Computer Security

03. Program Hijacking

Paul Krzyzanowski

Rutgers University

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Bugs and mistakes

- Most penetrations are due to
  - Social engineering
  - Or bugs
- Attacked system may be further weakened because of poor access control rules
  - Violate principle of least privilege
- Cryptography won't help us!
  - And cryptographic software can also be buggy … and often is

Assumptions can get you in trouble

- Unchecked assumptions can lead to vulnerabilities
- Attack:
  - Discover assumptions
  - Craft an exploit to render them invalid
- Two common assumptions
  - Buffer is large enough for the data
  - Integer overflow doesn't exist

November 5, 1988

"All the News That's Fit to Print"

The New York Times

Late Edition

VOL. CXXXVIII . . . No. 47,680 NEW YORK, SATURDAY, NOVEMBER 5, 1988 35 CENTS

Author of Computer 'Virus' Is Son Of N.S.A. Expert on Data Security

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Crucial Computer Networks Said to Be Impenetrable

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POLAND IS BUYING 3 BOEING AIRLINERS FOR $220 MILLION

EAST BLOC ORDER A FIRST

Sale to Be Financed Through a Lease-Purchase Accord With Western Banks

By AGIS SALPUKAS

MOSCOW SUSPENDS PULLOUT OF ITS AFGHANISTAN FORCES; CHARGES VIOLATIONS OF PACT

U.S. Expresses Disappointment

Aleksandr A. Bessmertnykh, a Soviet Deputy Foreign Minister, announced suspension of troop withdrawal from Afghanistan.

BETTER ARMS SENT

Soviets Hint at a Delay Past Feb. 15 Deadline for Full Withdrawal

By PHILIP TAUBMAN

Unemployment Declines to 5.2%, Matching Lowest Rate Since '74

By ROBERT D. HERSHEY Jr.

Hailed by Big Crowds, Dukakis Foresees an Upset

A large, vocal crowd greeted Michael S. Dukakis in Queens, often forcing him to pause in his speech.

By JOSEPH FINDER

Met Opera Manager, In a Surprise Move, Is Quitting His Post

By JOHN ROCKWELL

Study Says Immigration Law Is Leading to Discrimination

By MARVINE HOWE

INSIDE

English Cathedral Restored

Soviet Space Effort Faulted

Atlanta Editor Resigns

Author of Computer 'Virus' Is Son Of N.S.A. Expert on Data Security

Cornell Graduate Student Described as 'Brilliant'

By JOHN MARKOFF

The "virus" program that has plagued many of the nation's computer networks since Wednesday night was created by a computer science student who is the son of one of the Government's most respected computer security experts.

The program writer, Robert T. Morris Jr., a 23-year-old graduate student at Cornell University whom friends describe as "brilliant," devised the set of computer instructions as an experiment, three sources with detailed knowledge of the case have told The New York Times.

The program was intended to live innocently and undetected in the Arpanet, the Department of Defense computer network in which it was first introduced, and secretly and slowly make copies that would move from computer to computer. But a design error caused it instead to replicate madly out of control, ultimately jamming more than 6,000 computers nationwide in this country's most serious computer "virus" attack.

The dent's program jammed the computers of corporate research centers including the Rand Corporation and SRI International, universities like the University of California at Berkeley and the Massachusetts Institute of Technology as well as military research centers and bases all over the United States.

Meeting with the Authorities

The virus's creator could not be reached for comment yesterday. The sources said the student flew to Washington yesterday and is planning to hire a lawyer and meet with officials of the Defense Communications Agency, in charge of the Arpanet network.

Friends of the student said he did not intend to cause damage. They said he created the virus as an intellectual challenge to explore the security of computer systems.

His father, Robert T. Morris Sr., has written widely on the security of the Unix operating system, the computer master program that was the target of the son's virus program. He is now chief scientist at the National Computer Security Center in Bethesda, Md., the arm of the National Security Agency devoted to protecting comput-

'VIRUS' ELIMINATED, DEFENSE AIDES SAY

Crucial Computer Networks Said to Be Impenetrable

By MICHAEL WINES

Special to The New York Times

WASHINGTON, Nov. 4 — Defense Department officials said today that they had eliminated an electronic

POLAND IS BUYING 3 BOEING AIRLINERS FOR $220 MILLION

EAST BLOC ORDER A FIRST

Sale to Be Financed Through a Lease-Purchase Accord With Western Banks

By AGIS SALPUKAS

The Boeing Company received an order yesterday from the national airline of Poland, the first order for advanced American aircraft from an Eastern bloc country.

The order from the LOT airline is for three 767 wide-bodied aircraft and is worth about $220 million. The transacton is to be financed through a lease-purchase agreement with Western banks, under which the airline will own the planes after 12 years.

Airline officials, at a news conference at the Polish Consulate in New York yesterday, would not identify the Western banks involved in the transaction.

The airline is state-owned and Poland's troubled economy is deeply in debt. But the new planes will bring the carrier significant savings on fuel, and the modern, more spacious aircraft could attract more bookings from Western travelers.

Planes Can Be Repossessed

The banks are apparently relying on

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But Adminis nevertheless d Moscow's stat Soviet Union s here to the acc for the troop w complete by Fe

Article

Unempl Match

Robert Tappan Morris Jr.'s Internet Worm

Attacked VAX computers running BSD

1. Attempt to crack local passwords
   - Guess passwords via dictionary attack
   - 432 common passwords and combinations of account name and user name
2. Look for readable .rhost files – that may give you free rsh access to another system
3. Do a buffer overflow exploit on *fingerd* via *gets* to load a small program
   - 99 lines of C
   - Program connects to sender and downloads the full worm
4. Use the DEBUG command of *sendmail*
   - Allowed remote command execution on a remote system

Then propogate the program onto any system you can log into

Buffer Overflows

Some high-profile buffer overflow attacks

- 2001: Code Red worm
  - Buffer overflow attack on Microsoft's IIS
- 2003: SQL Slammer
  - Buffer overflow attack on Microsoft's SQL Server
- 2003: X-Box attack
  - Buffer overflow attack bypasses license checking
- 2010: PS2 Independence exploit
  - Buffer overflow attack bypasses license checking

