CSCI 335
Systems II

Lab 3: Attack Lab

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Agenda

Stack review

Attack lab overview

- **Phases 1-3: Buffer overflow attacks**
- **Phases 4-5: ROP attacks *(Return Oriented Programming)***

x86-64: Register Conventions

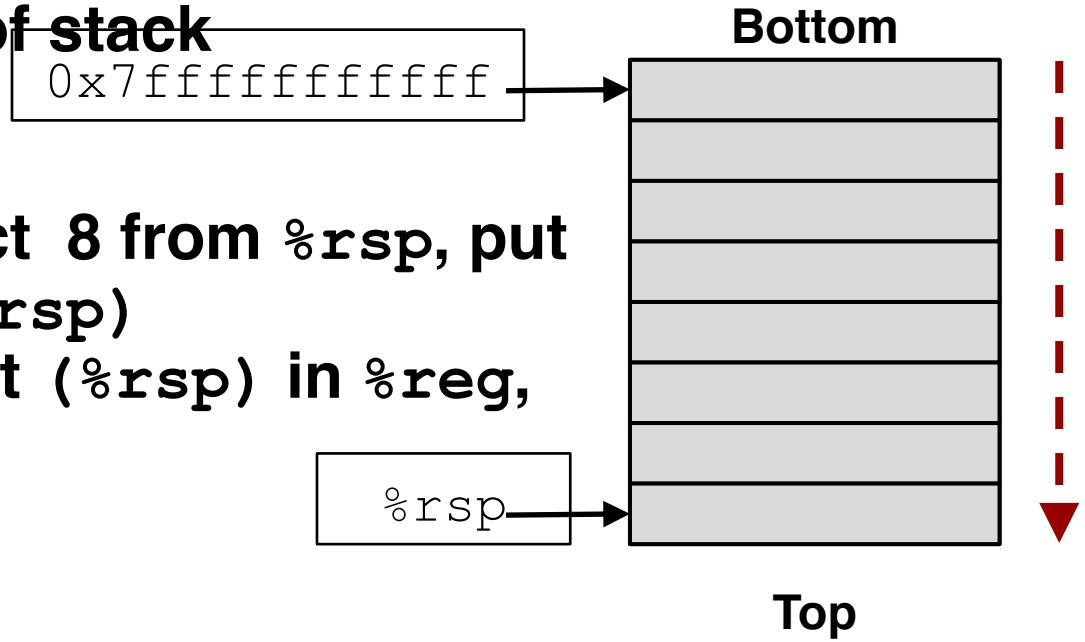
- **Arguments passed in registers:**
  `%rdi, %rsi, %rdx, %rcx, %r8, %r9`
- **Return value:** `%rax`
- **Callee-saved:** `%rbx, %r12, %r13, %r14, %rbp, %rsp`

