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Reference:
Elmasri, R., Shamkant B. Navathe, R.
*Fundamentals of Database Systems*

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# Concurrency Control Techniques

- One important set of protocols—known as *two-phase locking protocols*— employ the technique of **locking** data items to prevent multiple transactions from accessing the items concurrently
- Locking protocols are used in most commercial DBMSs.
- Another set of concurrency control protocols use **timestamps**.
- A timestamp is a unique identifier for each transaction, generated by the system. Timestamps values are generated in the same order as the transaction start times.
- **Multiversion** concurrency control protocols use multiple versions of a data item.

# Concurrency Control Techniques

- One multiversion protocol extends timestamp order to multiversion timestamp ordering, and another extends two-phase locking

- **optimistic protocols** are based on the concept of **validation** or **certification** of a transaction after it executes its operations

- Another factor that affects concurrency control is the **granularity** of the data items—that is, what portion of the database a data item represents.

- An item can be as small as a single attribute (field) value or as large as a disk block, or even a whole file or the entire database.

# Two-Phase Locking Techniques for Concurrency Control

- A **lock** is a variable associated with a data item that describes the status of the item with respect to possible operations that can be applied to it.
- Generally, there is one lock for each data item in the database.
- Locks are used as a means of synchronizing the access by concurrent transactions to the database items.

# 22.1.1 Types of Locks and System Lock Tables

**Binary Locks.** A **binary lock** can have two **states** or **values:** locked and unlocked (or 1 and 0, for simplicity).

A distinct lock is associated with each database item *X*.

If the value of the lock on *X* is 1, item *X cannot be accessed* by a database operation that requests the item.

If the value of the lock on *X* is 0, the item can be accessed when requested, and the lock value is changed to 1.

We refer to the current value (or state) of the lock associated with item *X* as **lock**(***X***).

# 22.1.1 Types of Locks and System Lock Tables

Two operations, lock_item and unlock_item, are used with binary locking.

A transaction requests access to an item *X* by first issuing a **lock_item(*X*)** operation. If LOCK(*X*) = 1, the transaction is forced to wait.

If LOCK(*X*) = 0, it is set to 1 (the transaction **locks** the item) and the transaction is allowed to access item *X*.

When the transaction is through using the item, it issues an **unlock_item(*X*)** operation, which sets LOCK(*X*) back to 0 (**unlocks** the item) so that *X* may be accessed by other transactions.

# 22.1.1 Types of Locks and System Lock Tables

A binary lock enforces **mutual exclusion** on the data item.

A description of the lock_item(*X*) and unlock_item(*X*) operations is shown in Figure 22.1.

```
lock_item(X):
B:   if LOCK(X) = 0                        (* item is unlocked *)
          then LOCK(X) ← 1                 (* lock the item *)
     else
          begin
          wait (until LOCK(X) = 0
               and the lock manager wakes up the transaction);
          go to B
          end;
unlock_item(X):
     LOCK(X) ← 0;                          (* unlock the item *)
     if any transactions are waiting
          then wakeup one of the waiting transactions;
```

**Figure 22.1** Lock and unlock operations for binary locks.

# 22.1.1 Types of Locks and System Lock Tables

- Lock_item and unlock_item operations must be implemented as indivisible units (known as **critical sections** in operating systems); that is, no interleaving should be allowed once a lock or unlock operation is started until the operation terminates or the transaction waits.
- The wait command within the lock_item(*X*) operation is usually implemented by putting the transaction in a waiting queue for item *X* until *X* is unlocked and the transaction can be granted access to it.
- Other transactions that also want to access *X* are placed in the same queue.
- Hence, the wait command is considered to be outside the lock_item operation.

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# 22.1.1 Types of Locks and System Lock Tables

- In its simplest form, each lock can be a record with three fields: <Data_item_name, LOCK, Locking_transaction> plus a queue for transactions that are waiting to access the item.

- The system needs to maintain *only these records for the items that are currently locked* in a **lock table**, which could be organized as a hash file on the item name. Items not in the lock table are considered to be unlocked.

- The DBMS has a **lock manager subsystem** to keep track of and control access to locks.

