Note of Database Review

Key definition

- Primary key: only one attribute
- Super key: a set of attributes that defines a unique instance
- Candidate key: minimum true subset of a super key
- Foreign key: referencing relation outside of the table

Relation algebra

- **Sigma**: select --> select a tuple
- **Pi**: shadow --> select an attribute
- **IXI**: join two table by their commom attributes
- **X**: Decal multiplication
- **U**: union of two tuple sets, and eliminates the common tuples
- **rho**: rename, rho x(y) --> to rename y as x
- **minus**: **a - b** means something in **a** but not in **b**.
- **<--**: assign a value to something
- G: group function, $G_{\text{sum(attributeName)}}\ (tableName)$

  sum, average, count, count_distinct

  G1,G2,G3 $G_{\text{ f1(a1),f2(a2)}}\ (tableName)$, g_i means attribute
- **^**: and
- **v**: or

SQL query

- Trigger format:
  - create trigger **triggerName** after/before **insert/delete/update** (of **attributeName**) on **tableName**

    referencing new row as **nrow**

    refrencing old row as orow

    for each row

    when (**nrow.attributeName** in/not in (

    select **attributeName**

    from **tableName**)

and orow.**attributeName** in/not in (

select ……))

begin (***atomic***)

rollback

end;

- alter/drop trigger **triggerName** disable

E-R diagram

- **Arrows**
  - A <———— B ————> C, means b is a relation between A and C, and it's a one-to-one relation;
  - A <———— B ———— C, means multi Cs are related to only one A;
  - A ———— B ———— C, means multi As and multi Cs
- **Weak entity set**: without a primary key; (strong entity set: has a primary key.)
  - The discriminator of a weak entity set will be underlined with a dotted line: _ _ _ _. (dicriminator is a set of attributes that defines a unique tuple, aka partial code)
  - The relation set between a weak entity set and a strong one will be a double diamond.
  - The double line means a multi-value attribute (an attribute that can have more than one value)
- **Relation set**
  - Multi-multi, 2 sets related: union of primary keys of the two sets
  - One-one, 2 sets: any primary of the two sets
  - Multi-one, 2 sets: the primary key of the 'multi' one.
  - Multi-multi, n sets: union of the primary keys of all the sets
  - Multi-one, n sets: the 'one' is unique in order to have only one meaning, so —— union of the primary keys of multi ones

Functional Dependent

- A1 -> A2 means if t1[a1] == t1[a1], then t1[a2] == t2[a2].
  - t1 does not have to be a super key or primary key
  - A trival FD means a2 C a1, while an untrival one does not.

Normal Forms

- 1NF: **all the domains of attributes are atomic**
- BCNF: **all the FDs in F+, they are either trival FDs, or a1 is a super key of relation R**
  - How to decompose a non-BCNF schema:
    - Example: a -> b, but a is not a super key or primary key, and b is not included by a (not trival);
      - **a U b -> (R - (b - a))**
  - Note: only the duplications of FD can be eliminated, not all

- 3NF: weaker than BCNF, by including another possibility saying **the attibutes in (b - a) is included in a candidate key of R.**

F+

- F is a set of FDs, and F+ is the complete closure of FDs.
- Armstrong's axiom: used to calculate the F+.
  - **Reflexive rule: if a is an attribute set and b $\subseteq$ a, then a -> b**
  - **Augmentation rule: if a -> b and y is an attribute set, then ya -> yb**
  - **Transitivity rule: if a -> b and b -> y, then a -> y**
- Addition to Armstrong's axiom: can be proved using the basic 3 axioms.
  - **Union rule: if a -> b and a -> y, then a -> by**
  - **Decomposition: if a -> by, then a -> b and a -> y**
  - **Pseudotransitivity rule: if a -> b and yb -> s, then ay -> s**
- Algorithm of calculating the F+:

```
F+ = F

    repeat:

        for FD in F+:

            use reflexive rule and augmentation rule

            add the results in F+

        for FD1 and FD2 in F+:

            if FD1 and FD2 can be related with transitivity rule:

                add the results in F+

    until F+ does not change.
```

