

# OS Security

## Memory

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  - ▶ Special file handles for stdin, stdout, stderr
  - ▶ Devices are handled through device files
  - ▶ Reading and writing kernel parameters through pseudo-file systems in /proc and sys
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- ▶ Processes have associated user ID and group IDs
- ▶ Files have access rights (read,write,execute) for owner,group,other
- ▶ Special flags associated to files, in particular `setuid` flag
- ▶ `Setuid` programs are run with effective UID of the *owner*
- ▶ Particularly important: `setuid-root` programs (have to be very careful!)

## Briefly back to file access: ACLs

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- ▶ Mount with option `acl`, for example:  

```
mount -o remount,acl /
```
- ▶ 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"

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- ▶ Grant read and execute rights for members of the group dialout:  
`setfacl -m group:dialout:r-x test.txt`
- ▶ Read and set permissions for test.txt from file test.perm:  
`setfacl -M test.perm test.txt`

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if (access("file", W_OK) != 0) {  
    exit(1);  
}
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fd = open("file", O_WRONLY);  
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- ▶ Attacker attempts to run `symlink("/etc/shadow", "file");` between `access()` and `open()`
- ▶ This is an example for a *race condition*
- ▶ Generally, a *race condition bug* is a bug where software behaviour depends on uncontrollable timing behavior in an unintended way

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- ▶ Details in the “Operating Systems” lecture
- ▶ More extensive example of a race condition later. . .

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- ▶ A system call has some hundred cycles overhead
- ▶ OS still needs control over memory access of processes!

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- ▶ Chop the memory into *pages* of fixed size (typically 4KB)
- ▶ Use a *page table* to establish the mapping
- ▶ Essentially, use a different page table for each process
- ▶ If there is no entry for a virtual address in a processes' page table:  
exit with segmentation fault

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- ▶ Can separate address spaces from different programs!
- ▶ OS can now ensure that one process cannot read/write another processes' memory
- ▶ Hmm, but looking up addresses for each memory access doesn't sound cheaper than a syscall...

# The MMU

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  - ▶ MMU looks up mapping from memory and remembers it in special cache
  - ▶ Page-table cache is called *translation lookaside buffer (TLB)*
- ▶ Need to invalidate TLB content on context switch:
  - ▶ Can flush the whole TLB content
  - ▶ Can mark the content invalid and “re-validate” when the process comes back

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  - ▶ Can request shared memory with `shm_open()` or `shmget()`
  - ▶ Shared-memory resources have access permissions similar to files
  - ▶ The “execute” flag is ignored
  - ▶ For shared memory we’re basically back to file access through syscalls

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- ▶ Virtual memory gives the OS the possibility to *separate memory of different processes*
- ▶ One process (or user) can still provide input to another process
- ▶ Virtual memory does not say anything about what a process is doing with its own memory!

## Reminder: Memory layout

The memory content of a process is *segmented* into:

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- ▶ The heap: (memory allocated by `malloc` and released by `free`)
- ▶ The stack: local data and return addresses
- ▶ Memory mapping segment: files, e.g., dynamic libraries mapped into memory

# Reminder: The stack frame

## Function call

```
void h() {
    int x = 7;
    int a = 6;
    f(42, 123);
    ...
}

void f(int a, int b) {
    char buf[20];
    ...
}
```

## Call stack

```
--- stack frame for h ---
    7
    6
-----
--- stack frame for f ---
    123
    42
    return address to h
    frame pointer to h
    buf[19]
    buf[18]
    ...
    buf[0]
-----
```

## A classic buffer-overflow attack

```
#include <stdio.h>

int vulnfunc(void) {
    char *ret;
    char buffer[100];
    ret = gets(buffer);
    printf(buffer);
    printf("\n");
    fflush(stdout);
    if (ret == NULL) return 0;
    else return 1;
}

int main(void) {
    int ret = 1;
    while (ret) {
        ret = vulnfunc();
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- ▶ `gets()` reads into buffer
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- ▶ Fill buffer with *shell code*
- ▶ Overwrite return address of `vulnfunc()` with address of shell code
- ▶ Can write some nops before shell code (“nop slide”)
- ▶ Program will jump to shell code and launch a shell

## A classic buffer-overflow: the shell code

