Confidentiality Policies

Chapter 5

Outline

- Overview
  - What is a confidentiality model
- Bell-LaPadula Model
  - General idea
  - Informal description of rules
  - Formal description of rules
- Tranquility
- Declassification
- Controversy
  - †-property
  - System Z

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

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

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

- Information flows up, not down
  - “Writes up” allowed, “writes down” disallowed
- *-Property (Step 2)
  - Subject *s* can write object *o* iff *L*(*o*) *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
  - *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

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
  - *privileged*(S, P) true if S can override or bypass part of security policy P
  - *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 ¬*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 ¬*privileged*(*S*, "change S_L"), then ¬*privileged*(*S*, "change S_L")
3. If ¬*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 ¬*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 ¬*privileged*(*S*, "override *O*'s mandatory read access control"), then write access to *O* is granted only if S_L *dom* O_L
   - Instantiation of simple security condition
6. For all subjects *S,* named objects *O*, if ¬*privileged*(*S*, "override *O*'s mandatory write access control"), then read access to *O* is granted only if O_L *dom* S_L and C_L *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 *dom* D_L
  - *S* has discretionary read, search access to *D*
  - O_L *dom* S_L and $O_L \neq S_L$
  - *S* has discretionary write access to *O*
  - C_L *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*

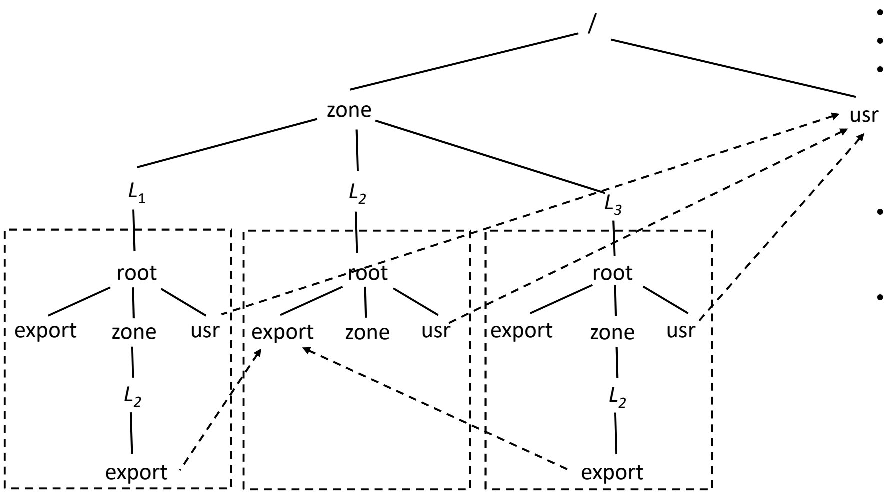
Labeled Zones

- 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

Formal Model Definitions

- S subjects, O objects, P rights
  - Defined rights: r read, a write, w read/write, e empty
- M set of possible access control matrices
- C set of clearances/classifications, K set of categories, $L = C \times K$ set of security levels
- $F = \{ (f_s, f_o, f_c) \}$
  - $f_s(s)$ maximum security level of subject s
  - $f_c(s)$ current security level of subject s
  - $f_o(o)$ security level of object o

More Definitions

- Hierarchy functions H: $O \to P(O)$
- Requirements
  1. $o_i \neq o_j \Rightarrow h(o_i) \cap h(o_j) = \varnothing$
  2. There is no set $\{ o_1, \ldots, o_k \} \subseteq O$ such that for $i = 1, \ldots, k$, $o_{i+1} \in h(o_i)$ and $o_{k+1} = o_1$.
- Example
  - Tree hierarchy; take $h(o)$ to be the set of children of o
  - No two objects have any common children (#1)
  - There are no loops in the tree (#2)

States and Requests

- *V* set of states
  - Each state is (*b*, *m*, *f*, *h*)
    - *b* is like *m*, but excludes rights not allowed by *f*
- *R* set of requests for access
- *D* set of outcomes
  - y allowed, n not allowed, i illegal, o error
- *W* set of actions of the system
  - $W \subseteq R \times D \times V \times V$