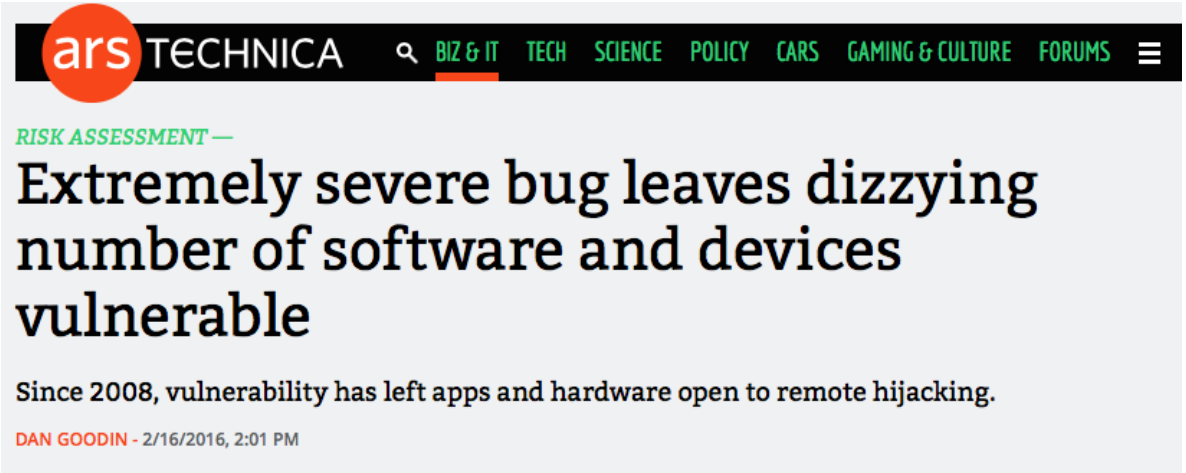
March 2013

http://blog.klocwork.com/software-security/buffer-overflows-are-the-top-software-security-vulnerability-of-the-past-25-years/

Buffer overflows

- Buffer overflows used to be responsible for up to ~50% of vulnerabilities
- We know how to defend ourselves but
  - Average time to patch a bug >> 1 year
  - People delay updating systems … or refuse to
  - Embedded systems often never get patched
    - Routers, set-top boxes, access points, phone switches
  - Insecure access rights often help with getting more privileges
  - We will continue to write buggy code!

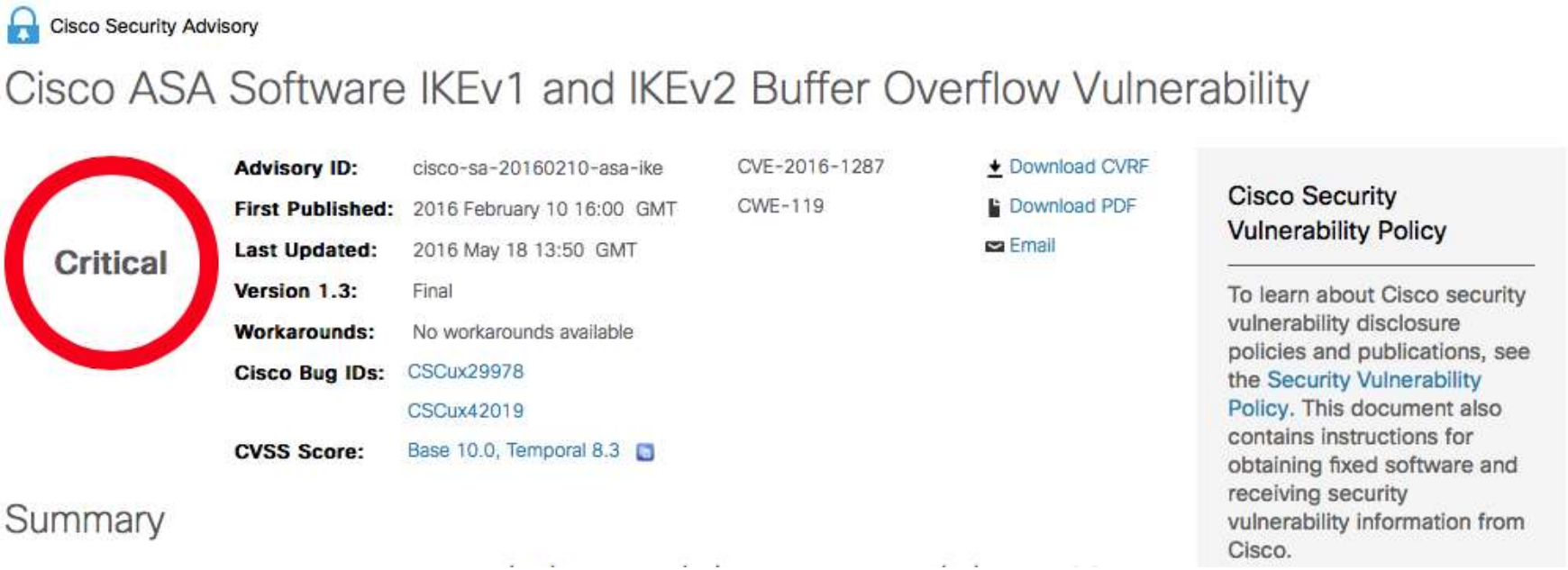
Still with us



A function known as getaddrinfo() that performs domain-name lookups contains a buffer overflow bug that allows attackers to remotely execute malicious code. It can be exploited when vulnerable devices or apps make queries to attacker-controlled domain names or domain name servers or when they're exposed to man-in-the-middle attacks where the adversary has the ability to monitor and manipulate data passing between a vulnerable device and the open Internet. All versions of glibc after 2.9 are vulnerable.

https://arstechnica.com/security/2016/02/extremely-severe-bug-leaves-dizzying-number-of-apps-and-devices-vulnerable/

Still with us



Cisco Security Advisory

Cisco ASA Software IKEv1 and IKEv2 Buffer Overflow Vulnerability

Critical

Advisory ID: cisco-sa-20160210-asa-ike
First Published: 2016 February 10 16:00 GMT
Last Updated: 2016 May 18 13:50 GMT
Version 1.3: Final
Workarounds: No workarounds available
Cisco Bug IDs: CSCux29978, CSCux42019
CVSS Score: Base 10.0, Temporal 8.3

CVE-2016-1287
CWE-119

Download CVRF
Download PDF
Email

Summary

Cisco Security Vulnerability Policy

To learn about Cisco security vulnerability disclosure policies and publications, see the Security Vulnerability Policy. This document also contains instructions for obtaining fixed software and receiving security vulnerability information from Cisco.

