COMP207
Database Development

Lecture 4

Transaction Management:
Serial and Concurrent Schedules

Labs start next week

- Lab start next week

- If you are not assigned to a session, tell me please

Team introduction

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In charge of assignments and labs

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Kortext drop in session

- Kortext (the guys giving the free e-books) will answer questions you have **Wednesday 2nd October** at **1pm** in **Lecture Theatre C** on the first floor of the **Central Teaching Hub**

Review

- Previous lecture:
  - Transactions
  - How transactions help to solve problems in practice
  - **ACID** properties
  - Which components of a DBMS are responsible for **ACID**
- Can you recall these?

Transactions

- Sequences of operations

  1. read(staffNo=1234, salary)
  2. salary=salary*1.1
  3. write(staffNo=1234, salary)

- Goals:
  - *Atomicity*: execute as a whole or not at all
  - *Serialisability*: the effect of executing it should be the same as if all transactions were executed serially

- In practice, avoids problems due to:
  - *Concurrency*: SQL queries that overlap in time
  - *Partial execution* of SQL statements (e.g., due to failures)

ACID Properties

A: Atomicity

C: Consistency

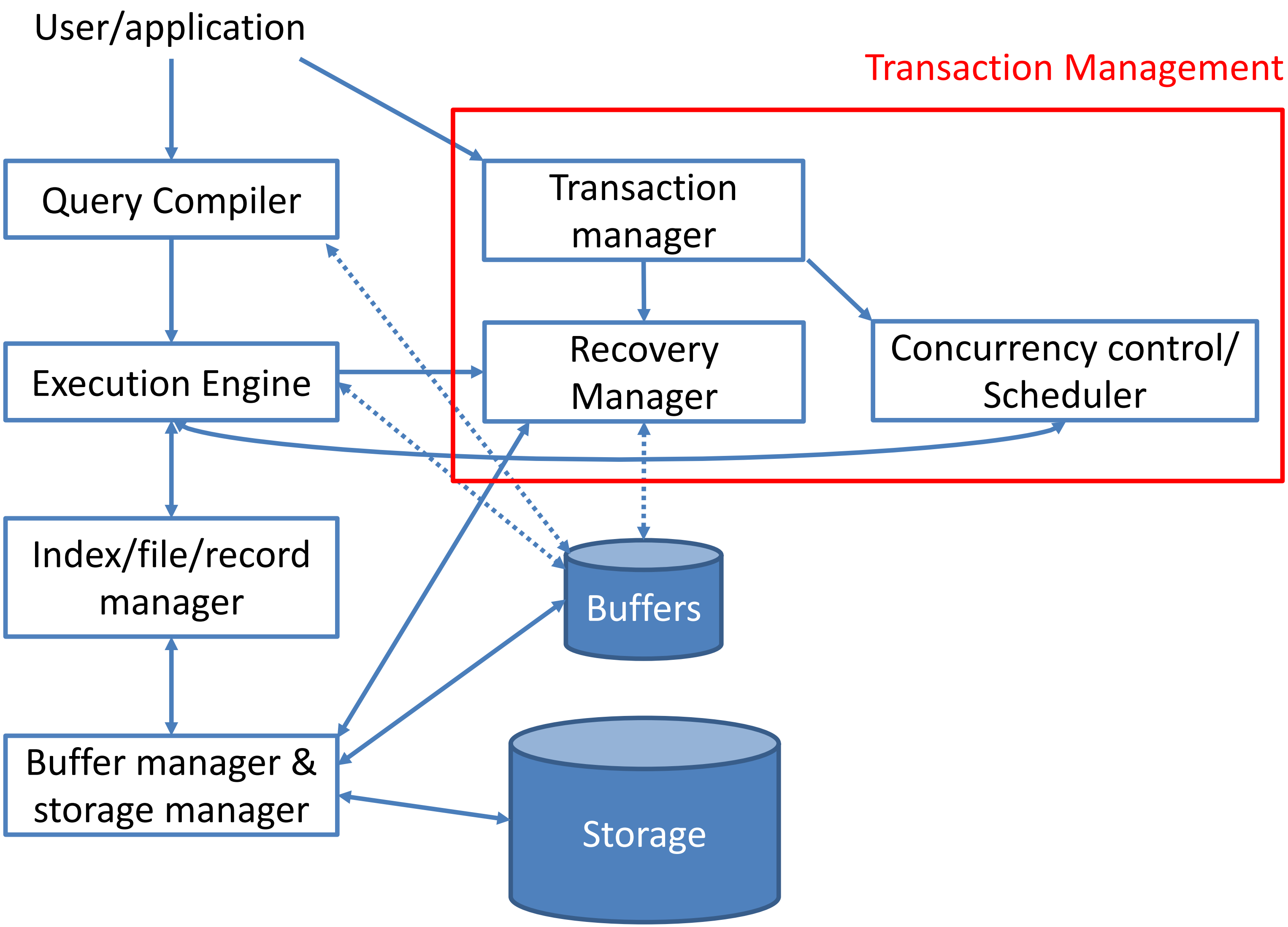
I: Isolation

D: Durability

Can you think of any situation where *Durability* might be violated?

Relational DBMS Components

(Simplified, from Lecture 1)



Relational DBMS Components

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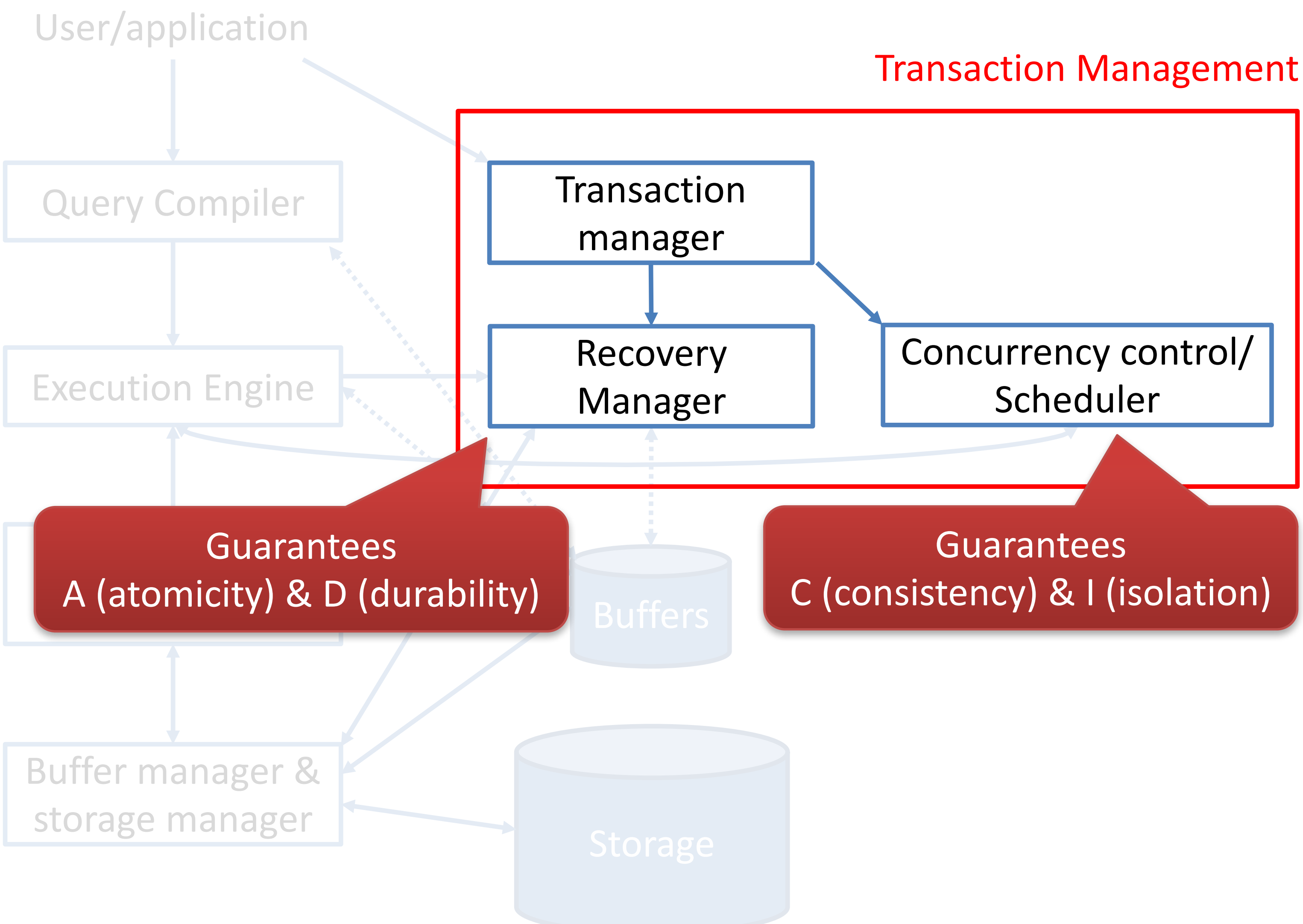