History

- $X = R^N$ set of sequences of requests
- $Y = D^N$ set of sequences of decisions
- $Z = V^N$ set of sequences of states
- Interpretation
  - At time $t \in N$, system is in state $z_{t-1} \in V$; request $x_t \in R$ causes system to make decision $y_t \in D$, transitioning the system into a (possibly new) state $z_t \in V$
- System representation: $\Sigma(R, D, W, z_0) \in X \times Y \times Z$
  - $(x, y, z) \in \Sigma(R, D, W, z_0)$ iff $(x_t, y_t, z_{t-1}, z_t) \in W$ for all t
  - (x, y, z) called an *appearance* of $\Sigma(R, D, W, z_0)$

Example

- S = { s }, O = { o }, P = { r, w }
- C = { High, Low }, K = { All }
- For every $f \in F$, either $f_c(s)$ = (High, { All }) or $f_c(s)$ = (Low, { All })
- Initial State:
  - b_1 = { (s, o, r) }, $m_1 \in M$ gives s read access over o, and for $f_1 \in F$, $f_{c,1}(s)$ = (High, {All}), $f_{o,1}(o)$ = (Low, {All})
  - Call this state $v_0 = (b_1, m_1, f_1, h_1) \in V$.

First Transition

- Now suppose in state v_0: $S = \{ s, s' \}$
- Suppose $f_{c,1}(s') = (\text{Low}, \{\text{All}\})$
- $m_1 \in M$ gives s and s' read access over o
- As s' not written to o, $b_1 = \{ (s, o, \underline{r}) \}$
- $z_0 = v_0$; if s' requests r_1 to write to o:
  - System decides $d_1 = \underline{y}$
  - New state $v_1 = (b_2, m_1, f_1, h_1) \in V$
  - $b_2 = \{ (s, o, \underline{r}), (s', o, \underline{w}) \}$
  - Here, $x = (r_1)$, $y = (\underline{y})$, $z = (v_0, v_1)$

Second Transition

- Current state $v_1 = (b_2, m_1, f_1, h_1) \in V$
  - b_2 = { (s, o, r), (s', o, w) }
  - $f_{c,1}(s)$ = (High, { All }), $f_{o,1}(o)$ = (Low, { All })
- s' requests r_2 to write to o:
  - System decides d_2 = n (as $f_{c,1}(s)$ *dom* $f_{o,1}(o)$)
  - New state $v_2 = (b_2, m_1, f_1, h_1) \in V$
  - b_2 = { (s, o, r), (s', o, w) }
  - So, $x = (r_1, r_2)$, y = (y, n), $z = (v_0, v_1, v_2)$, where $v_2 = v_1$

Basic Security Theorem

- Define action, secure formally
  - Using a bit of foreshadowing for “secure”
- Restate properties formally
  - Simple security condition
  - *-property
  - Discretionary security property
- State conditions for properties to hold
- State Basic Security Theorem

Action

- A request and decision that causes the system to move from one state to another
  - Final state may be the same as initial state
- $(r, d, v, v') \in R \times D \times V \times V$ is an *action* of $\Sigma(R, D, W, z_0)$ iff there is an $(x, y, z) \in \Sigma(R, D, W, z_0)$ and a $t \in N$ such that $(r, d, v, v') = (x_t, y_t, z_t, z_{t-1})$
  - Request r made when system in state v; decision d moves system into (possibly the same) state v'
  - Correspondence with (x_t, y_t, z_t, z_{t-1}) makes states, requests, part of a sequence

Simple Security Condition

- $(s, o, p) \in S \times O \times P$ satisfies the simple security condition relative to f (written *ssc rel f*) iff one of the following holds:
  1. $p = \underline{\mathrm{e}}$ or $p = \underline{\mathrm{a}}$
  2. $p = \underline{\mathrm{r}}$ or $p = \underline{\mathrm{w}}$ and $f_s(s)$ *dom* $f_o(o)$
- Holds vacuously if rights do not involve reading
- If all elements of *b* satisfy *ssc rel f*, then state satisfies simple security condition
- If all states satisfy simple security condition, system satisfies simple security condition

