Chapter 10

Transaction Management and Concurrency Control

Database Systems:
Design, Implementation, and Management,
Ninth Edition, Coronel, Morris & Rob

In this chapter, you will learn:

- What a database transaction is and what its properties are
- What concurrency control is and what role it plays in maintaining the database's integrity
- What locking methods are and how they work
- How stamping methods are used for concurrency control

In this chapter, you will learn (continued):

- How optimistic methods are used for concurrency control
- How database recovery management is used to maintain database integrity

Recall:

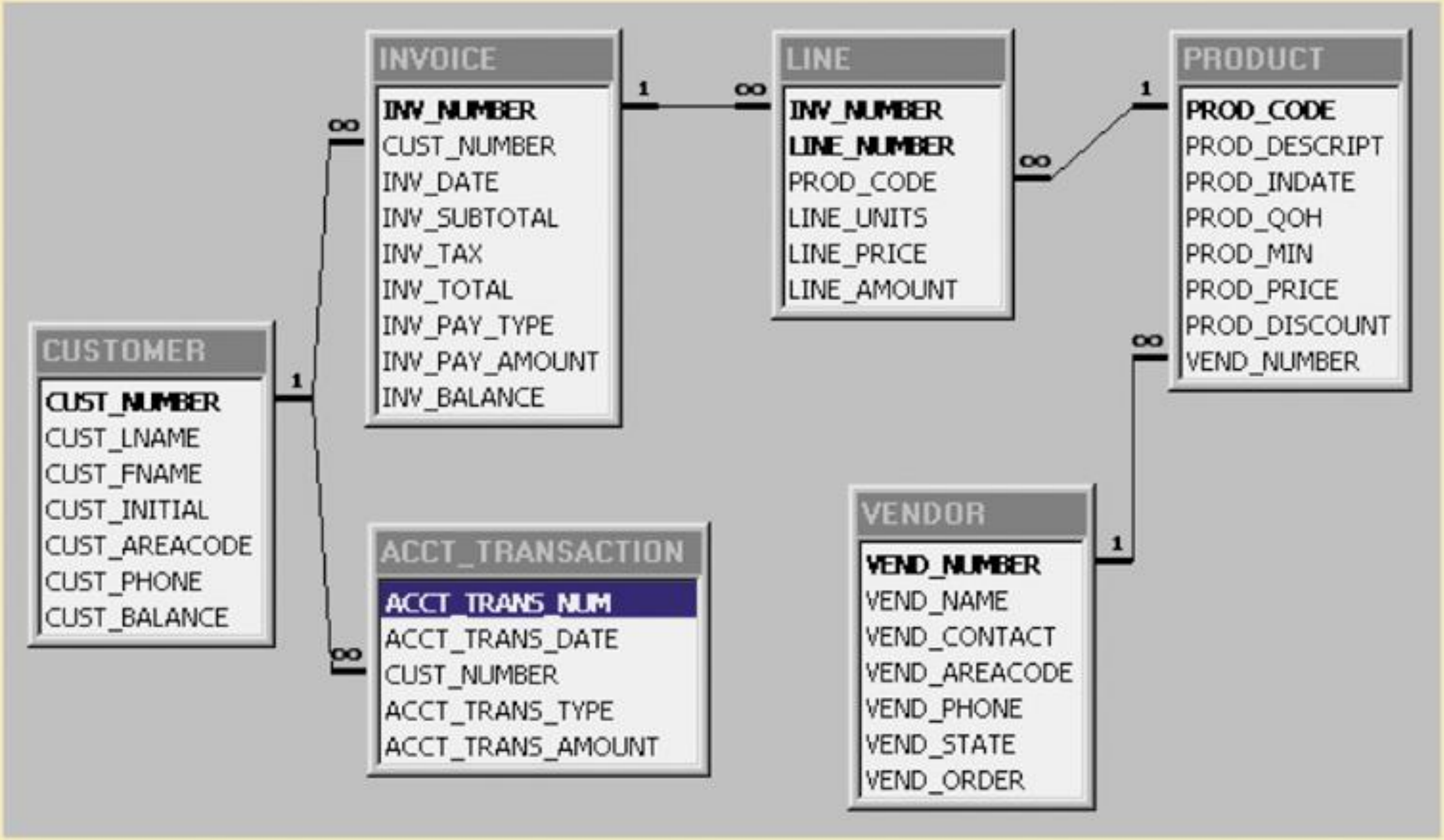
- **Database integrity** ensures
that data entered into the database is accurate, valid, and consistent.
- Any applicable integrity constraints and data validation rules must be satisfied before permitting a change to the database.

3 basic types of database integrity constraints

1. Entity integrity, not allowing multiple rows to have the same identity within a table.
2. Domain integrity, restricting data to predefined data types, e.g.: dates.
3. Referential integrity, requiring the existence of a related row in another table, e.g. a customer for a given customer ID.

What is a Transaction?

FIGURE 10.1 The Ch10_SaleCo database relational diagram



Consider this scenario

- suppose that you sell a product to a customer. Furthermore, suppose that the customer may charge the purchase to his or her account. What are the parts of the sales transaction?

Parts of the Sales Transaction

- You must **write a new customer invoice**.
- You must **reduce the quantity on hand in the product's inventory**.
- You must **update the account transactions**.
- You must **update the customer balance**.

