L15: Control Access to Files

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Acknowledgement

- Many slides are from or are revised from the slides of the author of the textbook
  - Matt Bishop, Introduction to Computer Security, Addison-Wesley Professional, October, 2004, ISBN-13: 978-0-321-24774-5. Introduction to Computer Security @ VSU's Safari Book Online subscription
  - http://nob.cs.ucdavis.edu/book/book-intro/slides/

Outline

- Access control lists
- Capability lists

Access Control Lists

- Store ***columns*** of access control matrix with the object it represents to form a list of pairs, e.g.,

	File1	**File2**	**File3**
Andy	rx	r	rwo
Betty	rwxo	r	
Charlie	rx	rwo	w

  - File1: {(Andy, rx), (Betty, rwxo), (Charlie, rx)}
  - File2: {(Andy, r), (Betty, r), (Charlie, rwo)}
  - File3: {(Andy, rwo), (Charlie, w)}

Definition

Let S be the set of subjects, and R the set of rights, of a system. An access control list (ACL) *l* is a set of pairs $l = \{ (s, r) : s \in S, r \subseteq R \}$. Let *acl* be a function that determines the access control list *l* associated with a particular object *o*. The interpretation of the access control list $acl(o) = \{ (s_i, r_i) : 1 \le i \le n \}$ is that subject s_i may access *o* using any right in r_i.

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 and given matched subjects default rights

Default Permission: Example

- UNICOS 7.0
  - ACL 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

- Combine subjects to make long access control lists short

Abbreviations: Example

- Unix divides users into three classes
  - Owner of the file
  - Group owner of the file
  - All other users (the rest)
- Unix systems provides read (r), write (w), and execute (x) rights
- Unix then represents the permissions as three triplets
- Unix assigns ownership based on creating process
  - Some systems: if directory has setgid permission, file group owned by group of directory (SunOS, Solaris)

Abbreviations: Discussion

- Suffer from a loss of granularity
- e.g., Unix system with 5 users
  - Anne wants to allow Beth to read her file, Caroline to write to it, Della to read and write to it, and Elizabeth to execute it.
  - Three triplets are insufficient to allow all desired modes of access
  - Cumbersome to express “everybody but user Fran”

ACLs + Abbreviations

- Augment abbreviated lists with full-blown ACLs
  - Intent is to shorten ACL
- Use abbreviations as the default permission controls
- Explicit ACLs override abbreviations
- Exact method varies

Example: IBM AIX

- Base permissions are abbreviations
- Extended permissions are ACLs with user, group
- ACL entries specify permissions to be added or deleted from the base permissions

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
```

Creation and Maintenance of ACLs

- Some issues …
  - Which subjects can modify an object's ACL?
  - If there is a privileged user (such as root in the UNIX system or administrator in Windows NT), do the ACLs apply to that user?
  - Does the ACL support groups or wildcards (that is, can users be grouped into sets based on a system notion of "group" or on pattern matching)?
  - How are contradictory access control permissions handled? If one entry grants read privileges only and another grants write privileges only, which right does the subject have over the object?
  - If a default setting is allowed, do the ACL permissions modify it, or is the default used only when the subject is not explicitly mentioned in the ACL?

ACL Modification

- Which subjects can modify an object's ACL?
  - 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

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

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

    line adds write permission for heidi when in that group
  - e.g., 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

- How are contradictory access control permissions handled?
  - Deny access if any entry would deny access
    - AIX: if any entry denies access, *regardless or 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

- How are default permissions handled?
  - 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

Icacls

```
C:\teaching\451>icacls vigenere.m
vigenere.m NT AUTHORITY\SYSTEM:(I)(F)
           BUILTIN\Administrators:(I)(F)
           TL_HM302SC\hui:(I)(F)
           TL_HM302SC\demousr:(I)(F)

Successfully processed 1 files; Failed processing 0
files

C:\teaching\451>
```

cacls

- Windows 8 and 10 reports, “NOTE: Cacls is now deprecated, please use Icacls.”

