CS216: Data-Intensive Computing Systems

Concurrency Control (II)

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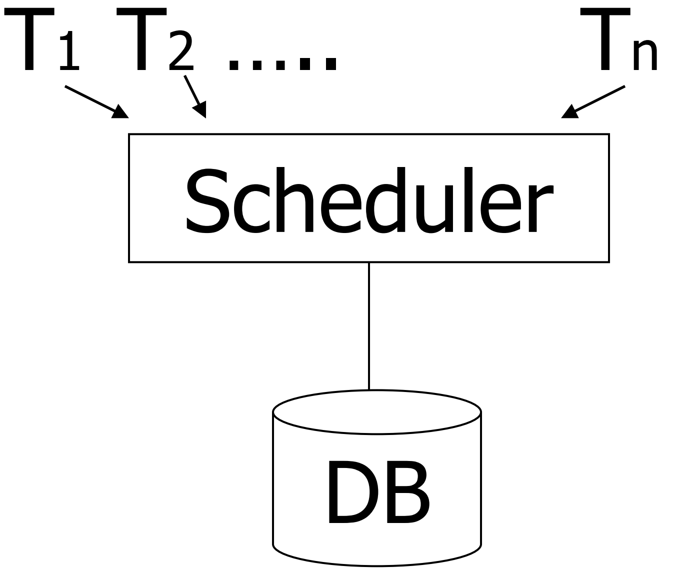
How to enforce serializable schedules?

Option 1: run system, recording P(S);
at end of day, check for P(S)
cycles and declare if execution
was good

How to enforce serializable schedules?

Option 2: prevent P(S) cycles from occurring

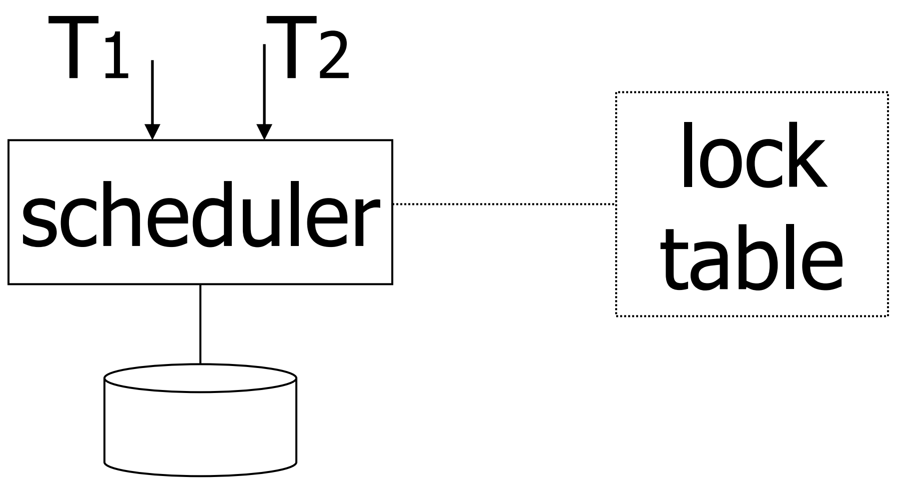


A locking protocol

Two new actions:

lock (exclusive): l_i (A)

unlock: u_i (A)



Rule #1: Well-formed transactions

T_i: … $l_i(A)$ … $p_i(A)$ … $u_i(A)$ ...

Rule #2 Legal scheduler

$S = \ldots\ldots.. \; l_i(A) \; \ldots\ldots\ldots\ldots \; u_i(A) \; \ldots\ldots\ldots$

no $l_j(A)$

Exercise:

- What schedules are legal?
  What transactions are well-formed?

$S1 = l_1(A)l_1(B)r_1(A)w_1(B)l_2(B)u_1(A)u_1(B)$
$r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

$S2 = l_1(A)r_1(A)w_1(B)u_1(A)u_1(B)$
$l_2(B)r_2(B)w_2(B)l_3(B)r_3(B)u_3(B)$

$S3 = l_1(A)r_1(A)u_1(A)l_1(B)w_1(B)u_1(B)$
$l_2(B)r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

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- What schedules are legal?
  What transactions are well-formed?