Outline

- Today:
  - Concurrency control – how to guarantee **C**onsistency and **I**solation?
  - Focus on basic concepts

Basic Operations of Transactions

- **read_item(X):** Reads a database item X into a program variable (also named X, for simplicity)
  - Find the address of the disk block (page) that contains item X
  - Copy that disk block into a buffer in main memory
    - if that disk block is not already in some main memory buffer
  - Copy item X from the buffer to the program variable X

- **write_item(X):** Writes the value of program variable X into the database item named X
  - Find the address of the disk block (page) that contains item X.
  - Copy that disk block into a buffer in main memory
    - if that disk block is not already in some main memory buffer.
    - Copy item X from the program variable X into its correct location in the buffer
    - Store the updated block from the buffer back to disk either immediately or at some later point in time.

Two Sample Transactions

T_1

```
Begin
read_item(X);
X := X + 100;
write_item(X);
read_item(Y);
Y := Y + 50;
write_item(Y);
commit;
End
```

Begin/End will often be omitted.

T_2

```
Begin
read_item(X);
read_item(Y);
X := X + Y;
write_item(X);
End
```

A Serial Transaction

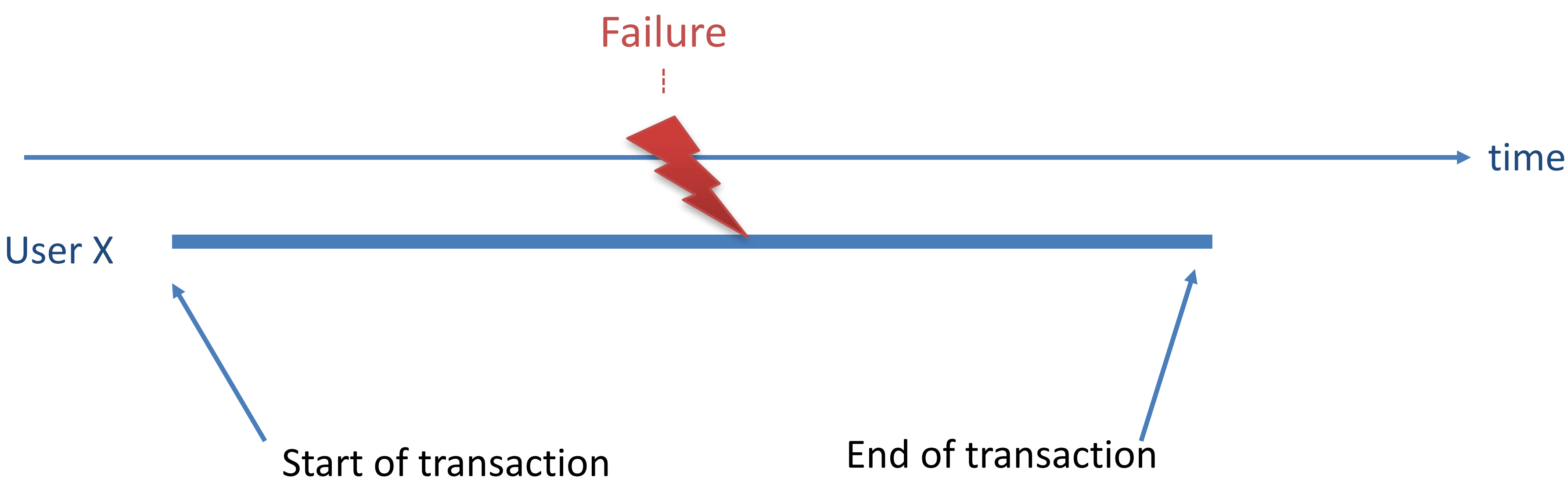
- These are run on their own – they execute serially and give correct results so they maintain consistency in the database

T_3

Begin
read_item(X);
X := X + 100;
write_item(X);
commit;
End

Time	T_3	X
t0		100
t1	Begin	100
t2	read_item(X)	100
t3	X = X + 100	200
t4	write_item(X)	200
t5	commit	200
t6	End	200

Atomicity is broken

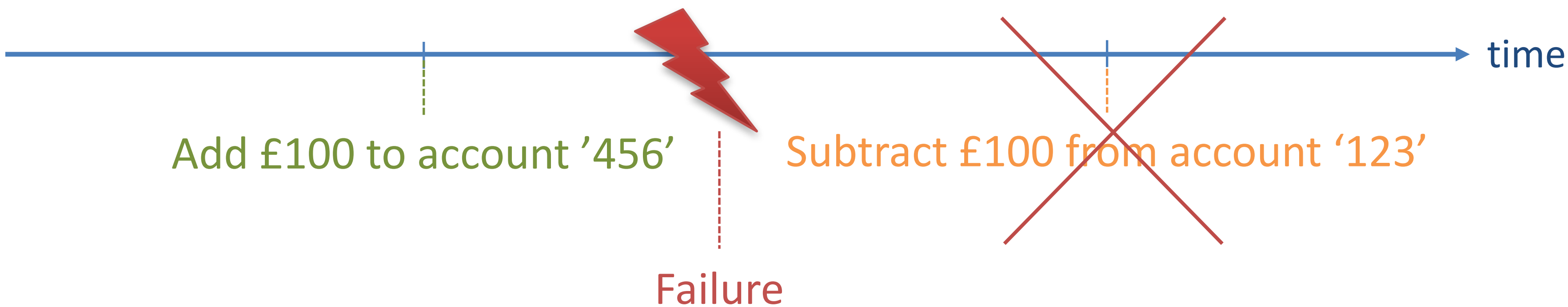


Example 2

(from Lecture 3)

Accounts(accountNo, accountHolder, balance)