Caller-saved: `%rdi, %rsi, %rdx, %rcx, %r8, %r9, %rax, %r10, %r11`

- **Stack pointer:** `%rsp`
- **Instruction pointer:** `%rip`

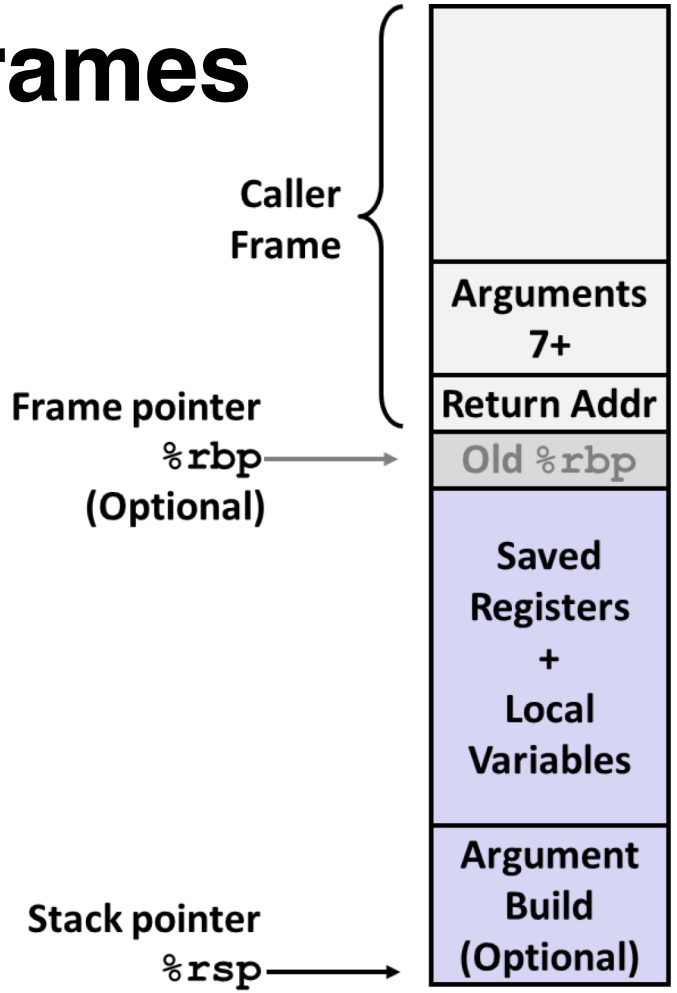
x86-64: The Stack

- Grows downward towards lower memory addresses
- `%rsp` points to top of stack
- `push %reg`: subtract 8 from `%rsp`, put val in `%reg` at `(%rsp)`
- `pop %reg`: put val at `(%rsp)` in `%reg`, add 8 to `%rsp`



x86-64: Stack Frames

- Every function call has its own stack frame.
- Think of a frame as a workspace for each call.
  - Local variables
  - Callee & Caller-saved registers
  - Optional arguments for a function call



x86-64: Function Call Setup

Caller:

Allocates stack frame large enough for saved registers, optional arguments

- **Save any caller-saved registers in frame**
- **Save any optional arguments (in reverse order) in frame**
- **`call foo`: push `%rip` to stack, jump to label `foo`**

Callee:

Push any callee-saved registers, decrease `%rsp` to make room for new frame

x86-64: Function Call Return

Callee:

Increase `%rsp`, pop any callee-saved registers (in reverse order), execute `ret: pop %rip`

Attack Lab Overview: Phases 1-3

Overview

- Exploit x86-64 by overwriting the stack
- Overflow a buffer, overwrite return address
- Execute injected code

Key Advice

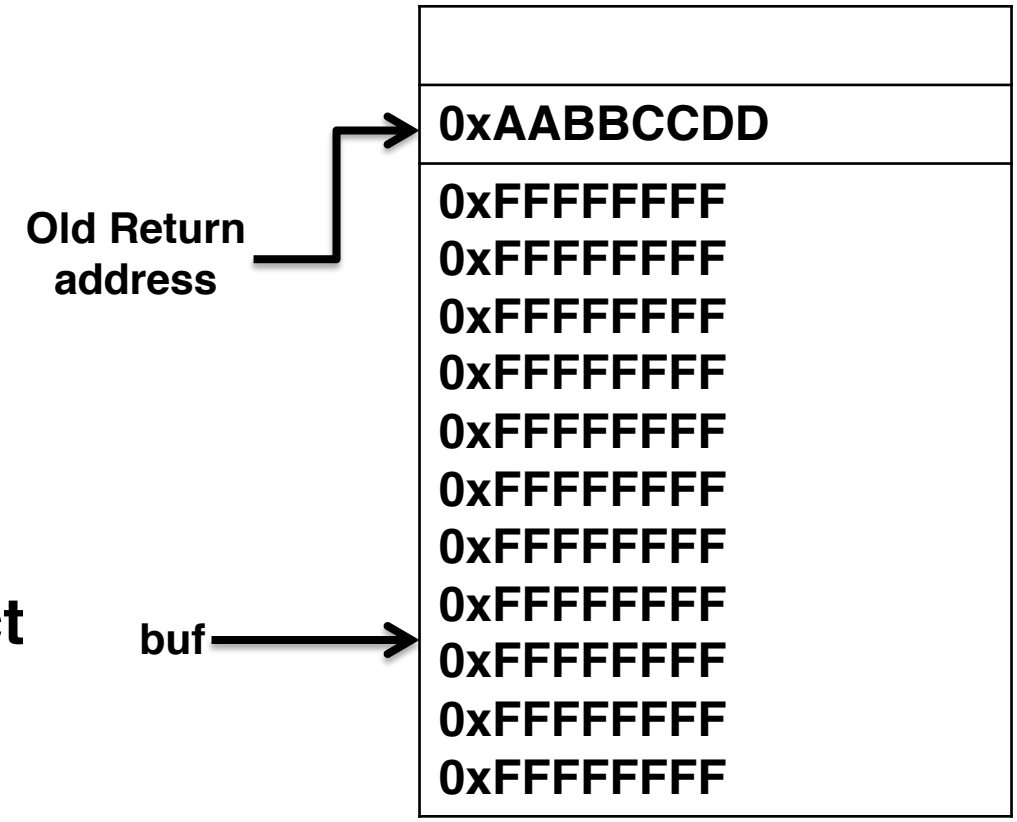
- Brush up on your x86-64 conventions!
- Use objdump –d to determine relevant offsets
- Use GDB to determine stack addresses

Buffer Overflows

- Exploit *strcpy vulnerability* to overwrite important info on stack
- When this function returns, where will it begin executing?
  - Recall

```
ret:pop %rip
```

- What if we want to inject new code to execute?



