Microsoft

Landlock Workshop: Sandboxing Application for Fun and Protection

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Mickaël Salaün

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Sandboxing application

Landlock is available in mainline since 2021 (Linux 5.13), but with some limitations due to the iterative approach.

Landlock is now enabled by default on multiple distros: Ubuntu 22.04 LTS, Fedora 35, Arch Linux, Alpine Linux, Gentoo, Debian Sid, chromeOS, CBL-Mariner, WSL2

This workshop is about sandboxing ImageMagick

Goal of this workshop

About the steps to sandbox a CLI application.

Use an old and vulnerable (long-been-fixed) ImageMagick version to illustrate how sandboxing can mitigate vulnerabilities.

Workshop setup

VM setup

See https://github.com/landlock-lsm/workshop-imagemagick

If you already cloned the repository:

```
git pull
vagrant up
vagrant ssh
```

Connect to the VM

```
# Once set up, take a snapshot and log in

vagrant snapshot push
vagrant ssh


# We can now also use virt-manager to connect to the VM
```

Steps done by the VM provisioning

1. Set up the build environment
2. Build a vulnerable version of ImageMagick
3. Install the created package

Sandboxing with Landlock

Developers and users

It is assumed that with enough skills and time, most applications could be compromised.

Problem (as developers):

- We don't want to participate to malicious actions through our software because of security bug exploitation.
- We have a responsibility for users, especially to protect their (personal) data: every **running app/service increases** (user) **attack surface**.

Sandboxing

A security approach to **isolate** a software component **from the rest of the system**. Namespaces/containers are not considered security sandboxes per se, but tools to “virtualize” resources.

An innocuous and trusted process can become malicious during its **lifetime** because of bugs exploited by attackers.

Sandbox properties:

- Follow the least privilege principle
- Innocuous and composable security policies

What is Landlock?

Landlock is an access control system available to **unprivileged** processes on Linux, thanks to 3 dedicated syscalls.

It enables developers to add **built-in** application **sandboxing**.

Useful as-is and still in gaining new features.

Filesystem access-control

Filesystem restrictions

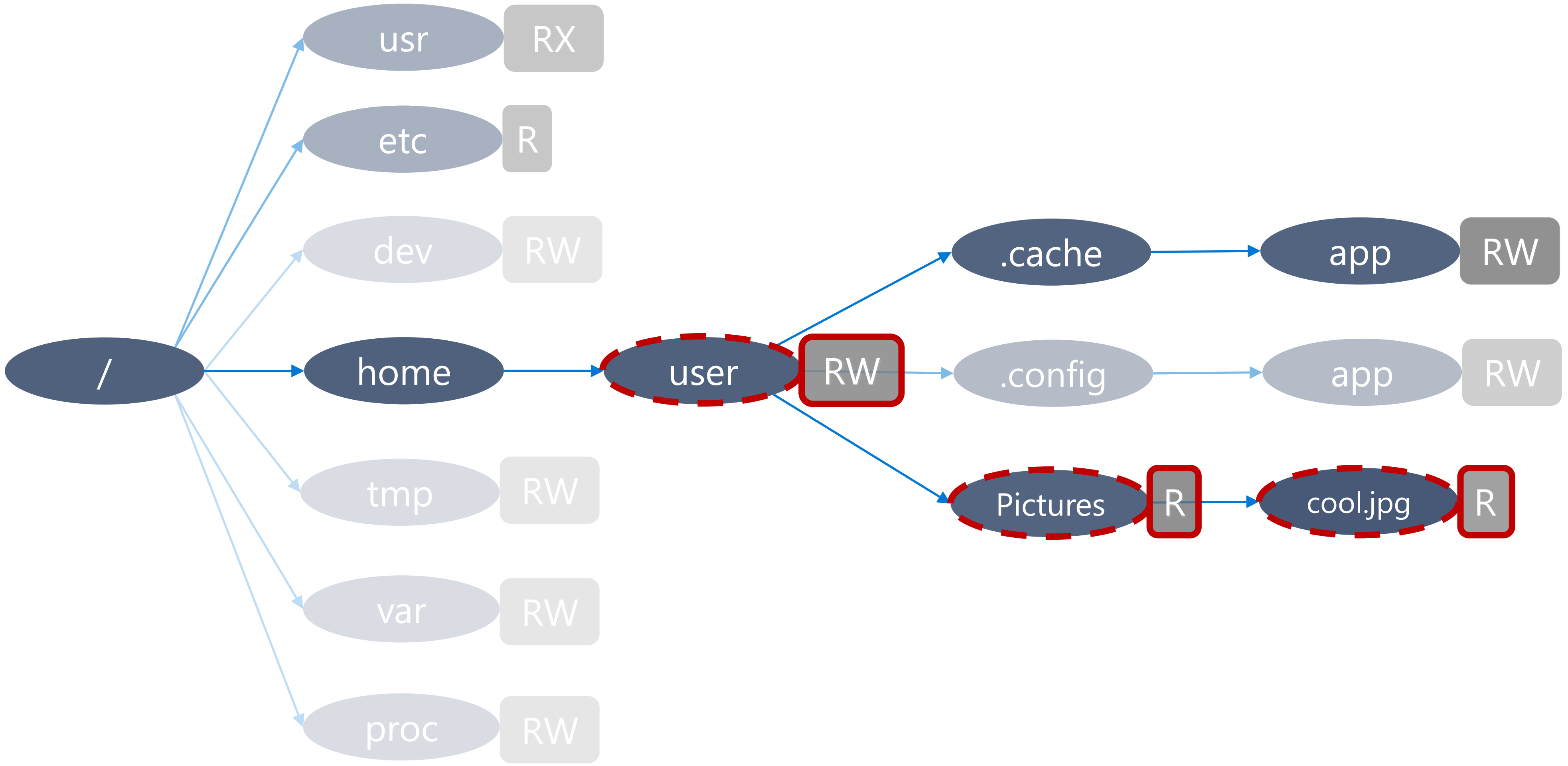
Access-control rights:

- Execute, read or write to a file
- List a directory or remove files
- Create files according to their type
- Rename or link files

File hierarchy identification: ephemeral inode tagging

Example of filesystem policy composition

3rd layer ✓
2nd layer ✓
1st layer ✓



R	Read
W	Write
X	eXecute

Implementing sandboxing

How to patch an application?

1. Define the threat model: which data is trusted or untrusted?
2. Identify the complex parts of the code: where there is a good chance to find bugs?
3. Identify and patch the configuration handling to infer a security policy.
4. Identify and patch the most generic places to enforce the security policy for the rest of the lifetime of the thread.

Application compatibility

Forward compatibility for applications is handled by the kernel development process.

Backward compatibility for applications is the responsibility of their developers.

Each new Landlock feature increments the ABI version, which is useful to leverage available features in a **best-effort security** approach.

Step 1: Check the Landlock ABI

```c
int abi = landlock_create_ruleset(NULL, 0, LANDLOCK_CREATE_RULESET_VERSION);

if (abi < 0)
    return 0;
```

Step 2: Create a ruleset

```
int ruleset_fd;
struct landlock_ruleset_attr ruleset_attr = {
    .handled_access_fs =
        LANDLOCK_ACCESS_FS_EXECUTE |
        LANDLOCK_ACCESS_FS_WRITE_FILE |
        […]
        LANDLOCK_ACCESS_FS_MAKE_REG,
};

ruleset_fd = landlock_create_ruleset(&ruleset_attr, sizeof(ruleset_attr), 0);
if (ruleset_fd < 0)
    error_exit("Failed to create a ruleset");
```

Step 3: Add rules

```c
int err;
struct landlock_path_beneath_attr path_beneath = {
    .allowed_access = LANDLOCK_ACCESS_FS_EXECUTE | […] ,
};

path_beneath.parent_fd = open("/usr", O_PATH | O_CLOEXEC);
if (path_beneath.parent_fd < 0)
    error_exit("Failed to open file");

err = landlock_add_rule(ruleset_fd, LANDLOCK_RULE_PATH_BENEATH, &path_beneath, 0);
close(path_beneath.parent_fd);
if (err)
    error_exit("Failed to update ruleset");
```

Step 4: Enforce the ruleset

```
if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
    error_exit("Failed to restrict privileges");

if (landlock_restrict_self(ruleset_fd, 0))
    error_exit("Failed to enforce ruleset");

close(ruleset_fd);
```

Full example: https://git.kernel.org/pub/scm/linux/kernel/git/stable/linux.git/tree/samples/landlock/sandboxer.c

Let’s patch ImageMagick!

ImageMagick

Pretty common set of tools to transform or display pictures: parse a lot of file formats

Use cases: CLI tool or (web) server

Attack scenario

CVE-2016-3714/ImageTragick: insufficient shell characters filtering that can lead to (potentially remote) code execution.

Let’s say we have a vulnerable version (not necessarily this one).

Sandboxing this kind of tool can help mitigate the impact of such vulnerability: e.g., deny access to secret files

Agenda

1. Test an exploit
2. Find the sweet spot to restrict the process
3. Patch + build + test

Test exploit with vulnerable version

```
# Convert from one image format to another

convert /vagrant/exploit/malicious.mvg /tmp/out.png

# Solution patches are available in /vagrant/imagemagick-patches/*.patch
```

Main steps to patch

1. Declare the Landlock syscalls
2. Find what we want to sandbox and where it would make sense
3. Create a ruleset
4. Add static rules
5. Add dynamic rules
6. Restrict the task before potentially-harmful computation

Patch ImageMagick 1/9

```
# 1/ Go to the source directory

cd ~/imagemagick/trunk/src/ImageMagick-*

# 2/ Prepare a clean repository to work on

/vagrant/imagemagick-patches/init-repo.sh
```

Patch ImageMagick 2/9

```
# 3/ Import Landlock syscall stubs and access right groups

cp /vagrant/sandboxer.c magick/landlock.h
vim magick/landlock.h

git add -A
git commit

# 4/ Look at the system’s Landlock definitions and types

vim /usr/include/linux/landlock.h
```