Necessary and Sufficient

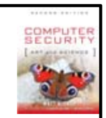
- $\Sigma(R, D, W, z_0)$ satisfies the simple security condition for any secure state z_0 iff for every action $(r, d, (b, m, f, h), (b', m', f', h'))$, W satisfies
  - Every $(s, o, p) \in b - b'$ satisfies *ssc rel f*
  - Every $(s, o, p) \in b'$ that does not satisfy *ssc rel f* is not in b
- Note: “secure” means z_0 satisfies *ssc rel f*
- First says every (s, o, p) added satisfies *ssc rel f*; second says any (s, o, p) in b' that does not satisfy *ssc rel f* is deleted

*-Property

- $b(s: p_1, \ldots, p_n)$ set of all objects that s has $p_1, \ldots, p_n$ access to
- State (b, m, f, h) satisfies the *-property iff for each $s \in S$ the following hold:
  1. $b(s: \underline{\text{a}}) \neq \varnothing \Rightarrow [\forall o \in b(s: \underline{\text{a}}) \ [f_o(o) \ dom \ f_c(s)]]$
  2. $b(s: \underline{\text{w}}) \neq \varnothing \Rightarrow [\forall o \in b(s: \underline{\text{w}}) \ [f_o(o) = f_c(s)]]$
  3. $b(s: \underline{\text{r}}) \neq \varnothing \Rightarrow [\forall o \in b(s: \underline{\text{r}}) \ [f_c(s) \ dom \ f_o(o)]]$
- Idea: for writing, object dominates subject; for reading, subject dominates object

*-Property

- If all states satisfy simple security condition, system satisfies simple security condition
- If a subset S' of subjects satisfy *-property, then *-property satisfied relative to $S' \subseteq S$
- Note: tempting to conclude that *-property includes simple security condition, but this is false
  - See condition placed on w right for each



Necessary and Sufficient

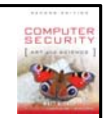
- $\Sigma(R, D, W, z_0)$ satisfies the *-property relative to $S' \subseteq S$ for any secure state z_0 iff for every action $(r, d, (b, m, f, h), (b', m', f', h'))$, W satisfies the following for every $s \in S'$
  - Every $(s, o, p) \in b - b'$ satisfies the *-property relative to S'
  - Every $(s, o, p) \in b'$ that does not satisfy the *-property relative to S' is not in b
- Note: "secure" means z_0 satisfies *-property relative to S'
- First says every (s, o, p) added satisfies the *-property relative to S'; second says any (s, o, p) in b' that does not satisfy the *-property relative to S' is deleted

Discretionary Security Property

- State (b, m, f, h) satisfies the discretionary security property iff, for each (s, o, p) $\in b$, then $p \in m[s, o]$
- Idea: if *s* can read *o*, then it must have rights to do so in the access control matrix *m*
- This is the discretionary access control part of the model
  - The other two properties are the mandatory access control parts of the model

Necessary and Sufficient

- $\Sigma(R, D, W, z_0)$ satisfies the ds-property for any secure state z_0 iff, for every action $(r, d, (b, m, f, h), (b', m', f', h'))$, W satisfies:
  - Every $(s, o, p) \in b - b'$ satisfies the ds-property
  - Every $(s, o, p) \in b'$ that does not satisfy the ds-property is not in b
- Note: "secure" means z_0 satisfies ds-property
- First says every (s, o, p) added satisfies the ds-property; second says any (s, o, p) in b' that does not satisfy the *-property is deleted



Secure

- A system is secure iff it satisfies:
  - Simple security condition
  - *-property
  - Discretionary security property
- A state meeting these three properties is also said to be secure

Basic Security Theorem

- $\Sigma(R, D, W, z_0)$ is a secure system if z_0 is a secure state and *W* satisfies the conditions for the preceding three theorems
    - The theorems are on the slides titled "Necessary and Sufficient"

