Context Switching your Kernel Fuzzing @BSides Stuttgart 2019

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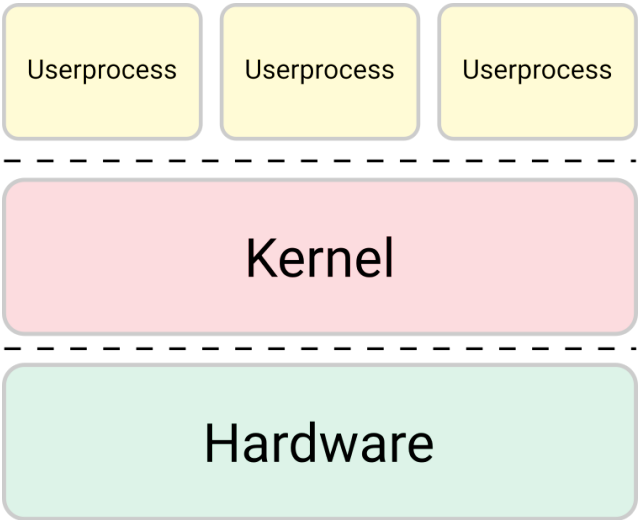
whoami

Eric Sesterhenn

- Pentesting/Code Auditing at X41
- Kernel stuff every now and then
- Recent topics: smartcards+fax machines

Kernel and Userspace



Why Kernel Fuzzing

- Kernel bugs offer high privileges
- Might allow sandbox escape
- In some cases even remotely exploitable
- Whatever, its fun :)

EULA

My code is crappy, I will not release anything related to this

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How do Others Fuzz the Linux Kernel

- fsfuzzer - bitflips in fs images
  `https://people.redhat.com/sgrubb/files/`
- trinity - random syscalls
  `https://codemonkey.org.uk/projects/trinity/`
- syzcaller - coverage guided syscalls
  `https://github.com/google/syzkaller`
- difuze - llvm analysis of ioctl `https://github.com/ucsb-seclab/difuze`
- kafl - afl for qemu `https://github.com/RUB-SysSec/kAFL`

What I dislike

- Fuzzing the currently running kernel might cause instabilities / side effects
- Virtualization and instrumentation might cause overhead
- Not enough pain for me ... ;-)

Why not Both?

Why don't we run the kernelcode in userspace?

Let the porting begin

- Ported EXT2 some years ago to userspace
- Crudely ripping stuff apart and adding glue
- Did so again with ASN1 parsers, QNXFS and CRAMFS

Head -> Table

```
struct page {
        unsigned long flags;
        struct address_space *mapping;
};
#define sysfs_remove_mount_point(a, b) 0
#define sysfs_create_file_ns(a, b, c) 0
#define sysfs_create_files(a, b) 0
#define sysfs_chmod_file(a, b, c) 0
#define kvmalloc(a, b) malloc(a)
#define kvfree(a) free((void *)a)
```

After a lot of pain... - sprint_oid()

```
while (v < end) {
        num = 0;
        n = *v++;
        ...
        num = n;
        ...
        ret += count = snprintf(buffer, bufsize, ".%lu", num);
        buffer += count;
        bufsize -= count;
        if (bufsize == 0)
        return -1;
}
```

Close, but no cigar

```
int vsnprintf(char *buf, size_t size, const char *fmt, va_list args)
{
        ...
        /* Reject out-of-range values early.  Large positive sizes are
        used for unknown buffer sizes. */
        if (WARN_ON_ONCE(size > INT_MAX))
                return 0;
```

Schmerz! What about UML?

User-mode Linux (UML) enables multiple virtual Linux kernel-based operating systems (known as guests) to run as an application within a normal Linux system (known as the host).

How?

```
make ARCH=um defconfig
make ARCH=um
./linux
```

How to AFL?

```
cp /usr/bin/ar /path-to-afl/afl-ar
cp /usr/bin/objcopy /path-to-afl/afl-objcopy
cp /usr/bin/nm /path-to-afl/afl-nm
cp /usr/bin/ld /path-to-afl/afl-ld
cp /usr/bin/objdump /path-to-afl/afl-objdump
CROSS_COMPILE=/path-to-afl/afl- make ARCH=um
```

How to AFL?

- *arch/x86/um/vdso/checkundef.sh* doesnt like us - just ***exit 0***
- *arch/x86/um/vdso/vma.c* ***init_vdso()*** neither - simply ***return -ENOMEM***
- Some *.config* tweaks

How to AFL?

- Lets start fuzzing filesystems ... seems easy
- `./linux udb0=root_fs`
- insert ***machine_halt()*** in *init/do_mounts.c* to exit as early as possible

Damn again!

