No cascading-rollbacks!

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- I.e. if we follow those, we can avoid breaking durability (because of cascading rollbacks)

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This video: Cascadeless schedules

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Recoverable schedules still cascades

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A recoverable schedule:

$$S_4: w_1(X); w_1(Y); w_2(X); r_2(Y); w_2(Y); c_1; c_2$$

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Suppose T_1 needs to be rolled back here

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Suppose T_1 needs to be rolled back here

T_1 rolls back → T_2 has to be rolled back

Cascadeless Schedules

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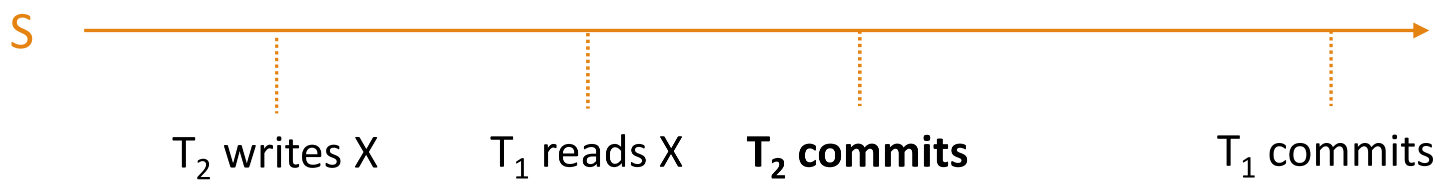

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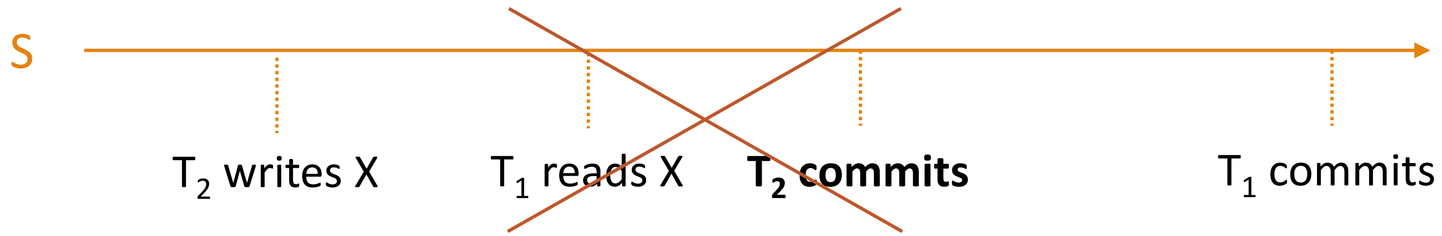

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As for recoverable schedules:
Log records have to reach disk in the right order.

Example

Example

The schedules S_1-S_4 in previous video are **not cascadeless**:

S_1: $w_2(X); w_1(Y); w_1(X); r_2(Y); w_2(Y); c_1; c_2$

S_2: $w_1(X); w_1(Y); w_2(X); r_2(Y); w_2(Y); c_2; c_1$

S_3: $w_2(X); w_1(Y); w_1(X); r_2(Y); w_2(Y); c_2; c_1$

S_4: $w_1(X); w_1(Y); w_2(X); r_2(Y); w_2(Y); c_1; c_2$

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The schedules S_1-S_4 in previous video are **not cascadeless**:

reads uncommitted data from T_1

S_1: $w_2(X)$; $w_1(Y)$; $w_1(X)$; $r_2(Y)$; $w_2(Y)$; c_1; c_2

S_2: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $r_2(Y)$; $w_2(Y)$; c_2; c_1

S_3: $w_2(X)$; $w_1(Y)$; $w_1(X)$; $r_2(Y)$; $w_2(Y)$; c_2; c_1

S_4: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $r_2(Y)$; $w_2(Y)$; c_1; c_2

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$$S_3: w_2(X); w_1(Y); w_1(X); r_2(Y); w_2(Y); c_2; c_1$$

$$S_4: w_1(X); w_1(Y); w_2(X); r_2(Y); w_2(Y); c_1; c_2$$

This variant of S_1 is **cascadeless**:

$$S_5: w_2(X); w_1(Y); w_1(X); c_1; r_2(Y); w_2(Y); c_2$$

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reads committed data from T_1

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reads uncommitted data from T_1

$$S_1: w_2(X);\ w_1(Y);\ w_1(X);\ r_2(Y);\ w_2(Y);\ c_1;\ c_2$$

$$S_2: w_1(X);\ w_1(Y);\ w_2(X);\ r_2(Y);\ w_2(Y);\ c_2;\ c_1$$

$$S_3: w_2(X);\ w_1(Y);\ w_1(X);\ r_2(Y);\ w_2(Y);\ c_2;\ c_1$$

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This variant of S_1 is **cascadeless**:

$$S_5: w_2(X);\ w_1(Y);\ w_1(X);\ c_1;\ r_2(Y);\ w_2(Y);\ c_2$$

Note: S_5 is **not serialisable**.