# 22.1.1 Types of Locks and System Lock Tables

If the simple binary locking scheme is used, every transaction must obey the following rules:

- **1.** A transaction *T* must issue the operation lock_item(*X*) before any read_item(*X*) or write_item(*X*) operations are performed in *T.*
- **2.** A transaction *T* must issue the operation unlock_item(*X*) after all read_item(*X*) and write_item(*X*) operations are completed in *T.*
- **3.** A transaction *T* will not issue a lock_item(*X*) operation if it already holds the lock on item *X*.
- **4.** A transaction *T* will not issue an unlock_item(*X*) operation unless it already holds the lock on item *X*.

# 22.1.1 Types of Locks and System Lock Tables

- These rules can be enforced by the lock manager module of the DBMS.
- Between the lock_item(*X*) and unlock_item(*X*) operations in transaction *T*, *T* is said to **hold the lock** on item *X*.
- At most one transaction can hold the lock on a particular item.
- Thus no two transactions can access the same item concurrently.

# 22.1.1 Types of Locks and System Lock Tables

**Shared/Exclusive (or Read/Write) Locks.**

- The preceding binary locking scheme is too restrictive for database items because at most, one transaction can hold a lock on a given item.
- We should allow several transactions to access the same item *X* if they all access *X* for *reading purposes only*.
- This is because read operations on the same item by different transactions are not conflicting.
- However, if a transaction is to write an item *X*, it must have exclusive access to *X*.
- For this purpose, a different type of lock called a **multiple-mode lock** is used.

# 22.1.1 Types of Locks and System Lock Tables

- In this scheme—called **shared/exclusive** or **read/write** locks—there are three locking operations: read_lock(*X*), write_lock(*X*), and unlock(*X*).

- A lock associated with an item *X*, LOCK(*X*), now has three possible states: *read-locked*, *write-locked*, or *unlocked*.

- A **read-locked item** is also called **share-locked** because other transactions are allowed to read the item, whereas a **write-locked item** is called **exclusive-locked** because a single transaction exclusively holds the lock on the item.

- One method for implementing the preceding operations on a read/write lock is to keep track of the number of transactions that hold a shared (read) lock on an item in the lock table. Each record in the lock table will have four fields: <Data_item_name, LOCK, No_of_reads, Locking_transaction(s)>.

# 22.1.1 Types of Locks and System Lock Tables

- Again, to save space, the system needs to maintain lock records only for locked items in the lock.
- The value (state) of LOCK is either read-locked or, suitably coded (if we assume no records are kept in the lock table for unlocked items).
- If LOCK(*X*)=write-locked, the value of locking_transaction(s) is a single transaction that holds the exclusive (write) lock on *X*.
- If LOCK(*X*)=read-locked, the value of locking transaction(s) is a list of one or more transactions that hold the shared (read) lock on *X*.
- The three operations read_lock(*X*), write_lock(*X*), and unlock(*X*) are described in Figure 22.2.2

# 22.1.1 Types of Locks and System Lock Tables

```
read_lock(X):
B:  if LOCK(X) = "unlocked"
        then begin LOCK(X) ← "read-locked";
                no_of_reads(X) ← 1
                end
    else if LOCK(X) = "read-locked"
        then no_of_reads(X) ← no_of_reads(X) + 1
    else begin
            wait (until LOCK(X) = "unlocked"
                and the lock manager wakes up the transaction);
            go to B
            end;
write_lock(X):
B:  if LOCK(X) = "unlocked"
        then LOCK(X) ← "write-locked"
    else begin
            wait (until LOCK(X) = "unlocked"
                and the lock manager wakes up the transaction);
            go to B
            end;
unlock (X):
    if LOCK(X) = "write-locked"
        then begin LOCK(X) ← "unlocked";
                wakeup one of the waiting transactions, if any
                end
    else it LOCK(X) = "read-locked"
        then begin
                no_of_reads(X) ← no_of_reads(X) −1 ;
                if no_of_reads(X) = 0
                    then begin LOCK(X) = "unlocked";
                            wakeup one of the waiting transactions, if any
                            end
                end;
```

