Access Control

- Chapter 2
  - Access Control Matrix Model
- Chapter 14
  - Access Control Mechanisms
- Chapter 4
  - Access Control Models

Overview

- Protection (secure) state of system
  - Describes current settings, values of system relevant to protection
- Access control matrix
  - **Describes protection state precisely**
  - Matrix describing rights of subjects
  - State transitions change elements of matrix

Description

objects (entities)

subjects

	o_1	…	o_m	s_1	…	s_n
s_1						
s_2						
…						
s_n						

- Subjects $S = \{ s_1,\dots,s_n \}$
- Objects $O = \{ o_1,\dots,o_m \}$
- Rights $R = \{ r_1,\dots,r_k \}$
- Entries $A[s_i, o_j] \subseteq R$
- $A[s_i, o_j] = \{ r_x, \dots, r_y \}$ means subject s_i has rights $r_x, \dots, r_y$ over object o_j

Description

- Objects (destinations)
  - Entities to be protected
  - Files, devices, memory blocks, instructions, functions, processes (services), hosts (addresses)
- Subjects (sources)
  - Entities that access the objects
  - Processes, users, hosts (addresses)

Description

- Rights (access rights)
  - Category of rights
    - Unix: read, write, execute, own (rights to change rights other than ownership)
    - Windows: ...
    - Network: connect, download, upload, ...
  - How are the rights related to confidentiality, integrity, availability?

Description

- Interpretation of rights
  - Read a file
  - Read a directory
    - In a file system
    - In a web server
  - Execute a file
  - Execute a directory
    - In a file system
    - In a web server

Case (homework)

- Policy: no copy of other's homework
- Subject: Alice, Bob, Charlie
- Object: A's hw, B's hw, C's hw
- Right: copy(read)
- ACM: ?
- Mechanism: ?

for directories

-x can't go inside (ideal)

-r ls in dir

-w name new object in dir

Case (continue)

- Incident: Charlie deleted Alice's homework.
- What's the security problem? Policy or mechanism?
- Improvement: policy, subjects, objects, rights, acm, mechanisms.

Case (web)

- Policy
  - All students and instructors can access TRACs.
  - Only instructors can access solutions.
- ACM?
  - Subjects, objects, rights
  - ACM
  - Mechanisms

Example 1 : File System

- Processes *p*, *q*
- Files *f*, *g*
- Rights *r*, *w*, *x*, *a*, *o*

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

Example 2 : Programming

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

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

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Access Control Mechanisms

- Access control lists
- Capabilities
- Ring-based access control

Implementation of Access Control

Policy

- Define security policy
- Create the access control matrix

Mecha-nism

- Implement and put the ACM in a storage
- When a user (s) requests an operation (p) on an object (o)
  - Check if p is in the entry A(s,o) of the ACM.
  - Yes, proceed; No, deny.

Problems

- Problems using a raw access control matrix
  - Too many subjects and objects
  - Too many blank entries
  - Too complicated operations to create and delete entries
- Problems in solutions
  - Restrict access control matrix in some manner
  - No precise solution

Access Control Lists

- Columns of access control matrix

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

ACLs: no empty entries

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

Access Control Lists

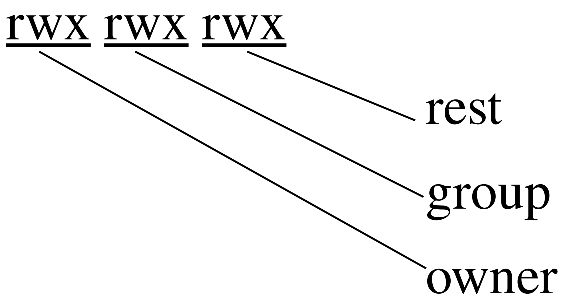
- Define security policy
- Create the access control matrix
- Implement and put the ACL in a storage
- When a user (s) requests an operation (p) on an object (o)
  - Retrieve the ACL(o)
  - Check if (s,p) matches (∈) an entry of ACL(o).
  - Yes, proceed; No, deny.

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
  - 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

Abbreviations

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



rest

group

owner

  - Ownership assigned based on creating process
    - Some systems: if directory has setgid permission, file group owned by group of directory (SunOS, Solaris)

Problem of Abbreviation

- Problem : loss of granularity
  - “Everyone but Alice can read”
    - Create a group excluding Alice
    - Set r on the group
  - “Everyone can read” + “Everyone but Alice can write”
    - Create a group excluding Alice
    - Set rw on the group, r on others
  - “Everyone but Alice can read” + “Everyone but Bob can write”
    - Abbreviation?

