Outline

- Introduction
- Background
- Distributed DBMS Architecture
- Distributed Database Design
- Distributed Query Processing
- Distributed Transaction Management
  - Concurrency Control Ideas
- Building Distributed Database Systems (RAID)
- Mobile Database Systems
- Privacy, Trust, and Authentication
- Peer to Peer Systems

Useful References

- J. D. Ullman, *Principles of Database Systems*. Computer Science Press, Rockville, 1982
- J. Gray and A. Reuter. *Transaction Processing - Concepts and Techniques*. Morgan Kaufmann, 1993
- B. Bhargava, *Concurrency Control in Database Systems*, IEEE Trans on Knowledge and Data Engineering,11(1), Jan.-Feb. 1999
- Textbook *Principles of Distributed Database Systems*,

  Chapter 11.1, 11.2

Concurrency Control

Interleaved execution of a set of transactions that satisfies given consistency constraints.

Concurrency Control Mechanisms:

- Locking (two-phase locking)
- Conflict graphs
- Knowledge about incoming transactions or transaction typing
- Optimistic: requires validation (backout and starvation)

Some Examples:

- Centralized locking
- Distributed locking
- Majority voting
- Local and centralized validation

Basic Terms for Concurrency Control

- Database
- Database entity (item, object)
- Distributed database
- Program
- Transaction, read set, write set
- Actions
- Atomic
- Concurrent processing
- Conflict
- Consistency
- Mutual consistency
- History
- Serializability
- Serial history

Basic Terms for Concurrency Control

- Serializable history
- Concurrency control
- Centralized control
- Distributed control
- Scheduler
- Locking
- Read lock, write lock
- Two phase locking, lock point
- Crash
- Node failure
- Network partition
- Log
- Live lock
- Dead lock
- Conflict graph (Acyclic)
- Timestamp
- Version number
- Rollback
- Validation and optimistic
- Commit
- Redo log
- Undo log
- Recovery
- Abort

Concurrency Control once again

- The problem of synchronizing concurrent transactions such that the consistency of the database is maintained while, at the same time, maximum degree of concurrency is achieved.
- Anomalies:
  - Lost updates
    - The effects of some transactions are not reflected on the database.
  - Inconsistent retrievals
    - A transaction, if it reads the same data item more than once, should always read the same value.

Execution Schedule (or History)

- An order in which the operations of a set of transactions are executed.
- A schedule (history) can be defined as a partial order over the operations of a set of transactions.

T_1: Read(x)	T_2: Write(x)	T_3: Read(x)
Write(x)	Write(y)	Read(y)
Commit	Read(z)	Read(z)
	Commit	Commit

$$H_1=\{W_2(x),R_1(x), R_3(x),W_1(x),C_1,W_2(y),R_3(y),R_2(z),C_2,R_3(z),C_3\}$$

Formalization of Schedule

A complete schedule $SC(T)$ over a set of transactions $T=\{T_1, \ldots, T_n\}$ is a partial order $SC(T)=\{\Sigma_T, <_T\}$ where

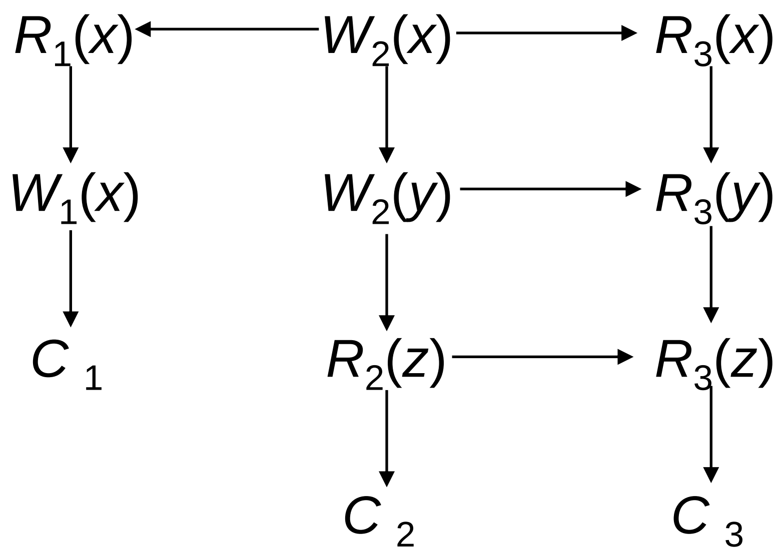
- $\Sigma_T = \cup_i \Sigma_i$, for $i = 1, 2, \ldots, n$
- $<_T \supseteq \cup_i <_i$, for $i = 1, 2, \ldots, n$
- For any two conflicting operations $O_{ij}, O_{kl} \in \Sigma_T$, either $O_{ij} <_T O_{kl}$ or $O_{kl} <_T O_{ij}$