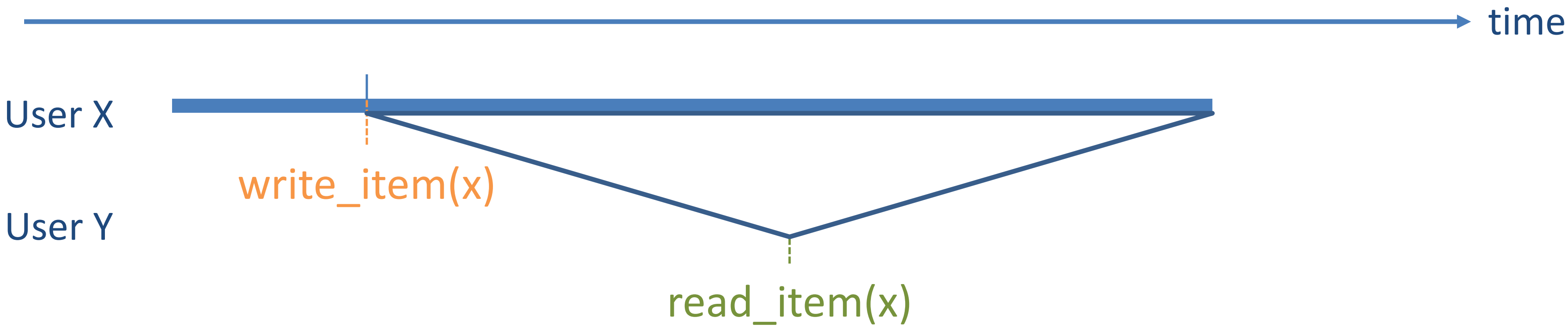
Goal: Transfer £100 from account ‘123’ to account ‘456’




```
UPDATE Accounts
SET    balance = balance + 100
WHERE  accountNo = 456;
```

```
UPDATE Accounts
SET    balance = balance - 100
WHERE  acountNo = 123;
```

Isolation is broken



Example 1

(from Lecture 3)

Flights(flightNo, date, seatNo, seatStatus)

time

User 1

Which seats on flight ‘123’ are still available?

Book seat ‘14B’

User 2

Which seats on flight ‘123’ are still available?

Book seat ‘14B’

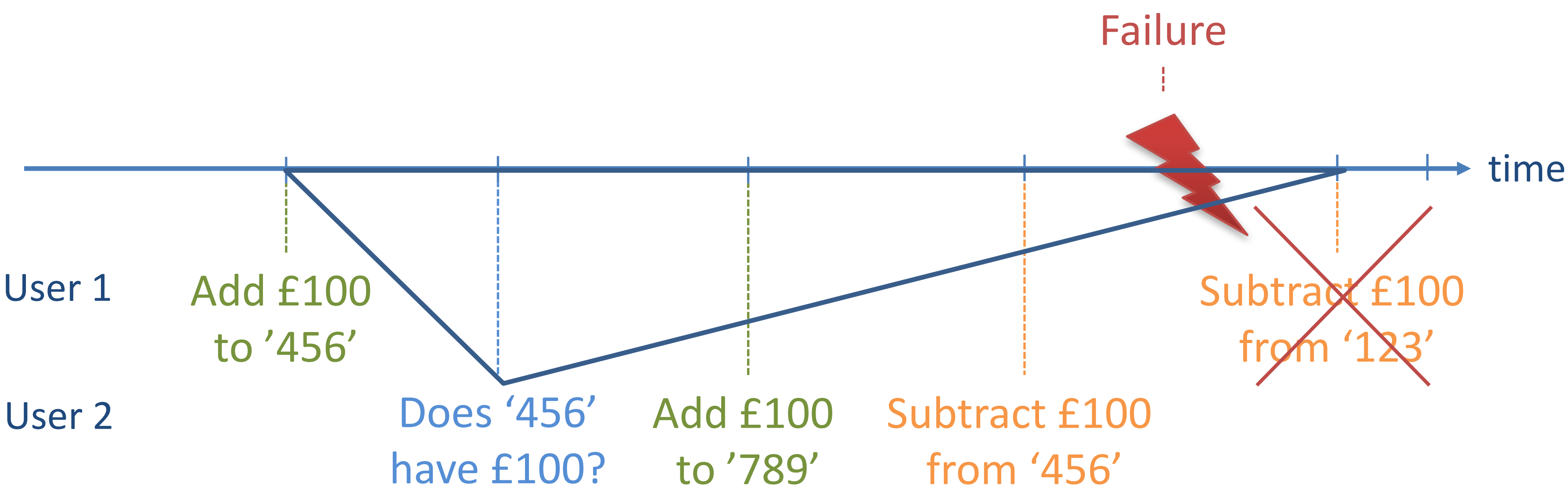
```
SELEC
FROM
WHERE
    AN
    AN
```

```
upied’
8’
```

No violation of isolation, because no triangle!

Example 3

(from Lecture 3)



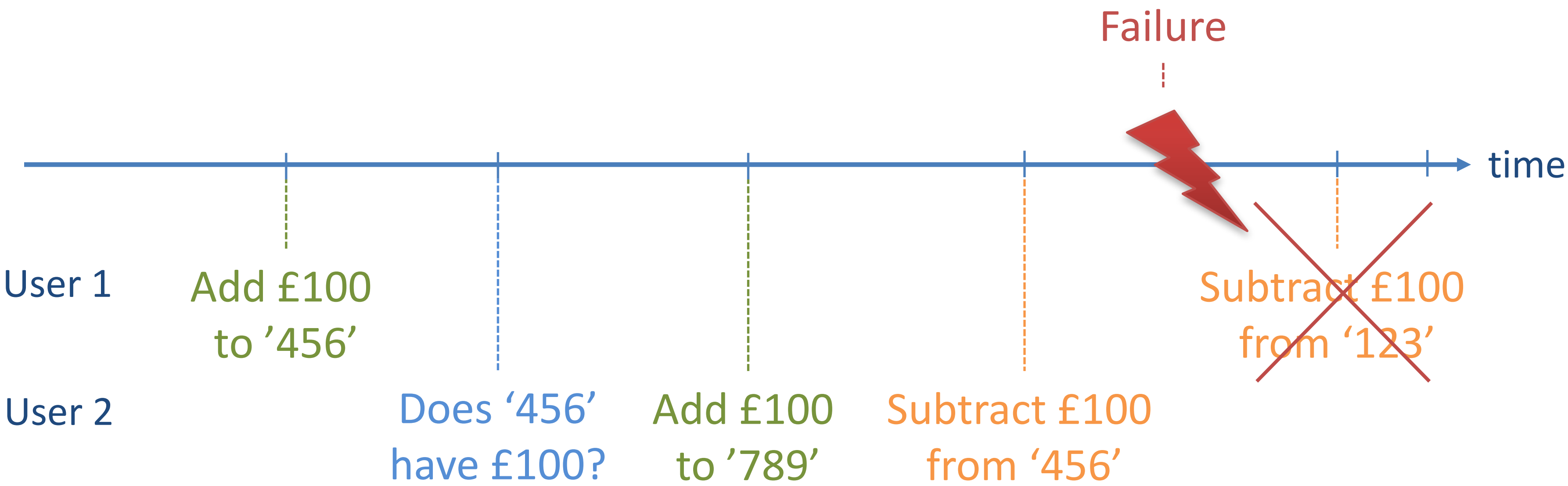
- Which of the ACID properties does this violate?
  - *Atomicity*
  - *Isolation*

Durability is broken

- Two cases:
    1. System and every backup breaks at the same time
    2. We rollback a completed transactions (e.g. to follow some other property)

Example 3

(from Lecture 3)



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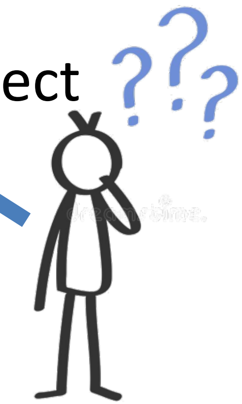
Must roll user 2's transaction back to satisfy isolation, but that breaks durability!

