OS Security

Authentication and Authorization

Radboud University, Nijmegen, The Netherlands

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There was once a programmer who was attached to the court of the warlord of Wu. The warlord asked the programmer: "Which is easier to design: an accounting package or an operating system?"

"An operating system," replied the programmer.

The warlord uttered an exclamation of disbelief. "Surely an accounting package is trivial next to the complexity of an operating system," he said.

"Not so," said the programmer, "When designing an accounting package, the programmer operates as a mediator between people having different ideas: how it must operate, how its reports must appear, and how it must conform to the tax laws. By contrast, an operating system is not limited by outside appearances. When designing an operating system, the programmer seeks the simplest harmony between machine and ideas. This is why an operating system is easier to design."

The warlord of Wu nodded and smiled. "That is all good and well, but which is easier to debug?"

The programmer made no reply.

—The Tao of Programming, 3.3

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Examples of shared resources

- Memory
- Input and Output (I/O) including
  - Files on the hard drive
  - Network
- Computation cycles on the processor(s)
- Peripheral hardware (keyboard, screen, ...)

What does that mean for security?

- Operating system needs to decide whether processes are allowed to perform certain operations
- Obvious security disasters:
  - One process reading the memory of another process
  - A process reading a "secret" file
  - A process preventing other processes from operating
  - One process reading (keyboard) input meant for another process

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- Worst-case authentication failure: impersonation

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- **Security nightmare:** an attacker who gets `root` access

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- Comparison of *password hash* against info stored in `/etc/shadow` (originally `/etc/passwd`)

Password hashing algorithms

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- Truncate the password to 8 characters, 7 bits each
- Encrypt the all-zero string with modified DES with this 56-bit key
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- Better algorithm through https://password-hashing.net/
- Winner announced on Nov 2, 2015: ARGON2

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  7. Concatenate the two ciphertexts to obtain the LM hash

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- Passwords shorter than 8 characters produce hash ending in `0xAAD3B435B51404EE`
- Cracking LM hashes is fairly easy, there are even online services, e.g., http://rainbowtables.it64.com/

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- Today, Windows uses multiple different approaches for passwords

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- Some students typically manage to do that in a week!

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- **Replay attack:** device-dependent, use challenge-response

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When a password is compromised, change your password. What if your fingerprint is compromised?

Some legal systems can force you to reveal your fingerprint, but not your password

Compromising fingerprints. . .

Politician's fingerprint reproduced using photos of her hands

At a Chaos Computer Club convention, hacker Starbug suggests notable people wear gloves.

by **Megan Geuss** - Dec 30, 2014 2:05am CET

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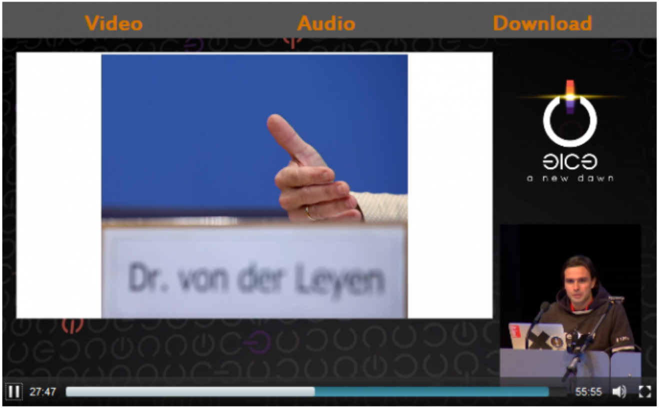

Pluggable authentication modules

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- This is handled by Pluggable Authentication Modules (PAM)
- Add a new module (e.g., for fingerprint authentication), directly available to all PAM enabled programs

