Distributed Systems (ICE 601)

Concurrency Control - Part2

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Class Overview

- Transactions
- Why Concurrency Control
- Concurrency Control Protocols
  - pessimistic
  - optimistic
  - time-based

Optimistic Concurrency Control

- Principle
  - transaction proceeds without checking conflict with others and prior to commit, *validates* its change by checking to see if data items have changed by *committed transactions*
  - each transaction has three phases
    - Read phase
      - committed version of data items for read - *read set*
      - tentative version of data items for write - *write set*
    - Validation phase
      - starts with EndTransaction request
      - validate its change by checking to see if data items have changed by other transactions
      - if no conflicts, commit; otherwise, abort
    - Write phase
      - make changes permanent

Optimistic Concurrency Control (cont.)

- Validation test rule
  - T*j* is *serializable* with respect to overlapping T*i* if their operations conform to the following rules

T*i*	T*j*	Rule
Read	*Write*	1. T*i* must not read data items written by T*j*
Write	*Read*	2. T*j* must not read data items written by T*i*
Write	*Write*	3. T*i* must not write data items written by T*j* and T*j* must not write data items written by T*i*

(Assumption: T*i* always preceeds T*j* if $i < j$ and T*i* overlaps with T*j*)

  - *transaction # is sequentially assigned when validation phase starts*
- Validation mechanisms
  - backward validation
  - forward validation

Optimistic Concurrency Control (cont.)

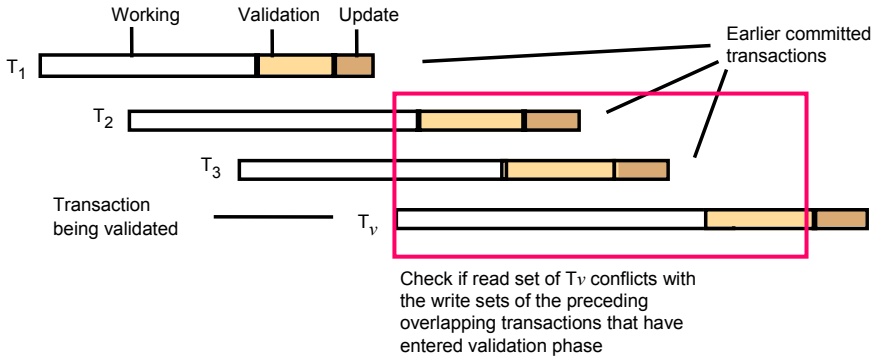
- Backward validation
  - algorithm
    - checks transaction in validation phase with other preceding overlapping transactions that have entered validation phase
      - *Write* operations are ok since Read operations of earlier transactions are done already (Rule1)
      - check if *Read* operations have any conflict with *Write* operations of earlier overlapping transactions (Rule 2) => if yes, abort transaction

```
Valid := True;
for Ti := startTn + 1 to finishTn
do
    if read set of Tj intersects write set of Ti
        Valid := False;
end
```

  - no check is needed for transaction with only *Write* operations

Optimistic Concurrency Control (cont.)

- Backward validation example



Optimistic Concurrency Control (cont.)

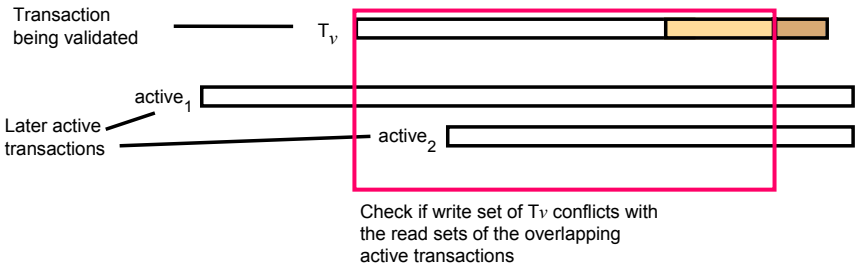
- Forward validation
  - algorithm
    - checks transaction in validation phase with other overlapping active transactions
      - *Read* operations are ok since later transactions do not write until the Tj is done (Rule 2)
      - check if *Write* operations have any conflict with *Read* operations of overlapping active transactions (Rule 1) => if yes, abort transaction

```
Valid := True;
for Ti := active1 to activeN
do
    if write set of Tj intersects read set of Ti
        Valid := False;
end
```

  - no check is needed for transaction with only *Read* operations
  - other options than aborting the current transaction
    - defer validation until conflicting transaction is done
    - abort conflicting transaction instead

Optimistic Concurrency Control (cont.)

- Forward validation example



Optimistic Concurrency Control (cont.)

- Issues in optimistic concurrency control
  - Overhead
    - Backward validation
      - if there exists long transaction, retention of old write sets of data item may be a problem
    - Forward validation
      - a new transaction can start during the validation process -> increase chances by which the current transaction is forced to abort or delay
  - Starvation
    - prevention of a transaction ever being able to commit

