EECS 388

Introduction to Computer Security

Lecture 18:

Access Control and Isolation

Nov. 2, 2023

Prof. Ensafi

Access Control

How do we *control access* to *resources*?

Security Model
System abstraction that enables us to discuss and formulate a policy.

Security Policy
Specifies what actions each subject is allowed to perform on each object.

Security Mechanism
Implementation of the policy. E.g., OS kernel, encryption

What we aim for: Principle of Least Privilege: Every program and user should operate using the least *privileges* necessary to complete their job.

- Limits the damage that can result from an accident or error.
- Reduces interactions among privileged programs to minimum for correct operation. Unintentional, unwanted, or improper uses of privilege less likely.
- Minimizes the number of programs that must be audited.
- Example: Classified information concept of "need-to know".

Models and Policies

Security Model

System abstraction that enables us to discuss and formulate a policy. Consists of:

Subjects (who)

UNIX: users

Android: apps

Web: origins

Objects (what)

UNIX: files, processes

Other: db tables, cookies, device sensors, etc.

Operations

Ways that subjects can operate on (e.g., read, write, call) objects

Security Policy

Defines an **access control matrix** that maps subjects and objects to allowed operations.

		Objects			
		File 1	**File 2**	**File 3**	**File 4**
Subjects	**Alice**	read	read/ write	no access	no access
	Bob	read	read/ write	no access	no access
	Carol	read	write	read/ write	read/ write
	Wendy	read/ write	read/ write	read	read

Implementing Access Control

What we aim for:

Principle of Complete Mediation

Every access to every object must be checked for authority by a mediator.

- Primary underpinning of access control protection systems.
- Implies that a foolproof method of identifying the source of every request must be devised.
- Be careful of caching checks!
  If change in authority occurs, cached results must be updated.
  Time-of-check, time-of-use vulnerabilities.

Unix Namespace Security Model

Subjects (Who?)

Users

Objects (What?)

Files, directories, processes

Access Operations

Read, Write, Execute

Unix Security Model: Users and Groups

Subjects (Who?)

Users

Every user has a unique **user name** and numeric user id

```
user@desktop:~$ whoami; id -u
user
1000
```

Objects (What?)

Files, directories, processes

A user may belong to several **groups**. Provides **role-based access control**

```
user@desktop:~$ groups
user adm faculty
```

Superuser (“root”, id 0) has authority to do anything.
Least privilege: *Only assume superuser role when necessary.*

Access Operations

Read, Write, Execute

Users in a specific group (adm) can temporarily **elevate** to root privileges

```
user@desktop:~$ sudo whoami
[sudo] password for user:
root
```

Unix Security Model: File Permissions

Subjects (Who?)

Users

Objects (What?)

Files, directories, processes

Access Operations

Read, Write, Execute

Every file and directory has an owner and group

```
user@desktop:~$ ls -l
total 3
d rwx rwx ---  1 user user    4096 Apr  2 15:56 go
- rw- rw- r--  1 user user       0 Apr 11 04:15 test.py
d rwx rwx ---  1 user faculty 4096 Dec 28 21:09 courses
```

Permission Bits | Owner | Group | Size | Last Modified | Name

File permissions bits specify what role can do what to the file:

```
rwx rwx rwx
```

Owner | Group | Others

If user == owner, owner permissions;
else if user in group, group permissions;
else other permissions. (If user is `root`, *override permissions*)

File owner (or `root`) can change permissions and ownership

Unix Security Model: Processes

Subjects (Who?)

Users

Objects (What?)

Files, directories, processes

Access Operations

Read, Write, Execute

Every process has an **Effective User ID (EUID)** that determines permissions of that process. Processes typically inherit user and group of their parent process, but can be changed by `root`

```
user@desktop:~$ ps -eo user,comm
USER   COMMAND
root   init
user   bash
user   ps
```

`login` and `sshd` run as root. Authenticate user, then *change* user id and group id to that of user and execute shell (e.g., `bash`).

