

Lecture 4

September 28, 2021

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

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
- $a \in \mathbb{C} \Rightarrow a = a_R + a_I i$, where a_R, a_I integers
- $a \leq_c b$ if, and only if, $a_R \leq b_R$ and $a_I \leq b_I$
- $a \leq_c b$ is reflexive, antisymmetric, transitive
 - As \leq is over integers, and a_R, a_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 $s, t \in S$, there exists a greatest lower bound under R
 - For every $s, t \in S$, 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

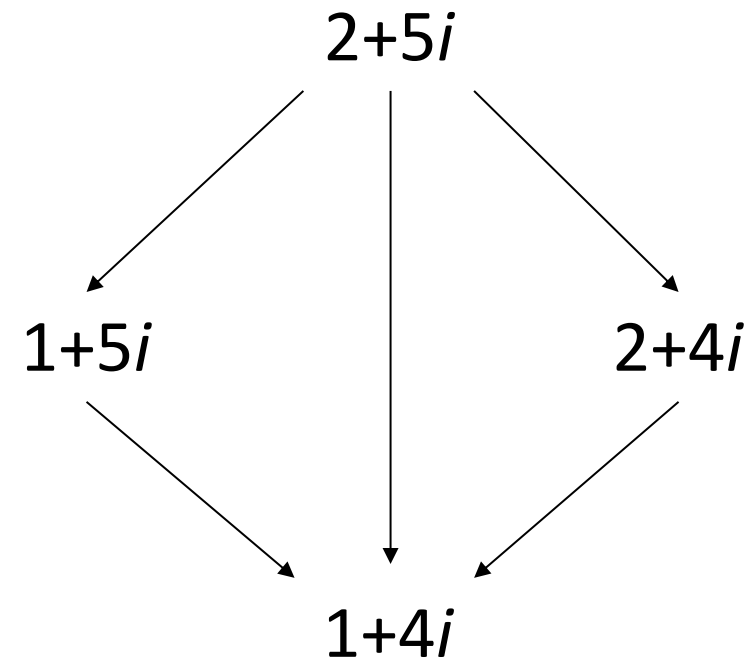


Arrows represent \geq ; this forms a total ordering

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 :
 - $c_R = \max(a_R, b_R), c_I = \max(a_I, b_I)$; then $c = c_R + c_I i$
 - Greatest lower bound for a and b :
 - $c_R = \min(a_R, b_R), c_I = \min(a_I, b_I)$; then $c = c_R + c_I i$

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

- $(A, C) \text{ dom } (A', C')$ 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
 - $\text{lub}(L) = (\max(A), C)$
 - $\text{glb}(L) = (\min(A), \emptyset)$

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 $L(o) \text{ dom } L(s)$ 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
 - $maxlevel(s) \text{ dom } curlevel(s)$
- 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 $L(\text{Major}) \text{ dom } curlevel(\text{Colonel})$
 - 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 $\neg\text{privileged}(S, \text{"change } S_L\text{"})$, then no sequence of operations can change S_L to a value that it has not previously assumed
2. If $\neg\text{privileged}(S, \text{"change } S_L\text{"})$, then $\neg\text{asserted}(S, \text{"change } S_L\text{"})$
3. If $\neg\text{privileged}(S, \text{"change } S_L\text{"})$, then no value of S_L can be outside the clearance of U_S
4. For all subjects S , named objects O , if $\neg\text{privileged}(S, \text{"change } O_L\text{"})$, 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 `lstat(".", &buf)` returns information about $/tmp$

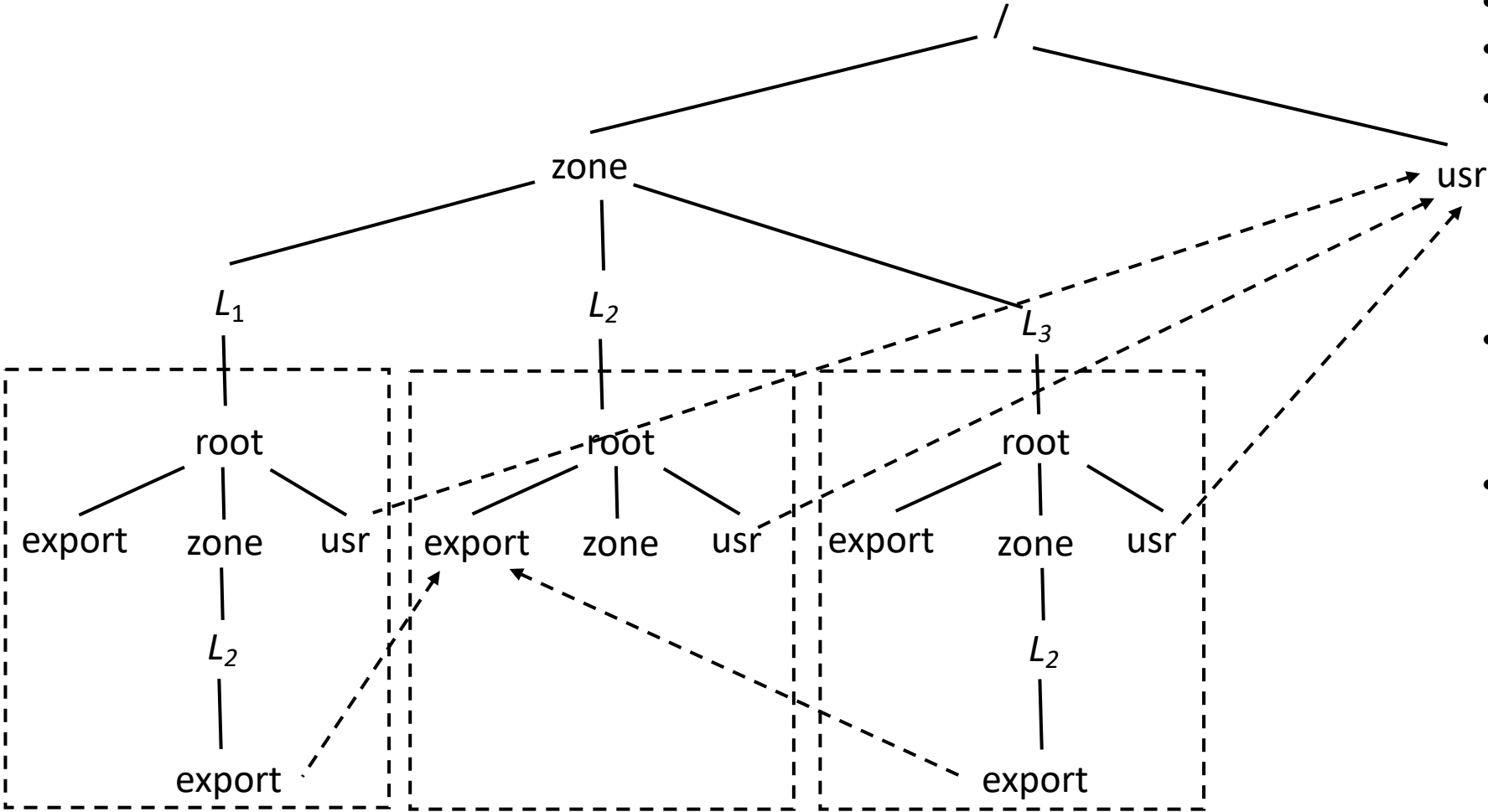
Labeled Zones

- 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



- $L_1 \text{ dom } L_2$
- $L_3 \text{ dom } L_2$
- 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