What is a Transaction? (continued)

- Any action that reads from and/or writes to a database may consist of:
  - Simple SELECT statement to generate list of table contents
  - Series of related UPDATE statements to change values of attributes in various tables
  - Series of INSERT statements to add rows to one or more tables
  - Combination of SELECT, UPDATE, and INSERT statements

What is a Transaction? (continued)

- Transaction is logical unit of work that must be either entirely completed or aborted
- Successful transaction changes database from one consistent state to another
  - One in which all data integrity constraints are satisfied
- Most real-world database transactions are formed by two or more database requests
  - Equivalent of a single SQL statement in an application program or transaction

Evaluating Transaction Results

- Suppose that you want to determine the current balance for customer number 10016

```
SELECT CUST_NUMBER, CUST_BALANCE
FROM CUSTOMER
WHERE CUST_NUMBER = 10016;
```

- Not all transactions update database

Evaluating Transaction Results

- SQL code represents a transaction because database was accessed
- Improper or incomplete transactions can have devastating effect on database integrity
  - Some DBMSs provide means by which user can define enforceable constraints
  - Other integrity rules are enforced automatically by the DBMS

Evaluating Transaction Results

- Suppose that on January 18, 2010 you register the credit sale of one unit of product 89-WRE-Q to customer 10016 in the amount of $277.55.
- The required transaction affects the INVOICE, LINE, PRODUCT, CUSTOMER, and ACCT_TRANSACTION tables.

Evaluating Transaction Results

```
INSERT INTO INVOICE
VALUES (1009, 10016,'18-Jan-2010', 256.99,
20.56, 277.55, 'cred', 0.00, 277.55);
```

```
INSERT INTO LINE
VALUES (1009, 1, '89-WRE-Q', 1, 256.99,
256.99);
```

Evaluating Transaction Results

```
UPDATE PRODUCT
SET PROD_QOH = PROD_QOH – 1
WHERE PROD_CODE = '89-WRE-Q';
```

```
UPDATE CUSTOMER
SET CUST_BALANCE = CUST_BALANCE +
277.55
WHERE CUST_NUMBER = 10016;
```

Evaluating Transaction Results

```
INSERT INTO ACCT_TRANSACTION
VALUES (10007, '18-Jan-10', 10016, 'charge',
277.55);
```

```
COMMIT;
```

Evaluating Transaction Results (continued)

FIGURE 10.2 Tracing the transaction in the Ch10_SaleCo database

INVOICE : Table

INV_NUMBER	CUST_NUMBER	INV_DATE	INV_SUBTOTAL	INV_TAX	INV_TOTAL	INV_PAY_TYPE	INV_PAY_AMOUNT	INV_BALANCE
1001	10014	16-Jan-06	54.92	4.39	59.31	cc	59.31	0.00
1002	10011	16-Jan-06	9.98	0.80	10.78	cash	10.78	0.00
1003	10012	16-Jan-06	270.70	21.66	292.36	cc	292.36	0.00
1004	10011	17-Jan-06	34.87	2.79	37.66	cc	37.66	0.00
1005	10018	17-Jan-06	70.44	5.64	76.08	cc	76.08	0.00
1006	10014	17-Jan-06	397.83	31.83	429.66	cred	100.00	329.66
1007	10015	17-Jan-06	34.97	2.80	37.77	chk	37.77	0.00
1008	10011	17-Jan-06	1033.08	82.65	1115.73	cred	500.00	615.73
1009	10016	18-Jan-06	256.99	20.56	277.55	cred	0.00	277.55

Record: 1 of 9

LINE : Table

INV_NUMBER	LINE_NUMBER	PROD_CODE	LINE_UNITS	LINE_PRICE	LINE_AMOUNT
1001	1	13-Q2/P2	3	14.99	44.97
1001	2	23109-HB	1	9.95	9.95
1002	1	54778-2T	2	4.99	9.98
1003	1	2238/QPD	4	38.95	155.80
1003	2	1546-QQ2	1	39.95	39.95
1003	3	13-Q2/P2	5	14.99	74.95
1004	1	54778-2T	3	4.99	14.97
1004	2	23109-HB	2	9.95	19.90
1005	1	PVC23DRT	12	5.87	70.44
1006	1	SM-18277	3	6.99	20.97
1006	2	2232/QTY	1	109.92	109.92
1006	3	23109-HB	1	9.95	9.95
1006	4	89-WRE-Q	1	256.99	256.99
1007	1	13-Q2/P2	2	14.99	29.98
1007	2	54778-2T	1	4.99	4.99
1008	1	PVC23DRT	5	5.87	29.35
1008	2	WR3/TT3	4	119.95	479.80
1008	3	23109-HB	1	9.95	9.95
1008	4	89-WRE-Q	2	256.99	513.98
1009	1	89-WRE-Q	1	256.99	256.99

Record: 1 of 20

PRODUCT : Table

PROD_CODE	PROD_DESCRIPT	PROD_INDATE	PROD_QOH	PROD_MIN	PROD_PRICE	PROD_DISCOUNT	VEND_NUMBER
11QER/31	Power painter, 15 psi., 3-nozzle	03-Nov-05	8	5	109.99	0.00	25595
13-Q2/P2	7.25-in. pwr. saw blade	13-Dec-05	32	15	14.99	0.05	21344
14-Q1/L3	9.00-in. pwr. saw blade	13-Nov-05	18	12	17.49	0.00	21344
1546-QQ2	Hrd. cloth, 1/4-in., 2x50	15-Jan-06	15	8	39.95	0.00	23119
1558-QW1	Hrd. cloth, 1/2-in., 3x50	15-Jan-06	23	5	43.99	0.00	23119
2232/QTY	B&D jigsaw, 12-in. blade	30-Dec-05	8	5	109.92	0.05	24288
2232/QWE	B&D jigsaw, 8-in. blade	24-Dec-05	6	5	99.87	0.05	24288
2238/QPD	B&D cordless drill, 1/2-in.	20-Jan-06	12	5	38.95	0.05	25595
23109-HB	Claw hammer	20-Jan-06	23	10	9.95	0.10	21225
23114-AA	Sledge hammer, 12 lb.	02-Jan-06	8	5	14.40	0.05	
54778-2T	Rat-tail file, 1/8-in. fine	15-Dec-05	43	20	4.99	0.00	21344
89-WRE-Q	Hicut chain saw, 16 in.	07-Jan-06	11	5	256.99	0.05	24288
PVC23DRT	PVC pipe, 3.5-in., 8-ft	06-Jan-06	188	75	5.87	0.00	
SM-18277	1.25-in. metal screw, 25	01-Mar-06	172	75	6.99	0.00	21225
SW-23116	2.5-in. wd. screw, 50	24-Feb-06	237	100	8.45	0.00	21231
WR3/TT3	Steel matting, 4'x8'x1/6", .5" mesh	17-Jan-06	18	5	119.95	0.10	25595

