CS590U

Access Control: Theory and Practice

Lecture 15 (March 1)

Overview of Trust Management

Review of HW3

- On Sandhu's "Lattice-Based Enforcement of Chinese Walls"
  - users, principals, and subjects
    - the distinction of users and subjects, which exist in BLP, are important; and this distinction does clarify some of the discussions related in the Chinese Wall policy paper
    - is the notion of principals relevant in this discussion? How about in BLP and RBAC?

Is the Lattice Structure in Sandhu's Construction Useful?

- What objects may be given each of the label in the lattice?
- What are the high-level requirements?
  - A user may not access two datasets in one COI class
  - A subject can only read/write one company dataset

Chinese Wall vs. BLP

- Why Brewer and Nash claim that Chinese Wall Policy cannot be implemented in BLP?
  - BLP does not provide access history to determine whether a user A can be given access to a company data set
  - BLP only works if subjects are not given the freedom to choose which company datasets they wish to access. In other words, these transformations totally ignore the free choice nature of the Chinese Wall policy.

Does Sandhu’s Construction allow Free Choice?

- Chinese Wall
  - a user may freely choose to access a new company dataset
- Sandhu’s construction
  - a user is assigned a label (maximum security level)
  - that a user accesses a new company dataset corresponds to upgrading the user’s security label
  - in BLP, this label cannot be changed
    - in any reasonable extension of BLP, an ordinary user cannot change her label, especially cannot upgrade her label

Summary

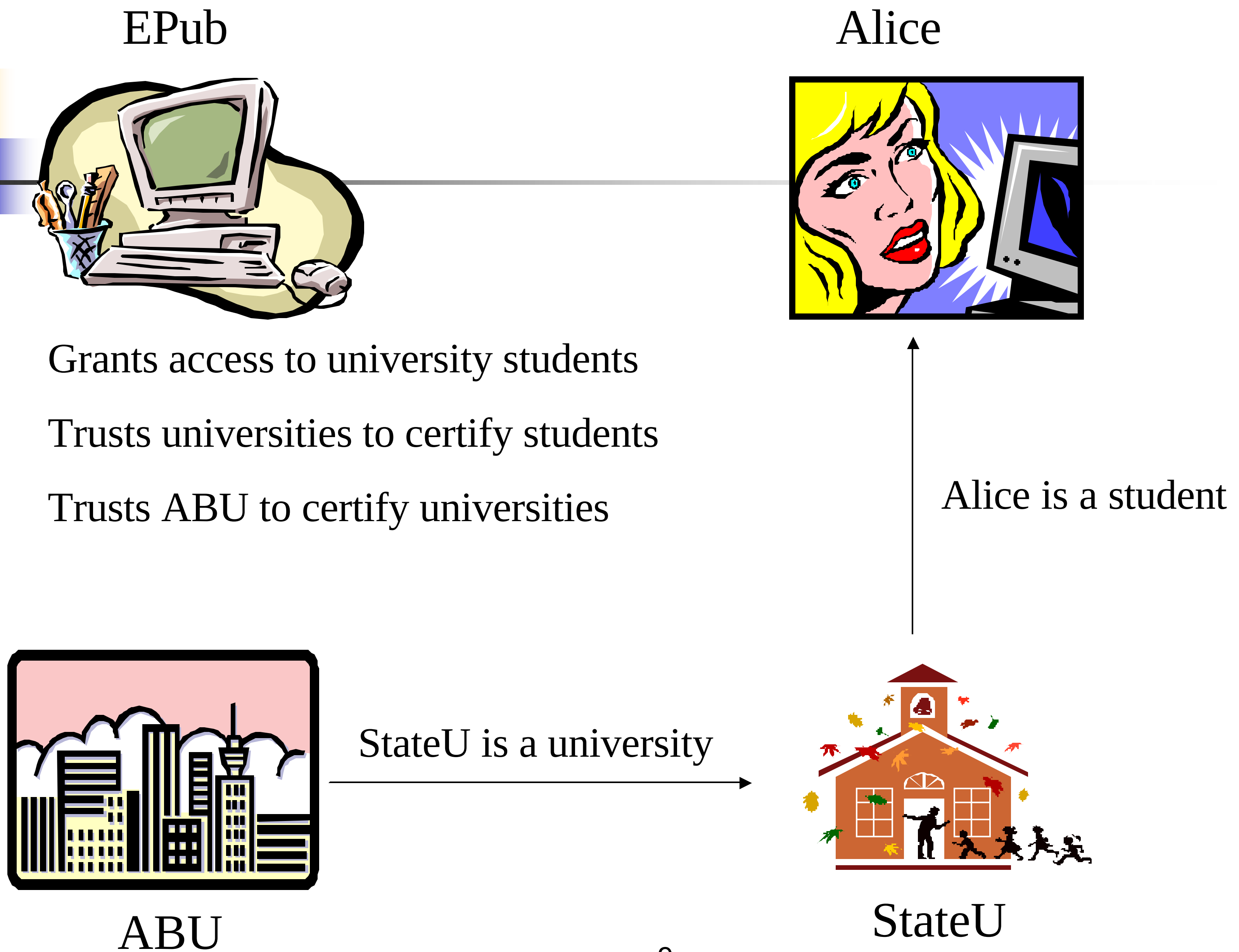
- The distinction between users and subjects is important
- The mandatory information flow part can be represented by information flow lattice
  - may be overkill, as it may be sufficient to restrict each subject to access one company dataset
- Sandhu's construction does not deal with the free choice nature of Chinese Wall policy
- Can BLP implement Chinese Wall is an open problem!
  - may be solved by formulating both as, say, i/o automata

