Formal methods and access control

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Information Security and Policy– Lecture 8

Today's topics:

Access control basics

- Access Control Model
- Matrix and protection states
- Access control lists and capability model

Looking at access control…

Definition

A state of access control is said to be *safe* if no permission can be leaked to an unauthorized or uninvited individual

- Access control systems come with a wide variety of features and administrative capabilities
- *Security models* are formal presentations of the security policy enforced by the access control system and are useful for proving theoretical limitations of a system

Types of Access Control Polices

- Discretionary Access Control (DAC, IBAC)
  - individual user sets access control mechanisms to allow or deny access to an object
  - Based on identity of subject and object involved
  - e.g. Diary
- Mandatory Access Control (MAC)
  - system controls access to objects and *individual cannot alter that access*
  - e.g. public court information, military systems
- Originator Controlled Access Control (ORCON)
  - originator (creator) of information controls who can access and disseminate information, not the owner
  - e.g. NDAs on code changes, licensing agreements
- Role Based Access Control (RBAC)
  - access control decisions based on the a user's role in an Organization
  - Roles may be expressed hierarchically
  - Can implement DAC and MAC
- Attributed Based Access Control
  - logical access control based on collections of attributes of objects and users
  - authorization to perform a set of operations is determined by evaluating attributes associated with the subject, object, requested operations, and environment conditions against policy, rules, or relationships that describe the allowable operations for a given set of attributes
- Others exist that are domain specific or are used for solutions to specific access problem

Access Control Models

- Regulate the logical access to information with the system
- Maintained by a collection of policies and enforcement mechanisms
- 4 processes that build on each other:
  - identification: Obtain the identity of the entity requesting access
  - authentication: Confirm the identity of the entity
  - authorization: Determine which actions the entity can perform
  - accountability: Document the activities of the entity and system
- Built on principles for
  - Least privilege – minimum access required for duties
  - Need to know – specific data at specific times
  - Separation of duties – segregating access responsibilities to limit powers

Definition

Access *control lists, matrices, and capability tables* are mechanisms that govern the rights and privileges of users

- Can control access to file storage systems, object brokers, or other network communications devices.

A capability table specifies which subjects and objects that users or groups can access

- Often considered user profiles or user policies
- Can take the form of complex matrices

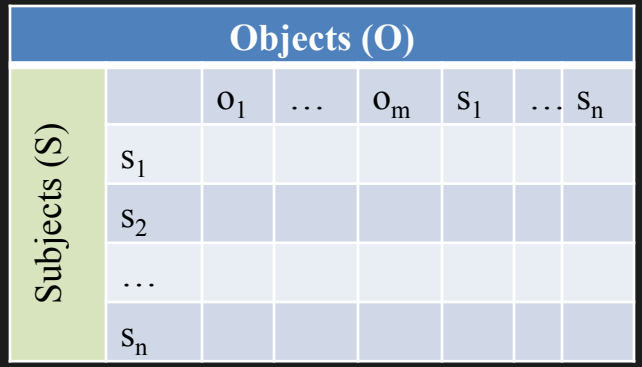
Access Control Tables

- Restrict access according to user, time, duration, and file to regulate the following
  - Who can use the system
  - What authorized users can access the system
  - Where authorized users can access the system from
  - When authorized users can access the system
  - How authorized users can access the system
- Administrators assign user privileges as rights
- Rights can include
  - Generic access (read, write, execute)
  - Domain specific
  - Functions that determine rights given the current state or historical access or states
  - Functions that determine rights given other current rights

Access Control Matrix

- Tool to describe current protection state
  - Privileges possessed by *subjects* (active entity) with respect to other entities
    - State transitions change elements of matrix
      - Matrix evolves by the autonomous activities of the subjects
    - The set of protection states of the system is represented by the triple (S, O, A) where S is the set of *Subjects*, O is the set of *Objects*, and A is the *matrix of rights*
  - Relies on an authorization scheme
    - Rules that direct how the protection state can be changed

Access Control Matrix as an Abstract Model of the Protection State



Matrix A

- Subjects $S = \{ s_1, \ldots, s_n \}$
  - each are subjects and objects that own themselves
- Objects $O = \{ o_1, \ldots, o_m \}$
  - *Could be devices, processes, messages, systems*
  - Subjects are objects (active) but not vice versa
- Rights $R = \{ r_1, \ldots, r_k \}$
  - *r* (read), *w* (write), *x* (execute), *a* (append), *o* (own)
  - meaning of a right may vary depending on the object involved
- Entries $A[s_i, o_j] \subseteq R$
- $A[s_i, o_j] = \{ r_x, \ldots, r_y \}$ means subject s_i has rights $r_x, \ldots, r_y$ over object o_j

can think of R in terms of reachability as well (a different R, from before)

