

Chapter 14: Access Control Mechanisms

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

Overview

- Access control lists
- Capability lists
- Locks and keys
- Rings-based access control
- Propagated access control lists

Access Control Lists

- Columns of access control matrix

| | <i>file1</i> | <i>file2</i> | <i>file3</i> |
|----------------|--------------|--------------|--------------|
| <i>Andy</i> | rx | r | rwo |
| <i>Betty</i> | rwxo | r | |
| <i>Charlie</i> | 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
 - 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)

ACLs + Abbreviations

- 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

Permissions in IBM AIX

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

ACL Modification

- Who can do this?
 - 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 ACLs apply to privileged users (*root*)?
 - Solaris: abbreviated lists do not, but full-blown ACL entries do
 - Other vendors: varies

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 of rights given so far*, access is denied
- 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

Handling Default Permissions

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

Revocation Question

- How do you remove subject's rights to a file?
 - Owner deletes subject's entries from ACL, or rights from subject's entry in ACL
- What if ownership not involved?
 - Depends on system
 - System R: restore protection state to what it was before right was given
 - May mean deleting descendent rights too ...

Windows NT ACLs

- Different sets of rights
 - Basic: read, write, execute, delete, change permission, take ownership
 - Generic: no access, read (read/execute), change (read/write/execute/delete), full control (all), special access (assign any of the basics)
 - Directory: no access, read (read/execute files in directory), list, add, add and read, change (create, add, read, execute, write files; delete subdirectories), full control, special access

Accessing Files

- User not in file's ACL nor in any group named in file's ACL: deny access
- ACL entry denies user access: deny access
- Take union of rights of all ACL entries giving user access: user has this set of rights over file

Capability Lists

- Rows of access control matrix

| | <i>file1</i> | <i>file2</i> | <i>file3</i> |
|----------------|--------------|--------------|--------------|
| <i>Andy</i> | rx | r | rwo |
| <i>Betty</i> | rwxo | r | |
| <i>Charlie</i> | rx | rwo | w |

C-Lists:

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

Semantics

- 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

Implementation

- Tagged architecture
 - Bits protect individual words
 - B5700: tag was 3 bits and indicated how word was to be treated (pointer, type, descriptor, *etc.*)
- Paging/segmentation protections
 - Like tags, but put capabilities in a read-only segment or page
 - CAP system did this
 - Programs must refer to them by pointers
 - Otherwise, program could use a copy of the capability — which it could modify

Implementation (*con't*)

- Cryptography
 - Associate with each capability a cryptographic checksum enciphered using a key known to OS
 - When process presents capability, OS validates checksum
 - Example: Amoeba, a distributed capability-based system
 - Capability is (*name, creating_server, rights, check_field*) and is given to owner of object
 - *check_field* is 48-bit random number; also stored in table corresponding to *creating_server*
 - To validate, system compares *check_field* of capability with that stored in *creating_server* table
 - ***Vulnerable if capability disclosed to another process***

Amplifying

- Allows *temporary* increase of privileges
- Needed for modular programming
 - Module pushes, pops data onto stack
`module stack ... endmodule.`
 - Variable x declared of type stack
`var x: module;`
 - *Only* stack module can alter, read x
 - So process doesn't get capability, but needs it when x is referenced—a problem!
 - Solution: give process the required capabilities while it is in module

Examples

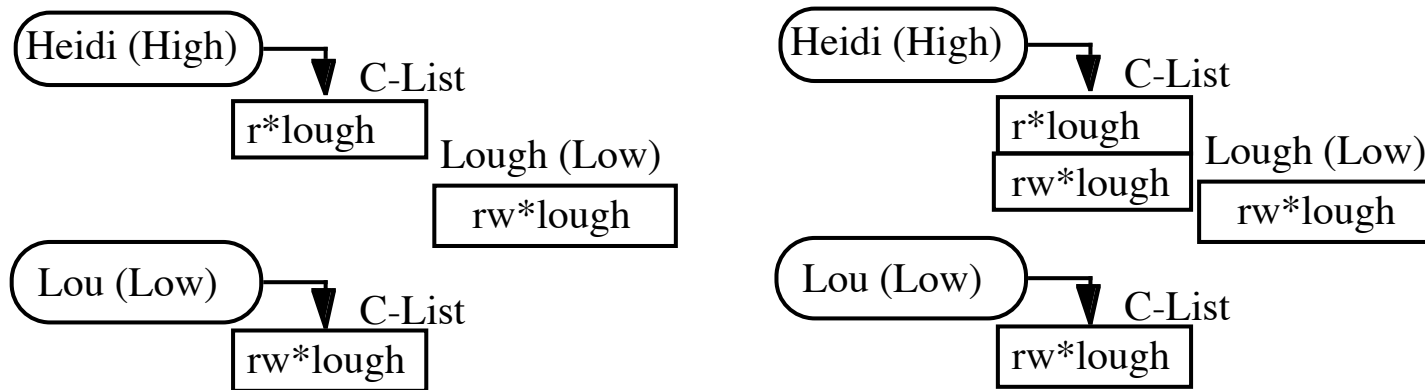
- HYDRA: templates
 - Associated with each procedure, function in module
 - Adds rights to process capability *while the procedure or function is being executed*
 - Rights deleted on exit
- Intel iAPX 432: access descriptors for objects
 - These are really capabilities
 - 1 bit in this controls amplification
 - When ADT constructed, permission bits of type control object set to what procedure needs
 - On call, if amplification bit in this permission is set, the above bits or'ed with rights in access descriptor of object being passed

Revocation

- Scan all C-lists, remove relevant capabilities
 - Far too expensive!
- Use indirection
 - Each object has entry in a global object table
 - Names in capabilities name the entry, not the object
 - To revoke, zap the entry in the table
 - Can have multiple entries for a single object to allow control of different sets of rights and/or groups of users for each object
 - Example: Amoeba: owner requests server change random number in server table
 - All capabilities for that object now invalid

Limits

- Problems if you don't control copying of capabilities



The capability to write file *lough* is Low, and Heidi is High so she reads (copies) the capability; now she can write to a Low file, violating the *-property!

