



EPL646 – Advanced Topics in Databases

Lecture 8

Transaction Management Overview

Chapter 17.1-17.6: Elmasri & Navathe, 5ED

Chapter 16.1-16.3 and 16.6: Ramakrishnan & Gehrke, 3ED

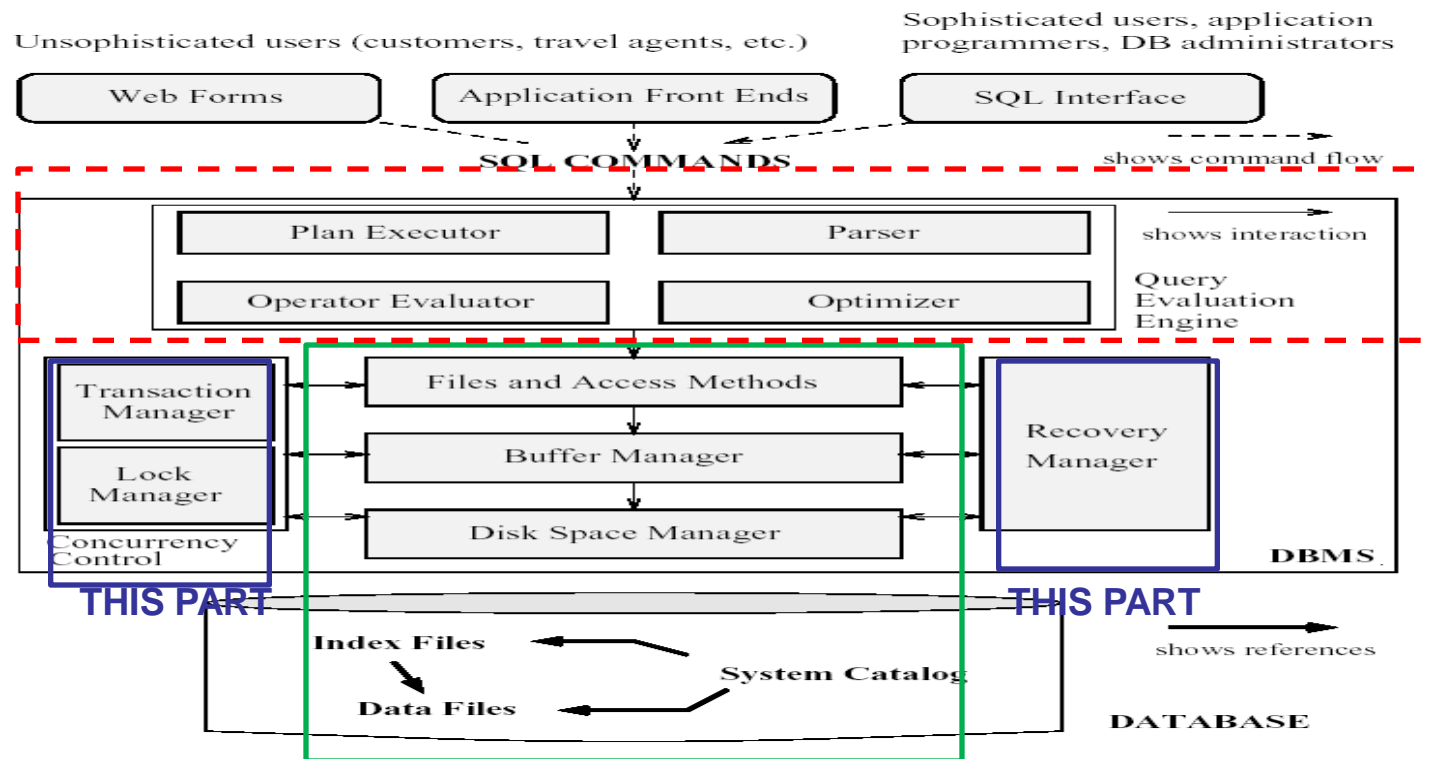
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Overview of Transaction Processing (Επισκόπηση Επεξεργασίας Δοσοληψιών)



- We will now focus on **Concurrency Control (Έλεγχος Ταυτοχρονίας)** and **Recovery Management (Τεχνικές Ανάκαμψης)** in cases of failures



Lecture Outline



Transaction Management Overview

- 16.0) Introduction to **Transactions** (Δοσοληψίες ή Συναλλαγές)
- 16.1) The **ACID** (Atomicity-Consistency-Isolation-Durability) Properties
- 16.2) **Transactions** and **Schedules** (Χρονοπρόγραμμα)
- 16.3) **Concurrent Executions** of Transactions (Ταυτόχρονες Εκτελέσεις Δοσοληψιών) and Problems
- 16.6) **Transaction Support in SQL**

Below topics will be covered as part of subsequent lectures

- 16.4) Concurrency with Locks (Κλειδαριές)
- 16.5) Concurrency with Timestamps (Χρονόσημα)
- 16.7) Introduction to Crash Recovery (Ανάκαμψη Σφαλμάτων)

Introduction to Transactions

(Εισαγωγή σε Δοσοληψίες)



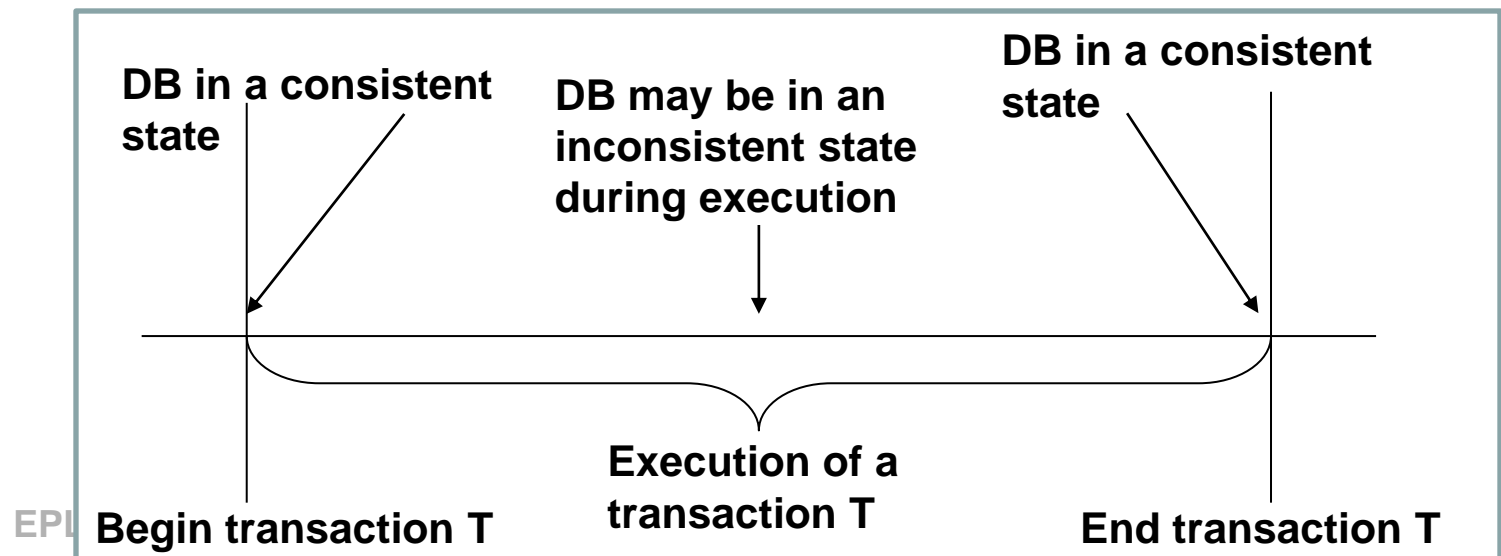
- The concept of **transaction (δοσοληψία)** provides a mechanism for describing logical units of database processing.
 - **Analogy:** A **transaction** is to a **DBMS** as a **process** is to an **Operating System**.
- **Transaction Processing Systems (Συστήματα Επεξεργασίας Δοσοληψιών)** are systems with large databases and hundreds of concurrent users executing database transactions
 - **Examples:** *Airline Reservations* (Αεροπορικές Κρατήσεις), *Banking* (Εφαρμογές Τραπεζικού Τομέα), *Stock Markets* (Χρηματιστήρια), *Supermarkets* (Υπεραγορές),

Introduction to Transactions

(Εισαγωγή σε Δοσοληψίες)



- **Transaction (Δοσοληψία) (Xact)**, is an **atomic** (i.e., all-or-nothing) sequence of **database operations** (i.e., read-write operations).
- It is the **DBMS's abstract view** of a **user program**!
- A **transaction** (collection of actions) makes **transformations** of system states while preserving the **database consistency (συνέπεια βάσης)** ... next slide.