Abbreviations + ACLs

- Augment abbreviated lists with ACLs
  - Intent is to shorten ACL
- ACLs override abbreviations
  - Exact method varies
- Example: IBM AIX
  - Base permissions are abbreviations
  - Extended permissions are ACLs with user, group
  - ACL entries can add rights, but on deny, access is denied

Abbreviations + ACLs

- Procedure
  - Get the base permission S from the abbreviated base permissions.
  - Modify S according the entries of the ACL
    - If an entry denies the requested permission, stop.
    - If no more entry, S is the permissions granted to the requesting user.

Abbreviations + ACLs

```
attributes:
base permissions
  owner(bishop):   rw-
  group(sys):      r--
  others:          ---
extended permissions enabled
  specify          rw-   u:holly
  permit           -w-   u:heidi, g=sys
  permit           rw-   u:matt
  deny             -w-   u:holly, g=faculty
```

Abbreviations + ACLs in Linux

- Enable ACL to the file system
  - /etc/fstab
- Grant or revoke permissions in the ACL
  - getfacl
  - setfacl

```
# file: foo
# owner: qijun
# group: qijun
user::rw-
user:root:r--
group::---
mask::r--
other::---
```

ACL Issues

- Who can modify the ACL of an object?
- What is the role of a privileged user?
- Does ACL support groups and wildcards?
- How are contradictory permissions handled?
- How to handle default permissions?
- How to revoke a subject's permission?

ACL Modification

- Which subjects can modify an object's ACL?
  - The right to change rights
  - Creator is given *own* right that allows this
  - System R provides a *grant* modifier (like a copy flag) allowing a right to be transferred, so ownership not needed
    - Transferring right to another modifies ACL

Privileged Users

- Do the ACLs apply to privileged users (*root*)?
  - – Solaris: abbreviated lists do not, but full-blown ACL entries do
    - If abbreviation denies read to root, root can read.
    - If ACL denies read to root, root cannot read
  - – Linux: no, in most cases
  - – Other vendors: varies

Groups and Wildcards

- Does the ACL support groups and wildcards?
- Classic form: no; in practice, usually
  - AIX: base perms gave group sys read only

    ```
    permit    -w-   u:heidi, g=sys
    ```

    line adds write permission for heidi when in that group
  - UNICOS:
    - holly : gleep : r
      - user holly in group gleep can read file
    - holly : * : r
      - user holly in any group can read file
    - * : gleep : r
      - any user in group gleep can read file

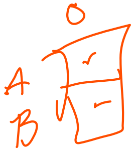
Conflicts

- Deny access if any entry would deny access
  - AIX: if any entry denies access, *regardless or rights given so far*, access is denied
- All access if any entry would allow access
- Apply first entry matching subject
  - Cisco routers: run packet through access control rules (ACL entries) in order; on a match, stop, and forward the packet; if no matches, deny
    - Note default is deny so honors principle of fail-safe defaults

Conflicts

- Examples
  - Subjects: A is a subset of B
  - Object: O
  - A is allowed to read C, but others in B cannot.
  - O's ACL should be {(A, r), (B-A, -)}
    - First apply: {(A, r) (B, -)} or {(B, -) (A, r)}?
    - Deny access: {(A, r) (B, -)} or {(B, -) (A, r)}?
    - Allow access: {(A, r) (B, -)} or {(B, -) (A, r)}?

Deny → ✗



Handling Default Permissions

- Apply ACL entry, and if none use defaults
  - Cisco router: apply matching access control rule, if any; otherwise, use default rule
- Augment defaults with those in the appropriate ACL entry
  - AIX: extended permissions augment base permissions

Revocation Question

- How to remove subject’s rights from a file?
  - Owner deletes subject’s entries from ACL, or rights from subject’s entry in ACL
- How to remove a subject from the system?
- What if ownership not involved?
  - Depends on system
  - System R: restore protection state to what it was before right was given

Example: iptables

- Linux firewall
  - Commands in Fedora/Centos/Redhat
    - Must be root
  - Enable or disable
    - chkconfig iptables on|off
    - systemctl enable|disable iptables
  - Status
    - service iptables status
    - systemctl status iptables
  - Start or stop
    - service iptables start|stop
    - systemctl start|stop iptables

iptables

- Firewall rules are organized in chains
  - Three default chains
  - INPUT: for incoming packets Ext → Internal
  - FORWARD: for traversing packets Ext → Int → Ext
  - OUTPUT: for outgoing packets Internal → External
- All network packets are inspected according to firewall rules in order
- The packet is accepted or rejected on the first matching rule