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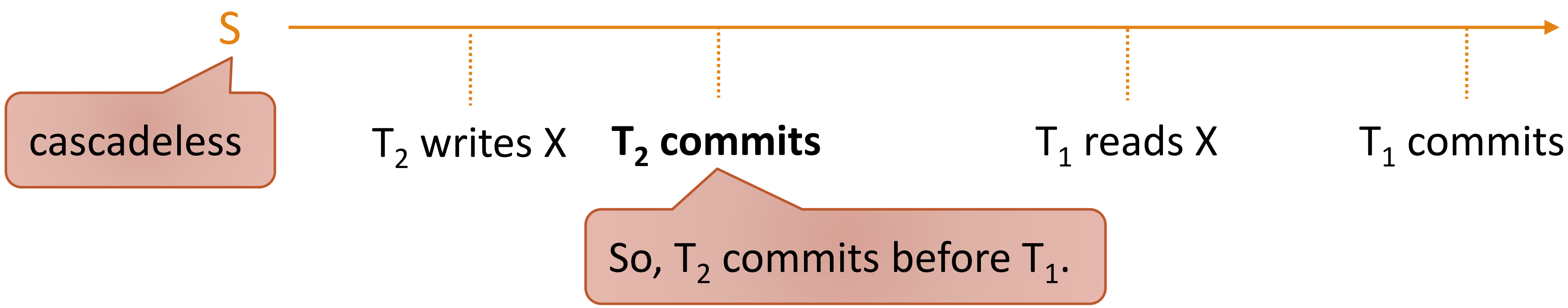
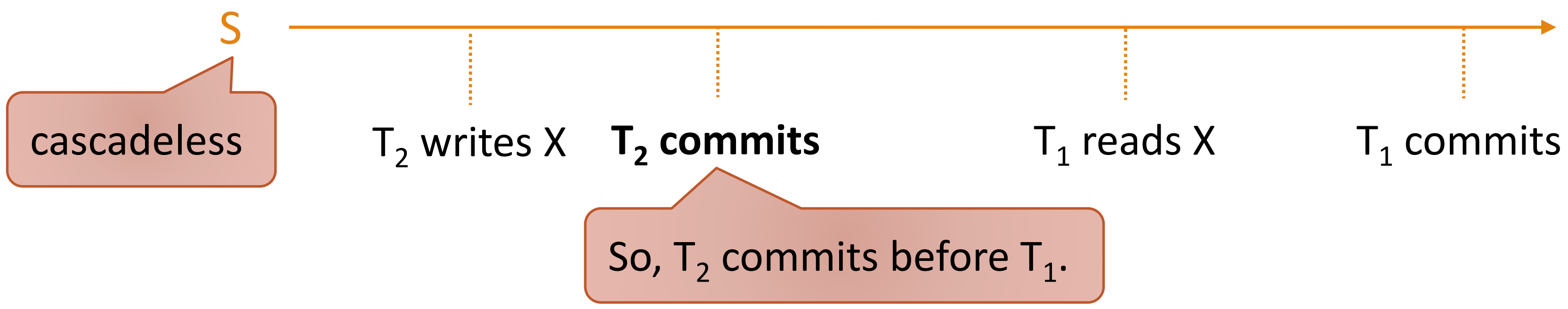


Cascadeless Schedules: Properties

Cascadeless schedules are **recoverable**:



Cascadeless schedules are in general **not serialisable**.
(recall example on previous slide)

Can We Have Both?

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No Cascading Aborts & Serialisability?

Strict Schedules

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A schedule is **strict** if each transaction in it reads and writes only values that were written by transactions that have already committed.

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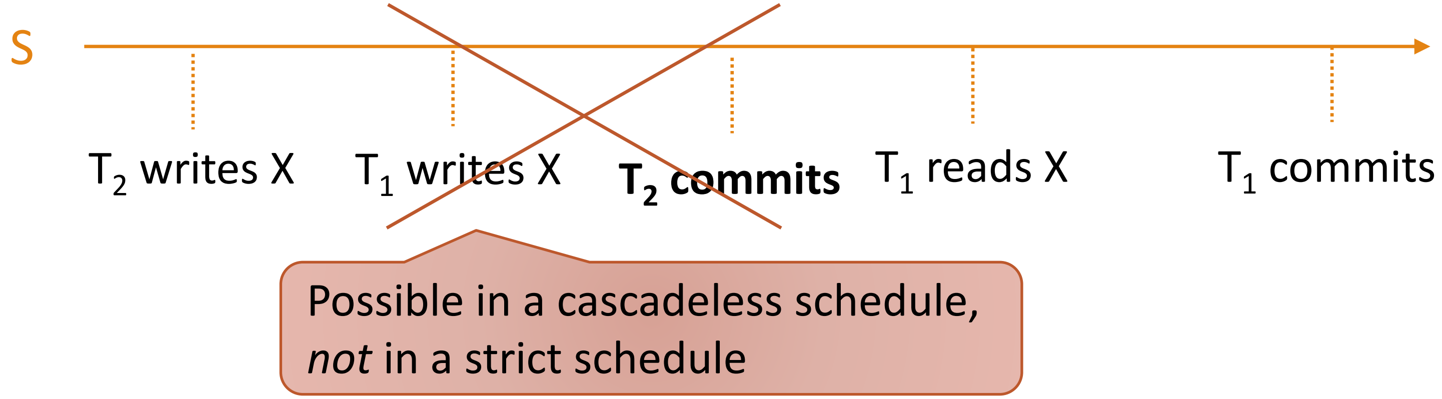

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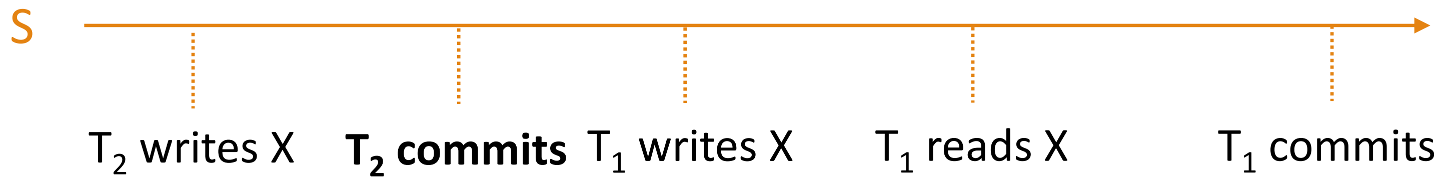

Strict Schedules

A schedule is **strict** if each transaction in it reads and writes only values that were written by transactions that have already committed.