**Figure 22.2**
Locking and unlocking operations for two mode (read-write or shared-exclusive) locks.

# 22.1.1 Types of Locks and System Lock Tables

When we use the shared/exclusive locking scheme, the system must enforce the following rules:

1. A transaction *T* must issue the operation read_lock(*X*) or write_lock(*X*) before any read_item(*X*) operation is performed in *T.*
2. A transaction *T* must issue the operation write_lock(*X*) before any write_item(*X*) operation is performed in *T.*
3. A transaction *T* must issue the operation unlock(*X*) after all read_item(*X*) and write_item(*X*) operations are completed in *T.*
4. A transaction *T* will not issue a read_lock(*X*) operation if it already holds a read lock or a write lock on item *X*.
5. A transaction *T* will not issue a write_lock(*X*) operation if it already holds a read lock or write lock on item *X*.
6. A transaction *T* will not issue an unlock(*X*) operation unless it already holds a read (shared) lock or a write (exclusive) lock on item *X*.

# 22.1.1 Types of Locks and System Lock Tables

- **Conversion of Locks.** Sometimes it is desirable to relax conditions 4 and 5 in the preceding list in order to allow **lock conversion**; that is, a transaction that already holds a lock on item *X* is allowed under certain conditions to **convert** the lock from one locked state to another.

- For example, it is possible for a transaction *T* to issue a read_lock(*X*) and then later to **upgrade** the lock by issuing a write_lock(*X*) operation.

- If *T* is the only transaction holding a read lock on *X* at the time it issues the write_lock(*X*) operation, the lock can be upgraded; otherwise, the transaction must wait.

- It is also possible for a transaction T to issue a write_lock(X) and then later to downgrade the lock by issuing a read_lock(X) operation.

- When upgrading and downgrading of locks is used, the lock table must include transaction identifiers in the record structure for each lock (in the locking_transaction(s) field) to store the information on which transactions hold locks on the item.

# 22.1.1 Types of Locks and System Lock Tables

- Using binary locks or read/write locks in transactions, does not guarantee serializability of schedules on its own. Figure 22.3 shows an example where the preceding locking rules are followed but a nonserializable schedule may result.

- This is because in Figure 22.3(a) the items *Y* in *T*1 and *X* in *T*2 were unlocked too early.

- This allows a schedule such as the one shown in Figure 22.3(c) to occur, which is not a serializable schedule and hence gives incorrect results.

- To guarantee serializability, we must follow *an additional protocol* concerning the positioning of locking and unlocking operations in every transaction.

## 22.1.1 Types of Locks and System Lock Tables

(a)

| $T_1$ | $T_2$ |
|---|---|
| read_lock($Y$);<br>read_item($Y$);<br>unlock($Y$);<br>write_lock($X$);<br>read_item($X$);<br>$X := X + Y$;<br>write_item($X$);<br>unlock($X$); | read_lock($X$);<br>read_item($X$);<br>unlock($X$);<br>write_lock($Y$);<br>read_item($Y$);<br>$Y := X + Y$;<br>write_item($Y$);<br>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

**Figure 22.3** 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.

# 22.1.1 Types of Locks and System Lock Tables

(c)

| $T_1$ | $T_2$ |
|---|---|
| read_lock($Y$);<br>read_item($Y$);<br>unlock($Y$); | |
| | read_lock($X$);<br>read_item($X$);<br>unlock($X$);<br>write_lock($Y$);<br>read_item($Y$);<br>$Y := X + Y$;<br>write_item($Y$);<br>unlock($Y$); |
| write_lock($X$);<br>read_item($X$);<br>$X := X + Y$;<br>write_item($X$);<br>unlock($X$); | |

Time

Result of schedule $S$:
$X$=50, $Y$=50
(nonserializable)

(c) A nonserializable schedule $S$ that uses locks.

# 22.1.2 Guaranteeing Serializability by Two-Phase Locking

- A transaction is said to follow the **two-phase locking protocol** if *all* locking operations (read_lock, write_lock) precede the *first* unlock operation in the transaction.

