Today

Transactions & Locking Protocols

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CS 143 -- Shubham Mittal

Today

1. Transactions (ACID)
2. Isolation: Concurrency Control
   - Serializability and conflict serializability
   - 2PL and its variants
3. Practice problems

Transaction

• Sequence of instructions you want to execute as if one:

```
CookieJar := CookieJar - 1
CookiesEaten := CookiesEaten + 1
```

• Want to ensure:

– Either both execute, or neither.

– No other transaction sees only part of this execution:

ACID

- Set of formal properties a transaction has:
  - Atomicity – all or nothing / commit or abort
    - Take cookie and eat it, or don't take cookie
  - Consistency – database remains in consistent state afterwards
    - CookiesInJar >= 0
  - Isolation – transaction runs as if it's the only one
  - Durability – changes are never lost

Isolation - Concurrency Control

- Could just execute 1 transaction at a time…
  – Slow!
- Want to maximize parallelism while maintaining a sense of isolation.
  – “Concurrency Control!”

Serializability

- Serial schedule – “run one at a time”
- Serializable schedule – schedule whose outcomes are equivalent to a serial schedule.

Time	Transaction 1	Transaction 2
1		CookiesBaking := 5
2		Jar := Jar + CookiesBaking
3	Jar := Jar – 1	
4	Ated := Ated + 1	

Serial, serializable, or neither?

Serializability Disclaimer

Serializable in databases:

From Wikipedia: “in concurrency control of databases, a transaction schedule is serializable if its outcome is equal to the outcome of of its transactions executed serially”

Serialization in rest of CS:

In the context of data storage and transmission, serialization is the process of translating data structures or object state into a format that can be stored.

Serializability

- Serial schedule – “run one at a time”
- Serializable schedule – schedule whose outcomes are equivalent to a serial schedule.

Time	Transaction 1	Transaction 2
1		CookiesBaking := 5
2	Jar := Jar – 1	
3	Ated := Ated + 1	
4		Jar := Jar + CookiesBaking

Serial, serializable, or neither?

Schedule Abstraction

• Talking about the actual semantics of a program becomes hard
– instead, we just simplify to Reads and Writes.

Time	Transaction 1	Transaction 2
1		CookiesBaking := 5
2	Jar := Jar – 1	
3	Ated := Ated + 1	
4		Jar := Jar + CookiesBaking

Schedule Abstraction

Time	Transaction 1	Transaction 2
1		CookiesBaking := 5
2	Jar := Jar – 1	
3	Ated := Ated + 1	
4		Jar := Jar + CookiesBaking

Time	Transaction 1	Transaction 2
1		W(CookiesBaking)
2	R(Jar)	
3	W(Jar)	
4	R(Ated)	
5	W(Ated)	
6		R(Jar)
7		W(Jar)

Serializability

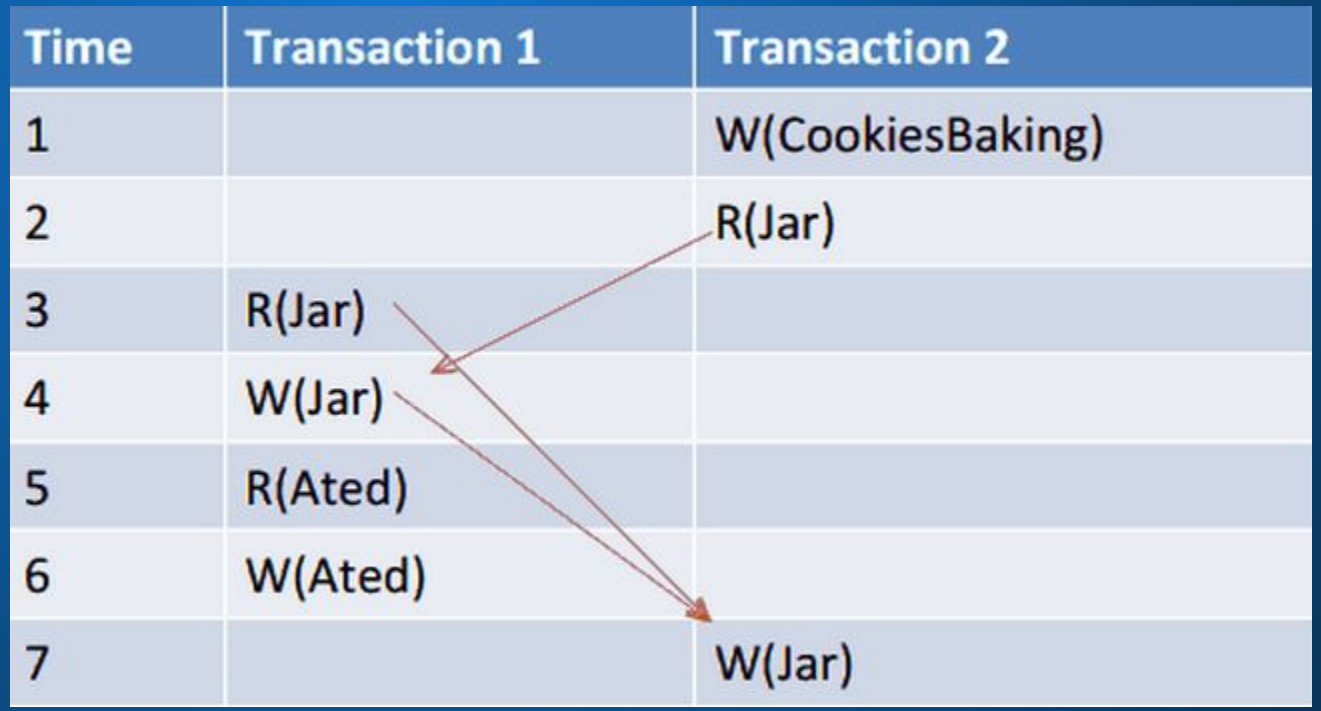
- Is this schedule serializable?
  - No!
  - How can we tell in general?

