Concurrency Control Techniques

Introduction

- Concurrency control protocols
  - Set of rules to guarantee serializability
- Two-phase locking protocols
  - Lock data items to prevent concurrent access
- Timestamp
  - Unique identifier for each transaction
- Multiversion currency control protocols
  - Use multiple versions of a data item
- Validation or certification of a transaction

21.1 Two-Phase Locking Techniques for Concurrency Control

- Lock
  - Variable associated with a data item describing status for operations that can be applied
  - One lock for each item in the database
- Binary locks
  - Two states (values)
    - Locked (1)
      - Item cannot be accessed
    - Unlocked (0)
      - Item can be accessed when requested

Two-Phase Locking Techniques for Concurrency Control (cont'd.)

- Transaction requests access by issuing a lock_item(X) operation

Two-Phase Locking Techniques for Concurrency Control (cont'd.)

- At most one transaction can hold the lock on an item at a given time
- Binary locking too restrictive for database items

Two-Phase Locking Techniques for Concurrency Control (cont'd.)

- Shared/exclusive or read/write locks
  - Read operations on the same item are not conflicting
  - Must have exclusive lock to write
  - Three locking operations
    - read_lock(X)
    - write_lock(X)
    - unlock(X)

Two-Phase Locking Techniques for Concurrency Control (cont'd.)

- Lock conversion
  - Transaction that already holds a lock allowed to convert the lock from one state to another
- Upgrading
  - Issue a read_lock operation then a write_lock operation
- Downgrading
  - Issue a read_lock operation after a write_lock operation

Guaranteeing Serializability by Two-Phase Locking

- Two-phase locking protocol
  - All locking operations precede the first unlock operation in the transaction
  - Phases
    - Expanding (growing) phase
      - New locks can be acquired but none can be released
      - Lock conversion upgrades must be done during this phase
    - Shrinking phase
      - Existing locks can be released but none can be acquired
      - Downgrades must be done during this phase

Figure 21.3 Transactions that do not obey two-phase locking (a) Two transactions *T*1 and *T*2 (b) Results of possible serial schedules of *T*1 and *T*2 (c) A nonserializable schedule *S* that uses locks

(a)

T_1	T_2

read_lock(Y);
read_item(Y);
unlock(Y);
write_lock(X);
read_item(X);
$X := X + Y$;
write_item(X);
unlock(X);
	read_lock(X);
	read_item(X);
	unlock(X);
	write_lock(Y);
	read_item(Y);
	$Y := X + Y$;
	write_item(Y);
	unlock(Y);

(b) Initial values: X=20, Y=30

Result serial schedule T_1 followed by T_2: X=50, Y=80

Result of serial schedule T_2 followed by T_1: X=70, Y=50

(c)

Time

T_1	T_2

read_lock(Y);
read_item(Y);
unlock(Y);	

	read_lock(X);
	read_item(X);
	unlock(X);
	write_lock(Y);
	read_item(Y);
	$Y := X + Y$;
	write_item(Y);
	unlock(Y);

write_lock(X);
read_item(X);
$X := X + Y$;
write_item(X);
unlock(X);	

Guaranteeing Serializability by Two-Phase Locking

- If every transaction in a schedule follows the two-phase locking protocol, schedule guaranteed to be serializable
- Two-phase locking may limit the amount of concurrency that can occur in a schedule
- Some serializable schedules will be prohibited by two-phase locking protocol

Variations of Two-Phase Locking

- Basic 2PL
  - Technique described on previous slides
- Conservative (static) 2PL
  - Requires a transaction to lock all the items it accesses before the transaction begins
    - Predeclare read-set and write-set
  - Deadlock-free protocol
- Strict 2PL
  - Transaction does not release exclusive locks until after it commits or aborts

Variations of Two-Phase Locking (cont'd.)

