Introduction to Database Systems
CSE 444

Lectures 12
Transactions: concurrency control
(part 2)

Outline

- Concurrency control by timestamps (18.8)
- Concurrency control by validation (18.9)

Timestamps

- Each transaction receives a unique timestamp TS(T)

Could be:

- The system's clock
- A unique counter, incremented by the scheduler

Timestamps

Main invariant:

The timestamp order defines
the serialization order of the transaction

Main Idea

- For any two conflicting actions, ensure that their order is the serialized order:

In each of these cases

- $w_U(X)$ . . . $r_T(X)$
- $r_U(X)$ . . . $w_T(X)$
- $w_U(X)$ . . . $w_T(X)$

Read too late ?

Write too late ?

Answer: Check that $TS(U) < TS(T)$

When T wants to read X, $r_T(X)$, how do we know U, and TS(U) ?

Timestamps

With each element X, associate

- RT(X) = the highest timestamp of any transaction that read X
- WT(X) = the highest timestamp of any transaction that wrote X
- C(X) = the commit bit: true when transaction with highest timestamp that wrote X committed

If 1 element = 1 page,
these are associated with each page X in the buffer pool

Time-based Scheduling

- Note: simple version that ignores the commit bit
- Transaction wants to read element X
  - If TS(T) < WT(X) abort
  - Else read and update RT(X) to larger of TS(T) or RT(X)
- Transaction wants to write element X
  - If TS(T) < RT(X) abort
  - Else if TS(T) < WT(X) ignore write & continue (Thomas Write Rule)
  - Otherwise, write X and update WT(X) to TS(T)

Details

Read too late:

- T wants to read X, and TS(T) < WT(X)

$\boxed{\text{START(T) … START(U) … } w_U(X) \text{ . . . } r_T(X)}$

Need to rollback T !

Details

Write too late:

- T wants to write X, and TS(T) < RT(X)

START(T) … START(U) … $r_U(X)$ . . . $w_T(X)$

Need to rollback T !

Details

Write too late, but we can still handle it:

- T wants to write X, and
  TS(T) >= RT(X) but WT(X) > TS(T)

$$\boxed{\text{START}(T) \ldots \text{START}(V) \ldots w_V(X) \ . \ . \ . \ w_T(X)}$$

Don't write X at all !
(but see later…)

More Problems

Read dirty data:

- T wants to read X, and WT(X) < TS(T)
- Seems OK, but…

START(U) … START(T) … w_U(X). . . r_T(X)… ABORT(U)

If C(X)=false, T needs to wait for it to become true

More Problems

Write dirty data:

- T wants to write X, and WT(X) > TS(T)
- Seems OK not to write at all, but …

START(T) … START(U)… w_U(X). . . w_T(X)… ABORT(U)

If C(X)=false, T needs to wait for it to become true

Timestamp-based Scheduling

- When a transaction T requests r(X) or w(X), the scheduler examines RT(X), WT(X), C(X), and decides one of:

- To grant the request, or
- To rollback T (and restart with later timestamp)
- To delay T until C(X) = true

Timestamp-based Scheduling

RULES including commit bit

- There are 4 long rules in Sec. 18.8.4
- You should be able to derive them yourself, based on the previous slides
- Make sure you understand them !

READING ASSIGNMENT: 18.8.4

Multiversion Timestamp

- When transaction T requests r(X) but WT(X) > TS(T), then T must rollback
- Idea: keep multiple versions of X: $X_t, X_{t-1}, X_{t-2}, \ldots$

  $\boxed{TS(X_t) > TS(X_{t-1}) > TS(X_{t-2}) > \ldots}$

- Let T read an older version, with appropriate timestamp

Details

- When $w_T(X)$ occurs,
  create a new version, denoted X_t where $t = TS(T)$

- When $r_T(X)$ occurs,
  find most recent version X_t such that $t < TS(T)$
  Notes:
  - $WT(X_t) = t$ and it never changes
  - $RT(X_t)$ must still be maintained to check legality of writes

- Can delete X_t if we have a later version X_{t1} and all active transactions T have $TS(T) > t1$

Tradeoffs

- Locks:
  - Great when there are many conflicts
  - Poor when there are few conflicts
- Timestamps
  - Poor when there are many conflicts (rollbacks)
  - Great when there are few conflicts

- Compromise
  - READ ONLY transactions → timestamps
  - READ/WRITE transactions → locks