- Algorithm to calculate the closure of attribute set **a** (the closure includes all the attributes dependent of a):

```
result = a
    repeat:
        for FD(b -> y) in F do:
                if b C result:
                    result = result U y
    until result does not change.
```

Extraneous

- Extraneous: if deleting an attribute does not change the closure F+, then the attibute is extraneous.
    - **If A belongs to a and F logically imply (F - {a -> b}) U {(a - A) -> b}, then A is extraneous in a.**
    - **If A belongs to a and (F - {a -> b}) U {a -> (b - A)} logically imply F, then A is extraneous in b.**
    - Eg1: if AB -> C and A -> C, then B is extraneous in AB -> C.
    - Eg2: if AB -> CD and A -> C, then C is extraneous in AB -> CD.
    - Note: the conditions will **always be true** if the logical implimention is reversed.

Canonical covers

- Canonical cover: a dependent set Fc where F logically imply Fc and Fc logically imply F.
    - **All the FD in Fc does not include an extraneous attribute.**
    - **All the FD in Fc, the left part is unique. (that is to say, a -> b and a -> c should be written as a -> bc)**
    - Note: canonical covers are not necessarily unique.
- Algorithm to calculate an Fc:

```
Fc = F
    repeat:
        use Union rule to replace all the FD with same left sets
        find an FD(a -> b) in Fc where a or b includes an extraneous attribute
            delete the attribute from a -> b
     until Fc does not change.
```

Decompositions

- Decomposition: a |X| b == R.
- **Lossless decomposition**
    - Either a ^ b -> a or a ^ b -> b belongs to F+.
    - Also can be mentioned as: **a ^ b is a super key on a or b**.
- **Dependency-preserving decomposition**
    - ……
- **BCNF decomposition**

```
result = [R]
    done = False

    # calculate F+:
    ......

    while not done:
        for Ri in result:
```

```
            if Ri is not BCNF:
                find such an a -> b that
                1. hold on Ri
                2. is not trival
                3. a -> Ri does not belong to F+
                4. a and b have no common attributes

                then result = (result - Ri) U (Ri - b) U (a, b)
    else done = True.
```

- This algorithm is **lossless decomposition** because when we replace Ri with (Ri - b) and (a, b), a -> b, and (Ri - b) ^ (a, b) = a.
- If **a ^ b <> empty set**, the attributes of a ^ b will not be in (Ri - b), and a -> b will **NOT** hold on R.

- **3NF decomposition**

```
Fc = cononical cover of F
i = -1

for FD(a -> b) in Fc:
    i += 1
    Ri = ab

for Rj in R(0:i):
    if Rj does not include the candidate of R:
        i += 1
        Ri = any candidate key of R.

# optional: delete duplicate relations, until no dup exists.
if Rj is included in Rk:
    i -= 1
    delete Rj.
```

