Hacking in C

Attacks, part III

Radboud University, Nijmegen, The Netherlands

Spring 2018

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  - Return to other **existing code**
  - Return to code **that we inject** $\leftarrow$ last week

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- Idea:
  - Somehow prepare arguments for `system()`
  - overwrite return address with address of `system()`
- Obtain the address of `libc` with
  `cat /proc/$PID/maps | grep libc`
- Obtain the offset of `system()` through

```
nm -D /lib/x86_64-linux-gnu/libc.so.6 | grep system
```

Preparing arguments

```
int system(const char *command);
```

- Target: first argument to `system()` should be address of `"/bin/sh"`
- Can write `"/bin/sh"` somewhere
- Alternative: find `"/bin/sh"` somewhere in the binary or libraries
- Then obtain address of `"/bin/sh"`

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  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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  - `retq` will return into `system()`
- ROP-technique generalizes this (later)

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- Can remove some critical functions from (reduced) libc
- Problems:
  - Can break functionality
  - What functions exactly can cause problems. . . ?

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

ROP: Example

vulnfunc()

```
...
retq
```

0xfeedface

```
...
xor %rax, %rax
retq
```

0xcafebabe

```
...
pop %rdi
retq
```

0xdeadbeef

```
...
mov %rdx, %rax
pop %rsi
retq
```

(corrupted) stack

0x7f1229d0f4a0 (execlp)
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registers

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Will now jump to `execlp` with arguments in `rdi`, `rsi`, `rdx`
i.e. `execlp("/bin/sh", "/bin/sh", NULL);`

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

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  - Shacham, Page, Pfaff, Goh, Modadugu, Boneh, 2004: brute-force attack that took 216 seconds on average

Spot the defect – Heartbleed

```
/* Process incoming message with the format
| hbtype | len | payload[0] .... payload [len-1] |
one byte two bytes len bytes payload */
unsigned char *p; // pointer to the incoming message
unsigned int len; // called payload in the original code
unsigned short hbtype;
hbtype = *p++;
 // Puts *p into hbtype
n2s(p, len);
 // Takes two bytes from p, and puts them in len
// This is the length of the payload
unsigned char* buffer = malloc(1 + 2 + len);
/* Enter response type, length and copy payload */
buffer++ = TLS1_HB_RESPONSE;
s2n(len, buffer);
 // takes 16-bit value len and puts it into two bytes
memcpy(buffer, p, len); // copy len bytes from p into buffer
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/* Enter response type, length and copy payload */
buffer++ = TLS1_HB_RESPONSE;
s2n(len, buffer);
 // takes 16-bit value len and puts it into two bytes
memcpy(buffer, p, len); // copy len bytes from p into buffer
```

↖ Possible uninitialized data read

Spot the defect – Cloudbleed

```
// char* p is a pointer to a buffer containing the
//         incoming messages to be processed
// char* end is a pointer to the end of this buffer
....
// code inspecting *p, which increases p
....
if ( ++p == end ) goto _test_eof;
```

More secure code

```
....
if ( ++p >= end ) goto _test_eof;
```

How common are these problems?

Look at websites such as

- https://www.us-cert.gov/ncas/bulletins
- http://cve.mitre.org/
- http://www.securityfocus.com/vulnerabilities

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Vulnerability descriptions that mention

- 'buffer'
- 'boundary condition error'
- 'lets remote users execute arbitrary code'
- or simply 'remote security vulnerability'

are often caused by buffer overflows. Some sites use the CWE (Common Weakness Enumeration) to classify vulnerabilities.

CWE classification

The CWE (Common Weakness Enumeration) provides a standardised classfication of security vulnerabilities https://cwe.mitre.org/ NB the classification is long (over 800 classes!) and confusing! Eg

- CWE-118 ... CWE-129, CWE-680, and CWE 787 are buffer errors
- CWE-822 ... CWE-835 and CWE-465 are pointer errors
- CWE-872 are integer-related issues

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- CWE-118 ... CWE-129, CWE-680, and CWE 787 are buffer errors
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- CWE-872 are integer-related issues

Have a look at

- `https://cwe.mitre.org/data/definitions/787.html` - buffer issues
- `https://cwe.mitre.org/data/definitions/465.html` - pointer issues
- `https://cwe.mitre.org/data/definitions/872.html` - integer issuess

Example vulnerable code

```
void m() {
  int x = 4;
  f(); // return_to_m
  printf ("x is %d", x);
}

void f() {
  int y = 7;
  g(); // return_to_f
  printf ("y+10 is %d", y+10);
}

void g() {
  char buf[80];
  gets(buf);    ← potential overflow of buf
  printf(buf);  ← potential format string attack
  gets(buf);    ← potential overflow of buf
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  char buf[80];
  gets(buf);      ← potential overflow of buf
  printf(buf);    ← potential format string attack
  gets(buf);      ← potential overflow of buf
}
```

