May 3: Trust and Hybrid Models

- Trust models
- Chinese Wall model
  - Aggressive Chinese Wall model

Types of Trust Models

- Policy-based trust management
- Recommendation-based trust management

Policy-Based Trust Management

- Policy *rules* determine whether to trust
- Credentials provide instantiation information
  - Credentials themselves may be input to rules
  - Trusted third parties may be involved
- Generally assume agents act autonomously

Keynote

- Rule-based trust management system
- Policy assertions: statements about policy
- Credential assertions: describe actions allowed by credentials
- Action environment: set of attributes describing action associated with set of credentials

Evaluator

- Inputs
  - Policy assertions describing local policy
  - Set of credentials
  - Action environment
- Applies instantiated assertions to action environment
- Outputs
  - Whether proposed action consistent with local policy

Example: Email Domain

Policy, credential assertions:

```
Local-Constants: Alice="cred1234", Bob="credABCD"
Authorizer: "authcred"
Licensees: Alice || Bob
Conditions: (app_domain == "RFC822-EMAIL") &&
     (address ~= "^.*@keynote\\.ucdavis\\.edu$")
Signature: "signed”
```

entity with “authcred” credentials trust holders of “cred1234”, “credABCD” to issue credentials (“signed”) for users in email domain when address ends in “@keynote.ucdavis.edu

Example: Email Domain

Compliance values: `_MAX_TRUST, _MIN_TRUST`

Action environment:

```
_ACTION_AUTHORIZERS=Alice
app_domain = "RFC822-EMAIL"
address = ”opus@keynote.ucdavis.edu"
```

Satisfied; output `_MAX_TRUST`

Example: Separation of Duty

Invoicing system delegates authority for payment of invoices to entity with credential `fundmgrcred`

Policy assertion:

```
Authorizer: "POLICY"
Licensee: "fundmgecred"
Conditions: (app_domain == "INVOICE" &&
                              @dollars < 10000)
```

Example: Separation of Duty

Credential assertion requiring at least 2 signatures on expenditure:

```
Comment: specifies a spending policy
Authorizer: "authcred"
Licensees: 2-of("cred1", "cred2", "cred3",
                              "cred4", "cred5")
Conditions: (app_domain=="INVOICE”)
      -> { (@dollars) < 2500) -> _MAX_TRUST;
       (@dollars < 7500) -> "ApproveAndLog"; };
Signature: "signed"
```

Example: Separation of Duty

Compliance values: `Reject, ApproveAndLog, Approve`

Action environment:

```
_ACTION_AUTHORIZERS = "cred1,cred4"
app_domain = "INVOICE"
dollars = "1000"
```

Satisfied; output `Approve`

Example: Separation of Duty

Action environment:

```
_ACTION_AUTHORIZERS = "cred1,cred2"
app_domain = "INVOICE"
dollars = "3541"
```

Satisfied; output `ApproveAndLog`

Example: Separation of Duty

Action environment:

```
_ACTION_AUTHORIZERS = "cred1"
app_domain = "INVOICE"
dollars = "1500”

_ACTION_AUTHORIZERS = "cred1,cred5"
app_domain = "INVOICE"
dollars = "8000”
```

Not satisfied; output `Reject`

Reputation-Based Trust Management

- Trust based on past behavior, especially during interactions, and other information
  - May include other recommendations
  - Each entity maintains its own list of relationships

Types of Trust

- Direct trust
  - Amy trusts Boris
- Recommender trust
  - Amy trusts Boris to make recommendations about others

Example: Abdul-Rahman, Hailes

- Trust value semantics

value	DT meaning	RT meaning
–1	Untrustworthy	Untrustworthy
0	Cannot make trust judgment	Cannot make trust judgment
1	Lowest trust level	*
2	Average trustworthiness	*
3	More trustworthy than most entities	*
4	Completely trustworthy	*

Example

- Amy needs Boris' recommendation about Danny
  - Amy trusts Boris recommendation with value 2
- Boris doesn't know Danny, so asks Carole
- Carole replies with recommendation of 3
- Boris adds his name to recommendation, sends it on