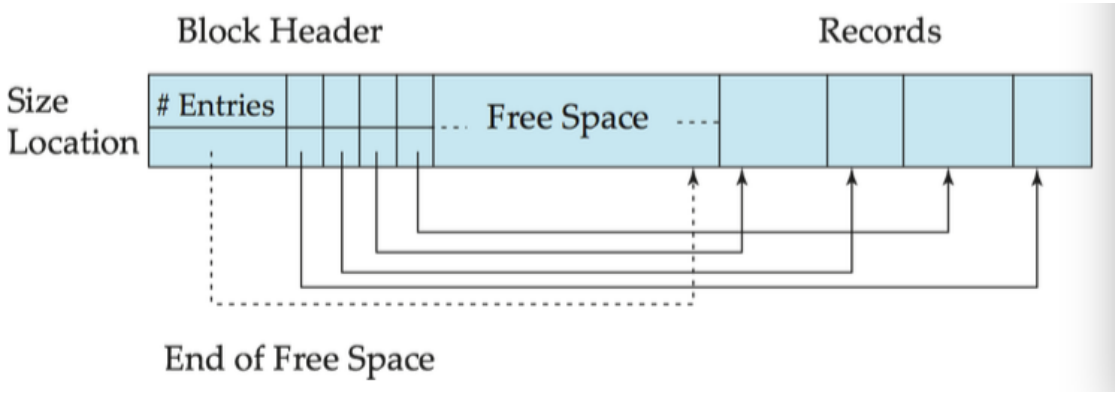
- **4NF**
  - ……

variable length record

- Implementation
  - Problems:
    - How to describe a record so that a single attribute can easily fetch it.
    - How to store the record in a block so that the record can be easily fetched.
  - **Null bitmap**
    - Overall structure:

      Attributes' values (values for fixed-length attributes and (offset, length) data for variable attributes) + Null bitmap + variable attributes' values

        - Null bitmap: a string of 0 and 1 will tell which attributes are NULL (1 if NULL).
    - **Slotted-page structure**



        - Each block has a blockhead that stores:
            1. the number of entries;
            2. a pointer to the end of free space in the block;
            3. an array consisting of position and size of each record.
        - Note:
            1. the free space is a continuous space, from the end of the array and the first record.
            2. when inserting a record, the new record will be placed at the end of the free space.
            3. when deleting a record, the size of this record in the array will be set -1, and the records before it will be moved and the pointer to the end of free space will be moved too.
    - Big objects are not directly stored in the database, but often stored by their pointers using **B+ tree**.

File storage

- **Heap file organization**: records are placed in random order.
- **Sequential file organization**: records are placed in the order of their searching-code.
- **Hasing file organization**: calculate a hashing function on one attribute of the records and store the records according to the hashing results.
- **Multiple clustering file organization**: several tables are stored in the same file.

Sequential file organization

- Pointer linked list
- Insert:
    1. locate the place to insert a record.
    2. if there is enough space to insert, do it; else the record will be inserted into a overflow block.
    3. Anyway, the pointer needs to be adjusted so that the record can be searched with searching-code.
    4. In some cases, the file needs reorganization.
- Delete: using pointer linked list.

Buffer

- **Buffer replacement strategy**: when there's little space left, the **LRU** (least recently used) block will be written to disk files and removed.
- **Pinned block**: when writting on a block, theblock is pinned and should not be written to files.
- **Forced output of block**: when the system break down, the block should be immediately written back to files.
- ……

B+Tree

- Time complexity: **O(log ceil(n/2) (N))**, and n is the maximum number of pointers in a node, and N is the number of records.
- Note: the pointer of index node will point at the leaf whose value equals to the value **ahead of** the pointer.
- Search

```
def find(value v):
    c = root
    while c != leafNode:
        let i be the minimum value such that v <= c.k[i]
        if i > MAXN: # no such value
            p[m] = the last not null pointer of c
            c = p[m]
        elif v == c.k[i]:
            c = c.p[i+1]
        else: # smaller than k[i]
            c = c.p[i]

    # c is a leaf node
    find c.k[i] = v
    if i exist:
        return c, i
```

- Insert
  - Follow the steps of search.
  - If the node can be placed in the node, insert it;
  - Else split the node; if the parent node is also full, split it too, and the the inserted new node will go to upper levels.
  - Note that every time a node split, the parent needs to add one pointer to point at it.
- Delete
  - Follow the steps of search.
  - Delete the node:

        - If the node is root:
            - If the root only has one child or its root can be merged, delete the node and let the child be root.
            - Change the root value.
        - If the leaf node has two values (deleting one value will make a rather empty node), check the leaf node before it.

          a. If the sibling (the node before the node to delete) can be merged with it, merge them.

          b. Else lend one value from the sibling.
        - Change the parent node: **delete** one value if a merge happened, or **alter** one value if a lend happened.
- Calculation

  maxn = the maximum of pointers in an index node.