- Rigorous 2PL
  - Transaction does not release any locks until after it commits or aborts
- Concurrency control subsystem responsible for generating read_lock and write_lock requests
- Locking generally considered to have high overhead

Dealing with Deadlock and Starvation

- Deadlock
  - Occurs when each transaction T in a set is waiting for some item locked by some other transaction *T'*
  - Both transactions stuck in a waiting queue

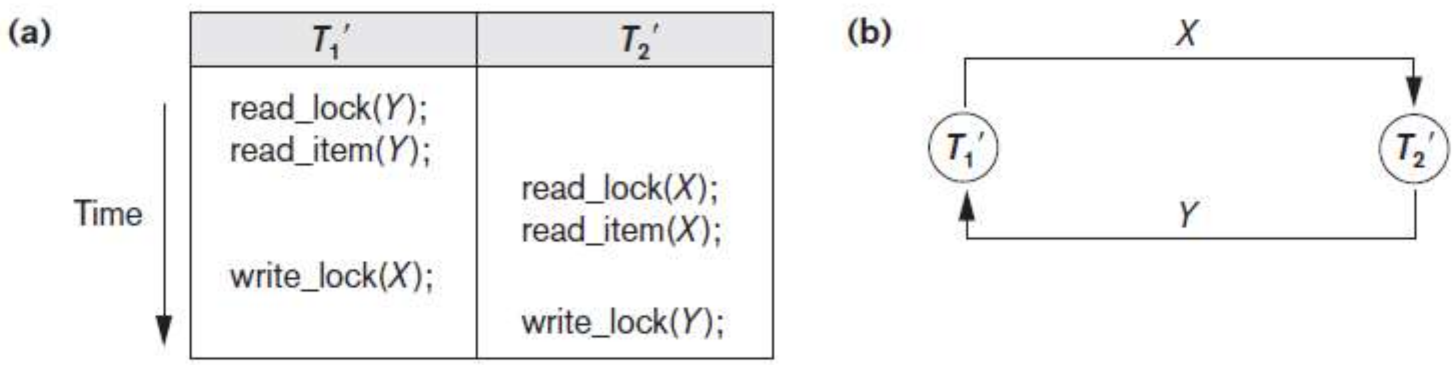

Figure 21.5 Illustrating the deadlock problem (a) A partial schedule of *T*1′ and *T*2′ that is in a state of deadlock (b) A wait-for graph for the partial schedule in (a)

Dealing with Deadlock and Starvation (cont'd.)

- Deadlock prevention protocols
  - Every transaction locks all items it needs in advance
  - Ordering all items in the database
    - Transaction that needs several items will lock them in that order
  - Both approaches impractical
- Protocols based on a timestamp
  - Wait-die
  - Wound-wait

Dealing with Deadlock and Starvation (cont'd.)

- No waiting algorithm
  - If transaction unable to obtain a lock, immediately aborted and restarted later
- Cautious waiting algorithm
  - Deadlock-free
- Deadlock detection
  - System checks to see if a state of deadlock exists
  - Wait-for graph

Dealing with Deadlock and Starvation (cont'd.)

- Victim selection
  - Deciding which transaction to abort in case of deadlock
- Timeouts
  - If system waits longer than a predefined time, it aborts the transaction
- Starvation
  - Occurs if a transaction cannot proceed for an indefinite period of time while other transactions continue normally
  - Solution: first-come-first-served queue

21.2 Concurrency Control Based on Timestamp Ordering

- Timestamp
  - Unique identifier assigned by the DBMS to identify a transaction
  - Assigned in the order submitted
  - Transaction start time
- Concurrency control techniques based on timestamps do not use locks
  - Deadlocks cannot occur

Concurrency Control Based on Timestamp Ordering (cont'd.)

- Generating timestamps
  - Counter incremented each time its value is assigned to a transaction
  - Current date/time value of the system clock
    - Ensure no two timestamps are generated during the same tick of the clock
- General approach
  - Enforce equivalent serial order on the transactions based on their timestamps

Concurrency Control Based on Timestamp Ordering (cont'd.)

- Timestamp ordering (TO)
  - Allows interleaving of transaction operations
  - Must ensure timestamp order is followed for each pair of conflicting operations
- Each database item assigned two timestamp values
  - read_TS(X)
  - write_TS(X)

Concurrency Control Based on Timestamp Ordering (cont'd.)

- Basic TO algorithm
  - If conflicting operations detected, later operation rejected by aborting transaction that issued it
  - Schedules produced guaranteed to be conflict serializable
  - Starvation may occur
- Strict TO algorithm
  - Ensures schedules are both strict and conflict serializable