Time	Transaction 1	Transaction 2
1		W(CookiesBaking)
2		R(Jar)
3	R(Jar)	
4	W(Jar)	
5	R(Ated)	
6	W(Ated)	
7		W(Jar)

Conflicts

- Conflict:
  - two operations in
  - different transactions on
  - the same object where
  - **at least one is a Write**.
- **Concurrency issues can only arise in the face of conflicts.**

Time	Transaction 1	Transaction 2
1		W(CookiesBaking)
2		R(Jar)
3	R(Jar)	
4	W(Jar)	
5	R(Ated)	
6	W(Ated)	
7		W(Jar)



Conflict Serializability

- A schedule is “conflict serializable” if it is equivalent to some **serial schedule with the conflicts in the same order**.
  - A schedule is conflict serializable if and only if its dependency graph is acyclic.
  - Another way to look at it: **Sliding operations** (convert it into a serial schedule by swapping transactions).

Locks

- We use locks to control access to objects.
  - Shared lock: multiple transactions can have a shared lock on the same item (e.g., reading)
  - Exclusive lock: only one (and no other lock) on this item (e.g., writing)

Time	Transaction 1	Transaction 2
1	Lock_X(Jar)	Lock_X(CookiesBaking)
2	R(Jar)	W(CookiesBaking)
3	W(Jar)	Unlock(CookiesBaking)
4	Unlock(Jar)	
5	Lock_X(Ated)	Lock_X(Jar)
6	R(Ated)	R(Jar)
7	W(Ated)	W(Jar)
8	Unlock(Ated)	Unlock(Jar)