An attacker could

1. first inspect the stack using a malicious format string (entered in first gets and printed with `printf`)
2. then overflow buf to corrupt the stack (with the second `gets`)

Example vulnerable code

```
void m() {
  int x = 4;
  f(); // return_to_m
  printf ("x is %d", x);
}

void f() {
  int y = 7;
  g(); // return_to_f
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void g() {
  char buf[80];
  gets(buf);
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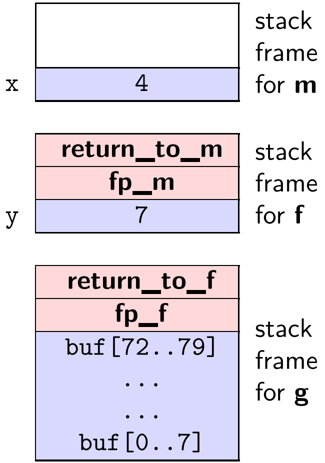


Normal execution

- After completing **g**

  execution continues with **f** from program point **return_to_f**

  This will print 17.

Normal execution

- After completing **g**

  execution continues with **f** from program point **return_to_f**

  This will print 17.
- After completing **f**

  execution continues with **main** from program point **return_to_m**

  This will print 4.

Normal execution

- After completing **g**

  execution continues with **f** from program point **return_to_f**

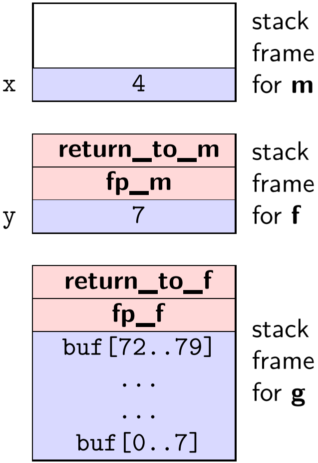
  This will print 17.
- After completing **f**

  execution continues with **main** from program point **return_to_m**

  This will print 4.

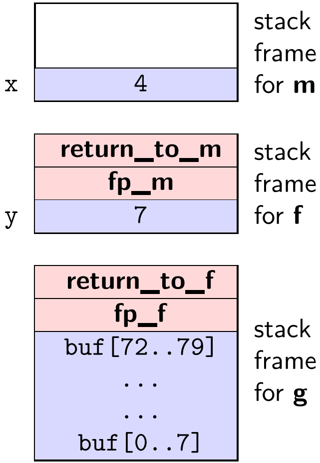
If we start smashing the stack different things can happen

Attack scenario 1



in **g()** we overflow **buf** to overwrite values of **x** or **y**.

Attack scenario 1



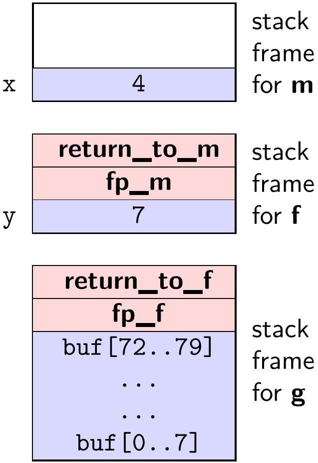
in **g()** we overflow **buf** to overwrite values of **x** or **y**.

- After completing **g**

  execution continues with **f** from program point **return_to_f**

  This will print whatever value we gave to **y** $+10$.

Attack scenario 1



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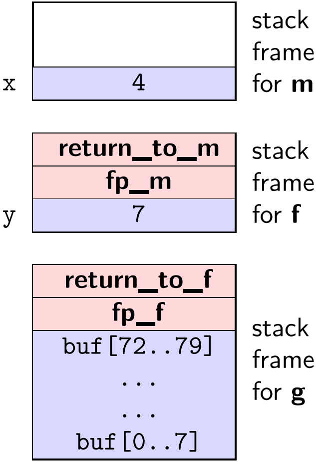

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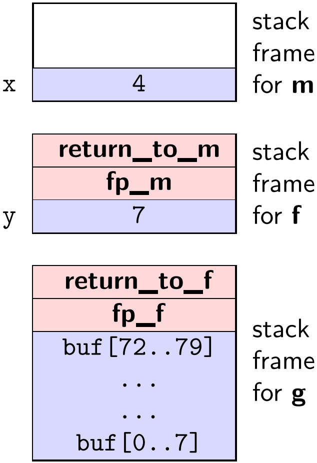
- After completing **f**