Distributed Authorization

- Flexible and scalable access control in large-scale, open, distributed, decetralized systems
  - electronic commerce:
    - transaction authorization
    - application-level / business-policy authorization
  - resource sharing in decentralized systems
    - coalitions, multi-centric collaborative systems
    - grid computing
  - health care
  - and so on

Characteristics of Distributed Authorization

- No central administration, each service makes its own decision
- No relationship between a service and a user prior to a request
  - knowing a user's name may not help
  - must rely on information from third-party to make authorization decision (delegation)
- Authorization information is distributed
- Communication channels may be insecure


EPub
Alice
Grants access to university students
Trusts universities to certify students
Trusts ABU to certify universities
Alice is a student
StateU is a university
ABU
StateU

Medical Database

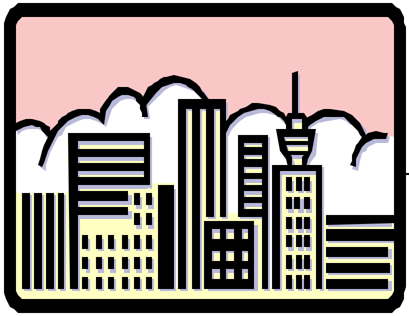
Alice

Grants access to physicians

Trusts CBH to certify hospitals

Trusts hospitals to certify physicians

Alice is a physician



Hospital A is a hospital

CBH

Hospital A

The Trust-Management (TM) Approach

- Multicentric access control using delegation
  - access control decisions are based on distributed policy statements issued by multiple principals
  - policy statements contain
    - attributes of principals such as permissions, roles, qualifications, characteristics
    - trust relationships

Common characteristics of TM systems

- Use public-key certificates for non-local statements
- Treat public keys as principals to be authorized
  - authentication consists of verifying signatures
- Adopt a peer model
  - an entity can be an authorizer, a requester, or a credential provider (trusted 3rd party)
- Treat the authorization decision problem as an application-independent *proof-of-compliance* problem

Public-Key Certificates

- A certificate is a data record together with a digital signature
- A certificate is signed using K^{-1}
  - we say that it is issued by a public key K
- A certificate binds some information to another public key (the subject key)
- Can be verified by anyone who knows the issuer's public key
  - can one trust the issuer's public key?

Existing Kinds of Public Key Infrastructures (PKIs)

- X.509 certificates
  - certificates are **issued** (signed) by **certification authorities (CA’s).**
  - **CA’s may be arranged in a hierarchy**
  - certificates form a chain
  - used by numerous applications: SSL, IPSec, etc.
- PGP
  - everyone can issue certificates, which bind email addresses to public keys

Early Trust Management Langugaes

- PolicyMaker
  - Blaze, Feigenbaum & Lacy: “Decentralized Trust Management”, S&P’96.
  - Blaze, Feigenbaum & Strauss: “Compliance-Checking in the PolicyMaker Trust Management System”, FC’98.
- KeyNote
  - Blaze, Feigenbaum, Ioannidis & Keromytis: “The KeyNote Trust-Management System, Version 2”, RFC 2714.
- SPKI (Simple Public Key Infrastructure) / SDSI (Simple Distributed Security Framework)
  - Rivest & Lampson: SDSI — A Simple Distributed Security Infrastructure, Web-page 1996.
  - Ellison et al.: SPKI Certificate Theory, RFC 2693.
  - Clarke et al.: Certificate Chain Discovery in SPKI/SDSI, JCS’01.

