Chapter 5: Confidentiality Policies

- Overview
  - What is a confidentiality model
- Bell-LaPadula Model
  - General idea
  - Informal description of rules

Overview

- Goals of Confidentiality Model
- Bell-LaPadula Model
  - Informally
  - Example Instantiation

Confidentiality Policy

- Goal: prevent the unauthorized disclosure of information
  - Deals with information flow
  - Integrity incidental
- Multi-level security models are best-known examples
  - Bell-LaPadula Model basis for many, or most, of these

Bell-LaPadula Model, Step 1

- Security levels arranged in linear ordering
  - Top Secret: highest
  - Secret
  - Confidential
  - Unclassified: lowest
- Levels consist of *security clearance* $L(s)$
  - Objects have *security classification* $L(o)$

Example

security level	*subject*	*object*
Top Secret	Tamara	Personnel Files
Secret	Samuel	E-Mail Files
Confidential	Claire	Activity Logs
Unclassified	Ulaley	Telephone Lists

- Tamara can read all files
- Claire cannot read Personnel or E-Mail Files
- Ulaley can only read Telephone Lists

Reading Information

- Information flows *up*, not *down*
  - "Reads up" disallowed, "reads down" allowed
- Simple Security Condition (Step 1)
  - Subject *s* can read object *o* iff $L(o) \le L(s)$ and *s* has permission to read *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no reads up" rule

Writing Information

- Information flows up, not down
  - "Writes up" allowed, "writes down" disallowed
- *-Property (Step 1)
  - Subject s can write object o iff $L(s) \leq L(o)$ and s has permission to write o
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no writes down" rule

Basic Security Theorem, Step 1

- If a system is initially in a secure state, and every transition of the system satisfies the simple security condition, step 1, and the *-property, step 1, then every state of the system is secure
  – Proof: induct on the number of transitions

Bell-LaPadula Model, Step 2

- Expand notion of security level to include categories
- Security level is (*clearance*, *category set*)
- Examples
  - (Top Secret, { NUC, EUR, ASI })
  - (Confidential, { EUR, ASI })
  - (Secret, { NUC, ASI })

Levels and Lattices

- (A, C) *dom* (A', C') iff $A' \le A$ and $C' \subseteq C$
- Examples
  - (Top Secret, {NUC, ASI}) *dom* (Secret, {NUC})
  - (Secret, {NUC, EUR}) *dom* (Confidential,{NUC, EUR})
  - (Top Secret, {NUC}) ¬*dom* (Confidential, {EUR})
- Let C be set of classifications, K set of categories. Set of security levels $L = C \times K$, *dom* form lattice
  - $lub(L) = (max(A), C)$
  - $glb(L) = (min(A), \emptyset)$

Levels and Ordering

- Security levels partially ordered
  - Any pair of security levels may (or may not) be related by *dom*
- "dominates" serves the role of "greater than" in step 1
  - "greater than" is a total ordering, though

Reading Information

- Information flows *up*, not *down*
  - "Reads up" disallowed, "reads down" allowed
- Simple Security Condition (Step 2)
  - Subject *s* can read object *o* iff *L*(*s*) *dom* *L*(*o*) and *s* has permission to read *o*
    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
  - Sometimes called "no reads up" rule

Writing Information

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    - Note: combines mandatory control (relationship of security levels) and discretionary control (the required permission)
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Basic Security Theorem, Step 2

- If a system is initially in a secure state, and every transition of the system satisfies the simple security condition, step 2, and the *-property, step 2, then every state of the system is secure
  - Proof: induct on the number of transitions
  - In actual Basic Security Theorem, discretionary access control treated as third property, and simple security property and *-property phrased to eliminate discretionary part of the definitions — but simpler to express the way done here.

Problem

- Colonel has (Secret, {NUC, EUR}) clearance
- Major has (Secret, {EUR}) clearance
  – Major can talk to colonel (“write up” or “read down”)
  – Colonel cannot talk to major (“read up” or “write down”)
- Clearly absurd!