Executable files have a **setuid bit**. If set, process has EUID (and privileges) of file's owner, rather than user that executed it.

E.g., `passwd` command is owned by root and has setuid bit set

Danger: Any vulnerability in `passwd` means attacker gets `root`

Process Isolation

Traditional thinking:

How to run bad/untrustworthy programs safely?

- Program from untrusted sites
- Apps exposed to adversarial data
- “Honeypots”

New thinking:

Be skeptical of all programs, isolate to achieve least privilege

General goal:

Confinement: ensure misbehaving process cannot harm rest of system

Can be implemented at many levels:

- System call interposition:
  (e.g., AppArmor, SELinux)
- Containers:
  isolated userspace instances
  (e.g., Dockers, Kubernetes)
- Virtual machines:
  isolate OSes on a single machine
- Physical isolation:
  E.g., separate hardware, air gaps

General isolation concept: Confinement

Key component: **reference monitor**

- **Mediates requests** from applications
  - Implements protection policy
  - Enforces isolation and confinement
- Must ***always*** be invoked:
  - Every application request must be mediated
- **Tamperproof**:
  - Reference monitor cannot be killed
  - … or if killed, then monitored process is killed too
- **Small** enough to be analyzed and validated

Approach: UNIX chroot system call

chroot "jails": Simple isolation mechanism provided by UNIX kernel

Early use included guest accounts on FTP sites

To use: (must be `root`)

```
root:/# chroot /tmp/guest
root:/# su guest
guest:/$ ./myapp
```

root dir is now `/tmp/guest`

EUID set to `guest`

In this example, `myapp` is confined such that it can only access files within `/tmp/guest` for which `guest` has permission

`open("/etc/passwd", "r")` actually opens `/tmp/guest/etc/passwd`

Application cannot access files outside of jail because it cannot even name them!

Many ways to evade `chroot` isolation

- Create device that lets you access raw disk
  Major/minor device number namespace is shared
- Send signals to non-`chrooted` process
  PID namespace is shared
- Reboot system
- Bind to privileged ports
  Network namespace is shared

System call interposition

Observation: to damage host system (e.g. persistent changes) app must make system calls:

- To delete/overwrite files: unlink, open, write
- To do network attacks: socket, bind, connect, send

Idea: monitor app's system calls and block unauthorized calls

Implementation options:

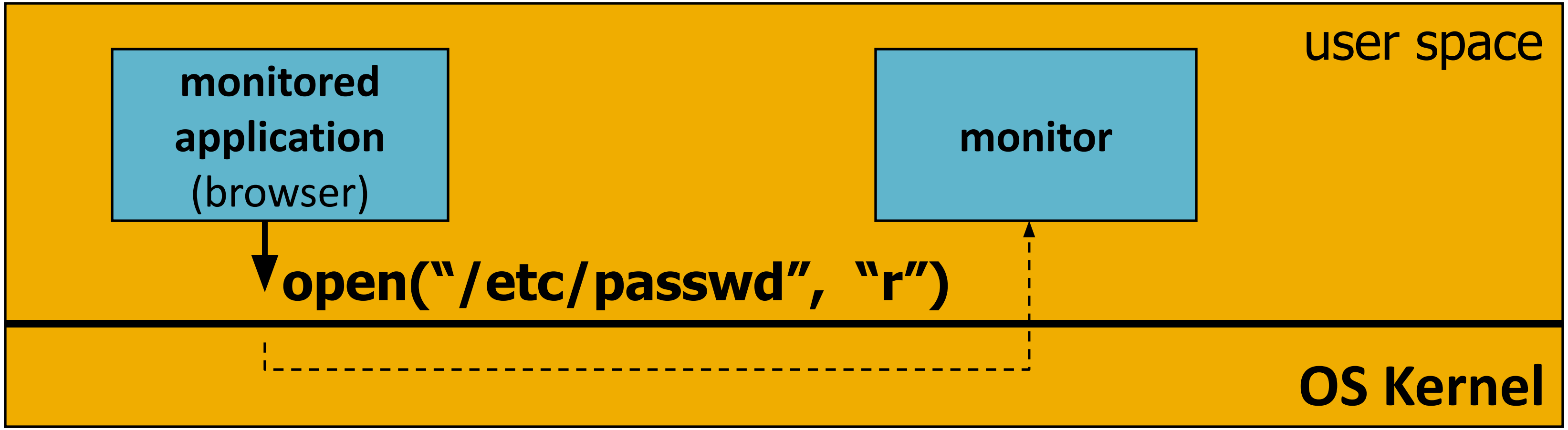
- Completely kernel space (e.g., SE Linux)
- Completely user space (e.g., program shepherding)
- Hybrid (e.g., Systrace)