DB Consistency vs. Trans. Consistency

(Συνέπεια ΒΔ vs. Συνέπεια Δοσοληψίας)



- **Database Consistency (Συνέπεια Βάσης)**

- A **database** is in a **consistent state** if it **obeys all of the Integrity Constraints (Κανόνες Ακεραιότητας)** defined over it.
- **Examples of Integrity Constraints:**
 - **Domain Constraints** (Πεδίου Ορισμού): e.g., SID must be integer
 - **Key Constraints** (Κλειδιού): e.g., no 2 students have the same SID
 - **Foreign Key Constraints** (Ξένου Κλειδιού): e.g., DepartmentID in Student must match the DepartmentID in Department's table.
 - **Single Table Constraints:** e.g., CHECK (age>18 AND age<25)
 - **Multiple Table Constraints:**
 - e.g., Create ASSERTION C CHECK ((SELECT A) + (SELECT B) < 10)

- **Transaction consistency (Συνέπεια Δοσοληψίας)**

- Complements Database consistency by incorporating user semantics (e.g., σημασιολογία όπως ορίζεται από τον χρήστη)
- T.C is the user's responsibility (e.g., previous example)

Introduction to Transactions

(Εισαγωγή σε Δοσοληψίες)



- One way of specifying the **transaction boundaries** is by specifying explicit **BEGIN TRANSACTION** and **END TRANSACTION** statements in an application program

- **Transaction Example in MySQL**

```
START TRANSACTION;
```

```
SELECT @A:=SUM(salary) FROM table1 WHERE type=1;
```

```
UPDATE table2 SET summary=@A WHERE type=1;
```

```
COMMIT;
```

- **Transaction Example in Oracle (same with SQL Server)**

- When you connect to the database with **sqlplus** (Oracle command-line utility that runs SQL and PL/SQL commands interactively or from a script) a transaction begins.
- Once the transaction begins, every SQL DML (Data Manipulation Language) statement you issue subsequently becomes a part of this transaction

- **Transaction Example in C: See Next Slide**

Note that the given example has no explicit START/END statements as the whole program is essentially 1 transaction (as the previous example with Oracle's sqlplus utility).

Transaction Consistency

Example with Embedded SQL



- The below example shows a Transaction constraint (not captured by ICs)

Consider an airline reservation example with the relations*:
FLIGHT(FNO, DATE, SRC, DEST, **STSOLD**)
CUST(CID, ADDR)
FC(FNO, DATE, CID, SPECIAL)

```
main {
```

```
...
```

```
EXEC SQL BEGIN DECLARE SECTION; // define C host program variables (accessible in SQL environment)
char flight_no[6], customer_id[20]; // these host-language variable are prefixed with ":" in SQL statements
char day;
EXEC SQL END DECLARE SECTION;
```

```
scanf("%s %d %s", flight_no, day, customer_id);
```

Sell a seat on a given flight and date by increasing the **SeaTSOLD** attribute

```
EXEC SQL UPDATE FLIGHT
SET STSOLD = STSOLD + 1
WHERE FNO = :flight_no AND DATE = :day;
```

Store the sale in the Flight-Customer table

```
EXEC SQL INSERT
INTO FC(FNO, DATE, CID, SPECIAL);
VALUES(:flight_no, :day, :customer_id, null);
```

DB in inconsistent state

If only the first action is executed then relations FLIGHT and FC will be inconsistent
➔ **Although not a concurrent program**, we need to ensure **transaction consistency** (all-or-nothing)!

```
printf("Reservation completed");
return(0);
```

```
}
```

* We make some **simplifying assumptions** regarding the schema and constraints

Introduction to Transactions

(Εισαγωγή σε Δοσοληψίες)



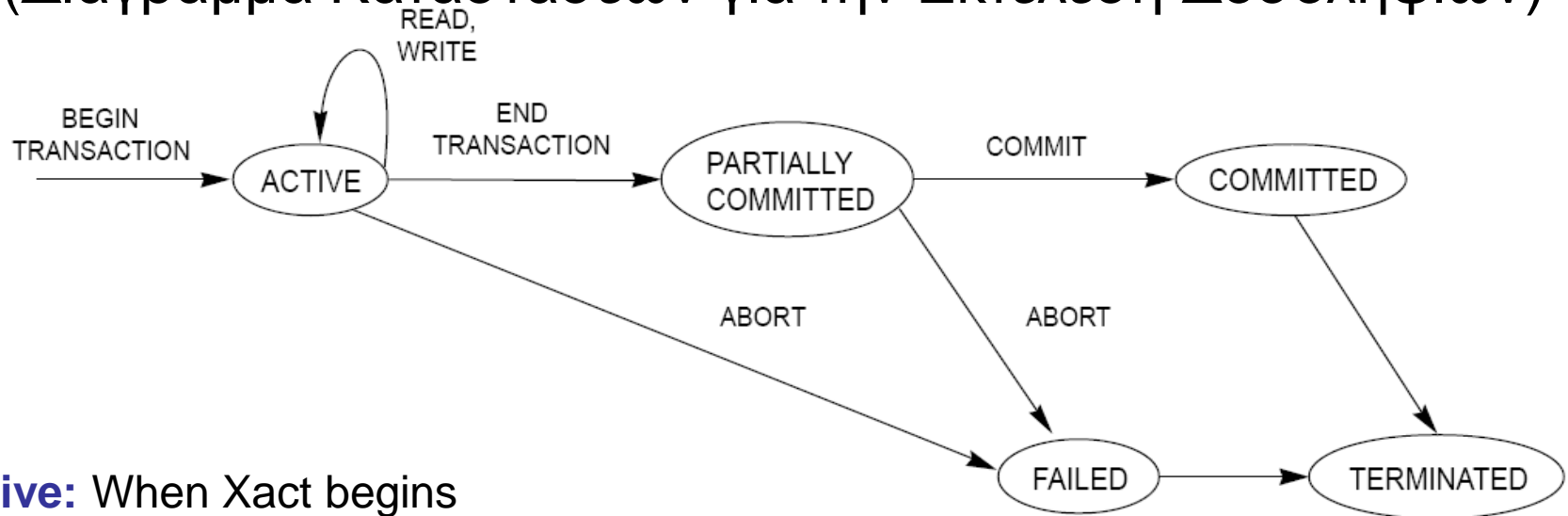
- Things get even **more complicated** if we have several DBMS programs (transactions) **executed concurrently**.
- **Why do we need concurrent executions?**
 - It is **essential** for good DBMS performance!
 - Disk accesses are frequent, and relatively slow
 - Overlapping I/O with CPU activity increases **throughput** and **response time**.
- **What is the problem with concurrent transactions?**
 - **Interleaving (Παρεμβάλλοντας)** transactions might lead the system to an inconsistent state (like previous example):
 - **Scenario:** A Xact prints the monthly bank **account statement** for a user U (one bank transaction at-a-time). **Before** finalizing the report another Xact **withdraws \$X** from user U.
 - **Result:** Although the report contains an updated **final balance**, it shows nowhere the bank transaction that caused the decrease (unrepeatable read problem, explained next)
- A DBMS **guarantees** that these **problems will not arise**.
 - *Users are given the impression that the transactions are executed **sequentially (σειριακά)**, the one after the other.*