Amy's Computation

- 4 entities involved: Amy, Boris, Carole, Danny
- *tv*(Amy:Boris)/4 × *tv*(Boris:Carole)/4 × *tv*(Carole:Danny)/4 =

  2/4 × 3/4 × 3 = 9/8

Main Issue

- How do you populate the initial matrix
  - That is, how do you set the trust values for each pair of entities

Example: PeerTrust

- Based on complaints as feedback
  - P peer-to-peer network, u node
  - $p(u, t)$ node that u interacts with in transaction t
  - $S(u, t)$ amount of satisfaction u gets from $p(u, t)$
  - $I(u)$ total number of transactions u does
  - $Cr(v)$ credibility of node v's feedback

Example: PeerTrust

- Trust value of *u* is:

$$T(u) = \sum_{t=1}^{I(u)} S(u,t) Cr(p(u,t))$$

- where *Cr*(*v*) is (one of many possible):

$$Cr(v) = \sum_{t=1}^{I(v)} S(v,i) \frac{T(p(v,t))}{\sum_{x=1} I(v) T(p(v,x))}$$

Key Points

- Integrity policies deal with trust
  - As trust is hard to quantify, these policies are hard to evaluate completely
  - Look for assumptions and trusted users to find possible weak points in their implementation
- Biba, Lipner based on multilevel integrity
- Clark-Wilson focuses on separation of duty and transactions

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

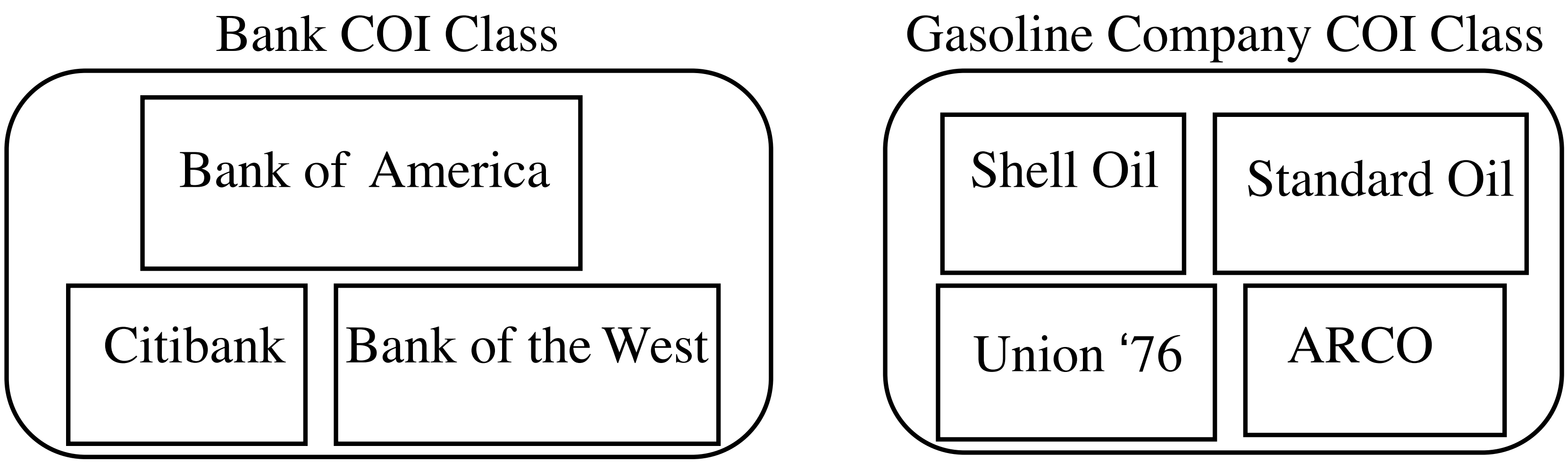
Organization

- 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, $PR(s) = \emptyset$, 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.