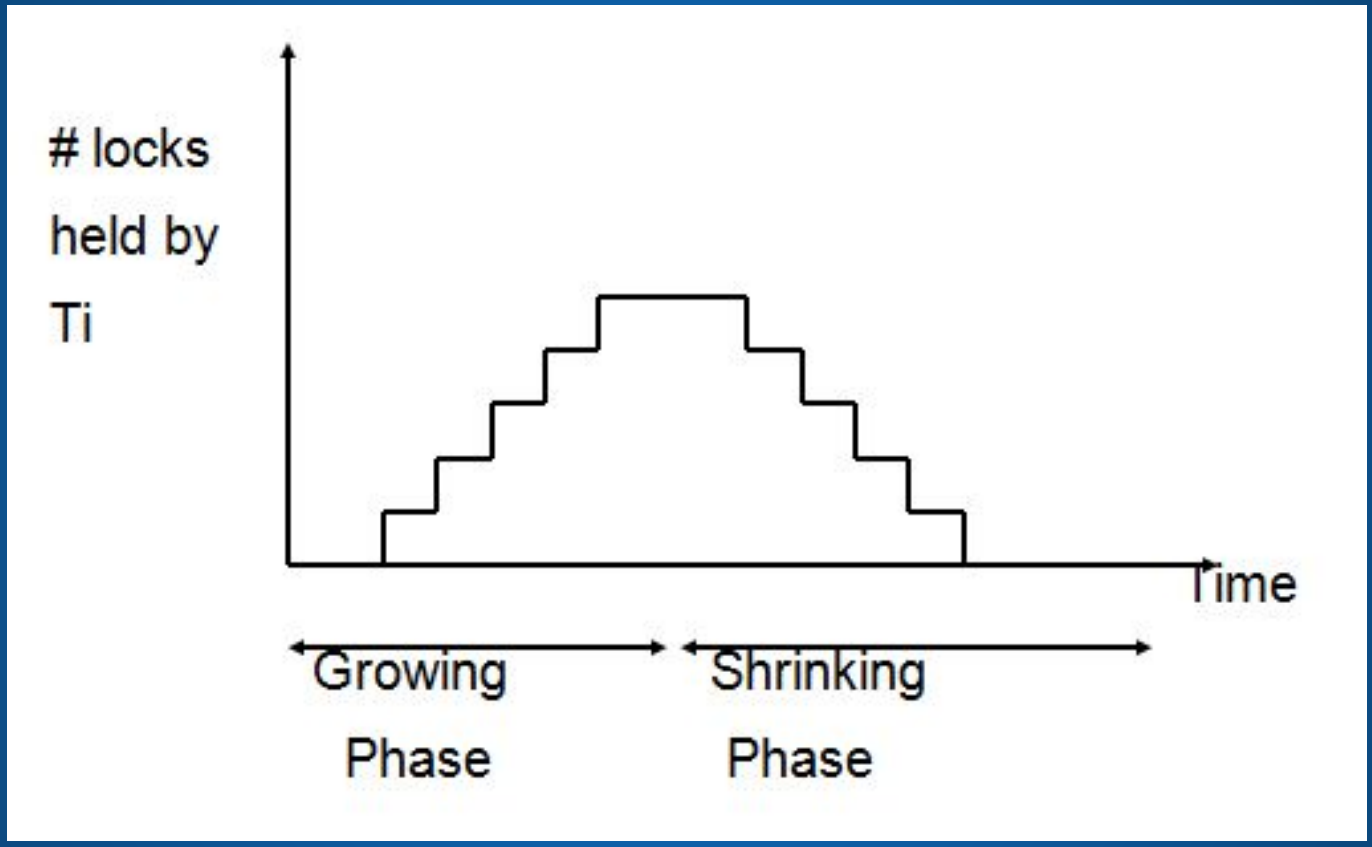
Two-Phase Locking (2PL)

- We add a rule for how a transaction may acquire locks:
  - – Once you release a lock, you may never acquire a new lock.
  - • Ensures conflict serializability!
    - – How?
    - – In order for a conflict cycle to occur, we need to release a lock so other guy can use our object, then acquire a lock to use the other guy's object
    - -You can convert into a serial schedule, where the transactions follow the order of the *locking points*.

Two-Phase Locking (2PL)

Rule (1)
Ti locks tuple A before read/write
Rule (2)
If Ti holds the lock on A, no other transaction is granted the lock on A
Rule (3):
Growing stage: Ti may obtain locks, but may not release any lock
Shrinking stage: Ti my release locks, but may not obtain any new locks

2PL



- Growing phase: Acquire + Upgrade (S to X)
- Shrinking phase: Release + Downgrade (X to S)

Cascading Aborts & Strict/Rigorous 2PL

- What happens here?