Example

- Built-in chains

```
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
```

- Other

-F flush
-S show

```
Chain INPUT (policy ACCEPT)
target     prot opt source               destination
f2b-SSH    tcp  --  anywhere             anywhere            tcp dpt:ssh
ACCEPT     all  --  anywhere             anywhere            state RELATED,ESTABLISHED
ACCEPT     tcp  --  anywhere             anywhere            state NEW tcp dpt:ssh
ACCEPT     tcp  --  anywhere             anywhere            state NEW tcp dpt:http
REJECT     all  --  anywhere             anywhere            reject-with icmp-host-prohibited

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination
REJECT     all  --  anywhere             anywhere            reject-with icmp-host-prohibited

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination

Chain f2b-SSH (1 references)
target     prot opt source               destination
RETURN     all  --  anywhere             anywhere
```

iptables -A INPUT -i lo --dport 80 -j REJECT --reject-with icmp-port-unreachable

replace
-R INPUT 1 -i lo -p tcp --dport 80 -j DROP
loopback

Iptables -D INPUT 1

Chain operations

- iptables -? chain [rule-specs]
- -P target : default chain policy
  - target : ACCEPT, DROP, RETURN, another chain
- -F [chain] : delete(flush) rules of the chain
- -X chain : delete the chain
- -N chain : create a new chain
- -E old-chain new-chain : rename the chain
- -L chain : list the chain
- -S chain : print the chain
- -A chain rule-spec : add a rule to the chain
- -D chain rule-num : delete the num-th rule of the chain
- -I chain rule-num rule-spec : insert a rule before the num-th rule
- -R chain rule-num rule-spec : replace the num-th rule with a rule

Rule Specs

- A combination of the following (common use)
  - outgoing Specific to protocol
    -i ifc -o ifc -p protocol -m pattern
    specify interface range
    -s address[/mask][,…] --sport spnum
    src src port
    range
    -d address[/mask][,…] --dport dpnum
    dest dst port
    -j target
    another chain
- Access control matrix
  - subject
  - object
  - right

Example

add pattern either

- iptables -A INPUT -m state --state RELATED,ESTABLISHED -j ACCEPT

  No -i; -o; -p, usually first rule

- iptables -A INPUT -p tcp --dport 80 -j ACCEPT
- iptables -A INPUT -i lo -j ACCEPT
- iptables -A INPUT -j REJECT --reject-with icmp-host-prohibited
- iptables -A OUTPUT -p tcp -d www.facebook.com -j DROP
- iptables -A INPUT -s 192.168.1.0/24 -j DROP
- iptables -A INPUT -p icmp -j ACCEPT

  if no rule applied, default is to accept

- iptables -N f2b-SSH new chain
- iptables -A INPUT -p tcp --dport 22 -j f2b-SSH
- iptables -A f2b-SSH -s 218.65.30.4/32 -j REJECT --reject-with icmp-port-unreachable

  object oriented routing

- iptables -A f2b-SSH -j RETURN

Capability Lists

- ACL: When Subjects and Objects are Changing
  - Add a subject
  - Add an object
  - Remove a subject
  - Remove an object
- Is ACL good for all systems?
  - A file system: files are objects and change often.
  - A web server: users are subjects and change often.

Good to have file access lists

ACL

Unique Process for each user

300 webs
100 user

List of what you can do

Capability List

CL

Capability Lists

- 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) }

Capability Lists

- Define security policy
- Create the access control matrix
- Implement and put the CL in a storage
- When a user (s) requests an operation (p) on an object (o)
    - Retrieve the CL(s)
    - Check if (o,p) matches (∈) an entry of CL(s).
    - Yes, proceed; No, deny.

Capability Example

- File descriptor
  - int fd = open("file", O_RDONLY);
  - The fd can be transferred from one process to another process.
  - But, no matter which process obtains fd, the process can only read the file.
  - So, fd references to a capability on the file (o) with the read (p) permission.

ACLs vs. Capabilities

- The procedure
  - A subject or an object is created.
  - Rights are added to ACLs or CLs
  - When a subject tries to access an object, rights are checked.
- Assume a system of 100 subjects and 1000 objects.