Introduction to Transactions (Εισαγωγή σε Δοσοληψίες)



State Diagram for Transaction Execution

(Διάγραμμα Καταστάσεων για την Εκτέλεση Δοσοληψιών)



Active: When Xact begins

Partially Committed: When Xact ends, several recovery checks take place making sure that the DB can always recover to a consistent state

Failed: If Xact **aborts** for any reason (**rollback** might be necessary to return the system to a consistent state)

Committed: After partial committed checks are successful. Once committed we never return (roll-back) to a previous state

The ACID properties

(Οι ιδιότητες ACID)



- What are the **fundamental (θεμελιώδεις) properties** that a DBMS must **enforce** so that **data remains consistent** (in the face of **concurrent access & failures**)?
- A DBMS needs to enforce **four (4) properties**:
Atomicity – Consistency – Isolation - Durability
Ατομικότητα – Συνέπεια - Απομόνωση – Μονιμότητα
- Jim Gray defined the key transaction properties of a reliable system in the late 1970.
- Acronym **ACID** was coined by Reuter and Haerder in 1983
 - Reuter, Andreas; Haerder, Theo "Principles of Transaction-Oriented Database Recovery". ACM Computing Surveys (ACSUR) 15 (4): pp. 287-317, 1983

The ACID properties

(Οι ιδιότητες ACID)



1. **Atomicity (Ατομικότητα): All or nothing!**

- An executing transaction completes in its **entirety** (i.e., ALL) or it is **aborted altogether** (i.e., NOTHING).
- e.g., **Transfer_Money(Amount, X, Y)** means i) **DEBIT(Amount, X)**; ii) **CREDIT(Amount, Y)**. **Either both** take place **or none**.
- Reasons for Incomplete Transactions
 - **Anomaly Detection** (e.g., Constraint violation) or **System Crash** (e.g., power)
- **Responsibility:** Recovery Manager (use log file to record all writes)

2. **Consistency (Συνέπεια): Start & End Consistent!**

- If each **Transaction is consistent**, and the **DB starts consistent**, then the **Database ends up consistent**.
- If a **transaction violates** the database's **consistency rules**, the entire transaction will be **rolled back** and the database will be **restored to a state consistent** with **those rules**
- **Responsibility: User** (DB only enforcing IC rules)

The ACID properties

(Οι ιδιότητες ACID)



3. Isolation (Απομόνωση): See your own data only!

- An executing transaction cannot **reveal its** (incomplete) results before **it commits**.
- Consequently, the **net effect** is **identical** to **executing** all transactions, the **one after the other** in some **serial order**.
 - e.g., if two transactions T1 and T2 exists, then the output is guaranteed to be either T1, T2 or T2, T1 (The DBMS cannot guarantee the order of execution, that is the user's job!) ... see example next page
- **Responsibility:** Lock Manager (i.e., Concurrency Control Manager)

4. Durability (Μονιμότητα): DBMS Cannot Regret!

- Once a **transaction commits**, the system must **guarantee** that the results of its operations will **never be lost**, in spite of subsequent failures.
- **Responsibility:** Recovery Manager (use log file to record all writes)

Notation for Transactions

(Σημειογραφία για Δοσοληψίες)



- **Actions** executed by a transaction include **reads** and **writes** of **database objects**
- **Notation**
 - **$R_T(O)$** : The Transaction **T Reads** an Object **O**.
 - **$W_T(O)$** : The Transaction **T Writes** an Object **O**.
 - When Transaction is clear in context we shall omit the T
 - Although written, the data is in really **pending** until **committed**.
 - **$Commit_T$** : Complete successfully **writing** data to disk
 - **$Abort_T$** : Terminate and **undo** all carried out actions
- **Assumptions**
 - Transaction **Communication** only **through** the **DBMS**
 - Database Objects: **Static Collection** (i.e., tables, etc. not **added/removed** in dynamic case more complex)

Transactions and Schedules



(Δοσοληψίες και Χρονοπρόγραμμα)

- **Schedule (Χρονοπρόγραμμα)**

- List of **actions** (read, write, abort, or commit) from a **set (ομάδας)** of transactions (T1, T2, ...) where the **order of actions** inside each transaction **does not change**.
 - e.g., if T1=R(A), W(A) then W(A), R(A) is not the same schedule (as it is in opposite order)

Schedule	
T1	T2

R(A)	
W(A)	
	R(B)
	W(B)
R(C)	
W(C)	

- Note that the DBMS might carry out **other actions** as **well** (e.g., evaluation arithmetic expressions) .
- Yet these do not affect the other transactions, thus will be omitted from our presentation
- We shall introduce **Commits/Aborts** subsequently.

Transactions and Schedules



(Δοσοληψίες και Χρονοπρόγραμμα)

- **Serial Schedule (Σειριακό Χρονοπρόγραμμα)**
 - A schedule in which the different **transactions** are **NOT interleaved** (i.e., transactions are executed from start to finish one-by-one)

Serial Schedule

T1	T2
<hr/>	
R(B) W(B)	R(A) W(A)

Serial Schedule

T1	T2
<hr/>	
R(B) W(B)	R(A) W(A)



N! Possible
Serial Schedules,
where N the
number of Xacts

Problems due to Interleaved Xact

(Προβλήματα από την Παρεμβολή Δοσοληψιών)



Problems that arise when interleaving Transactions.

- **Problem 1: Reading Uncommitted Data (WR Conflicts)**
 - *Reading the value of an uncommitted object might yield an inconsistency*
 - **Dirty Reads** or **Write-then-Read (WR) Conflicts**.A diagram showing a sequence of operations: 'W' (Write) followed by 'R' (Read) on a gray background.
 - **In Greek:** Ασυνεπείς αναγνώσεις
- **Problem 2: Unrepeatable Reads (RW Conflicts)**
 - *Reading the same object twice might yield an inconsistency*
 - **Read-then-Write (RW) Conflicts** (ή Write-After-Read)A diagram showing a sequence of operations: 'R' (Read), 'W' (Write), and 'R' (Read) on a gray background.
 - **In Greek:** Μη-επαναλήψιμες αναγνώσεις
- **Problem 3: Overwriting Uncommitted Data (WW Conflicts)**
 - *Overwriting an uncommitted object might yield an inconsistency*
 - **Lost Update** or **Write-After-Write (WW) Conflicts**.A diagram showing a sequence of operations: 'W' (Write) followed by 'W' (Write) on a gray background.
 - **In Greek:** Απώλειες ενημερώσεων
- **Remark:** There is no notion of **RR-Conflict** as no object is changed

Reading Uncommitted Data (WR Conflicts)

(Ασυνεπείς αναγνώσεις)



“Reading the value of an uncommitted object yields an inconsistency”

- To illustrate the **WR-conflict** consider the following problem:
T1: Transfer \$100 from Account **A** to Account **B**
T2: Add the annual interest of 6% to both **A** and **B**.

(Correct)Serial Schedule

<u>Trace</u>	T1	T2
	R(A)	
$A=A-100$	W(A)	
	R(B)	
$B=B+100$	W(B)	
		R(A)
$A=A*1.06$		W(A)
		R(B)
$B=B*1.06$		W(B)

(Correct)Serial Schedule

<u>Trace</u>	T1	T2
		R(A)
$A=A*1.06$		W(A)
		R(B)
$B=B*1.06$		W(B)
	R(A)	
$A=A-100$	W(A)	
	R(B)	
$B=B+100$	W(B)	

WR-Conflict (Wrong)

<u>Trace</u>	T1	T2
	R(A)	
$A=A-100$	W(A)	
		Dirty Read → R(A)
$A=A*1.06$		W(A)
		R(B)
$B=B*1.06$		W(B)
	R(B)	
$B=B+100$	W(B)	

Problem caused by the WR-Conflict? Account **B** was credited with the interest on **a smaller amount (i.e., 100\$ less)**, thus the result is not equivalent to the serial schedule

Unrepeatable Reads (RW Conflicts)

(Μη-επαναλήψιμες αναγνώσεις)

“Reading the same object twice yields an inconsistency”



- To illustrate the **RW-conflict** consider the following problem:

T1: Print Value of **A**

T2: Decrease Global counter **A** by 1.