Patch ImageMagick 3/9

```
# 5/ Look at the convert code and find a sweat spot for sandboxing

vim wand/convert.c

# Imagemagick doesn’t have a clear separation between argument parsing and
their evaluation: we need to patch the loop parsing arguments.

# 6/ Include landlock.h and prepare a ruleset

(void) CopyMagickString(image_info->filename,filename,MaxTextExtent);

+   const struct landlock_ruleset_attr ruleset_attr = {
+       .handled_access_fs = ACCESS_FS_ROUGHLY_READ | ACCESS_FS_ROUGHLY_WRITE,
+   };
```

0003-WORKSHOP-Create-a-ruleset.patch

Build and test the patched ImageMagick

```
# Regularly build and check convert

make
./utilities/convert /vagrant/exploit/malicious.mvg /tmp/out.png
```

Patch ImageMagick 4/9

```
# 7/ Create the ruleset

int ruleset_fd = landlock_create_ruleset(&ruleset_attr, sizeof(ruleset_attr), 0);

# 8/ Check for errors and log them

if (ruleset_fd < 0) {
    perror("LANDLOCK: Failed to create a ruleset");
    return MagickFalse;
}

# 9/ Close the ruleset

close(ruleset_fd);
```

0003-WORKSHOP-Create-a-ruleset.patch

Patch ImageMagick 5/9

```
# 10/ Include landlock.h and create the ruleset in network_server_init()

if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
    perror("LANDLOCK: Failed to lock privileges");

if (landlock_restrict_self(ruleset_fd, 0)) {
    perror("LANDLOCK: Failed to restrict thread");
    return MagickFalse;
}
```

0004-WORKSHOP-Restrict-and-break-everything.patch

Build and test the patched ImageMagick

```
# Regularly build and check convert

make
./utilities/convert /vagrant/exploit/malicious.mvg /tmp/out.png
```

Patch ImageMagick 6/9

```
  # 11/ Add static rules: exceptions to the denied-by-default policy

+   struct landlock_path_beneath_attr rule;
+
+   printf("LANDLOCK: Adding rule for /usr");
+   rule.parent_fd = open("/usr", O_PATH | O_CLOEXEC);
+   rule.handled_access_fs = ACCESS_FS_ROUGHLY_READ;
+   if (landlock_add_rule(ruleset_fd, LANDLOCK_RULE_PATH_BENEATH, &rule, 0))
+       perror("LANDLOCK: Failed to create rule");


    if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
```

0005-WORKSHOP-Add-static-restrictions.patch

Patch ImageMagick 7/9

```
   # 12/ Add more static rules: /dev/null and /tmp

+  printf("LANDLOCK: Adding rule for /dev/null");
+  rule.parent_fd = open("/dev/null", O_PATH | O_CLOEXEC);
+  rule.handled_access_fs = LANDLOCK_ACCESS_FS_READ_FILE;
+  if (landlock_add_rule(ruleset_fd, LANDLOCK_RULE_PATH_BENEATH, &rule, 0))
+      perror("LANDLOCK: Failed to create rule");
+
+
+  [...]


   if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
```

`0005-WORKSHOP-Add-static-restrictions.patch`

Patch ImageMagick 8/9

```
   # 13/ Add a dynamic rule according to CLI arguments

+  printf("LANDLOCK: Adding rule for %s", filename);
+  rule.parent_fd = open(filename, O_PATH | O_CLOEXEC);
+  rule.handled_access_fs = ACCESS_FS_ROUGHLY_READ;
+  if (landlock_add_rule(ruleset_fd, LANDLOCK_RULE_PATH_BENEATH, &rule, 0))
+      perror("LANDLOCK: Failed to create rule");
+
+
+  [...]


   if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
```

0006-WORKSHOP-Handle-input-and-output-files.patch

Patch ImageMagick 9/9

```
   # 14/ Add more dynamic rules

+  char *out_path = strdup(argv[i+1]);
+  const char *out_dir = dirname(out_path);
+  [...]


   if (prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0))
```

0006-WORKSHOP-Handle-input-and-output-files.patch

Build and install the patched ImageMagick

```
# Once everything looks OK, build and install the package

cd ../../..
makepkg -efi --nocheck

convert /vagrant/exploit/malicious.mvg /tmp/out.png
```

Exercise left to the readers

- Make the code more generic and maintainable
- Support the “fd:” URI scheme
- Support more commands
- Build a new kernel with the audit patches (see previous talk), install it, and test it
- Test with different kernel versions thanks to the Landlock test tools

- …and send your patch upstream!

Wrap-up

ImageMagick patch

- Use the native CLI arguments:
  - Transparent for users
  - Well integrated with all supported use cases
- Quick to implement a first PoC
- Quicker when we already know the app code

Contribute

- Develop new (kernel) features (e.g., new access types)
- Write new tests (e.g., kunit)
- Challenge the implementation
- Improve documentation
- **Sandbox your applications** and others'
  - Secure Open Source Rewards
  - Google Patch Rewards

Questions?

https://docs.kernel.org/userspace-api/landlock.html

Past talks: https://landlock.io

landlock@lists.linux.dev

Thank you!