Record: 1 of 16

CUSTOMER : Table

CUST_NUMBER	CUST_LNAME	CUST_FNAME	CUST_INITIAL	CUST_AREACODE	CUST_PHONE	CUST_BALANCE
10010	Ramas	Alfred	A	615	844-2573	0.00
10011	Dunne	Leona	K	713	894-1238	615.73
10012	Smith	Kathy	W	615	894-2285	0.00
10013	Olowski	Paul	F	615	894-2180	0.00
10014	Orlando	Myron		615	222-1672	0.00
10015	O'Brian	Amy	B	713	442-3381	0.00
10016	Brown	James	G	615	297-1228	277.55
10017	Williams	George		615	290-2556	0.00
10018	Farriss	Anne	G	713	382-7185	0.00
10019	Smith	Olette	K	615	297-3809	0.00

Record: 1 of 10

ACCT_TRANSACTION : Table

ACCT_TRANS_NUM	ACCT_TRANS_DATE	CUST_NUMBER	ACCT_TRANS_TYPE	ACCT_TRANS_AMOUNT
10003	17-Jan-06	10014	charge	329.66
10004	17-Jan-06	10011	charge	615.73
10006	29-Jan-06	10014	payment	329.66
10007	18-Jan-06	10016	charge	277.55

Record: 1 of 4

- Suppose that the DBMS completes the first three SQL statements.
- Suppose that during the execution of the fourth statement (the UPDATE of the CUSTOMER table's CUST_BALANCE value for customer 10016), the computer system experiences a loss of electrical power.
- If the computer does not have a backup power supply, the transaction cannot be completed.

- Therefore, the INVOICE and LINE rows were added, the PRODUCT table was updated to represent the sale of product 89-WRE-Q, but customer 10016 was not charged, nor was the required record in the ACCT_TRANSACTION table written.
- The database is now in an inconsistent state, and it is not usable for subsequent transactions.

- Assuming that the DBMS supports transaction management, *the DBMS will roll back the database to a previous consistent state*.
- Note: by default, MS Access does not support transaction management as discussed here. More sophisticated DBMSs, such as Oracle, SQL Server, and DB2, do support the transaction management components discussed.

- Although the DBMS is designed to recover a database to a previous consistent state when an interruption prevents the completion of a transaction, the transaction itself is defined by the end user or programmer and must be semantically correct. *The DBMS cannot guarantee that the semantic meaning of the transaction truly represents the real-world event.*

- For example, suppose that following the sale of 10 units of product 89-WRE-Q, the inventory UPDATE commands were written this way:

```
UPDATE PRODUCT
SET PROD_QOH = PROD_QOH + 10
WHERE PROD_CODE = '89-WRE-Q';
```

Transaction Properties

- Atomicity
  - Requires that all operations (SQL requests) of a transaction be completed
- Consistency
  - Indicates the permanence of database's consistent state

Transaction Properties (continued)

- Isolation
  - Data used during execution of a transaction cannot be used by second transaction until first one is completed
- Durability
  - Indicates permanence of database’s consistent state Isolation

Transaction Properties (continued)

- Serializability
  - Ensures that concurrent execution of several transactions yields consistent results

Transaction Management with SQL

- ANSI has defined standards that govern SQL database transactions
- Transaction support is provided by two SQL statements: COMMIT and ROLLBACK

Transaction Management with SQL (continued)

- ANSI standards require that, when a transaction sequence is initiated by a user or an application program, it must continue through all succeeding SQL statements until one of four events occurs
  - COMMIT statement is reached
  - ROLLBACK statement is reached
  - End of program is reached
  - Program is abnormally terminated

Using COMMIT

```
UPDATE PRODUCT
SET PROD_QOH = PROD_QOH – 2
WHERE PROD_CODE = '1558-QW1';
UPDATE CUSTOMER
SET CUST_BALANCE = CUST_BALANCE +
87.98
WHERE CUST_NUMBER = '10011';
COMMIT;
```

The Transaction Log

- Transaction log stores:
  - A record for the beginning of transaction
  - For each transaction component (SQL statement):
    - Type of operation being performed (update, delete, insert)
    - Names of objects affected by transaction
    - "Before" and "after" values for updated fields
    - Pointers to previous and next transaction log entries for the same transaction
  - Ending (COMMIT) of the transaction

The Transaction Log (continued)

TABLE 10.1 A Transaction Log

TRL_ ID	TRX_ NUM	PREV PTR	NEXT PTR	OPERATION	TABLE	ROW ID	ATTRIBUTE	BEFORE VALUE	AFTER VALUE
341	101	Null	352	START	****Start Transaction				
352	101	341	363	UPDATE	PRODUCT	1558-QW1	PROD_ QOH	25	23
363	101	352	365	UPDATE	CUSTOMER	10011	CUST_ BALANCE	525.75	615.73
365	101	363	Null	COMMIT	**** End of Transaction				

TRL_ID = Transaction log record ID
TRX_NUM = Transaction number
(Note: The transaction number is automatically assigned by the DBMS.)
PTR = Pointer to a transaction log record ID

Concurrency Control

- Coordination of simultaneous transaction execution in a multiprocessing database system
- Objective is to ensure serializability of transactions in a multiuser database environment

Concurrency Control (continued)

- Simultaneous execution of transactions over a shared database can create several data integrity and consistency problems
  - Lost updates
  - Uncommitted data
  - Inconsistent retrievals

Lost Updates

TABLE 10.2 Normal Execution of Two Transactions

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	PROD_QOH = 35 + 100	
3	T1	Write PROD_QOH	135
4	T2	Read PROD_QOH	135
5	T2	PROD_QOH = 135 − 30	
6	T2	Write PROD_QOH	105