- Such a transaction can be divided into two phases: an **expanding** or **growing (first) phase**, during which new locks on items can be acquired but none can be released; and a **shrinking (second) phase**, during which existing locks can be released but no new locks can be acquired.

- If lock conversion is allowed, then upgrading of locks (from read-locked to write-locked) must be done during the expanding phase, and downgrading of locks (from write-locked to read-locked) must be done in the shrinking phase. Hence, a read_lock(*X*) operation that downgrades an already held write lock on *X* can appear only in the shrinking phase.

# 22.1.2 Guaranteeing Serializability by Two-Phase Locking

- Transactions *T*1 and *T*2 in Figure 22.3(a) do not follow the two-phase locking protocol because the write_lock(*X*) operation follows the unlock(*Y*) operation in *T*1, and similarly the write_lock(*Y*) operation follows the unlock(*X*) operation in *T*2.

- If we enforce two-phase locking, the transactions can be rewritten as *T*1' and *T*2', as shown in Figure 22.4.

**(a)**

| $T_1$ | $T_2$ |
|---|---|
| read_lock(*Y*);<br>read_item(*Y*);<br>unlock(*Y*);<br>write_lock(*X*);<br>read_item(*X*);<br>$X := X + Y$;<br>write_item(*X*);<br>unlock(*X*); | read_lock(*X*);<br>read_item(*X*);<br>unlock(*X*);<br>write_lock(*Y*);<br>read_item(*Y*);<br>$Y := X + Y$;<br>write_item(*Y*);<br>unlock(*Y*); |

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# 22.1.2 Guaranteeing Serializability by Two-Phase Locking

Now, the schedule shown in Figure 22.3(c) is not permitted for *T*1’ and *T*2’ under the rules of locking because *T*1’ will issue its write_lock(*X*) *before* it unlocks item *Y*; consequently, when *T*2’ issues its read_lock(*X*), it is forced to wait until *T*1’ releases the lock by issuing an unlock (*X*) in the schedule.

| $T_1{}'$ | $T_2{}'$ |
|---|---|
| read_lock($Y$); | read_lock($X$); |
| read_item($Y$); | read_item($X$); |
| write_lock($X$); | write_lock($Y$); |
| unlock($Y$) | unlock($X$) |
| read_item($X$); | read_item($Y$); |
| $X := X + Y$; | $Y := X + Y$; |
| write_item($X$); | write_item($Y$); |
| unlock($X$); | unlock($Y$); |

**Figure 22.4**
Transactions $T_1{}'$ and $T_2{}'$, which are the same as $T_1$ and $T_2$ in Figure 22.3, but follow the two-phase locking protocol. Note that they can produce a deadlock.

## 22.1.2 Guaranteeing Serializability by Two-Phase Locking

- Two-phase locking may limit the amount of concurrency that can occur in a schedule because a transaction T may not be able to release an item X after it is through using it if T must lock an additional item Y later; or conversely, T must lock the additional item Y before it needs it so that it can release X.

- Hence, X must remain locked by T until all items that the transaction needs to read or write have been locked; only then can X be released by T. Meanwhile, another transaction seeking to access X may be forced to wait, even though T is done with X.

- Conversely, if Y is locked earlier than it is needed, another transaction seeking to access Y is forced to wait even though T is not using Y yet.

# Basic, Conservative, Strict, and Rigorous Two-Phase Locking

- There are a number of variations of two-phase locking (2PL). The technique just described is known as **basic 2PL**.

- A variation known as **conservative 2PL** (or **static 2PL**) requires a transaction to lock all the items it accesses *before the transaction begins execution*, by **predeclaring** its *read-set* and *write-set*.

- The **read-set** of a transaction is the set of all items that the transaction reads, and the **write-set** is the set of all items that it writes.

- If any of the predeclared items needed cannot be locked, the transaction does not lock any item; instead, it waits until all the items are available for locking.

- Conservative 2PL is a deadlock-free protocol. However, it is difficult to use in practice because of the need to predeclare the read-set and writeset, which is not possible in many situations.

# Basic, Conservative, Strict, and Rigorous Two-Phase Locking

- In practice, the most popular variation of 2PL is **strict 2PL**, which guarantees strict schedules.