Of course, log records have to reach disk in order.

Strict Two-Phase Locking (Strict 2PL)

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Most popular variant of two-phase locking (2PL)

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Strict locking condition
(in addition to 2PL condition):

A transaction T **must not release any lock (that allows T to write data)** until:

- T has committed or aborted, and
- the commit/abort log record has been written to disk.

Strict Two-Phase Locking (Strict 2PL)

Most popular variant of two-phase locking (2PL)

Enforces both:

- Conflict-serialisability
- Strict schedules

Strict locking condition
(in addition to 2PL condition):

- with simple locking: **any lock**
- with shared/exclusive locks: **just exclusive locks**

A transaction T **must not release any lock (that allows T to write data)** until:

- T has committed or aborted, and
- the commit/abort log record has been written to disk.

Example 1

Transaction T
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
unlock(X)
read_item(Y)
Y := Y + 100
write_item(Y)
unlock(Y)
commit

Example 1

2PL transaction

Transaction T
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read_item(X)
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For undo logging, we assume that **commit**…

1. Writes all log records to disk
2. Writes all modified database items to disk
3. Writes the commit record to disk

Example 1

2PL transaction

Not strict 2PL

Transaction T
lock(X)
read_item(X)
X := X + 100
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lock(Y)
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For undo logging, we assume that **commit**…

1. Writes all log records to disk
2. Writes all modified database items to disk
3. Writes the commit record to disk

Example 2

2PL transaction

Transaction T
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
unlock(X)
read_item(Y)
Y := Y + 100
write_item(Y)
unlock(Y)
commit

New transaction T’
lock(X)
read_item(X)
X := X + 100
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read_item(Y)
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write_item(Y)
commit
unlock(X)
unlock(Y)

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2PL transaction

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Strict 2PL transaction

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unlock(X)
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Locks released only after fully committed, and all log records written to disk

Example With Shared/Exclusive Locks

Transaction T
s-lock(X)
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x-lock(Y)
unlock(X)
read_item(Y)
Y := X + Y
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Example With Shared/Exclusive Locks

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T can release the shared lock on X here (shared locks do not allow T to write data)

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Strict 2PL

T can release the shared lock on X here (shared locks do not allow T to write data)

T is allowed to release the exclusive lock on Y only here.

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If S is a schedule consisting of strict 2PL transactions:

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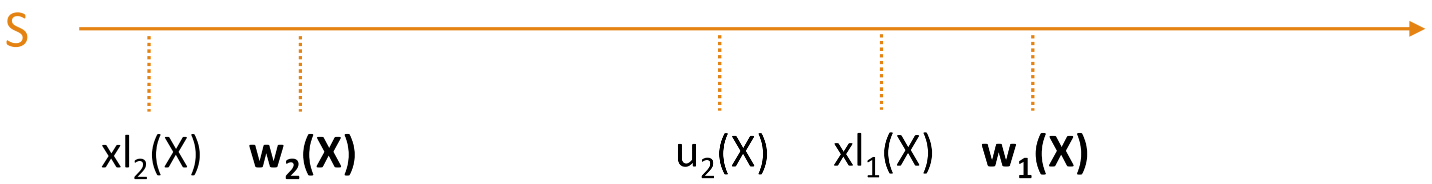

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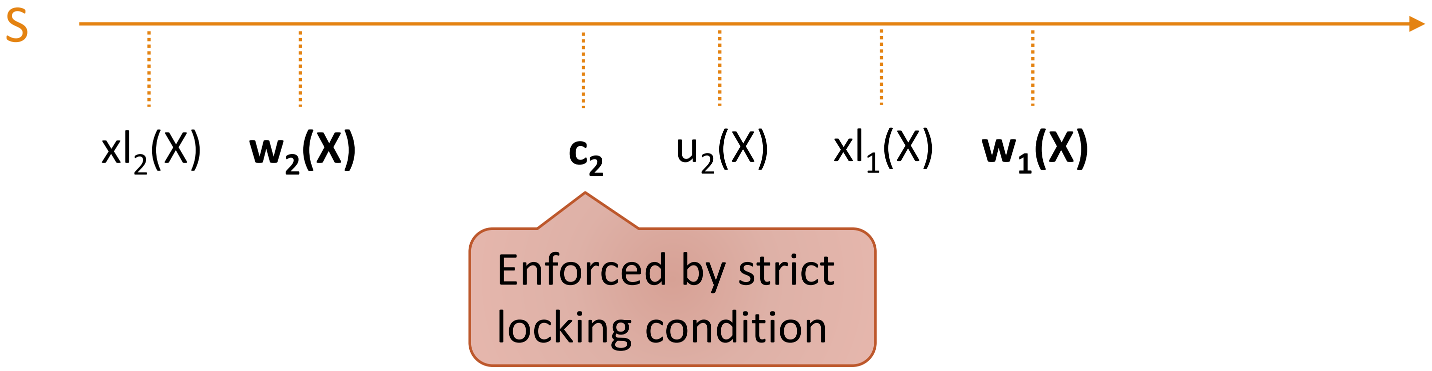