Outline

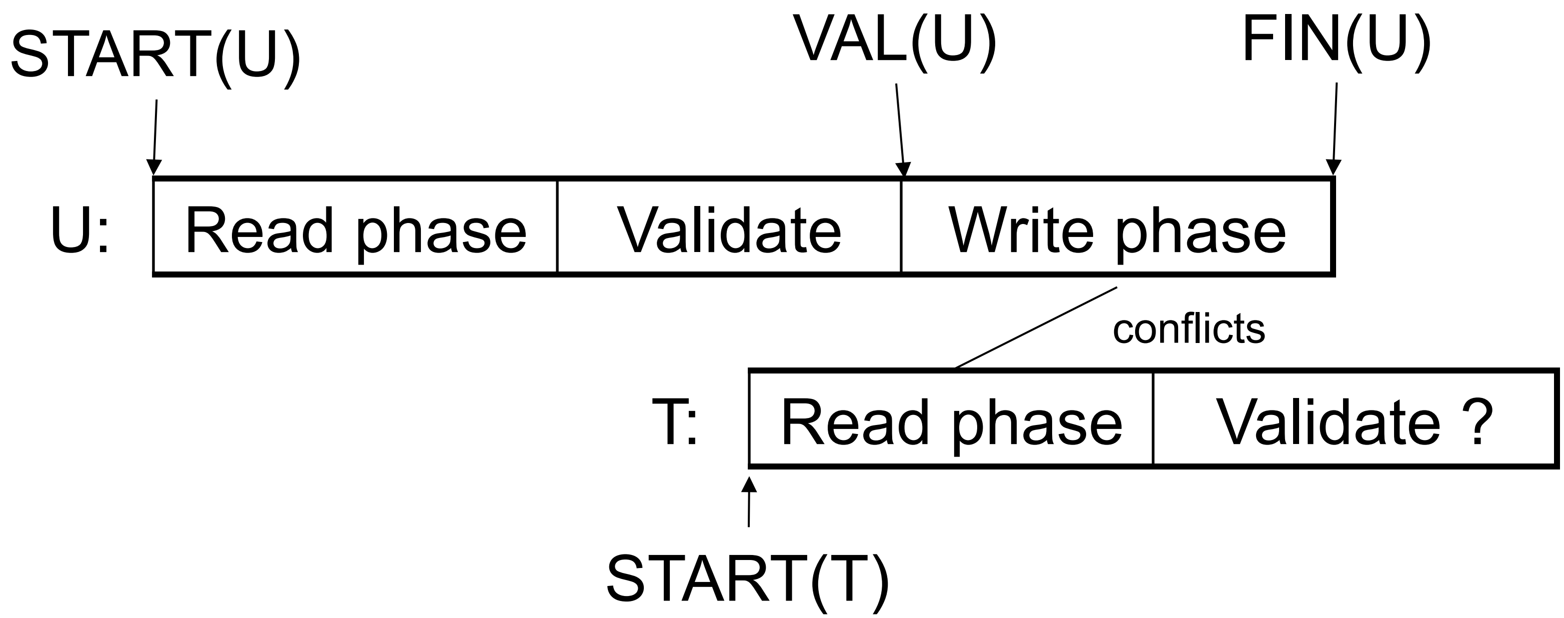
- Concurrency control by timestamps (18.8)
- Concurrency control by validation (18.9)

Concurrency Control by Validation

- Each transaction T defines a *read set* RS(T) and a *write set* WS(T)
- Each transaction proceeds in three phases:
  - Read all elements in RS(T). Time = START(T)
  - Validate (may need to rollback). Time = VAL(T)
  - Write all elements in WS(T). Time = FIN(T)

Main invariant: the serialization order is VAL(T)

Avoid $r_T(X)$ - $w_U(X)$ Conflicts

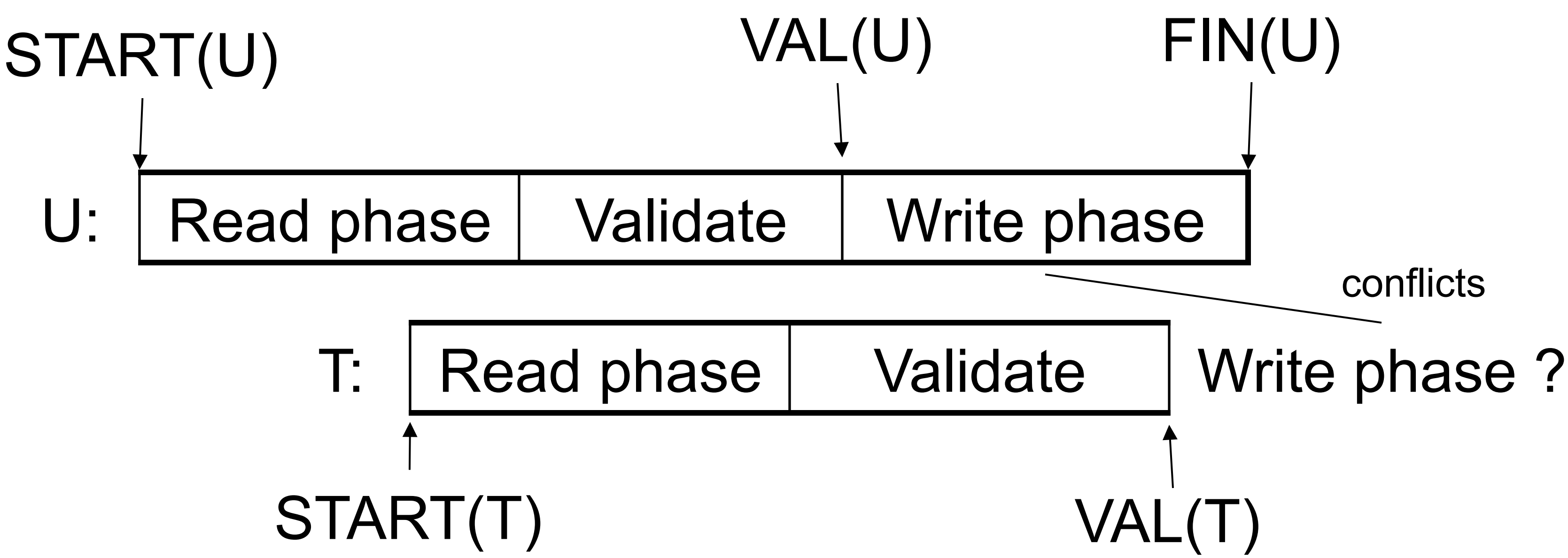


IF RS(T) ∩ WS(U) and FIN(U) > START(T)

(U has validated and U has not finished before T begun)

Then ROLLBACK(T)

Avoid $w_T(X)$ - $w_U(X)$ Conflicts



IF WS(T) ∩ WS(U) and FIN(U) > VAL(T)
(U has validated and U has not finished before T validates)
Then ROLLBACK(T)