Distributed Transactions

From

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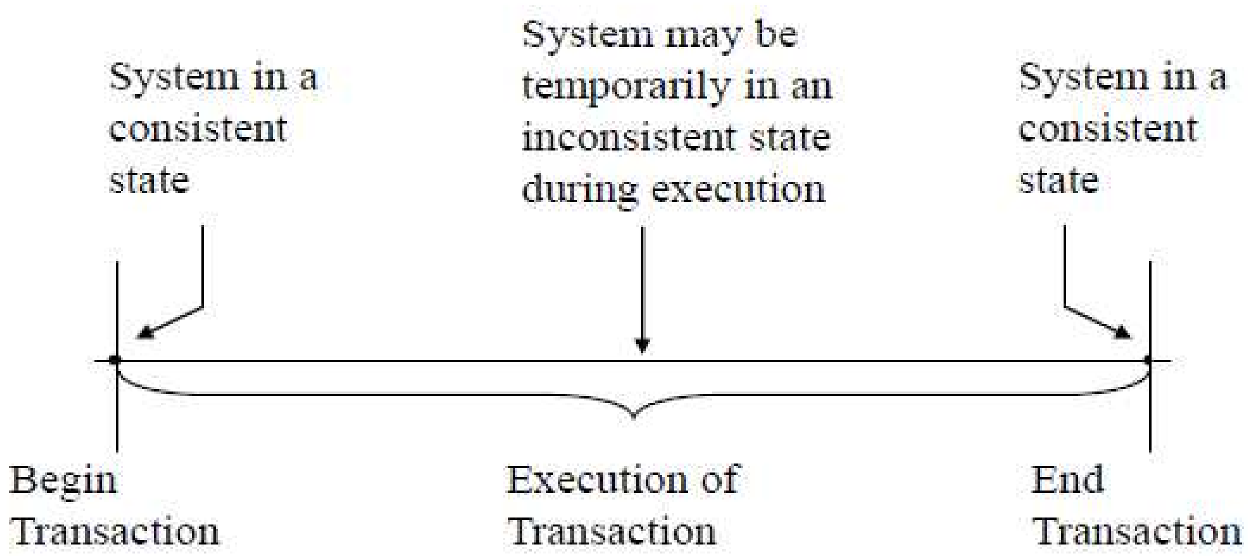
Transaction

A transaction is a collection of actions that make consistent transformations of system states while preserving system consistency.

- concurrency transparency
- failure transparency



Example of Transaction

```
begin
    input(flight_no, date, customer_name);
    Begin_transaction Reservation
    begin
        Write(flight(date).stsold++);
        Write(flight(date).cname, customer_name);
        Commit
    end. {Reservation}
    output("reservation completed")
...
end
```

Transaction Primitives

- Special primitives required for programming using transactions
  - Supplied by the operating system or by the language runtime system
- Examples of transaction primitives:
  - BEGIN_TRANSACTION: Mark the start of a transaction
  - END_TRANSACTION (EOT): Terminate the transaction and try to commit (there may or may not be a separate COMMIT command)
  - ABORT_TRANSACTION: Kill the transaction and restore the old values
  - READ: Read data from a file (or other object)
  - WRITE: Write data to a file (or other object)

Operations of the *Account* interface

deposit(amount)
deposit amount in the account
withdraw(amount)
withdraw amount from the account
getBalance() -> amount
return the balance of the account
setBalance(amount)
set the balance of the account to amount