  Eg: maxn = 4, 10000 index items (which means 10000 **records**).
    - Node ——> Height:
        - There are 2-3 keys in a leaf node, and 2-4 children in an index node.
        - minimum height = log 4 (10000/3) + 1.
        - maximum height = log 2 (10000/2) + 1.
    - Height ——> Node:
        - leafNodes = ceil(10000/3).
        - Total nodes = ceil(10000/3) + ceil(ceil(1000/3)/4) + ceil(ceil(ceil(1000/3)/4)/4) + ... + 1.
- Bulk load
    - When inserting a lot of tuples, sort them first and insert in order will be more efficient than inserting randomly.
    - When creating an index from current tuples, we can directly build a B+-tree, that is called 'Bottom-up build', which is faster than inserting ('up-bottom method').

Hashing

- Close addressing: use a overflow bucket (implemented by a **linked list**)
- Open addressing: use **linear probing** or other methods if a overflow happened; because delete will be hard for it, a database will **NOT** use this method.

Query execution

- Cost estimation

	算　法	开　销	原　因
A1	线性搜索	$t_s + b_r * t_T$	一次初始搜索加上 b_r 个块传输，b_r 表示在文件中的块数量
A1	线性搜索，码属性等值比较	平均情形 $t_s + (b_r/2) * t_T$	因为最多一条记录满足条件，所以只要找到所需的记录，扫描就可以终止。在最坏的情形下，仍需要 b_r 个块传输
A2	B⁺树主索引，码属性等值比较	$(h_i + 1) * (t_T + t_s)$	（其中 h_i 表示索引的高度）。索引查找穿越树的高度，再加上一次 *I/O* 来取记录；每个这样的 *I/O* 操作需要一次搜索和一次块传输
A3	B⁺树主索引，非码属性等值比较	$h_i * (t_T + t_s) + b * t_T$	树的每层一次搜索，第一个块一次搜索。b 是包含具有指定搜索码记录的块数。假定这些块是顺序存储（因为是主索引）的叶子块并且不需要额外搜索
A4	B⁺树辅助索引，码属性等值比较	$(h_i + 1) * (t_T + t_s)$	这种情形和主索引相似
A4	B⁺树辅助索引，非码属性等值比较	$(h_i + n) * (t_T + t_s)$	（其中 n 是所取记录数。）索引查找的代价和 *A3* 相似，但是每条记录可能在不同的块上，这需要每条记录一次搜索。如果 n 值比较大，代价可能会非常高
A5	B⁺树主索引，比较	$h_i * (t_T + t_s) + b * t_T$	和 *A3*，非码属性等值比较情形一样
A6	B⁺树辅助索引，比较	$(h_i + n) * (t_T + t_s)$	和 *A4*，非码属性等值比较情形一样

图 12-3　选择算法代价估计

Cost of Link

- n = number of records, b = number of blocks.
- **Nested-loop join**
  - Worst case:
    - Search times = n1 + b1.
    - Transport times = n1 * b2 + b1.
  - Best case:
    - Search times = 2.
    - Transport times = b1 + b2.
  - Total = Ts + Tt.
- **Block nested-loop join**
  - Worst case:
    - Search times = 2b1.
    - Transport times = b1 * b2 + b1.
  - Best case:
    - Search times = 2.
    - Transport times = b1 + b2.
  - Total = Ts + Tt.

Very important !!!

