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

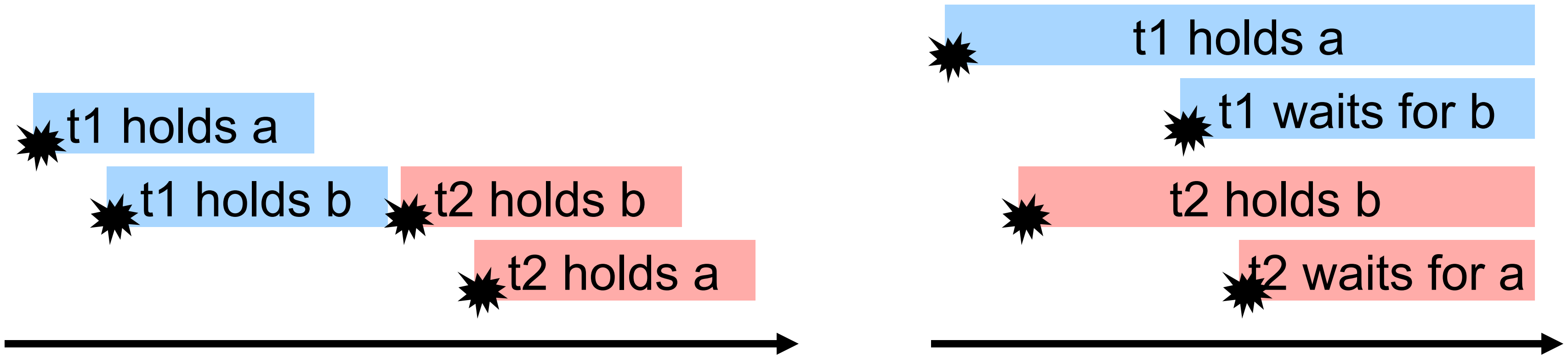
- Ensures serializability
  - if transactions have no conflicting lock access
    - order arbitrarily
  - for any transactions with conflicting lock access
    - order transactions based on order lock is acquired
  - transactions are serialized
    - because, no lock is acquired after first release
    - 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