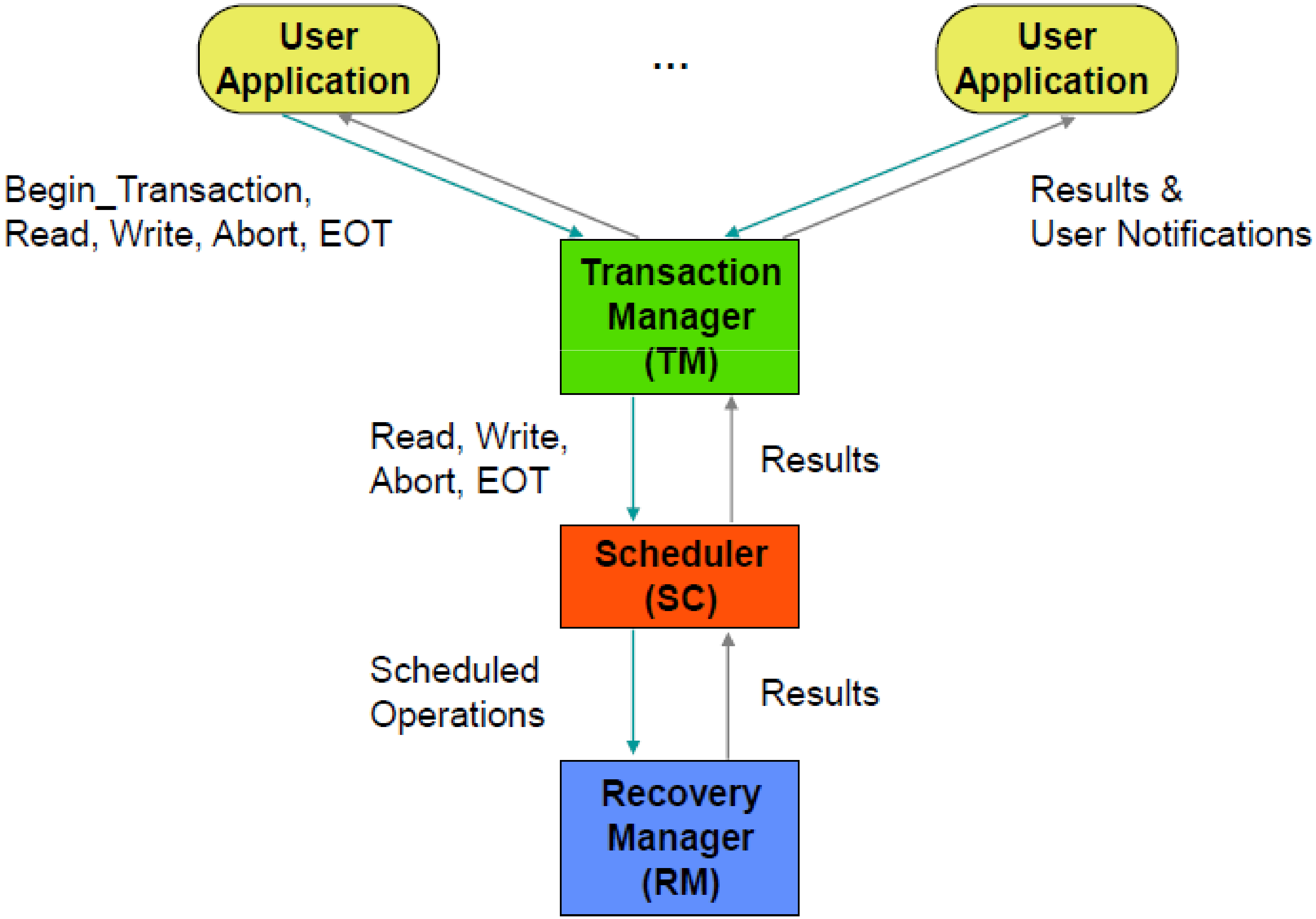
Operations of the Branch interface

create(name) -> account
create a new account with a given name
lookUp(name) -> account
return a reference to the account with the given name
branchTotal() -> amount
return the total of all the balances at the branch

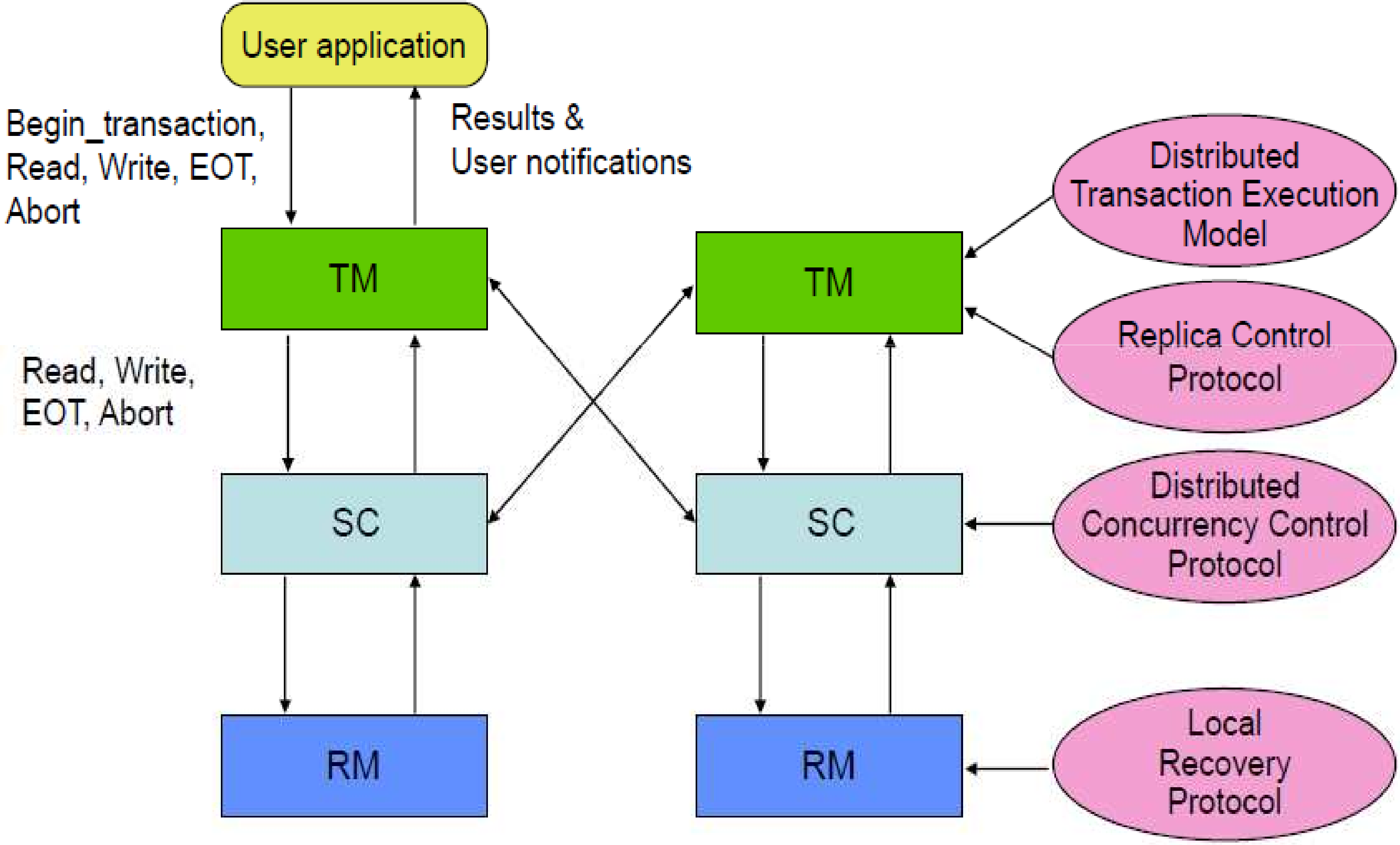
Enhancing Client Cooperation by Signaling