What is a buffer overflow?

- Programming error that allows more data to be stored in an array than there is space
- Buffer = stack, heap, static data
- Overflow means…
  - Adjacent memory will be overwritten
  - Program data can be corrupted
  - New code can be injected
  - Unexpected transfer of control can be launched

The classic buffer overflow bug

gets.c from OS X: © 1990,1992 The Regents of the University of California.

```
gets(buf)
char *buf;
   register char *s;
   static int warned;
   static char w[] = "warning: this program uses gets(), which is unsafe.\r\n";

   if (!warned) {
      (void) write(STDERR_FILENO, w, sizeof(w) - 1);
      warned = 1;
   }
   for (s = buf; (c = getchar()) != '\n';)
      if (c == EOF)
           if (s == buf)
                return (NULL);
           else
                break;
      else
           *s++ = c;
   *s = 0;
   return (buf);
}
```

Buffer overflow examples

```
void test(void) {
    char name[10];

    strcpy(name, “krzyzanowski”);
}
```

That’s easy to spot!

Another example

How about this?

```
char configfile[256];
char *base = getenv("BASEDIR");

if (base != NULL)
    sprintf(configfile, "%s/config.txt", base);
else {
    fprintf(stderr, "BASEDIR not set\n");
}
```

Yet another example

Classic

```
char line[80];
while (gets(line) != NULL) {

    /* process a line of input */

}
```

You might not notice

You made unchecked assumptions on the maximum password length

```
char passwd1[80], passwd2[80];

printf("Enter password: ");
gets(passwd1);
printf("Enter password again: ");
gets(passwd2);
if (strcmp(passwd1, passwd2) != 0) {
    fprintf(stderr, "passwords don't match\n");
    exit(1);
}
...
```

Buffer overflow attacks

To exploit a buffer overflow

- Identify overflow vulnerability in a program
  - Inspect source
  - Trace execution
  - Use fuzzing tools (more on that …)

- Understand where the buffer is in memory and whether there is potential for corrupting surrounding data

What's the harm?

- Execute arbitrary code, such as starting a shell
  - *Code injection*, *stack smashing*
- Code runs with the privileges of the program
  - If the program is *setuid root* then you have root privileges
  - If the program is on a server, you can run code on that server
- Even if you cannot execute code…
  - You may crash the program
  - Denial of service attack
- Sometimes the crashed code can leave a core dump
  - You can access that and grab data the program had in memory

