CSci 5271
Introduction to Computer Security
Day 9: OS security basics

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Outline

OS security topics

- Resource protection
- Process isolation
- User authentication
- Access control

Protection and isolation

- Resource protection: prevent processes from accessing hardware
- Process isolation: prevent processes from interfering with each other
- Design: by default processes can do neither
- Must request access from operating system

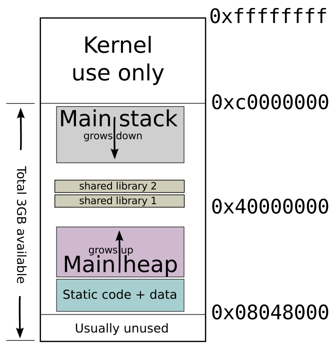
Reference monitor

- Complete mediation: all accesses are checked
- Tamperproof: the monitor is itself protected from modification
- Small enough to be thoroughly verified

Hardware basis: memory protection

- Historic: segments
- Modern: paging and page protection
  - Memory divided into pages (e.g. 4k)
  - Every process has own virtual to physical page table
  - Pages also have R/W/X permissions

Linux 32-bit example



Hardware basis: supervisor bit

- Supervisor (kernel) mode: all instructions available
- User mode: no hardware or VM control instructions
- Only way to switch to kernel mode is specified entry point
- Also generalizes to multiple "rings"

Outline

OS security: protection and isolation

OS security: authentication

Announcements intermission

Basics of access control

Unix-style access control

Authentication factors

- Something you know (password, PIN)
- Something you have (e.g., smart card)
- Something you are (biometrics)
- CAPTCHAs, time and location, ...
- Multi-factor authentication

Passwords: love to hate

- Many problems for users, sysadmins, researchers
- But familiar and near-zero cost of entry
- User-chosen passwords proliferate for low-stakes web site authentication

Password entropy

- Model password choice as probabilistic process
- If uniform, $\log_2 |S|$
- Controls difficulty of guessing attacks
- Hard to estimate for user-chosen passwords
  - Length is an imperfect proxy

Password hashing

- Idea: don't store password or equivalent information
- Password 'encryption' is a long-standing misnomer
  - E.g., Unix `crypt(3)`
- Presumably hard-to-invert function h
- Store only $h(p)$

Dictionary attacks

- Online: send guesses to server
- Offline: attacker can check guesses internally
- Specialized password lists more effective than literal dictionaries
  - Also generation algorithms (s $\rightarrow$ $, etc.)
- ~25% of passwords consistently vulnerable

Better password hashing

- Generate random salt s, store $(s, h(s, p))$
  - Block pre-computed tables and equality inferences
  - Salt must also have enough entropy
- Deliberately expensive hash function
  - AKA password-based key derivation function (PBKDF)
  - Requirement for time and/or space

Password usability

- User compliance can be a major challenge
  - Often caused by unrealistic demands
- Distributed random passwords usually unrealistic
- Password aging: not too frequently
- Never have a fixed default password in a product

Backup authentication

- Desire: unassisted recovery from forgotten password
- Fall back to other presumed-authentic channel
  - Email, cell phone
- Harder to forget (but less secret) shared information
  - Mother's maiden name, first pet's name
- Brittle: ask Sarah Palin or Mat Honan

Centralized authentication

- Enterprise-wide (e.g., UMN ID)
- Anderson: Microsoft Passport
- Today: Facebook Connect, Google ID
- May or may not be single-sign-on (SSO)

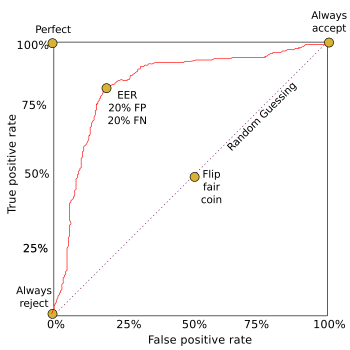
Biometric authentication

- Authenticate by a physical body attribute
- \+ Hard to lose
- — Hard to reset
- — Inherently statistical
- — Variation among people

Example biometrics

- (Handwritten) signatures
- Fingerprints, hand geometry
- Face and voice recognition
- Iris codes

Error rates: ROC curve



Outline

OS security: protection and isolation

OS security: authentication

Announcements intermission

Basics of access control

Unix-style access control

Note to early readers

- This is the section of the slides most likely to change in the final version
- If class has already happened, make sure you have the latest slides for announcements

Project progress

- Meetings run through tomorrow
- First progress reports due tomorrow night
- Regrouping is still possible

BCLPR vulnerability discovered!

