ECS 289M Lecture 11

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Requirements of 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.

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

Certification Rules 1 and 2

CR1 When any IVP is run, it must ensure all CDIs are in a valid state

CR2 For some associated set of CDIs, a TP must transform those CDIs in a valid state into a (possibly different) valid state

- Defines relation *certified* that associates a set of CDIs with a particular TP
- Example: TP balance, CDIs accounts, in bank example

Enforcement Rules 1 and 2

ER1 The system must maintain the certified relations and must ensure that only TPs certified to run on a CDI manipulate that CDI.

ER2 The system must associate a user with each TP and set of CDIs. The TP may access those CDIs on behalf of the associated user. The TP cannot access that CDI on behalf of a user not associated with that TP and CDI.

- System must maintain, enforce certified relation
- System must also restrict access based on user ID (*allowed* relation)

Users and Rules

CR3 The allowed relations must meet the requirements imposed by the principle of separation of duty.

ER3 The system must authenticate each user attempting to execute a TP

- Type of authentication undefined, and depends on the instantiation
- Authentication *not* required before use of the system, but *is* required before manipulation of CDIs (requires using TPs)

Logging

CR4 All TPs must append enough information to reconstruct the operation to an append-only CDI.

- This CDI is the log
- Auditor needs to be able to determine what happened during reviews of transactions

Handling Untrusted Input

CR5 Any TP that takes as input a UDI may perform only valid transformations, or no transformations, for all possible values of the UDI. The transformation either rejects the UDI or transforms it into a CDI.

- In bank, numbers entered at keyboard are UDIs, so cannot be input to TPs. TPs must validate numbers (to make them a CDI) before using them; if validation fails, TP rejects UDI

Separation of Duty In Model

ER4 Only the certifier of a TP may change the list of entities associated with that TP. No certifier of a TP, or of an entity associated with that TP, may ever have execute permission with respect to that entity.

– Enforces separation of duty with respect to certified and allowed relations

Comparison With Requirements

1. Users can't certify TPs, so CR5 and ER4 enforce this
2. Procedural, so model doesn't directly cover it; but special process corresponds to using TP
   - No technical controls can prevent programmer from developing program on production system; usual control is to delete software tools
3. TP does the installation, trusted personnel do certification

Comparison With Requirements

4. CR4 provides logging; ER3 authenticates trusted personnel doing installation; CR5, ER4 control installation procedure
   - New program UDI before certification, CDI (and TP) after
5. Log is CDI, so appropriate TP can provide managers, auditors access
   - Access to state handled similarly

Comparison to Biba

- Biba
  - No notion of certification rules; trusted subjects ensure actions obey rules
  - Untrusted data examined before being made trusted
- Clark-Wilson
  - Explicit requirements that *actions* must meet
  - Trusted entity must certify *method* to upgrade untrusted data (and not certify the data itself)

Chinese Wall Model

Problem:

- Tony advises American Bank about investments
- He is asked to advise Toyland Bank about investments

- Conflict of interest to accept, because his advice for either bank would affect his advice to the other bank

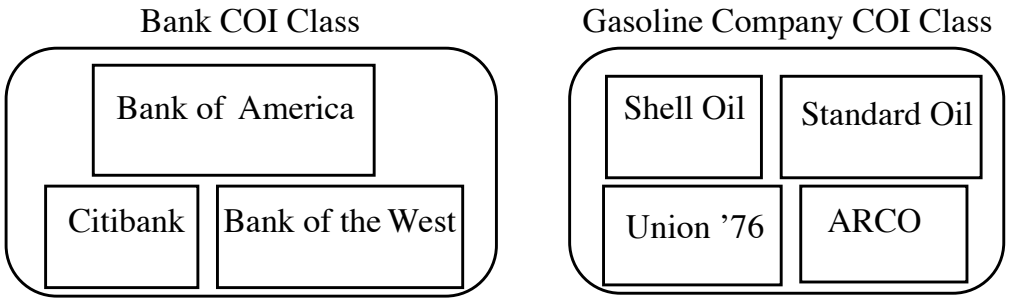
Organization

- Organize entities into “conflict of interest” classes
- Control subject accesses to each class
- Control writing to all classes to ensure information is not passed along in violation of rules
- Allow sanitized data to be viewed by everyone