Complete Schedule – Example

Given three transactions

T_1: Read(x)	T_2: Write(x)	T_3: Read(x)
Write(x)	Write(y)	Read(y)
Commit	Read(z)	Read(z)
	Commit	Commit

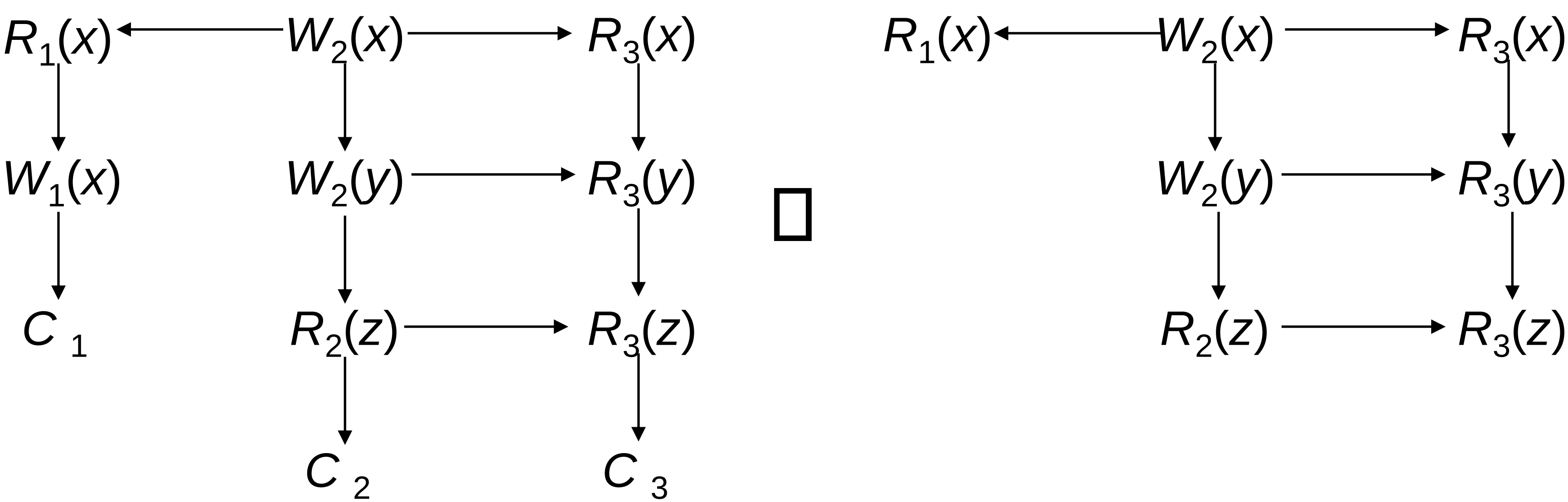
A possible complete schedule is given as the DAG



Schedule Definition

A schedule is a prefix of a complete schedule such that only some of the operations and only some of the ordering relationships are included.

T_1: Read(x)	T_2: Write(x)	T_3: Read(x)
Write(x)	Write(y)	Read(y)
Commit	Read(z)	Read(z)
	Commit	Commit



Serial History

- All the actions of a transaction occur consecutively.
- No interleaving of transaction operations.
- If each transaction is consistent (obeys integrity rules), then the database is guaranteed to be consistent at the end of executing a serial history.