- **Clients** may use a **server** as a means of **sharing** some **resources**. E.g. some clients update the server's objects and other clients access them.
- However, in some applications, **threads** need to **communicate** and **coordinate** their actions.
- **Producer** and **Consumer** problem.
  - **Wait** and **Notify** actions.

Centralized Transaction Execution



Distributed Transaction Execution



Properties of Transactions

ATOMICITY

- All or nothing
- Multiple operations combined as an atomic transaction

CONSISTENCY

- No violation of integrity constraints
  - → System specific rules. In a distributed database, the index should always reflect the data, foreign key constraints are not violated, triggers are issued, replicas have the same value, etc.
- Transactions are correct programs

ISOLATION ⇐ Our focus in this module

- Concurrent changes invisible → serializable

DURABILITY

- Committed updates persist
- Database recovery

Serializability of Transactions

- Serializability
  - If several transactions are executed concurrently, the results must be the same as if they were executed serially in some order.
- Incomplete results
  - An incomplete transaction cannot reveal its results to other transactions before its commitment.
  - Necessary to avoid cascading aborts.
  - Anomalies:
    - → Lost updates
      - – The effects of some transactions are not reflected on the database.
    - → Inconsistent retrievals
      - – E.g. a transaction, if it reads the same object more than once, should always read the same value.

Introduction to Transaction Processing (6)

Why Concurrency Control is needed:

- **The Lost Update Problem**
  - This occurs when two transactions that access the same database items have their operations interleaved in a way that makes the value of some database item incorrect.
- **The Temporary Update (or Dirty Read) Problem**
  - This occurs when one transaction updates a database item and then the transaction fails for some reason
  - The updated item is accessed by another transaction before it is changed back to its original value.
- **The Incorrect Summary Problem**
  - If one transaction is calculating an aggregate summary function on a number of records while other transactions are updating some of these records, the aggregate function may calculate some values before they are updated and others after they are updated.

Concurrent execution is uncontrolled: (a) The lost update problem.

(a)