Definitions

- *Objects*: items of information related to a company
- *Company dataset* (CD): contains objects related to a single company
  - Written *CD*(*O*)
- *Conflict of interest class* (COI): contains datasets of companies in competition
  - Written *COI*(*O*)
  - Assume: each object belongs to exactly one *COI* class

Example



Temporal Element

- If Anthony reads any CD in a COI, he can *never* read another CD in that COI
  - Possible that information learned earlier may allow him to make decisions later
  - Let $PR(S)$ be set of objects that S has already read

CW-Simple Security Condition

- s can read o iff either condition holds:
  1. There is an o' such that s has accessed o' and $CD(o') = CD(o)$
     - Meaning s has read something in o's dataset
  2. For all $o' \in O$, $o' \in PR(s) \Rightarrow COI(o') \neq COI(o)$
     - Meaning s has not read any objects in o's conflict of interest class
- Ignores sanitized data (see below)
- Initially, $PR(s) = \varnothing$, so initial read request granted

Sanitization

- Public information may belong to a CD
  - As is publicly available, no conflicts of interest arise
  - So, should not affect ability of analysts to read
  - Typically, all sensitive data removed from such information before it is released publicly (called *sanitization*)
- Add third condition to CW-Simple Security Condition:
  3. *o* is a sanitized object

Writing

- Anthony, Susan work in same trading house
- Anthony can read Bank 1's CD, Gas' CD
- Susan can read Bank 2's CD, Gas' CD
- If Anthony could write to Gas' CD, Susan can read it
  - Hence, indirectly, she can read information from Bank 1's CD, a clear conflict of interest

CW-*-Property

- *s* can write to *o* iff both of the following hold:
  1. The CW-simple security condition permits *s* to read *o*; and
  2. For all *unsanitized* objects *o′*, if *s* can read *o′*, then *CD*(*o′*) = *CD*(*o*)
- Says that *s* can write to an object if all the (unsanitized) objects it can read are in the same dataset

Formalism

- Goal: figure out how information flows around system
- *S* set of subjects, *O* set of objects, $L = C \times D$ set of labels
- $I_1: O \rightarrow C$ maps objects to their COI classes
- $I_2: O \rightarrow D$ maps objects to their CDs
- *H*(*s*, *o*) true iff *s* has *or had* read access to *o*
- *R*(*s*, *o*): *s*'s request to read *o*

Axioms

- Axiom 7-1. For all o, $o' \in O$,
  if $l_2(o) = l_2(o')$, then $l_1(o) = l_1(o')$
  - CDs do not span COIs.
- Axiom 7-2. $s \in S$ can read $o \in O$ iff, for all $o' \in O$ such that $H(s, o')$, either
  $l_1(o') \neq l_1(o)$ or $l_2(o') = l_2(o)$
  - s can read o iff o is either in a different COI than every other o' that s has read, or in the same CD as o.

More Axioms

- Axiom 7-3. $\neg H(s, o)$ for all $s \in S$ and $o \in O$ is an initially secure state
  - Description of the initial state, assumed secure
- Axiom 7-4. If for some $s \in S$ and all $o \in O$, $\neg H(s, o)$, then any request $R(s, o)$ is granted
  - If s has read no object, it can read any object

Which Objects Can Be Read?

- Suppose $s \in S$ has read $o \in O$. If s can read $o' \in O$, $o' \neq o$, then $I_1(o') \neq I_1(o)$ or $I_2(o') = I_2(o)$.
  - Says s can read only the objects in a single CD within any COI

Proof

Assume false. Then

$H(s, o) \wedge H(s, o') \wedge I_1(o') = I_1(o) \wedge I_2(o') \neq I_2(o)$

Assume s read o first. Then $H(s, o)$ when s read o, so by Axiom 7-2, either $I_1(o') \neq I_1(o)$ or $I_2(o') = I_2(o)$, so

$(I_1(o') \neq I_1(o) \vee I_2(o') = I_2(o)) \wedge (I_1(o') = I_1(o) \wedge I_2(o') \neq I_2(o))$

Rearranging terms,

$(I_1(o') \neq I_1(o) \wedge I_2(o') \neq I_2(o) \wedge I_1(o') = I_1(o)) \vee$

$(I_2(o') = I_2(o) \wedge I_2(o') \neq I_2(o) \wedge I_1(o') = I_1(o))$

which is obviously false, contradiction.