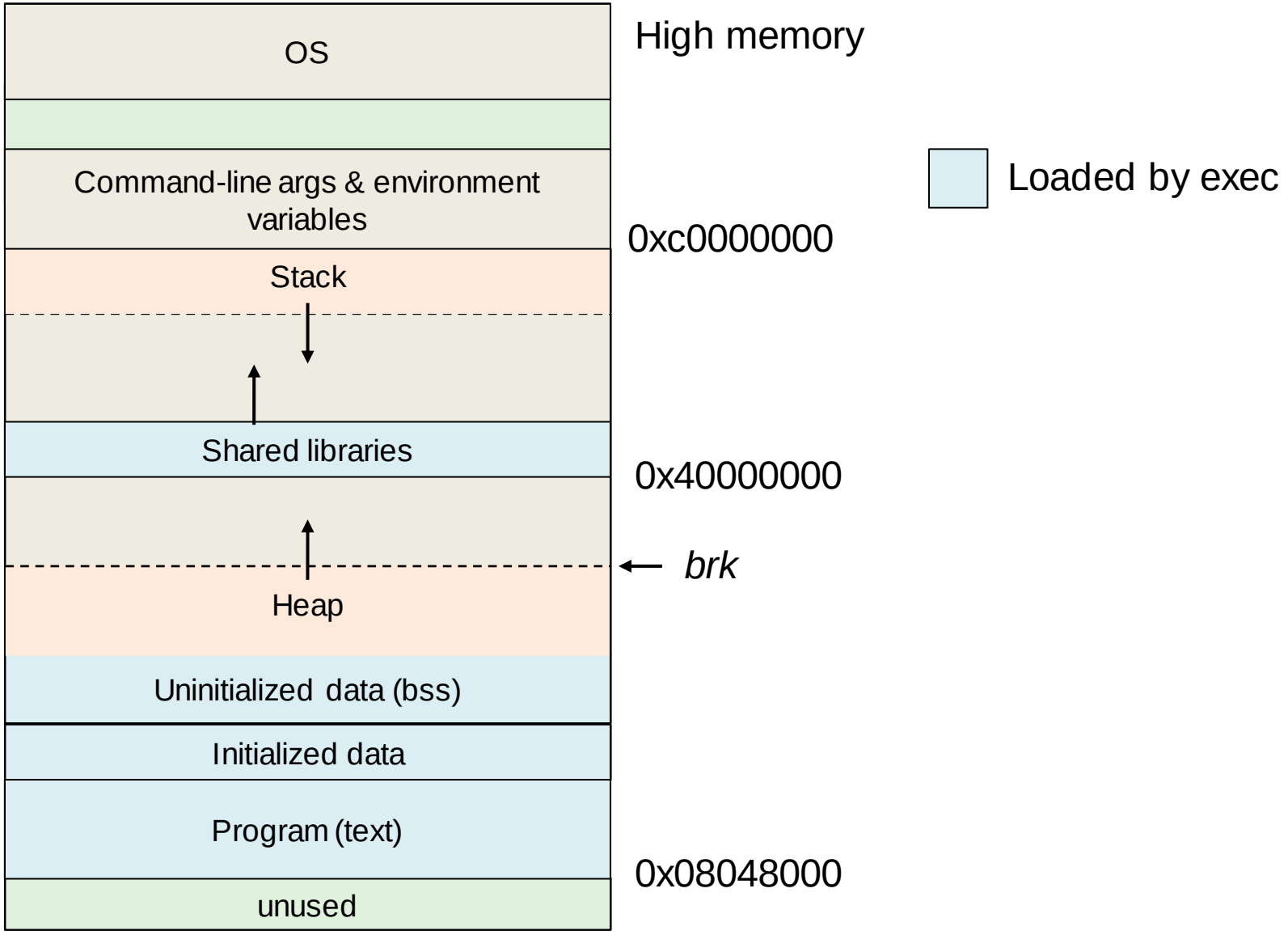
It's a bounds checking problem

- C and C++
  - Allow direct access to memory
  - Do not check array bounds
  - Functions often do not know array bounds
    - They just get passed a pointer to the start of the structure
- This is not a problem with strongly typed languages
  - Java, C#, Python, etc. check sizes of structures
- But C is in the top 3 of popular programming languages
  - Dominant for system programming & embedded systems

Programming at the machine level

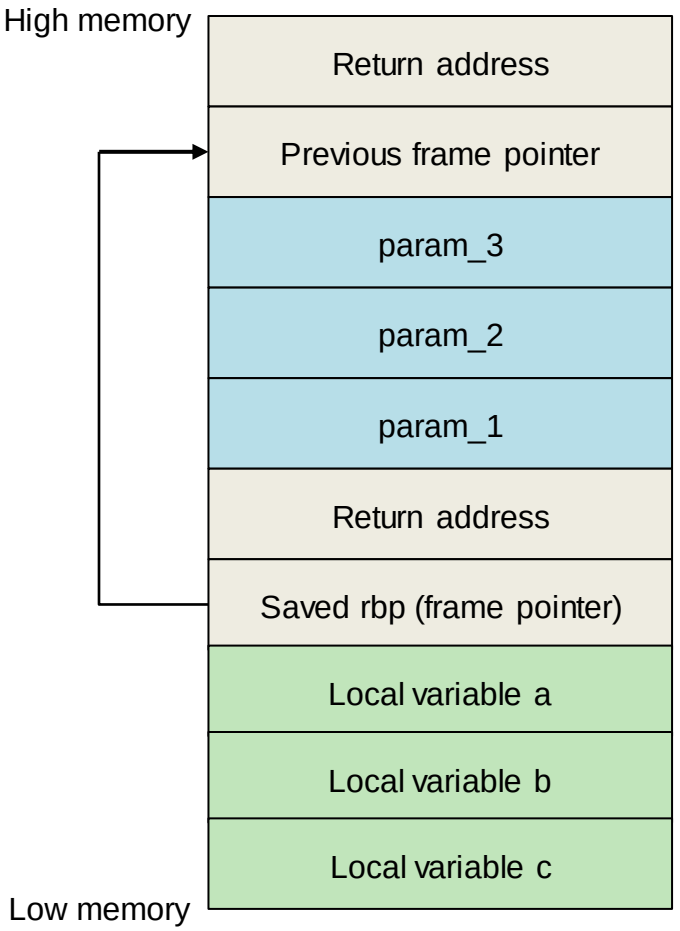
- High level languages (even C) constrain you in
  - Access to variables (local vs. global)
  - Control flows in predictable ways
    - Loops, function entry/exit, exceptions
- At the machine code level
  - No restriction on where you can jump
    - Jump to the middle of a function … or to the middle of a C statement
    - Returns will go to whatever address is on the stack
    - Unused code can be executed (e.g., library functions you don't use)

Linux process memory map



Stack overflows

The stack



rbp (current base pointer)

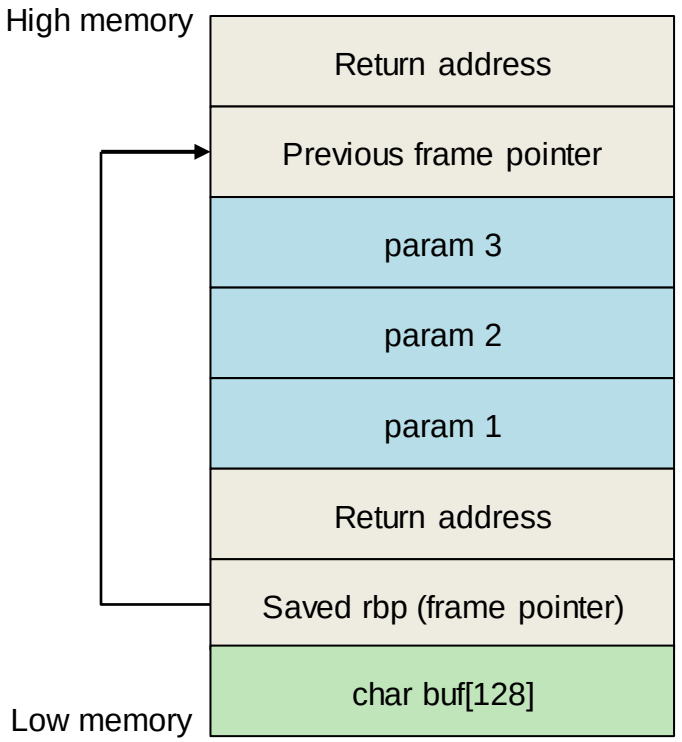
rsp (current stack pointer)

```
func(param_1, param_2, param_3)

        pushl param_3
        pushl param_2
        pushl param_1
        call func
        . . .

func:   pushl rbp
        movl %rsp, %rbp
        subl $20, %rsp
        . . .
```