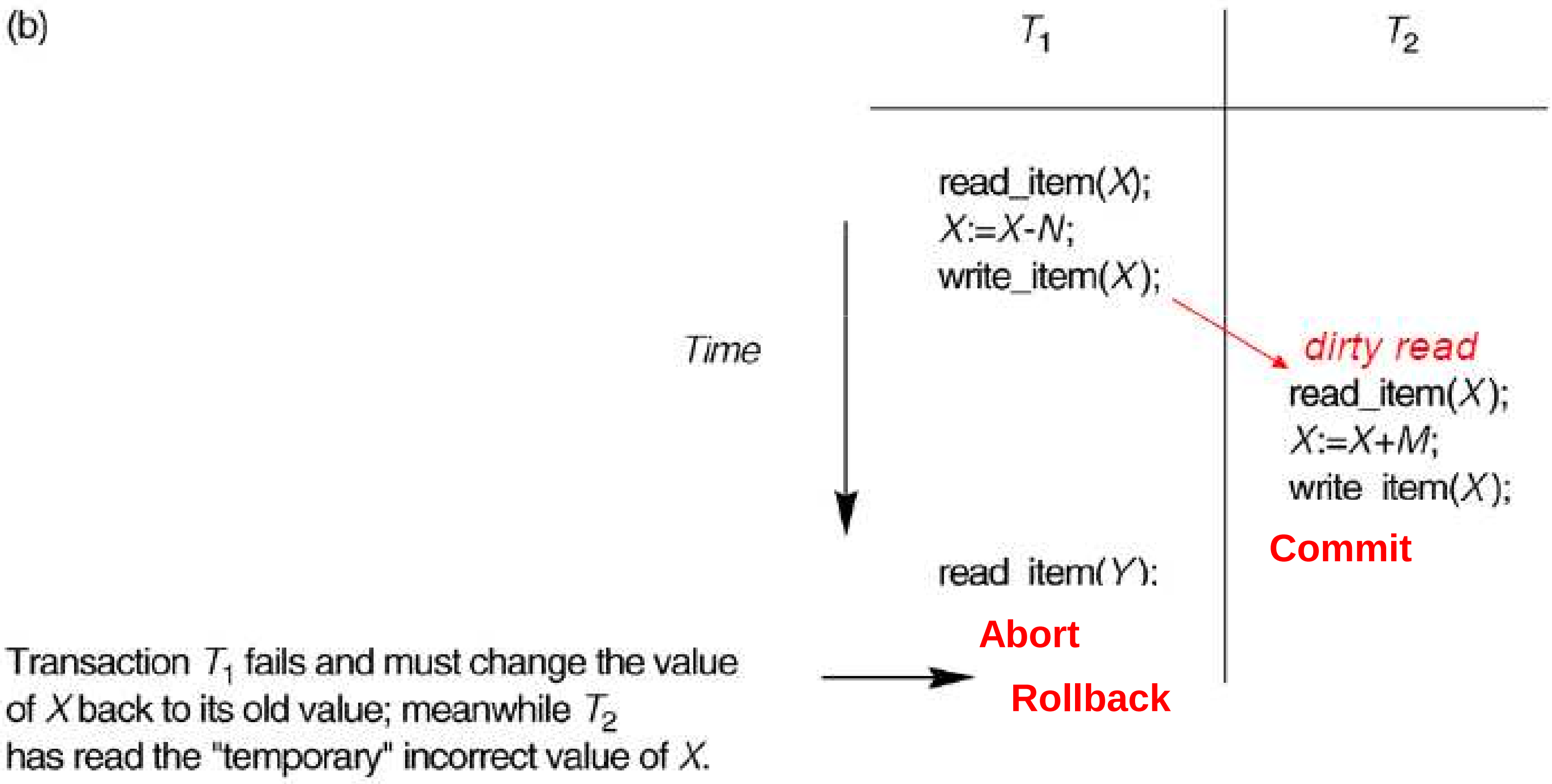
Time

T_1	T_2
read_item(X); X:=X-N;	
	read_item(X); X:=X+M;
write_item(X); read_item(Y);	
	write_item(X);
Y:=Y+N; write_item(Y);	

Item X has an incorrect value because its update by T_1 is "lost" (overwritten)

Lost Update: T_2 reads the value of X *before* T_1 changes it in the database

Concurrent execution is uncontrolled: (b) The temporary update problem.



Temporary Update: T_2 reads the *temporary* value of X *before* T_1 commits

Concurrent execution is uncontrolled: (c) The incorrect summary problem.

(c)

T_1	T_3

	sum:=0;
	read_item(*A*);
	sum:=*sum*+*A*;
	⋮

read_item(*X*);
X:=*X*-N;
write_item(*X*);	

	read_item(*X*);
	sum:=*sum*+*X*;
	read_item(*Y*);
	sum:=*sum*+*Y*;

read_item(*Y*);
Y:=*Y*+*N*;
write_item(*Y*);	

T_3 reads *X* after *N* is subtracted and reads *Y* before *N* is added; a wrong summary is the result (off by *N*).

Serially Equivalent

- **If these transactions are done one at a time in some order, then the final result will be correct.**
- If we do not want to sacrifice the concurrency, an **interleaving** of the **operations** of **transactions** may lead to the **same effect** as if the **transactions** had been **performed one** at a **time** in **some order**.
- We say it is a **serially equivalent.**
- The use of **serial equivalence** is a criterion for **correct concurrent execution** to prevent lost updates and inconsistent retrievals.