  execution continues with **main** from program point **return_to_m**

  This will print whatever value we gave to **x**.

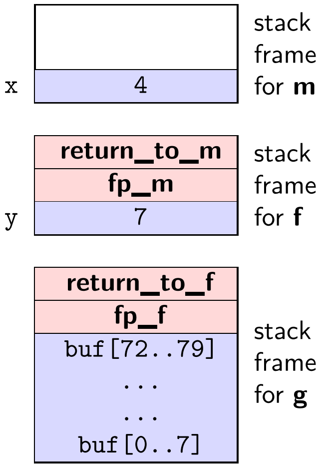
Of course, it is easier to overwrite local variables in the current frame than variables in 'lower' frames

Attack scenario 2



in **g()** we overflow **buf** to overwrite return address **return_to_f** with **return_to_m**

Attack scenario 2



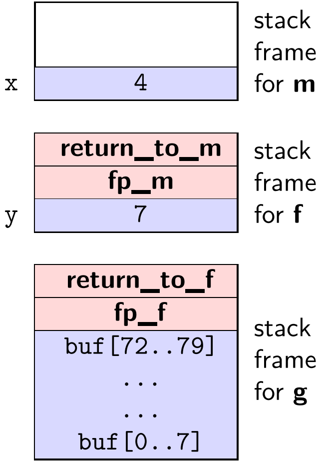
in **g()** we overflow **buf** to overwrite return address **return_to_f** with **return_to_m**

- After completing **g**

  execution continues with **m** instead of **f** but with **f**'s stack frame.

  This will print 7.

Attack scenario 2



in **g()** we overflow **buf** to overwrite return address **return_to_f** with **return_to_m**

- After completing **g**

  execution continues with **m** instead of **f** but with **f**'s stack frame.

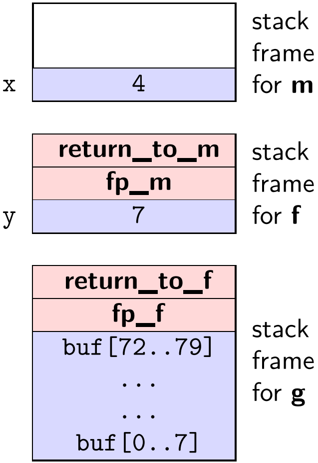
  This will print 7.

- After completing **m**

  execution continues with **m**

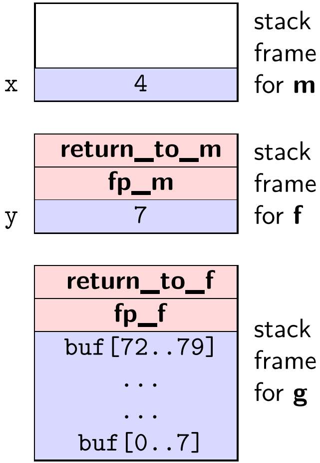
  This will print 4;

Attack scenario 3



in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_m**.

Attack scenario 3



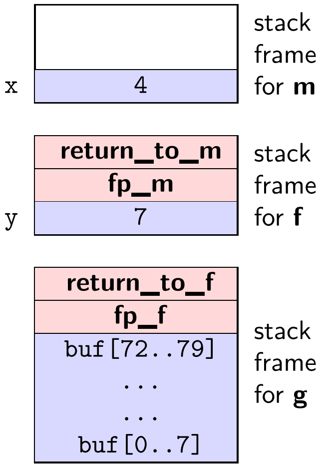
in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_m**.

- After completing **g**

  execution continues with **f** but with **m**'s stack frame.

  This will print 14.

Attack scenario 3



in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_m**.

- After completing **g**

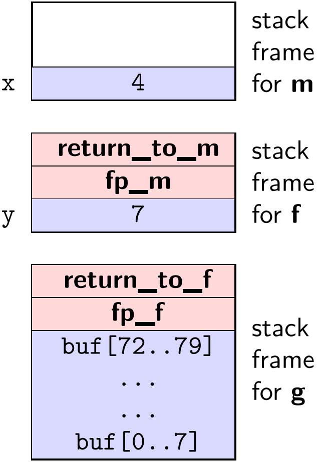
  execution continues with **f** but with **m**'s stack frame.

  This will print 14.

- After completing **f**

  execution continues with whatever code called **m**.

Attack scenario 3



in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_m**.

- After completing **g**

  execution continues with **f** but with **m**'s stack frame.

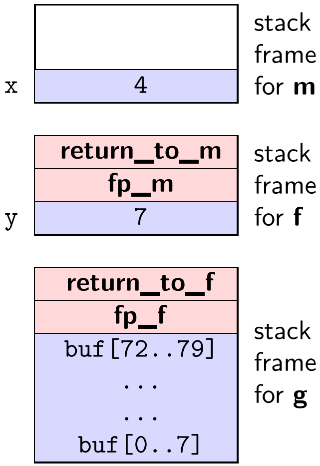
  This will print 14.

- After completing **f**