Datalog-based Trust Management Languages

- Delegation Logic
  - Li, Grosof & Feigenbaum: "Delegation Logic: A Logic-based Approach to Distributed Authorization", TISSEC'03. (Conference versions appeared in CSFW'99 and S&P'00)
- SD3 (Secure Dynamically Distributed Datalog)
  - Jim: "SD3: A Trust Management System with Certified Evaluation", S&P'01.
- Binder
  - DeTreville: "Binder, a Logic-Based Security Language", S&P'02.
- RT: A Family of Role-based Trust-management Languages
- PeerTrust

Other Closely Related Logic-based Security Languages

- ABLP logic (Abadi, Burrows, Lampson, et al.)
  - Lampson et al.: “Authentication in Distributed Systems: Theory and Practice”, TOCS’92.
  - Abadi et al.: “A Calculus for Access Control in Distributed Systems”, TOPLAS’93.
- QCM (Query Certificate Managers)
  - Gunter & Jim: “Policy-directed Certificate Retrieval”, SPE’00
- AF logic
  - Appel & Felton: “Proof-Carrying Authentication”, CCS’99

Issues in Designing Trust Management Languages

- Say what you want
  - succinctly and directly
  - with confidence that you said what you meant
- Enforcement
  - deduction, proof of compliance
- Policy development tools
  - manage policy lifecycle
  - analysis of safety, availability, and other security properties

Decentralized Trust Management

Matt Blaze, Joan Feigenbaum, Jack Lacy

Oakland’1996

Cited 439 times from Google Scholar

The PolicyMaker Language

- A query has the form
  - K_1, K_2, ⋯, K_n REUESTS *ActionString*
- Policies & credentials are encoded as assertions of the form
  - *Source* ASSERTS *AuthorityStruct* WHERE *Filter*
  - *Source* is either a public key or the keyword LOCAL
  - *AuthorityStruct* is a key, a list of keys, or a k-out-of-n threshold structure
  - *Filter* is a program that can be safety interpreted, it may be
    - a predicate, that returns yes/no
    - an annotator, returns yes/no and add to *ActionString*

Certificate chain discovery in SPKI/SDSI

Clarke et al.

JCS 2001

History of SPKI/SDSI

- SDSI (Simple Distributed Security Infrastructure)
  - SDSI 1.0 and 1.1
  - Rivest & Lampson 96
- SPKI (Simple Public Key Infrastructure)
  - SPKI 1.0 (Ellison 1996)
- SPKI/SDSI 2.0
  - RFC 2693 [1999]
  - [Clarke et al. JCS'01]

An Example in SDSI 2.0

- SDSI Certificates
  - (K_C access ⇨ K_C mit faculty secretary)
  - (K_C mit ⇨ K_M)
  - (K_M faculty ⇨ K_{EECS} faculty)
  - (K_{EECS} faculty ⇨ K_{Rivest})
  - (K_{Rivest} secretary ⇨ K_{Rivest} alice)
  - (K_{Rivest} alice ⇨ K_{Alice})
- From the above certificates, K_C concludes that K_{Alice} has access

4-tuple Reduction in RFC 2693

- Name strings can be reduced using 4-tuples
  - $(K_1\ A_1 \Rightarrow K_2)$ reduces "$K_1\ A_1\ A_2 \ldots A_n$"
    to "$K_2\ A_2 \ldots A_n$"
    - e.g., $(K_C$ mit $\Rightarrow K_M)$ reduces "K_C mit faculty secretary" to "K_M faculty secretary"
  - $(K_1\ A_1 \Rightarrow K_2\ B_1 \ldots B_m)$
    reduces "$K_1\ A_1\ A_2 \ldots A_n$"
    to "$K_2\ B_1 \ldots B_m\ A_2 \ldots A_n$"
    - e.g., $(K_M$ faculty $\Rightarrow K_{EECS}$ faculty) reduces "K_M faculty secretary" to "K_{EECS} faculty secretary"

Applying 4-tuple Reduction in the Example

- From (K_C access)
  to (K_C mit faculty secretary)
  to (K_M faculty secretary)
  to (K_{EECS} faculty secretary)
  to (K_{Rivest} secretary)
  to (K_{Rivest} alice)
  to (K_{Alice})

(K_C access ⇨ K_C mit faculty secretary) (K_C mit ⇨ K_M)
(K_M faculty ⇨ K_{EECS} faculty) (K_{EECS} faculty ⇨ K_{Rivest})
(K_{Rivest} secretary ⇨ K_{Rivest} alice) (K_{Rivest} alice ⇨ K_{Alice})