- Lots of non-reproducible crashes (0.5%)
- Debugging...
- Not caused by me :(

```
#66 0x0000000060024dad in write_sigio_workaround () at
↪  arch/um/os-Linux/sigio.c:309
#67 sigio_broken (fd=<optimized out>, read=<optimized out>) at
↪  arch/um/os-Linux/sigio.c:344
#68 0x0000000060003c44 in rng_init () at arch/um/drivers/random.c:137
#69 0x0000000060016429 in do_one_initcall (fn=0x60003bbc <rng_init>) at
↪  init/main.c:887
#70 0x0000000060001d7b in do_initcall_level (level=<optimized out>) at
↪  ./include/linux/init.h:131
#71 do_initcalls () at init/main.c:964
#72 do_basic_setup () at init/main.c:982
#73 kernel_init_freeable () at init/main.c:1138
#74 0x0000000060236ef3 in kernel_init (unused=<optimized out>) at
↪  init/main.c:1055
#75 0x0000000060017ca1 in new_thread_handler () at arch/um/kernel/process.c:133
#76 0x0000000000000000 in ?? ()
```

Third time is the charm

- Lets combine the approaches
- Use UML for easy AFL/Userspace compilation

Link UML

```
$ afl-gcc  ./fs/cifs/asn1.o
afl-cc 2.51b by <lcamtuf@google.com>
/usr/bin/ld: /usr/lib/gcc/ .. /Scrt1.o: in function `_start':
(.text+0x20): undefined reference to `main'
/usr/bin/ld: ./fs/cifs/asn1.o: in function `kmalloc_array':
./include/linux/slab.h:668: undefined reference to `__kmalloc'
/usr/bin/ld: ./fs/cifs/asn1.o: in function `asn1_oid_decode':
fs/cifs/asn1.c:466: undefined reference to `kfree'
/usr/bin/ld: ./fs/cifs/asn1.o: in function `decode_negTokenInit':
fs/cifs/asn1.c:526: undefined reference to `kfree'
/usr/bin/ld: fs/cifs/asn1.c:526: undefined reference to `kfree'
collect2: error: ld returned 1 exit status
```

Link UML

```
void *__kmalloc(size_t size, int flags) {
        return malloc(size);
}

void kfree(void *objp) {
        free(objp);
}

int main(int argc, char **argv) {
        ...
        return decode_negTokenInit(blob, i, server);
}
```

What else

- *-Wl,–unresolved-symbols=ignore-in-object-files*
- *AFL_HARDEN / AFL_USE_ASAN work as well*

What to fuzz

- I dont care about the actual bugs, only the approach
- Priority: Easy to fuzz targets
- `egrep -r "\(.*char \*.*,.*size_t .*\)"`

Lets try

842 compression is used by zram, yeah unlikely attack surface, maybe wireguard uses it at some point ;-)

```
AFL_HARDEN=1 ~/tools/afl/afl-2.51b/afl-gcc test.c
↪  ./lib/842/842_decompress.o
↪  -Wl,--unresolved-symbols=ignore-in-object-files
```

Baam

```
--- a/lib/842/842_decompress.c
+++ b/lib/842/842_decompress.c
@@ -211,6 +211,8 @@ static int __do_index(struct sw842_param *p, u8 size, u8 bits, u64 fsize)
(unsigned long)total,
(unsigned long)beN_to_cpu(&p->ostart[offset], size));

+       if (p->olen < size)
+               return -EINVAL;
        memcpy(p->out, &p->ostart[offset], size);
        p->out += size;
        p->olen -= size;
@@ -354,6 +356,8 @@ int sw842_decompress(const u8 *in, unsigned int ilen,
if (!bytes || bytes > SHORT_DATA_BITS_MAX)
return -EINVAL;

+                       if (p.olen < bytes)
+                               return -EINVAL;
                        while (bytes-- > 0) {
                                ret = next_bits(&p, &tmp, 8);
                                if (ret)
```

Google VPD

- ChromeOS Vital Product Data (VPD) Binary Blob
- Parsed in linux kernel
- Should usually be a trusted source

Baam

```
--- a/drivers/firmware/google/vpd_decode.c
+++ b/drivers/firmware/google/vpd_decode.c
@@ -69,7 +69,7 @@ int vpd_decode_string(const s32 max_len, const u8 *input_buf, s32 *consumed,
                /* key */
                res = vpd_decode_len(max_len - *consumed, &input_buf[*consumed],
                                     &key_len, &decoded_len);
-               if (res != VPD_OK || *consumed + decoded_len >= max_len)
+               if (res != VPD_OK || *consumed + decoded_len + key_len >= max_len)
                        return VPD_FAIL;

                *consumed += decoded_len;
@@ -79,7 +79,7 @@ int vpd_decode_string(const s32 max_len, const u8 *input_buf, s32 *consumed,
                /* value */
                res = vpd_decode_len(max_len - *consumed, &input_buf[*consumed],
                                     &value_len, &decoded_len);
-               if (res != VPD_OK || *consumed + decoded_len > max_len)
+               if (res != VPD_OK || *consumed + decoded_len + value_len > max_len)
                        return VPD_FAIL;

                *consumed += decoded_len;
```

Next Steps / Future work

- Userspace fuzzing with clang/libfuzzer
- Add more fuzzing targets
- Think about in-kernel IPC

Thanks

- Q & A
- VOTE!!!
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