Transactions

Intel (TX memory): Transactional Synchronization Extensions (TSX)

Transactions - Definition

- A transaction is a sequence of data operations with the following properties:
  - * **A** Atomic
    - All or nothing
  - * **C** Consistent
    - Consistent state in => consistent state out
  - * **I** Independent (Isolated)
    - Partial results are not visible to concurrent transactions
  - * **D** Durable
    - Once completed, new state survives crashes

Summary

Isolation and serializability

- Definitions
  - isolation
    - no transaction can see incomplete results of another
  - serializability
    - actual execution same as some serial order
- Algorithms (based on locks)
  - two-phase locking
    - serializability
  - strict two-phase locking
    - isolation and serializability

Two Possible (pessimistic) Approaches

- Two Phase Locking
- Strict Two Phase Locking

Two Phase Locking

- Locks
  * reader/writer locks
  * acquired **as** transaction proceeds
  * no more acquires after first release
- Phase 1
  - acquire locks and access data, but release no locks
- Phase 2
  - access data, release locks, but acquire no new locks

Semantics of two-phase locking

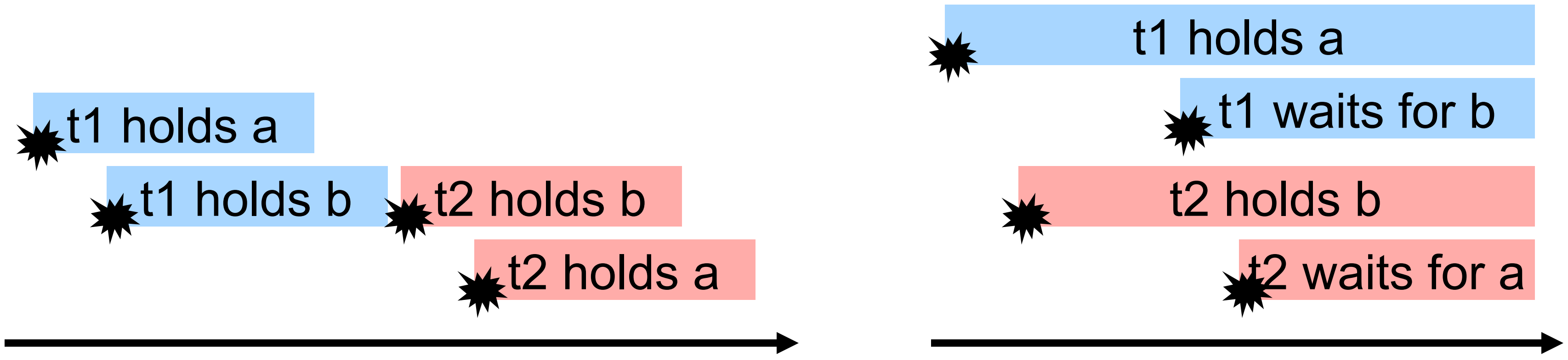
- Ensures serializability
  - * if transactions have no conflicting lock access
    - order arbitrarily
  - * for any transactions with conflicting lock access
    - order transactions based on order lock is acquired
  - * transactions are serialized
    - because, no lock is acquired after first release
    - deadlocks are still possible
- Does not ensure independence
  - * we still have *premature write* problem
  - * t1 releases x, t2 acquires x, then t1 aborts

