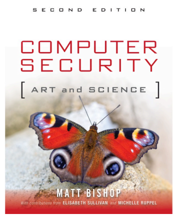
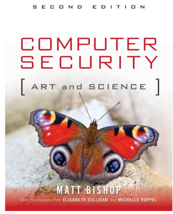


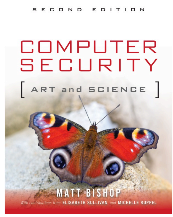
Access Control Mechanisms

Chapter 16



Overview

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



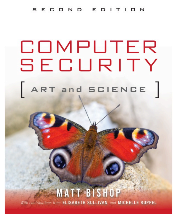
Access Control Lists

- 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
  - 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

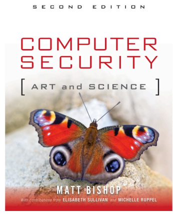
Abbreviations

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

    rest

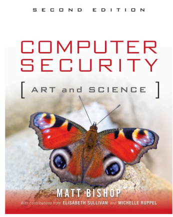
    group

    owner
  - Ownership assigned based on creating process
    - Most UNIX-like systems: if directory has setgid permission, file group owned by group of directory (Solaris, Linux)



ACLs + Abbreviations

- Augment abbreviated lists with ACLs
  - Intent is to shorten ACL
- ACLs override abbreviations
  - Exact method varies
- Example: Extended permissions (Linux, FreeBSD, others)
  - Minimal ACLs are abbreviations, extended ACLs give specific users, groups permissions
  - Extended ACL entries give rights provided those rights are in mask

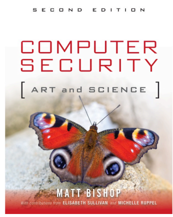


Minimal and Extended ACL

user *heidi*, group *family* owns file with permissions:

```
user::rw-
user:skyler:rwx
group::rw-
group:child:r--
mask::rw-
other::r--
```

- *heidi* can read, write file (first line)
- *matt*, not in group *child*, can read file (last line)
- *skyler* can read, write file (second line masked by fifth line)
- *sage*, in group *family*, can read, write the file (third line masked by fifth line)
- *steven*, in group *child*, can read file (fourth line masked by fifth line)

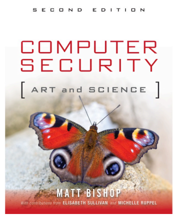


ACL Modification

- 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

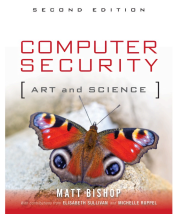
- Classic form: no; in practice, usually
- UNICOS:
  - `holly : gleep : r`
    user *holly* in group *gleep* can read file
  - `holly : * : r`
    user *holly* in any group can read file
  - `* : gleep : r`
    any user in group *gleep* can read file

Conflicts

- Deny access if any entry would deny access
  - AIX: if any entry denies access, *regardless or rights given so far*, access is denied
- 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

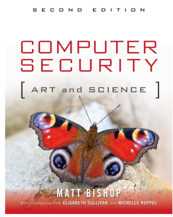
Handling Default Permissions

- 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 …

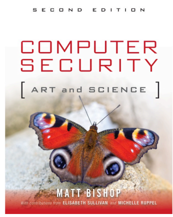


Windows 10 NTFS ACLs

- 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

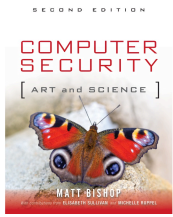
Accessing Files

- 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



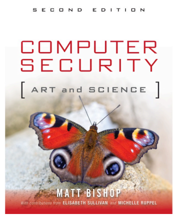
Example

- Paul, Quentin in group *students*
- Quentin, Regina in group *staff*
- ACL entries for *e:\stuff*
  1. *staff,* create files/write data, allow
  2. Quentin, delete subfolders and files, allow
  3. *students,* delete subfolders and files, deny
- Regina can create files or subfolders (1)
- Quentin cannot delete subfolders and files
  - Even with 2; Quentin in *students*, and explicit deny in 3 overrides allow in 2



Example (*con’t*)

- Regina wants to create folder *e:\stuff\plugh* and set it up so:
  - Paul doesn’t have delete subfolders and files access
  - Quentin has delete subfolders and files access
- How does she do this?