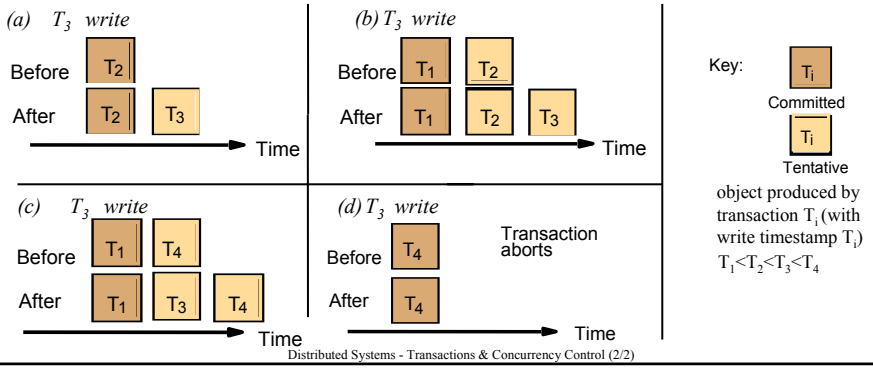
Timestamp Ordering

- Assumption
  - each transaction is given a unique timestamp when it starts
  - there is only one version of data item and only one transaction can access it at a time => multiple tentative versions of data to increase concurrency
- Rule
  - *Write* operation is valid only if the data was last read and written by earlier transaction
    - *Rule1*: Tj must not write data item read by any Ti where Ti > Tj (i.e. Tj >= max read time stamp of data item)
    - *Rule 2*: Tj must not write data item written by any Ti where Ti > Tj (i.e. Tj > max write time stamp of committed data item)
  - *Read* operation is valid only if the data was last written by earlier transaction
    - *Rule 3*: Tj must not read data item written by T*i* where Ti > Tj (i.e. Tj > write time stamp of committed data item)

Timestamp Ordering (cont.)

- Write operations and time stamp

  if ($T_c \geq$ maximum read timestamp on D &&
  $T_c >$ write timestamp on committed version of D)
  perform write operation on tentative version of D with write timestamp T_c
  else /* write is too late */
  Abort transaction T_c



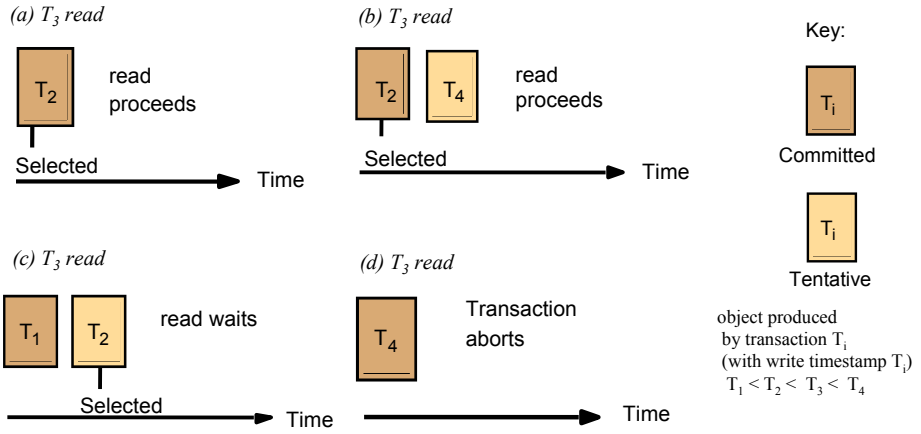
Timestamp Ordering (cont.)

- Read operations and time stamp

  if ($T_c >$ write timestamp on committed version of D) {
  let $D_{selected}$ be the version of D with the maximum write timestamp $\leq T_c$
  if ($D_{selected}$ is committed)
  perform *read* operation on the version $D_{selected}$
  else
  Wait until the transaction that made version $D_{selected}$ commits or aborts
  then reapply the *read* rule
  } else
  Abort transaction T_c

Timestamp Ordering (cont.)

- Read operations and time stamp - example

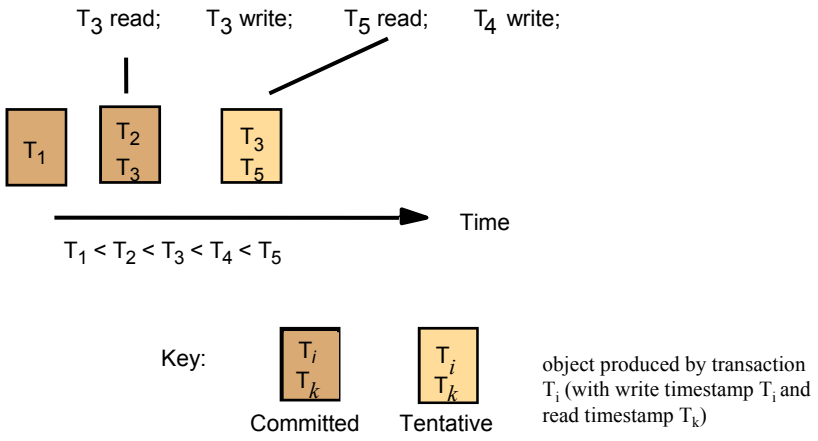


Timestamp Ordering (cont.)

- Multi-version timestamp ordering
  - keep old versions of committed data as well as tentative versions
    - read operation is always allowed; may need to wait for earlier transactions to complete
    - no conflict between write operations since each transaction writes its own committed version (remove rule 2)
  - write rule
    - if read time stamp (most recent version) <= Tj then perform write operation on a tentative version with write time stamp Tj

Timestamp Ordering (cont.)

- Multi-version timestamp ordering - example



Comparison

- Locking vs. timestamp ordering
  - both are pessimistic
  - dynamic vs static ordering
  - write-dominated vs. read-dominated
- Optimistic
  - efficient when there are few conflicts
- New requirements to concurrency control
  - multi-user applications
    - immediate notification of change (relaxed isolation)
    - need to be able to access uncommitted data item
  - co-operative CAD/CAM
    - co-operations of users to resolve data conflicts