Causing overflow

- Overflows can occur when programs do not validate the length of data being written to a buffer
- This could be in your code or one of several “unsafe” libraries
  - strcpy(char *dest, const char *src);
  - strcat(char *dest, const char *src);
  - gets(char *s);
  - scanf(const char *format, …)
  - Others…

Overflowing the buffer



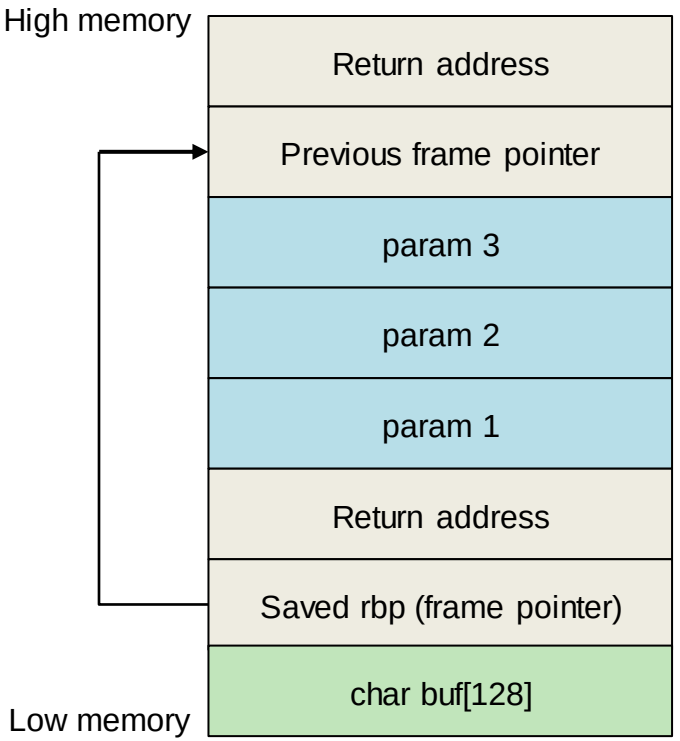

```
void func(char *s) {
    char buf[128];

    strcpy(buf, s);
    /* ... */
}
```

rbp (current base pointer)

rsp (current stack pointer)

What if s is >128 bytes?

Overflowing the buffer




```
void func(char *s) {
    char buf[128];

    strcpy(buf, s);
    /* ... */
}
```

rbp (current base pointer)

rsp (current stack pointer)

What if s is >128 bytes?

You overwrite *rbp* and then the *return address*

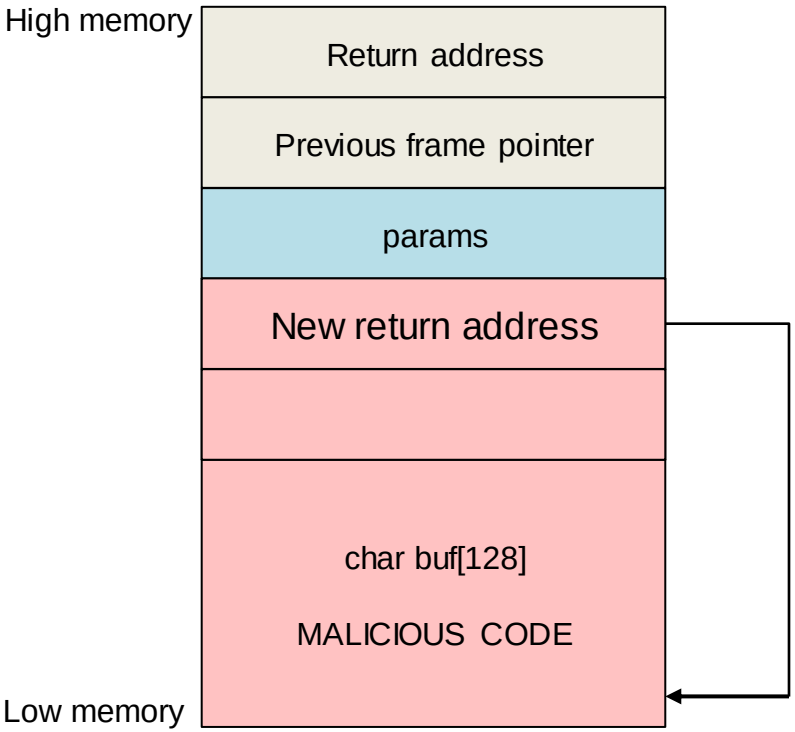
Overwriting the return address

- If we overwrite the return address
  - We change what the program executes when it returns from the function
- "Benign" overflow
  - Overflow with garbage data
  - Chances are that the return address will be invalid
  - Program will die with a SEGFAULT
  - Availability attack

Subverting control flow

Malicious overflow

- Fill the buffer with malicious code
- Overflow to overwrite saved %rbp
- Then overwrite saved the %rsp (return address) with the address of the malicious code in the buffer



Address Uncertainty

- What if we're not sure what the exact address is?
- NOP Slide = landing zone
  - Pre-pad the code with a bunch of NOP instructions
  - NOP, moving a register to itself, adding 0, etc.
  - Set the return address on the stack to any address within the landing zone