Lost Updates (continued)

TABLE 10.3 Lost Updates

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T2	Read PROD_QOH	35
3	T1	PROD_QOH = 35 + 100	
4	T2	PROD_QOH = 35 − 30	
5	T1	Write PROD_QOH (**Lost update**)	135
6	T2	Write PROD_QOH	5

Uncommitted Data

TABLE 10.4 Correct Execution of Two Transactions

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	PROD_QOH = 35 + 100	
3	T1	Write PROD_QOH	135
4	T1	*****ROLLBACK *****	35
5	T2	Read PROD_QOH	35
6	T2	PROD_QOH = 35 − 30	
7	T2	Write PROD_QOH	5

Uncommitted Data (continued)

TABLE 10.5 An Uncommitted Data Problem

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Read PROD_QOH	35
2	T1	PROD_QOH = 35 + 100	
3	T1	Write PROD_QOH	135
4	T2	Read PROD_QOH **(Read uncommitted data)**	135
5	T2	PROD_QOH = 135 – 30	
6	T1	***** **ROLLBACK** *****	35
7	T2	Write PROD_QOH	105

Inconsistent Retrievals

TABLE 10.6 **Retrieval During Update**

TRANSACTION T1	TRANSACTION T2
SELECT SUM(PROD_QOH) FROM PRODUCT	UPDATE PRODUCT SET PROD_QOH = PROD_QOH + 10 WHERE PROD_CODE = '1546-QQ2'
	UPDATE PRODUCT SET PROD_QOH = PROD_QOH − 10 WHERE PROD_CODE = '1558-QW1'
	COMMIT;

Inconsistent Retrievals (continued)

TABLE 10.7 Transaction Results: Data Entry Correction

	BEFORE	AFTER
PROD_CODE	PROD_QOH	PROD_QOH
11QER/31	8	8
13-Q2/P2	32	32
1546-QQ2	15	(15 + 10) → 25
1558-QW1	23	(23 − 10) → 13
2232-QTY	8	8
2232-QWE	6	6
Total	92	92

Inconsistent Retrievals (continued)

TABLE 10.8 Inconsistent Retrievals

TIME	TRANSACTION	ACTION	VALUE	TOTAL
1	T1	Read PROD_QOH for PROD_CODE = '11QER/31'	8	8
2	T1	Read PROD_QOH for PROD_CODE = '13-Q2/P2'	32	40
3	T2	Read PROD_QOH for PROD_CODE = '1546-QQ2'	15	
4	T2	PROD_QOH = 15 + 10		
5	T2	Write PROD_QOH for PROD_CODE = '1546-QQ2'	25	
6	T1	Read PROD_QOH for PROD_CODE = '1546-QQ2'	25	(After) 65
7	T1	Read PROD_QOH for PROD_CODE = '1558-QW1'	23	(Before) 88
8	T2	Read PROD_QOH for PROD_CODE = '1558-QW1'	23	
9	T2	PROD_QOH = 23 − 10		
10	T2	Write PROD_QOH for PROD_CODE = '1558-QW1'	13	
11	T2	***** COMMIT *****		
12	T1	Read PROD_QOH for PROD_CODE = '2232-QTY'	8	96
13	T1	Read PROD_QOH for PROD_CODE = '2232-QWE'	6	102

The Scheduler

- Special DBMS program
  - Purpose is to establish order of operations within which concurrent transactions are executed
- Interleaves execution of database operations to ensure serializability and isolation of transactions

The Scheduler (continued)

- Bases its actions on concurrency control algorithms
- Ensures computer’s central processing unit (CPU) is used efficiently
- Facilitates data isolation to ensure that two transactions do not update same data element at same time

The Scheduler (continued)

TABLE 10.9 Read/Write Conflict Scenarios: Conflicting Database Operations Matrix

	TRANSACTIONS		
	T1	T2	RESULT
Operations	Read	Read	No conflict
	Read	Write	Conflict
	Write	Read	Conflict
	Write	Write	Conflict

Concurrency Control with Locking Methods

- Lock
  - Guarantees exclusive use of a data item to a current transaction
  - Required to prevent another transaction from reading inconsistent data
- Lock manager
  - Responsible for assigning and policing the locks used by transactions

Lock Granularity

- Indicates level of lock use
- Locking can take place at following levels:
  - Database
  - Table
  - Page
  - Row
  - Field (attribute)

Lock Granularity (continued)