Access Control by Boolean Expression Evaluation

- ACM controls access to objects
  - Objects are records and fields
  - Subjects are authorized users with attributes
  - Verbs define type of access (rights)
  - Rules associated with objects, verb pair
- Subject attempts to access object
  - Rule for object, verb evaluated, grants or denies access

Example

- Subject (s) **Abe**
  - role (clerk), group (courthouse)
- Verb (activity) **sign**
  - Default: Deny
- Object **tax-doc**
  - Access Rule for tax-doc

    sign: 'clerk' in s.role and
    'courthouse' in s.group and
    0800 ≤ hour ≤ 1700 and
    "Monday" ≤ day ≤ "Friday"

Activity	**Default Access**
Read	Granted
Write	Deny
Sign	Deny

maps to policy:

$\forall s \in Subjects, t \in Times, d \in Days,$

$sign(s) \Leftrightarrow (role(s) = clerk) \wedge (0800 \leq t \leq 1700) \wedge d \in \{M, T, W, Th, F\}$

Access Control Matrix for Abe

- Protection state changes according to hour and day

- At 1am on Monday

- At 3pm on Wednesday

- At 3pm on Saturday

	…	tax_doc	…
…			
Abe			
…			

	…	tax_doc	…
…			
Abe		sign	
…			

	…	tax_doc	…
…			
Abe			
…			

State Transitions

- Change the protection state of system –
  - $X_0 = (S_0, O_0, A_0)$ be the initial state
  - $T = [\tau_1, \tau_2, \ldots]$ commands
- Commands are transformation procedures that follow the authorization scheme
    - Change the triple
      - Alter subject or object set based on τ
      - Change entries in the access control matrix rights
    - Use parameters to state how the change is made
- Given the initial state and the authorization scheme, it is a formal process to characterize all of the protection states that are reachable

Primitive Commands, τ

- To maintain proper logical values for pre- and post-conditions
  - Protection *before* state: (S,O,A)
  - Protection *after* state: (S′, O ′, A ′)
- **create subject** *s*
  - Creates new **row** and **column** in ACM, but does not alter rights
  - Precondition (subject does not exist) : $s \notin S$
  - Postconditions:

$S' = S \cup \{ s \} \wedge$	[subject exists]
$O' = O \cup \{ s \} \wedge$	[subject object exists]
$(\forall y \in O)[a'[s, y] = \varnothing] \wedge$	[initialize access to all objects to null, i.e. deny]
$(\forall x \in S)[a'[x, s] = \varnothing] \wedge$	[ensure no other subject has access to the new subject object
$a'[s, s] = \{\text{“own”}\} \wedge$	[establish ownership of self]
$(\forall x \in S)(\forall y \in O)[a'[x, y] = a[x, y]]$	[everything else stays the same as it was before]

- **create object** *o*
  - Creates new **column** in ACM, but does not alter rights
- **destroy subject** *s*
  - Deletes **row**, **column** from ACM
- **destroy object** *o*
  - Deletes **column** from ACM

Sample Command Logic

- Allows for provability
- enter *r* into A[*s*, *o*]
  - Adds *r* rights for subject s over object *o*
  - Precondition: $s \in S, o \in O$
  - Postconditions:

    $S' = S \wedge O' = O \wedge$

    $a'[s, o] = a[s, o] \cup \{ r \} \wedge$

    $(\forall x \in S')(\forall y \in O' - \{ o \})\ [a'[x, y] = a[x, y]] \wedge$

    $(\forall x \in S' - \{ s \})(\forall y \in O')\ [a'[x, y] = a[x, y]]$
- delete r from A[s, o]
  - Removes r rights from subject s over object o
- Make subject *p* the owner of file *g*

```
command make-owner(p, g)
        enter own into A[p, g];
end
```

- Conditional commands
  - Let *p* give *q* *r* and *w* rights over *f*, if *p* owns *f* and *p* has *copy* (*c*) rights over *q*

```
command grant-read-file(p, f, q)
        if own in A[p, f] and c in A[p, q]
        then
            enter r into A[q, f];
            enter w into A[q, f];
end
```

Copying Rights

- Allows possessor to give rights to another
- Often attached to only the applicable right
  - r is read right that cannot be copied
  - rc is read right that can be copied
- Depending on the model, the copy flag may copied when giving r rights

Owning Rights

- Usually the possessor (owner) can change entries in ACM column by adding and deleting rights for others with respect to that object
  - May depend on what system allows
    - Can't give rights to specific (set of) users
    - Can't pass copy flag to specific (set of) users

Principle: Attenuation of Privilege

- says you can't give rights you do not possess
  - Restricts addition of rights within a system
  - Usually *ignored* for owner since owner gives self rights, gives them to others, deletes self rights.