Demonstration: Generating Byte Codes

- Use gcc and objdump to generate byte codes for assembly instruction sequences

Attack Lab Overview: Phases 4-5

Overview

Utilize return-oriented programming to execute arbitrary code

- **Useful when stack is non-executable or randomized**

Find gadgets, string together to form injected code

Key Advice

Use mixture of pop & mov instructions + constants to perform specific task

ROP Example

Draw a stack diagram and ROP exploit to pop a value 0xBBBBBBBB into %rbx and move it into %rax

```
void foo(char *input){
   char buf[32];
   ...
   strcpy (buf, input);
   return;
}
```

Gadgets:

address$_1$: mov %rbx, %rax; ret

address$_2$: pop %rbx; ret

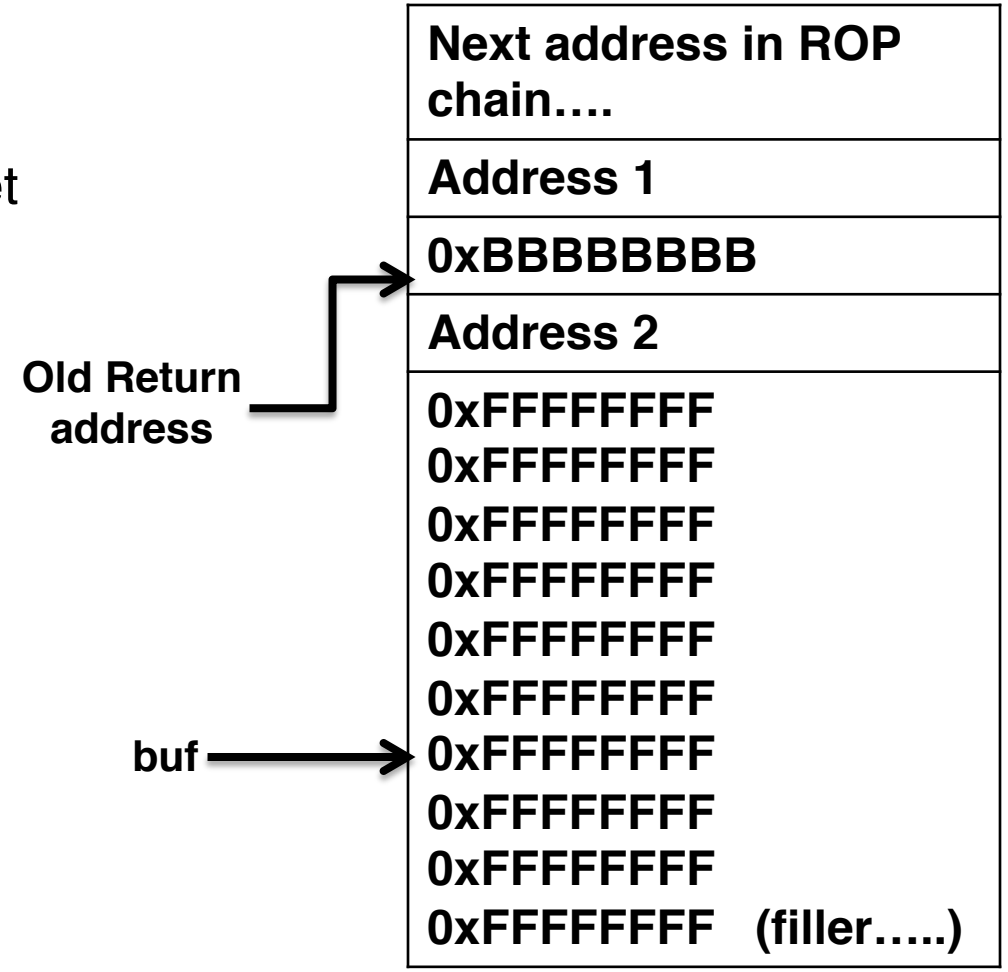
ROP Example: Solution

Gadgets:

Address 1: mov %rbx, %rax; ret

Address 2: pop %rbx; ret

```
void foo(char *input){
   char buf[32];
   ...
   strcpy (buf, input);
   return;
}
```



ROP Demonstration: Looking for Gadgets

How to identify useful gadgets in your code

Tools

objdump –d

- View byte code and assembly instructions, determine stack offsets

./hex2raw

- Pass raw ASCII strings to targets

gdb

- Step through execution, determine stack addresses

gcc –c

- Generate object file from assembly language file

More Tips

- Draw stack diagrams
- Be careful of byte ordering (little endian)