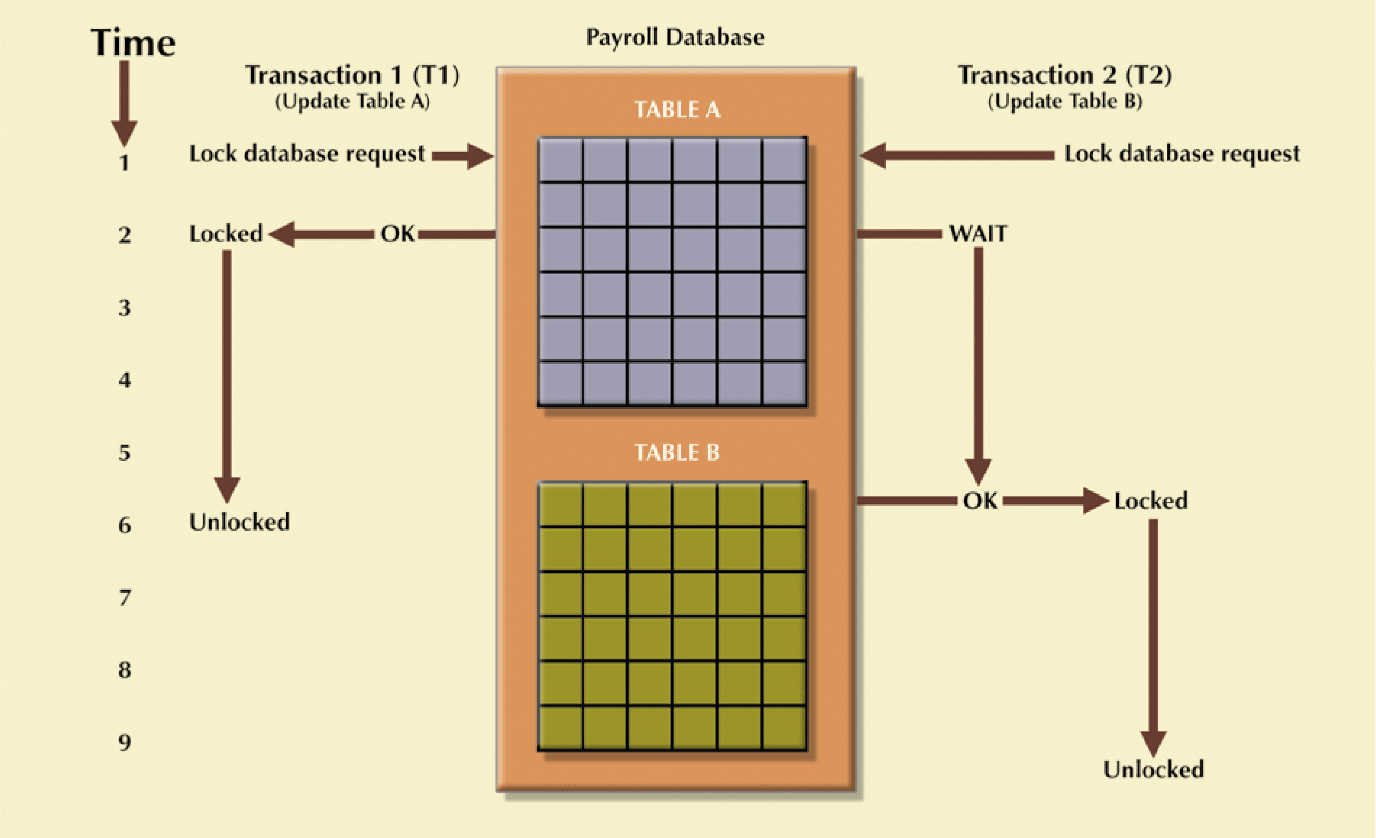
- Database-level lock
  - Entire database is locked
- Table-level lock
  - Entire table is locked
- Page-level lock
  - Entire diskpage is locked

Lock Granularity (continued)

- Row-level lock
  - Allows concurrent transactions to access different rows of same table, even if rows are located on same page
- Field-level lock
  - Allows concurrent transactions to access same row, as long as they require use of different fields (attributes) within that row

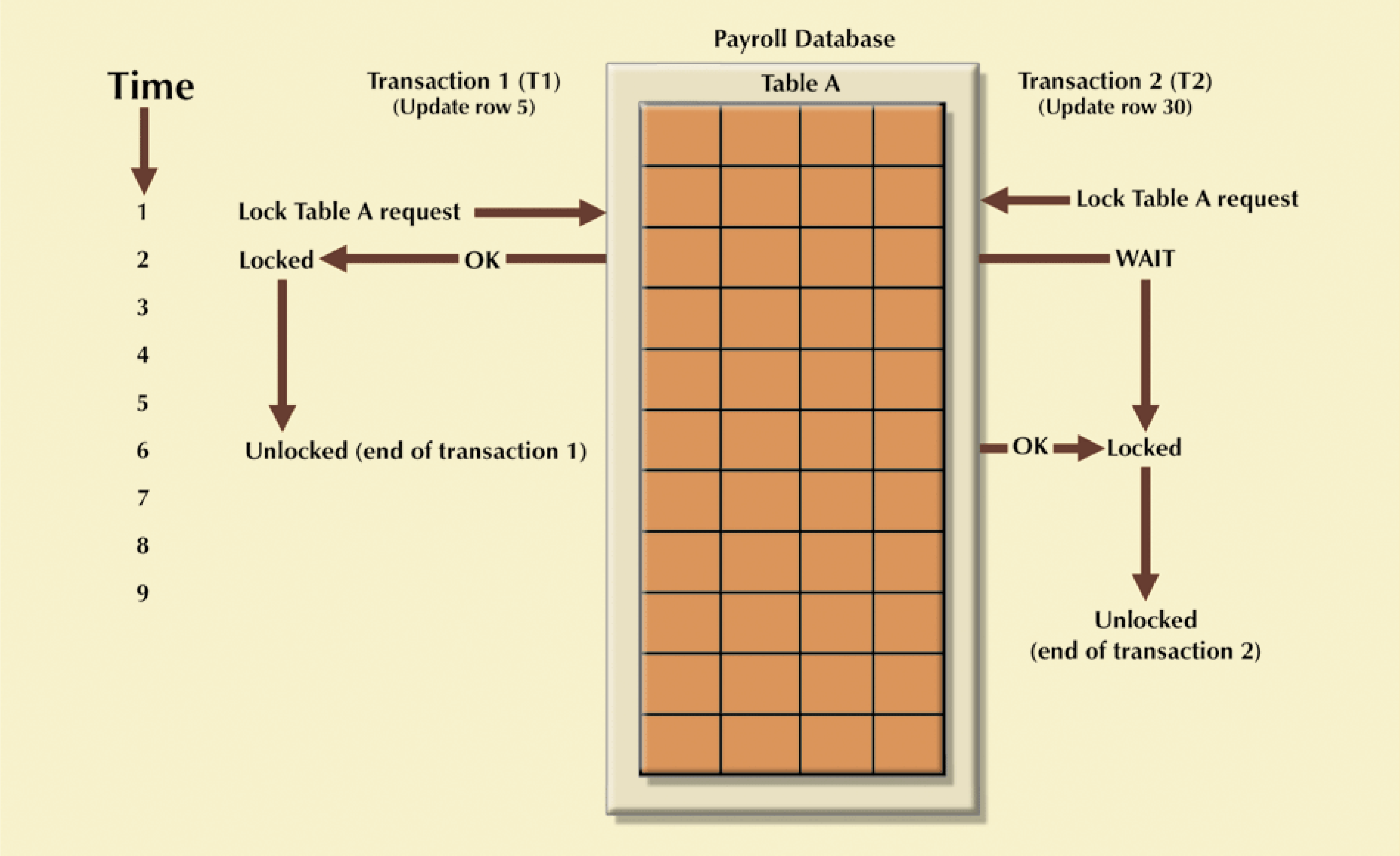
Lock Granularity (continued)