Off-by-one overflows

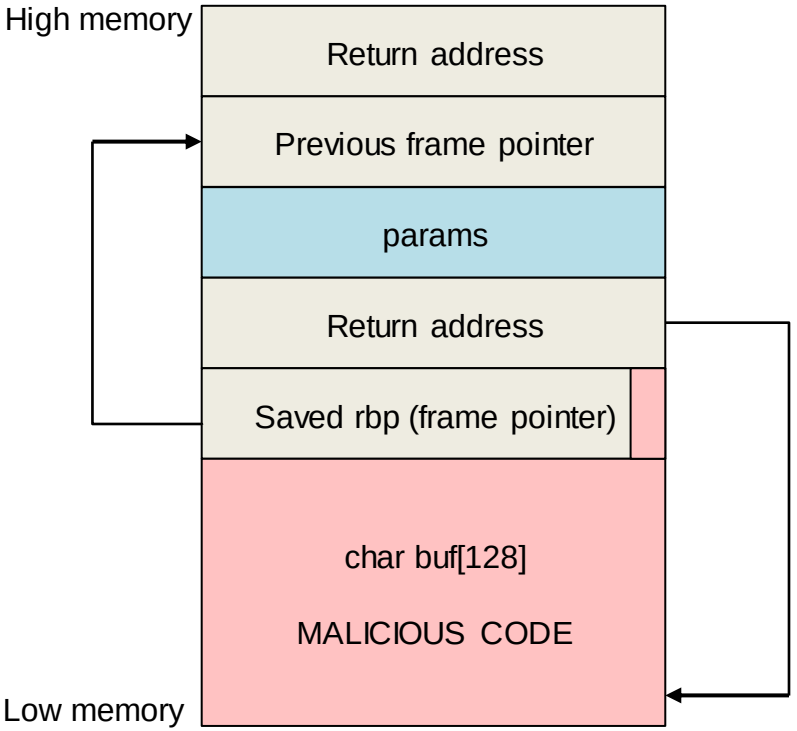
Safe functions aren't always safe

- Safe counterparts require a count
  - strcpy → strncpy
  - strcat → strncat
  - sprintf → snprintf
- But programmers can miscount!

```
char buf[512];
int i;

for (i=0; i<=512; i++)
    buf[i] = stuff[i];
```

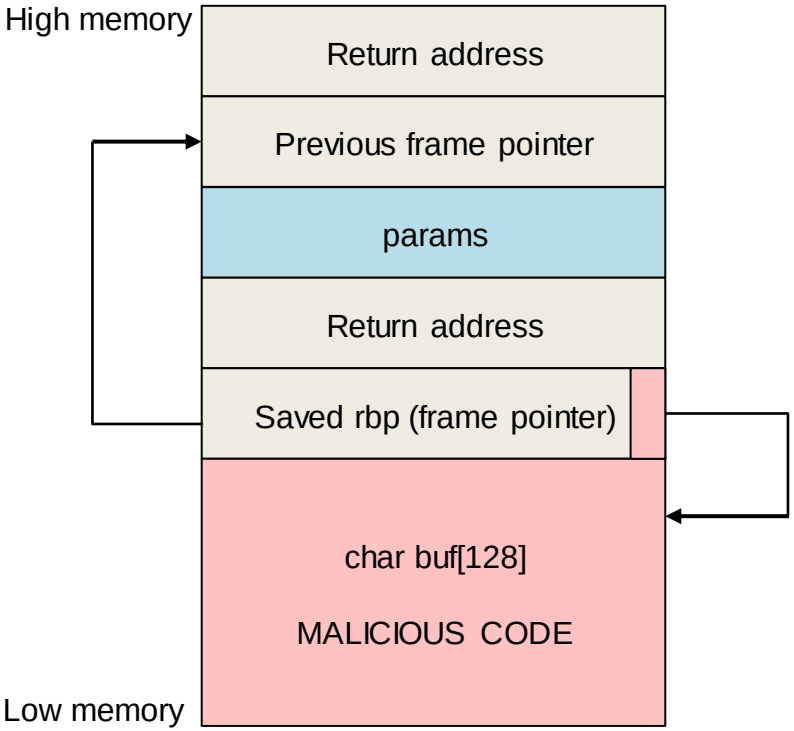
Off-by-one errors

- We can't overwrite the return address
- But we can overwrite one byte of the saved frame pointer
  - Least significant byte on Intel/ARM systems
    - Little-endian architecture