Concurrency Control – Lost Update Problem

Initial values: A=100, B=200, C=300

Transaction *T*:		Transaction *U*:	
balance = b.getBalance();		*balance = b.getBalance();*	
*b.setBalance(balance*1.1);*		*b.setBalance(balance*1.1);*	
a.withdraw(balance/10)		*c.withdraw(balance/10)*	
balance = b.getBalance();	$200		
		balance = b.getBalance();	$200
		*b.setBalance(balance*1.1);*	$220
*b.setBalance(balance*1.1);*	$220		
a.withdraw(balance/10)	$80		
		c.withdraw(balance/10)	$280

a, b and c initially have bank account balance are: 100, 200, and 300.
T transfers an amount from a to b. U transfers an amount from c to b.
b is increased by 10% on its balance in each. Totally 20 % hike

Concurrency Control – Inconsistent Retrieval Problem

Initial values: A=200, B=200

Transaction *V*: *a.withdraw(100)* *b.deposit(100)*		**Transaction *W*:** *aBranch.branchTotal()*	
a.withdraw(100);	\$100		
		total = a.getBalance()	\$100
		total = total+b.getBalance()	\$300
		total = total+c.getBalance()	
b.deposit(100)	\$300	:	

A serially equivalent interleaving of *T* and *U*

Transaction *T*:		**Transaction *U*:**	
balance = b.getBalance()		***balance = b.getBalance()***	
b.setBalance(balance*1.1)		***b.setBalance(balance*1.1)***	
a.withdraw(balance/10)		***c.withdraw(balance/10)***	
balance = b.getBalance()	**$200**		
b.setBalance(balance*1.1)	**$220**		
		balance = b.getBalance()	**$220**
		b.setBalance(balance*1.1)	**$242**
a.withdraw(balance/10)	**$80**		
		c.withdraw(balance/10)	**$278**

A serially equivalent interleaving of *V* and *W*

Transaction *V*:		**Transaction *W*:**	
a.withdraw(100); ***b.deposit(100)***		***aBranch.branchTotal()***	
a.withdraw(100);	**$100**		
b.deposit(100)	**$300**		
		total = a.getBalance()	**$100**
		total = total+b.getBalance()	**$400**
		total = total+c.getBalance()	
		...	

Read and *write* operation conflict rules

Operations of different transactions		Conflict	Reason
read	read	No	Because the effect of a pair of read operations does not depend on the order in which they are executed
read	write	Yes	Because the effect of a read and a write operation depends on the order of their execution
write	write	Yes	Because the effect of a pair of write operations depends on the order of their execution

A non-serially equivalent interleaving of operations of transactions *T* and *U*

Transaction *T*:	**Transaction *U*:**
x = read(i)	
write(i, 10)	
	y = read(j)
	write(j, 30)
write(j, 20)	
	z = read (i)

Access to objects i & j are serial, but transactions are not serially equivalent

Solutions to Concurrency control problems

– **Locks** used to order transactions that access the same object according to request order.

– **Optimistic concurrency control** allows transactions to proceed until they are ready to commit, whereupon a check is made to see any conflicting operation on objects.

– **Timestamp ordering** uses timestamps to order transactions that access the same object according to their starting time

A dirty read when transaction *T* aborts

Transaction *T*:		**Transaction *U*:**	
a.getBalance()		***a.getBalance()***	
a.setBalance(balance + 10)		***a.setBalance(balance + 20)***	
balance = a.getBalance()	**$100**		
a.setBalance(balance + 10)	**$110**		
		balance = a.getBalance()	**$110**
		a.setBalance(balance + 20)	**$130**
		commit transaction	
abort transaction			

Recoverability of Transactions

- The strategy for recoverability is to **delay commits** until after the **commitment** of any **other transaction** whose **uncommitted** state has been observed.
- In our example, *U delays its commit until after T commits.*
- *In* the case that *T aborts, then U must abort as well*

Cascading aborts

- Abort of one transaction will cause other transactions to abort.
- Transactions are **only allowed** to **read objects** that were **written** by **committed transactions**.
- To ensure that this is the case, any ***read*** *operation must be* ***delayed until*** *other* ***transactions*** *that applied a* ***write operation*** *to the* ***same object*** *have* ***committed*** *or* ***aborted***.