$S1 = l_1(A)l_1(B)r_1(A)w_1(B)l_2(B)u_1(A)u_1(B)$
$r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

$S2 = l_1(A)r_1(A)w_1(B)u_1(A)u_1(B)$
$l_2(B)r_2(B)w_2(B)l_3(B)r_3(B)u_3(B)$

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$l_2(B)r_2(B)w_2(B)u_2(B)l_3(B)r_3(B)u_3(B)$

Schedule F

T1	T2
$l_1(A)$;Read(A)	
$A \leftarrow A+100$;Write(A);$u_1(A)$	
	$l_2(A)$;Read(A)
	$A \leftarrow Ax2$;Write(A);$u_2(A)$
	$l_2(B)$;Read(B)
	$B \leftarrow Bx2$;Write(B);$u_2(B)$
$l_1(B)$;Read(B)	
$B \leftarrow B+100$;Write(B);$u_1(B)$	

Schedule F

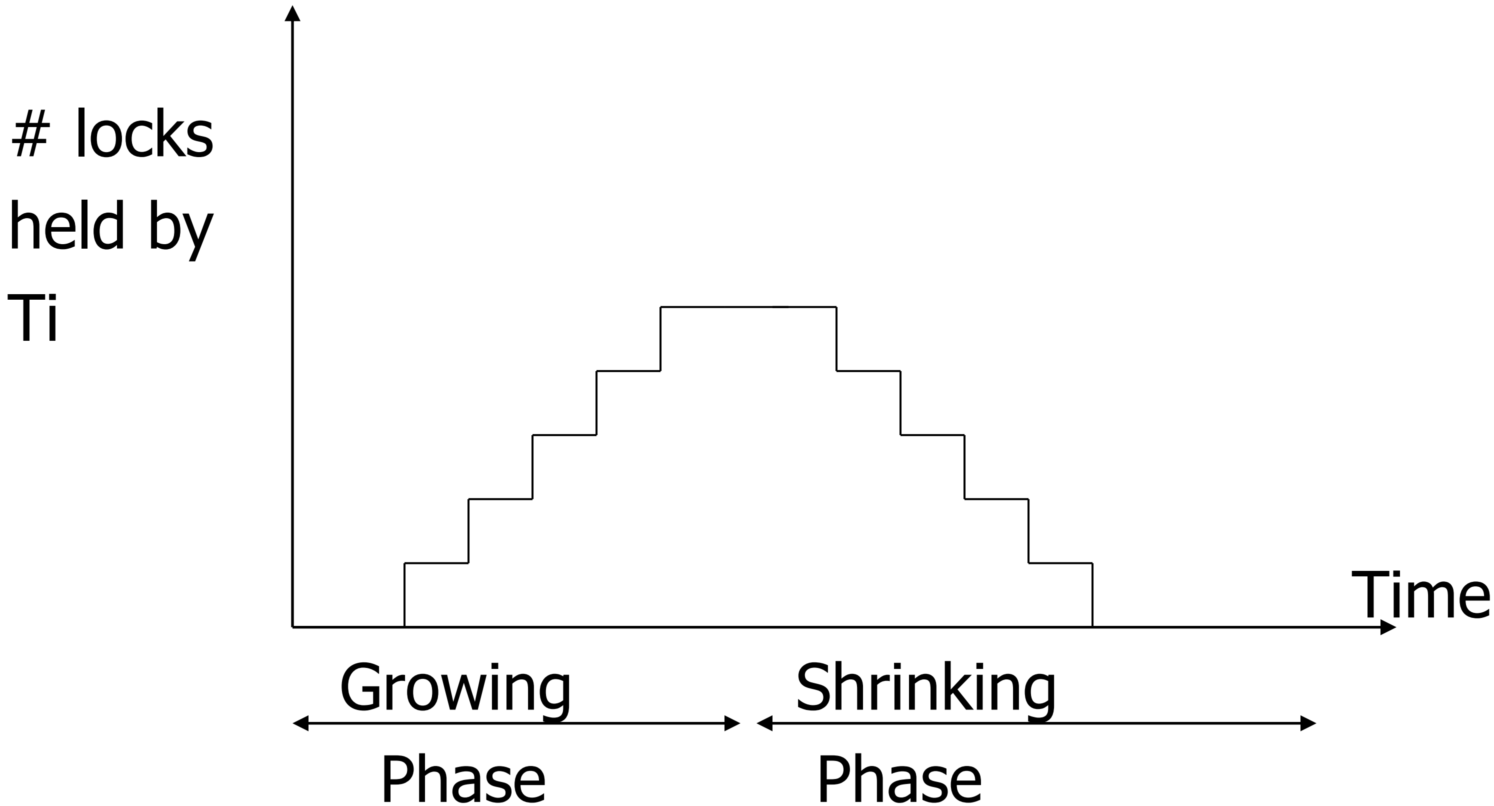
T1	T2	A	B
		25	25
l_1(A);Read(A)			
A $\leftarrow$ A+100;Write(A);u_1(A)		125	
	l_2(A);Read(A)		
	A $\leftarrow$ Ax2;Write(A);u_2(A)	250	
	l_2(B);Read(B)		
	B $\leftarrow$ Bx2;Write(B);u_2(B)		50
l_1(B);Read(B)			
B $\leftarrow$ B+100;Write(B);u_1(B)			150
		250	150

