Lecture 4
October 4, 2023

Types of Access Control

- Discretionary Access Control (DAC, IBAC)
  - individual user sets access control mechanism to allow or deny access to an object
- Mandatory Access Control (MAC)
  - system mechanism controls access to object, and individual cannot alter that access
- Originator Controlled Access Control (ORCON)
  - originator (creator) of information controls who can access information

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, $L(o) \le L(s)$ 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

Lattices

- Lattices used to analyze several models
  - Bell-LaPadula confidentiality model
  - Biba integrity model
- A lattice consists of a set and a relation
- Relation must partially order set
  - Relation orders some, but not all, elements of set

Sets and Relations

- S set, R: $S \times S$ relation
  - If a, $b \in S$, and $(a, b) \in R$, write aRb
- Example
  - $I = \{ 1, 2, 3 \}$; R is $\leq$
  - $R = \{ (1, 1), (1, 2), (1, 3), (2, 2), (2, 3), (3, 3) \}$
  - So we write $1 \leq 2$ and $3 \leq 3$ but not $3 \leq 2$

Relation Properties

- Reflexive
  - For all $a \in S$, aRa
  - On I, $\leq$ is reflexive as $1 \leq 1$, $2 \leq 2$, $3 \leq 3$
- Antisymmetric
  - For all $a, b \in S$, $aRb \wedge bRa \Rightarrow a = b$
  - On I, $\leq$ is antisymmetric as $1 \leq x$ and $x \leq 1$ means $x = 1$
- Transitive
  - For all $a, b, c \in S$, $aRb \wedge bRc \Rightarrow aRc$
  - On I, $\leq$ is transitive as $1 \leq 2$ and $2 \leq 3$ means $1 \leq 3$

Example

- $\mathbb{C}$ set of complex numbers
- $a \in \mathbb{C} \Rightarrow a = a_{\mathbf{R}} + a_{\mathbf{I}}i$, where $a_{\mathbf{R}}$, $a_{\mathbf{I}}$ integers
- $a \leq_{\mathbf{C}} b$ if, and only if, $a_{\mathbf{R}} \leq b_{\mathbf{R}}$ and $a_{\mathbf{I}} \leq b_{\mathbf{I}}$
- $a \leq_{\mathbf{C}} b$ is reflexive, antisymmetric, transitive
  - As ≤ is over integers, and $a_{\mathbf{R}}$, $a_{\mathbf{I}}$ are integers

Partial Ordering

- Relation *R* orders some members of set *S*
  - If all ordered, it's a total ordering
- Example
  - $\leq$ on integers is total ordering
  - $\leq_{\mathbb{C}}$ is partial ordering on $\mathbb{C}$
    - Neither $3+5i \leq_{\mathbb{C}} 4+2i$ nor $4+2i \leq_{\mathbb{C}} 3+5i$ holds

Upper Bounds

- For a, $b \in S$, if u in S with aRu, bRu exists, then u is an *upper bound*
  - A *least upper bound* if there is no $t \in S$ such that aRt, bRt, and tRu
- Example
  - For $1 + 5i$, $2 + 4i \in \mathbb{C}$
    - Some upper bounds are $2 + 5i$, $3 + 8i$, and $9 + 100i$
    - Least upper bound is $2 + 5i$

Lower Bounds

- For a, $b \in S$, if l in S with lRa, lRb exists, then l is a *lower bound*
  - A *greatest lower bound* if there is no $t \in S$ such that tRa, tRb, and lRt
- Example
  - For $1 + 5i$, $2 + 4i \in \mathbb{C}$
    - Some lower bounds are 0, $-1 + 2i$, $1 + 1i$, and $1+4i$
    - Greatest lower bound is $1 + 4i$

Lattices

- Set *S*, relation *R*
  - *R* is reflexive, antisymmetric, transitive on elements of *S*
  - For every *s*, *t* ∈ *S*, there exists a greatest lower bound under *R*
  - For every *s*, *t* ∈ *S*, there exists a least upper bound under *R*

Example

- $S = \{ 0, 1, 2 \}$; $R = \leq$ is a lattice
  - R is clearly reflexive, antisymmetric, transitive on elements of S
  - Least upper bound of any two elements of S is the greater of the elements
  - Greatest lower bound of any two elements of S is the lesser of the elements

Picture

2

↓

1

↓

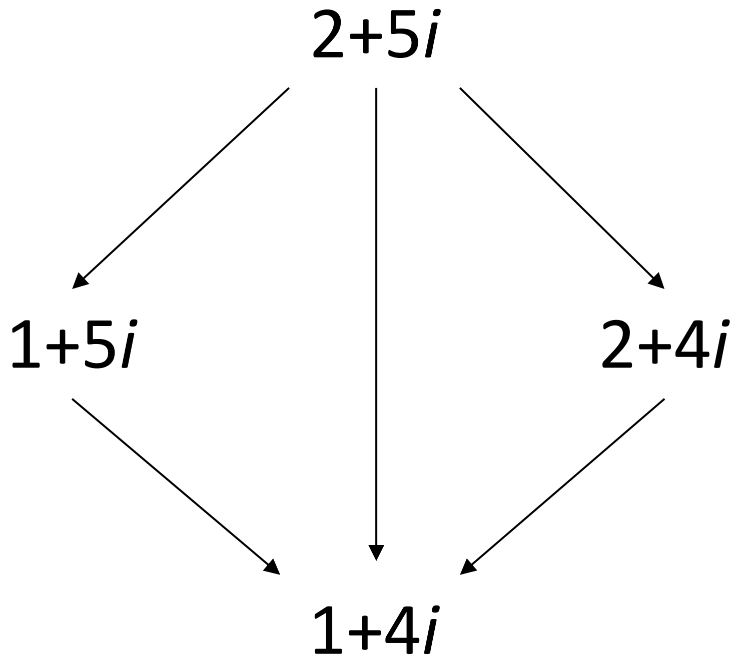
0

Arrows represent ≤; this forms a total ordering

Example

- $\mathbb{C}$, $\leq_{\mathbb{C}}$ form a lattice
  - $\leq_{\mathbb{C}}$ is reflexive, antisymmetric, and transitive
    - Shown earlier
  - Least upper bound for *a* and *b*:
    - $c_{\mathbf{R}} = \max(a_{\mathbf{R}}, b_{\mathbf{R}})$, $c_{\mathbf{I}} = \max(a_{\mathbf{I}}, b_{\mathbf{I}})$; then $c = c_{\mathbf{R}} + c_{\mathbf{I}} i$
  - Greatest lower bound for *a* and *b*:
    - $c_{\mathbf{R}} = \min(a_{\mathbf{R}}, b_{\mathbf{R}})$, $c_{\mathbf{I}} = \min(a_{\mathbf{I}}, b_{\mathbf{I}})$; then $c = c_{\mathbf{R}} + c_{\mathbf{I}} i$

Picture



Arrows represent $\leq_{\mathbb{C}}$

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 ¬ *asserted*(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 read 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 write access to *O* is granted only if O_L *dom* S_L and C_L *dom* O_L
   - Instantiation of *-property