How She Does It

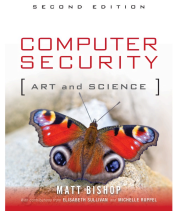
Inherited from *e:\stuff*:

staff, create files/write data, allow

Quentin, delete subfolder and files, allow

~~*students*, delete subfolder and files,~~ deny

Paul, delete subfolders and files, deny



Capability Lists

- Columns of access control matrix

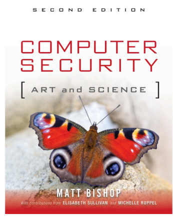
	file1	*file2*	*file3*
Andy	rx	r	rwo
Betty	rwxo	r	
Charlie	rx	rwo	w

C-Lists:

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

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

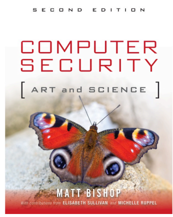


Implementation

- 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
    - EROS does 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

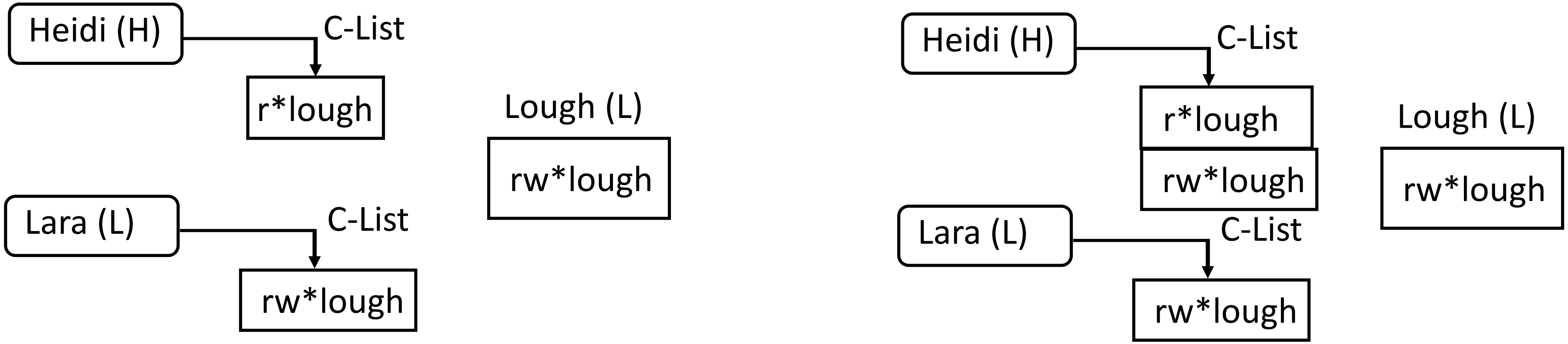
- HYDRA: templates
  - Associated with each procedure, function in module
  - Adds rights to process capability *while the procedure or function is being executed*
  - Rights deleted on exit
- Intel iAPX 432: access descriptors for objects
  - These are really capabilities
  - 1 bit in this controls 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

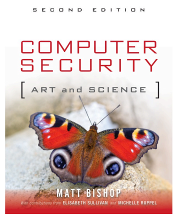
- Scan all C-lists, remove relevant capabilities
  - Far too expensive!
- Use indirection
  - Each object has entry in a global object table
  - Names in capabilities name the entry, not the object
    - To revoke, zap the entry in the table
    - Can have multiple entries for a single object to allow 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

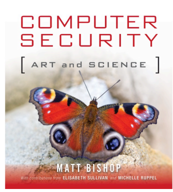


- The capability to write file *lough* is Low, and Heidi is High so she reads (copies) the capability; now she can write to a Low file, violating the *-property!