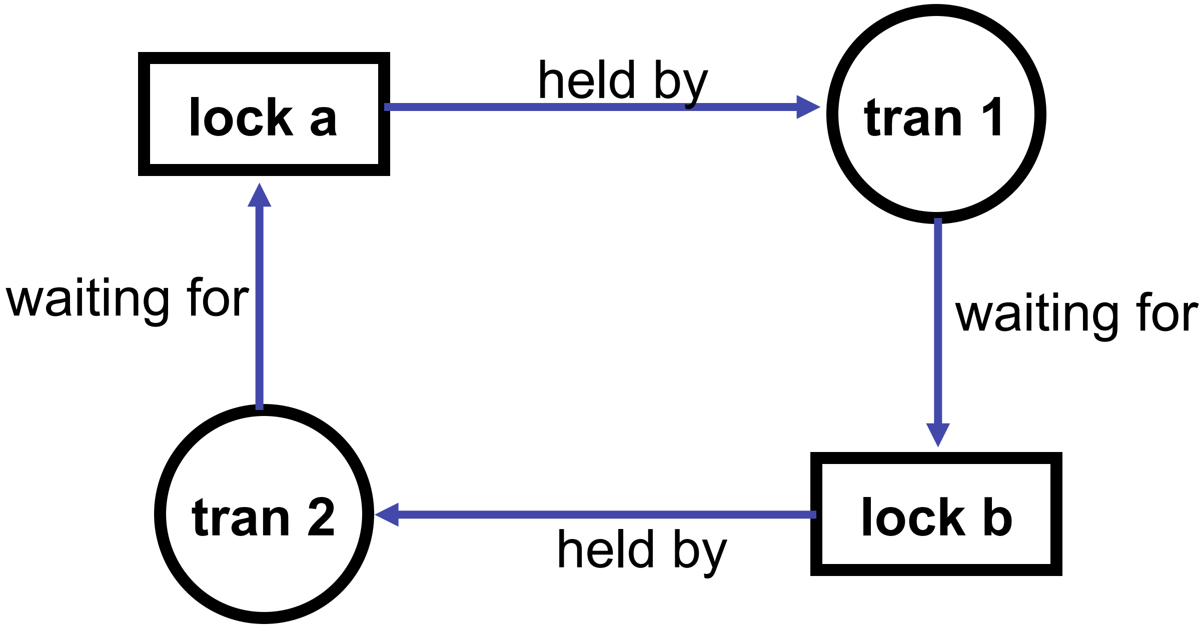


Deadlock

- 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

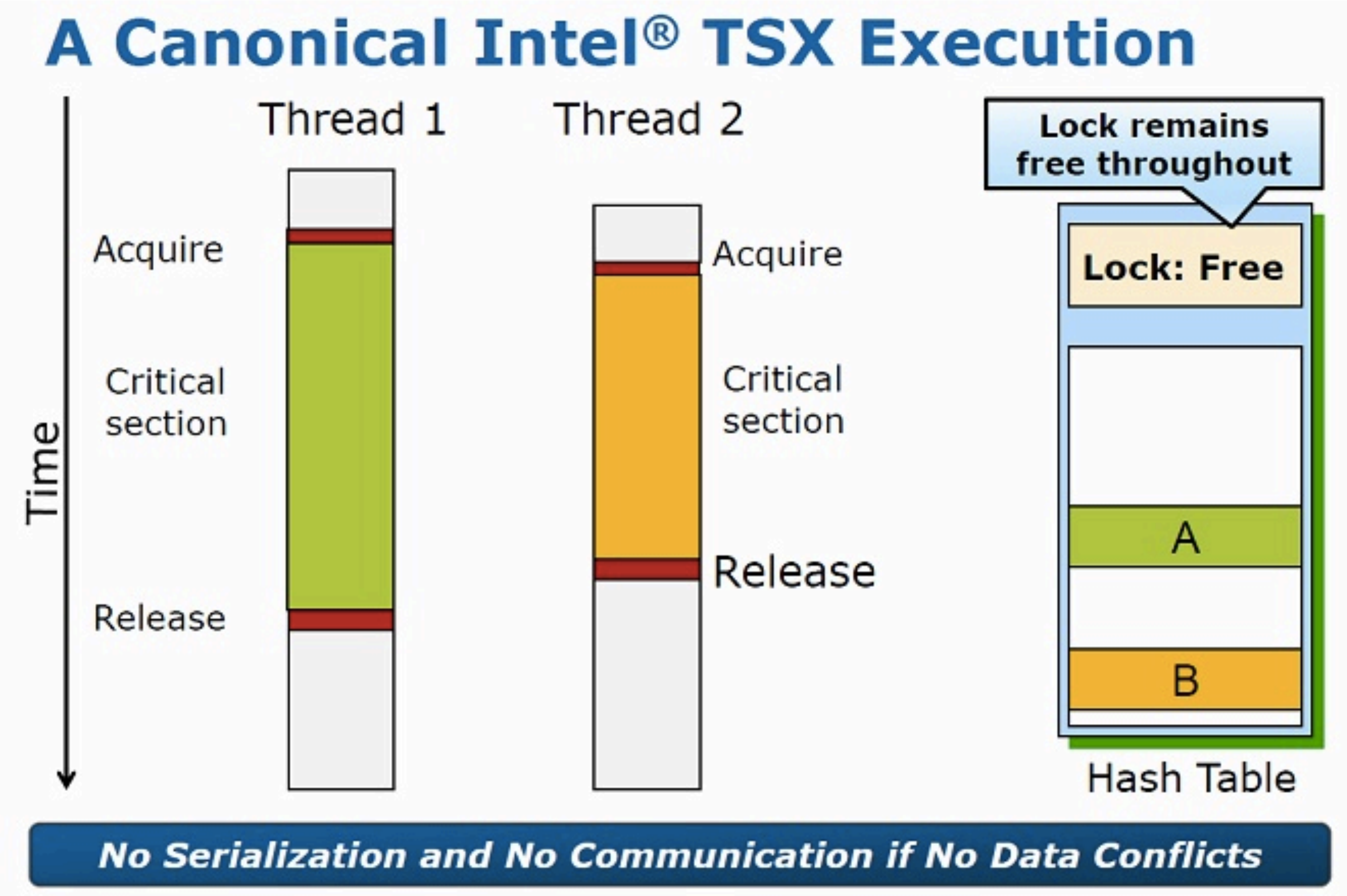


Optimistic concurrency control

- 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

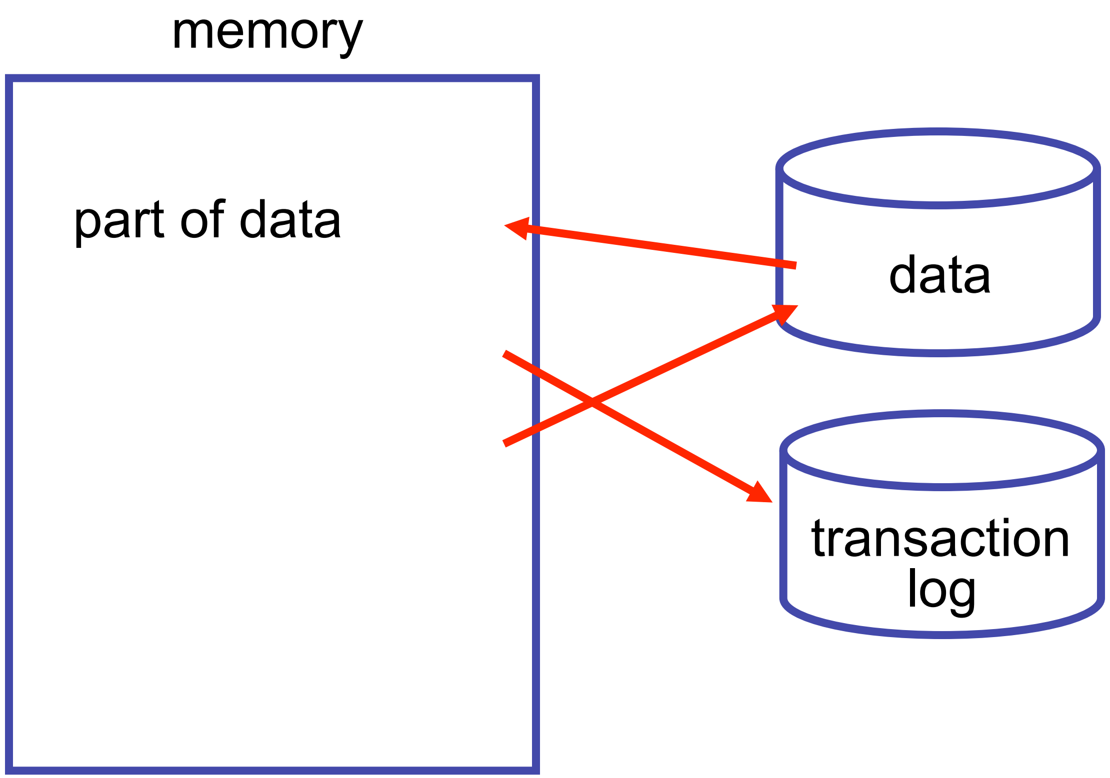
Logging

- **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

Normal operation

1

- 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

Redo logging - roll forward
Recovery

- When the system restarts after a failure
  - use log to roll forward committed transactions
  - normal access stopped until recovery is completed
- Complete committed, but untruncated transaction
  - for every trans with a *commit* but no *truncate*
  - read new values from log and update disk values
  - write *truncate* record to log
- Abort all uncommitted transactions
  - for every transaction with no *commit* or *abort*
    - write *abort* record to log

Redo logging - roll forward
Disadvantage

- No disk writes until commit so you have lots of I/O at the end to commit the transaction
- Must integrate cache of data in memory and transaction logging
  - complicates design of both systems
- This lock-in of memory degrades performance
  - particularly if transactions are long running or modify lots of data

Undo logging - roll backward

Normal operation

2

- For each transactional update
  - write old value to log
  - modify data and then write new value to disk any time
- Commit
  - ensure that all updates have been written to disk
    - i.e., “force” or ‘flush’ updates to disk
  - write commit record to log
- Abort
  - use log to recover disk to old values

Log what you need to undo

Undo logging - roll backward
Recovery