Rule

- $\rho: R \times V \rightarrow D \times V$
- Takes a state and a request, returns a decision and a (possibly new) state
- Rule ρ *ssc-preserving* if for all $(r, v) \in R \times V$ and v satisfying *ssc rel f*, $\rho(r, v) = (d, v')$ means that v' satisfies *ssc rel f′*.
  - Similar definitions for *-property, ds-property
  - If rule meets all 3 conditions, it is *security-preserving*

Unambiguous Rule Selection

- Problem: multiple rules may apply to a request in a state
  - if two rules act on a read request in state v …
- Solution: define relation $W(\omega)$ for a set of rules $\omega = \{ \rho_1, \ldots, \rho_m \}$ such that a state $(r, d, v, v') \in W(\omega)$ iff either
  - $d = \underline{i}$; or
  - for exactly one integer j, $\rho_j(r, v) = (d, v')$
- Either request is illegal, or only one rule applies

Rules Preserving *SSC*

- Let ω be set of *ssc*-preserving rules. Let state z_0 satisfy simple security condition. Then $\Sigma(R, D, W(\omega), z_0)$ satisfies simple security condition
  - Proof: by contradiction.
    - Choose $(x, y, z) \in \Sigma(R, D, W(\omega), z_0)$ as state not satisfying simple security condition; then choose $t \in N$ such that (x_t, y_t, z_t) is first appearance not meeting simple security condition
    - As $(x_t, y_t, z_t, z_{t-1}) \in W(\omega)$, there is unique rule $\rho \in \omega$ such that $\rho(x_t, z_{t-1}) = (y_t, z_t)$ and $y_t \neq \underline{i}$.
    - As ρ ssc-preserving, and z_{t-1} satisfies simple security condition, then z_t meets simple security condition, contradiction.

Adding States Preserving *SSC*

- Let $v = (b, m, f, h)$ satisfy simple security condition. Let $(s, o, p) \notin b$, $b' = b \cup \{ (s, o, p) \}$, and $v' = (b', m, f, h)$. Then v' satisfies simple security condition iff:
    1. Either p = <u>e</u> or p = <u>a</u>; or
    2. Either p = <u>r</u> or p = <u>w</u>, and $f_c(s)$ *dom* $f_o(o)$
    - Proof
        1. Immediate from definition of simple security condition and v' satisfying *ssc rel f*
        2. v' satisfies simple security condition means $f_c(s)$ *dom* $f_o(o)$, and for converse, $(s, o, p) \in b'$ satisfies *ssc rel f*, so v' satisfies simple security condition

Rules, States Preserving *-Property

- Let ω be set of *-property-preserving rules, state z_0 satisfies the *-property. Then $\Sigma(R, D, W(\omega), z_0)$ satisfies *-property
- Let $v = (b, m, f, h)$ satisfy *-property. Let $(s, o, p) \notin b$, $b' = b \cup \{ (s, o, p) \}$, and $v' = (b', m, f, h)$. Then v' satisfies *-property iff one of the following holds:
    1. p = e̲ or p = a̲
    2. p = r̲ or p = w̲ and $f_c(s)$ *dom* $f_o(o)$

Rules, States Preserving ds-Property

- Let ω be set of ds-property-preserving rules, state z_0 satisfies ds-property. Then $\Sigma(R, D, W(\omega), z_0)$ satisfies ds-property
- Let $v = (b, m, f, h)$ satisfy ds-property. Let $(s, o, p) \notin b$, $b' = b \cup \{ (s, o, p) \}$, and $v' = (b', m, f, h)$. Then v' satisfies ds-property iff $p \in m[s, o]$.