WR-Conflict (Wrong)		
Trace	T1	T2
A=10	R(A)	
A=10		R(A)
A=A-1=9		W(A)
A=9	R(A)	

Note that if I read at this point we would see 9 rather than 10 (i.e., read is unrepeatable)

Problem caused by the RW-Conflict?

Although the “A” counter is read twice within T1 (without any intermediate change) it has two different values (unrepeatable read)! ... what happens if T2 aborts?

→ T1 has shown an incorrect result.

Overwriting Uncommitted Data (WW Conflicts)

(Μη-επαναλήψιμες αναγνώσεις)



“Overwriting an uncommitted object yields an inconsistency”

- To illustrate the **WW-conflict** consider the following problem:
Constr: Salary of employees **A** and **B** must be **kept equal**
T1: Set Salary to 1000; **T2:** Set Salary equal to 2000

(Correct)Serial Schedule

<u>Trace</u>	T1	T2
	R(A)	
<i>A=1000</i>	W(A)	
	R(B)	
<i>B=1000</i>	W(B)	
		R(A)
<i>A=2000</i>		W(A)
		R(B)
<i>B=2000</i>		W(B)

(Correct)Serial Schedule

<u>Trace</u>	T1	T2
		R(A)
<i>A=2000</i>		W(A)
		R(B)
<i>B=2000</i>		W(B)
	R(A)	
<i>A=1000</i>	W(A)	
	R(B)	
<i>B=1000</i>	W(B)	

WW-Conflict (Wrong)

<u>Trace</u>	T1	T2
	R(A)	
<i>A=1000</i>	W(A)	
		R(A)
<i>A=2000</i>		W(A)
		R(B)
<i>B=2000</i>		W(B)
	R(B)	
<i>B=1000</i>	W(B)	

Lost Update (from T1 W(A) to T2 W(A))
 Lost Update (from T2 W(B) to T1 W(B))

* **Note:** Client certainly prefers the 1st than the 2nd schedule (final amount is larger)!

Problem caused by the WW-Conflict?

Employee “A” gets a salary of 2000 while employee “B” gets a salary of 1000, thus result is not equivalent to the **serial schedule!**

Lecture Roadmap

Transactions and Schedules



- 16.2) **Transactions and Schedules** (Χρονοπρόγραμμα)
 - **Serial Schedule** (Σειριακό Χρονοπρόγραμμα) ... one after the other...
 - **Complete Schedule** (Πλήρες Χρονοπρόγραμμα) ... with **Commit, Abort**
- 17.1) **Serializability** (Σειριοποιησιμότητα)
 - **“Correctness Measure”** of some Schedule
 - **Why is it useful?** It answers the question: “Will an interleaved schedule execute correctly
 - i.e., a Serializable schedule will execute as **correctly as serial** schedule ... but in an **interleaved manner!**
- 17.1) **Recoverability** (Επαναφερσιμότητα)
 - **“Recoverability Measure”** of some Schedule.
 - **Why is it useful?** It answers the question: “Do we need to rollback a some (or all) transactions in an interleaved schedule after some Failure (e.g., ABORT)”
 - i.e., in a Recoverable schedule no transaction needs to be **rolled back (διαδικασία επιστροφής)** once committed!

Transactions and Schedules



(Δοσοληψίες και Χρονοπρόγραμμα)

- **Serial Schedule (Σειριακό Χρονοπρόγραμμα)**
 - A schedule in which the different **transactions** are **NOT interleaved** (i.e., transactions are executed from start to finish one-by-one)

Serial Schedule

T1	T2
<hr/>	
R(B) W(B)	R(A) W(A)

Serial Schedule

T1	T2
<hr/>	
R(B) W(B)	R(A) W(A)

N! Possible
Serial Schedules,
where N the
number of
Transactions

Transactions and Schedules



(Δοσοληψίες και Χρονοπρόγραμμα)

- **Complete Schedule (Πλήρες Χρονοπρόγραμμα)**

- A schedule that contains either a **commit** (ολοκλήρωση δοσοληψίας) or an **abort** (ματαίωση δοσοληψίας) action for **EACH** transaction.*

Complete Schedule

T1	T2
<hr/>	
R(A)	
	R(B)
W(A)	
	W(B)
Commit	Abort

Complete Schedule

T1	T2
<hr/>	
R(A)	
W(A)	
Commit	R(B)
	W(B)
	Abort

Complete (Serial) Schedule

T1	T2
<hr/>	
R(A)	
W(A)	
Commit	
	R(B)
	W(B)
	Abort

* **Note:** consequently, a complete schedule **will not** contain any **active transactions at the end of the schedule**

Transactions and Schedules

(Δοσοληψίες και Χρονοπρόγραμμα)



- **Interleaved Schedules** of transactions **improve performance**
 - **Throughput (ρυθμαπόδοση):** *More Xacts per seconds; and*
 - **Response Time (χρόνος απόκρισης):** A **short** transaction will not get stuck behind a **long-running** transaction
- Yet it might lead the DB to an **inconsistent state as we have shown**
- **Serial schedule** (σειριακό χρονοπρόγραμμα) is **slower but** guarantees consistency (correctness)
- We seek to identify schedules that are:
 - **As fast as interleaved** schedules.
 - **As consistent as serial** schedules

Transactions and Schedules (Δοσοληψίες και Χρονοπρόγραμμα)



- We shall now **characterize** different schedules based on the following two **properties**:

A. Based on Serializability (Σειριοποιησιμότητα)

- We shall ignore **Commits** and **Aborts** for this section

Characterize which schedules are **correct** when **concurrent transactions** are **executing**.

- **Conflict Serializable Schedule** (Σειριοποιησιμότητα Συγκρούσεων)
- **View Serializable Schedule** (Σειριοποιησιμότητα Όψεων)

B. Based on Recoverability (Επαναφερσιμότητα)

- **Commits** and **Aborts** become important for this section!

Characterize which schedules **can be recovered** and **how easily**.

- **Recoverable Schedule** (Επαναφέρσιμο Χρονοπρόγραμμα).
- **Cascadeless schedule** (Χρονοπρ. χωρίς διαδιδόμενη ανάκληση).
- **Strict Schedules** (Αυστηρό Χρονοπρόγραμμα).

Conflicting Actions (Συγκρουόμενες Πράξεις)



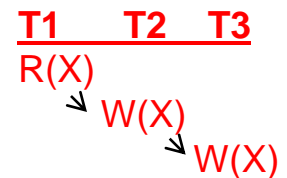
- **Conflicting Actions (Συγκρουόμενες Πράξεις)**

Two or more **actions** are said to be **in conflict** if:

- The actions belong to **different transactions**.
- **At least** one of the actions is a **write operation**.
- The actions **access** the **same object** (read or write).