Overwriting uncommitted values or Pre-mature Writes

Transaction *T*:		**Transaction *U*:**	
a.setBalance(105)		*a.setBalance(110)*	
	$100		
a.setBalance(105)	$105		
		a.setBalance(110)	$110

Before Image : 100

Before Image : 105

Overwriting uncommitted values or Pre-mature Writes

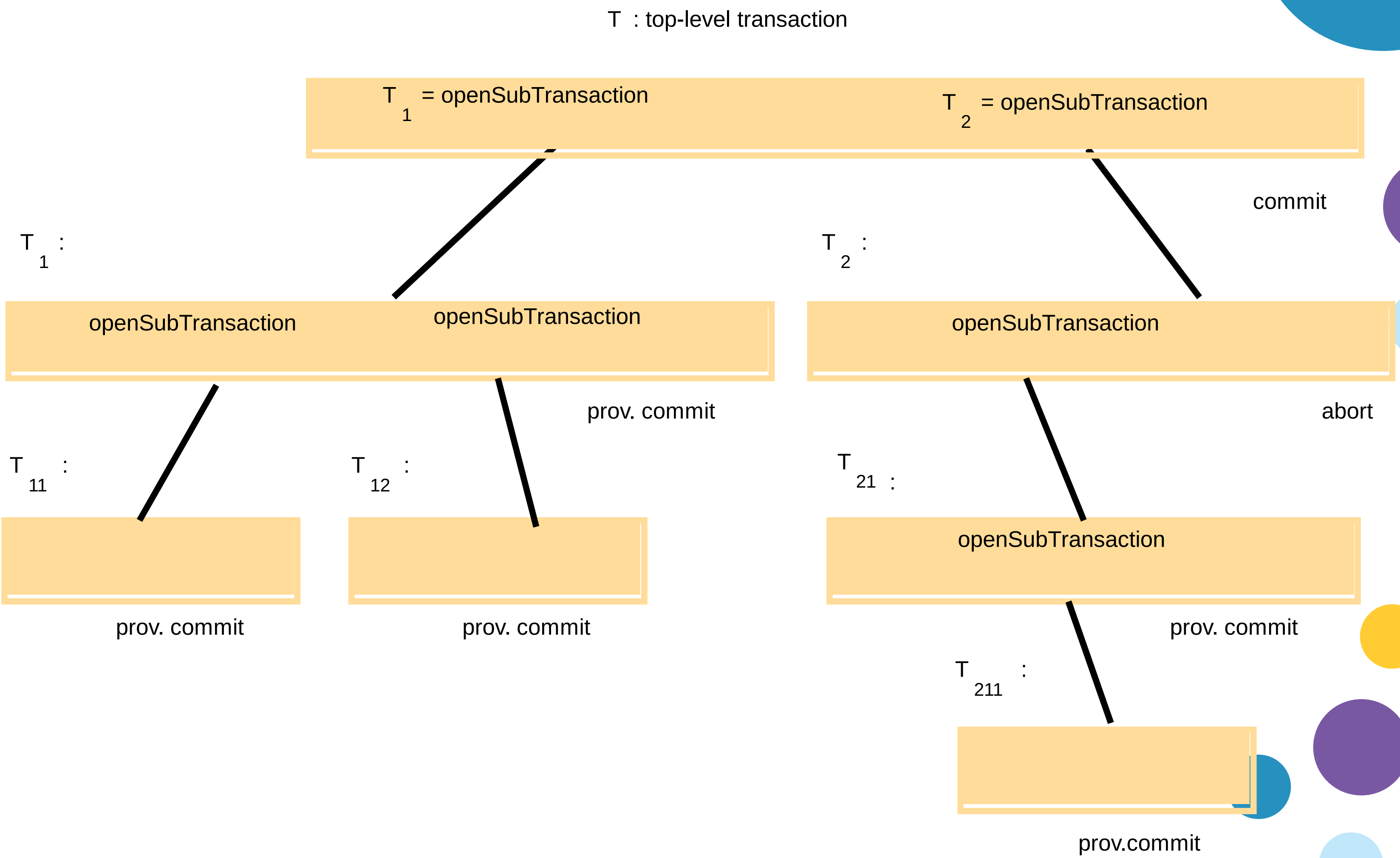
- **Strict Execution of Transactions**:

  If the transaction **delays** both **read** and **write** operations on an **object until** all **transactions** that **previously wrote** that **object** have either **committed** or **aborted**.
- **Tentative Version**: Make changes to tentative versions of objects. If transaction commits, transfer updates to objects, else delete tentative version.

Nested transactions

- **Nested transactions** extend the above transaction model by allowing **transactions** to be **composed** of **other transactions**.
- Thus **several transactions** may be **started** from **within** a **transaction**.

Nested transactions



Nested transactions

- **Subtransactions** at one **level** (and their descendants) may **run concurrently** with other **subtransactions** at the same level in the hierarchy.
- **Subtransactions** can **commit** or **abort independently**.