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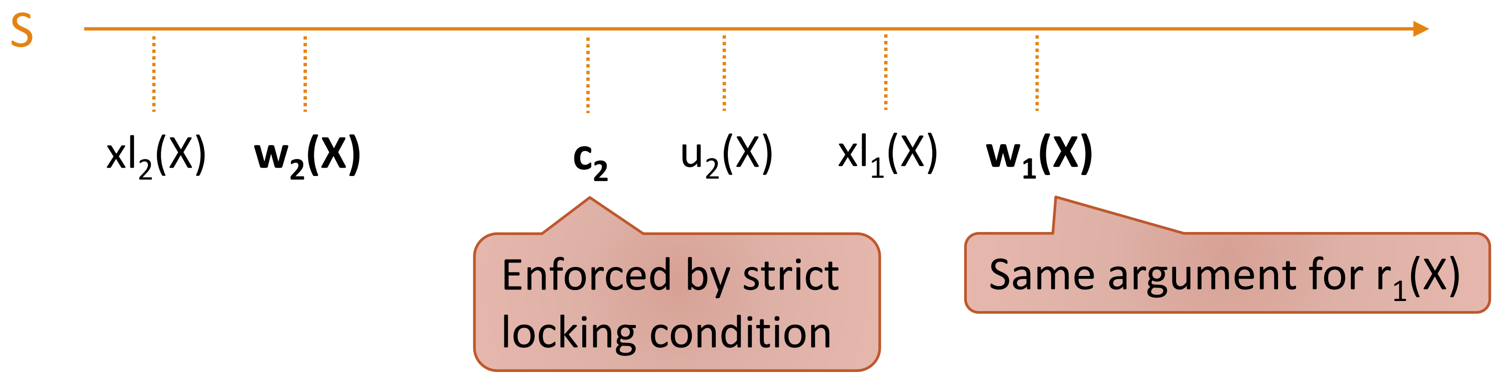

How the Types of Schedules are Related

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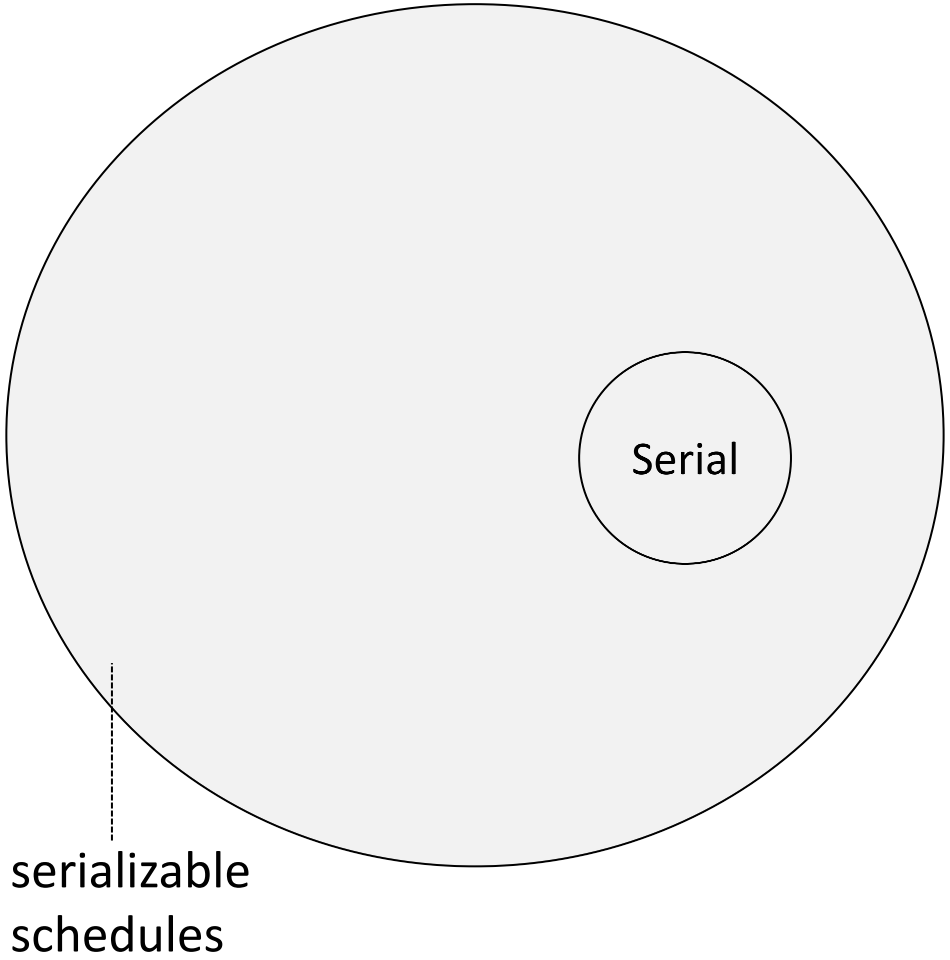