Strict two phase locking

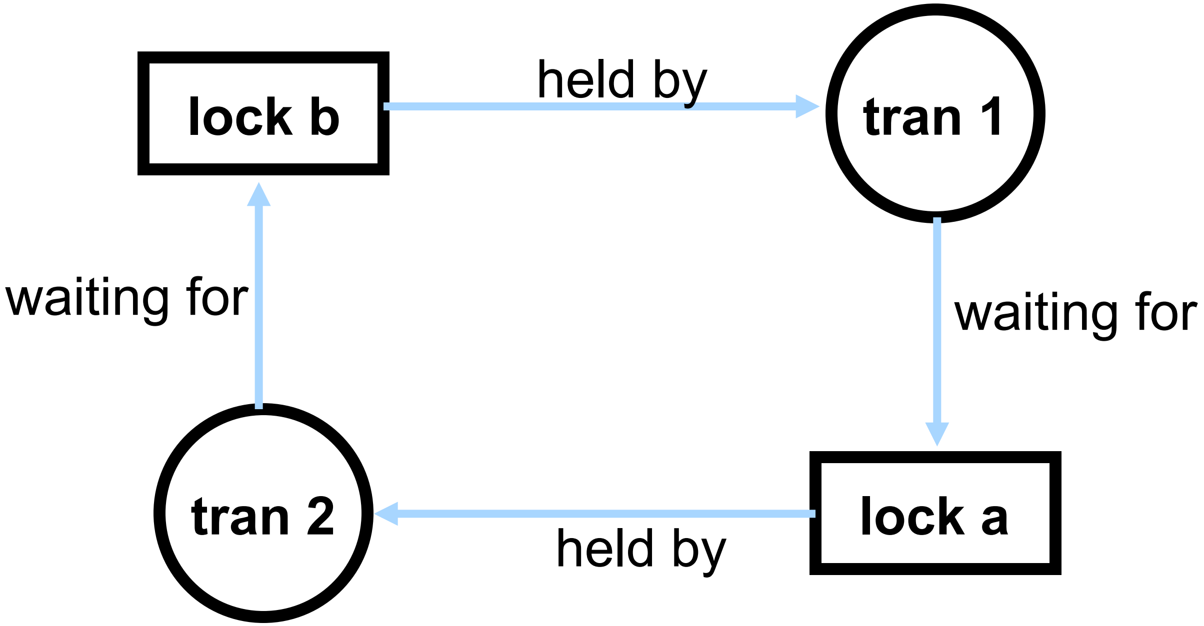
- Like two-phase locking, but
  - release no locks until transaction commits
- Phase 1:
  - acquire locks and access data, but release no locks
- Phase 2:
  - Commit/abort transaction and then release all locks
- Ensures both serializability and independence

Serializability and two-phase locking

- Two-phase locking and ordering
  * serial order is acquisition order for shared locks
  * two-phase ensures that ordering is unambiguous
- Simple illustration of potential deadlock
  * t1 acquires a then b
  * t2 acquires b then a



Deadlock Wait Graph

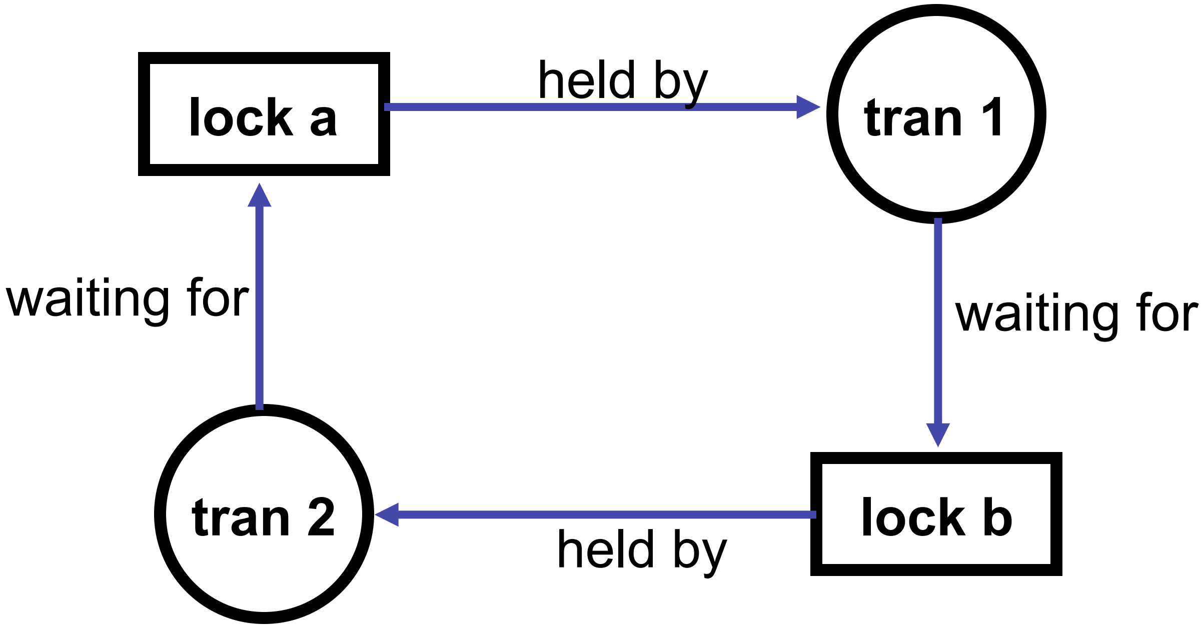


Deadlock

- Transactions increase likelihood of deadlock
  * must hold lock until transaction commits
  * model encourages programmers to forget about locks
- Dealing with deadlock
  * try to prevent it
  * detect it and abort transactions to break deadlock

