Chapter A: Network Model

- Basic Concepts
- Data-Structure Diagrams
- The DBTG CODASYL Model
- DBTG Data-Retrieval Facility
- DBTG Update Facility
- DBTG Set-Processing Facility
- Mapping of Networks to Files

Basic Concepts

- Data are represented by collections of *records*.
  - similar to an entity in the E-R model
  - Records and their fields are represented as *record type*

```
type customer = record              type account = record
        customer-name: string;              account-number: integer;
        customer-street: string;            balance: integer;
        customer-city: string;
end                                 end
```

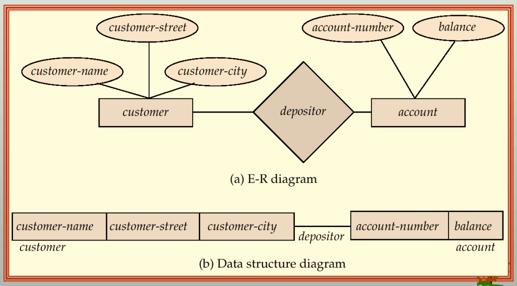
- Relationships among data are represented by *links*
  - similar to a restricted (binary) form of an E-R relationship
  - restrictions on links depend on whether the relationship is many-many, many-to-one, or one-to-one.

Data-Structure Diagrams

- Schema representing the design of a network database.
- A data-structure diagram consists of two basic components:
  - **Boxes**, which correspond to record types.
  - **Lines**, which correspond to links.
- Specifies the overall logical structure of the database.

Data-Structure Diagrams (Cont.)

- For every E-R diagram, there is a corresponding data-structure diagram.

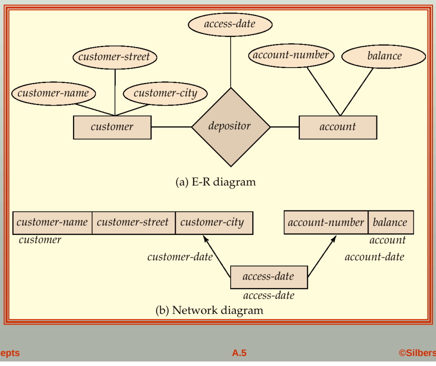


(a) E-R diagram

(b) Data structure diagram

Data-Structure Diagrams (Cont.)

- Since a link cannot contain any data value, represent an E-R relationship with attributes with a new record type and links.



(a) E-R diagram

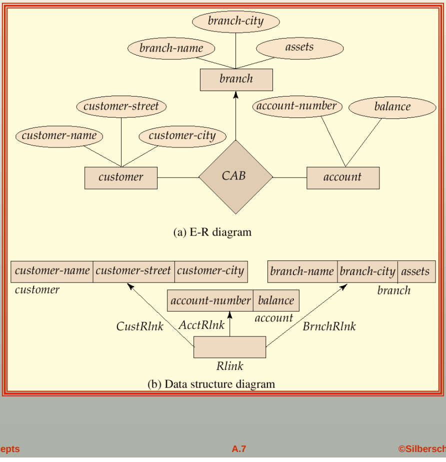
(b) Network diagram

General Relationships

- To represent an E-R relationship of degree 3 or higher, connect the participating record types through a new record type that is linked directly to each of the original record types.

1. Replace entity sets *account, customer,* and *branch* with record types *account, customer,* and *branch,* respectively.
2. Create a new record type *Rlink* (referred to as a *dummy* record type).
3. Create the following many-to-one links:
   - *CustRlink* from *Rlink* record type to *customer* record type
   - *AcctRlnk* from *Rlink* record type to *account* record type
   - *BrncRlnk* from *Rlink* record type to *branch* record type

Network Representation of Ternary Relationship

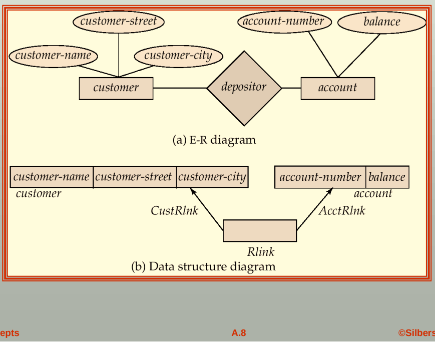


(a) E-R diagram

(b) Data structure diagram

The DBTG CODASYL Model

- All links are treated as many-to-one relationships.
- To model many-to-many relationships, a record type is defined to represent the relationship and two links are used.



(a) E-R diagram

(b) Data structure diagram

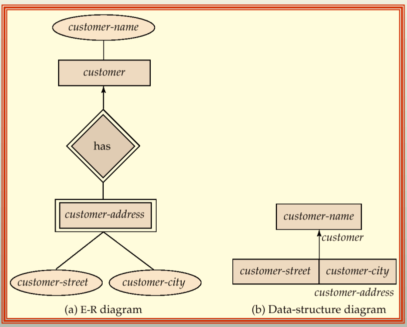
DBTG Sets

- The structure consisting of two record types that are linked together is referred to in the DBTG model as a *DBTG set*
- In each DBTG set, one record type is designated as the *owner,* and the other is designated as the *member*, of the set.
- Each DBTG set can have any number of *set occurrences* (actual instances of linked records).
- Since many-to-many links are disallowed, each set occurrence has precisely one owner, and has zero or more member records.
- No member record of a set can participate in more than one occurrence of the set at any point.
- A member record can participate simultaneously in several set occurrences of *different* DBTG sets.