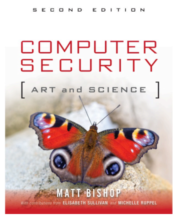
Remedies

- 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” and “take”)



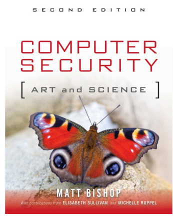
ACLs vs. Capabilities

- 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



Privileges

- In Linux, used to override or add access restrictions by adding, masking rights
  - Not capabilities as no particular object associated with the (added or deleted) rights
- 3 sets of privileges
  - Bounding set (all privileges process may assert)
  - Effective set (current privileges process may assert)
  - Saved set (rights saved for future purpose)
- Example: UNIX effective, saved UID



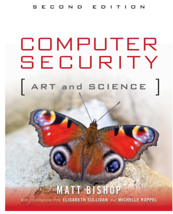
Trusted Solaris

- Associated with each executable:
  - *Allowed set* (*AS*) are privileges assigned to process created by executing file
  - *Forced set* (*FS*) are privileges process must have when it begins execution
  - $FS \subseteq AS$

Trusted Solaris Privileges

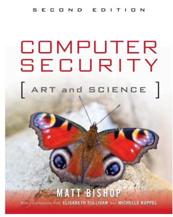
Four sets:

- *Inheritable set* (*IS*): privileges inherited from parent process
- *Permitted set* (*PS*): all privileges process may assert; ($FS \cup IS$) $\cap$ AS
    - Corresponds to bounding set
- *Effective set* (*ES*): privileges program requires for current task; initially, *PS*
- *Saved set* (*SS*): privileges inherited from parent process and allowed for use; that is, $IS \cap AS$



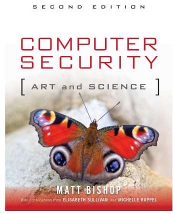
Bracketing Effective Privileges

- Process needs to read file at particular point
- *file_mac_read, file_dac_read* ∈ *PS*, *ES*
- Initially, program deletes these from *ES*
  - So they can’t be used
- Just before reading file, add them back to *ES*
  - Allowed as these are in *PS*
- When file is read, delete from *ES*
  - And if no more reading, can delete from *PS*



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)



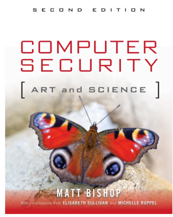
Cryptographic Implementation

- 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

$$o' = (E_1(o), \ldots, E_n(o))$$

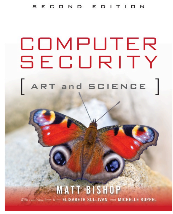
  - Requires consent of all *n* to access *o*: store

$$o' = (E_1(E_2(\ldots(E_n(o))\ldots)))$$



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

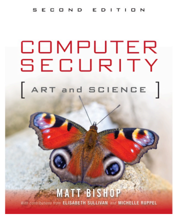
- Lock is type, key is operation
  - Example: UNIX system call *write* won’t work on directory object but does work on file
  - Example: split I&D space of PDP-11
  - Example: countering buffer overflow attacks on the stack by putting stack on non-executable pages/segments
    - Then code uploaded to 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)