  execution continues with whatever code called **m**.

So we never finish the function call **m**, the remaining part of the code (after the call to **f**) will never be executed.

Attack scenario 4



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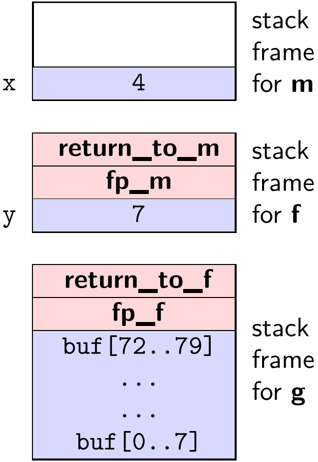


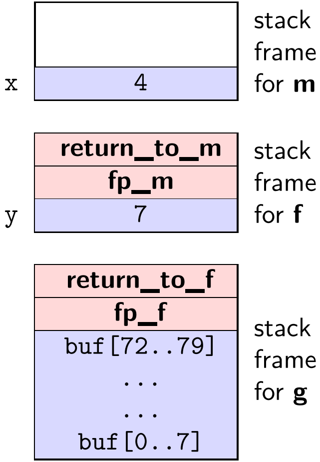
in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_g**.

- After completing **g**

  execution continues with **f**
  but with **g**'s stack frame.

  This will print (some bytes of **buf** +10).

Attack scenario 4



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- After completing **g**

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- After completing **f**

  execution might continue with **f**, again with **g**'s stack frame, repeating this forever.

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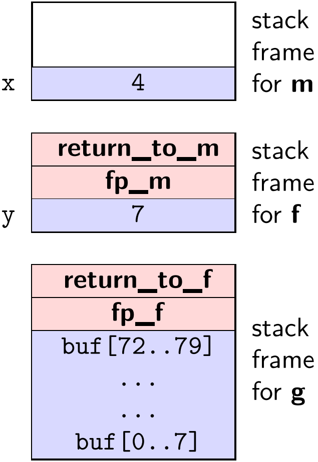


in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with **fp_g**.

- After completing **g**

  execution continues with **f** but with **g**'s stack frame.

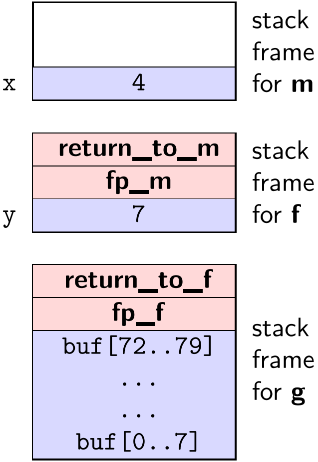
  This will print (some bytes of **buf** +10).

- After completing **f**

  execution might continue with **f**, again with **g**'s stack frame, repeating this forever.

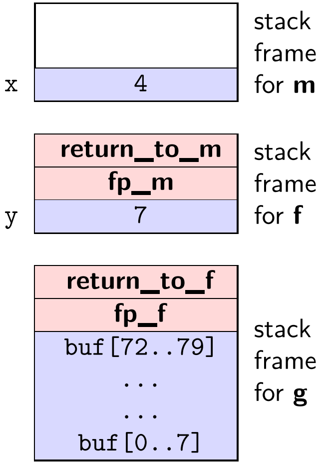
This depends on whether the compiled code looks up values from the top of **g**'s stack frame, or the bottom of **g**'s stack frame. In the latter case the code will jump to some code depending on the contents of **buf**.

Attack scenario 5



in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with some pointer into **buf**.

Attack scenario 5



in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with some pointer into **buf**.

- After completing **g**

  execution continues with **f**
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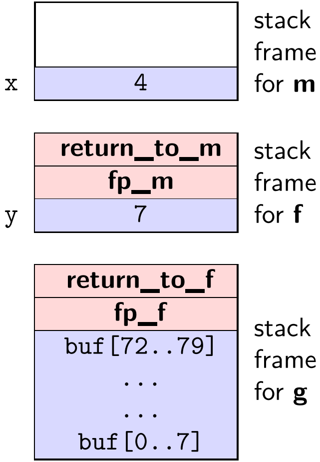

