# Concurrency control

# (OCC and MVCC)

COS 418/518
Lecture 16

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## Serializability

Execution of a set of transactions over multiple items is equivalent to *some* serial execution of txns



## Lock-based concurrency control

- **Big Global Lock:** Results in a **serial** transaction schedule at the cost of performance
- **Two-phase locking with finer-grain locks:**
  - **Growing phase** when txn acquires locks
  - **Shrinking phase** when txn releases locks (typically commit)
  - Allows txn to execute concurrently, improving performance



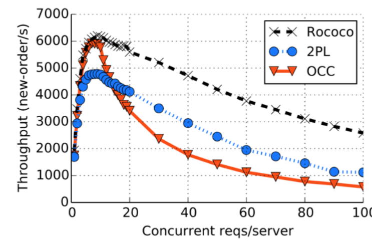
## Q: What if access patterns rarely, if ever, conflict?

## Be optimistic!

- Goal: Low overhead for non-conflicting txns
- Assume success!
  - Process transaction as if would succeed
  - Check for serializability only at commit time
  - If fails, abort transaction
- **Optimistic Concurrency Control (OCC)**
  - Higher performance when few conflicts vs. locking
  - Lower performance when many conflicts vs. locking

5

## 2PL vs OCC




- From "Rococo" paper in OSDI 2014. Focus on 2PL vs. OCC.
- Observe OCC better when write rate lower (fewer conflicts), worse than 2PL with write rate higher (more conflicts)

6

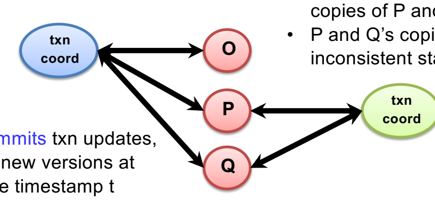
## OCC: Three-phase approach

- **Begin:** Record timestamp marking the transaction's beginning
- **Modify** phase:
  - Txn can read values of committed data items
  - Updates only to local copies (versions) of items (in db cache)
- **Validate** phase
- **Commit** phase
  - If validates, transaction's updates applied to DB
  - Otherwise, transaction restarted
  - Care must be taken to avoid "TOCTTOU" issues

7

## OCC: Why validation is necessary

- New txn creates shadow copies of P and Q
- P and Q's copies at inconsistent state




When commits txn updates, create new versions at some timestamp t

8

## OCC: Validate Phase

- Transaction is about to commit.
  System must ensure:
  - Initial consistency: Versions of accessed objects at start consistent
  - No conflicting concurrency: No other txn has committed an operation at object that conflicts with one of this txn's invocations

9

## OCC: Validate Phase

- Validation needed by transaction T to commit:
- For all other txns O either **committed** or **in validation** phase, one of following holds:
  A. O completes commit before T starts modify
  B. T starts commit after O completes commit, and ReadSet T and WriteSet O are disjoint
  C. Both ReadSet T and WriteSet T are disjoint from WriteSet O, and O completes modify phase.
- When validating T, first check (A), then (B), then (C). If all fail, validation fails and T aborted

10

## 2PL & OCC = strict serialization

- Provides semantics as if only one transaction was running on DB at time, in serial order
  + Real-time guarantees
- 2PL: Pessimistically get all the locks first
- OCC: Optimistically create copies, but then recheck all read + written items before commit

11

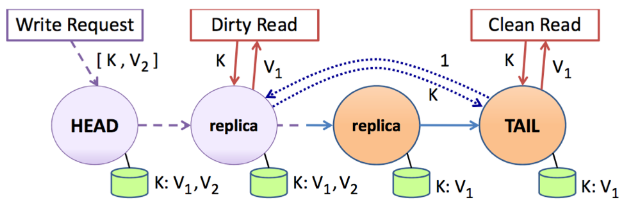
## Multi-version concurrency control

Generalize use of multiple versions of objects

12

## Multi-version concurrency control

- Maintain multiple versions of objects, each with own timestamp. Allocate correct version to reads.
- Prior example of MVCC:






## Multi-version concurrency control

- Maintain multiple versions of objects, each with own timestamp. Allocate correct version to reads.
- Unlike 2PL/OCC, reads never rejected
- Occasionally run garbage collection to clean up



## MVCC Intuition

- Split transaction into read set and write set
  - All reads execute as if one "snapshot"
  - All writes execute as if one later "snapshot"
- Yields snapshot isolation < serializability



## Timestamps in MVCC

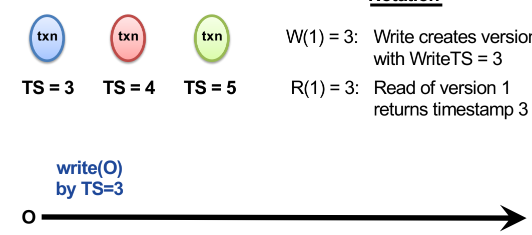
- Transactions are assigned timestamps, which may get assigned to objects those txns read/write
- Every object version $O_V$ has both read and write TS
  - ReadTS: Largest timestamp of txn that reads $O_V$
  - WriteTS: Timestamp of txn that wrote $O_V$