Implementing System Call Interposition

Linux **ptrace**: process tracing

process calls: `ptrace (…, pid_t pid, …)`

and wakes up when **pid** makes a system call.



Monitor checks policy, kills application if request is disallowed.

System Call Interposition Policies

Sample policy file:

```
path allow   /tmp/*
path deny   /etc/passwd
network deny all
```

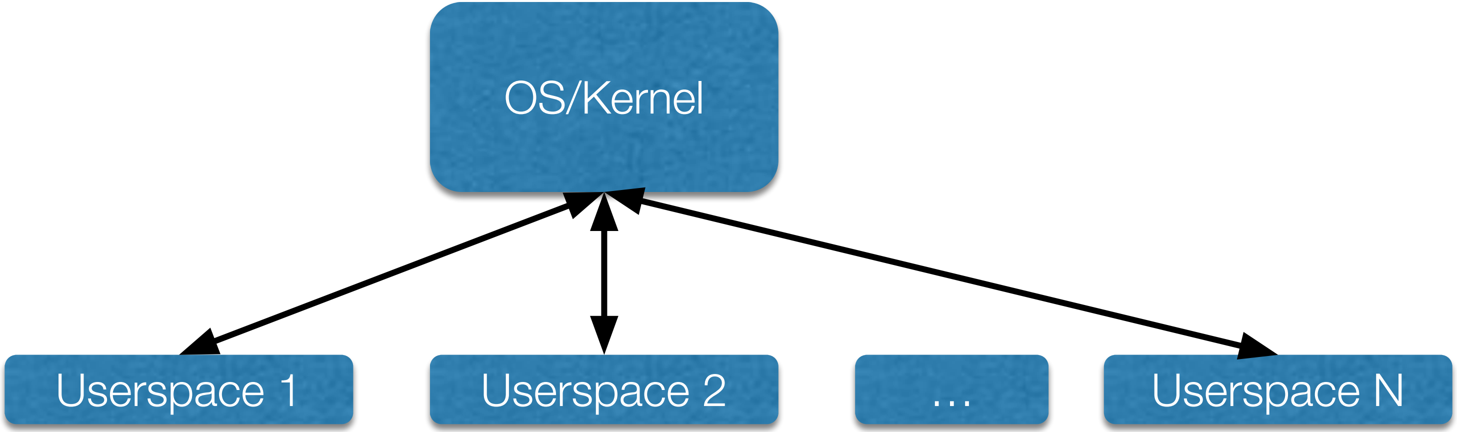
Manually specifying policy for an app can be difficult:

- Can try to auto-generate policy by learning how app behaves on “good” inputs. (But what are “good” inputs?)
- If policy does not cover a specific system call, ask user
  (But how is the user supposed to decide?)

