Lecture 5
October 6, 2023

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

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*

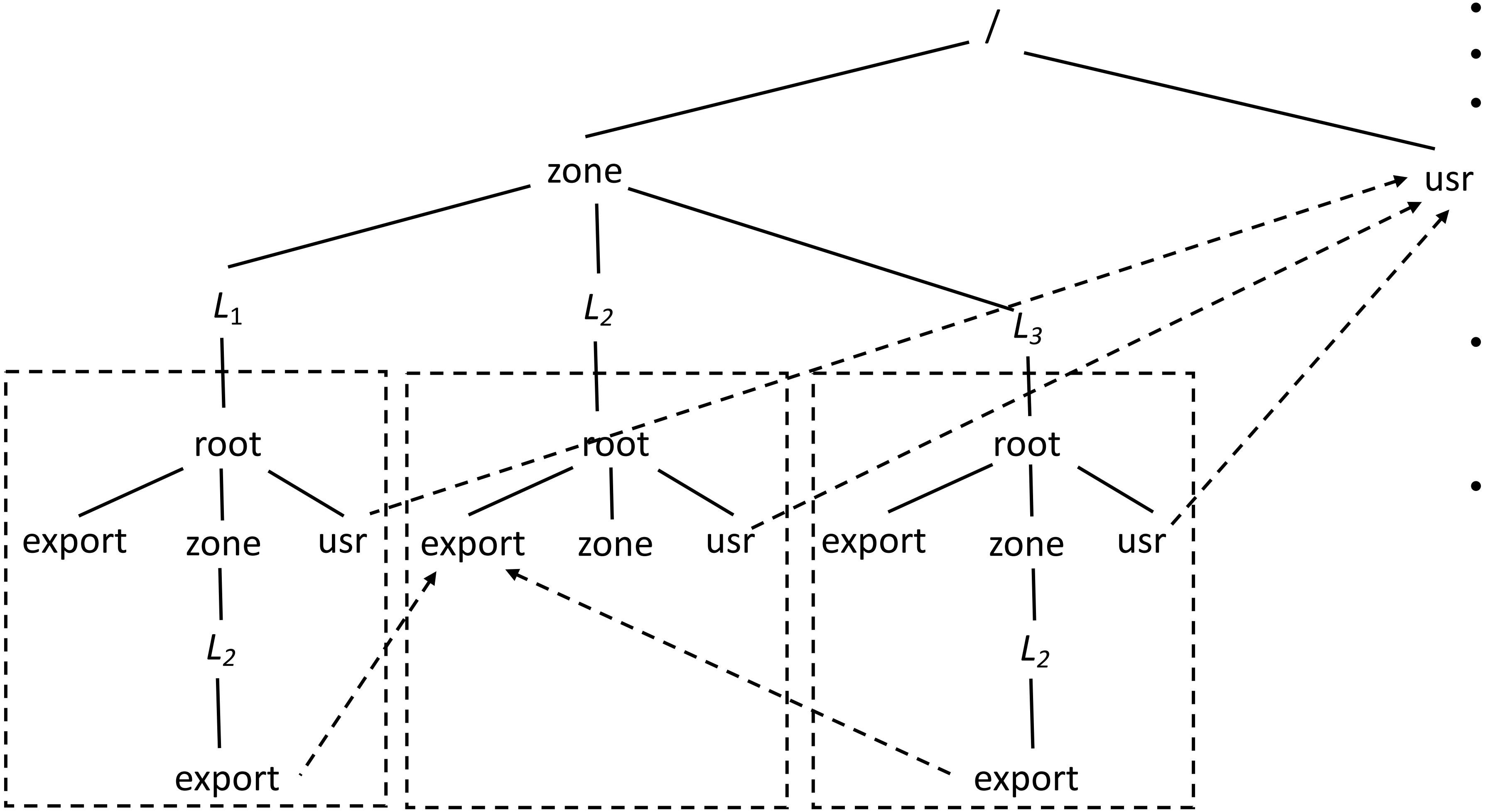
Labeled Zones

- 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

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

Requirements of Integrity Policies

1. Users will not write their own programs, but will use existing production programs and databases.
2. Programmers will develop and test programs on a non-production system; if they need access to actual data, they will be given production data via a special process, but will use it on their development system.
3. A special process must be followed to install a program from the development system onto the production system.
4. The special process in requirement 3 must be controlled and audited.
5. The managers and auditors must have access to both the system state and the system logs that are generated.

Principles of Operation

- *Separation of duty*: if two or more steps are required to perform a critical function, at least two different people should perform the steps
- *Separation of function*: different entities should perform different functions
- *Auditing*: recording enough information to ensure the abilities to both recover and determine accountability

Biba Integrity Model

Basis for all 3 models:

- Set of subjects S, objects O, integrity levels I, relation $\leq \subseteq I \times I$ holding when second dominates first
- min: $I \times I \rightarrow I$ returns lesser of integrity levels
- i: $S \cup O \rightarrow I$ gives integrity level of entity
- $\underline{\text{r}}$: $S \times O$ means $s \in S$ can read $o \in O$
- $\underline{\text{w}}$, $\underline{\text{x}}$ defined similarly

Intuition for Integrity Levels

- The higher the level, the more confidence
  - That a program will execute correctly
  - That data is accurate and/or reliable
- Note relationship between integrity and trustworthiness
- Important point: *integrity levels are **not** security levels*

Information Transfer Path

- An *information transfer path* is a sequence of objects $o_1, ..., o_{n+1}$ and corresponding sequence of subjects $s_1, ..., s_n$ such that s_i r o_i and s_i w o_{i+1} for all i, $1 \leq i \leq n$.
- Idea: information can flow from o_1 to o_{n+1} along this path by successive reads and writes

Strict Integrity Policy

- Dual of Bell-LaPadula model
    1. $s \in S$ can read $o \in O$ iff $i(s) \le i(o)$
    2. $s \in S$ can write to $o \in O$ iff $i(o) \le i(s)$
    3. $s_1 \in S$ can execute $s_2 \in S$ iff $i(s_2) \le i(s_1)$
- Add compartments and discretionary controls to get full dual of Bell-LaPadula model
- If there is an information transfer path from $o_1 \in O$ to $o_{n+1} \in O$, the low-water-mark policy requires $i(o_{n+1}) \le i(o_1)$ for all $n > 1$.
- Term “Biba Model” refers to this

LOCUS and Biba

- Goal: prevent untrusted software from altering data or other software
- Approach: make levels of trust explicit
  - *credibility rating* based on estimate of software's trustworthiness (0 untrusted, *n* highly trusted)
  - *trusted file systems* contain software with a single credibility level
  - Process has *risk level* or highest credibility level at which process can execute
  - Must use *run-untrusted* command to run software at lower credibility level

Clark-Wilson Integrity Model

- Integrity defined by a set of constraints
  - Data in a *consistent* or valid state when it satisfies these
- Example: Bank
  - *D* today's deposits, *W* withdrawals, *YB* yesterday's balance, *TB* today's balance
  - Integrity constraint: $D + YB - W$
- *Well-formed transaction* move system from one consistent state to another
- Issue: who examines, certifies transactions done correctly?

Entities

- CDIs: constrained data items
  - Data subject to integrity controls
- UDIs: unconstrained data items
  - Data not subject to integrity controls
- IVPs: integrity verification procedures
  - Procedures that test the CDIs conform to the integrity constraints
- TPs: transaction procedures
  - Procedures that take the system from one valid state to another