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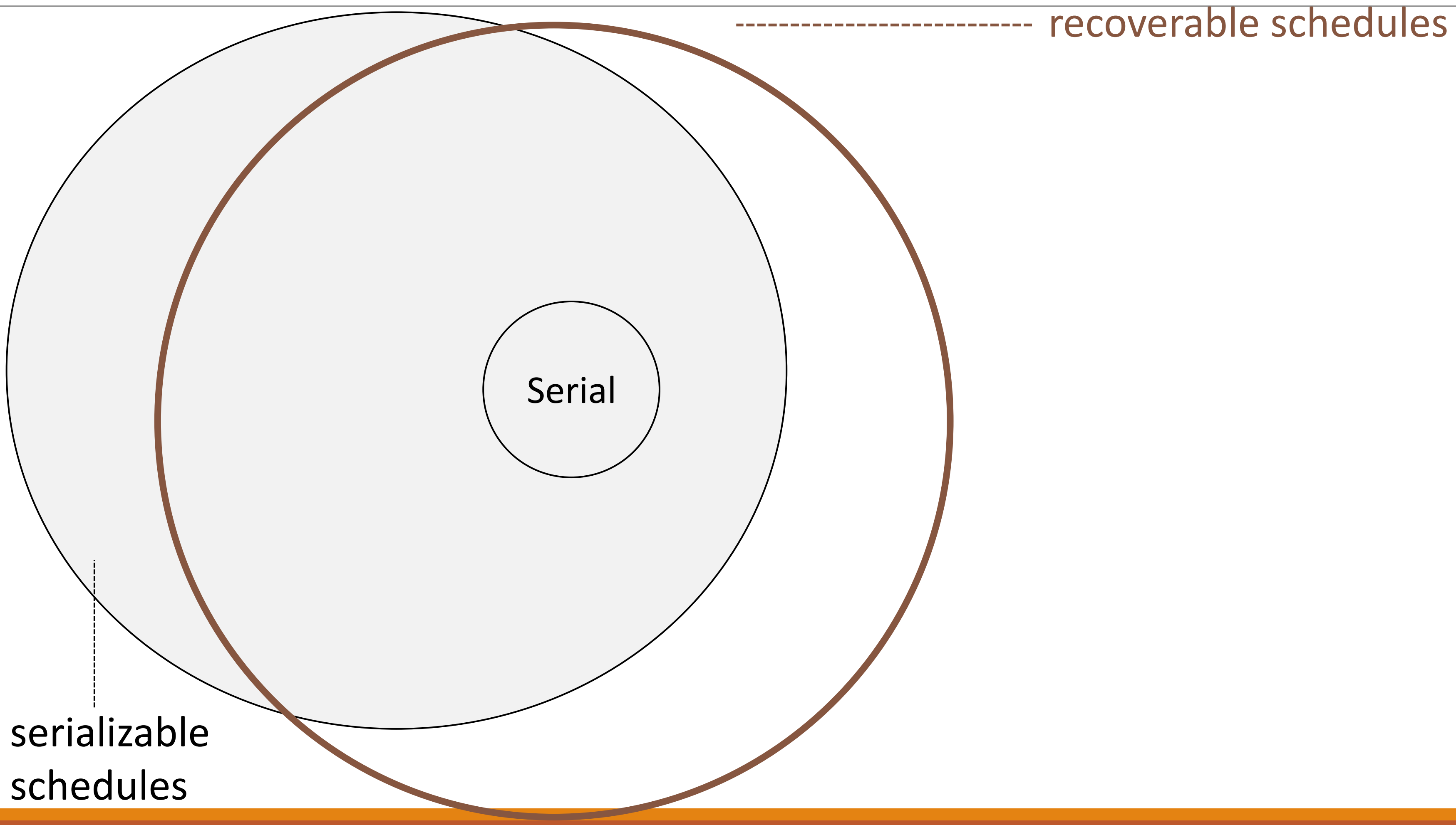

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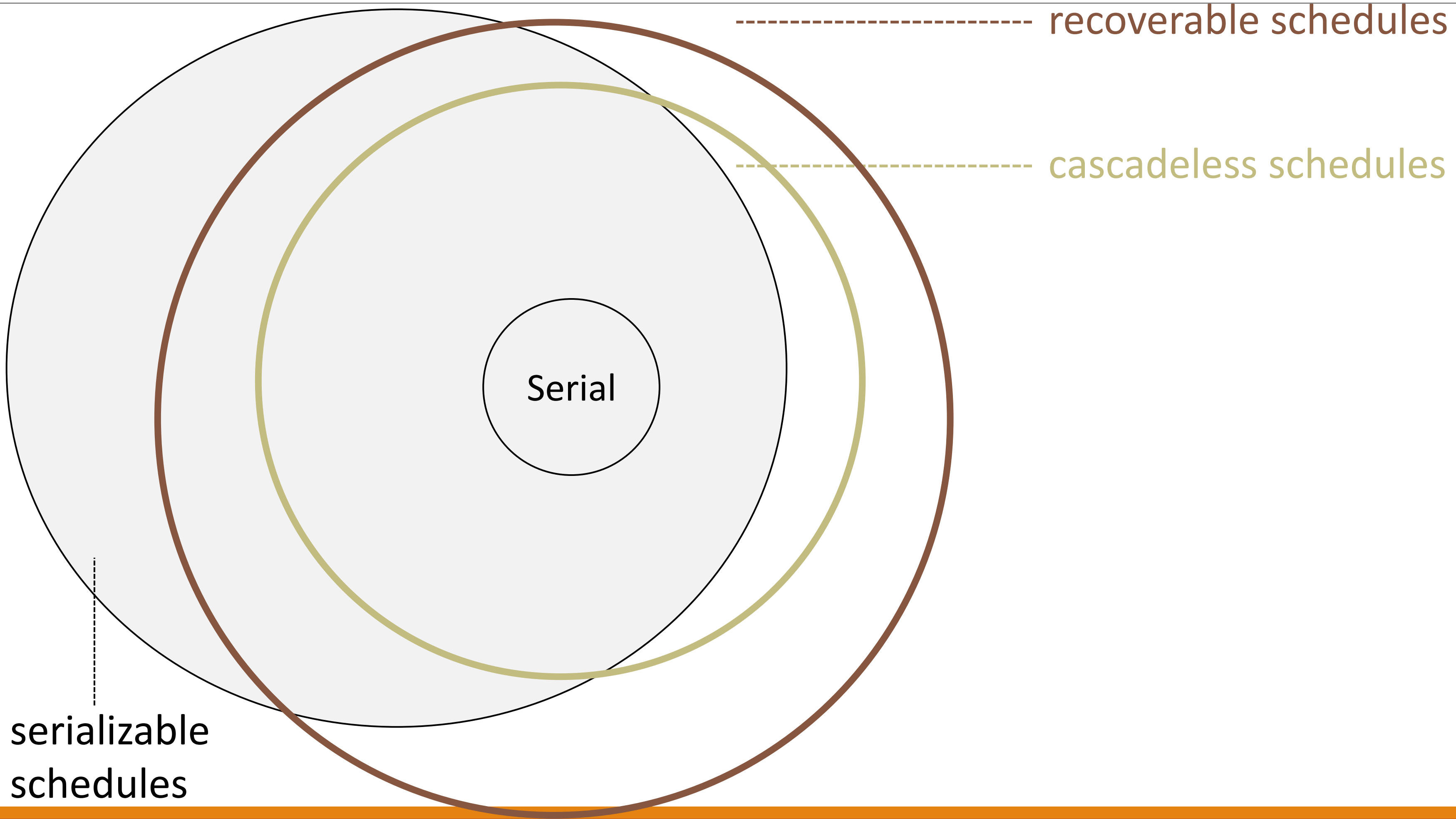

