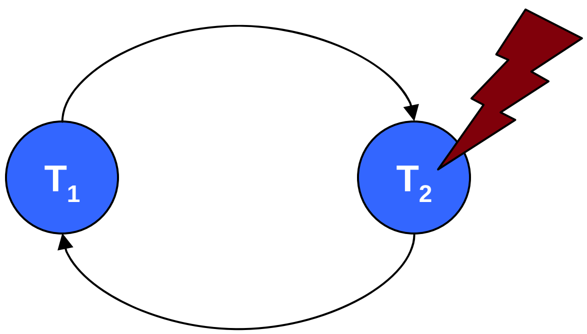
Two Phase Locking (2PL)

- Deadlocks still can happen:

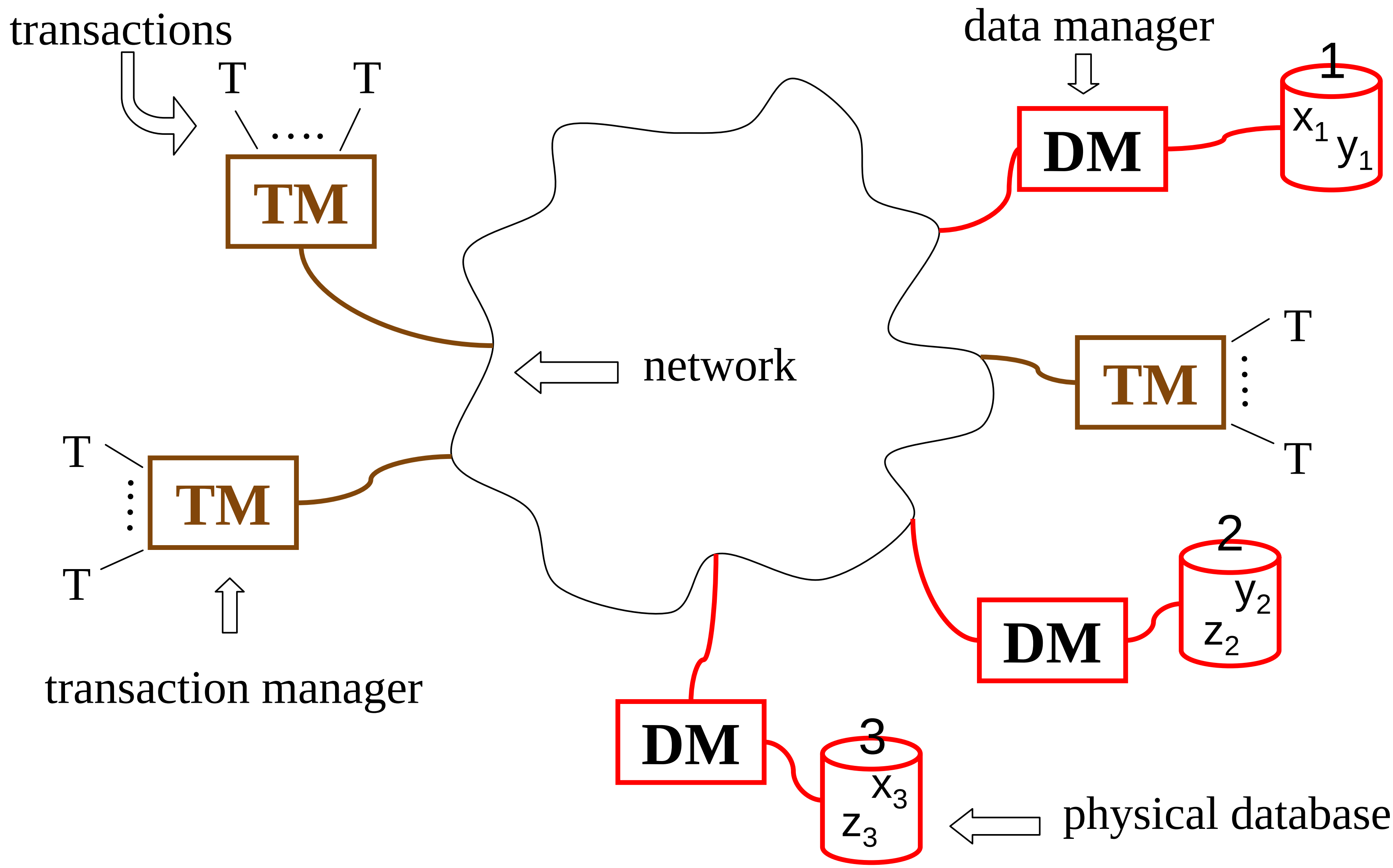
T_1: $w_1[x] \rightarrow w_1[y] \rightarrow c_1$ T_2: $w_2[y] \rightarrow w_2[x] \rightarrow c_2$

L_1: $wl_1[x]\ w_1[x]\ wl_2[y]\ w_2[y]$ …?

- The scheduler constructs a waits-for graph (WFG), where deadlocks appear as cycles.
- To resolve a deadlock, a *victim* transaction is selected and is forced to abort.