- ***Improved block nested-loop join***

- 在块嵌套循环连接算法中，外层关系可以不用磁盘块作为分块的单位，而以内存中最多能容纳的大小为单位，当然同时要留出足够的缓冲空间给内层关系及输出结果使用。也就是说，如果内存有 M 块，我们一次读取外层关系中的 $M-2$ 块，当我们读取到内层关系中的每一块时，我们把它与外层关系中的所有 $M-2$ 块做连接。这种改进使内层关系的扫描次数从 b_s 次减少到 $\lceil b_r/(M-2) \rceil$ 次，这里的 b_s 是外层关系所占的块数。这样全部代价为 $\lceil b_r/(M-2) \rceil * b_s + b_r$ 次块传输和 $2\lceil b_r/(M-2) \rceil$ 次磁盘搜索。

  - **Indexed nested-loop join**
    - Total = b1 * (Ts + Tt) + n1 * c.
  - **Merge join**
    - Search time = ceil(b1/bb) + ceil(b2/bb).
    - Transport time = b1 + b2.
    - Merge sort
      - Search = 2 * ceil(br/M) + ceil(br/bb) * (2 * ceil(log floor(M/bs)-1 (br/M)) - 1).
      - Transport = br * (2 * ceil(log M-1 (br/M)) + 1).
      - Merge times = ceil(log M-1 (br/M))
  - **Hashing join**
    - NOT recursive partitioning:
      - Search times = 2 * ceil(b1/b2) + ceil(b2/bb) + 2 * nh. (Bb: blocks offered to buffer)
      - Transport times = 3 * (b1 + b2) + 4 * nh. (nh: partitioning number)
    - recursive partitioning:
      - Search times = 2 * (ceil(b1/bb) + ceil(b2/bb)) * ceil(log M-1 (b2) - 1).
      - Transport times = 2 * (b1 + b2) * ceil(log M-1(b2) - 1) + b1 + b2. (M: number of buffers for each partition)
    - Big main storage:
      - nh = 0.
      - Search times = 2.
      - Transport times = b1 + b2.

Equivalence rules

- Cascade of sig: sig cond1^cond2 (E) = sig cond1(sig cond2 (E))
- Communitive: sig cond1 (sig cond2 (E)) = sig cond2 (sig cond1 (E))
- Cascade of pi: pi l1 (pi l2 (pi l3 (pi l4 (...(pi ln (E)))))) = pi l1 (E), where l1 $\subseteq$ l2 $\subseteq$ l3 $\subseteq$ ... $\subseteq$ ln.
- ......

ACID

- **Atomicity**: done or not done.
- **Consistency**: constrains that make sure for the data is consistent.
- **Isolation**: each transaction is done free of other transactions' disturbance.
- **Durability**: the results will stay still in the DB when the transaction is done.

- Works related to ACID:
    - A - recovery system (commit.)
    - C - constrains (like primary key, unique, etc.)
    - I - concurrency-control system (locks.)
    - D - recovery system (write the changes to disk files.)

Serializable

- Precedence graphs
    - Rules: (assume operation t1.a is ahead of operation t2.b)
        - If a = r and b = w, draw t1 -> t2.
        - If a = w and b = r, draw t1 -> t2.
        - If a = w and b = w, draw t1 -> t2
        - In a word, if a or b is write, draw a line between the former(a) to the latter(b).
    - Note: if there is no **loops** in the graph, then the schedule is serializable and vice versa.
- If a schedule is serializable, give the series according to the graph, in the format of <T1, T2, T3>.

Schedule and Isolation

- Status of a schedule
    - **Active**: initial status.
    - **Partially committed**: after the last query is being executed.
    - **Failed**: fail to execute.
    - **Aborted**: failed and rolled back.
    - **Committed**: finished.
    - **Terminated**: committed or aborted.