Papers on Semantics for SPKI/SDSI

- Develop specialized modal logics
  - Abadi: “On SDSI's Linked Local Name Spaces”, CSFW’97, JCS’98.
  - Halpern & van der Meyden:
    - “A logic for SDSI's linked local name spaces”, CSFW’99, JCS’01
    - “A Logical Reconstruction of SPKI”, CSFW’01, JCS’03
  - Howell & Kotz: “A Formal Semantics for SPKI”, ESORICS’00
- Other approaches
  - Li: “Local Names in SPKI/SDSI”, CSFW’00
  - Jha & Reps: “Analysis of SPKI/SDSI Certificates Using Model Checking”, CSFW’02
  - Li & Mitchell: “Understanding SPKI/SDSI Using First-Order Logic”, CSFW’03, IJIS’2005

Concepts in SDSI

- Concepts
  - principals — K, K_1
  - identifiers — A, B, A_1
    e.g., mit, faculty, alice
  - local names — $K\ A$, $K_1\ A_1$
    e.g., K_M faculty, K_{Rivest} alice
  - name strings — $K\ A_1\ A_2\ \ldots\ A_n$
    ω, ω_1
    e.g., K_C mit faculty secretary

Statements in SDSI

- 4-tuple (K, A, ω, V)
  - K is the issuer principal
  - A is an identifier
  - ω is a name string
  - V is the validity specification
- We write (K A ⇨ ω) for a 4-tuple
  - ignoring validity specification

A Rewriting Semantics for SDSI

- A set P of 4-tuples defines a set of rewriting rules, denoted by RS[P]
- Queries have the form “can ω_1 rewrite into ω_2?”
- Answer a query is not easy.
  - cannot naively search for all ways of rewriting ω_1, as there may be recursions
    - e.g., (K friend ⇨ K friend friend)
- What can we do?

Deduction Based on the Rewriting Semantics (1)

- Limit queries to the form “can ω_1 rewrite into K?”
  - In [Clarke et al.’01], the following closure mechanism is used
    - rewrite 4-tuples
      - e.g., apply (K_C mit ⇨ K_M) to rewrite (K_C access ⇨ K_C mit faculty secretary), one gets (K_C access ⇨ K_M faculty secretary)
    - compute the closure of a set of 4-tuples,
      - obtained by applying 4-tuples that rewrites to a principal
    - then use the resulting shortening 4-tuples to rewrite ω_1
  - Search is not goal-directed

Deduction Based on the Rewriting Semantics (2)

- Limit to queries like "can ω_1 rewrite into K?"
  - In [Li CSFW'00], the following XSB logic program is given

```
:- table(contains/2).
contains([P0, N0 | T], P2) :-
        contains([P0, N0], P1),
        contains([P1 | T], P2).
contains([P0, N0], P) :-
        credential([P0, N0], CN2),
        contains(CN2, P).
contains([P], P, []) :- isPrincipal(P).
```

Deduction Based on the Rewriting Semantics (3)

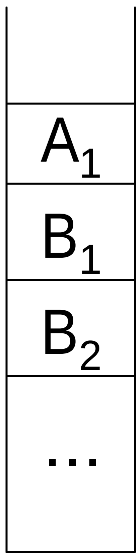
- [Li, Winsborough & Mitchell, JCS'03]
  - develop a graph-based search algorithm for a language RT_0, a superset of SDSI
    - combines bottom-up search and goal-directed top-down search with tabling specifically for the kind of rules in RT_0
    - can deal with distributed discovery
  - we will talk about this later

Deduction Based on the Rewriting Semantics (4)

- Use techniques for model checking pushdown systems [Jha & Reps CSFW'02]
  - SDSI rewriting systems correspond to string rewriting systems modeled by pushdown systems
  - algorithms for model checking pushdown systems can be used
    - takes time O(N^3), where N is the total size of the SDSI statements

SDSI and Pushdown Systems

Stack:

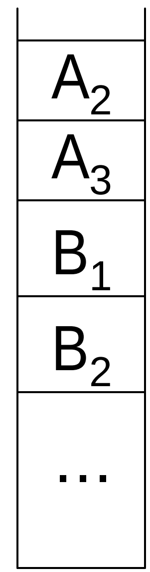


State: K_1

Apply the rewriting rule:

$K_1\ A_1$ to $K_2\ A_2\ A_3$

Stack:



State: K_2

A name string corresponds to a configuration

“rewrites into” equivalent to “reaches”

Recap of the Rewriting-based Semantics

- Defines answers to queries having the form "can ω_1 rewrite into ω_2?"
- Specialized algorithms (either developed for SDSI or for model checking pushdown systems) are needed
- Papers by Abadi and Halpern and van der Meyden try to come up with axiom systems for the rewriting semantics

Next Lecture

- Distributed Credential Chain Discovery in RT0