PAM design

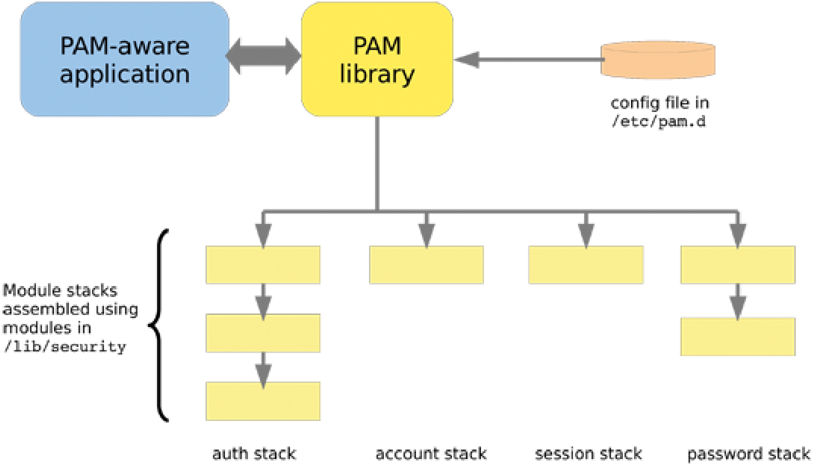


Image from http://www.tuxradar.com/content/how-pam-works

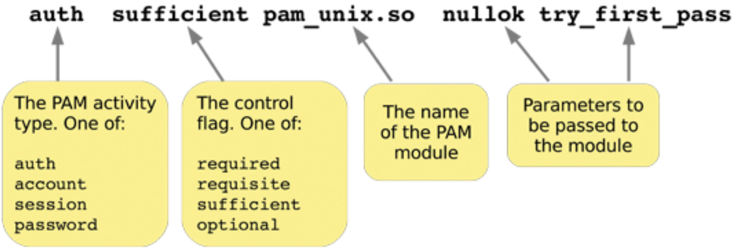
PAM activities

PAM knows 4 different authentication-related *activities*:

- **auth:** The activity of user authentication; typically by password, but can also use tokens, fingerprints etc.
- **account:** After a user is identified, decide whether he is allowed to log in. For example, can restrict login times.
- **session:** Allocates resources, for example mount home directory, set resource usage limits, print greeting message with information.
- **password:** Update the user's credentials (typically the password)

PAM configuration syntax

Configuration for program `progname` is in `/etc/pam.d/progname`



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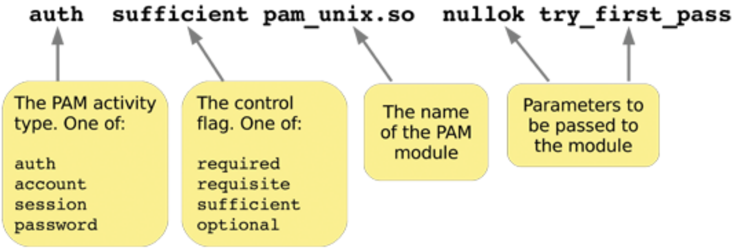

PAM control flags

- **requisite:** if module fails, immediately return failure and stop
- **required:** if module fails, return failure but continue
- **sufficient:** if module passes, return pass and stop
- **optional:** pass/fail result is ignored

Image source: http://www.tuxradar.com/content/how-pam-works

Examples of PAM modules

Name	Activities	Description
pam_unix	auth, session, password	Standard UNIX authentication through /etc/shadow passwords
pam_permit	auth, account, session, password	Always returns true
pam_deny	auth, account, session, password	Always returns false
pam_rootok	auth	Returns true iff you're root
pam_warn	auth, account, session, password	Write a log message to the system log
pam_cracklib	password	Perform checks of the password strength

Some PAM config examples

- Prevent all users from using su (/etc/pam.d/su)

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auth       requisite  pam_deny.so
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- Prevent all users from using `su` (`/etc/pam.d/su`)

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- Prevent non-root users to halt (`/etc/pam.d/halt`)

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- Enforce passwords with at least 10 characters and at least 2 special characters, use SHA-512 for password hash (/etc/pam.d/passwd):

```
password   required   pam_cracklib.so minlen=10 ocredit=-2
password   required   pam_unix.so     sha512
```