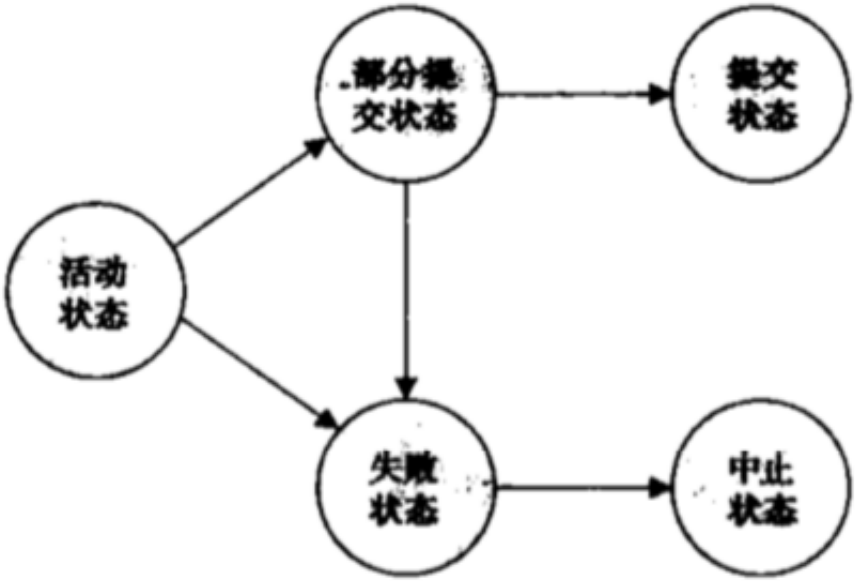


图 14-1　事务状态图

- **Recoverable**: A recoverable schedule is one where, for each pair of Transaction Ti and Tj such that Tj reads data item previously written by Ti the commit operation of Ti appears before the **commit** operation Tj.
- **Cascadeless**: A cascadeless schedule is one where for each pair of transaction Ti and Tj such that Tj reads data item, previously written by Ti the commit operation of Ti appears before the **read** operation of Tj. (*if not, once Ti fails, all the transactions dependent on Ti will have to roll back, and that is called cascade rollback.*)
- **Every Cascadeless schedule is also recoverable schedule.**
- **Class of Isolation** (from highest to lowest)
    - Serializable
    - Repeatable read
    - Read commit
    - Read uncommitted

Lock

- Types of lock
    - **S** —— shared lock: read but not write
    - **X** —— exclusive lock: no read or write
    - S and S are compatible, but S and X / X and X are not.
    - A transaction can request for a lock, but before the system give it the lock, the transaction has to wait for the previous owner of lock to unlock it.
    - If a transaction is waiting for so long that it can never be executed, it is called **starve**.
- **2PL** ———— two-phase locking protocol
    - ***growing*** phase: a transaction can get a lock but not unlocking one.
    - ***shrinking*** phase: a transaction can unlock a lock but not getting one.
    - lock point: after getting the last lock.
    - Lock conversion: an S-lock can be upgraded to X during growing phase, and an X-lock can be downgraded to S during shrinking phase.
    - Strict mode: X-locks have to be unlocked ***after*** the transaction is committed.
    - Rigorous mode: Each lock has to be unlocked ***after*** the transaction is committed.
    - An easier mode:
        - When Ti tries to read, system will add a lock-S before executing the read operation.
        - When Ti tries to write, system will check if the item is under a lock-S, and will either:
            - Upgrade the lock-S;
            - Add a lock-X;

          and then do the write operation.
        - When Ti is terminated (either committed or failed), the locks owned by it will be unlocked.
    - Lock manager:

- Each data item has a linked list.
- Black rectangle means the lock has been granted, and white ones means waiting for granting.
- How to maintain:
    - When a transaction asks for adding a lock, extend the list of the data item if it exist and create one if not.

      If it' s the first lock for the data item, the system will always agree to add it; else only if the request agrees with other locks and all other requests are satisfied, the system will agree to give a lock.
    - When a transaction asks for unlocking a lock, the system will first delete the lock from the list, then check the list for requests and see if there are any available requests.
    - If a transaction terminates, the system will delete all the lock requests of it.
- Eg:
    - data item: I7, I23, I912, I4, I44.