```
"\x48\x31\xd2" // xor %rdx, %rdx
"\x48\xbb\x2f\x2f\x62\x69\x6e\x2f\x73\x68" // mov $0x68732f6e69622f2f, %rbx
"\x48\xc1\xeb\x08" // shr $0x8, %rbx
"\x53" // push %rbx
"\x48\x89\xe7" // mov %rsp, %rdi
"\x52" // push %rdx
"\x57" // push %rdi
"\x48\x89\xe6" // mov %rsp, %rsi
"\xb0\x3b" // mov $0x3b, %al
"\x0f\x05" // syscall
}
```

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  - ▶ Not really helpful with software today
- ▶ Two steps to the straight-forward attack:
  1. Change program's control flow
  2. Inject and execute attacker's code
- ▶ OS can help to prevent in particular 2
- ▶ Compilers can help to prevent 1 (e.g, stack canaries)
- ▶ Modern operating systems in fact *do* help

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- ▶ Ideally this is implemented in the CPU’s MMU
- ▶ Supported by many recent CPUs (e.g., AMD64, ARM)
- ▶ Various software solutions for CPUs without hardware support
- ▶ Software solutions add overhead to memory access

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  - ▶ Boot parameter `noexec32=off` (for AMD64)

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  - ▶ Boot parameter `noexec=off` (for x86)
  - ▶ Boot parameter `noexec32=off` (for AMD64)
- ▶ Reasons to disable NX protection:
  - ▶ Creating homework for Software and Websecurity
  - ▶ Generally, trying out “classical” attacks
  - ▶ Some programs need executable stack!

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- ▶ Overwrite the return address to point to `system()`
- ▶ For clean exit, set return address of `system` to address of `exit()`

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- ▶ Idea: put suitable arguments for `system()` somewhere in memory (e.g., `"/bin/sh"`)
- ▶ Overwrite the return address to point to `system()`
- ▶ For clean exit, set return address of `system` to address of `exit()`
- ▶ Obtain the address of `libc` with  
`cat /proc/$PID/maps | grep libc`
- ▶ Obtain the offset of `system()` and `exit()` through  
`nm -D /lib/x86_64-linux-gnu/libc.so.6 | grep system`

## Return to libc ctd.

- ▶ Place the string `"/bin/sh"` somewhere and obtain its address
- ▶ Write behind buffer
  1. Address of `system()`
  2. Address of `exit()`
  3. Address of `"/bin/sh"`
- ▶ Address of `system()` must overwrite return address in current frame
- ▶ Code will return to `system()` with
  - ▶ return address pointing to `exit()`, and
  - ▶ argument pointing to `/bin/sh`

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- ▶ Many functions (like `gets`) won't read past the `\0`
- ▶ Does not generally help, can overflow some buffers also with `\0`
- ▶ Can remove some critical functions from (reduced) `libc`
- ▶ Problems:
  - ▶ Can break functionality
  - ▶ What functions exactly can cause problems...?

# ROP

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- ▶ Important concept: can obtain *malicious computation* without *malicious code!*
- ▶ Searching for gadgets (and to some extent chaining) can be automated

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- ▶ Disable ASLR for one process:  
`setarch 'uname -m' -R PROGRAMNAME`

# Attacks against ASLR

- ▶ ASLR is generally very effective as a defense
- ▶ Problem if address of one instruction leaks to the attacker:
  - ▶ Format-string attacks
  - ▶ Using overflows to overwrite null-termination
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  - ▶ Shacham, Page, Pfaff, Goh, Modadugu, Boneh, 2004: brute-force attack that took 216 seconds on average

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  - ▶ Forward the rest to the other side
- ▶ Important to notice: Two processes can write to the same pty
- ▶ Call sequence from userspace program to pty buffer:  
`write(pty_fd)` in userspace → `sys_write()` in kernelspace →  
`tty_write()` → `pty_write()` →  
`tty_insert_flip_string_fixed_flag()`

## The vulnerable code

```
int tty_insert_flip_string_fixed_flag(struct tty_struct *tty,
                                     const unsigned char *chars,
                                     char flag, size_t size)
{
    int copied = 0;
    do {
        int goal = min_t(size_t, size - copied, TTY_BUFFER_PAGE);
        int space = tty_buffer_request_room(tty, goal);
        struct tty_buffer *tb = tty->buf.tail;
        if (unlikely(space == 0))
            break;
        memcpy(tb->char_buf_ptr + tb->used, chars, space);
        memset(tb->flag_buf_ptr + tb->used, flag, space);
        tb->used += space;
        copied += space; chars += space;
    } while (unlikely(size > copied));
    return copied;
}
```

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Process A

Process B

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- ▶ `memcpy(buf+tb->used, ...)`
- ▶ `tb->used += space;`

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- ▶ `memcpy(s)` of A fill the buffer(s) and increase used
- ▶ `memcpy(s)` of B will write behind the buffer
- ▶ Local-root exploit needs some more bits and pieces, for details see <http://blog.includesecurity.com/2014/06/exploit-walkthrough-cve-2014-0196-pty-kernel-race-condition.html>