Lemma

- Suppose a subject $s \in S$ can read an object $o \in O$. Then s can read no o' for which $l_1(o') = l_1(o)$ and $l_2(o') \neq l_2(o)$.
  - So a subject can access at most one CD in each COI class
  - Sketch of proof: Initial case follows from Axioms 7-3, 7-4. If $o' \neq o$, theorem immediately gives lemma.

COIs and Subjects

- Theorem: Let $c \in C$ and $d \in D$. Suppose there are n objects $o_i \in O$, $1 \leq i \leq n$, such that $l_1(o_i) = d$ for $1 \leq i \leq n$, and $l_2(o_i) \neq l_2(o_j)$, for $1 \leq i, j \leq n$, $i \neq j$. Then for all such o, there is an $s \in S$ that can read o iff $n \leq |S|$.
  - If a COI has n CDs, you need at least n subjects to access every object
  - Proof sketch: If s can read o, it cannot read any o' in another CD in that COI (Axiom 7-2). As there are n such CDs, there must be at least n subjects to meet the conditions of the theorem.

Sanitized Data

- $v(o)$: sanitized version of object o
  - For purposes of analysis, place them all in a special CD in a COI containing no other CDs
- Axiom 7-5. $I_1(o) = I_1(v(o))$ iff $I_2(o) = I_2(v(o))$

Which Objects Can Be Written?

- Axiom 7-6. $s \in S$ can write to $o \in O$ iff the following hold simultaneously
  1. $H(s, o)$
  2. There is no $o' \in O$ with $H(s, o')$, $I_2(o) \neq I_2(o')$, $I_2(o) \neq I_2(v(o))$, $I_2(o') = I_2(v(o))$.
  - Allow writing iff information cannot leak from one subject to another through a mailbox
  - Note handling for sanitized objects

How Information Flows

- Definition: information may flow from o to o' if there is a subject such that $H(s, o)$ and $H(s, o')$.
  - Intuition: if s can read 2 objects, it can act on that knowledge; so information flows between the objects through the nexus of the subject
  - Write the above situation as (o, o')

Key Result

- Set of all information flows is
  $\{ (o, o') \mid o \in O \wedge o' \in O \wedge I_2(o) = I_2(o') \vee I_2(o) = I_2(v(o)) \}$
- Sketch of proof: Definition gives set of flows:
  $F = \{(o, o') \mid o \in O \wedge o' \in O \wedge \exists\ s \in S$ such that $H(s, o) \wedge H(s, o'))\}$
  Axiom 7-6 excludes the following flows:
  $X = \{ (o, o') \mid o \in O \wedge o' \in O \wedge I_2(o) \neq I_2(o') \wedge I_2(o) \neq I_2(v(o)) \}$
  So, letting F^* be transitive closure of F,
  $F^* - X = \{(o, o') \mid o \in O \wedge o' \in O \wedge \neg(I_2(o) \neq I_2(o') \wedge I_2(o) \neq I_2(v(o))) \}$
  which is equivalent to the claim.

Compare to Bell-LaPadula

- Fundamentally different
  - CW has no security labels, B-LP does
  - CW has notion of past accesses, B-LP does not
- Bell-LaPadula can capture state at any time
  - Each (COI, CD) pair gets security category
  - Two clearances, *S* (sanitized) and *U* (unsanitized)
    - *S dom U*
  - Subjects assigned clearance for compartments without multiple categories corresponding to CDs in same COI class

Compare to Bell-LaPadula

- Bell-LaPadula cannot track changes over time
  - Susan becomes ill, Anna needs to take over
    - C-W history lets Anna know if she can
    - No way for Bell-LaPadula to capture this
- Access constraints change over time
  - Initially, subjects in C-W can read any object
  - Bell-LaPadula constrains set of objects that a subject can access
    - Can't clear all subjects for all categories, because this violates CW-simple security condition

Compare to Clark-Wilson

- Clark-Wilson Model covers integrity, so consider only access control aspects
- If “subjects” and “processes” are interchangeable, a single person could use multiple processes to violate CW-simple security condition
  - Would still comply with Clark-Wilson Model
- If “subject” is a specific person and includes all processes the subject executes, then consistent with Clark-Wilson Model