Difficulty with choosing policy for specific apps (e.g. browser) is the main reason this approach is not widely used

Containers: Further limiting process interference

A virtualization at the level of the operating system which creates multiple isolated userspace instances (e.g. Docker and Kubernetes)



Restrictions: must be same OS/kernel

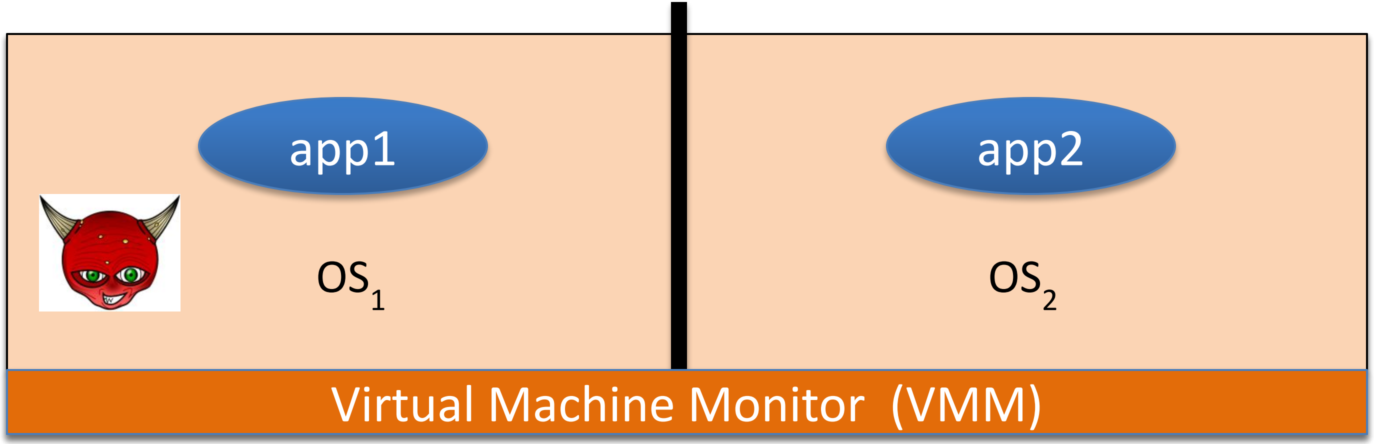
Cool things: disk quotas, CPU/RAM limits, root privilege isolation, etc…

Approach: Virtual Machines

Confinement: ensure misbehaving app cannot harm rest of system

Can be implemented at many levels:

Virtual machines: isolate OSes on a single machine



Virtual Machine Security

VMM Security assumption:

Malware can infect ***guest OS*** and guest apps

But malware cannot escape from the infected VM

- Cannot infect ***host OS***
- Cannot infect other VMs on the same hardware

Requires that VMM protect itself and is not buggy

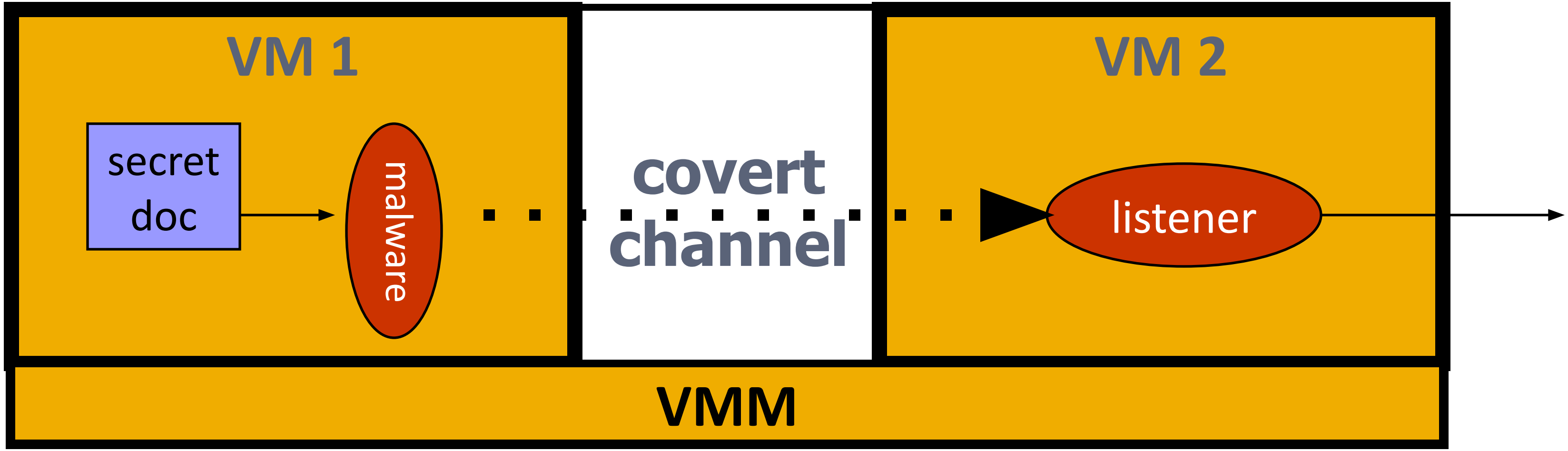
- VMM is much simpler than full OS

  … but device drivers run in Host OS

Problem: Covert Channels

Covert channel: unintended communication channel between isolated components

Can be used to leak classified data from secure component to public component



Covert Channel Example

Both VMs use the same underlying hardware

To send a bit $b \in \{0,1\}$ malware does:

- b= 1: at 1:00am do CPU intensive calculation
- b= 0: at 1:00am do nothing

At 1:00am listener does CPU intensive calculation and measures completion time

$$b = 1 \quad \Rightarrow \quad \text{completion-time} > \text{threshold}$$

Many covert channels exist in running system:

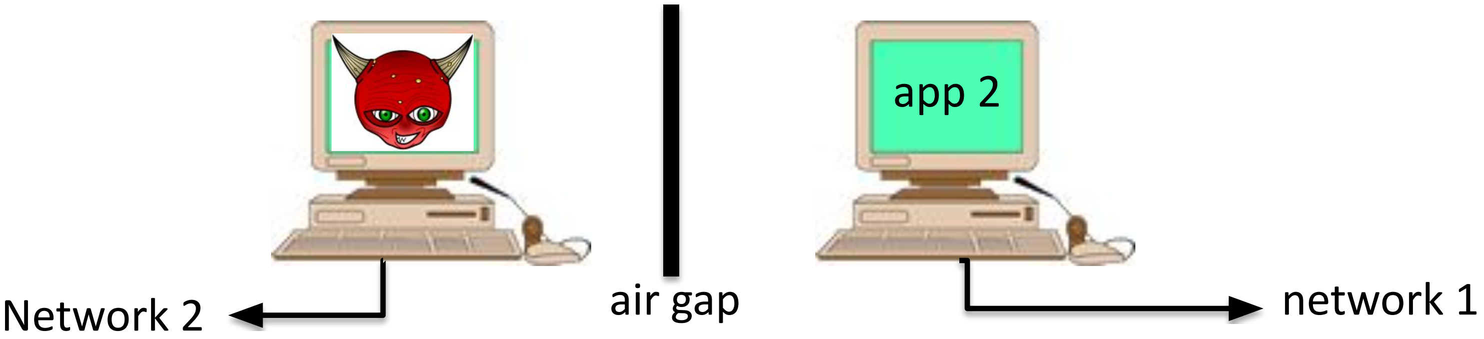
- File lock status, cache contents, interrupts, …
- Difficult to eliminate all

Approach: Physical Air Gap

Confinement: ensure misbehaving app cannot harm rest of system

Can be implemented at many levels:

Hardware: run application on isolated hardware (air gap)



⇒ but restrictive, expensive, difficult to manage

Coming Up

Reminders:

Lab 4 due today at 6 p.m.

Quiz on Canvas after each lecture

Tuesday Nov 7

Election Cybersecurity

Vulnerabilities, defenses, policy

Thursday Nov 9

Machine Learning Security

Kexin Pei, University of Chicago