- In this variation, a transaction *T* does not release any of its exclusive (write) locks until *after* it commits or aborts.

- Hence, no other transaction can read or write an item that is written by *T* unless *T* has committed, leading to a strict schedule for recoverability.

- Strict 2PL is not deadlock-free.

# Basic, Conservative, Strict, and Rigorous Two-Phase Locking

- A more restrictive variation of strict 2PL is **rigorous 2PL**, which also guarantees strict schedules.

- In this variation, a transaction *T* does not release any of its locks (exclusive or shared) until after it commits or aborts, and so it is easier to implement than strict 2PL.

- Notice the difference between conservative and rigorous 2PL: the former must lock all its items *before it starts*, so once the transaction starts it is in its shrinking phase; the latter does not unlock any of its items until *after it terminates* (by committing or aborting), so the transaction is in its expanding phase until it ends.

## 22.1.3 Dealing with Deadlock and Starvation

**Deadlock** occurs when *each* transaction *T* in a set of *two or more transactions* is waiting for some item that is locked by some other transaction *T'* in the set.

Hence, each transaction in the set is in a waiting queue, waiting for one of the other transactions in the set to release the lock on an item.

But because the other transaction is also waiting, it will never release the lock.

A simple example is shown in Figure 22.5(a), where the two transactions *T*1' and *T*2' are deadlocked in a partial schedule; *T*1' is in the waiting queue for *X*, which is locked by *T*2', while *T*2' is in the waiting queue for *Y*, which is locked by *T*1'.

Meanwhile, neither *T*1' nor *T*2' nor any other transaction can access items *X* and *Y*.

# 22.1.3 Dealing with Deadlock and Starvation

(a)

Time

| $T_1'$ | $T_2'$ |
|---|---|
| read_lock($Y$); | |
| read_item($Y$); | |
| | read_lock($X$); |
| | read_item($X$); |
| write_lock($X$); | |
| | write_lock($Y$); |

**Figure 22.5**
Illustrating the deadlock problem. (a) A partial schedule of $T_1'$ and $T_2'$ that is in a state of deadlock.

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# 22.1.3 Dealing with Deadlock and Starvation

**Deadlock Prevention Protocols.**

- One way to prevent deadlock is to use a **deadlock prevention protocol**.
- One deadlock prevention protocol, which is used in conservative two-phase locking, requires that every transaction lock *all the items it needs in advance* (which is generally not a practical assumption)—if any of the items cannot be obtained, none of the items are locked.
- Rather, the transaction waits and then tries again to lock all the items it needs. Obviously this solution further limits concurrency.
- A second protocol, which also limits concurrency, involves *ordering all the items* in the database and making sure that a transaction that needs several items will lock them according to that order.

# 22.1.3 Dealing with Deadlock and Starvation

- This requires that the programmer (or the system) is aware of the chosen order of the items, which is also not practical in the database context.

- Some of these techniques use the concept of **transaction timestamp** TS(*T*), which is a unique identifier assigned to each transaction.

- The timestamps are typically based on the order in which transactions are started; hence, if transaction *T*1 starts before transaction *T*2, then TS(*T*1) < TS(*T*2).

- Notice that the *older* transaction (which starts first) has the *smaller* timestamp value. Two schemes that prevent deadlock are called *wait-die* and *woundwait*.

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# 22.1.3 Dealing with Deadlock and Starvation

Suppose that transaction *Ti* tries to lock an item *X* but is not able to because *X* is locked by some other transaction *Tj* with a conflicting lock. The rules followed by these schemes are:

- **Wait-die.** If TS(*Ti*) < TS(*Tj*), then (*Ti* older than *Tj*) *Ti* is allowed to wait; otherwise (*Ti* younger than *Tj*) abort *Ti* (*Ti dies*) and restart it later *with the same timestamp.*

- **Wound-wait.** If TS(*Ti*) < TS(*Tj*), then (*Ti* older than *Tj*) abort *Tj* (*Ti wounds Tj*) and restart it later *with the same timestamp;* otherwise (*Ti* younger than *Tj*) *Ti* is allowed to wait.