## Executing transaction T in MVCC

- Find version of object O to read:
  - # Determine the last version written before read snapshot time
  - Find $O_V$ s.t. max { WriteTS($O_V$) | WriteTS($O_V$) <= TS(T) }
  - ReadTS($O_V$) = max(TS(T), ReadTS($O_V$))
  - Return $O_V$ to T
- Perform write of object O or abort if conflicting:
  - Find $O_V$ s.t. max { WriteTS($O_V$) | WriteTS($O_V$) <= TS(T) }
  - # Abort if another T' exists and has read O after T
  - If ReadTS($O_V$) > TS(T)
    - Abort and roll-back T
  - Else
    - Create new version $O_W$
    - Set ReadTS($O_W$) = WriteTS($O_W$) = TS(T)

17

## Digging deeper



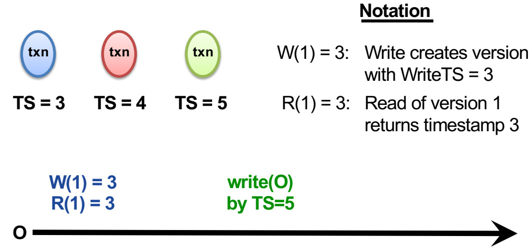

**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

18

## Digging deeper




**Notation**

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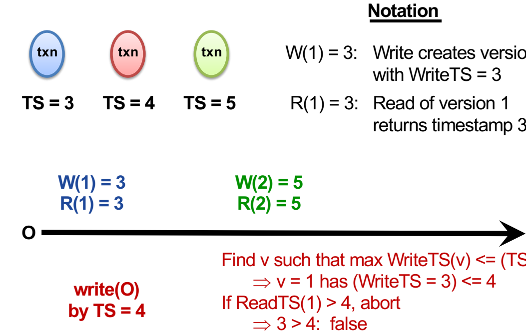
19

## Digging deeper




**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

Find v such that max WriteTS(v) <= (TS = 4)
⇒ v = 1 has (WriteTS = 3) <= 4
If ReadTS(1) > 4, abort
⇒ 3 > 4: false
Otherwise, write object

20

## Digging deeper

**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

txn **TS = 3** txn **TS = 4** txn **TS = 5**

**W(1) = 3** **W(3) = 4** **W(2) = 5**
**R(1) = 3** **R(3) = 4** **R(2) = 5**

O ————→

Find v such that max WriteTS(v) <= (TS = 4)
⇒ v = 1 has (WriteTS = 3) <= 4
If ReadTS(1) > 4, abort
⇒ 3 > 4: false
Otherwise, write object



## Digging deeper

**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

txn **TS = 3** txn **TS = 4** txn **TS = 5**

**W(1) = 3**
**R(1) = 5**

O ————→

**BEGIN Transaction**
**tmp = READ(O)**
**WRITE (O, tmp + 1)**
**END Transaction**

Find v such that max WriteTS(v) <= (TS = 5)
⇒ v = 1 has (WriteTS = 3) <= 5
Set R(1) = max(5, R(1)) = 5



## Digging deeper

**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

txn **TS = 3** txn **TS = 4** txn **TS = 5**

**W(1) = 3** **W(2) = 5**
**R(1) = 5** **R(2) = 5**

O ————→

**BEGIN Transaction**
**tmp = READ(O)**
**WRITE (O, tmp + 1)**
**END Transaction**

Find v such that max WriteTS(v) <= (TS = 5)
⇒ v = 1 has (WriteTS = 3) <= 5
If ReadTS(1) > 5, abort
⇒ 5 > 5: false
Otherwise, write object



## Digging deeper

**Notation**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

txn **TS = 3** txn **TS = 4** txn **TS = 5**

**W(1) = 3** **W(2) = 5**
**R(1) = 5** **R(2) = 5**

O ————→

**write(O)**
**by TS = 4**

Find v such that max WriteTS(v) <= (TS = 4)
⇒ v = 1 has (WriteTS = 3) <= 4
If ReadTS(1) > 4, abort
⇒ 5 > 4: **true**

# Digging deeper

**Notation**

txn txn txn

**TS = 3** **TS = 4** **TS = 5**

W(1) = 3: Write creates version 1 with WriteTS = 3

R(1) = 3: Read of version 1 returns timestamp 3

**W(1) = 3**
**R(1) = 5**

**W(2) = 5**
**R(2) = 5**

**O**

**BEGIN Transaction**
**tmp = READ(O)**
**WRITE (P, tmp + 1)**
**END Transaction**

Find v such that max WriteTS(v) <= (TS = 4)
⇒ v = 1 has (WriteTS = 3) <= 4
Set R(1) = max(4, R(1)) = 5

Then write on P succeeds as well

25