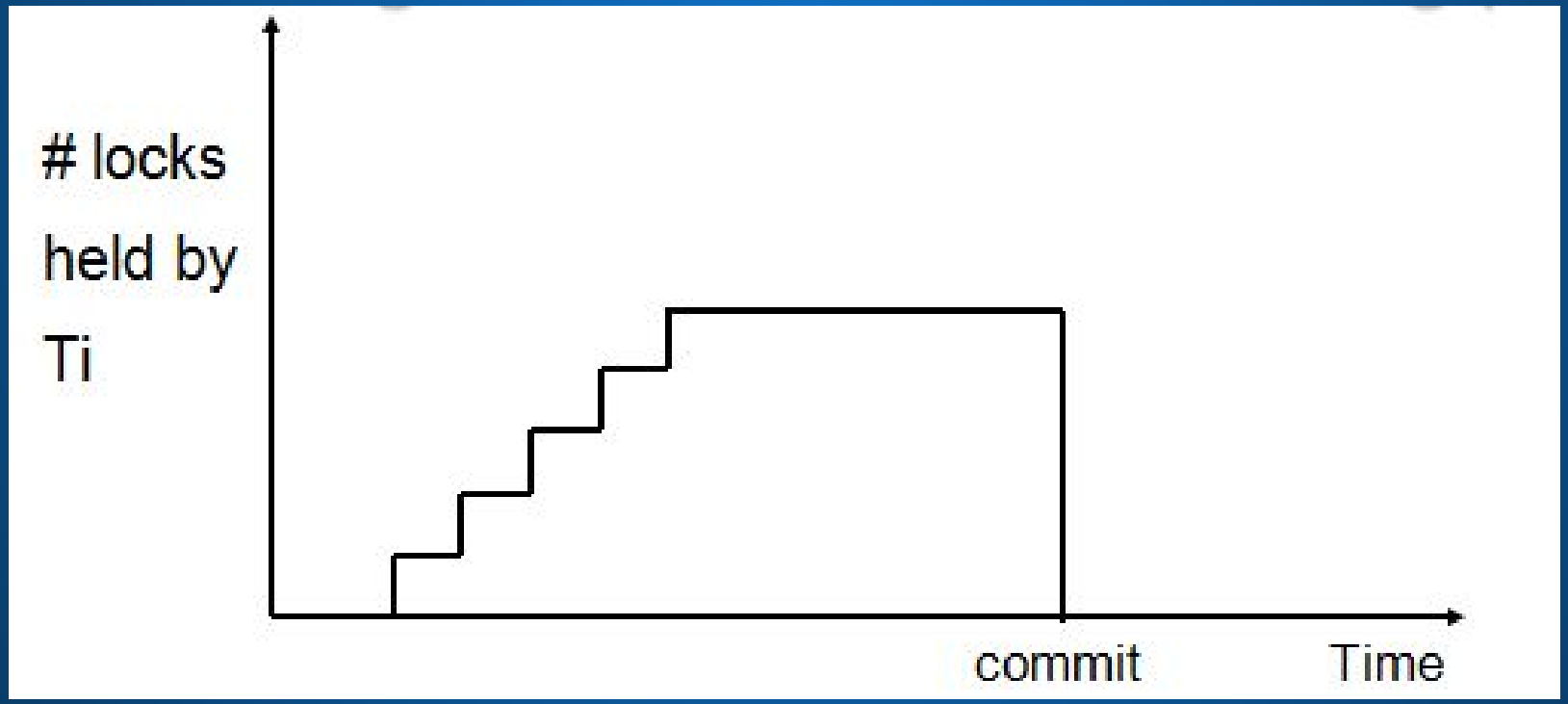
T1: R(A), W(A), Abort

T2: R(A), W(A)

- How to fix?
- Strict Two-Phase Locking:
  - All *x*-locks held by transaction are only released at the end of the transaction.

  Rigorous Two-Phase Locking:
  - All locks held by transaction are only released at the end of the transaction.

Rigorous 2PL



Deadlocks

- Dealing with deadlocks:
  - Prevention – stop them from occurring
  - Detection – stop them while occurring
  - In practice: timer

Time	Transaction 1	Transaction 2
1	Lock_X(A) (granted)	
2		Lock_X(B) (granted)
3	Lock_X(B) (waiting)	
4		Lock_X(A) (waiting)
5	…	…

Deadlock Prevention

- Disallow deadlocks from ever occurring.
- Two transactions T_{old} and T_{young}.