Detecting and breaking deadlock

- Construct a Wait Graph as program executes
  - all deadlocks appear as cycles in graph
- Abort transactions until cycles are broken

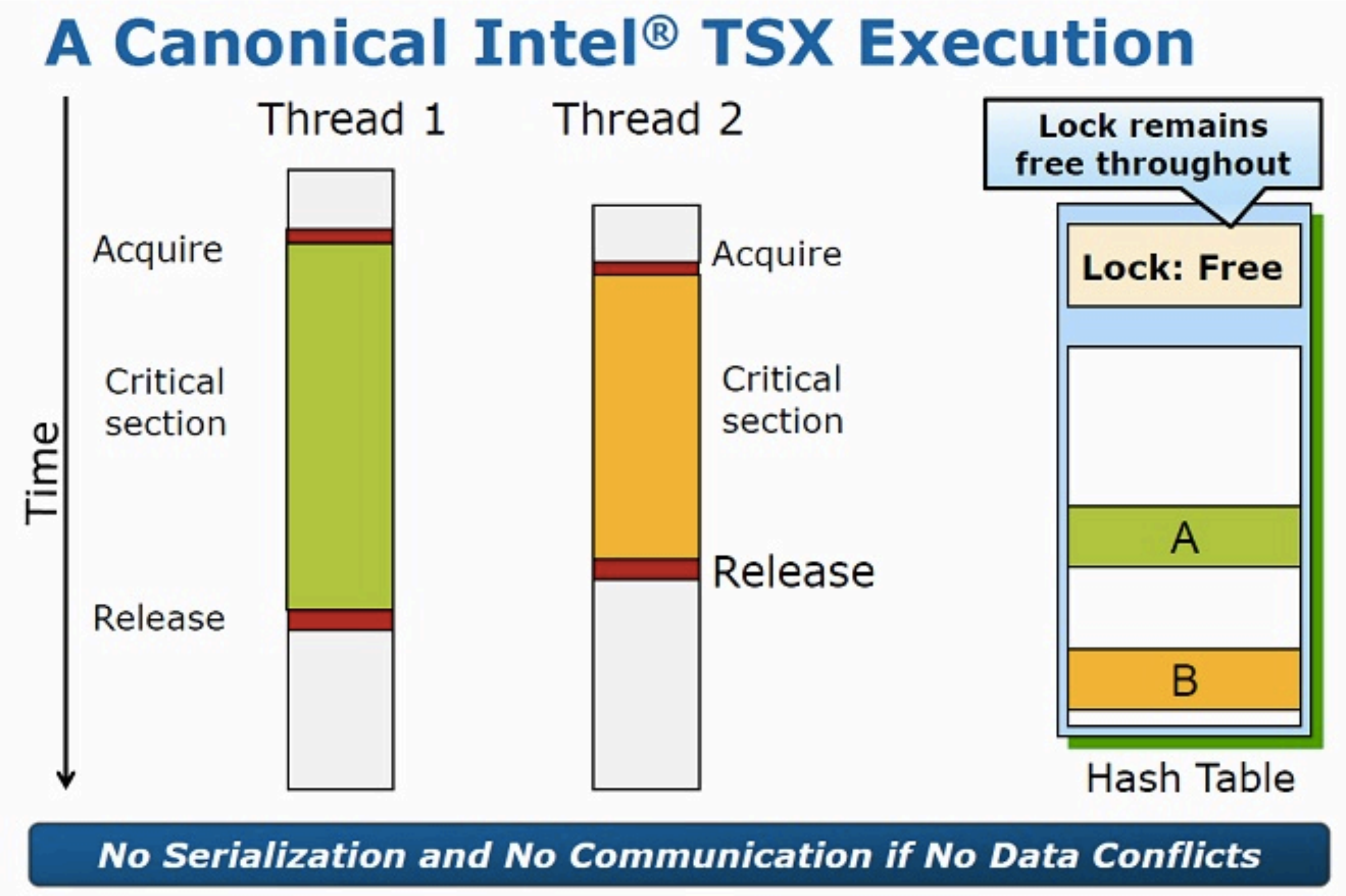


Optimistic concurrency control

- Two-Phase locking is a paranoid approach
  * creates more lock conflicts than necessary
  * especially for long running transactions
- Optimistic concurrency control
  * no locks – process works on copies of data
  * during commit, check for conflicts and abort if any otherwise write the copies
- Analysis
  * (+) no overhead locking when there's no conflict
  * (–) copies of data
  * (–) if conflicts are common overhead much higher

Optimistic concurrency control: TX memory (note: no **d**urability!)