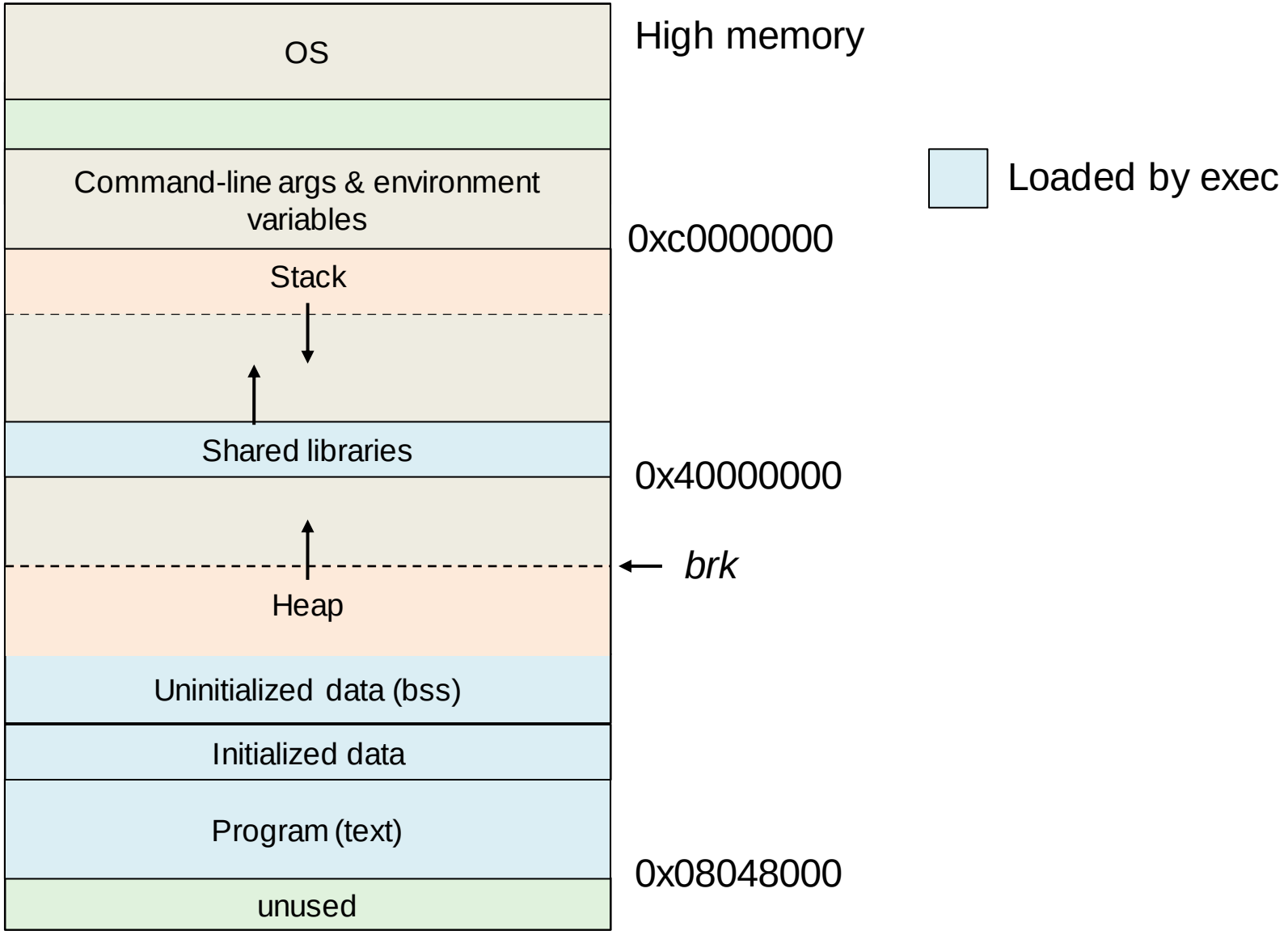
Off-by-one errors

- Depends on the compiler but…
  - Sometimes the compiler restores the old stack pointer from the saved frame pointer
    mov %rsp, %rbp
  - Stack frame pointer will now point to the location of the buffer
- Stuff the buffer with
  - Local variables
  - "saved" %rbp
  - "saved" %rip (return address)
  - Malicious code, pointed to by "saved" %rip
  - When the function returns
    - It will return to the "saved" %rip, which points to malicious code in the buffer



Heap & text overflows

Linux process memory map



Only local variables are on the stack

- Statically allocated variables & dynamically allocated memory (*malloc*) are not on the stack
- Heap data & static data do not contain return addresses
  - No ability to overwrite a return address
- Are we safe?

Memory overflow

The program

```
#include <string.h>
#include <stdlib.h>
#include <stdio.h>

char a[15];
char b[15];

int
main(int argc, char **argv)
{
strcpy(b, "abcdefghijklmnopqrstuvwxyz");
printf("a=%s\n", a);
printf("b=%s\n", b);
exit(0);
}
```

The output
(Linux 4.4.0-59, gcc 5.4.0)

```
a=qrstuvwxyz
b=abcdefghijklmnopqrstuvwxyz
```

Memory overflow

- We may be able to overflow a buffer and overwrite other variables in *higher* memory
- For example
  - Overwrite a file name
  - Change a variable

Memory overflow

The program

```
#include <string.h>
#include <stdlib.h>
#include <stdio.h>

char afile[20];
char mybuf[15];
int main(int argc, char **argv)
{
    strncpy(afile, "/etc/secret.txt", 20);
    printf("planning to write to %s\n", afile);
    strcpy(mybuf, "abcdefghijklmnop/usr/paul/writehere.txt");
    printf("about to open afile=%s\n", afile); exit(0);
}
```

The output
(Linux 4.4.0-59, gcc 5.4.0)

```
planning to write to /etc/secret.txt
about to open afile=/usr/paul/writehere.txt
```

Overwriting variables

- Even if a buffer overflow does not touch the stack, it can modify global or variables
- Example:
  - Overwrite a function pointer
  - Function pointers often used in callbacks

```
Int callback(const char* msg)
{
    printf("callback called: %s\n", msg);
}
int main(int argc, char **argv)
{
    static char buffer[16];
    static int (*fp)(const char *msg);

    fp = (int(*)(const char *msg))callback;
    strcpy(buffer, argv[1]);
    (int)(*fp)(argv[2]);  // call the callback
}
```

The exploit

- The program takes the first two arguments from the command line
- It copies `argv[1]` into a buffer with no bounds checking
- It then calls the callback, passing it the message from the 2nd argument
- The exploit
  - Overflow the buffer
  - The overflow bytes will contain the address of the function you really want to call
    - They're strings, so bytes with 0 in them will not work … making this a more difficult attack

printf attacks

printf and its variants

- Standard C library functions for formatted output
  - printf: print to the standard output
  - wprintf: wide character version of printf
  - fprintf, wfprintf: print formatted data to a FILE stream
  - sprintf, swprintf: print formatted data to a memory location
  - vprintf, vwprintf: print formatted data containing a pointer to argument list
  - vfprintf, vwfprintf: print formatted data containing a pointer to argument list
- Usage

```
printf(format_string, arguments…)
printf("The number %d in decimal is %x in hexadecimal\n", n, n);
printf("my name is %s\n", name);
```

Bad usage of printf

- Programs often make mistakes with printf
  - Valid:

    ```
    printf("hello, world!\n")
    ```

  - Also accepted … but not right

    ```
    char *message = "hello, world\n");
    printf(message);
    ```

- This works but exposes the risk that *message* may be changed maliciously

Dumping memory with printf

```
#include <stdio.h>
#include <string.h>

int
show(char *buf)
{
    printf(buf); putchar('\n');
    return 0;
}

int
main(int argc, char **argv)
{
    char buf[256];

    if (argc == 2) {
        strncpy(buf, argv[1], 255);
        show(buf);
    }
}
```

```
$ ./tt hello
hello

$ ./tt "hey: %012lx"
hey: 7fffe14a287f
```

printf does not know how many arguments it has. It deduces that from the format string.