# 22.1.3 Dealing with Deadlock and Starvation

In wait-die, an older transaction is allowed to *wait for a younger transaction*, whereas a younger transaction requesting an item held by an older transaction is aborted and restarted.

The wound-wait approach does the opposite: A younger transaction is allowed to *wait for an older one*, whereas an older transaction requesting an item held by a younger transaction *preempts* the younger transaction by aborting it.

Both schemes end up aborting the *younger* of the two transactions (the transaction that started later) that *may be involved* in a deadlock, assuming that this will waste less processing.

# 22.1.3 Dealing with Deadlock and Starvation

- Another group of protocols that prevent deadlock do not require timestamps. These include the no waiting (NW) and cautious waiting (CW) algorithms.
- In the **no waiting algorithm**, if a transaction is unable to obtain a lock, it is immediately aborted and then restarted after a certain time delay without checking whether a deadlock will actually occur or not.
- In this case, no transaction ever waits, so no deadlock will occur. However, this scheme can cause transactions to abort and restart needlessly.

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# 22.1.3 Dealing with Deadlock and Starvation

- The **cautious waiting** algorithm was proposed to try to reduce the number of needless aborts/restarts. Suppose that transaction *Ti* tries to lock an item *X* but is not able to do so because *X* is locked by some other transaction *Tj* with a conflicting lock.
- The cautious waiting rules are as follows:
- ■ **Cautious waiting.** If *Tj* is not blocked (not waiting for some other locked item), then *Ti* is blocked and allowed to wait; otherwise abort *Ti.*

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# 22.1.3 Dealing with Deadlock and Starvation

- A second, more practical approach to dealing with deadlock is **deadlock detection**, where the system checks if a state of deadlock actually exists.

- This solution is attractive if we know there will be little interference among the transactions—that is, if different transactions will rarely access the same items at the same time.

- This can happen if the transactions are short and each transaction locks only a few items, or if the transaction load is light.

- On the other hand, if transactions are long and each transaction uses many items, or if the transaction load is quite heavy, it may be advantageous to use a deadlock prevention scheme.

# 22.1.3 Dealing with Deadlock and Starvation

- A simple way to detect a state of deadlock is for the system to construct and maintain a **wait-for graph**.
- One node is created in the wait-for graph for each transaction that is currently executing.
- Whenever a transaction *Ti* is waiting to lock an item *X* that is currently locked by a transaction *Tj*, a directed edge (*Ti* → *Tj*) is created in the wait-for graph.
- When *Tj* releases the lock(s) on the items that *Ti* was waiting for, the directed edge is dropped from the wait-for graph.

# 22.1.3 Dealing with Deadlock and Starvation

- We have a state of deadlock if and only if the wait-for graph has a cycle.
- One problem with this approach is the matter of determining *when* the system should check for a deadlock.
- One possibility is to check for a cycle every time an edge is added to the wait-for graph, but this may cause excessive overhead.
- Criteria such as the number of currently executing transactions or the period of time several transactions have been waiting to lock items may be used instead to check for a cycle.

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# 22.1.3 Dealing with Deadlock and Starvation

- Figure 22.5(b) shows the wait-for graph for the (partial) schedule shown in Figure 22.5(a).
- If the system is in a state of deadlock, some of the transactions causing the deadlock must be aborted.
- Choosing which transactions to abort is known as **victim selection**.
- The algorithm for victim selection should generally avoid selecting transactions that have been running for a long time and that have performed many updates, and it should try instead to select transactions that have not made many changes (younger transactions).

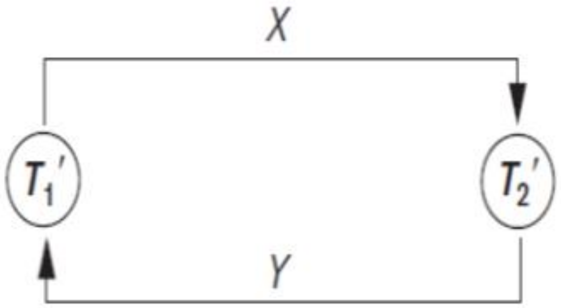
# 22.1.3 Dealing with Deadlock and Starvation

(a)

| $T_1'$ | $T_2'$ |
|---|---|
| read_lock($Y$); | |
| read_item($Y$); | |
| | read_lock($X$); |
| | read_item($X$); |
| write_lock($X$); | |
| | write_lock($Y$); |

Time

(b)




(b) A wait-for graph for the partial schedule in (a).