Repeating Groups

- Provide a mechanism for a field to have a set of values rather than a single value.
- Alternative representation of weak entities from the E-R model
- Example: Two sets.
  - *customer (customer-name)*
  - *customer-address (customer-street, customer-city)*
- The following diagrams represent these sets without the repeating-group construct.

Repeating Groups (Cont.)



- With the repeating-group construct, the data-structure diagram consists of the single record type *customer.*

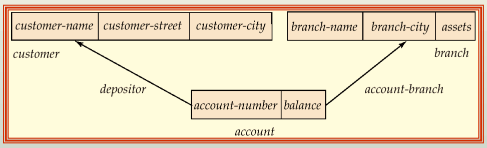
DBTG Data-Retrieval Facility

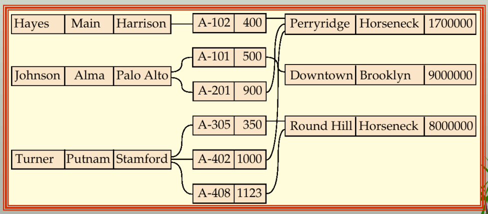
- The DBTG data manipulation language consists of a number of commands that are embedded in a host language.
- *Run unit* — system application program consisting of a sequence of host language and DBTG command statements. Statements access and manipulate database items as well as locally declared variables.
- *Program work-area* (or *user work area*) — a buffer storage area the system maintains for each application program

DBTG Variables

- Record Templates
- Currency pointers
  - Current of record type
  - Current of set type
  - Current of run unit
- Status flags
  - **DB-status** is most frequently used
  - Additional variables: **DB-set-name, DB-record-name,** and **DB-data-name**

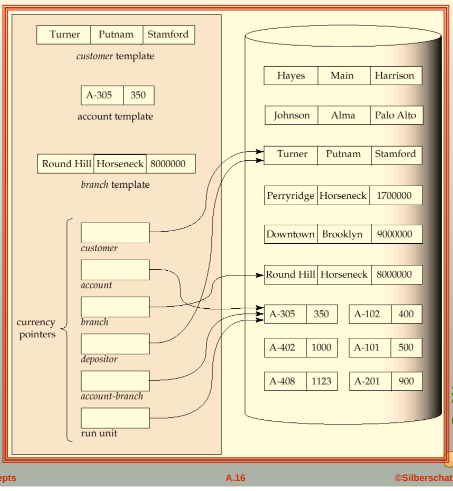
Example Schema





Example Program Work Area

- Templates for three record types: *customer, account,* and *branch.*
- Six currency pointers
  - Three pointers for record types: one each tot he most recently accessed *customer, account,* and *branch* record
  - Two pointers for set types: one to the most recently accessed record in an occurrence of the set *depositor,* one to the most recently accessed record in an occurrence of the set *account-branch*
  - One run-unit pointer.
- Status flags: four variables defined previously
- Following diagram shows an example program work area state.



The Find and Get Commands

- **find** locates a record in the database and sets the appropriate currency pointers
- **get** copies of the record to which the current of run-unit points from the database to the appropriate program work area template
- Example: Executing a **find** command to locate the customer record belonging to Johnson causes the following changes to occur in the state of the program work area.
  - The current of the record type *customer* now points to the record of Johnson.
  - The current of set type *depositor* now points to the set owned by Johnson
  - The current of run unit now points to *customer* record Johnson.

Access of Individual Records

- **find any** <record type> **using** <record-field>
  Locates a record of type <record type> whose <record-field> value is the same as the value of <record-field> in the <record type> template in the program work area.
- Once such a record is found, the following currency pointers are set to point to that record:
  - The current of run-unit pointer
  - The record-type currency pointer for <record type>
  - For each set in which that record belongs, the appropriate set currency pointer
- **find duplicate** <record type> **using** <record-field>
  Locates (according to a system-dependent ordering) the next record that matches the <record-field>

Access of Records Within a Set

- Other **find** commands locate records in the DBTG set that is pointed to by the <set-type> currency pointer.
- **find first** <record type> **within** <set-type>
  Locates the first database record of type <record type> belonging to the current <set-type>.
- To locate the other members of a set,k we use

  find next <record type> **within** <set-type>

  which finds the next element in the set <set-type>.
- **find owner within** <set-type>
  Locates the owner of a particular DBTG set

Predicates

- For queries in which a field value must be matched with a specified range of values, rather than to only one, we need to:
  - **get** the appropriate records into memory
  - examine each one separately for a match
  - determine whether each is the; target of our **find** statement

Example DBTG Query

- Print the total number of accounts in the Perryridge branch with a balance greater than $10,000.

```
count := 0;
branch.branch-name := “Perryridge”;
find any branch using  branch-name;
find first account within account-branch;
while DB-status = 0 do
     begin
        get account
        if account.balance > 10000 then count := count  + 1;
        find next account within  account-branch;
     end
print (count);
```

DBTG Update Facility

- DBTG mechanisms are available to update information in the database.
- To create a new record of type <record type>
  - insert the appropriate values in the corresponding <record type> template
  - add this new record to the database by executing

    store <record type>
- Can create and add new records only one at a time

DBTG Update Facility (Cont.)