FIGURE 10.3 Database-level locking sequence



Lock Granularity (continued)

FIGURE 10.4 An example of a table-level lock



Lock Granularity (continued)

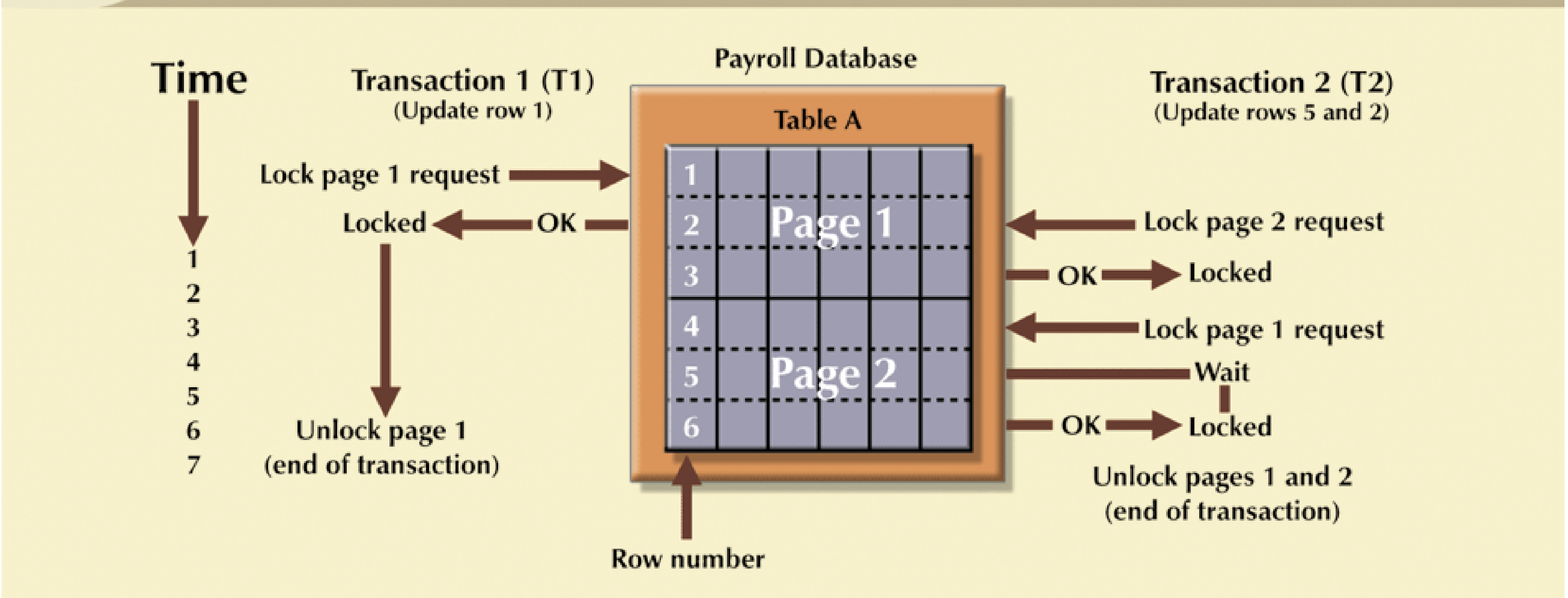
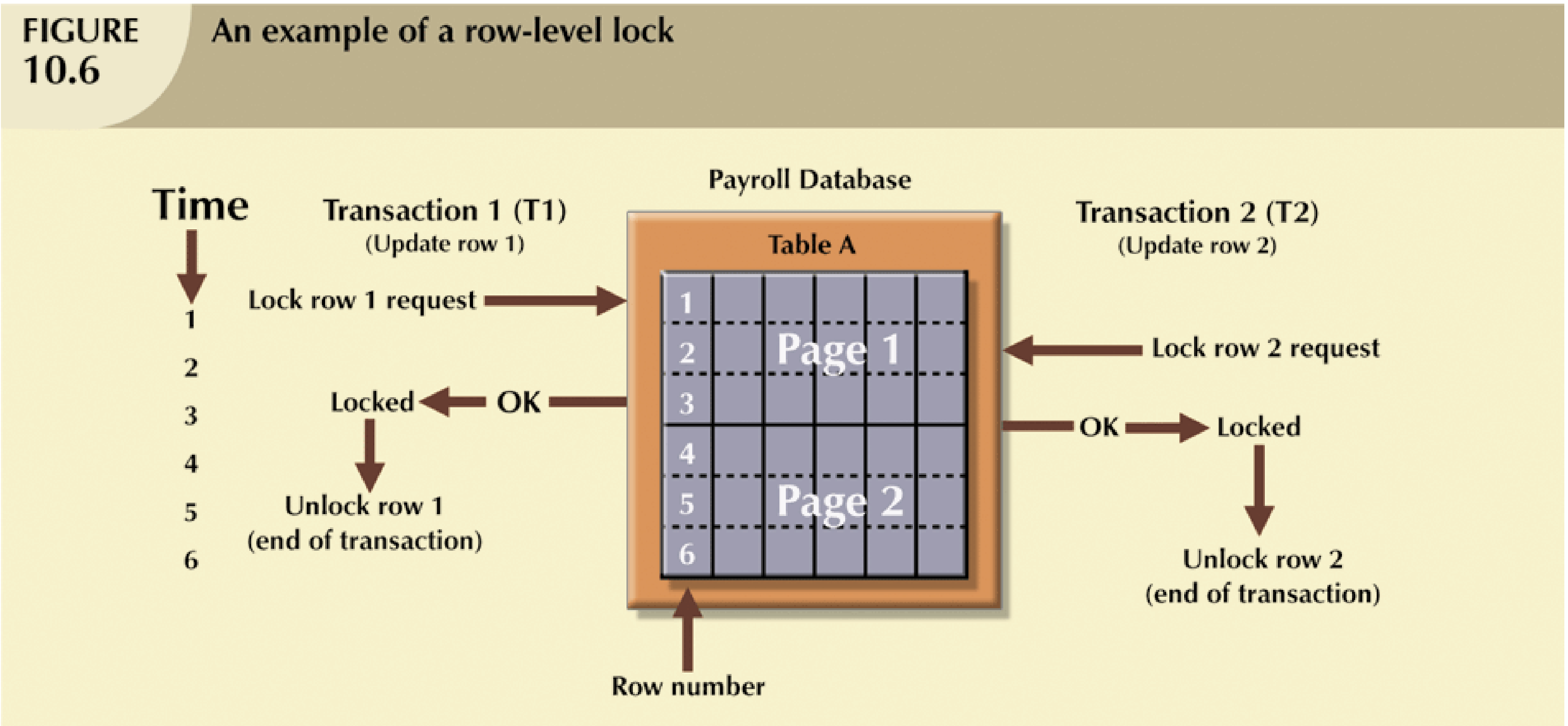


