These Slides are prepared from
Matt Bishop slides and book "Introduction to Computer Security"
Benefiting from the Slides posted by Ahmad Al-Mulhem

Access Control

Access Control Matrix ***Ch 2***

Access Control Mechanisms Ch 14

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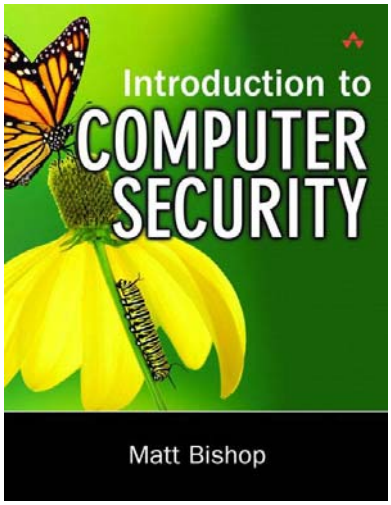

Ch 2: Access Control Matrix

- Protection State
- Access Control Matrix Model
- Protection State Transitions
  - Commands
    - Operational
    - Conditional

Protection State

- The "state" of a system is the collection of the current values of all memory locations (RAM, registers, secondary storage, etc.)
- The "protection state" of a system is the subset of states that deals with protection
  - Describes current settings, values of system relevant to protection
- Access control matrix model - tool
  - Describes protection state precisely
  - Matrix describing rights of subjects
  - State transitions change elements of matrix

Access Control

- subjects (e.g. users or processes) ➔ objects (e.g. files)
  - Subjects (active) need to access objects (passive)
- Two main categories:
  - Discretionary access control (DAC):
    - defined by user ------- Discretionary = optional
  - Mandatory access control (MAC):
    - enforced by the system

Access Control Matrix (ACM)

The set of all protected entities is the set *O*

Processes and users constitute the set *S*

objects (entities)

subjects

	o_1	…	o_m	s_1	…	s_n
s_1						
s_2						
…						
s_n						

- Subjects $S = \{ s_1,\ldots,s_n \}$
- Objects $O = \{ o_1,\ldots,o_m \}$
- Rights $R = \{ r_1,\ldots,r_k \}$
- 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

Example 1

- Processes: p, q
- Files: f, g
- Rights: read, write, execute, append, own

	f	*g*	*p*	*q*
p	*rwo*	*r*	*rwxo*	*w*
q	*a*	*ro*	*r*	*rwxo*

Example 2

- Processes: telegraph, nob, toadflax
- Rights: own, ftp, nfs, mail

host names	*telegraph*	*nob*	*toadflax*
telegraph	own	ftp	ftp
nob		ftp, nfs, mail, own	ftp, nfs, mail
toadflax		ftp, mail	ftp, nfs, mail, own

Example 3

- Procedures: inc_ctr, dec_ctr, manage
- Variable: counter
- Rights: +, –, call

	counter	*inc_ctr*	*dec_ctr*	*manage*
inc_ctr	+			
dec_ctr	–			
manage		*call*	*call*	*call*

State Transitions

- As processes execute, the protection state of system changes
  - Based on history, time, day, functions, rights of other subjects…etc
  - Conditions (no access to file while being in writing function) …etc
- The initial state of the system $X_0 = (S_0, O_0, A_0)$
  - State Transitions set of operations is represented as: $\tau_1, \tau_2, \ldots$
  - Successive states $X_0, X_1, X_2, \ldots$
- $\vdash$ represents transition
  - $X_i \vdash_{\tau_{i+1}} X_{i+1}$: command τ_{i+1} moves system from state X_i to X_{i+1}
  - $X_i \vdash^{*} X_{??}$: a sequence of commands moves system from state X_i to $X_{??}$
- Commands often called *transformation procedures*

Primitive Operation Commands

- **create subject** *s*
  - Creates new row, column in ACM
- **create object** *o*
  - Creates new column in ACM
- **enter** *r* **into** *A*[*s*, *o*]
  - Adds *r* rights for subject *s* over object *o*
- **delete** *r* **from** *A*[*s*, *o*]
  - Removes *r* rights from subject *s* over object *o*
- **destroy subject** *s*
  - Deletes row, column from ACM
- **destroy object** *o*
  - Deletes column from ACM

Multi-Operational Commands Creating File

- Process *p* creates file *f* with *r* and *w* permission

```
command create•file(p, f)
   create object f;
   enter own into A[p, f];
   enter r into A[p, f];
   enter w into A[p, f];
end
```


Mono-Operational Commands

- Make process *p* the owner of file *g*

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

- Mono-operational command
  - Single primitive operation in this command

Mono-Conditional Commands

- Let *p* give *q* *r* rights over *f*, if *p* owns *f*

```
command grant•read•file•1(p, f, q)
    if own in A[p, f]
    then
         enter r into A[q, f];
end
```

- Mono-conditional & Mono-operational command
  - Single condition & single primitive operation in this command

Multi-Conditions Commands

- Let *p* give *q* *r* and *w* rights over *f*, if *p* owns *f* and *p* has *c* rights over *q*

```
command grant•read•file•2(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
```

Commands with 2 conditions = bi-conditional
Commands with 2 primitive commands = bi-operational

Conditions are joined by `and` only

- All multi-conditions are joined by `and` and never `or` !! Why ??
- Also, conditions cannot be based on negation such as:

```
if r not in A[p, f]    xxx
```


Key Points

- Access control matrix (ACM) is a simple theoretical (not practical) tool for representing protection state
- Transitions - commands- alter protection state
- 6 primitive operations change matrix
  - Transitions can be expressed as commands composed of these operations and, possibly, conditions