- To modify an existing record of type <record type>
  - find that record in the database
  - get that record into memory
  - change the desired fields in the template of <record type>
  - reflect the changes to the record to which the currency point of <record type> points by executing

    modify <record type>

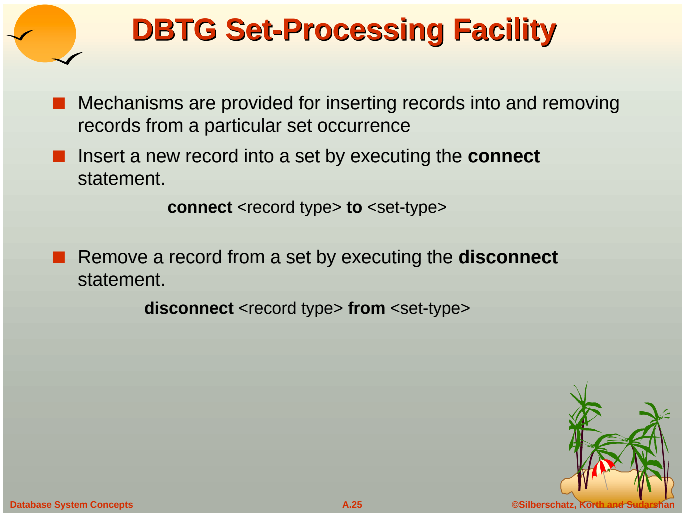
DBTG Update Facility (Cont.)

- To delete an existing record of type <record type>
  - make the currency pointer of that type point to the record in the database to be deleted
  - delete that record by executing

    erase <record type>
- Delete an entire set occurrence by finding the owner of the set and executing

  erase all <record type>

  - Deletes the owner of the set, as well as all the set’s members.
  - If a member of the set is an owner of another set, the members of that second set also will be deleted.
  - **erase all** is recursive.



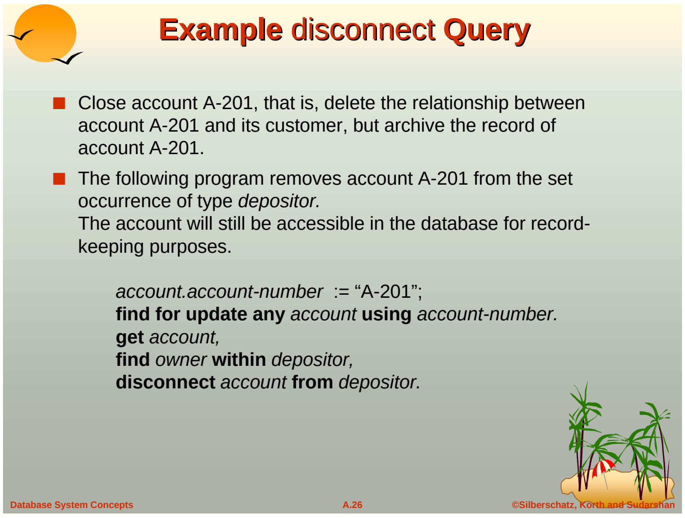
DBTG Set-Processing Facility

- Mechanisms are provided for inserting records into and removing records from a particular set occurrence
- Insert a new record into a set by executing the **connect** statement.

  connect <record type> **to** <set-type>

- Remove a record from a set by executing the **disconnect** statement.

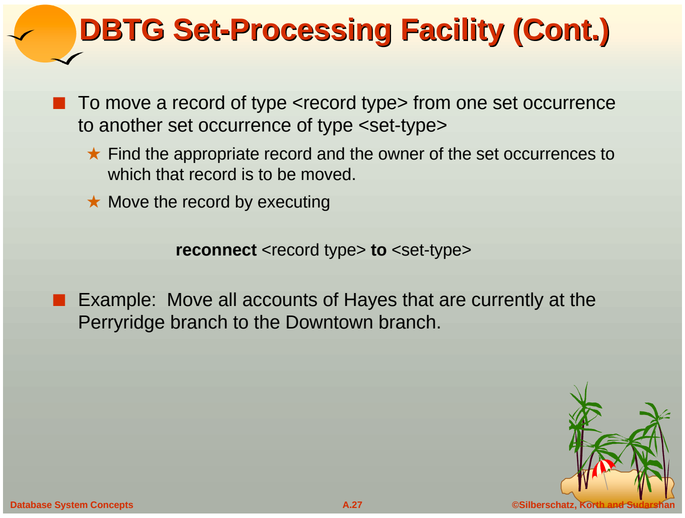
  disconnect <record type> **from** <set-type>