FIGURE 10.5 An example of a page-level lock

Lock Granularity (continued)



Lock Types

- Binary lock
  - Has only two states: locked (1) or unlocked (0)
- Exclusive lock
  - Access is specifically reserved for transaction that locked object
  - Must be used when potential for conflict exists
- Shared lock
  - Concurrent transactions are granted Read access on basis of a common lock

Lock Types (continued)

TABLE 10.10 An Example of a Binary Lock

TIME	TRANSACTION	STEP	STORED VALUE
1	T1	Lock PRODUCT	
2	T1	Read PROD_QOH	15
3	T1	PROD_QOH = 15 + 10	
4	T1	Write PROD_QOH	25
5	T1	Unlock PRODUCT	
6	T2	Lock PRODUCT	
7	T2	Read PROD_QOH	23
8	T2	PROD_QOH = 23 − 10	
9	T2	Write PROD_QOH	13
10	T2	Unlock PRODUCT	

Two-Phase Locking to Ensure Serializability

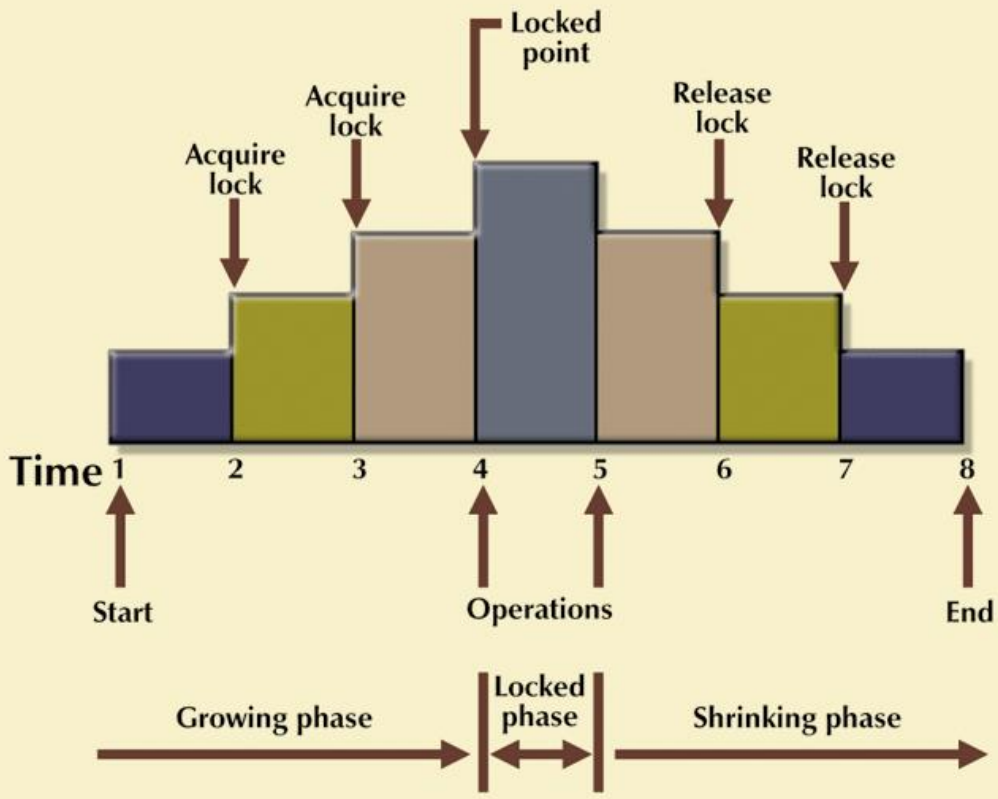
- Defines how transactions acquire and relinquish locks
- Guarantees serializability, but it does not prevent deadlocks
  - Growing phase - Transaction acquires all required locks without unlocking any data
  - Shrinking phase - Transaction releases all locks and cannot obtain any new lock

Two-Phase Locking to Ensure Serializability (continued)

- Governed by the following rules:
  - Two transactions cannot have conflicting locks
  - No unlock operation can precede a lock operation in the same transaction
  - No data are affected until all locks are obtained—that is, until transaction is in its locked point

Two-Phase Locking to Ensure Serializability (continued)

FIGURE 10.7 Two-phase locking protocol



Deadlocks

- Condition that occurs when two transactions wait for each other to unlock data
- Possible only if one of the transactions wants to obtain an exclusive lock on a data item
  - No deadlock condition can exist among shared locks

Deadlocks (continued)

- Control through:
  - Prevention
  - Detection
  - Avoidance

Deadlocks (continued)

TABLE 10.11 How a Deadlock Condition Is Created

TIME	TRANSACTION	REPLY	LOCK STATUS	
0			Data X	Data Y
1	T1:LOCK(X)	OK	Unlocked	Unlocked
2	T2: LOCK(Y)	OK	Locked	Unlocked
3	T1:LOCK(Y)	WAIT	Locked	Locked
4	T2:LOCK(X)	WAIT	Locked	Locked
5	T1:LOCK(Y)	WAIT	Locked	Locked
6	T2:LOCK(X)	WAIT	Locked	Locked
7	T1:LOCK(Y)	WAIT	Locked	Locked
8	T2:LOCK(X)	WAIT	Locked	Locked
9	T1:LOCK(Y)	WAIT	Locked	Locked
...	....	....	....	....
...	....	....	....	....
...	....	....	....	....
...	....	....	....	....