Consistency is broken

- From definition:
  - It should correctly transform the database state to reflect the effect of a real world event
  - Transactions may not violate integrity constraints



Easy!

- That said, we assume that consistency is satisfied for serial transactions (or equivalent) – see next slide!

Schedules

- Schedules hold many transactions for execution
- **Serial Schedule**
  - holds transactions, one after another
  - preserves the order of the operations of transactions
- Simplest form of schedule that guarantees *Consistency* and *Isolation* properties
- No interleaving of operations of the transactions (this would make it a ‘concurrent schedule’ → later)

A Serial Schedule

```
Begin (T1)
    read_item(X);
    X := X + 100;
    write_item(X);
    read_item(Y);
    Y := Y + 50;
    write_item(Y);
    commit;
End (T1)
Begin (T2)
    read_item(X);
    read_item(Y);
    X := X + Y;
    write_item(X);
    commit;
End (T2)
```

- Executes all operations in transaction T1, then all operations in transaction T2.
- As we are concerned with maintaining ACID properties, we will often ignore non-database operations such as X := X + 100 in future notation

Shorthand Notation for Schedules

Begin (T1)

    read_item(X);
    X := X + 100;
    write_item(X);
    read_item(Y);
    Y := Y + 50;
    write_item(Y);
    commit;

End (T1)

Begin (T2)

    read_item(X);
    read_item(Y);
    X := X + Y;
    write_item(X);
    commit;

End (T2)

- Shorthand notation for this schedule:

  $\mathbf{S_a\text{: } r_1(X); w_1(X); r_1(Y); w_1(y); c_1; r_2(X); r_2(Y); w_2(X); c_2}$

- Symbols:
  - $\mathbf{S}_{id}$ = schedule (*id* is the schedule ID)
  - $\mathbf{r}_i\mathbf{(X)}$ = read_item(X) in transaction *i*
  - $\mathbf{w}_i\mathbf{(X)}$ = write_item(X) in transaction *i*
  - $\mathbf{c}_i$ = commit in transaction *i*
  - $\mathbf{a}_i$ = abort (“rollback”) in transaction *i*

- Will be used much more in the next lectures

Another Example

Time	S_b	X
t0		100
t1	read_item(X)	100
t2	X = X - 10	90
t3	write_item (X)	90
t4	commit	90
t5	read_item(X)	90
t6	X = X + 100	190
t7	write_item(X)	190
t8	commit	190

What is the shorthand notation for this schedule?

Another Example

Time	S_b	X
t0		100
t1	read_item(X)	100
t2	X = X - 10	90
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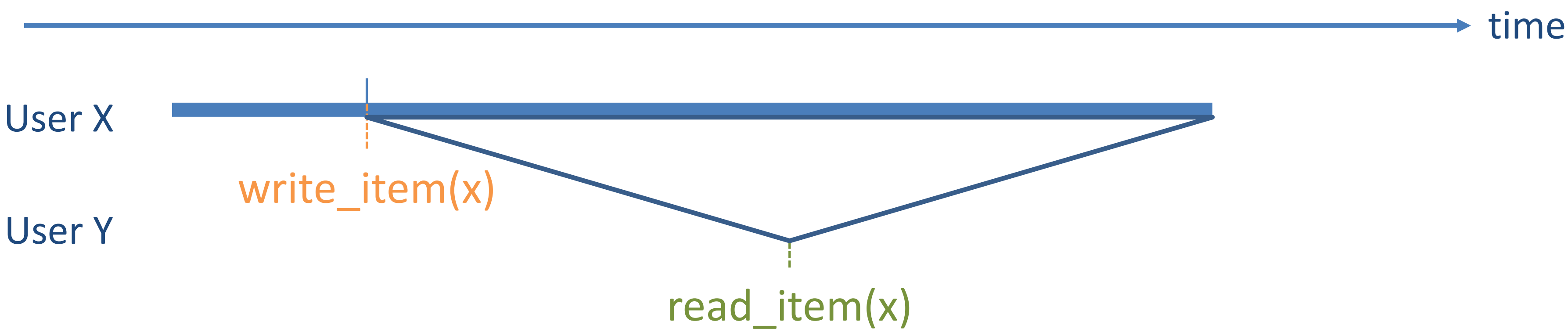
t5	read_item(X)	90
t6	X = X + 100	190
t7	write_item(X)	190
t8	commit	190

What is the shorthand notation for this schedule?

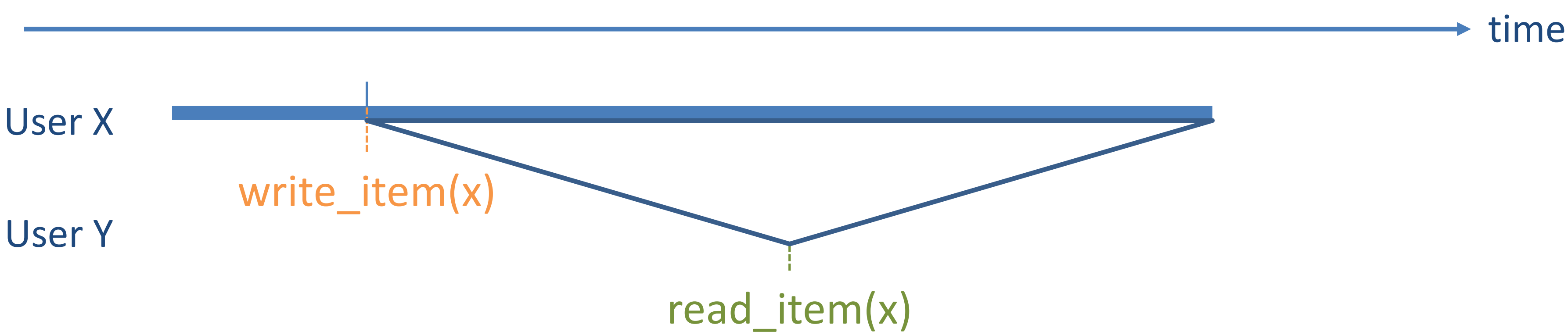
S_b: $r_1(x)$; $w_1(x)$; c_1; $r_2(x)$; $w_2(x)$; c_2

Isolation is broken



What is the shorthand notation for when isolation is broken?

Isolation is broken



What is the shorthand notation for when isolation is broken?

S_c: $w_x(x)$; … $r_y(x)$; … c_x; or
S_d: $w_x(x)$; … $r_y(x)$; … a_x; for $x \neq y$

Order Matters

Time	Schedule	X
t0		0
t1	read_item(X)	0
t2	X = X + 100	100
t3	write_item(X)	100
t4	commit	100
t5	read_item(X)	100
t6	X = X * 2	200
t7	write_item(X)	200
t8	commit	200

vs

Time	Schedule	X
t0		0
t1	read_item(X)	0
t2	X = X * 2	0
t3	write_item(X)	0
t4	commit	0
t5	read_item(X)	0
t6	X = X + 100	100
t7	write_item(X)	100
t8	commit	100

Concurrent Schedule

- Serial schedules waste time:
  - While executing a transaction, other transactions have to wait (assumes a single processor system).
  - Transactions may take a long time.
- *More efficient:* interleave operations of different transactions to maximize CPU usage
- **Concurrent Schedule:**
  - Executes operations from several transactions *concurrently* in an *interleaved* fashion
  - Operations of an individual transaction T appear in the same order in which they occur in T

A Serial Schedule

$r_1(x); w_1(x); r_1(y); w_1(y); c_1; r_2(x); w_2(x); c_2$

Time	Schedule	
t0		
t1	read_item(X)	
t2	X := X - N	
t3	write_item(X)	
t4	read_item(Y)	
t5	Y := Y + N	
t6	write_item(Y)	
t7	commit	
t8		read_item(X)
t9		X := X + M
t10		write_item(X)
t11		commit

A Concurrent Schedule

$r_1(x); r_2(x); w_1(x); r_1(y); w_2(x); c_2; w_1(y); c_1$

Time	Schedule	
t0		
t1	read_item(X)	
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Is this schedule always equivalent to the original one?