Rule #3 Two phase locking (2PL)

for transactions

T_i = ……. $l_i(A)$ ………… $u_i(A)$ ………

no unlocks | no locks


locks
held by
Ti
Time
Growing
Phase
Shrinking
Phase

Schedule G

T1	T2
$l_1(A)$;Read(A)	
$A \leftarrow A+100$;Write(A)	
$l_1(B)$; $u_1(A)$	
	$l_2(A)$;Read(A)
	$A \leftarrow Ax2$;Write(A);$l_2(B)$ (delayed)

Schedule G

T1	T2
$l_1(A)$;Read(A)	
A ← A+100;Write(A)	
$l_1(B)$; $u_1(A)$	
	$l_2(A)$;Read(A)
	A ← Ax2;Write(A); $l_2(B)$ [delayed]
Read(B);B ← B+100	
Write(B); $u_1(B)$	

Schedule G

T1	T2
$l_1(A)$;Read(A)	
A←A+100;Write(A)	
$l_1(B)$; $u_1(A)$	
	$l_2(A)$;Read(A)
	A←Ax2;Write(A); $l_2(B)$ (delayed)
Read(B);B ← B+100	
Write(B); $u_1(B)$	
	$l_2(B)$; $u_2(A)$;Read(B)
	B ← Bx2;Write(B);$u_2(B)$;

Schedule H (T2 reversed)

T1	T2
l_1(A); Read(A)	l_2(B);Read(B)
A ← A+100;Write(A)	B ← Bx2;Write(B)
l_1(B) (delayed)	l_2(A) (delayed)

- Assume deadlocked transactions are rolled back
  - They have no effect
  - They do not appear in schedule

E.g., Schedule H = ⏟

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Next step:

Show that rules #1,2,3 $\Rightarrow$ conflict-serializable schedules

Conflict rules for $l_i(A)$, $u_i(A)$:

- $l_i(A)$, $l_j(A)$ conflict
- $l_i(A)$, $u_j(A)$ conflict

Note: no conflict $< u_i(A), u_j(A)>$, $< l_i(A), r_j(A)>$,...

Theorem Rules #1,2,3 $\Rightarrow$ conflict
(2PL) serializable
schedule

To help in proof:

Definition Shrink(Ti) = SH(Ti) =
first unlock action of Ti

Lemma

$Ti \rightarrow Tj$ in S $\Rightarrow$ SH(Ti) $<_S$ SH(Tj)

Proof of lemma:

$Ti \rightarrow Tj$ means that

S = … $p_i(A)$ … $q_j(A)$ …; p,q conflict

By rules 1,2:

S = … $p_i(A)$ … $u_i(A)$ … $l_j(A)$ ... $q_j(A)$ …

By rule 3: SH(Ti) SH(Tj)

So, SH(Ti) $<_S$ SH(Tj)

Theorem Rules #1,2,3 $\Rightarrow$ conflict
(2PL) serializable
schedule

Proof:

(1) Assume P(S) has cycle

$$T_1 \rightarrow T_2 \rightarrow .... T_n \rightarrow T_1$$

(2) By lemma: $SH(T_1) < SH(T_2) < ... < SH(T_1)$

(3) Impossible, so P(S) acyclic

(4) $\Rightarrow$ S is conflict serializable

- Beyond this simple 2PL protocol, it is all a matter of improving performance and allowing more concurrency….
  - Shared locks
  - Multiple granularity
  - Inserts, deletes, and phantoms
  - Other types of C.C. mechanisms