Two Approaches

- ACL – Access Control List for specifying object access
- Capability Lists - for specifying subject capabilities

Access Control Lists

	Obj_1	Obj_2	Obj_3
Allen	rwxo	r	rw
Bea	rx	rwo	
Cody	rx	r	rwo

- Uses the columns of access control matrix
- ACLs:
  - Obj_1: { (Allen, *rwxo*) (Bea, *rx*) (Cody, *rx*) }
  - Obj_2: { (Allen, *r*) (Bea, *rwo*) (Cody, *r*) }
  - Obj_3: { (Allen, *rw*) (Cody, *rwo*) }
- The normal use is if not named, *no* rights over file
  - Based on Principle of Fail-Safe Defaults
  - Extended to composed policies

ACL Usage

- Who can modify the ACL?
  - Creator is given *own* right for modification
  - Can be a something available like a copy flag that allows a right to be transferred, so ownership not needed
- ACL application to privileged users varies across vendors and with respect to abbreviated or full blown entries
- Denying access
  - If ACL entry denies user access, then deny access
  - If the user is not in file's ACL nor in any group named in file's ACL then deny access
  - If there are conflicts, the norm is to deny access if any entry denies access

Capability Lists

- Rows of access control matrix
- C-Lists:
  - Allen: { (Obj_1, rwxo) (Obj_2, r) (Obj_3, rw) }
  - Bea: { (Obj_1, rx) (Obj_2, rwo) }
  - Cody : { (Obj_1, rx) (Obj_2, r) (Obj_3, rwo) }

	Obj_1	Obj_2	Obj_3
Allen	rwxo	r	rw
Bea	rx	rwo	
Cody	rx	r	rwo

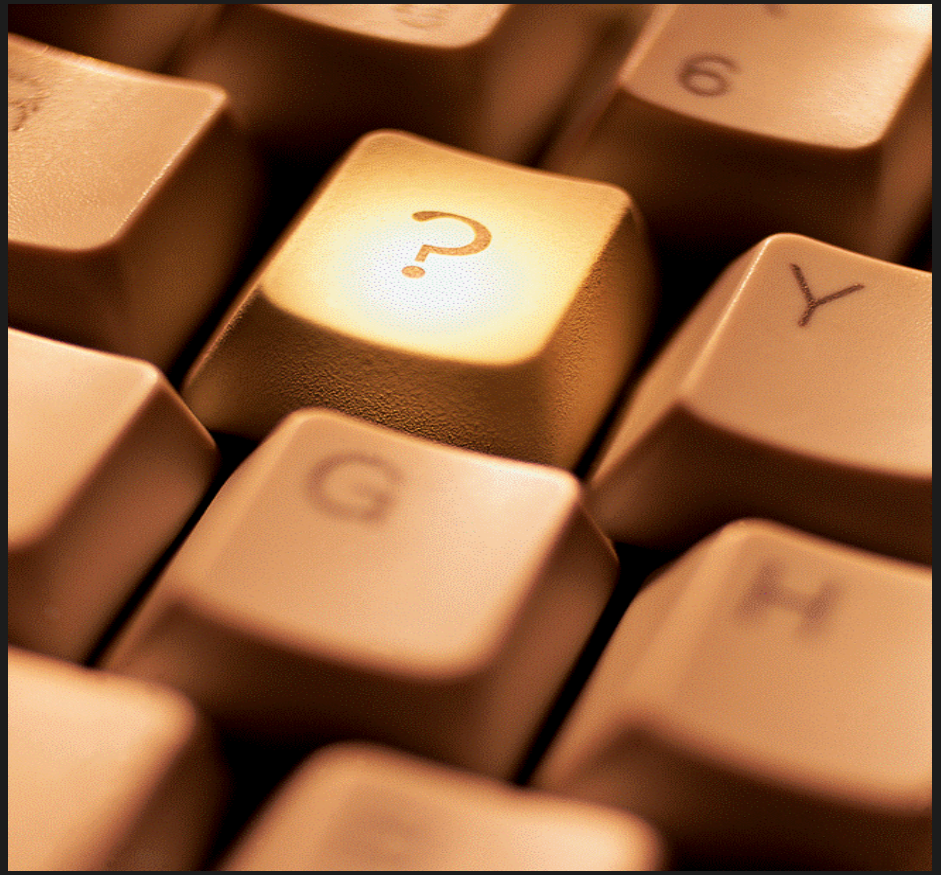
ACLs vs. Capabilities

- Theoretically equivalent
  1. Given a subject, what objects can it access, and how? (answered by C-Lists)
  2. Given an object, what subjects can access it, and how? (answered by ACLs)
- Second question has in past been of most interest making ACL-based emerge as more common
- First question becomes more important for incident response

Homework

None

Questions?



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