in **g()** we overflow **buf** to overwrite frame pointer **fp_f** with some pointer into **buf**.

- After completing **g**

  execution continues with **f**
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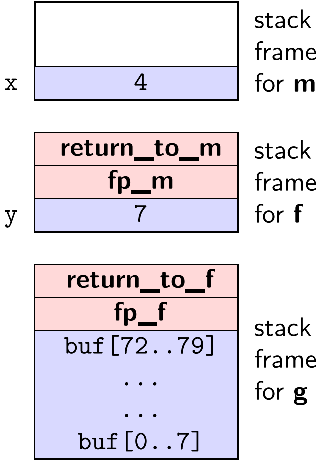
  This will print (some bytes of **buf** +10).

- After completing **f**

  execution continues with an address and frame pointer taken from **buf**

Attack scenario 6



in **g()** we overflow **buf** to overwrite the return address **return_to_f** to point in some code somewhere, and the framepointer to point inside **buf**.

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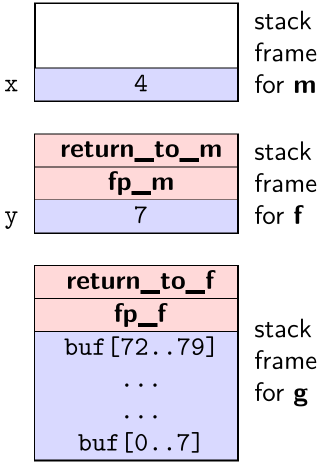

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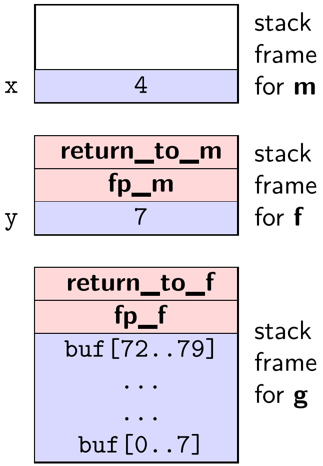
  execution continues executing that code using part of **buf** as stack frame.

  This can do all sorts of things!
  If we have enough code to choose from, this can do anything we want.

Attack scenario 6



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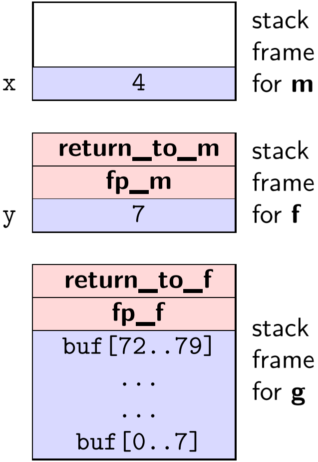
Often the address of a function in libc is used, in what is called a return-to-libc attack.

Attack scenario 7



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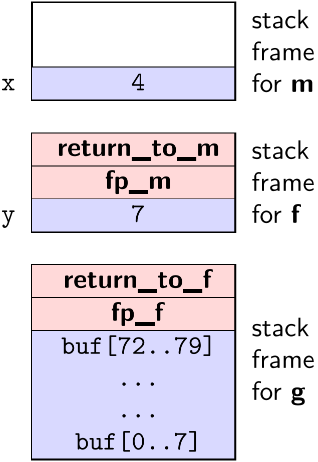

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- After completing **g**

  execution continues with whatever code (aka shell code) was written in **buf**, using **f**'s stack frame. This can do anything we want.

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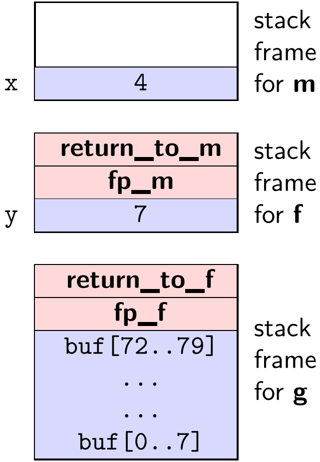

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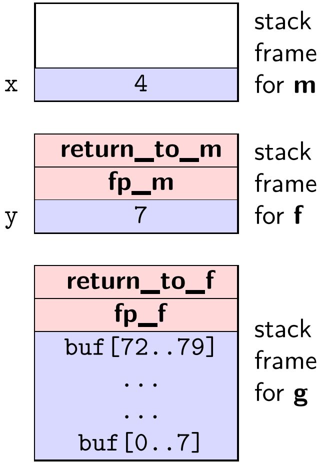

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This is the classic buffer overflow attack discussed last week

- The attack requires that the computer (OS + hardware) can be tricked into executing data allocated on the stack. Many systems will no longer execute data (code) on the stack or on the heap (last week).