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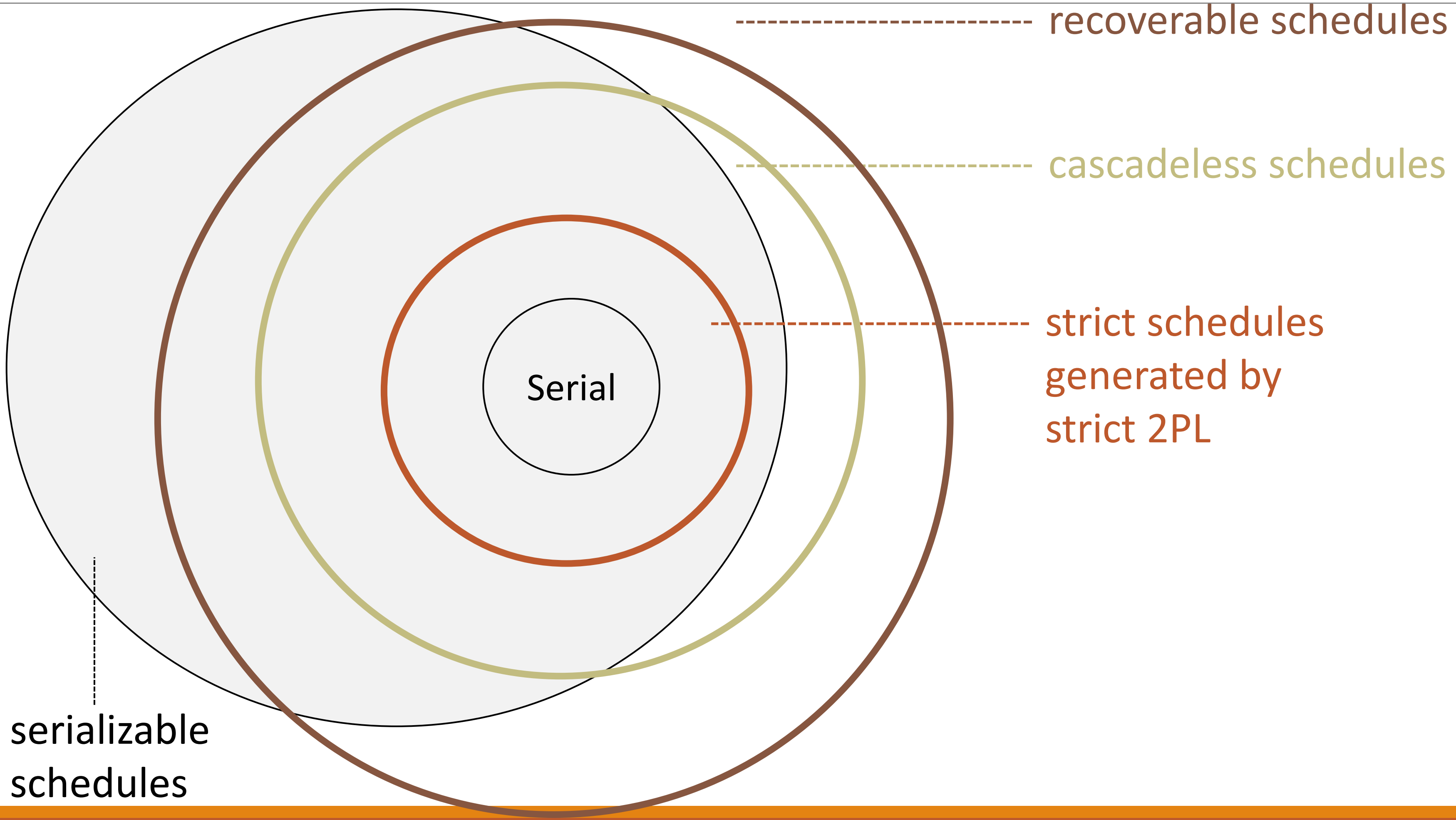