Combining

- Let ρ be a rule and $\rho(r, v) = (d, v')$, where $v = (b, m, f, h)$ and $v' = (b', m', f', h')$. Then:
  1. If $b' \subseteq b$, $f' = f$, and v satisfies the simple security condition, then v' satisfies the simple security condition
  2. If $b' \subseteq b$, $f' = f$, and v satisfies the *-property, then v' satisfies the *-property
  3. If $b' \subseteq b$, $m[s, o] \subseteq m'[s, o]$ for all $s \in S$ and $o \in O$, and v satisfies the ds-property, then v' satisfies the ds-property

Proof

1. Suppose *v* satisfies simple security property.
   a) $b' \subseteq b$ and $(s, o, \underline{r}) \in b'$ implies $(s, o, \underline{r}) \in b$
   b) $b' \subseteq b$ and $(s, o, \underline{w}) \in b'$ implies $(s, o, \underline{w}) \in b$
   c) So $f_c(s)$ *dom* $f_o(o)$
   d) But $f' = f$
   e) Hence $f'_c(s)$ *dom* $f'_o(o)$
   f) So v' satisfies simple security condition

2, 3 proved similarly

Example Instantiation: Multics

- 11 rules affect rights:
  - set to request, release access
  - set to give, remove access to different subject
  - set to create, reclassify objects
  - set to remove objects
  - set to change subject security level
- Set of "trusted" subjects $S_T \subseteq S$
  - *-property not enforced; subjects trusted not to violate it
- $\Delta(\rho)$ domain
  - determines if components of request are valid

get-read Rule

- Request $r = (get, s, o, \underline{\mathrm{r}})$
  - *s* gets (requests) the right to read *o*
- Rule is $\rho_1(r, v)$:

if $(r \neq \Delta(\rho_1))$ **then** $\rho_1(r, v) = (\underline{\mathrm{i}}, v)$;
else if $(f_s(s)\ dom\ f_o(o)$ **and** $[s \in S_T$ **or** $f_c(s)\ dom\ f_o(o)]$ **and** $r \in m[s, o])$
  then $\rho_1(r, v) = (y, (b \cup \{ (s, o, \underline{\mathrm{r}}) \}, m, f, h))$;
else $\rho_1(r, v) = (\underline{\mathrm{n}}, v)$;

Security of Rule

- The get-read rule preserves the simple security condition, the *-property, and the ds-property

  Proof:

  - Let v satisfy all conditions. Let $\rho_1(r, v) = (d, v')$. If $v' = v$, result is trivial. So let $v' = (b \cup \{ (s_2, o, \underline{r}) \}, m, f, h)$.

Proof

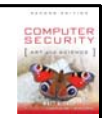
- Consider the simple security condition.
  - From the choice of v', either $b' - b = \varnothing$ or $\{ (s_2, o, \underline{\text{r}}) \}$
  - If $b' - b = \varnothing$, then $\{ (s_2, o, \underline{\text{r}}) \} \in b$, so $v = v'$, proving that v' satisfies the simple security condition.
  - If $b' - b = \{ (s_2, o, \underline{\text{r}}) \}$, because the *get-read* rule requires that $f_c(s)$ *dom* $f_o(o)$, an earlier result says that v' satisfies the simple security condition.

Proof

- Consider the *-property.
  - Either $s_2 \in S_T$ or $f_c(s)$ *dom* $f_o(o)$ from the definition of *get-read*
  - If $s_2 \in S_T$, then s_2 is trusted, so *-property holds by definition of trusted and S_T.
  - If $f_c(s)$ *dom* $f_o(o)$, an earlier result says that v' satisfies the simple security condition.

Proof

- Consider the discretionary security property.
  - Conditions in the *get-read* rule require $\underline{r} \in m[s, o]$ and either $b' - b = \varnothing$ or $\{ (s_2, o, \underline{r}) \}$
  - If $b' - b = \varnothing$, then $\{ (s_2, o, \underline{r}) \} \in b$, so $v = v'$, proving that v' satisfies the simple security condition.
  - If $b' - b = \{ (s_2, o, \underline{r}) \}$, then $\{ (s_2, o, \underline{r}) \} \notin b$, an earlier result says that v' satisfies the ds-property.