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- Possible disadvantage of central login server: single point of failure
- Different common protocols (NIS, LDAP, Kerberos)

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- Conveniently automated in `metasploit`

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- This attack is known as “pass the hash” attack
- Conveniently automated in `metasploit`
- Almost any larger Windows network still has NTLM somewhere

Part II

Authorization

Protection rings

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- Idea: Access to resources only for highly-privileged code
- Non-privileged code needs to ask the OS to perform operations on resources

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- Separate code in *protection rings*
- Ring 0: OS *kernel*
- Outer rings: less privileged software (drivers, userspace programs)

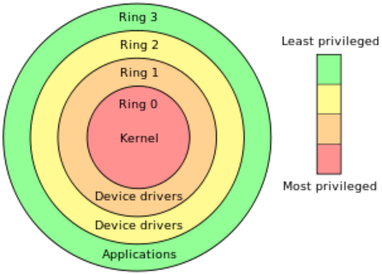

Image source: http://en.wikipedia.org/wiki/Protection_ring

Protection rings in Linux

- Protection rings are supported by hardware
- Certain instructions can only be executed by privileged (ring-0) code
- X86 and AMD64 support 4 different rings (ring 0–3)
- Trying to execute a ring-0 instruction from ring-3 results in SIGILL (illegal instruction)
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  - Call ring-0 code *kernel space*
  - Call ring-3 code *user space*

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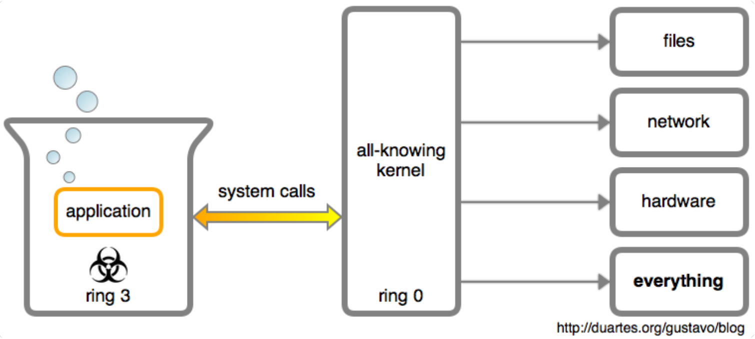
- Sometimes don't use system calls that directly, e.g., `printf` also calls `write`
- Can print (trace) all syscalls of a program: `strace`
- Very helpful for understanding what's happening "behind the scenes"

Applications and the OS



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- Answer: Modify OS kernel (add syscall), reboot
- Better answer: Modify OS kernel *at runtime*
- Linux kernel typically allows to load *kernel modules*
- Modules run in kernel space (ring 0)
- Load module into kernel with program `insmod`

A kernel module example

```c
#include <linux/module.h>
#include <linux/kernel.h>
MODULE_LICENSE("Dual BSD/GPL");

#define DEVICE_NAME "enableccnt"

static int enableccnt_init(void)
{
  printk(KERN_INFO DEVICE_NAME " starting\n");
  asm volatile("mcr p15, 0, %0, c9, c14, 0" :: "r"(1));
  return 0;
}

static void enableccnt_exit(void)
{
  asm volatile("mcr p15, 0, %0, c9, c14, 0" :: "r"(0));
  printk(KERN_INFO DEVICE_NAME " stopping\n");
}

module_init(enableccnt_init);
module_exit(enableccnt_exit);
```

Files

- Persistent data on background storage is organized in *files*
- Files are logical units of information organized by a *file system*
- Files have names and additional associated information:
  - Date and time of last access
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- Files are logically organized in a tree hierarchy of *directories*
- The file system maps logical information to bits and bytes on the storage device
- The file system runs in kernel space (typically through device drivers)
- Access to files goes through system calls

“Everything is a file”