Example disconnect Query

- Close account A-201, that is, delete the relationship between account A-201 and its customer, but archive the record of account A-201.
- The following program removes account A-201 from the set occurrence of type *depositor.*
  The account will still be accessible in the database for record-keeping purposes.

```
account.account-number := "A-201";
find for update any account using account-number.
get account,
find owner within depositor,
disconnect account from depositor.
```

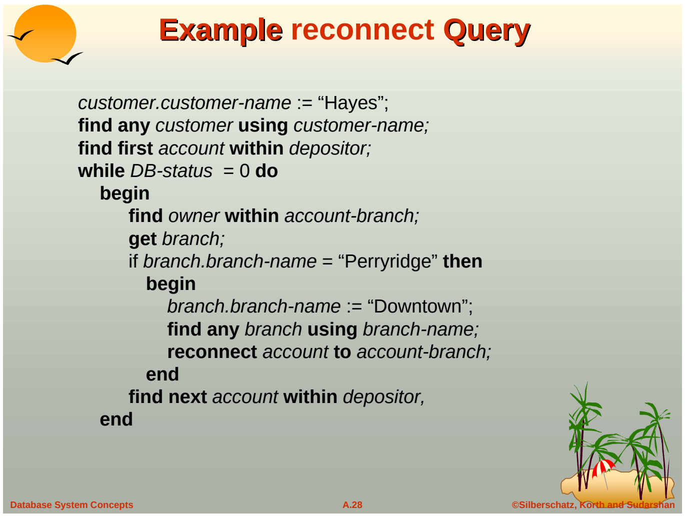


DBTG Set-Processing Facility (Cont.)

- To move a record of type <record type> from one set occurrence to another set occurrence of type <set-type>
  - Find the appropriate record and the owner of the set occurrences to which that record is to be moved.
  - Move the record by executing

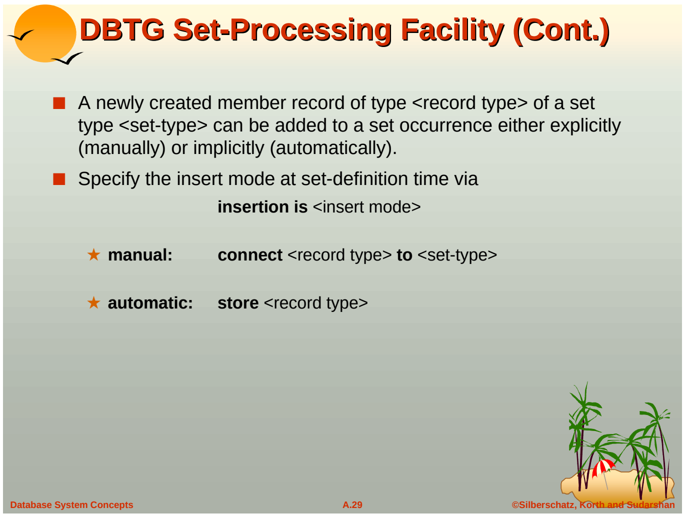
    reconnect <record type> **to** <set-type>

- Example: Move all accounts of Hayes that are currently at the Perryridge branch to the Downtown branch.



Example reconnect Query

```
customer.customer-name := "Hayes";
find any customer using customer-name;
find first account within depositor;
while DB-status = 0 do
   begin
      find owner within account-branch;
      get branch;
      if branch.branch-name = "Perryridge" then
        begin
           branch.branch-name := "Downtown";
           find any branch using branch-name;
           reconnect account to account-branch;
        end
      find next account within depositor,
   end
```

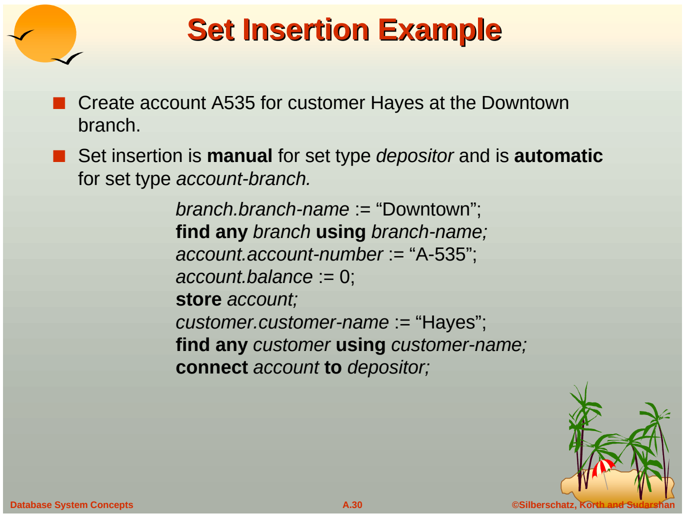


DBTG Set-Processing Facility (Cont.)