give-read Rule

- Request $r = (s_1, give, s_2, o, \underline{r})$
  - s_1 gives (request to give) s_2 the (discretionary) right to read o
  - Rule: can be done if giver can alter parent of object
    - If object or parent is root of hierarchy, special authorization required
- Useful definitions
  - $root(o)$: root object of hierarchy h containing o
  - $parent(o)$: parent of o in h (so $o \in h(parent(o))$)
  - $canallow(s, o, v)$: s specially authorized to grant access when object or parent of object is root of hierarchy
  - $m \wedge m[s, o] \leftarrow \underline{r}$: access control matrix m with $\underline{r}$ added to $m[s, o]$

give-read Rule

- Rule is $\rho_6(r, v)$:

  if $(r \neq \Delta(\rho_6))$ **then** $\rho_6(r, v) = (\underline{i}, v)$;

  else if $([o \neq root(o)$ **and** $parent(o) \neq root(o)$ **and** $parent(o) \in b(s_1{:}\underline{w})]$ **or**

  $[parent(o) = root(o)$ **and** $canallow(s_1, o, v)\ ]$ **or**

  $[o = root(o)$ and $canallow(s_1, o, v)\ ])$

  then $\rho_6(r, v) = (y, (b, m \wedge m[s_2, o] \leftarrow \underline{r}, f, h))$;

  else $\rho_1(r, v) = (\underline{n}, v)$;

Security of Rule

- The *give-read* rule preserves the simple security condition, the *-property, and the ds-property
  - Proof: Let v satisfy all conditions. Let $\rho_1(r, v) = (d, v')$. If $v' = v$, result is trivial. So let $v' = (b, m[s_2, o] \leftarrow \underline{r}, f, h)$. So $b' = b$, $f' = f$, $m[x, y] = m'[x, y]$ for all $x \in S$ and $y \in O$ such that $x \neq s$ and $y \neq o$, and $m[s, o] \subseteq m'[s, o]$. Then by earlier result, v' satisfies the simple security condition, the *-property, and the ds-property.

Principle of Tranquility

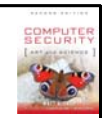
- Raising object’s security level
  - Information once available to some subjects is no longer available
  - Usually assume information has already been accessed, so this does nothing
- Lowering object’s security level
  - The *declassification problem*
  - Essentially, a “write down” violating *-property
  - Solution: define set of trusted subjects that *sanitize* or remove sensitive information before security level lowered

Types of Tranquility

- Strong Tranquility
  - The clearances of subjects, and the classifications of objects, do not change during the lifetime of the system
- Weak Tranquility
  - The clearances of subjects, and the classifications of objects, do not change in a way that violates the simple security condition or the *-property during the lifetime of the system

Example: Trusted Solaris

- Security administrator can provide specific authorization for a user to change the MAC label of a file
  - “downgrade file label” authorization
  - “upgrade file label” authorization
- User requires additional authorization if not the owner of the file
  - “act as file owner” authorization



Principles of Declassification

- Principle of Semantic Consistency
  - As long as semantics of components that do not do declassification do not change, the components can be altered without affecting security
- Principle of Occlusion
  - A declassification operation cannot conceal an *improper* declassification
- Principle of Conservativity
  - Absent any declassification, the system is secure
- Principle of Monotonicity of Release
  - When declassification is performed in an authorized manner by authorized subjects, the system remains secure

Controversy

- McLean:
  - “value of the BST is much overrated since there is a great deal more to security than it captures. Further, what is captured by the BST is so trivial that it is hard to imagine a realistic security model for which it does not hold.”
  - Basis: given assumptions known to be non-secure, BST can prove a non-secure system to be secure

†-Property

- State (b, m, f, h) satisfies the †-property iff for each $s \in S$ the following hold:
  1. $b(s\text{: }\underline{a}) \neq \varnothing \Rightarrow [\forall o \in b(s\text{: }\underline{a})\ [\ f_c(s)\ dom\ f_o(o)\ ]\ ]$
  2. $b(s\text{: }\underline{w}) \neq \varnothing \Rightarrow [\forall o \in b(s\text{: }\underline{w})\ [\ f_o(o) = f_c(s)\ ]\ ]$
  3. $b(s\text{: }\underline{r}) \neq \varnothing \Rightarrow [\forall o \in b(s\text{: }\underline{r})\ [\ f_c(s)\ dom\ f_o(o)\ ]\ ]$
- Idea: for writing, subject dominates object; for reading, subject also dominates object
- Differs from *-property in that the mandatory condition for writing is reversed
  - For *-property, it's object dominates subject