Deadlock

Concurrency Control with Time Stamping Methods

- Assigns global unique time stamp to each transaction
- Produces explicit order in which transactions are submitted to DBMS
- Uniqueness
  - Ensures that no equal time stamp values can exist
- Monotonicity
  - Ensures that time stamp values always increase

Wait/Die and Wound/Wait Schemes

- Wait/die
  - Older transaction waits when requests lock first.
  - Younger is rolled back when requests lock first.
- Wound/wait
  - Older transaction rolls back younger transaction when requests lock first.
  - Younger transaction waits when requests lock first.

Wait/Die and Wound/Wait Schemes (continued)

TABLE 10.12 Wait/Die and Wound/Wait Concurrency Control Schemes

TRANSACTION REQUESTING LOCK	TRANSACTION OWNING LOCK	WAIT/DIE SCHEME	WOUND/WAIT SCHEME
T1 (11548789)	T2 (19562545)	• T1 waits until T2 is completed and T2 releases its locks.	• T1 preempts (rolls back) T2. • T2 is rescheduled using the same time stamp.
T2 (19562545)	T1 (11548789)	• T2 dies (rolls back). • T2 is rescheduled using the same time stamp.	• T2 waits until T1 is completed and T1 releases its locks.

Concurrency Control with Optimistic Methods

- Optimistic approach
  - Based on assumption that majority of database operations do not conflict
  - Does not require locking or time stamping techniques
  - Transaction is executed without restrictions until it is committed
  - Phases are read, validation, and write

Database Recovery Management

- Database recovery
  - Restores database from given state, usually inconsistent, to previously consistent state
  - Based on atomic transaction property
    - All portions of transaction must be treated as single logical unit of work, so all operations must be applied and completed to produce consistent database
  - If transaction operation cannot be completed, transaction must be aborted, and any changes to database must be rolled back (undone)

Transaction Recovery

- Makes use of deferred-write and write-through techniques
- Deferred write
  - Transaction operations do not immediately update physical database
  - Only transaction log is updated
  - Database is physically updated only after transaction reaches its commit point using transaction log information

Transaction Recovery (continued)

- Write-through
  - Database is immediately updated by transaction operations during transaction's execution, even before transaction reaches its commit point

Transaction Recovery (continued)

TABLE 10.13 A Transaction Log for Transaction Recovery Examples

TRL ID	TRX NUM	PREV PTR	NEXT PTR	OPERATION	TABLE	ROW ID	ATTRIBUTE	BEFORE VALUE	AFTER VALUE
341	101	Null	352	START	**** Start Transaction				
352	101	341	363	UPDATE	PRODUCT	54778-2T	PROD_QOH	45	43
363	101	352	365	UPDATE	CUSTOMER	10011	CUST_BALANCE	615.73	675.62
365	101	363	Null	COMMIT	**** End of Transaction				
397	106	Null	405	START	**** Start Transaction				
405	106	397	415	INSERT	INVOICE	1009			1009,10016, ...
415	106	405	419	INSERT	LINE	1009,1			1009,1, 89-WRE-Q,1, ...
419	106	415	427	UPDATE	PRODUCT	89-WRE-Q	PROD_QOH	12	11
423				CHECKPOINT					
427	106	419	431	UPDATE	CUSTOMER	10016	CUST_BALANCE	0.00	277.55
431	106	427	457	INSERT	ACCT_TRANSACTION	10007			1007,18-JAN-2004, ...
457	106	431	Null	COMMIT	**** End of Transaction				
521	155	Null	525	START	**** Start Transaction				
525	155	521	528	UPDATE	PRODUCT	2232/QWE	PROD_QOH	6	26
528	155	525	Null	COMMIT	**** End of Transaction				
* * * * * C *R*A* S* H * * * * *									

Summary

- Transaction
  - Sequence of database operations that access database
  - Represents real-world events
  - Must be logical unit of work
    - No portion of transaction can exist by itself
  - Takes database from one consistent state to another
    - One in which all data integrity constraints are satisfied

Summary (continued)

- Transactions have five main properties: atomicity, consistency, isolation, durability, and serializability
- SQL provides support for transactions through the use of two statements: COMMIT and ROLLBACK
- SQL transactions are formed by several SQL statements or database requests

Summary (continued)

- Transaction log keeps track of all transactions that modify database
- Concurrency control coordinates simultaneous execution of transactions
- Scheduler is responsible for establishing order in which concurrent transaction operations are executed

Summary (continued)

- Lock guarantees unique access to a data item by transaction
- Two types of locks can be used in database systems: binary locks and shared/exclusive locks
- Serializability of schedules is guaranteed through the use of two-phase locking

Summary (continued)

- When two or more transactions wait indefinitely for each other to release lock, they are in deadlock, or deadly embrace
- Three deadlock control techniques: prevention, detection, and avoidance

Summary (continued)

- Concurrency control with time stamping methods assigns unique time stamp to each transaction and schedules execution of conflicting transactions in time stamp order

Summary (continued)

- Concurrency control with optimistic methods assumes that the majority of database transactions do not conflict and that transactions are executed concurrently, using private copies of the data
- Database recovery restores database from given state to previous consistent state