- A newly created member record of type <record type> of a set type <set-type> can be added to a set occurrence either explicitly (manually) or implicitly (automatically).
- Specify the insert mode at set-definition time via

  insertion is <insert mode>

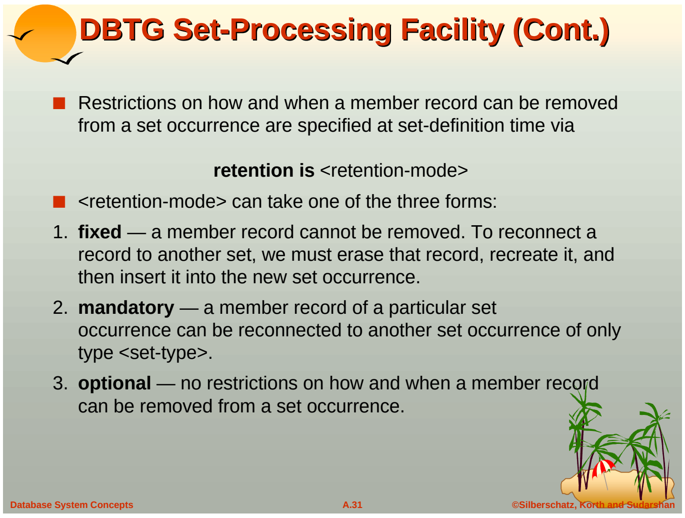
  - **manual:** **connect** <record type> **to** <set-type>
  - **automatic:** **store** <record type>



Set Insertion Example

- Create account A535 for customer Hayes at the Downtown branch.
- Set insertion is **manual** for set type *depositor* and is **automatic** for set type *account-branch.*

```
branch.branch-name := "Downtown";
find any branch using branch-name;
account.account-number := "A-535";
account.balance := 0;
store account;
customer.customer-name := "Hayes";
find any customer using customer-name;
connect account to depositor;
```



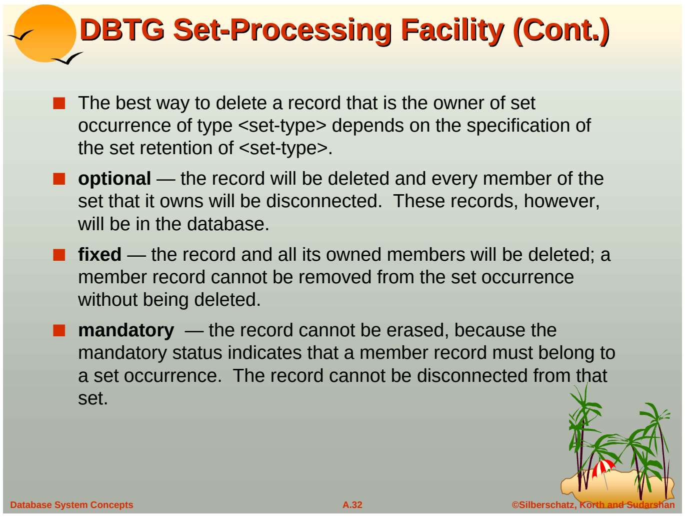
DBTG Set-Processing Facility (Cont.)

- Restrictions on how and when a member record can be removed from a set occurrence are specified at set-definition time via

  retention is <retention-mode>

- <retention-mode> can take one of the three forms:

1. **fixed** — a member record cannot be removed. To reconnect a record to another set, we must erase that record, recreate it, and then insert it into the new set occurrence.
2. **mandatory** — a member record of a particular set occurrence can be reconnected to another set occurrence of only type <set-type>.
3. **optional** — no restrictions on how and when a member record can be removed from a set occurrence.



DBTG Set-Processing Facility (Cont.)

- The best way to delete a record that is the owner of set occurrence of type <set-type> depends on the specification of the set retention of <set-type>.
- **optional** — the record will be deleted and every member of the set that it owns will be disconnected. These records, however, will be in the database.
- **fixed** — the record and all its owned members will be deleted; a member record cannot be removed from the set occurrence without being deleted.
- **mandatory** — the record cannot be erased, because the mandatory status indicates that a member record must belong to a set occurrence. The record cannot be disconnected from that set.

Set Ordering

Set ordering is specified by a programmer when the set is defined:

order is <order-mode>

- **first.** A new record is inserted in the first position; the set is in reverse chronological ordering.
- **last.** A new record is inserted in the final position; the set is in chronological ordering.
- **next.** Suppose that the currency pointer or <set-type> points to record *X*.
  - If *X* is a member type, a new record is inserted in the next position following *X*.
  - If *X* is an owner type, a new record is inserted in the first position.

Set Ordering (Cont.)

- **prior.** If *X* is a member type, a new record is inserted in the position just prior to *X*. If *X* is an owner type, a new record is inserted in the last position.
- **system default.** A new record is inserted in an arbitrary position determined by the system.
- **sorted.** A new record is inserted in a position that ensures that the set will remain sorted. The sorting order is specified by a particular key value when a programmer defines the set.
- Example: Consider the set occurrence of type *depositor* with the owner-record customer Turner and member-record accounts A-305, A-402, and A-408 ordered as indicated in our example schema (page A.14).