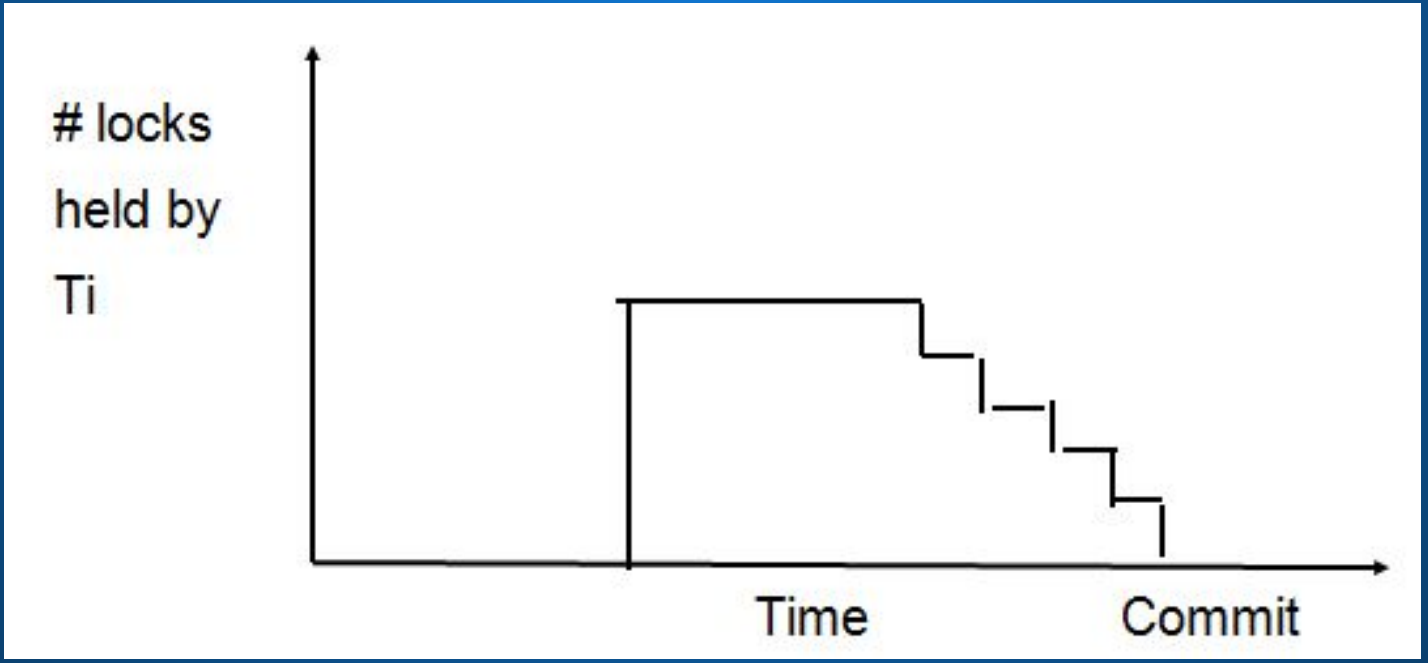
– Wait-Die:
  - If T_{old} is waiting for a lock from T_{young}, he just waits.
  - If T_{young} is waiting for a lock from T_{old}, he kills himself.

– Wound-Wait:
  - If T_{old} is waiting for a lock from T_{young}, he kills T_{young}.
  - If T_{young} is waiting for a lock from T_{old}, he just waits.
  - If you die, you restart with ***original*** timestamp.

Deadlock Prevention

- Conservative 2PL.
- Our transaction requests all the locks at the beginning,

If it does not get them it does not start. If it gets the resources and starts, it will complete.



Deadlock Detection

- Waits-for graph of all transactions.

$G = (V,E)$,
V is a set of Transactions
E is a set of arcs between transactions: $A \rightarrow B$
$A \rightarrow B$ if A is waiting for B to release a lock on some data item.

- If cycle exists, shoot one of the transactions in the cycle.

Summary

- For isolation, we need a serializable schedule.
- Strict 2PL gives us conflict serializability automatically, and avoids cascading aborts.
- Can either detect deadlocks using waits-for graph or prevent it using wait-for or wound-wait or conservative 2PL.

Practice!

Lock_X(B)	
Read(B)	
B=B*10	
Write(B)	
Lock_X(F)	
Unlock(B)	
F = B*100	
Write(F)	
COMMIT	
Unlock(F)	
	Lock_S(F)
	Read(F)
	Unlock(F)
	Lock_S(B)
	Read(B)
	Print(F+B)
	COMMIT
	Unlock(B)

1. Consider the following schedules:

T1		R(A)	W(A)	R(B)					
T2					W(B)	R(C)	W(C)	W(A)	
T3	R(C)								W(D)

(a) Draw the dependency graph (precedence graph) for the schedule.

(b) Is the schedule conflict serializable? If so, what are all the (conflict) equivalent serial schedules? If not, why not?

T1	R(A)		R(B)				W(A)	
T2		R(A)		R(B)				W(B)
T3					R(A)			
T4						R(B)		

(a) Draw the dependency graph (precedence graph) for the schedule.

(b) Is the schedule conflict serializable? If so, what are all the (conflict) equivalent serial schedules? If not, why not?

2) a. What will be printed in the following execution (B=3, F=300)?

Lock_X(B)	
Read(B)	
B = B*10	
Write(B)	Lock_S(B)
Lock_X(F)	
F = B*100	
Write(F)	
Unlock(B)	
Unlock(F)	
	Lock_S(F)
	Read(F)
	Read(B)
	Print(F+B)
	Unlock(B)
	Unlock(F)

b. Does the execution use: (a) 2PL or (b) Strict 2PL?