Nested transactions

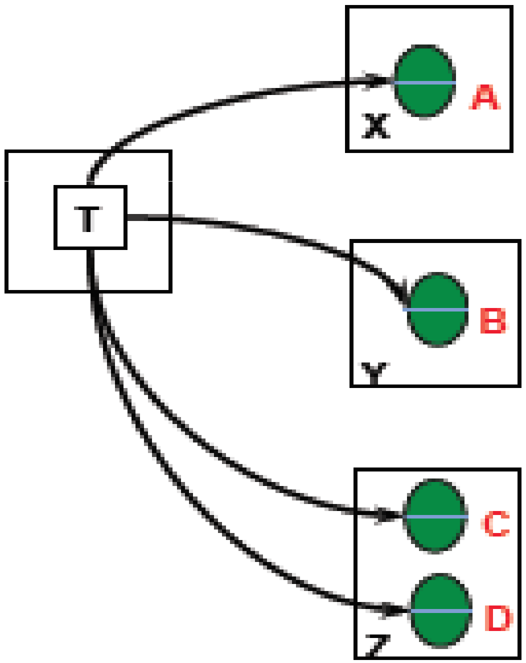
- The rules for committing of nested transactions
  - A transaction may **commit** or **abort** only after its **child** transactions have completed.
  - When a **subtransaction completes**, it makes an **independent** decision either to commit provisionally or to abort. Its decision to abort is final.
  - When a **parent aborts**, **all** of its **subtransactions** are aborted.

Nested transactions

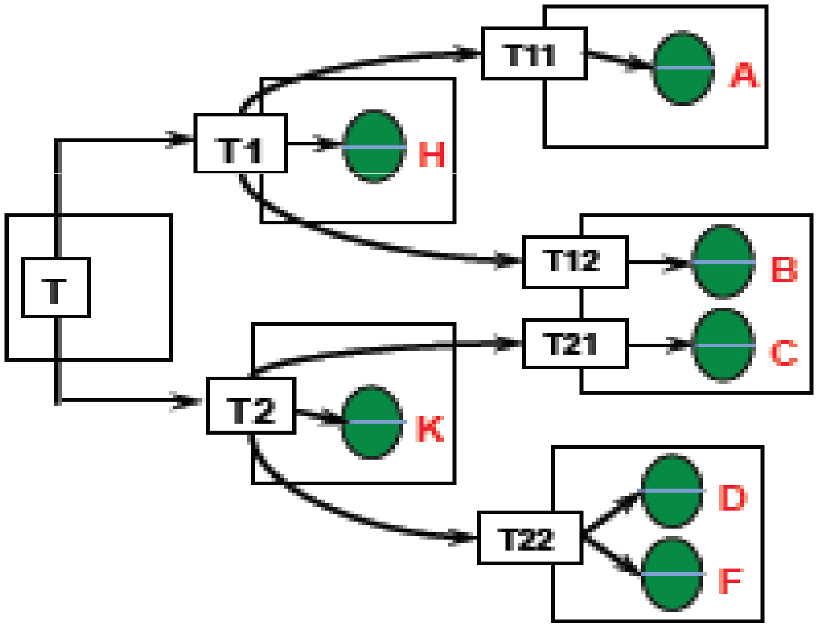
- When a **subtransaction aborts**, the **parent** can **decide** whether to **abort** or **not**.
- If the **top-level transaction commits**, then all of the **subtransactions** that have provisionally **committed** can **commit** too, provided that **none** of their **ancestors** has **aborted**.