Set Ordering Example

- Add a new account A-125. For each <order-mode> option, the new set ordering is as follows:
- **first**: {A-125,A-305,A-402,A-408}
- **last**: {A-305,A-402,A-408,A-125}
- **next**: Suppose that the currency pointer points to record "Turner"; then the new set order is {A-125,A-305,A-402,A-408}
- **prior**: Suppose that the currency pointer points to record A-402; then the new set order is {A-305,A-125,A-402,A-408}
- **system default**: Any arbitrary order is acceptable; thus, {A-305,A-402,A-125,A-408} is a valid set ordering
- **sorted**: The set must be ordered in ascending order with account number being the key; thus, the ordering must be {A-125,A-305,A-402,A-408}

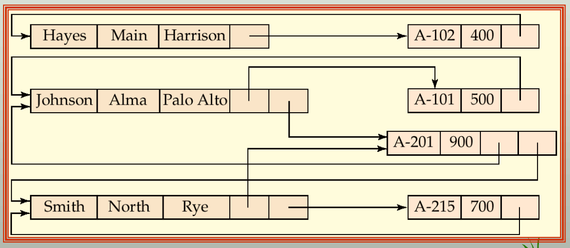
Mapping of Networks to Files

- We implement links by adding *pointer fields* to records that are associated via a link
- Each record must have one pointer field for each link with which it is associated.
- Example data-structure diagram and corresponding database.

Figure missing

Mapping of Networks to Files (Cont.)

- Diagram showing the sample instance with pointer fields to represent the links. Each link is replaced by two pointers.



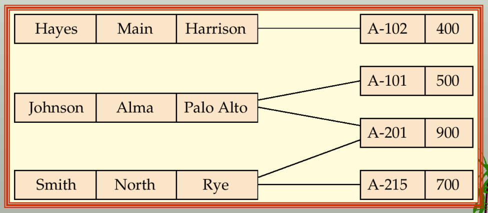
Mapping of Networks to Files (Cont.)

- Since the *depositor* link is many to many, each record can be associated with an arbitrary number of records (e.g., the *account* record would have a pointer to the *customer* record for each customer who has that account).
- Direct implementation of many-to-many relationships requires the use of variable length records.
- The DBTG model restricts links to be either one to one or one to many; the number of pointers needed is reduced, and it is possible to retain fixed-length records.

Mapping of Networks to Files (Cont.)

- Assume that the *depositor* link is one to many and is represented by the DBTG set *depositor* and this corresponding sample database.

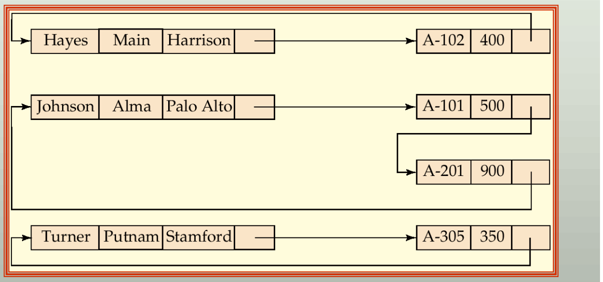
set name is *depositor*
owner is *customer*
member is *account*



Mapping of Networks to Files (Cont.)

- Because an *account* record can be associated with only one *customer* record, we need only one pointer in the *account* record to represent the *depositor* relationship.
- A *customer* record can be associated with many *account* records.
- Rather ant using multiple pointers in the *customer* record, we can use a *ring structure* to represent the entire occurrence of the DBTG set *depositor.*
- In a ring structure, the records of both the owner an member types for a set occurrence are organized into a circular list.
- There is one circular list for each set occurrence (that is, for each record of the owner type).

Example Ring Structure



Hayes | Main | Harrison — A-102 | 400

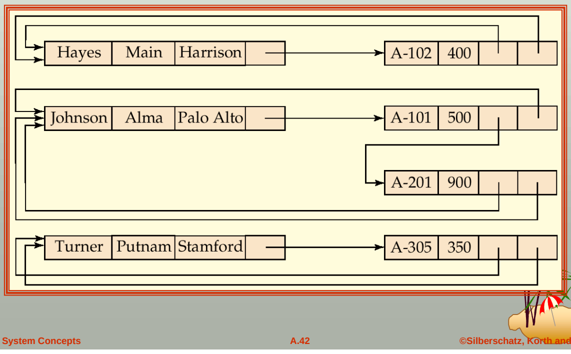
Johnson | Alma | Palo Alto — A-101 | 500

A-201 | 900

Turner | Putnam | Stamford — A-305 | 350

Modified Ring Structures

- Execute **find owner** via a ring structure in which every member-type record contains a second pointer which points to the owner record.