- When the system restarts after a failure
  - use log to rollback uncommitted transactions
  - normal access stopped until recovery completed
- Undo effect with many uncommitted transactions
  - For every trans with no *commit* or *abort*
    - use log to recover disk to old values
    - write *abort* record to log

Undo logging - roll backward
Log records

- Begin
  * log += [b, tid]
- Update
  * log += [u, tid, addr, size, oldValue], update disk anytime
- Commit
  * complete disk update, log += [c, tid]
- Abort and Recovery
  * reapply old values for trans with <u>b</u> but no <u>c</u> or <u>a</u>,
    log += [a, tid]

Undo logging - roll backward
Disadvantage

- Must modify disk data before commit can be written to log
- Performance impact
  - slows commit (can't commit until all data is modified)
    - transactions hold locks longer
    - higher chance of conflicts

Write-ahead logging

- Idea
  * combine undo and redo logging
- How
  * write old values to log
  * modify data
  * write new values to log anytime before commit
  * write commit record to log
  * write data back to disk at anytime, when done write truncate record to log

Failure Recovery

- Commit but no truncate
  - Use roll forward based on new values
- No commit
  - Use old value to roll back

Shrinking the Log File (Truncation)

- Truncation is the process of
  - removing unneeded records from transaction log
- For redo logging
  - remove transactions with t or a
- For undo logging
  - remove transactions with c or a

Transactions summary

- Key properties
  * ACID
- Serializability and Independence
  * two phase locking
    - serializability
  * strict two phase locking
    - Serializability and Independence
- Recovery
  * redo and/or undo logging