Analogues

The following two theorems can be proved

- $\Sigma(R, D, W, z_0)$ satisfies the †-property relative to $S' \subseteq S$ for any secure state z_0 iff for every action $(r, d, (b, m, f, h), (b', m', f', h'))$, W satisfies the following for every $s \in S'$
    - Every $(s, o, p) \in b - b'$ satisfies the †-property relative to S'
    - Every $(s, o, p) \in b'$ that does not satisfy the †-property relative to S' is not in b
- $\Sigma(R, D, W, z_0)$ is a secure system if z_0 is a secure state and W satisfies the conditions for the simple security condition, the †-property, and the ds-property.

Problem

- This system is *clearly* non-secure!
  - Information flows from higher to lower because of the †-property

Discussion

- Role of Basic Security Theorem is to demonstrate that rules preserve security
- Key question: what is security?
  - Bell-LaPadula defines it in terms of 3 properties (simple security condition, *-property, discretionary security property)
  - Theorems are assertions about these properties
  - Rules describe changes to a *particular* system instantiating the model
  - Showing system is secure requires proving rules preserve these 3 properties

Rules and Model

- Nature of rules is irrelevant to model
- Model treats “security” as axiomatic
- Policy defines “security”
  - This instantiates the model
  - Policy reflects the requirements of the systems
- McLean’s definition differs from Bell-LaPadula
  - … and is not suitable for a confidentiality policy
- Analysts cannot prove “security” definition is appropriate through the model

System Z

- System supporting weak tranquility
- On *any* request, system downgrades *all* subjects and objects to lowest level and adds the requested access permission
  - Let initial state satisfy all 3 properties
  - Successive states also satisfy all 3 properties
- Clearly not secure
  - On first request, everyone can read everything

Reformulation of Secure Action

- Given state that satisfies the 3 properties, the action transforms the system into a state that satisfies these properties and eliminates any accesses present in the transformed state that would violate the property in the initial state, then the action is secure
- BST holds with these modified versions of the 3 properties

Reconsider System Z

- Initial state:
  - subject s, object o
  - C = {High, Low}, K = {All}
- Take:
  - $f_c(s)$ = (Low, {All}), $f_o(o)$ = (High, {All})
  - $m[s, o] = \{ \underline{w} \}$, and $b = \{ (s, o, \underline{w}) \}$.
- s requests $\underline{r}$ access to o
- Now:
  - $f'_o(o)$ = (Low, {All})
  - $(s, o, \underline{r}) \in b'$, $m'[s, o] = \{\underline{r}, \underline{w}\}$

Non-Secure System Z

- As $(s, o, \underline{\mathrm{r}}) \in b' - b$ and $f_o(o)$ *dom* $f_c(s)$, access added that was illegal in previous state
  - Under the new version of the Basic Security Theorem, System Z is not secure
  - Under the old version of the Basic Security Theorem, as $f'_c(s) = f'_o(o)$, System Z is secure

Response: What Is Modeling?

- Two types of models
  1. Abstract physical phenomenon to fundamental properties
  2. Begin with axioms and construct a structure to examine the effects of those axioms
- Bell-LaPadula Model developed as a model in the first sense
  - McLean assumes it was developed as a model in the second sense

Reconciling System Z

- Different definitions of security create different results
  - Under one (original definition in Bell-LaPadula Model), System Z is secure
  - Under other (McLean's definition), System Z is not secure

Key Points

- Confidentiality models restrict flow of information
- Bell-LaPadula models multilevel security
  - Cornerstone of much work in computer security
- Controversy over meaning of security
  - Different definitions produce different results