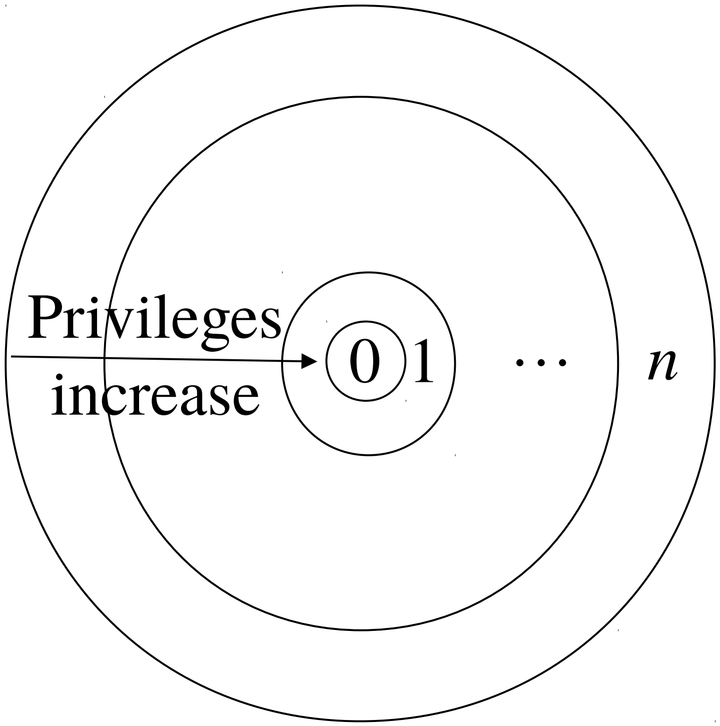
ACLs vs. Capabilities

- ACLs
  - Add a subject
  - Add an object
  - Remove a subject
  - Remove an object
  - Copy an object and its permissions
- CLs

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, that has many unknown subjects), this may change.

Ring-Based Access Control



- Process (segment) accesses another segment
  - Read
  - Execute
- *Gate* is an entry point for calling segment
- Rights:
  - *r* read
  - *w* write
  - *e* execute

Reading/Writing/Appending

- Procedure executing in ring *r*
- Data segment with *access bracket* (a_1, a_2)
- Mandatory access rule
  - $r \le a_1$ allow access
  - $a_1 < r \le a_2$ allow *r* access; not *w* access
  - $a_2 < r$ deny all access

Rings and Access Control Matrix

- A process with ring 3 needs to access an object with an access bracket [2, 4]
  - What access does the process have?
  - How to describe this access control in access control matrix?
  - What kind of access control matrix cannot rings implement?
    - S1 and S2; O1 and O2
    - S1 rw O1; S1 r O2
    - S2 r O1; S2 rw O2
    - Not possible

Executing

- Procedure executing in ring *r*
- Call procedure in segment with *access bracket* (a_1, a_2) and *call bracket* (a_2, a_3)
  - Often written (a_1, a_2 , a_3)
- Mandatory access rule
  - $r < a_1$ allow access; ring-crossing fault
  - $a_1 \leq r \leq a_2$ allow access; no ring-crossing fault
  - $a_2 < r \leq a_3$ allow access if through valid gate
  - $a_3 < r$ deny all access

Versions

- Multics
  - 8 rings (from 0 to 7)
- Digital Equipment’s VAX
  - 4 levels of privilege: user, monitor, executive, kernel
- Older systems
  - 2 levels of privilege: user, supervisor

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Models of Access Control

- Involved entities in AC
  - System, subject, object, the owner of the object, the creator of the object
  - System checks AC, but not necessarily sets AC.
- Discretionary AC : owner
- Mandatory AC : system
- Originator Controlled AC : creator

Models of Access Control

- Discretionary Access Control (DAC, IBAC)
  – Individual user sets access control mechanism to allow or deny access to an object
- Example
  – A child controls who can read his/her diary.
  – A user controls the access of the files he/she owns.

Models of Access Control

- Mandatory Access Control (MAC)
  - System mechanism controls access to object, and individual cannot alter that access
- Example
  - The law allows a court to access individual's driving records.
  - The system controls the ownership of the files.

Models of Access Control

- Originator Controlled Access Control (ORCON)
  - Originator (creator) of information controls who can access information
- Example
  - The distribution of a company's software is only allowed by the company.
    - A user owns (purchased) the software.