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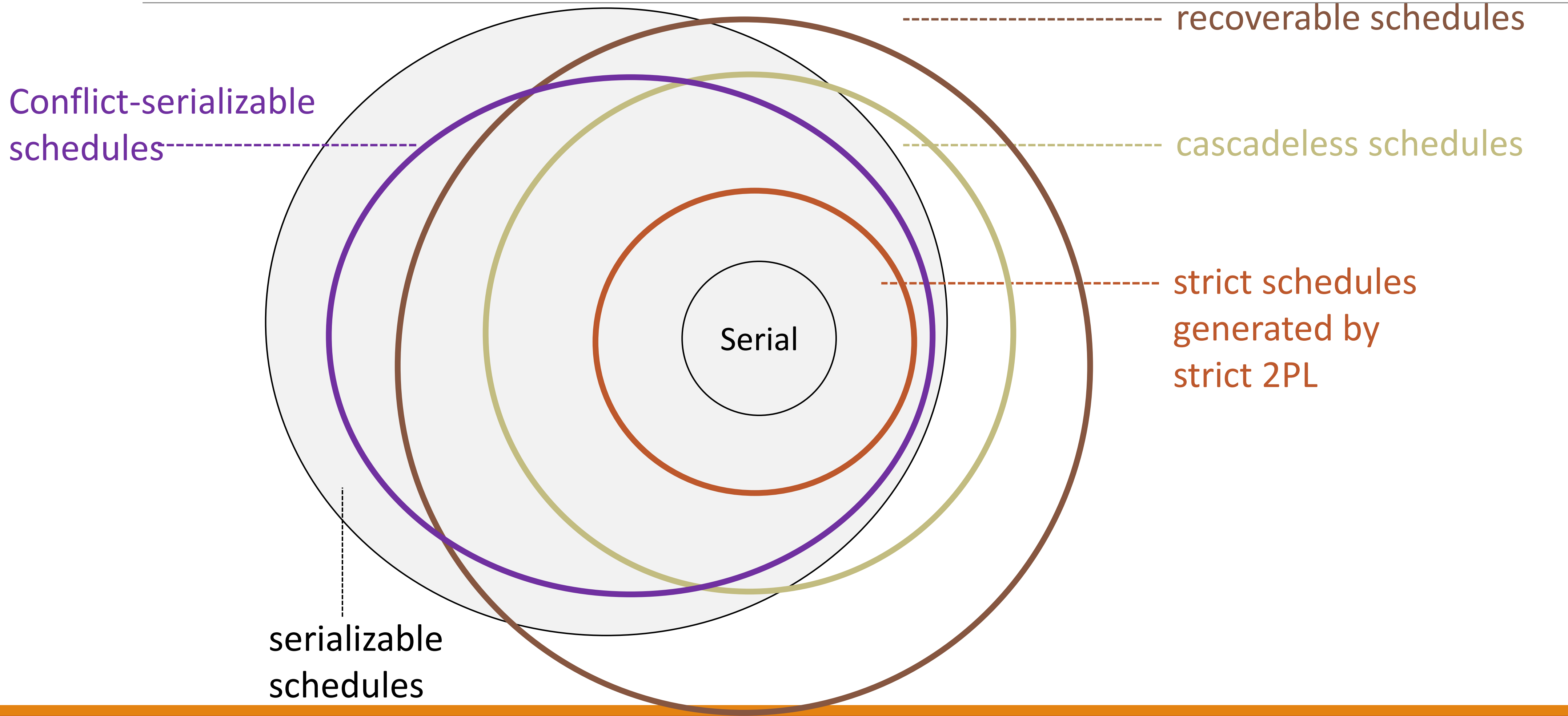

Examples for serializable schedules

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1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
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3. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y)$; $w_3(X)$; c_2; c_3; c_1
   - This is recoverable and serializable, but not conflict-serializable nor cascadeless

Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is conflict-serializable, but not recoverable
3. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3; c_1$
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Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y);\ w_3(X);\ c_3;\ c_2;\ c_1$
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X);\ w_1(Y);\ w_2(X);\ w_2(Y);\ r_3(Y);\ w_3(X);\ c_3;\ c_2;\ c_1$
   - This is conflict-serializable, but not recoverable
3. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3;\ c_1$
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4. example: $w_1(X);\ w_1(Y);\ w_2(X);\ w_2(Y);\ r_3(Y);\ w_3(X);\ c_2;\ c_3;\ c_1$

Examples for serializable schedules

1. example: $w_2(X)$; $w_1(X)$; $w_1(Y)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
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Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is conflict-serializable, but not recoverable
3. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3; c_1$
   - This is recoverable and serializable, but not conflict-serializable nor cascadeless
4. example: $w_1(X); w_1(Y); w_2(X); w_2(Y);$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3; c_1$
   - This is recoverable and conflict-serializable, but not cascadeless

Examples for serializable schedules

1. example: $w_2(X); w_1(X); w_1(Y); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
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2. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
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4. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_2; c_3; c_1$
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $w_2(X); w_1(X); w_1(Y); w_2(Y); c_2; r_3(Y); w_3(X); c_3; c_1$

Examples for serializable schedules

1. example: $w_2(X); w_1(X); w_1(Y); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
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4. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_2; c_3; c_1$
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $w_2(X); w_1(X); w_1(Y); w_2(Y); c_2; r_3(Y); w_3(X); c_3; c_1$
   - This is cascadeless and serializable, but not conflict-serializable

Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
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2. example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
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   - This is recoverable and serializable, but not conflict-serializable nor cascadeless
4. example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; $\boxed{r_3(Y);}$ $w_3(X)$; $\boxed{c_2;}$ c_3; c_1
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ c_2; $r_3(Y)$; $w_3(X)$; c_3; c_1
   - This is cascadeless and serializable, but not conflict-serializable

Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is serializable, but not conflict-serializable or recoverable

2. example: $w_1(X); w_1(Y); w_2(X); w_2(Y); r_3(Y); w_3(X); c_3; c_2; c_1$
   - This is conflict-serializable, but not recoverable

3. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3; c_1$
   - This is recoverable and serializable, but not conflict-serializable nor cascadeless

4. example: $w_1(X); w_1(Y); w_2(X); w_2(Y);$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3; c_1$
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $c_2; r_3(Y); w_3(X); c_3; c_1$
   - This is cascadeless and serializable, but not conflict-serializable