```
C:\teaching\451>cacls vigenere.m
C:\teaching\451\vigenere.m NT AUTHORITY\SYSTEM:(ID)F
                           BUILTIN\Administrators:(ID)F
                           TL_HM302SC\hui:(ID)F
                           TL_HM302SC\demousr:(ID)F
C:\teaching\451>
```

icacls /?

ICACLS preserves the canonical ordering of ACE entries:

- Explicit denials
- Explicit grants
- Inherited denials
- Inherited grants

perm is a permission mask and can be specified in one of two forms:

- a sequence of simple rights:
  - N - no access
  - F - full access
  - M - modify access
  - RX - read and execute access
  - R - read-only access
  - W - write-only access
  - D - delete access
- a comma-separated list in parentheses of specific rights:
  - DE - delete
  - RC - read control
  - WDAC - write DAC
  - WO - write owner
  - S - synchronize
  - AS - access system security
  - MA - maximum allowed
  - GR - generic read
  - GW - generic write
  - GE - generic execute
  - GA - generic all
  - RD - read data/list directory
  - WD - write data/add file
  - AD - append data/add subdirectory
  - REA - read extended attributes
  - WEA - write extended attributes
  - X - execute/traverse
  - DC - delete child
  - RA - read attributes
  - WA - write attributes

inheritance rights may precede either form and are applied only to directories:

- (OI) - object inherit
- (CI) - container inherit
- (IO) - inherit only
- (NP) - don't propagate inherit
- (I) - permission inherited from parent container

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

- Store ***rows*** of access control matrix with the object it represents to form a list of pairs, e.g.,

	File1	**File2**	**File3**
Andy	rx	r	rwo
Betty	rwxo	r	
Charlie	rx	rwo	w

  - 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

Definition

Let O be the set of objects, and R the set of rights, of a system. A capability list c is a set of pairs $c = \{ (o, r) : o \in O, r \subseteq R \}$. Let cap be a function that determines the capability list c associated with a particular subject s. The interpretation of the capability list $cap(s) = \{ (o_i, r_i) : 1 \leq i \leq n \}$ is that subject s may access o_i using any right in r_i.

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

- 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

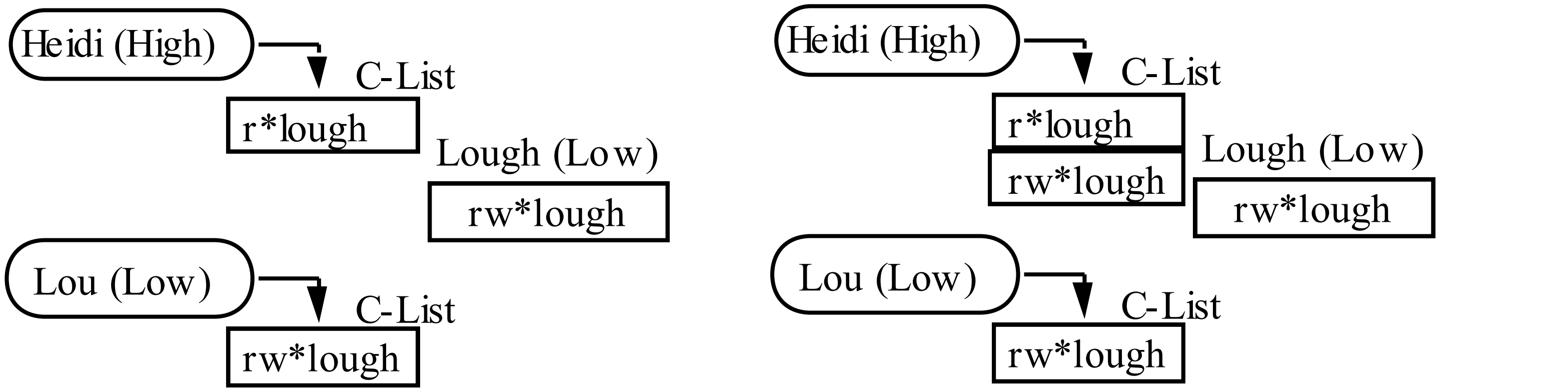
- HYDRA: templates
  - Associated with each procedure, function in module
  - Adds rights to process capability *while the procedure or function is being executed*
  - Rights deleted on exit
- Intel iAPX 432: access descriptors for objects
  - These are really capabilities
  - 1 bit in this controls 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 capability-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 do not 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 (of the Bell-Lapadula Model)!

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; Capablity-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

Summary

- Access control mechanisms provide controls for users accessing files
- Many different forms
  - ACLs
  - Capabilities
  - ACLs vs. Capabilities
- Forthcoming
  - Ring-based mechanisms (Mandatory)