- **The following set of actions is conflicting:**

T1:R(X), T2:W(X), T3:W(X)



- **While the following sets of actions are not:**

T1:R(X), T2:R(X), T3:R(X) // No Write on same object

T1:R(X), T2:W(Y), T3:R(X) // No Write on same object



Conflict Equivalence

(Ισοδυναμία Συγκρούσεων)

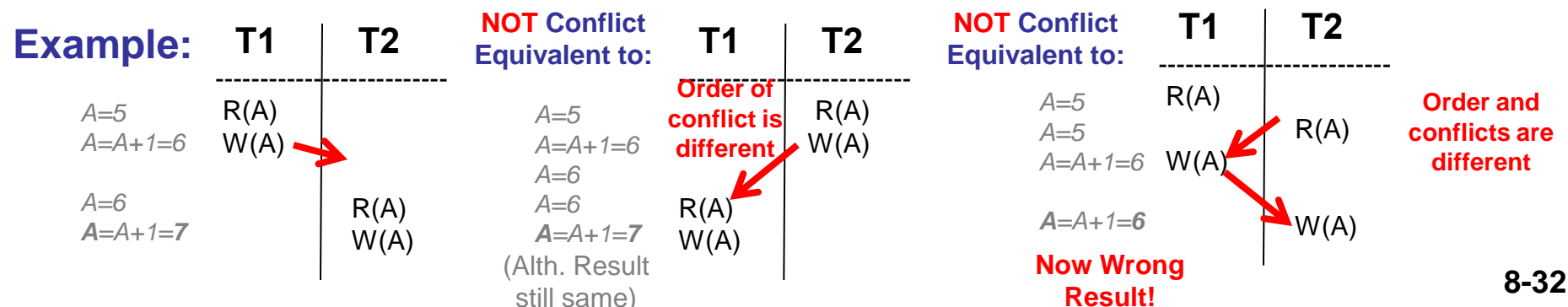
Characterizing
Schedules based on:
Serializability
Recoverability

• Conflict Equivalence (Ισοδυναμία Συγκρούσεων)

The schedules **S1** and **S2** are said to be **conflict-equivalent** if the following conditions are satisfied:

- Both schedules **S1** and **S2** involve the **same set of transactions** (including ordering of actions within each transaction).
- The **order (διάταξη)** of each pair of conflicting actions in **S1** and **S2** are the same.

- **Why is the order of Conflicts important?** If two **conflicting operations** are **applied in different orders**, the **net effect** can be **different** on the database or on other transactions in the schedule. See example below:





Conflict Serializability

(Σειριοποιησιμότητα Συγκρούσεων)

Characterizing
Schedules based on:
Serializability
Recoverability

- Conflict Serializability (Σειριοποιήσιμο Συγκρούσεων)**

When the schedule is **conflict-equivalent** (ισοδύναμο συγκρούσεων) to some (**any!**) serial schedule.

Serializable == Conflict Serializable

(that definition is in some textbooks different)

Serial Schedule

T1	T2
R(A)	
W(A)	
R(B)	
W(B)	
	R(A)
	W(A)
	R(B)
	W(B)

Serializable Schedule A

T1	T2
R(A)	
W(A)	
	R(A)
	W(A)
R(B)	
W(B)	
	R(B)
	W(B)

Serializable Schedule B

T1	T2
	R(A)
	W(A)
R(A)	
	R(B)
	W(B)
W(A)	
R(B)	
W(B)	



Conflict Serializability

(Σειριοποιησιμότητα Συγκρούσεων)

Characterizing
Schedules based on:
Serializability
Recoverability

- **Why is Conflict Serializability important?**
- We have already said that any **serial schedule** leaves the DB in a **consistent (correct)** state, but is **inefficient**
 - i.e., T1; T2 is as correct as T2; T1 (although they might have a different outcome).

Serializable != Serial: NOT the same thing

- Being **Serializable** implies:
 - A. That the schedule is a correct schedule.**
 - It will leave the database in a **consistent state**.
 - The **interleaving** is **appropriate** and will result in a state as if the transactions were **serially executed**.
 - B. That a schedule is a efficient (interleaved) schedule**
 - That parameter makes it better than Serial 😊!

Testing for Serializability

(Έλεγχος Σειριοποιησιμότητας)



Characterizing
Schedules based on:
Serializability
Recoverability

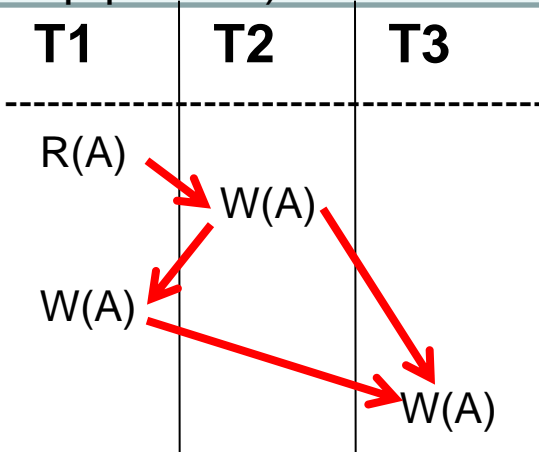
- **How can we test if a schedule is Conflict Serializable?**
 - There is a simple algorithm **detailed next** (that is founded on a **Precedence Graph**)
- **Does the DBMS utilizes this algorithm? NO**
 - We detail it only to gain a better understanding of the definitions.
- **Why is the DBMS not using it?**
 - Serializability is hard to check at runtime
 - Difficult to **determine beforehand** how the **operations** in a schedule will be **interleaved** (as it depends on the OS)
- In the next lecture, we will see that a DBMS utilizes a set of **protocols** (e.g., **2PL** or other **Concurrency Control techniques w/out locking**) that **guarantee** that a schedule is always **serializable**.



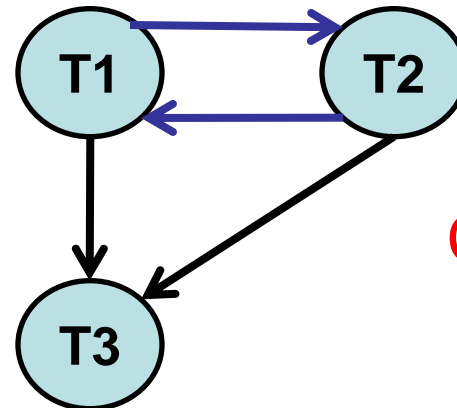
Precedence Graph (Γράφος Προτεραιότητας)

Characterizing
Schedules based on:
Serializability
Recoverability

- **Why is it useful?** To find if a schedule is Conflict Serializable
- A **Precedence Graph (Γράφος Προτεραιότητας)** for a schedule S contains:
 - A **node** for each **committed transaction** in S
 - An arch from T_i to T_j , if an action of T_i precedes (προηγείται) and conflicts (συγκρούεται) with one of T_j 's actions.



Precedence Graph

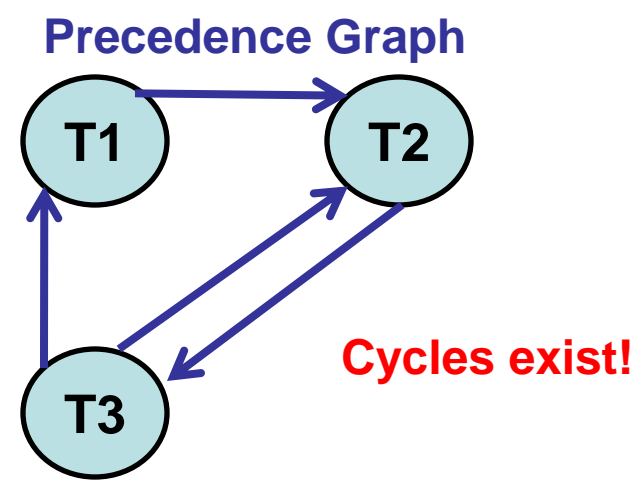
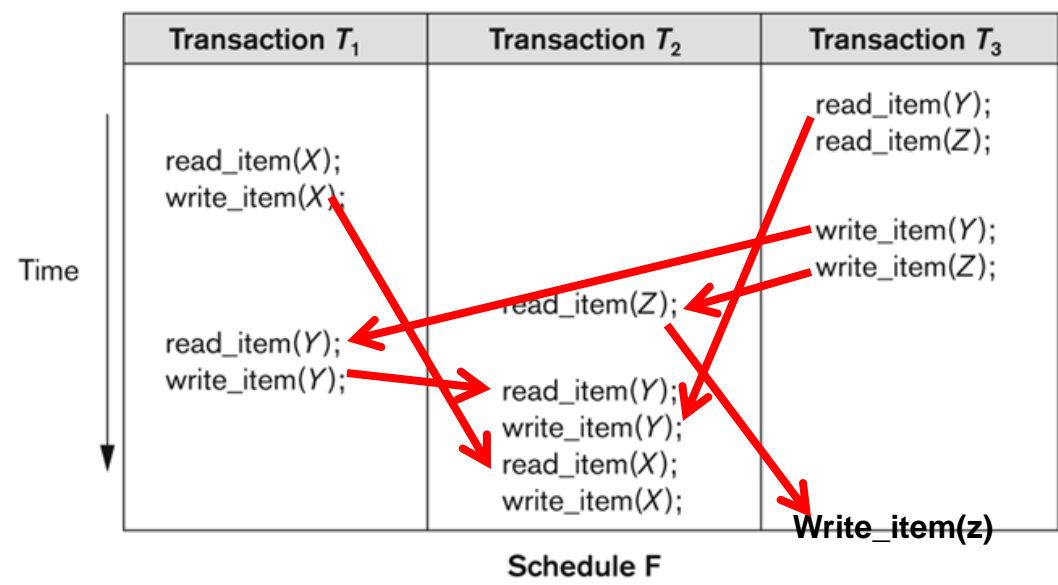


Cycle exists!

