IT Security

Multilevel Databases

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All infos about the database part in this lecture

http://dbresearch.uni-salzburg.at/teaching/2016ws/its/

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Mandatory Access Control (MAC)

- Why is discretionary access control (DAC) not enough?
  - users have the freedom to give other users access to data
  - all users see the same data (if they have access)
  - security policies cannot be centrally enforced
- Some applications need multilevel security
  - government, military, intelligence service
  - many industrial and corporate applications
- MAC is implemented in some DBMS (e.g., Oracle Label Security since 2009) or special versions of DBMS (e.g., SE-PostgreSQL)
- also operating systems implement MAC (SE-Linux, Windows Vista and later)

MAC Basics

- Security classes: levels of trust
  - TS (top secret) $>$ S (secret) $>$ C (confidential) $>$ U (unclassified, public)
- Subjects s
  - users, roles, accounts, programs
  - clearance $clear(s)$ is the trustworthiness of s
  - $clear(s)$ is a security class
- Objects o:
  - data objects (e.g., relation, tuple, attribute values)
  - classification $class(o)$ is the sensitivity of the data object
  - $class(o)$ is a security class

Bell LaPadula

- Example of MAC used in database (and many other) systems
- Named after developers D. E. Bell and L. J. LaPadula
- Access control rules
  - no read-up: s is allowed to read o only if $clear(s) \geq class(o)$
  - no write-down: s is allowed to write o only if $clear(s) \leq class(o)$ (also called $*$-property)
  - respect DAC: respect discretionary access control rules
- Trusted subjects
  - must be trustworthy according to security policy
  - not restricted by the $*$-property
  - can transfer data from higher to lower sensitivity

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Multilevel Model

- Multilevel relation
  - each attribute and each tuple in $R(A_1, A_2, \ldots, A_n)$ are classified
  - $C_i = class(A_i)$ is an attribute classification
  - $TC \geq max\{C_i \mid 1 \leq i \leq n\}$ is the tuple classification
  - the schema of the multilevel relation is

$$R(A_1, C_1, A_2, C_2, \ldots, A_n, C_n, TC)$$

Reading from Multilevel Relations

- Security requirement
  - users should not even know which data they cannot access
  - system should not reject requests for non-authorized data
  - but still the user should see a consistent view of the table
- Each clearance class c sees a different instance R^c of R:

$$R^c = (A_1^c, C_1^c, A_2^c, C_2^c, \ldots, A_n^c, C_n^c, TC^c)$$

- Attributes A_i^c visible by s with $clear(s) = c$:
  - $A_i^c = A_i$ if $C_i \leq c$
  - $A_i^c =$NULL if $C_i > c$
- Classifications C_i^c and TC^c:
  - $C_i^c = \min\{C_i, c\}$
  - $TC^c = \min\{TC, c\}$

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How to Deal with Updates?

- Problem:
  - subject with low clearance sees NULL value and tries to change it
  - but this NULL value is due to the low clearance
- Option 1 (bad): update value
  - values of subjects with higher clearance get lost
  - writers do not even realize that they are doing something harmful
- Option 2 (bad): reject update
  - writing subject can infer that there is a sensitive non-NULL value
  - can be systematically exploited
- Option 3 (good): Polyinstantiation
  - maintain multiple versions of tuples
  - versioned tuples must differ by sensitivity class TC
  - new model for integrity is required!

Integrity in Multi-Level Databases

- Entity integrity
- Null integrity
- Inter-instance integrity
- Polyinstantiation integrity

Enitity Integrity

- Keys in instance R^c are called apparent key
- Entity integrity: for each R^c and for each tuple in R^c
  1. key values must not be NULL
  2. all key attributes must have identical sensitivity class
  3. non-keys must be at least as sensitive as key

Null Integrity

- Null integrity: for each R^c
  1. NULL values always have sensitivity of key
  2. freedom of subsumption (= no unnecessary tuples)

Inter Instance Integrity

- Inter instance integrity: for any pair $R^c, R^{c'}$ with $c' < c$

$$R^{c'} = f(R^c)$$

  where f is called filter.
- The filter has the following properties
  1. for each tuple in R^c with key visible by c' a tuple must exist in $R^{c'}$
  2. no other tuples exist in $R^{c'}$
  3. subsumed tuples are eliminated

Polyinstantiation Integrity

- Polyinstantiation integrity: uniqueness of tuples in R
  - functional dependency

$$(key, C_{key}, C_i) \rightarrow A_i$$

must hold for any A_i in instance R^c

Implementation of Multilevel Databases

- integrity constraints allow implementation on top of “normal” relational system
- multilevel relation is fragmented into normal relations
- user queries compute answer from fragmented relations

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Example: Oracle Label Security/1

- Label security provides MAC for Oracle DBMS
- Each tuple and each user has a label
- Labels consist of
  - level (class / clearance)
  - compartments: segregate data within a given level
  - groups: segregate data within level using organizational hierarchy
- subject s can access object o if
  - label of s must be at least level of o
  - s must have at least one compartments of o
  - s must have at least one group or supergroup of o

User labels

- User labels
  - max read clearance
  - min write clearance
  - default clearance (at login)
  - row level: default for inserted tuples
  - read and write compartments
  - read and write groups
- Trusted users / stored procedures
  - read / writeup / writedown
  - write across: change compartment and group
  - profile access: become other user (like Unix 'su')