Sharing Secrets

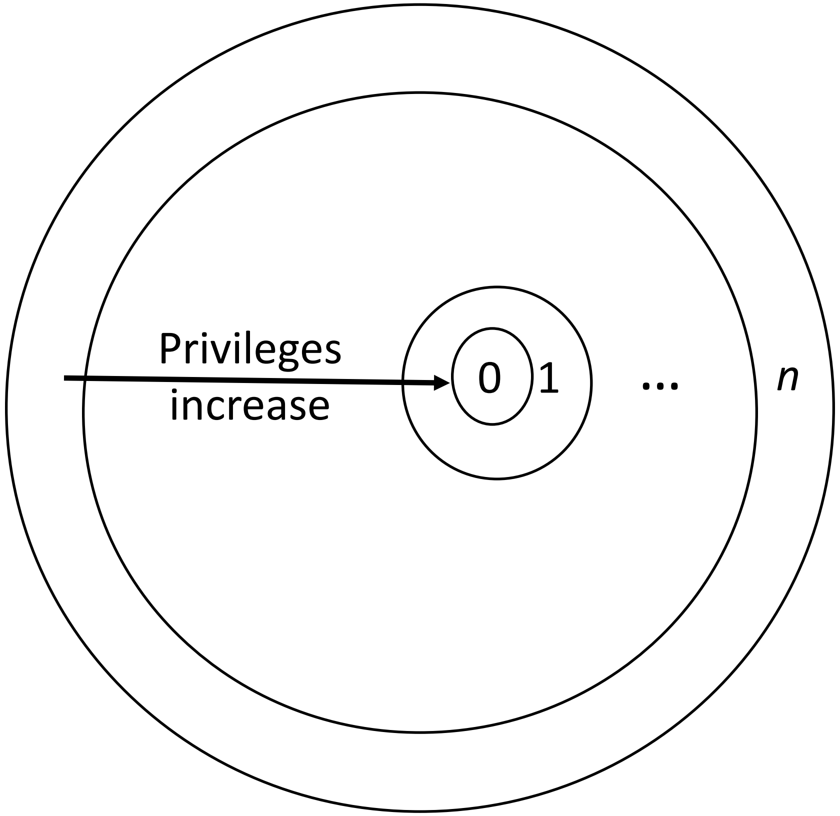
- Implements separation of privilege
- Use (t, n)-*threshold scheme*
  - Data divided into n parts
  - Any t parts sufficient to derive original data
- Or-access and and-access can do this
  - Increases the number of representations of data rapidly as n, t grow
  - Cryptographic approaches more common



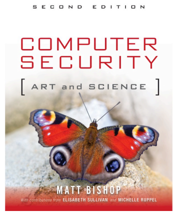
Shamir's Scheme

- Goal: use (*t*, *n*)-threshold scheme to share cryptographic key encoding data
  - Based on Lagrange polynomials
  - Idea: take polynomial *p*(*x*) of degree *t*–1, set constant term (*p*(0)) to key
  - Compute value of *p* at *n* points, *excluding* x = 0
  - By algebra, need values of *p* at any *t* distinct points to derive polynomial, and hence constant term (key)

Ring-Based Access Control

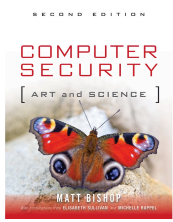


- Process (segment) accesses another segment
  - read
  - execute
- *Gate* is an entry point for calling segment
- Rights:
  - *r* read
  - *w* write
  - *a* append
  - *e* execute



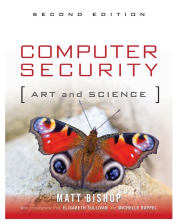
Reading/Writing/Appending

- Procedure executing in ring r
- Data segment with *access bracket* (a_1, a_2)
- Mandatory access rule
  - $r \le a_1$ allow access
  - $a_1 < r \le a_2$ 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)
- Intel’s Itanium chip
  - 4 levels of privilege: 0 the highest, 3 the lowest
- Older systems
  - 2 levels of privilege: user, supervisor

PACLs

- Propagated Access Control List
  - Implements ORCON
- 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*

  $PACL(Betty) = PACL_{Betty} \cap PACL(dates)$

  $= PACL_{Betty} \cap PACL_{Ann}$

- Betty creates file *dc*

  $PACL(dc) = PACL_{Betty} \cap PACL_{Ann}$

- $PACL_{Betty}$ 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)