Remedies

- Label capability itself
 - Rights in capability depends on relation between its compartment and that of object to which it refers
 - In example, as as capability copied to High, and High dominates object compartment (Low), write right removed
- Check to see if passing capability violates security properties
 - In example, it does, so copying refused
- Distinguish between “read” and “copy capability”
 - Take-Grant Protection Model does this (“read”, “take”)

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)

Cryptographic Implementation

- Enciphering key is lock; deciphering key is key
 - Encipher object o ; store $E_k(o)$
 - Use subject's key k' to compute $D_{k'}(E_k(o))$
 - Any of n can access o : store
$$o' = (E_1(o), \dots, E_n(o))$$
 - Requires consent of all n to access o : store
$$o' = (E_1(E_2(\dots(E_n(o))\dots)))$$

Example: IBM

- IBM 370: process gets access key; pages get storage key and fetch bit
 - Fetch bit clear: read access only
 - Fetch bit set, access key 0: process can write to (any) page
 - Fetch bit set, access key matches storage key: process can write to page
 - Fetch bit set, access key non-zero and does not match storage key: no access allowed

Example: Cisco Router

- Dynamic access control lists

```
access-list 100 permit tcp any host 10.1.1.1 eq telnet
access-list 100 dynamic test timeout 180 permit ip any host \
  10.1.2.3 time-range my-time
time-range my-time
  periodic weekdays 9:00 to 17:00
line vty 0 2
  login local
  autocommand access-enable host timeout 10
```

- Limits external access to 10.1.2.3 to 9AM–5PM
 - Adds temporary entry for connecting host once user supplies name, password to router
 - Connections good for 180 minutes
 - Drops access control entry after that

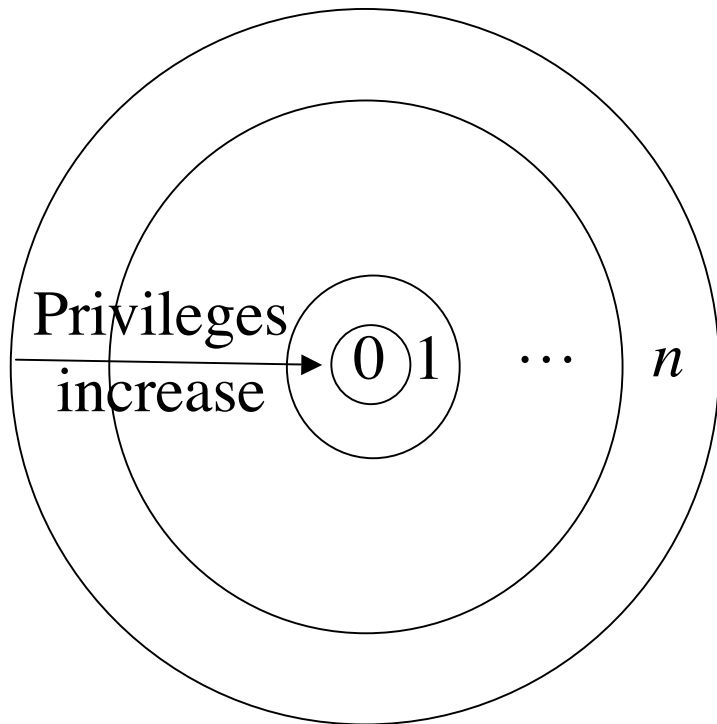
Type Checking

- Lock is type, key is operation
 - Example: UNIX system call *write* can't work on directory object but does work on file
 - Example: split I&D space of PDP-11
 - Example: countering buffer overflow attacks on the stack by putting stack on non-executable pages/segments
 - Then code uploaded to buffer won't execute
 - Does not stop other forms of this attack, though ...

More Examples

- LOCK system:
 - Compiler produces “data”
 - Trusted process must change this type to “executable” before program can be executed
- Sidewinder firewall
 - Subjects assigned domain, objects assigned type
 - Example: ingress packets get one type, egress packets another
 - All actions controlled by type, so ingress packets cannot masquerade as egress packets (and vice versa)

Ring-Based Access Control



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

Reading/Writing/Appending

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

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

PACLs

- Propagated Access Control List
 - Implements ORGON
- Creator kept with PACL, copies
 - Only owner can change PACL
 - Subject reads object: object's PACL associated with subject
 - Subject writes object: subject's PACL associated with object
- Notation: $PACL_s$ means s created object;
 $PACL(e)$ is PACL associated with entity e

Multiple Creators

- Betty reads Ann's file *dates*
$$\text{PACL}(\text{Betty}) = \text{PACL}_{\text{Betty}} \cap \text{PACL}(\text{dates})$$
$$= \text{PACL}_{\text{Betty}} \cap \text{PACL}_{\text{Ann}}$$
- Betty creates file *dc*
$$\text{PACL}(\text{dc}) = \text{PACL}_{\text{Betty}} \cap \text{PACL}_{\text{Ann}}$$
- $\text{PACL}_{\text{Betty}}$ allows Char to access objects, but PACL_{Ann} does not; both allow June to access objects
 - June can read *dc*
 - Char cannot read *dc*

Key Points

- Access control mechanisms provide controls for users accessing files
- Many different forms
 - ACLs, capabilities, locks and keys
 - Type checking too
 - Ring-based mechanisms (Mandatory)
 - PACLs (ORCON)