Hayes | Main | Harrison — A-102 | 400

Johnson | Alma | Palo Alto — A-101 | 500

A-201 | 900

Turner | Putnam | Stamford — A-305 | 350

Physical Placement of Records

- To specify the storage strategy for DBTG set, add a **placement** clause to the definition of the member record type.
- The clause

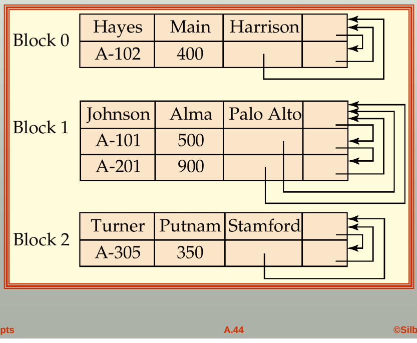
  placement clustered via *depositor*

  will store members of each set occurrence close to one another physically on disk, if possible, in the same block.
- Store owner and member records close to one another physically on disk by adding the clause **near owner.**

  placement clustered via *depositor* **near owner**

Physical Placement of Records (Cont.)

- Storing member records in the same block as the owner reduces the number of block accesses required to read an entire set occurrence.



Block 0

Hayes | Main | Harrison

A-102 | 400

Block 1

Johnson | Alma | Palo Alto

A-101 | 500

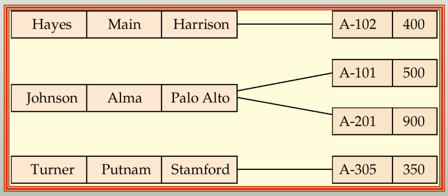
A-201 | 900

Block 2

Turner | Putnam | Stamford

A-305 | 350

Sample Database



Hayes | Main | Harrison — A-102 | 400

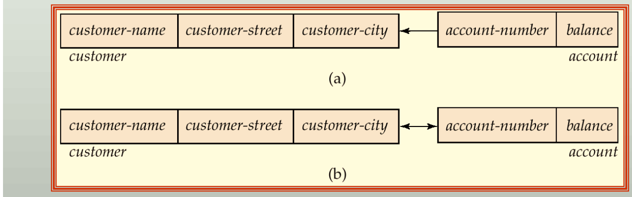
A-101 | 500

Johnson | Alma | Palo Alto

A-201 | 900

Turner | Putnam | Stamford — A-305 | 350

Two Data-Structure Diagrams



customer-name | *customer-street* | *customer-city* ← *account-number* | *balance*

customer *account*

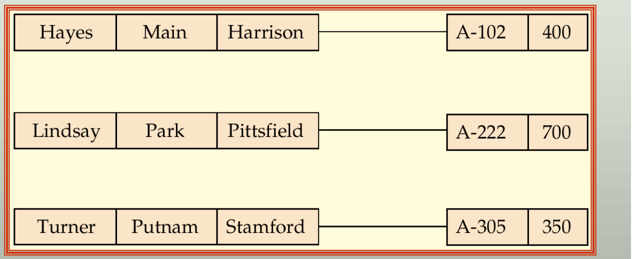
(a)

customer-name | *customer-street* | *customer-city* ↔ *account-number* | *balance*

customer *account*

(b)