Hardware TX memory (Intel's Haswell)



Recoverability (Atomicity)

- Problem
  - ensure atomic update in face of failure
- If no failure, it's easy
  - just do the updates
- If failure occurs while updates are performed
  - Roll back to remove updates or
  - Roll forward to complete updates
  - What we need to do and when will depend on just when we crash

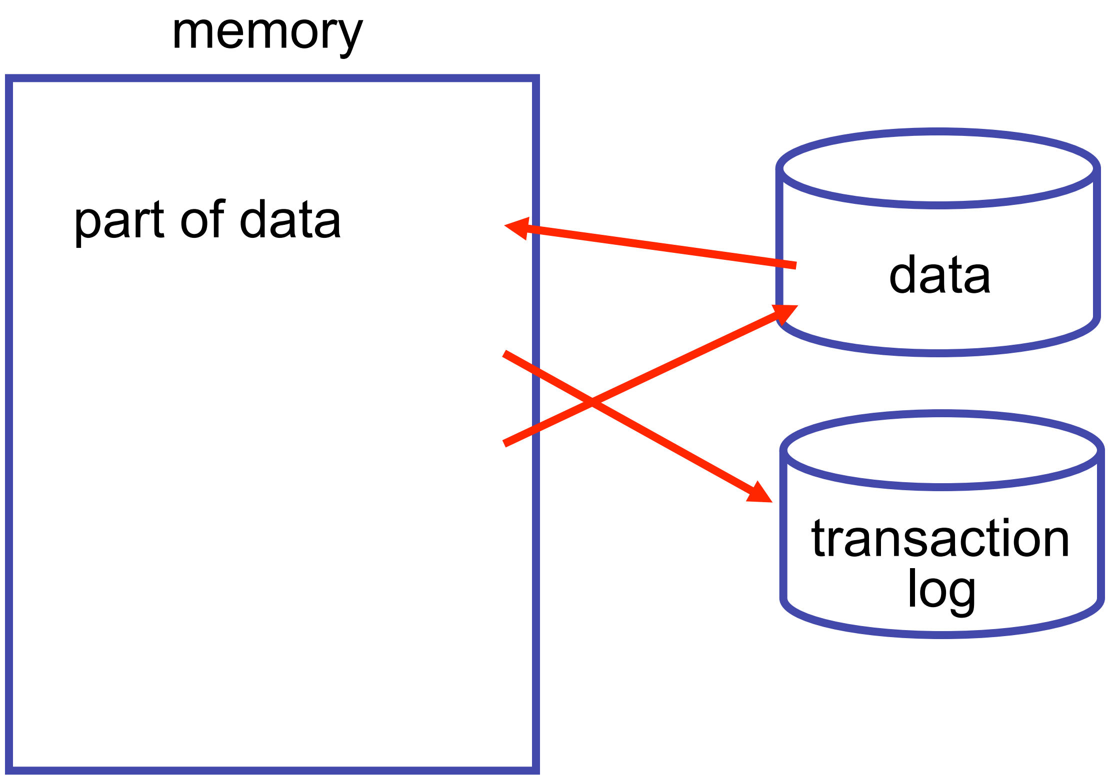
Logging

- **Persistent (on disk)** log
  - records information to support recovery and abort
- Types of logging
  - redo logging --- roll forward
  - undo logging--- roll back (and abort)
  - Write-ahead logging --- roll forward and back
- Types of log records
  - *begin*, *update*, *abort*, *commit*, and *truncate*
- Atomic update
  - atomic operation is write of *commit* record to disk
  - transaction committed iff *commit* record in log

Approaches to logging an update

- Value logging
  - * write old or new value of modified data to log
  - * simple, but not always space efficient or easy
    - E.g., hard for some things such as malloc and system calls
- Operation logging
  - * write name of operation and its arguments
  - * usually used for redo logging
    - undo is possible, but requires a reversing operation

Transaction and persistent data



Redo logging - roll forward

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Normal operation

- For each transactional update
  - change in-memory copy (or work on a disk copy)
  - write new value to log
  - do not change on-disk copy until commit
- Commit
  - write *commit* record to log
  - write changed data to disk
  - write *truncate* record to log
- Abort
  - write *abort* record to log
  - invalidate in-memory data
  - reread from disk

Log what you need to redo