- A schedule S is **conflict serializable** if and only if its **precedence graph** is **acyclic**.
 - The above schedule is **not** Conflict Serializable!

Conflict Serializability Testing

(Έλεγχος Σειριοποιησιμότητας Συγκρούσεων)



Above schedule is NOT Conflict Serializable!
Although efficient (interleaved) the above will NOT produce a correct result!

View Equivalence

(Ισοδυναμία Όψεων)



Characterizing
Schedules based on:
Serializability
Recoverability

- Let us now **relax (χαλαρώσουμε)** the definition of **equivalence** (and **serializability**) of schedules by introducing the notion of view equivalence serializability.
- In **View Equivalence**, respective transactions in the two schedules **read and write the same data values** ("view" the same data values).
 - While in **Conflict Equivalence**, respective transactions in two schedules have the **same order of conflicting actions**
- Formal definitions and examples will follow...

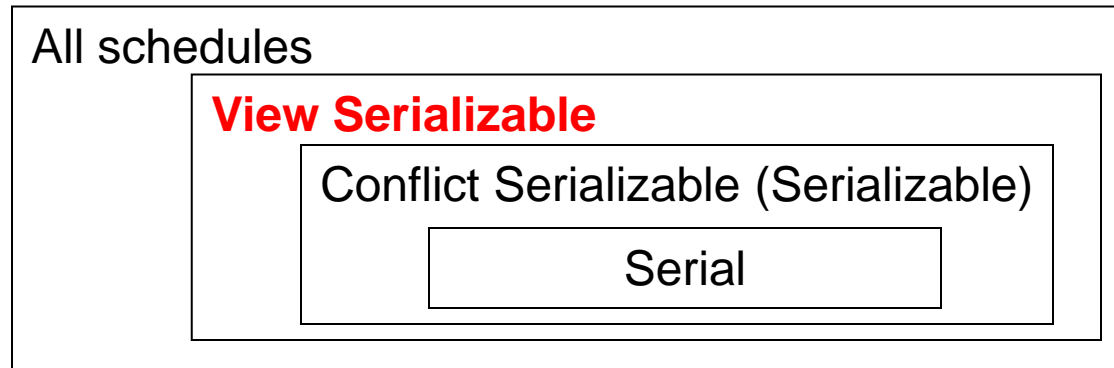
View Serializability

(Σειριοποιησιμότητα Όψεων)



- **View Serializable (Σειριοποιησιμότητα Όψεων):**
 - A Schedule is View Serializable if it is **view equivalent** to some **serial schedule**

VENN Diagram



- Conflict serializable \Rightarrow View serializable, but not vice versa.
- **Testing** for View Serializability is **NP-hard**, meaning that finding an efficient polynomial time algorithm to this problem is highly unlikely.
 - We will only work on small examples for which we can characterize the type of serializability by observation (so no algorithm is necessary)

View Equivalence (Ισοδυναμία Όψεων)



View Equivalence (Formal Definition)

- (1) **Same WR order:** If in $S1: w_j(A) \Rightarrow r_i(A)$; i, j are identifiers of Transactions
then in $S2: w_j(A) \Rightarrow r_i(A)$
- (2) **First Read:** If in $S1: r_i(A)$ reads initial DB value,
then in $S2: r_i(A)$ also reads initial DB value
- (3) **Last Write:** If in $S1: w_i(A)$ does last write on A ,
then in $S2: w_i(A)$ also does last write on A

\Rightarrow means,
Schedule
“reads
value produced”

- **The premise behind view equivalence:**
 - “**The view**”: the read operations are said to **see the same view in both schedules**.
 - **Rule:** As long as each **read operation** of a transaction **reads the result of the same write operation** in **both schedules**, the **write operations** of each transaction **must produce the same results**.



View Serializability

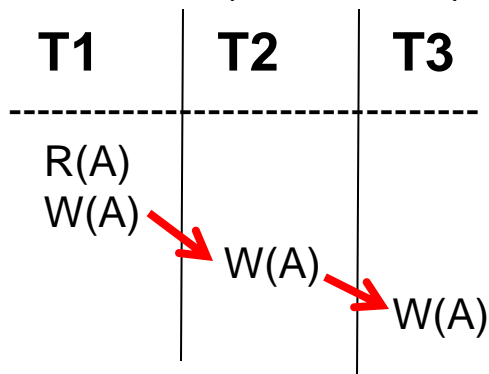
(Σειριοποιησιμότητα Όψεων)

Characterizing
Schedules based on:
Serializability
Recoverability

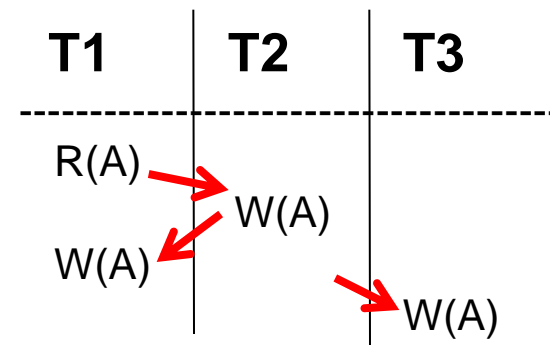
• View Serializability Summary:

- I. Same Transaction **Reads Data First**.
- II. Same Transaction **Writes Data Last**.
- III. Same **WR Order** of actions.

b) Conflict & View Serializable Schedule (also serial)



c) View Serializable but NOT Conflict Serializable



Why is the second schedule View Serializable?

In both schedules (a) and (b): **First Read** by T1 and **Final Write** performed by T3 and **WR order does not change** (actually we have no reads in T2 and T3)

Order of conflicts not
same with any serial
schedule

Introduction to Recoverability

(Εισαγωγή στην Επαναφερσιμότητα)



- So far we have characterized schedules based on **serializability (σειριοποιησιμότητα)**, i.e., correctness.
- Now it is **time** to characterize schedules based on **recoverability (επαναφερσιμότητα)**
- **Why is this important?**
 - For some schedules it is easier to recover from transaction failures than others.
- In summary, a **Recoverable Schedule (Επαναφέρσιμο Χρονοπρόγραμμα)** is a schedule where no transaction needs to be **rolled back (διαδικασία επιστροφής)** once committed.
- Commit/Abort points now become quite important!



Recoverable Schedule

Characterizing
Schedules based on:
Serializability
Recoverability

(Επαναφέρσιμο Χρονοπρόγραμμα)

- **Recoverable Schedule (Επαναφέρσιμο Χρονοπρόγραμμα)**

- A **schedule S** is **recoverable** if no transaction **T** in **S** commits until all transactions **T'**, that have written an item that **T** reads, have **committed**.