Sample Database Corresponding to Diagram of Figure A.3b

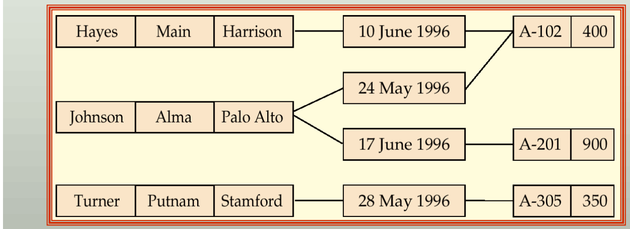


Hayes | Main | Harrison — A-102 | 400

Lindsay | Park | Pittsfield — A-222 | 700

Turner | Putnam | Stamford — A-305 | 350

Sample Database Corresponding to Diagram of Figure A.6b



Hayes | Main | Harrison — 10 June 1996 — A-102 | 400

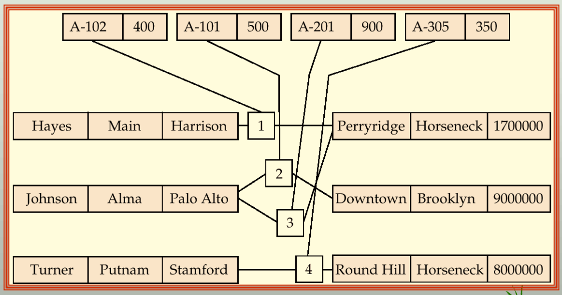
24 May 1996

Johnson | Alma | Palo Alto

17 June 1996 — A-201 | 900

Turner | Putnam | Stamford — 28 May 1996 — A-305 | 350

Sample Database Corresponding to Diagram of Figure A.8b



A-102 400
A-101 500
A-201 900
A-305 350

Hayes Main Harrison
1
Perryridge Horseneck 1700000

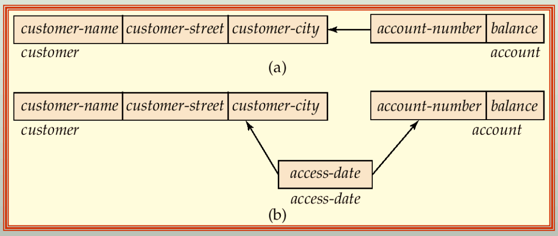
2

Johnson Alma Palo Alto
Downtown Brooklyn 9000000

3

Turner Putnam Stamford
4
Round Hill Horseneck 8000000

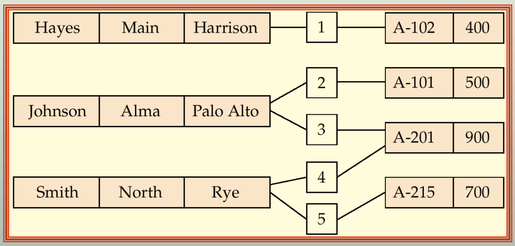
Two Data-Structure Diagrams



customer-name *customer-street* *customer-city*
customer
account-number *balance*
account
(a)

customer-name *customer-street* *customer-city*
customer
account-number *balance*
account
access-date
access-date
(b)

Sample Database Corresponding to the Diagram of Figure A.11



Hayes Main Harrison
1
A-102 400

2
A-101 500

Johnson Alma Palo Alto

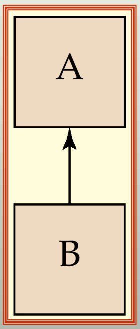
3
A-201 900

4

Smith North Rye
A-215 700

5

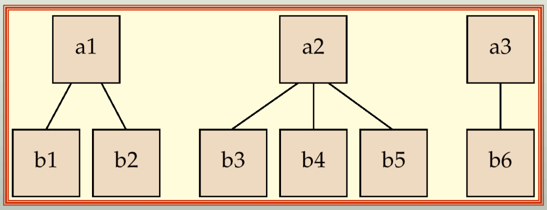
DBTG Set



A

B

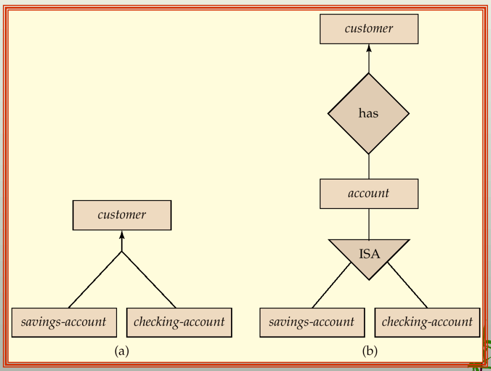
Three Set Occurrences



a1 a2 a3

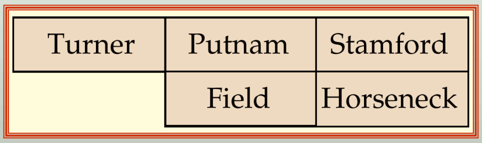
b1 b2 b3 b4 b5 b6

Data-Structure and E-R Diagram



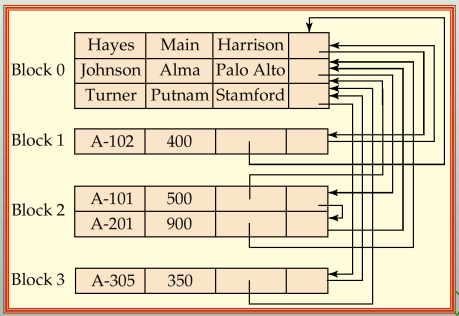
customer
has
account
customer
ISA
savings-account *checking-account*
(a)
savings-account *checking-account*
(b)

A *customer* Record



Turner Putnam Stamford
Field Horseneck

Clustered Record Placement for Instance for Figure A.1



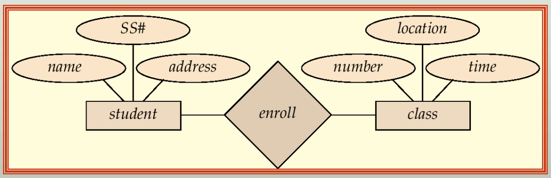
Block 0
Hayes Main Harrison
Johnson Alma Palo Alto
Turner Putnam Stamford

Block 1
A-102 400

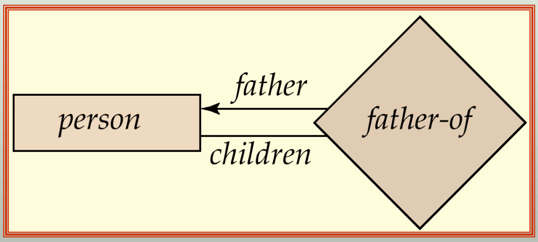
Block 2
A-101 500
A-201 900

Block 3
A-305 350

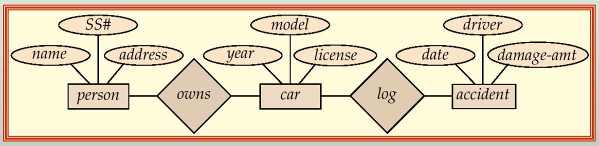
Class Enrollment E-R Diagram



Parent—Child E-R Diagram



Car-Insurance E-R Diagram


SS#
name
address
person
owns
model
year
license
car
log
driver
date
damage-amt
accident