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  - (User-space programs also operate on memory, but that's for next lecture)

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- `access()`: Check access rights based on real user ID (more later)

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  - `echo powersave > /sys/.../cpu0/cpufreq/scaling_governor`: Switch CPU0 to "powersave" mode

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- Important for access control: reading/writing those parameters is implemented through operations on (pseudo-)files

Device files

- Hardware devices are represented as files in `/dev/`
- Examples:
  - `/dev/sda`: First hard drive
  - `/dev/sda1`: First partition on first hard drive
  - `/dev/tty*`: Serial devices and terminals
  - `/dev/input/*`: Input devices
  - `/dev/zero`: Pseudo-devices that prints zeros
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Symbolic links and pipes

- A *symbolic link* is a special file that "links" to another file
- Accessing a symbolic link really accesses the file it points to
- Create a symbolic link to /home/peter/teaching/ with name /home/peter/ru:

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- Pipes for inter-process communication are also implemented through file handles

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- Important system-wide variables:
  - `PATH`: colon-separated list of directories to search for programs
  - `LD_LIBRARY_PATH`: colon-separated list of directories to search for libraries

MAC and DAC

Protection system

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Discretionary Access Control

A system implements *discretionary access control* (DAC) if the protection state can be modified by untrusted users. The protection of a user's files is then "at the discretion of the user".

Access Matrix

An *access matrix* is a set of subjects S, a set of objects O, a set of operations X and a function $op : S \times O \to \mathcal{P}(X)$. Given $s \in S$ and $o \in O$, the function op returns the set of operations that s is allowed to perform on o.

Access Matrix

	File 1	File 2	File 3	File 4
Process 1	read	read	read,write	
Process 2		read		
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- When a user creates a file, she adds a column to the table
- Adding a column means modifying the protection state
- The access-matrix model leads to a DAC system

UNIX/Linux protection model

- *Trusted code base* (TCB) of Linux is all code running in kernel space and several processes running with `root` permissions, e.g.:
  - `init` process
  - `login` (user authentication)
  - network services
- Goal: protect users' processes from each other and the TCB from all user processes

UNIX/Linux protection model: subjects

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- Each process also has associated a set of *group IDs*
- The groups of all users are defined in `/etc/group`
- Each user has a primary group defined in `/etc/passwd`
- When you are logged in, you can see your groups with the command `groups`

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- Command `ls -l` shows files with corresponding permissions, e.g.

```
peter@tyrion:/etc$ ls -l passwd shadow
-rw-r--r-- 1 root root   2217 Nov 16 18:13 passwd
-rw-r----- 1 root shadow 1454 Nov 16 18:13 shadow
```

UNIX/Linux protection model: matching

- When a process wants to access a file, check the following
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- `execute`: Can traverse the directory (`cd` into or across the directory)

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- Most important application: setuid root
- Setuid root process can drop privileges (effective ID)
- Can regain root rights as long as saved ID is still 0!

setuid example: `su`

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- Other prominent example: passwd (needs write access to /etc/shadow)
- Again, authenticate against PAM before doing anything

Privilege escalation

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  - Bugs in the kernel
  - Bugs in how `root` programs process user-provided input
  - Bugs in suid-root programs (escape intended functionality)

Privilege escalation

- Attack that expands attacker's privileges is called *privilege escalation*
- Two types of privilege escalation:
  - horizontal: obtain privileges of another un-privileged user
  - vertical: obtain privileges of root (or the kernel), "privilege elevation"
- Typicall enabled by bugs in privileged software:
  - Bugs in the kernel
  - Bugs in how `root` programs process user-provided input
  - Bugs in suid-root programs (escape intended functionality)
- An exploit that lets an unprivileged (logged in, local) user gain root rights is called *local root exploit*

Access control lists

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- Set ACL entries with the program `setfacl` (set file access control lists)
- Read ACL entries with `getfacl` (get file access control lists)
- Note: `ls -l` will not show ACLs, only a '+' to indicate that "there's more"