A Concurrent Schedule

$r_1(x); r_2(x); w_1(x); r_1(y); w_2(x); c_2; w_1(y); c_1$

Time	Schedule	
t0		
t1	read_item(X)	
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t3		X := X + M
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Is this schedule always equivalent to the original one?

No!

Concurrent Schedules Do Not Guarantee Consistency

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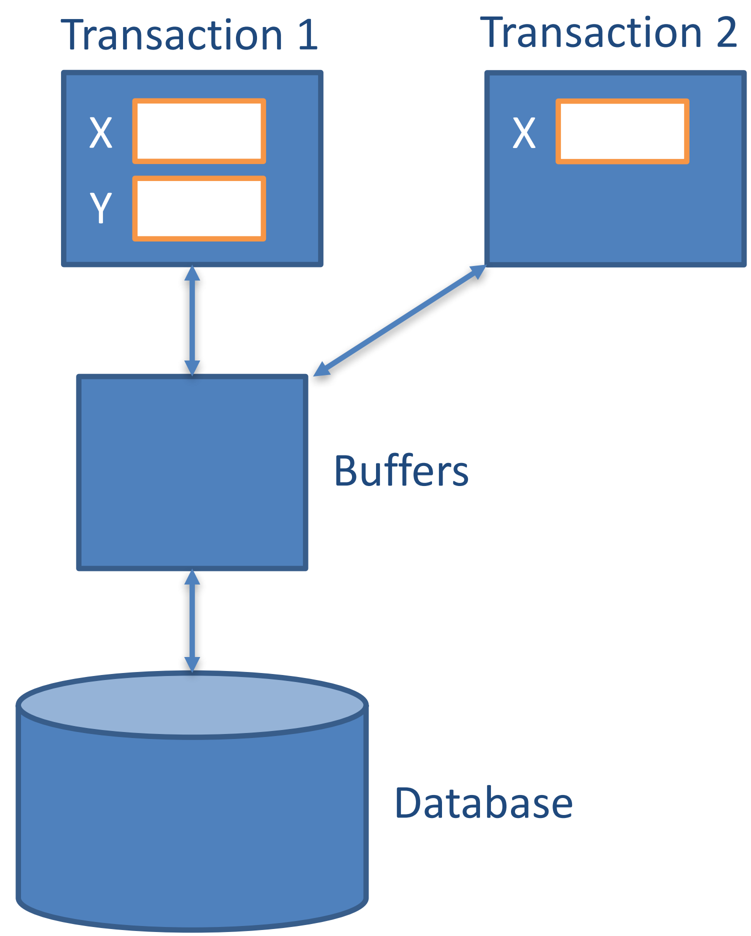

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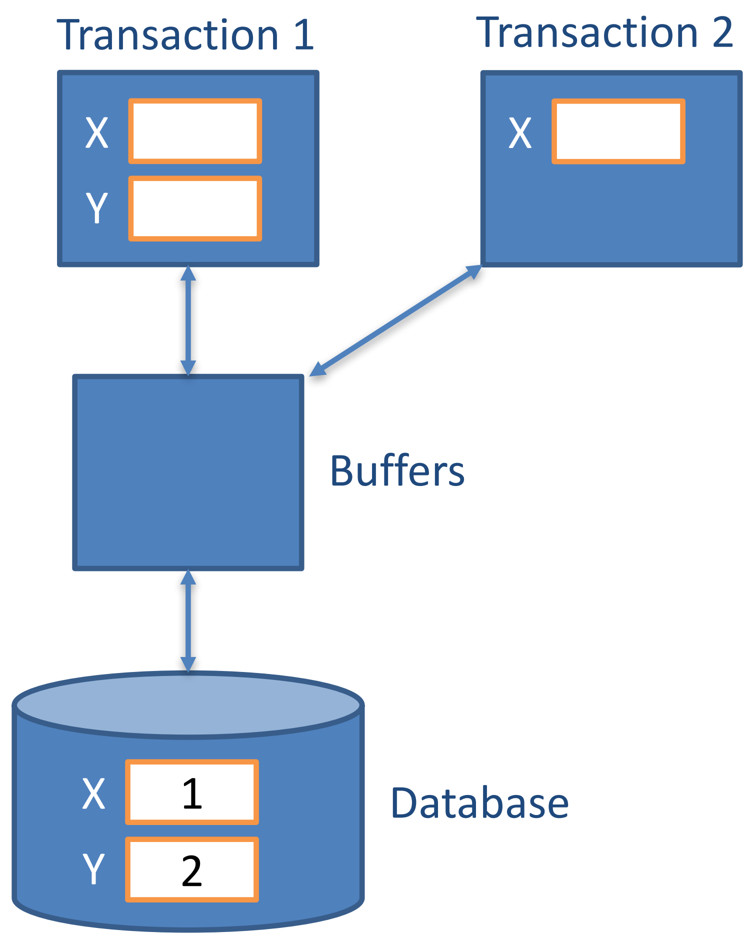

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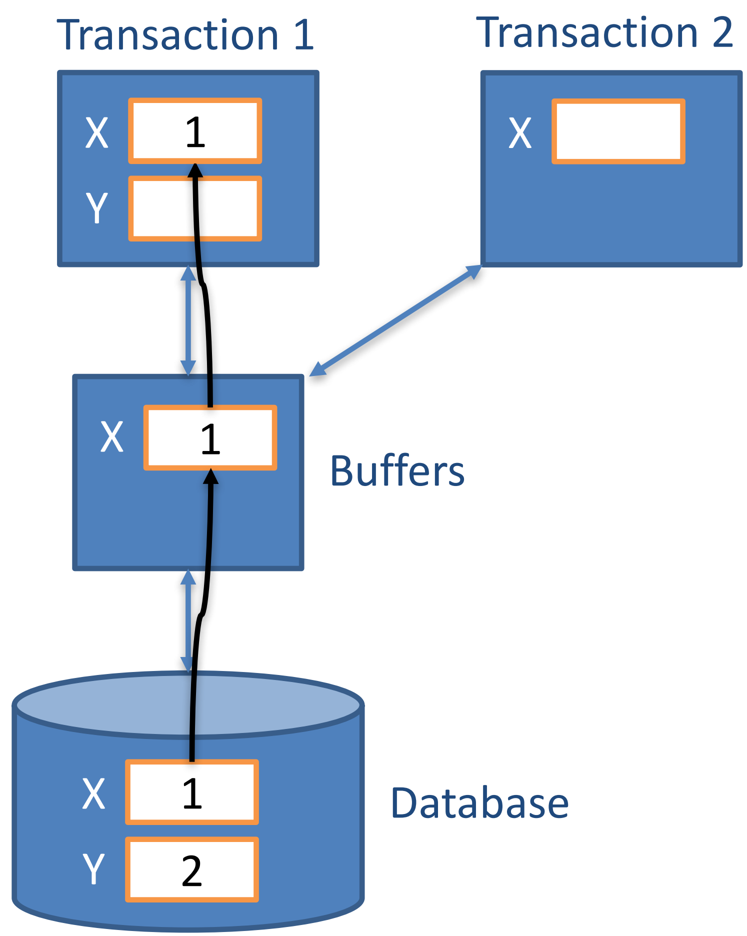