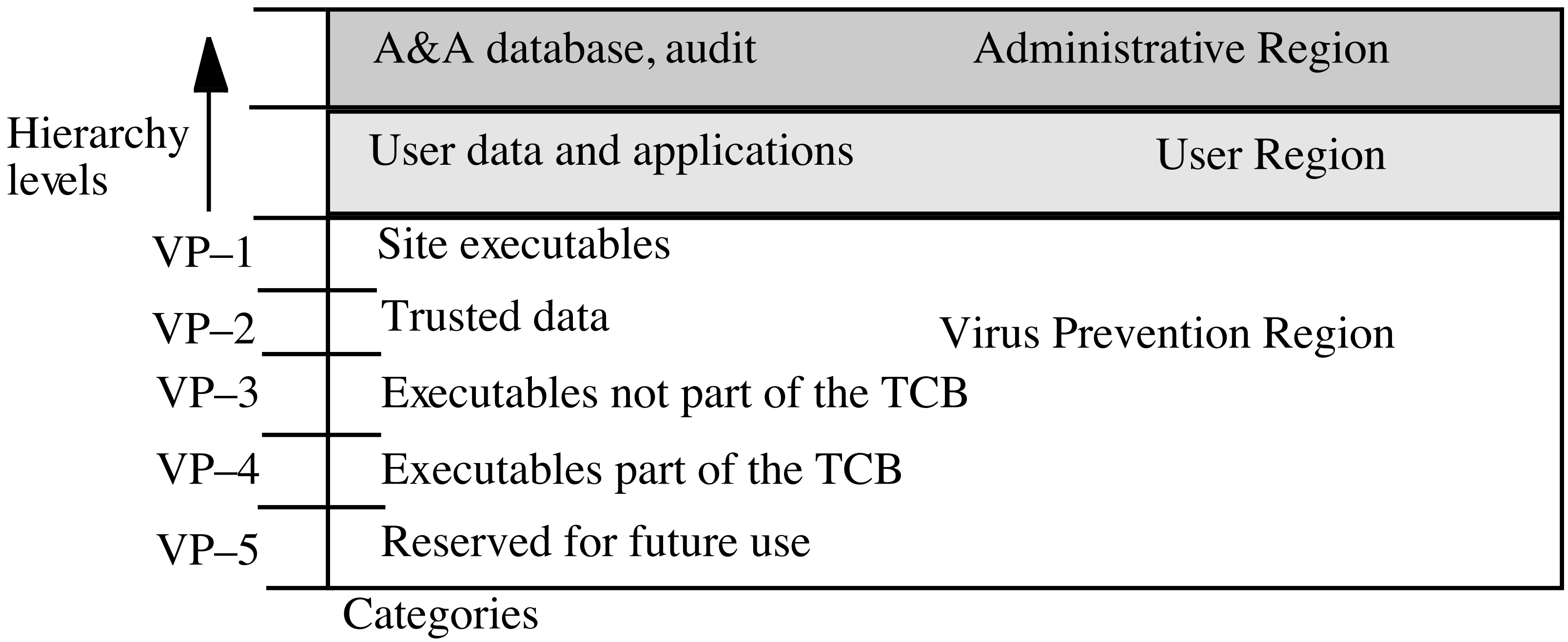
Solution

- Define maximum, current levels for subjects
  - *maxlevel*(*s*) *dom curlevel*(*s*)
- Example
  - Treat Major as an object (Colonel is writing to him/her)
  - Colonel has *maxlevel* (Secret, { NUC, EUR })
  - Colonel sets *curlevel* to (Secret, { EUR })
  - Now *L*(Major) *dom curlevel*(Colonel)
    - Colonel can write to Major without violating “no writes down”
  - Does *L*(*s*) mean *curlevel*(*s*) or *maxlevel*(*s*)?
    - Formally, we need a more precise notation

DG/UX System

- Provides mandatory access controls
  - MAC label identifies security level
  - Default labels, but can define others
- Initially
  - Subjects assigned MAC label of parent
    - Initial label assigned to user, kept in Authorization and Authentication database
  - Object assigned label at creation
    - Explicit labels stored as part of attributes
    - Implicit labels determined from parent directory

MAC Regions



IMPL_HI is "maximum" (least upper bound) of all levels
IMPL_LO is "minimum" (greatest lower bound) of all levels

Directory Problem

- Process *p* at MAC_A tries to create file */tmp*/*x*
- */tmp*/*x* exists but has MAC label MAC_B
  - Assume MAC_B dom MAC_A
- Create fails
  - Now *p* knows a file named *x* with a higher label exists
- Fix: only programs with same MAC label as directory can create files in the directory
  - Now compilation won't work, mail can't be delivered