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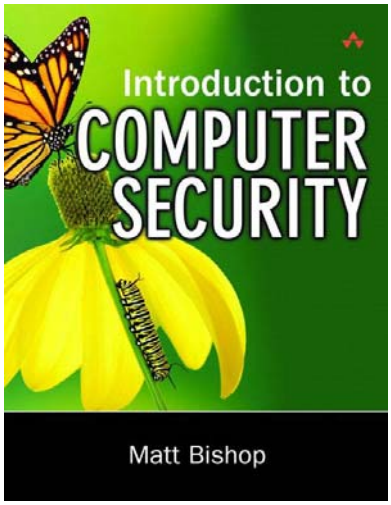


Chapter 14: Access Control Mechanisms

- Access control lists
- Capabilities
- Locks and keys
- Ring-based access control
- Propagated access control lists

Problems with Access control matrix:

- number of subjects and objects can be very large
- most entries are blank/empty
- creations and deletions are expensive

Access Control Lists (ACL)

- ACL = Columns of "access control matrix"

		file1	*file2*	*file3*
Andy	rx	r	rwo	
Betty	rwxo	r		
Charlie	rx	rwo	w	

- ACLs:
- file1: { (Andy, rx) (Betty, rwxo) (Charlie, rx) }
- file2: { (Andy, r) (Betty, r) (Charlie, rwo) }
- file3: { (Andy, rwo) (Charlie, w) }

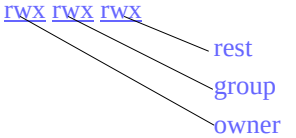
Default Permissions

- Normal: if not named, *no* rights over file
  - Principle of Fail-Safe Defaults
- If many subjects, may use groups or wildcards in ACL

- Example (UNICOS)
  - entries are (*user*, *group*, *rights*)
    - If *user* is in *group*, has rights over file
    - '*' is wildcard for *user*, *group*
      - (holly, *, r): holly can read file regardless of her group
      - (*, gleep, w): anyone in group gleep can write file

ACL Abbreviations

- ACLs can be long … so combine users
  - Example (UNIX): 3 classes of users: owner, group, rest
  - rwx rwx rwx



  - Separate read, write, execute rights for user, group and rest
  - Ownership assigned based on creating process
    - "-" means no right (e.g. rw- r- - r- -)

Abbreviated ACL + Full ACL

- Problem: Abbreviated ACL results in loss of granularity
- Solution: Augment abbreviated lists with full ACLs
  - Intent is to shorten ACL
- ACLs override abbreviations
  - Exact method varies

- Example: IBM AIX
  - Base permissions are abbreviated ACL, extended permissions are ACLs with user, group
  - ACL entries can add rights, but on deny, access is denied

Creation and Maintenance of ACLs

- Which subjects can modify an object's ACL?
  - creator is given own right that allows this
- Are there privileged users (root)? Do ACLs apply to them?
- Does the ACL support groups or wildcards?
- How are conflicts in access control permissions handled?

Capability Lists (C-List)

- C-List: Rows of access control matrix

		file1	*file2*	*file3*
Andy	rx	r	rwo	
Betty	rwxo	r		
Charlie	rx	rwo	w	

- C-Lists:
- Andy: { (file1, rx) (file2, r) (file3, rwo) }
- Betty: { (file1, rwxo) (file2, r) }
- Charlie: { (file1, rx) (file2, rwo) (file3, w) }

C-List Meaning

- Like a bus ticket
  - Mere possession indicates rights that subject has over object
  - Object identified by capability (as part of the token)
    - Name may be a reference, location, or something else
  - Architectural construct in capability-based addressing; this just focuses on protection aspects
- Must prevent process from altering capabilities
  - Otherwise subject could change rights encoded in capability or object to which they refer
- C-List typically supported by hardware

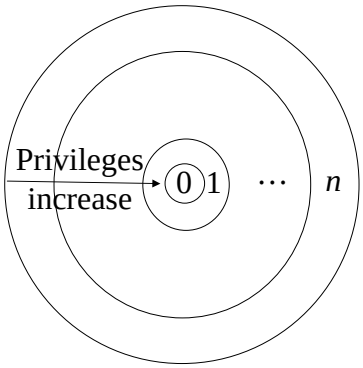
ACLs vs. Capabilities

- Both theoretically equivalent; consider 2 questions
  1. Given a subject, what objects can it access, and how?
  2. Given an object, what subjects can access it, and how?
  - ACLs answer second easily; C-Lists, first
- Suggested that the second question, which in the past has been of most interest, is the reason ACL-based systems more common than capability-based systems
  - As first question becomes more important (in incident response, for example), this may change

Locks and Keys

- Associate information (*lock*) with object, information (*key*) with subject
  - Latter controls what the subject can access and how
  - Subject presents key; if it corresponds to any of the locks on the object, access granted
- This can be dynamic
  - ACLs, C-Lists static and must be manually changed
  - Locks and keys can change based on system constraints, other factors (not necessarily manual)

Ring-Based Access Control



- n layers of privilege (rings)
  - ring 0 is most privileged
  - ring n is least privileged
- Introduced by Multics (1964-2000)
- Typically hardware enforced
- Special gates between rings are provided to allow an outer ring to access an inner ring's resources

Key Points

- Access control matrix (ACM) is a simple tool to model protection state but:
  - most entries are blank/empty
  - expensive to manage (creations, modification and deletions)
- Access control mechanisms provide controls for users accessing files & resources
- Many different forms
  - ACLs, capabilities, locks and keys
  - Ring-based mechanisms (Mandatory)