Distributed DBMS Model



Serialization of Distributed Logs

- Two operations $P_j(A_X)$ and $Q_i(B_Y)$ conflict if all of the following apply:
  - P and Q are not both READ *(concurrent READs never conflict)*
  - A = B *(both access the same record)*
  - i != j *(they belong to different transactions)*
  - X = Y *(both appear in the same log)*

- **Theorem**: *Distributed logs are serializable if there exists a total ordering of the transactions such that for conflicting operations P_j and Q_i a log shows $P_j \rightarrow Q_i$ only if $T_j \rightarrow T_i$*

Distributed Transaction Processing

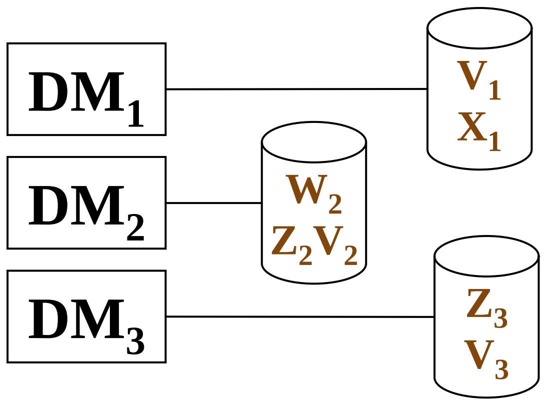
Transactions:

T_1 : WRITE(V);

T_2 : READ(X); WRITE(Z);

T_3 : READ(W); WRITE(V); READ(Z);

T_4: READ(V); READ(Z);



Logs:

L_1: $R_4(V_1)$ $W_3(V_1)$ $R_2(X_1)$ $W_1(V_1)$

L_2: $R_3(W_2)$ $W_3(V_2)$ $R_1(W_2)$ $W_1(Z_2)$ $W_1(V_2)$ $W_2(Z_2)$

L_3: $R_3(Z_3)$ $W_3(V_3)$ $R_1(V_3)$ $R_4(Z_3)$ $W_1(V_3)$ $W_2(Z_3)$

Are these logs equivalent to some serial execution of the transactions?

Serialization of Distributed Logs

<u>Conflict:</u> $P_j(A_X)$ and $Q_i(B_Y)$ conflict if

(1) P and Q are not both READ, and

(2) A = B, and

(3) $i \neq j$, and

(4) X = Y

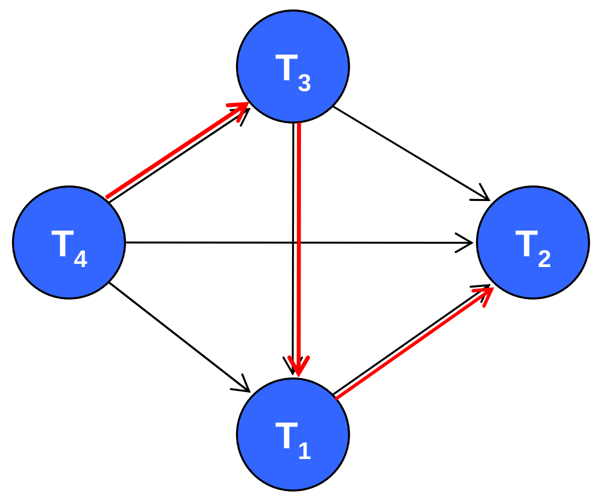
L_1: $R_4(V_1)$ $W_3(V_1)$ $R_2(X_1)$ $W_1(V_1)$

L_2: $R_3(W_2)$ $W_3(V_2)$ $R_1(W_2)$ $W_1(Z_2)$ $W_1(V_2)$ $W_2(Z_2)$

L_3: $R_3(Z_3)$ $W_3(V_3)$ $R_1(V_3)$ $R_4(Z_3)$ $W_1(V_3)$ $W_2(Z_3)$

Serializability Graph

a) $R_4(V_1) \rightarrow W_3(V_1)$ $[T_4 \rightarrow T_3]$
b) $R_4(V_1) \rightarrow W_1(V_1)$ $[T_4 \rightarrow T_1]$
c) $W_3(V_1) \rightarrow W_1(V_1)$ $[T_3 \rightarrow T_1]$
d) $W_3(V_2) \rightarrow W_1(V_2)$ $[T_3 \rightarrow T_1]$
e) $W_1(Z_2) \rightarrow W_2(Z_2)$ $[T_1 \rightarrow T_2]$
f) $R_3(Z_3) \rightarrow W_2(Z_3)$ $[T_3 \rightarrow T_2]$
g) $W_3(V_3) \rightarrow R_1(V_3)$ $[T_3 \rightarrow T_1]$
h) $W_3(V_3) \rightarrow W_1(V_3)$ $[T_3 \rightarrow T_1]$
i) $R_4(Z_3) \rightarrow W_2(Z_3)$ $[T_4 \rightarrow T_2]$



Graph is cycle free → Serializable