**Figure 22.5**
Illustrating the deadlock problem. (a) A partial schedule of $T_1'$ and $T_2'$ that is in a state of deadlock.

## 22.1.3 Dealing with Deadlock and Starvation

- **Timeouts.** Another simple scheme to deal with deadlock is the use of **timeouts**.
- This method is practical because of its low overhead and simplicity.
- In this method, if a transaction waits for a period longer than a system-defined timeout period, the system assumes that the transaction may be deadlocked and aborts it—regardless of whether a deadlock actually exists or not.

# 22.1.3 Dealing with Deadlock and Starvation

- **Starvation.** Another problem that may occur when we use locking is **starvation**, which occurs when a transaction cannot proceed for an indefinite period of time while other transactions in the system continue normally.

- This may occur if the waiting scheme for locked items is unfair, giving priority to some transactions over others.

- One solution for starvation is to have a fair waiting scheme, such as using a **first-come-first-served** queue; transactions are enabled to lock an item in the order in which they originally requested the lock.

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# 22.1.3 Dealing with Deadlock and Starvation

- Another scheme allows some transactions to have priority over others but increases the priority of a transaction the longer it waits, until it eventually gets the highest priority and proceeds.
- Starvation can also occur because of victim selection if the algorithm selects the same transaction as victim repeatedly, thus causing it to abort and never finish execution.
- The algorithm can use higher priorities for transactions that have been aborted multiple times to avoid this problem.
- The wait-die and wound-wait schemes discussed previously avoid starvation, because they restart a transaction that has been aborted with its same original timestamp, so the possibility that the same transaction is aborted repeatedly is slim.

# 22.1.3 Dealing with Deadlock and Starvation

**Recovery from Deadlock**

- When a detection algorithm determines that a deadlock exists, the system must recover from the deadlock.
- The most common solution is to roll back one or more transactions to break the deadlock. Three actions need to be taken:

**1. Selection of a victim.**

- Given a set of deadlocked transactions, we must determine which transaction (or transactions) to roll back to break the deadlock.
- We should roll back those transactions that will incur the minimum cost.

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## 22.1.3 Dealing with Deadlock and Starvation

Many factors may determine the cost of a rollback, including:

a. How long the transaction has computed, and how much longer the transaction will compute before it completes its designated task.

b. How many data items the transaction has used.

c. How many more data items the transaction needs for it to complete.

d. How many transactions will be involved in the rollback.

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# 22.1.3 Dealing with Deadlock and Starvation

**2. Rollback.**

- Once we have decided that a particular transaction must be rolled back, we must determine how far this transaction should be rolled back.
- The simplest solution is a total rollback: Abort the transaction and then restart it.
- However, it is more effective to roll back the transaction only as far as necessary to break the deadlock.
- Such partial rollback requires the system to maintain additional information about the state of all the running transactions.
- Specifically, the sequence of lock requests/grants and updates performed by the transaction needs to be recorded.

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# 22.1.3 Dealing with Deadlock and Starvation

- The deadlock detection mechanism should decide which locks the selected transaction needs to release in order to break the deadlock.
- The selected transaction must be rolled back to the point where it obtained the first of these locks, undoing all actions it took after that point.
- The recovery mechanism must be capable of performing such partial rollbacks.
- Furthermore, the transactions must be capable of resuming execution after a partial rollback.

# 22.1.3 Dealing with Deadlock and Starvation

**3. Starvation.**

- In a system where the selection of victims is based primarily on cost factors, it may happen that the same transaction is always picked as a victim.
- As a result, this transaction never completes its designated task, thus there is starvation.
- We must ensure that a transaction can be picked as a victim only a (small) finite number of times.
- The most common solution is to include the number of rollbacks in the cost factor.

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# END