February 6, 2014

- Hybrid models
  - Chinese Wall model

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

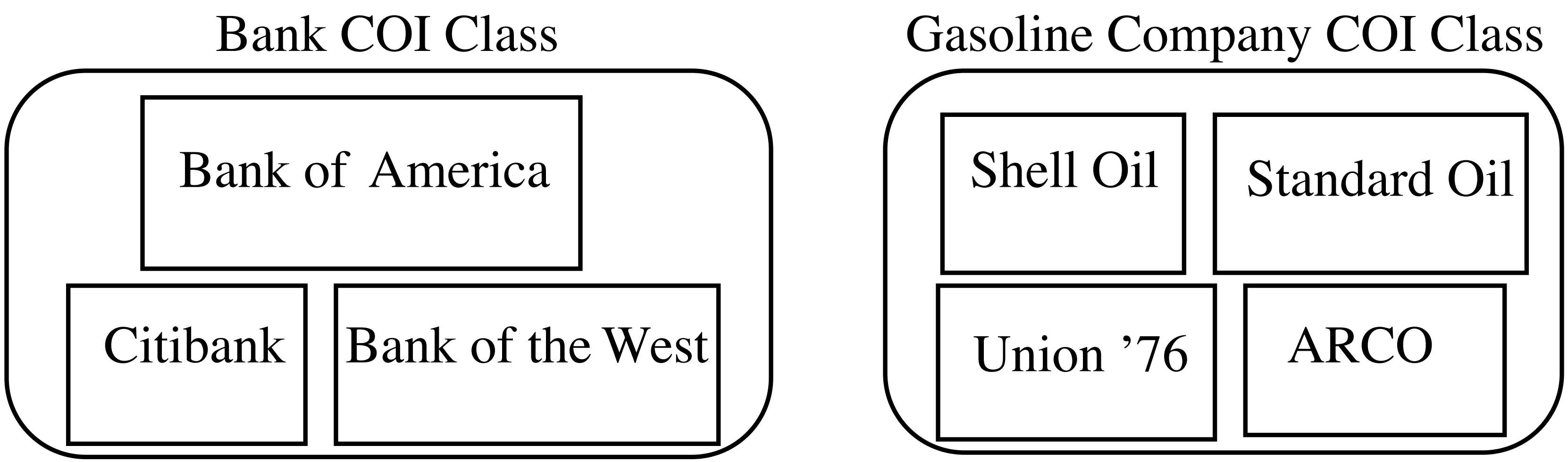
Organization

- 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



Bank COI Class
Bank of America
Citibank
Bank of the West
Gasoline Company COI Class
Shell Oil
Standard Oil
Union '76
ARCO

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
- $l_1 : O \rightarrow C$ maps objects to their COI classes
- $l_2 : O \rightarrow D$ 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 $l_1(o') \neq l_1(o)$ or $l_2(o') = l_2(o)$.
  - Says s can read only the objects in a single CD within any COI

Proof

Assume false. Then

$$H(s, o) \wedge H(s, o') \wedge l_1(o') = l_1(o) \wedge l_2(o') \neq l_2(o)$$

Assume s read o first. Then $H(s, o)$ when s read o, so by Axiom 7-2, either $l_1(o') \neq l_1(o)$ or $l_2(o') = l_2(o)$, so

$$(l_1(o') \neq l_1(\mathrm{o}) \vee l_2(o') = l_2(o)) \wedge (l_1(o') = l_1(o) \wedge l_2(o') \neq l_2(o))$$

Rearranging terms,

$$(l_1(o') \neq l_1(o) \wedge l_2(o') \neq l_2(o) \wedge l_1(o') = l_1(o)) \vee$$
$$(l_2(o') = l_2(o) \wedge l_2(o') \neq l_2(o) \wedge l_1(o') = l_1(o))$$

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 $o_i \in O$, $1 \le i \le n$, such that $l_1(o_i) = d$ for $1 \le i \le n$, and $l_2(o_i) \ne l_2(o_j)$, for $1 \le i, j \le n$, $i \ne j$. Then for all such o, there is an $s \in S$ that can read o iff $n \le |S|$.
  - 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. $l_1(o) = \mathrm{l}_1(v(o))$ iff $l_2(o) = l_2(v(o))$
  - This means all sanitized objects in same CD and COI

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 $H(s, o')$, $l_2(o) \neq l_2(o')$, $l_2(o) \neq l_2(v(o))$, $l_2(o') = l_2(v(o))$.
  - 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

  $\{ (o, o') \mid o \in O \land o' \in O \land l_2(o) = l_2(o') \lor l_2(o) = l_2(v(o)) \}$
- Sketch of proof: Definition gives set of flows:

  $F = \{(o, o') \mid o \in O \land o' \in O \land \exists\, s \in S \text{ such that } H(s, o) \land H(s, o')\}$

  Axiom 7-6 excludes the following flows:

  $X = \{ (o, o') \mid o \in O \land o' \in O \land l_2(o) \neq l_2(o') \land l_2(o) \neq l_2(v(o)) \}$

  So, letting F^* be transitive closure of F,

  $F^* - X = \{(o, o') \mid o \in O \land o' \in O \land$
  $\neg(l_2(o) \neq l_2(o') \land l_2(o) \neq l_2(v(o))) \}$

  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