Multilevel Directory

- Directory with a set of subdirectories, one per label
  - Not normally visible to user
  - p creating */tmp*/*x* actually creates */tmp*/*d*/*x* where *d* is directory corresponding to MAC_A
  - All *p*'s references to */tmp* go to */tmp*/*d*
- *p* cd's to */tmp*/*a*, then to ..
  - System call stat(".", &buf) returns inode number of real directory
  - System call dg_stat(".", &buf) returns inode of */tmp*

Object Labels

- Requirement: every file system object must have MAC label

1. Roots of file systems have explicit MAC labels
   - If mounted file system has no label, it gets label of mount point
2. Object with implicit MAC label inherits label of parent

Object Labels

- Problem: object has two names
  - /*x*/*y*/*z*, /*a*/*b*/*c* refer to same object
  - *y* has explicit label IMPL_HI
  - *b* has explicit label IMPL_B
- Case 1: hard link created while file system on DG/UX system, so …

3. Creating hard link requires explicit label
   - If implicit, label made explicit
   - Moving a file makes label explicit

Object Labels

- Case 2: hard link exists when file system mounted
  - No objects on paths have explicit labels: paths have same *implicit* labels
  - An object on path acquires an explicit label: implicit label of child must be preserved

  so …

4. Change to directory label makes child labels explicit *before* the change

Object Labels

- Symbolic links are files, and treated as such, so …

5. When resolving symbolic link, label of object is label of target of the link
   - System needs access to the symbolic link itself

Using MAC Labels

- Simple security condition implemented
- *-property not fully implemented
  - Process MAC must equal object MAC
  - Writing allowed only at same security level
- Overly restrictive in practice

MAC Tuples

- Up to 3 MAC ranges (one per region)
- MAC range is a set of labels with upper, lower bound
  - Upper bound must dominate lower bound of range
- Examples
  1. [(Secret, {NUC}), (Top Secret, {NUC})]
  2. [(Secret, ∅), (Top Secret, {NUC, EUR, ASI})]
  3. [(Confidential, {ASI}), (Secret, {NUC, ASI})]

MAC Ranges

1. [(Secret, {NUC}), (Top Secret, {NUC})]
2. [(Secret, ∅), (Top Secret, {NUC, EUR, ASI})]
3. [(Confidential, {ASI}), (Secret, {NUC, ASI})]

- (Top Secret, {NUC}) in ranges 1, 2
- (Secret, {NUC, ASI}) in ranges 2, 3
- [(Secret, {ASI}), (Top Secret, {EUR})] not valid range
  - as (Top Secret, {EUR}) ¬*dom* (Secret, {ASI})

Objects and Tuples

- Objects must have MAC labels
  - May also have MAC label
  - If both, tuple overrides label
- Example
  - Paper has MAC range:
    [(Secret, {EUR}), (Top Secret, {NUC, EUR})]

MAC Tuples

- Process can read object when:
  - Object MAC range (*lr*, *hr*); process MAC label *pl*
  - *pl dom hr*
    - Process MAC label grants read access to upper bound of range
- Example
  - Peter, with label (Secret, {EUR}), cannot read paper
    - (Top Secret, {NUC, EUR}) *dom* (Secret, {EUR})
  - Paul, with label (Top Secret, {NUC, EUR, ASI}) can read paper
    - (Top Secret, {NUC, EUR, ASI}) *dom* (Top Secret, {NUC, EUR})

MAC Tuples

- Process can write object when:
  - Object MAC range (*lr*, *hr*); process MAC label *pl*
  - $pl \in (lr, hr)$
    - Process MAC label grants write access to any label in range
- Example
  - Peter, with label (Secret, {EUR}), can write paper
    - (Top Secret, {NUC, EUR}) *dom* (Secret, {EUR}) and (Secret, {EUR}) *dom* (Secret, {EUR})
  - Paul, with label (Top Secret, {NUC, EUR, ASI}), cannot read paper
    - (Top Secret, {NUC, EUR, ASI}) *dom* (Top Secret, {NUC, EUR})

Key Points

- Confidentiality models restrict flow of information
- Bell-LaPadula models multilevel security
  - Cornerstone of much work in computer security