Distributed Transactions

- Transactions that invoke operations at multiple servers



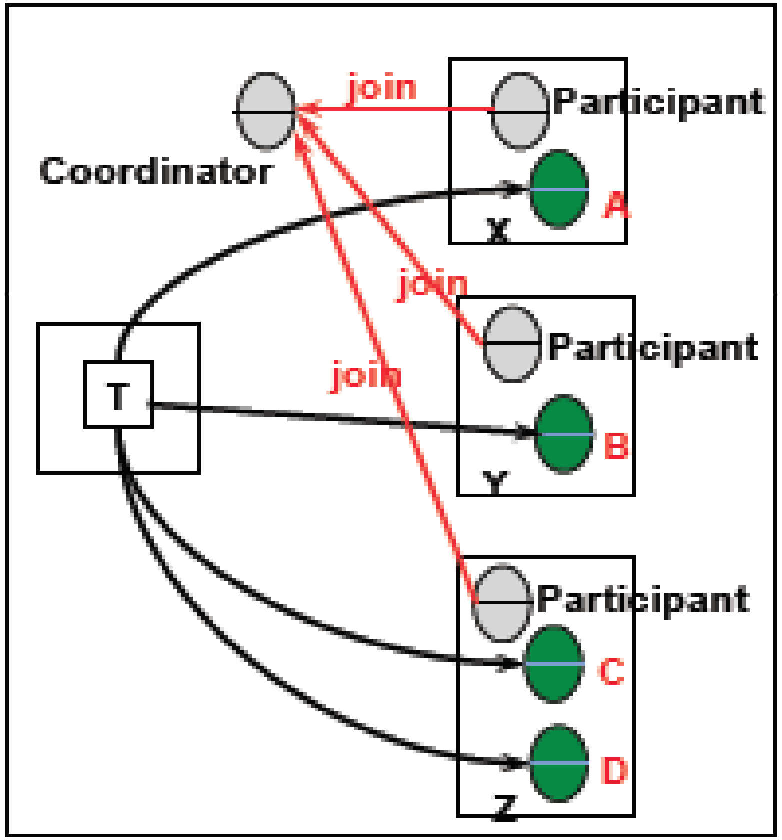
Flat Distributed Transaction



Nested Distributed Transaction

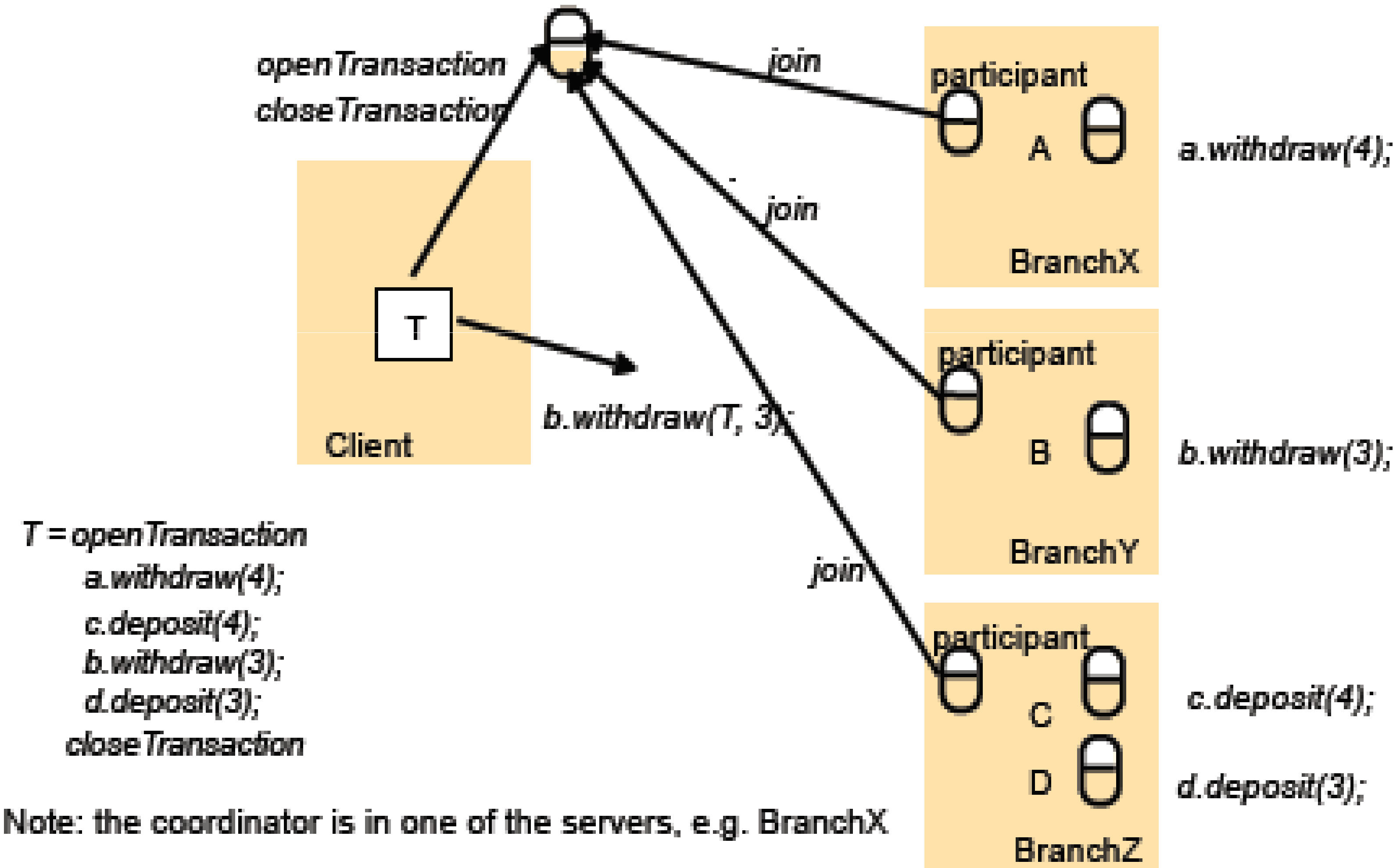
Distributed Transactions

- Coordinator
  - In charge of begin, commit, and abort
- Participants
  - Server processes that handle local operations



Coordinator & Participants

Distributed Transactions - Example



Note: the coordinator is in one of the servers, e.g. BranchX

Thank You