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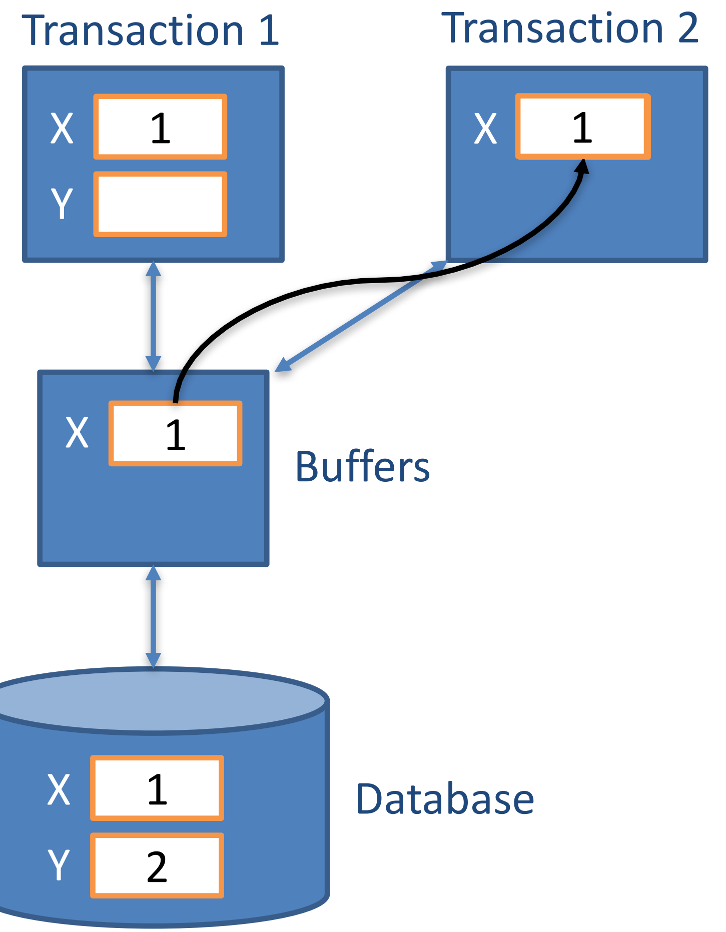

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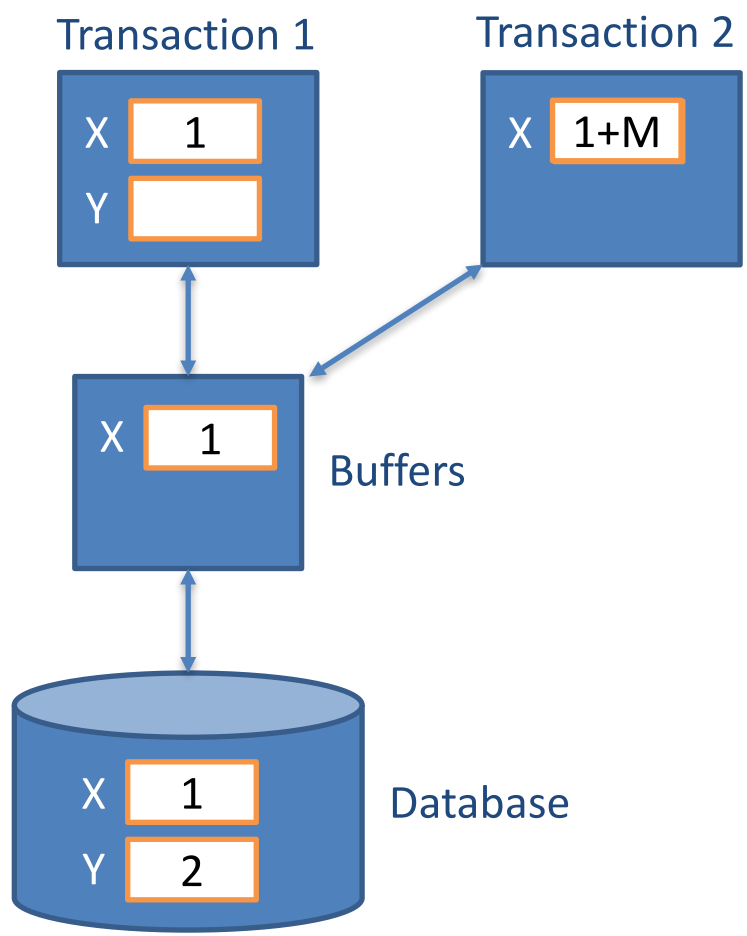

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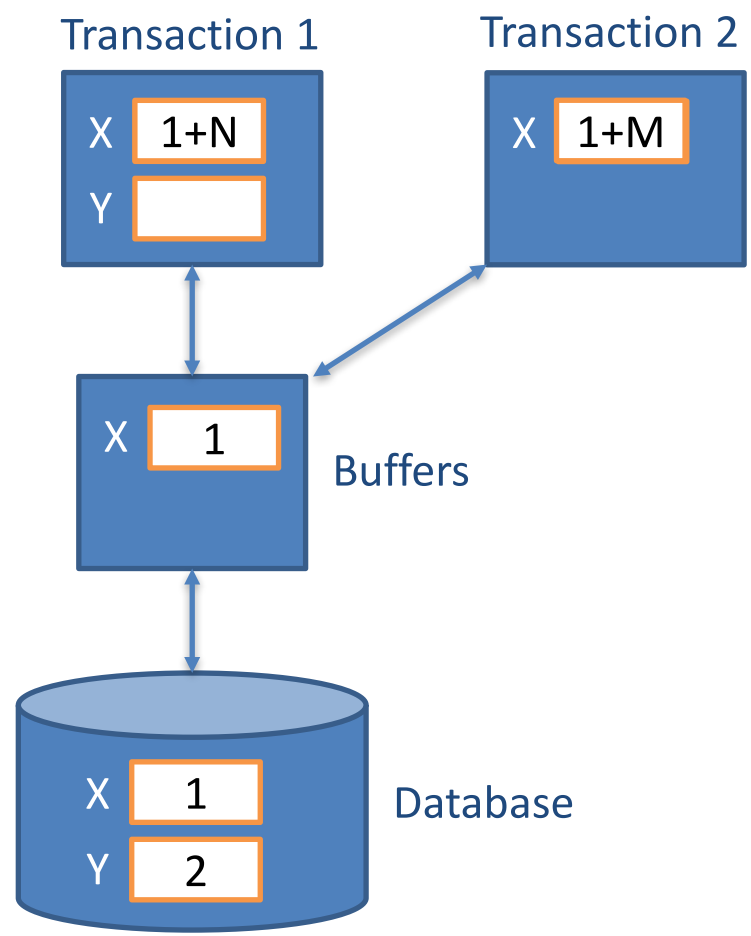