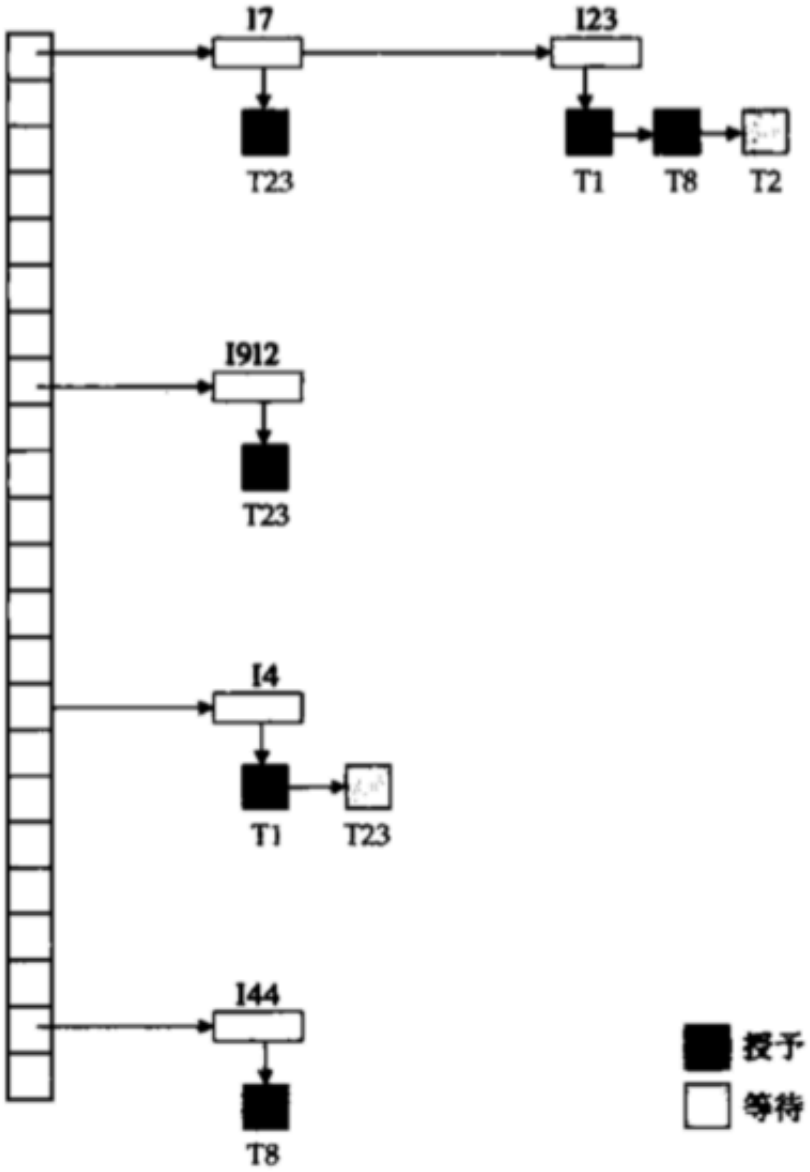


图 15-10 锁表

- Tree protcol:

  ……

XML —— some examples

- **Head of XML file**: <xs: schema xmlns:xs = "http://www.fuckDatabase.com">
- **Sequence of attributes**: <xs: sequence>...</xs: sequence>
- **Ways to define a relation set**:
  - <xs: element name = "xxxx" type = "xs: string" // "xs: decimal"//"xxxx_type"(**DIY type**) />

    //……definition of other things……

    <xs: complexType name = "xxxx_type">

    //……definition of xxxx_type……

    </ xs: complexType>

    </ xs: element>

    - <xs: emelemt name = "xxxx">

      <xs: complexType>

      //……definition of xxxx_type……

      </ xs: complexType>
    - **MAX and MIN occurance**: <xs: element …… minOccurs = "0" maxOccurs = "unbounded">
- **End of XML file**: </ xs: schema>

DTD

- ……