- **Rule:** In other words, the parents of **dirty reads** need to commit before their children can commit

Consider the
Following
schedule:

T1	T2
R(X)	
W(X)	
	R(X)
R(Y)	
	W(X)
	Commit
<i>T1 should have committed first!</i> Abort	

Is this schedule recoverable?

Answer: **NO**

Why NOT recoverable?

- Because **T2** made a **dirty read** and committed before **T1** ... next slide explains why this is a problem ...

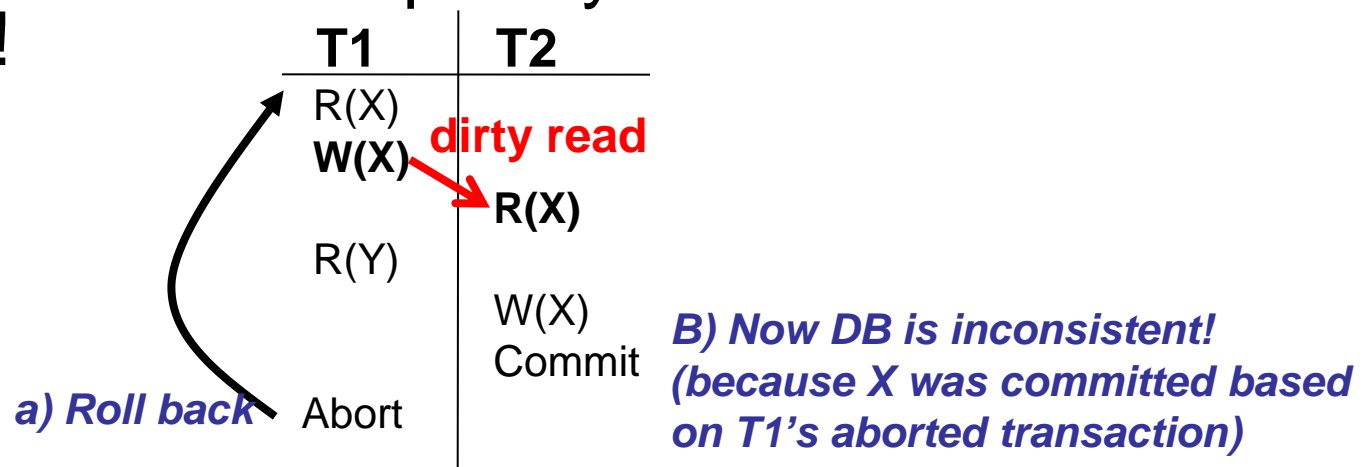
Recoverable Schedule



Characterizing
Schedules based on:
Serializability
Recoverability

(Επαναφέρσιμο Χρονοπρόγραμμα)

- But why is the schedule **Nonrecoverable (Μη-επαναφέρσιμο)**?
 - Because when the **recovery manager** rolls back (step a) **T1** then A gets its initial value.
 - But T2 has already utilized this wrong value and committed something to the DB
 - The DB is consequently in an inconsistent state!



Nonrecoverable

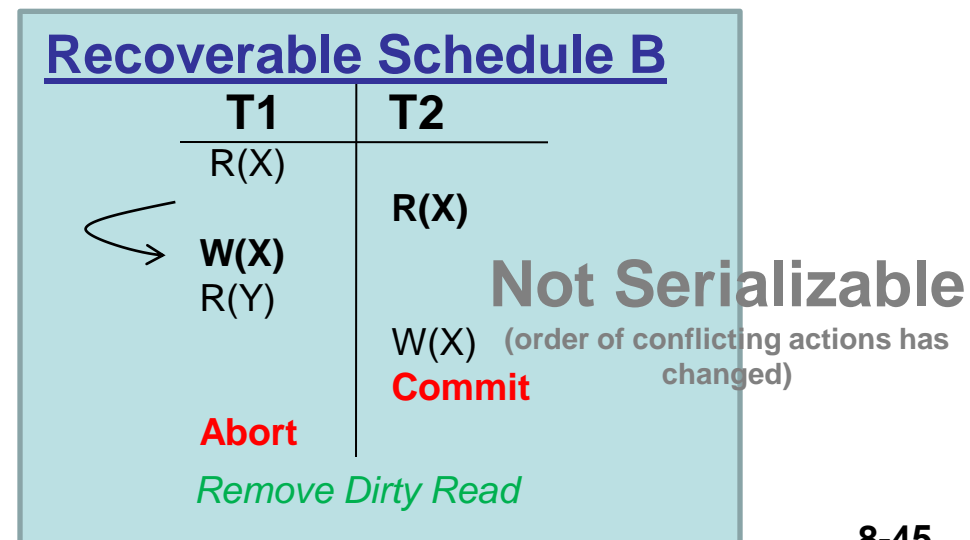
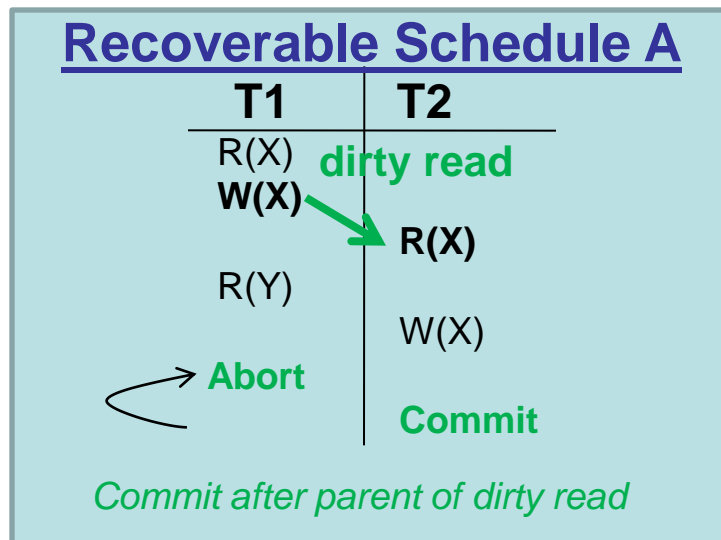
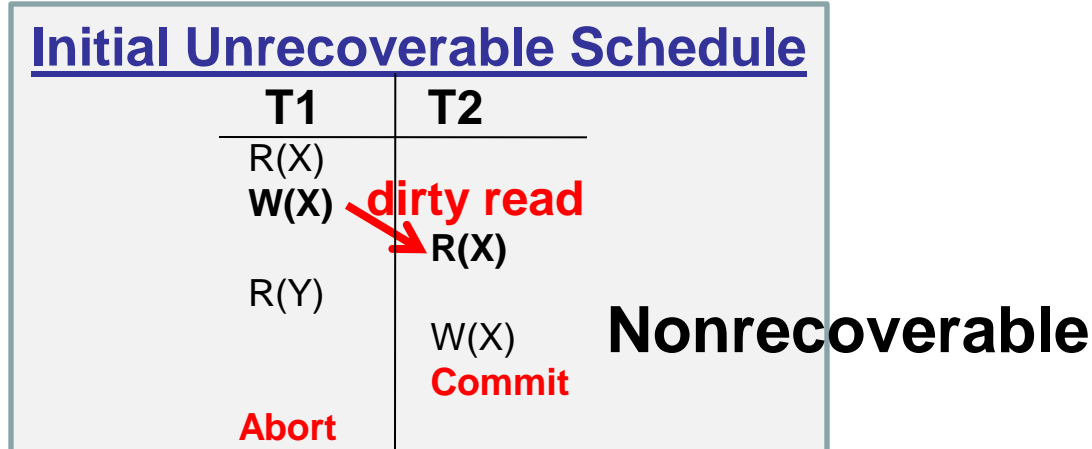
Recoverable Schedule



Characterizing
Schedules based on:
Serializability
Recoverability

(Επαναφέρσιμο Χρονοπρόγραμμα)

- How can we make the Schedule Recoverable?