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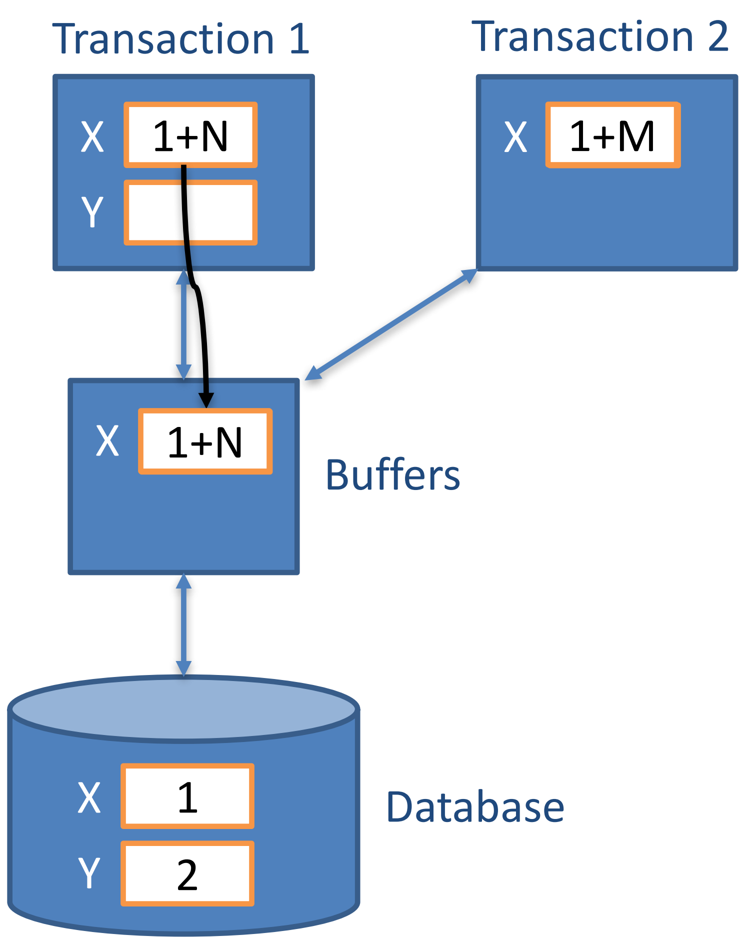

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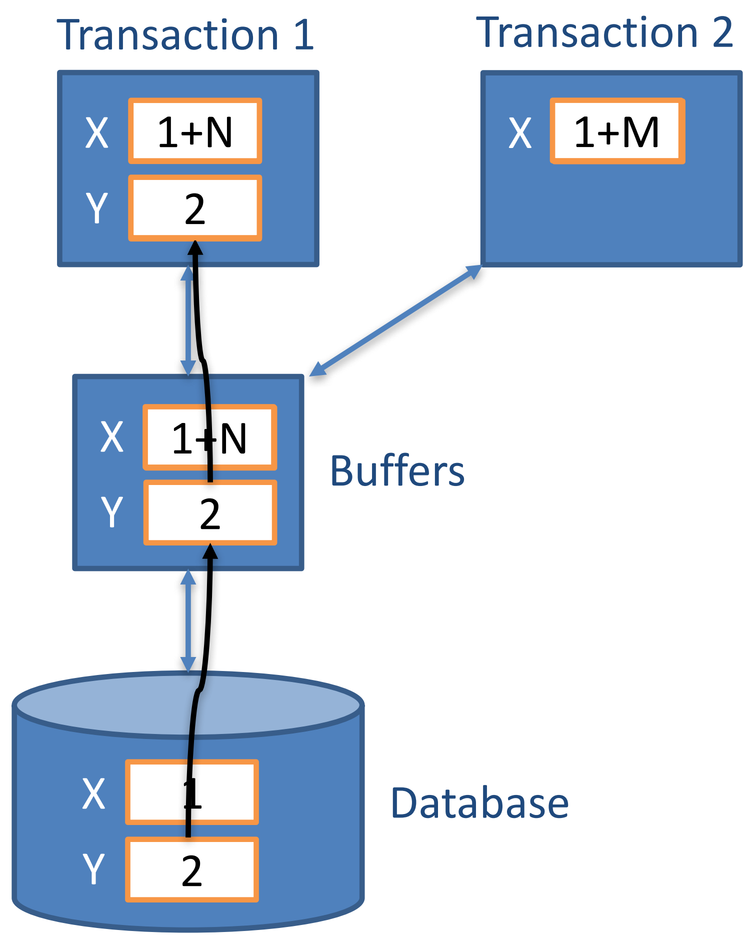

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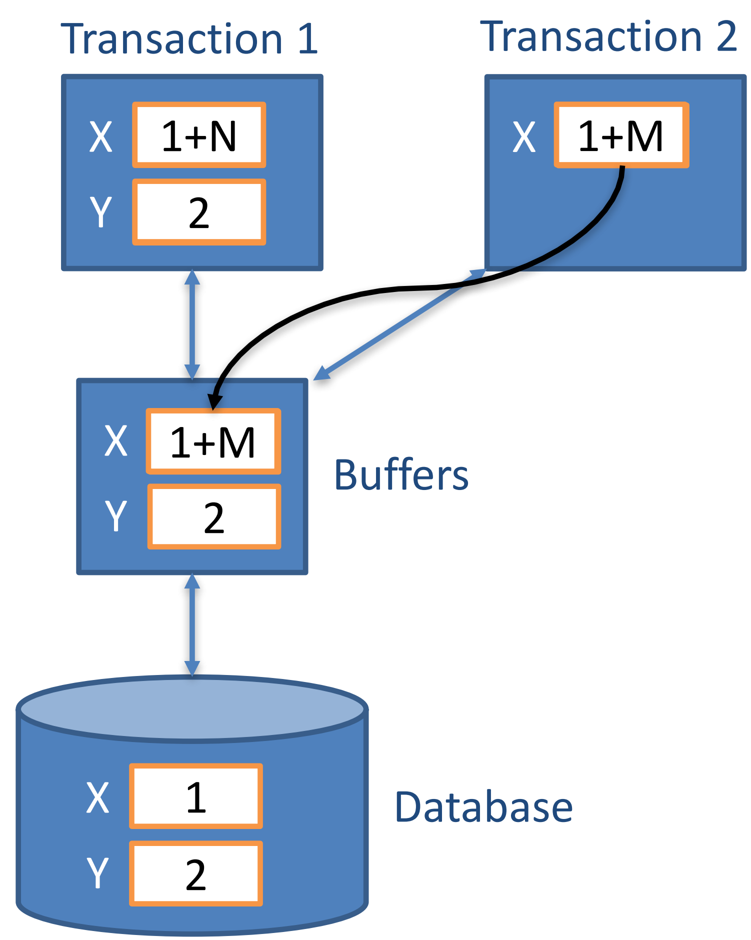

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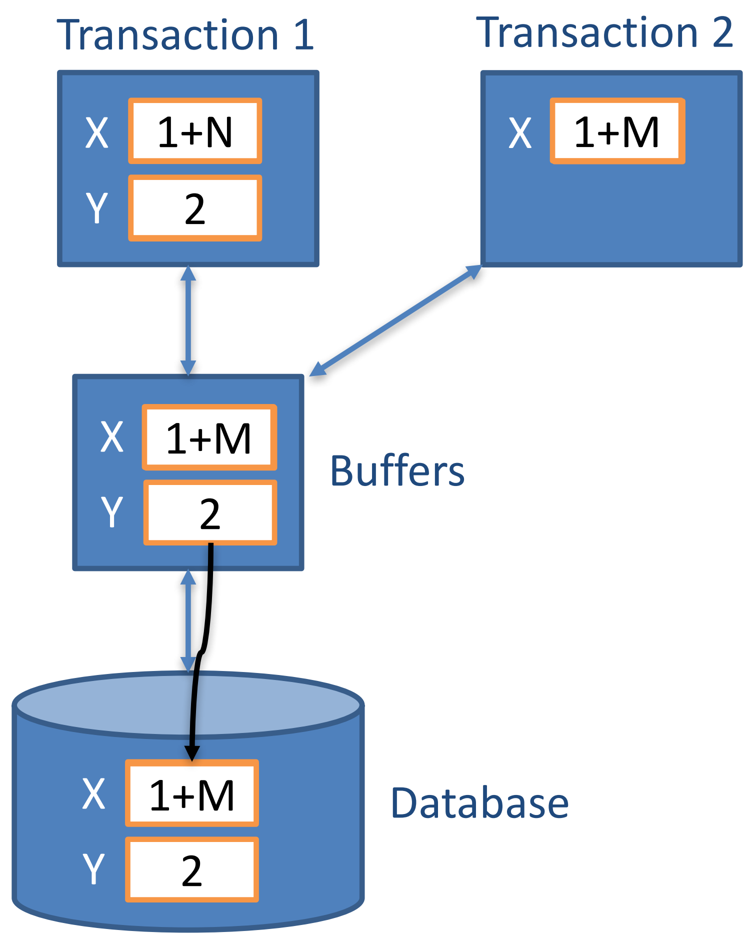