T_1:	T_2:	T_3:
Read(x)	Write(x)	Read(x)
Write(x)	Write(y)	Read(y)
Commit	Read(z)	Read(z)
	Commit	Commit

$$H_s=\{W_2(x),W_2(y),R_2(z),C_2,R_1(x),W_1(x),C_1,R_3(x),R_3(y),R_3(z),C_3\}$$

Serializable History

- Transactions execute concurrently, but the net effect of the resulting history upon the database is *equivalent* to some *serial* history.
- Equivalent with respect to what?
  - ***Conflict equivalence***: the relative order of execution of the conflicting operations belonging to unaborted transactions in two histories are the same.
  - ***Conflicting operations***: two incompatible operations (e.g., Read and Write) conflict if they both access the same data item.
    - Incompatible operations of each transaction is assumed to conflict; do not change their execution orders.
    - If two operations from two different transactions conflict, the corresponding transactions are also said to conflict.

Serializable History

T_1: Read(x)	T_2: Write(x)	$T3$: Read(x)
Write(x)	Write(y)	Read(y)
Commit	Read(z)	Read(z)
	Commit	Commit

The following are not conflict equivalent

$$H_s=\{W_2(x),W_2(y),R_2(z),C_2,R_1(x),W_1(x),C_1,R_3(x),R_3(y),R_3(z),C_3\}$$

$$H_1=\{W_2(x),R_1(x), R_3(x),W_1(x),C_1,W_2(y),R_3(y),R_2(z),C_2,R_3(z),C_3\}$$

The following are conflict equivalent; therefore H_2 is *serializable*.

$$H_s=\{W_2(x),W_2(y),R_2(z),C_2,R_1(x),W_1(x),C_1,R_3(x),R_3(y),R_3(z),C_3\}$$

$$H_2=\{W_2(x),R_1(x),W_1(x),C_1,R_3(x),W_2(y),R_3(y),R_2(z),C_2,R_3(z),C_3\}$$

Serializability in Distributed DBMS

- Somewhat more involved. Two histories have to be considered:
  - local histories
  - global history
- For global transactions (i.e., global history) to be serializable, two conditions are necessary:
  - Each local history should be serializable.
  - Two conflicting operations should be in the same relative order in all of the local histories where they appear together.

Global Non-serializability

T_1: Read(x)
$x \leftarrow x+5$
Write(x)
Commit

T_2: Read(x)
$x \leftarrow x*15$
Write(x)
Commit

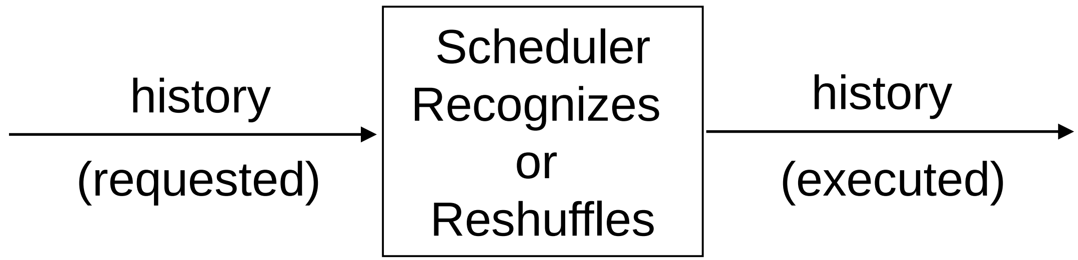
The following two local histories are individually serializable (in fact serial), but the two transactions are not globally serializable.

$$LH_1=\{R_1(x), W_1(x), C_1, R_2(x), W_2(x), C_2\}$$

$$LH_2=\{R_2(\mathrm{x}), W_2(\mathrm{x}), C_2, R_1(\mathrm{x}), W_1(\mathrm{x}), C_1\}$$

Evaluation Criterion for Concurrency Control

1. Degree of Concurrency



Less reshuffle ⇒ High degree of concurrency

2. Resources used to recognize
   - Lock tables
   - Time stamps
   - Read/write sets
   - Complexity
3. Costs
   - Programming ease

General Comments

- Information needed by Concurrency Controllers
  - Locks on database objects
  - Time stamps on database objects
  - Time stamps on transactions

- Observations
  - Time stamps mechanisms more fundamental than locking
  - Time stamps carry more information
  - Checking locks costs less than checking time stamps

General Comments (cont.)

- When to synchronize
  - First access to an object (Locking, pessimistic validation)
  - At each access (question of granularity)
  - After all accesses and before commitment (optimistic validation)
- Fundamental notions
  - Rollback
  - Identification of useless transactions
  - Delaying commit point
  - Semantics of transactions