6: example: $w_1(X); w_1(Y); w_2(X); w_2(Y); c_2; r_3(Y); w_3(X); c_3; c_1$

Examples for serializable schedules

1. example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $r_3(Y);\ w_3(X);\ c_3;\ c_2;\ c_1$
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X);\ w_1(Y);\ w_2(X);\ w_2(Y);\ r_3(Y);\ w_3(X);\ c_3;\ c_2;\ c_1$
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   - This is recoverable and serializable, but not conflict-serializable nor cascadeless
4. example: $w_1(X);\ w_1(Y);\ w_2(X);\ w_2(Y);$ $\boxed{r_3(Y);}$ $w_3(X);$ $\boxed{c_2;}$ $c_3;\ c_1$
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $\boxed{w_2(X);}$ $\boxed{w_1(X);}$ $\boxed{w_1(Y);}$ $\boxed{w_2(Y);}$ $c_2;\ r_3(Y);\ w_3(X);\ c_3;\ c_1$
   - This is cascadeless and serializable, but not conflict-serializable

6: example: $w_1(X);\ w_1(Y);\ w_2(X);\ w_2(Y);\ c_2;\ r_3(Y);\ w_3(X);\ c_3;\ c_1$

Conflict-serializable and cascadeless but not strict

Examples for serializable schedules

1. example: $w_2(X)$; $w_1(X)$; $w_1(Y)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
   - This is serializable, but not conflict-serializable or recoverable
2. example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_3; c_2; c_1
   - This is conflict-serializable, but not recoverable
3. example: $w_2(X)$; $w_1(X)$; $w_1(Y)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_2; c_3; c_1
   - This is recoverable and serializable, but not conflict-serializable nor cascadeless
4. example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; $r_3(Y)$; $w_3(X)$; c_2; c_3; c_1
   - This is recoverable and conflict-serializable, but not cascadeless

5: example: $w_2(X)$; $w_1(X)$; $w_1(Y)$; $w_2(Y)$; c_2; $r_3(Y)$; $w_3(X)$; c_3; c_1
   - This is cascadeless and serializable, but not conflict-serializable

6: example: $w_1(X)$; $w_1(Y)$; $w_2(X)$; $w_2(Y)$; c_2; $r_3(Y)$; $w_3(X)$; c_3; c_1

Conflict-serializable and cascadeless but not strict

Still… Risk of Deadlocks

T_1
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
commit
unlock(X)
unlock(Y)

T_2
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
lock(X)
read_item(X)
X := X + 100
write_item(X)
commit
unlock(X)
unlock(Y)

Still… Risk of Deadlocks

T_1
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
commit
unlock(X)
unlock(Y)

T_2
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
lock(X)
read_item(X)
X := X + 100
write_item(X)
commit
unlock(X)
unlock(Y)

$l_1(X); r_1(X); w_1(X);$

Still… Risk of Deadlocks

T_1
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
commit
unlock(X)
unlock(Y)

T_2
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
lock(X)
read_item(X)
X := X + 100
write_item(X)
commit
unlock(X)
unlock(Y)

$l_1(X); r_1(X); w_1(X);$ $l_2(Y); r_2(Y); w_2(Y);$

Still… Risk of Deadlocks

T_1
lock(X)
read_item(X)
X := X + 100
write_item(X)
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
commit
unlock(X)
unlock(Y)

T_2
lock(Y)
read_item(Y)
Y := Y + 100
write_item(Y)
lock(X)
read_item(X)
X := X + 100
write_item(X)
commit
unlock(X)
unlock(Y)

$l_1(X); r_1(X); w_1(X);$ $l_2(Y); r_2(Y); w_2(Y);$ __?__

Still… Risk of Deadlocks

T_1		T_2
lock(X)		lock(Y)
read_item(X)		read_item(Y)
X := X + 100		Y := Y + 100
write_item(X)		write_item(Y)
lock(Y)		lock(X)
read_item(Y)		read_item(X)
Y := Y + 100		X := X + 100
write_item(Y)		write_item(X)
commit		commit
unlock(X)		unlock(X)
unlock(Y)		unlock(Y)

T_2's request for lock on X denied

$l_1(X); r_1(X); w_1(X);\ l_2(Y); r_2(Y); w_2(Y);\ \underline{\ ?\ }$

Still… Risk of Deadlocks

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	lock(X)
read_item(Y)	read_item(X)
Y := Y + 100	X := X + 100
write_item(Y)	write_item(X)
commit	commit
unlock(X)	unlock(X)
unlock(Y)	unlock(Y)

T_2's request for lock on X denied

$l_1(X); r_1(X); w_1(X);$ $l_2(Y); r_2(Y); w_2(Y);$ _?_

T_1's request for lock on Y denied

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Strict 2PL and Deadlocks

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Problem: **deadlocks**

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T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$?

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$ _?_

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$ _?_

Roll back (and restart) one of the transactions

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$ _?_

Roll back (and restart) one of the transactions

Two approaches for deadlock prevention:

- **Detect deadlocks & fix them**
- **Enforce deadlock-free schedules**

Strict 2PL and Deadlocks

Strict 2PL yields **conflict-serialisable**, **strict schedules**

Problem: **deadlocks**

T_1	T_2
lock(X)	lock(Y)
read_item(X)	read_item(Y)
X := X + 100	Y := Y + 100
write_item(X)	write_item(Y)
lock(Y)	**lock(X)**
…	…

$l_1(X); r_1(X); w_1(X);$

$l_2(Y); r_2(Y); w_2(Y);$?

Roll back (and restart) one of the transactions

Two approaches for deadlock prevention:

- **Detect deadlocks & fix them**
- **Enforce deadlock-free schedules**

Not based on (strict) 2PL

Summary

Cascadeless schedules are a more restrictive form of schedules

- You can only read things that are already committed

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- You can only read things that are already committed

Instead of implementing that, we use Strict

- You can only read or overwrite things that are already committed

We then finally use Strict 2PL

- Like 2PL, but where you can only unlock (locks that could write) after commit