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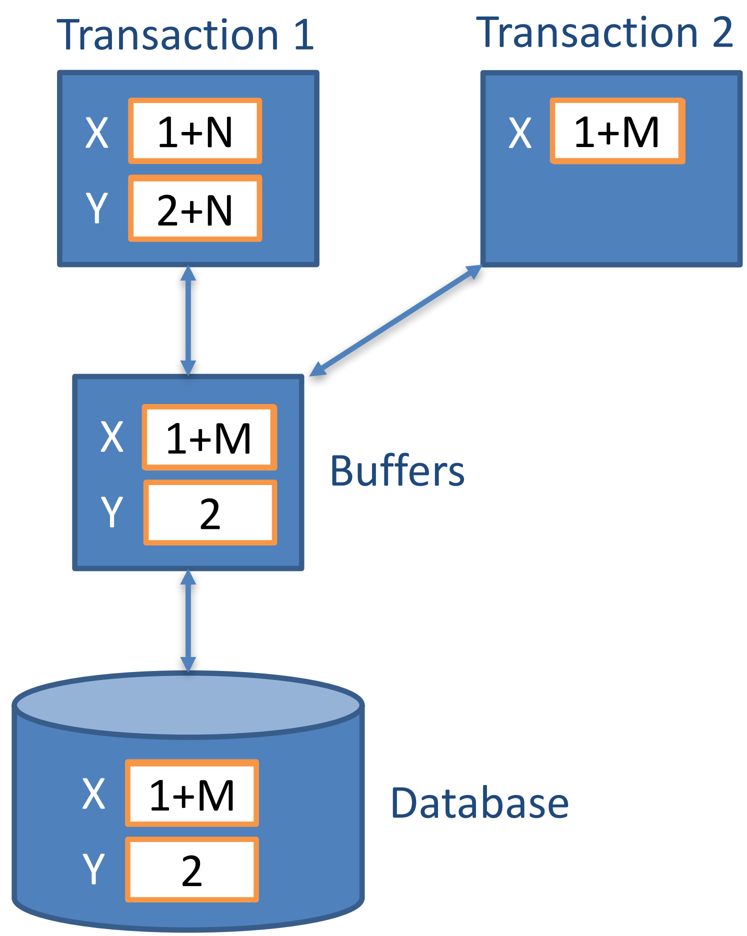

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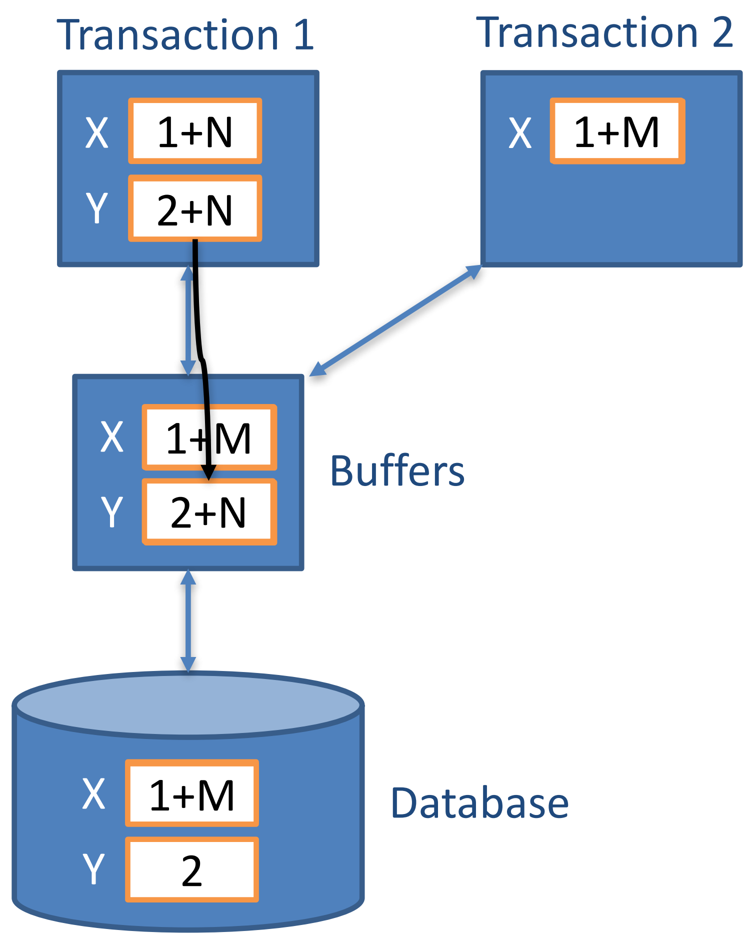

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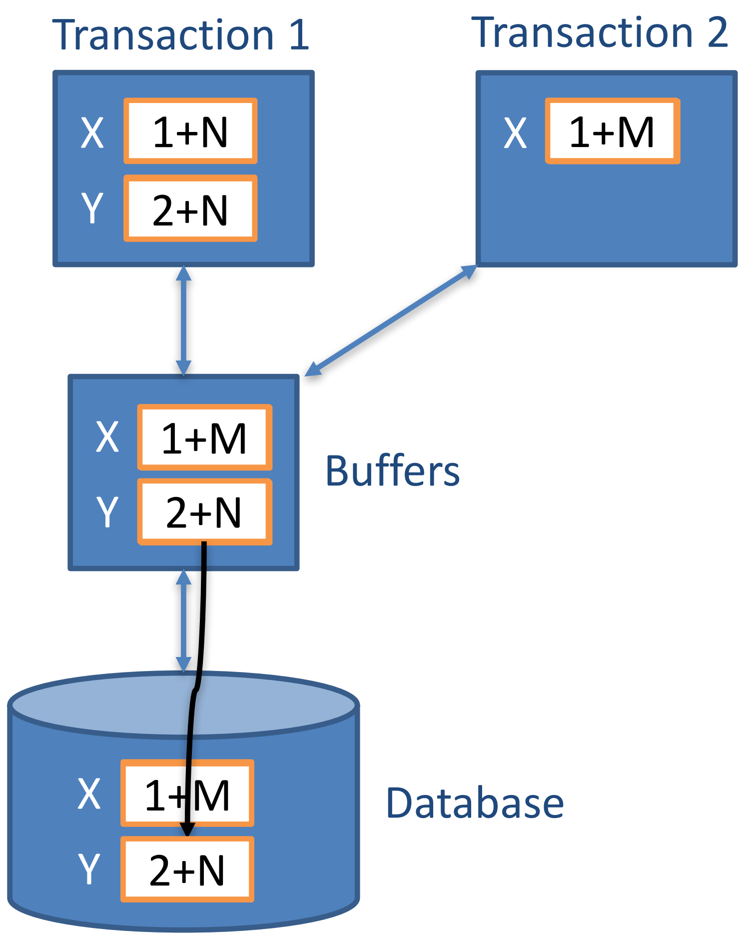

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