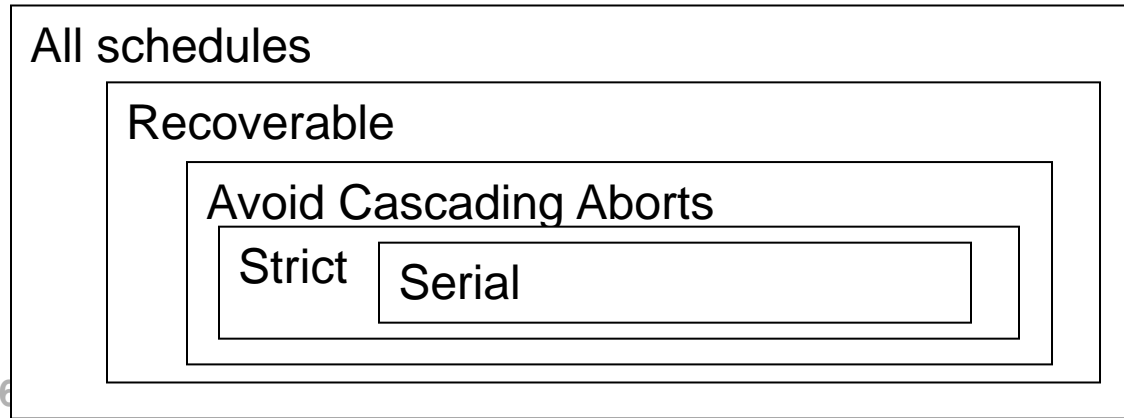


Other Schedules based on Recoverability



(Άλλα χρονοπρογράμματα βάση Επαναφερσιμότητας)

- There are **more strict types** of Schedules (based on the **Recoverability properties**)
 - **Cascadeless schedule (Χρονοπρόγραμμα χωρίς διαδιδόμενη ανάκληση):**
(or Schedule that **Avoids Cascading Rollbacks**)
 - Refers to cases where we have aborts.
 - **Strict Schedules (Αυστηρό Χρονοπρόγραμμα)**
 - These schedules are very simple to be recovered!
 - Thus, the DBMS prefers this class of Schedules.



Cascadeless Schedule



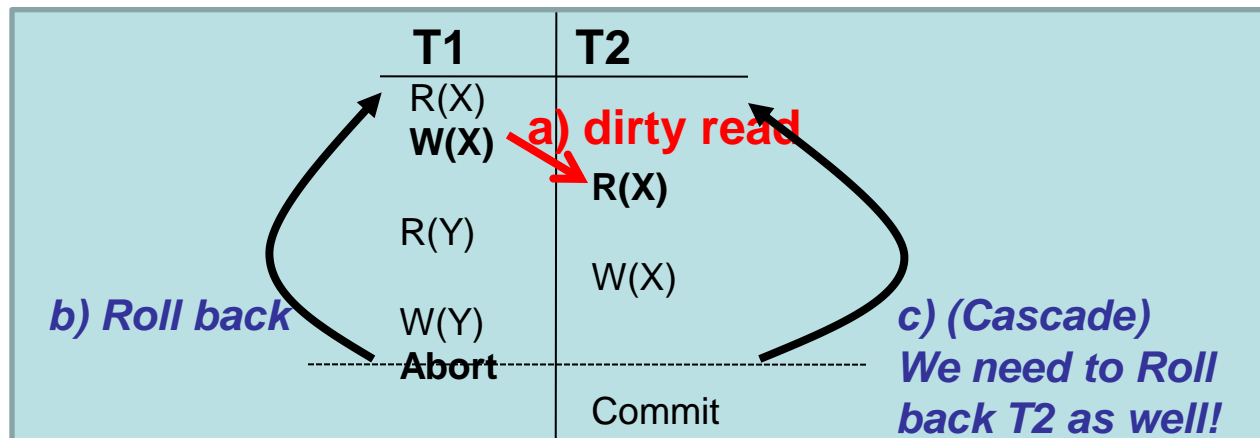
Characterizing
Schedules based on:

Serializability

Recoverability

(Χρονοπρόγραμμα χωρίς διαδιδόμενη ανάκληση)

- **Cascadeless schedule (Χρονοπρόγραμμα χωρίς διαδιδόμενη ανάκληση):** or Schedule that **Avoids Cascading Rollbacks**
 - One where a rollback does not cascade to other Xacts
 - Why is this necessary? **Rollbacks are Costly!**
 - How can we achieve it? Every transaction **reads** only the items that are **written** by **committed** transactions.



NOT Cascadeless (but Recoverable)



Cascadeless Schedule

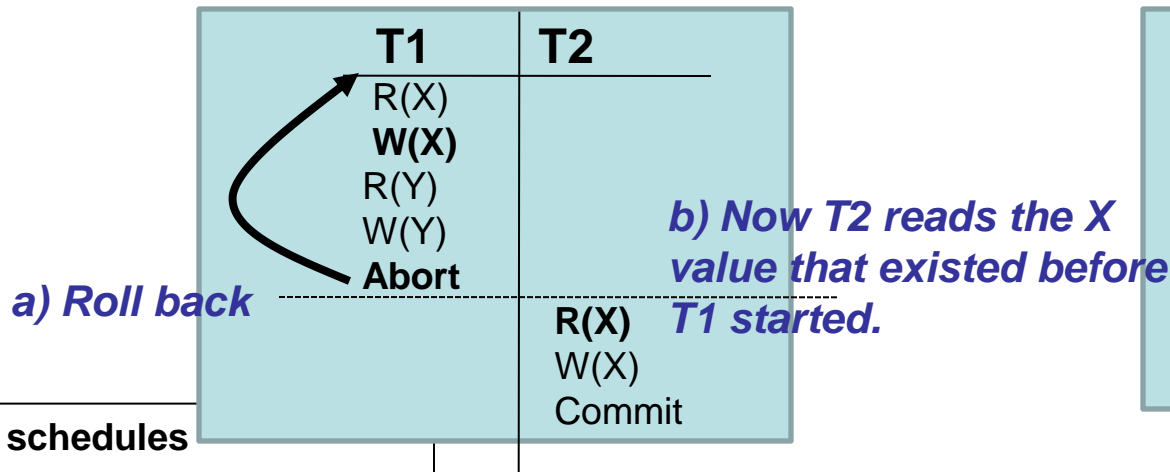
Characterizing
Schedules based on:
Serializability
Recoverability

(Χρονοπρόγραμμα χωρίς διαδιδόμενη ανάκληση)

- Let us turn the previous example into a Cascadeless Schedule
 - Recall, in order to get a Cascadeless Schedule, every transaction **must read** only **committed data**

Cascadeless Schedule

Another Cascadeless Schedule



T1	T2
R(X)	
W(X)	
R(Y)	
	W(X)
W(Y)	
Abort	
	Commit

... but not strict

All schedules

Recoverable

Avoid Cascading Aborts

Strict

Serial



Strict Schedule

(Αυστηρό Χρονοπρόγραμμα)

Characterizing
Schedules based on:
Serializability
Recoverability

- **Strict Schedule (Αυστηρό Χρονοπρόγραμμα):**
- A schedule is strict if overriding of uncommitted data is not allowed.
- Formally, if it satisfies the following conditions:
 - T_j **reads** a data item X **after** T_i has terminated (aborted or committed)
 - T_j **writes** a data item X **after** T_i has terminated (aborted or committed)



- Why is this necessary? **Eliminates Rollbacks!**
 - If a schedule is strict, a rollback can be achieved simply by resetting the Xact variables to the value before its start value, e.g.,

Cascadeless but NOT Strict

	T1	T2
	// X=9 W(X,5)	
b) Rollback X=9 now	Abort	W(X,8) Commit

c) Why is this a problem?

Because X now became again 9 rather than X=8 or X=5!

a) Changing an item that
has not been committed
yet (X=8 now)



Characterizing Schedules

Characterizing
Schedules based on:

Serializability
Recoverability

(Χαρακτηρίζοντας Χρονοπρογράμματα)

- **Venn Diagram** Illustrating the Different ways to characterize a Schedule based on **Serializability** and **Recoverability**

