ECS 235B Module 17
Confidentiality Policies and the Bell-LaPadula Model
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 are called security clearance $L(s)$ for subjects and security classification $L(o)$ for objects
### Example

<table>
<thead>
<tr>
<th>security level</th>
<th>subject</th>
<th>object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Secret</td>
<td>Tamara</td>
<td>Personnel Files</td>
</tr>
<tr>
<td>Secret</td>
<td>Samuel</td>
<td>E-Mail Files</td>
</tr>
<tr>
<td>Confidential</td>
<td>Claire</td>
<td>Activity Logs</td>
</tr>
<tr>
<td>Unclassified</td>
<td>Ulaley</td>
<td>Telephone Lists</td>
</tr>
</tbody>
</table>

- 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 $L(o) \leq L(s)$ 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 \((\text{clearance}, \text{category set})\)
• Examples
  • ( Top Secret, \{ NUC, EUR, ASI \} )
  • ( Confidential, \{ EUR, ASI \} )
  • ( Secret, \{ NUC, ASI \} )
Levels and Lattices

• \((A, C) \text{ dom } (A`, C`) \iff A` \leq A \text{ and } C` \subseteq C\)

• Examples
  • (Top Secret, \{NUC, ASI\}) \text{ dom } (Secret, \{NUC\})
  • (Secret, \{NUC, EUR\}) \text{ dom } (Confidential,\{NUC, EUR\})
  • (Top Secret, \{NUC\}) \n\text{ dom } (Confidential, \{EUR\})

• Let \(C\) be set of classifications, \(K\) set of categories. Set of security levels \(L = C \times K\), \text{ dom } form lattice
  • \(\text{lub}(L) = (\max(A), C)\)
  • \(\text{glb}(L) = (\min(A), \emptyset)\)
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 $L(s) \text{ dom } L(o)$ 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

• Information flows up, not down
  • “Writes up” allowed, “writes down” disallowed

• *-Property (Step 2)
  • Subject $s$ can write object $o$ iff $L(o) \subseteq \text{dom} L(s)$ 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 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
  • $\text{maxlevel}(s)$ dom $\text{curlevel}(s)$

• Example
  • Treat Major as an object (Colonel is writing to him/her)
  • Colonel has $\text{maxlevel}$ (Secret, { NUC, EUR })
  • Colonel sets $\text{curlevel}$ to (Secret, { EUR })
  • Now $L(\text{Major})$ dom $\text{curlevel}(\text{Colonel})$
    • Colonel can write to Major without violating “no writes down”
  • Does $L(s)$ mean $\text{curlevel}(s)$ or $\text{maxlevel}(s)$?
    • Formally, we need a more precise notation
Example: Trusted Solaris

• Provides mandatory access controls
  • Security level represented by sensitivity label
  • Least upper bound of all sensitivity labels of a subject called clearance
  • Default labels ADMIN_HIGH (dominates any other label) and ADMIN_LOW (dominated by any other label)

• $S$ has controlling user $U_S$
  • $S_L$ sensitivity label of subject
  • $\text{privileged}(S, P)$ true if $S$ can override or bypass part of security policy $P$
  • $\text{asserted} (S, P)$ true if $S$ is doing so
Rules

$C_L$ clearance of $S$, $S_L$ sensitivity label of $S$, $U_S$ controlling user of $S$, and $O_L$ sensitivity label of $O$

1. If $\neg$privileged($S$, “change $S_L$”), then no sequence of operations can change $S_L$ to a value that it has not previously assumed

2. If $\neg$privileged($S$, “change $S_L$”), then $\neg$privileged($S$, “change $S_L$”)

3. If $\neg$privileged($S$, “change $S_L$”), then no value of $S_L$ can be outside the clearance of $U_S$

4. For all subjects $S$, named objects $O$, if $\neg$privileged($S$, “change $O_L$”), then no sequence of operations can change $O_L$ to a value that it has not previously assumed
Rules (con’t)

$C_L$ clearance of $S$, $S_L$ sensitivity label of $S$, $U_S$ controlling user of $S$, and $O_L$ sensitivity label of $O$

5. For all subjects $S$, named objects $O$, if $\neg{\text{privileged}}(S, \text{“override } O\text{’s mandatory read access control”})$, then read access to $O$ is granted only if $S_L \text{ dom } O_L$
   • Instantiation of simple security condition

6. For all subjects $S$, named objects $O$, if $\neg{\text{privileged}}(S, \text{“override } O\text{’s mandatory write access control”})$, then write access to $O$ is granted only if $O_L \text{ dom } S_L$ and $C_L \text{ dom } O_L$
   • Instantiation of *-property
Initial Assignment of Labels

• Each account is assigned a label range [clearance, minimum]
• On login, Trusted Solaris determines if the session is single-level
  • If clearance = minimum, single level and session gets that label
  • If not, multi-level; user asked to specify clearance for session; must be in the label range
  • In multi-level session, can change to any label in the range of the session clearance to the minimum
Writing

• Allowed when subject, object labels are the same or file is in downgraded directory $D$ with sensitivity label $D_L$ and all the following hold:
  • $S_L \text{ dom } D_L$
  • $S$ has discretionary read, search access to $D$
  • $O_L \text{ dom } S_L$ and $O_L \neq S_L$
  • $S$ has discretionary write access to $O$
  • $C_L \text{ dom } O_L$

• Note: subject cannot read object
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`
  - System call `stat(“.”, &buf)` returns information about `/tmp/d`
  - System call `mldstat(“.”, &buf)` returns information about `/tmp`
Labeled Zones

- Used in Trusted Solaris Extensions, various flavors of Linux
- **Zone**: virtual environment tied to a unique label
  - Each process can only access objects in its zone
- **Global zone** encompasses everything on system
  - Its label is ADMIN_HIGH
  - Only system administrators can access this zone
- Each zone has a unique root directory
  - All objects within the zone have that zone’s label
  - Each zone has a unique label
More about Zones

• Can import (mount) file systems from other zones provided:
  • If importing *read-only*, importing zone’s label must dominate imported zone’s label
  • If importing *read-write*, importing zone’s label must equal imported zone’s label
    • So the zones are the same; import unnecessary
  • Labels checked at time of import

• Objects in imported file system retain their labels
Example

- \(L_1\) dom \(L_2\)
- \(L_3\) dom \(L_2\)

- Process in \(L_1\) can read any file in the export directory of \(L_2\) (assuming discretionary permissions allow it)
- \(L_1, L_3\) disjoint
  - Do not share any files
- System directories imported from global zone, at ADMIN_LOW
  - So can only be read
Quiz

In a system implementing the Bell-LaPadula model, Tom’s file $f$ is in the compartment $SC_f = (\text{secret}, \{a, b\})$. He wants Tina, whose process is in the compartment $SC_{Tina} = (\text{confidential}, \{a\})$ to be able to read the file, so he sets turns on the discretionary permission \textit{read} for Tina. Can Tina now read Tom’s file?

- Yes, because Tom has set the discretionary permissions to allow this.
- Yes, because $SC_f$ \textit{dom} $SC_{Tina}$, and reads up are allowed.
- No, because $SC_f$ \textit{dom} $SC_{Tina}$ and reads up are not allowed.
- No, because $SC_f$ \textit{dom} $SC_{Tina}$, so Tom must set the special discretionary right that allows the discretionary right \textit{read} to override the mandatory controls, and he has not done so.