- Buffer overflow in `cleanup_spoolfile`, patched using `strlcat`
- Upgrade process for 1.3: same old drill

HA1 week 4

- Both OS/logic and memory safety bugs still exist
- Remaining ones are complex for various reasons
- Also this week: design analysis and suggestions

Exercise set 2

- Posted last night, due a week from Thursday
- Covers defensive programming and OS security
- Probably not returned before the midterm

Outline

OS security: protection and isolation

OS security: authentication

Announcements intermission

Basics of access control

Unix-style access control

Mechanism and policy

- Decision-making aspect of OS
- Should subject S (user or process) be allowed to access object (e.g., file) O?
- Complex, since admin must specify what should happen

Access control matrix

	grades.txt	/dev/hda	/opt/bcvs/bcvs
Alice	r	rw	rx
Bob	rw	-	rx
Carol	r	-	rx

Slicing the matrix

- $O(nm)$ matrix impractical to store, much less administer
- Columns: access control list (ACL)
  - Convenient to store with object
  - E.g., Unix file permissions
- Rows: capabilities
  - Convenient to store by subject
  - E.g., Unix file descriptors

Groups/roles

- Simplify by factoring out commonality
- Before: users have permissions
- After: users have roles, roles have permissions
- Simple example: Unix groups
- Complex versions called role-based access control (RBAC)

Outline

OS security: protection and isolation

OS security: authentication

Announcements intermission

Basics of access control

Unix-style access control

UIDs and GIDs

- To kernel, users and groups are just numeric identifiers
- Names are a user-space nicety
  - E.g., `/etc/passwd` mapping
- Historically 16-bit, now 32
- User 0 is the special superuser `root`
  - Exempt from all access control checks

File mode bits

- Core permissions are 9 bits, three groups of three
- Read, write, execute for user, group, other
- `ls` format: `rwx r-x r--`
- Octal format: 0754

Interpretation of mode bits

- File also has one user and group ID
- Choose one set of bits
  - If users match, use user bits
  - If subject is in the group, use group bits
  - Otherwise, use other bits
- Note no fallback, so can stop yourself or have negative groups
  - But usually, $O \subseteq G \subseteq U$

Directory mode bits

- Same bits, slightly different interpretation
- Read: list contents (e.g., `ls`)
- Write: add or delete files
- Execute: traverse
- X but not R means: have to know the names

Process UIDs and `setuid(2)`

- UID is inherited by child processes, and an unprivileged process can't change it
- But there are syscalls root can use to change the UID, starting with `setuid`
- E.g., login program, SSH server

Setuid programs, different UIDs

- If 04000 "setuid" bit set, newly exec'd process will take UID of its file owner
  - Other side conditions, like process not traced
- Specifically the *effective UID* is changed, while the *real UID* is unchanged
  - Shows who called you, allows switching back

More different UIDs

- Two mechanisms for temporary switching:
  - Swap real UID and effective UID (BSD)
  - Remember *saved UID*, allow switching to it (System V)
- Modern systems support both mechanisms at the same time
- Linux only: *file-system UID*
  - Once used for NFS servers, now mostly obsolete

Setgid, games

- Setgid bit 02000 mostly analogous to setuid
- But note no supergroup, so UID 0 is still special
- Classic application: setgid `games` for managing high-score files

Special case: `/tmp`

- We'd like to allow anyone to make files in `/tmp`
- So, everyone should have write permission
- But don't want Alice deleting Bob's files
- Solution: "sticky bit" 01000

Special case: group inheritance

- When using group to manage permissions, want a whole tree to have a single group
- When 02000 bit set, newly created entries with have the parent's group
  - (Historic BSD behavior)
- Also, directories will themselves inherit 02000

Other permission rules

- Only file owner or root can change permissions
- Only root can change file owner
  - Former System V behavior: "give away `chown`"
- Setuid/gid bits cleared on `chown`
  - Set owner first, then enable setuid

Non-checks

- File permissions on `stat`
- File permissions on link, unlink, rename
- File permissions on read, write
- Parent directory permissions generally
  - Except traversal
  - I.e., permissions not automatically recursive

"POSIX" ACLs

- Based on a withdrawn standardization
- More flexible permissions, still fairly Unix-like
- Multiple user and group entries
  - Decision still based on one entry
- Default ACLs: generalize group inheritance
- Command line: `getfacl`, `setfacl`

ACL legacy interactions

- Hard problem: don't break security of legacy code
  - Suggests: "fail closed"
- Contrary pressure: don't want to break functionality
  - Suggests: "fail open"
- POSIX ACL design: old group permission bits are a mask on all novel permissions

"POSIX" "capabilities"

- Divide root privilege into smaller (~35) pieces
- Note: not real capabilities
- First runtime only, then added to FS similar to setuid
- Motivating example: `ping`
- Also allows permanent disabling

Privilege escalation dangers

- Many pieces of the root privilege are enough to regain the whole thing
  - Access to files as UID 0
  - CAP_DAC_OVERRIDE
  - CAP_FOWNER
  - CAP_SYS_MODULE
  - CAP_MKNOD
  - CAP_PTRACE
  - CAP_SYS_ADMIN (mount)

Legacy interaction dangers

- Former bug: take away capability to drop privileges
- Use of temporary files by no-longer setuid programs
- For more details: "Exploiting capabilities", Emeric Nasi

Next time

- Object capability systems
- Mandatory access control
- Information-flow security