If you don't give it enough arguments, it keeps reading from the stack

We can dump arbitrary memory by walking up the stack

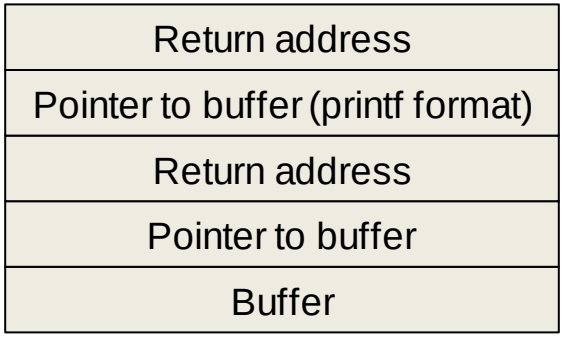
```
$ ./tt %08x.%08x.%08x.%08x
00000009.00000000.b8875c20.0000000f
```

Getting into trouble with printf

- Have you ever used `%n` ?
- Format specifier that will store into memory the number of bytes written so far

  ```
  printf("paul%n says hi", &printbytes);
  ```

  – Will store the number 4 (strlen("paul")) into the variable `printbytes`.
- If we combine this with the ability to change the format specifier, we can write to arbitrary memory locations



Bad usage of printf

```
#include <stdio.h>
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int
show(char *buf)
{
    printf(buf); putchar('\n');
    return 0;
}

int
main(int argc, char **argv)
{
    char buf[256];

    if (argc == 2) {
        strncpy(buf, argv[1], 255);
        show(buf);
    }
}
```
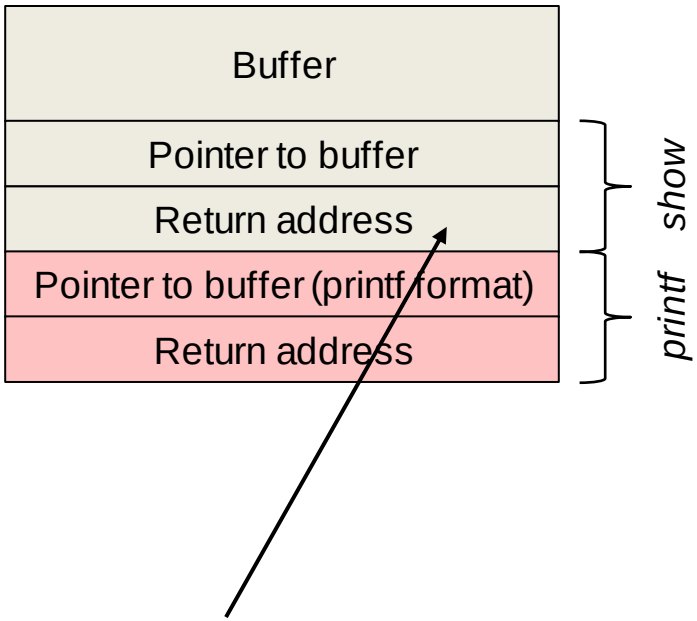



printf treats this as the 1st parameter after the format string.

- We can skip parameters with formatting strings such as %x.
- The buffer can contain the address that we want to overwrite – e.g., any return address.

Printf attacks

- What good is %n when it's just # of bytes written?
  - You can specify an arbitrary number of bytes in the format string
  - printf("%.622404x%.622400%n" . . .
    - Will write the value 622404+622400 = 1244804 = 0x12fe84
    - %622404x says to print a hex number and have it take 622,404 characters

- Note we have two controls here:
  1. Put more % controls in printf: this determines *where* we write in memory
     - Each % represents an argument – we don't care what they are but each one takes us to the next element on the stack ... Until we get to the one we want to overwrite with %n
  2. Have printf output more data: this determines *what* we write in memory
     - E.g., with formats like %.1234x
     - That defines what the value of %n will be that gets written to memory

Defending against hijacking attacks

Fix bugs

- Audit software
- Check for buffer lengths whenever adding to a buffer
- Search for unsafe functions
  - Use *nm* and *grep* to look for function names
- Use automated tools
  - Clockwork, CodeSonar, Coverity, Parasoft, PolySpace, Checkmarx, PREfix, PVS-Studio, PCPCheck, Visual Studio
- Most compilers and/or linkers now warn against bad usage

tt.c:7:2: warning: format not a string literal and no format arguments [-Wformat-security]

zz.c:(.text+0x65): warning: the `gets' function is dangerous and should not be used.

Fix bugs: Fuzzing

- Technique for locating buffer overflow problems
- Enter long strings with well-defined patterns
  - E.g., "$$$$$$$"
- If the app crashes
  - Search the core dump for "$$$" to find where it died
- Automated *fuzzer* tools help with this
- Or … try to construct exploits using gdb

Don’t use C or C++

- Buffer overflows are mostly a C/C++ problem
- Most other languages feature
  - Run-time bounds checking
  - Parameter count checking
  - Disallow reading from or writing to arbitrary memory locations
- Hard to avoid in many cases

Specify & test code

- If it's in the specs, it is more likely to be coded & tested
- Document acceptance criteria
  - "File names longer than 1024 bytes must be rejected"
  - "User names longer than 32 bytes must be rejected"
- Ensure consistent checks to the criteria across entire source
  - Example, you might #define limits in a header file but some files might use a mismatched number.
- Check results from *printf*

Dealing with buffer overflows: No Execute

Data Execution Protection (DEP)

- Disallow code execution in data areas - on the stack or heap
- Set MMU per-page execute permissions to no-execute
- Intel and AMD added this support in 2004

- Examples
  - Microsoft DEP (Data Execution Prevention) (since Windows XP SP2)
  - Linux PaX patches
  - OS X ≥10.5

No Execute – not a complete solution

No Execute Doesn't solve all problems

- Some applications need an executable stack (LISP interpreters)
- Some applications need an executable heap (code loading/patching)
- Does not protect against heap & function pointer overflows
- Does not protect against printf problems

Return-to-libc

- Allows bypassing need for non-executable memory
  - We can still corrupt the stack … just not execute code from it
- No need for injected code
- Instead, reuse functionality within the exploited app
- Use a buffer overflow attack to create a fake frame on the stack
  - Transfer program execution to the start of a library function
  - libc = standard C library
  - Most common function to exploit: *system*
    - Runs the shell
    - New frame contains the parameters for the shell: the command
      - E.g., `system("/bin/sh")`

Return Oriented Programming (ROP)

- Overwrite return address with address of a library function
  - Does not have to be the start of the library routine
    - "borrowed chunks"
  - When the library gets to RET, that location is on the stack, under the attacker's control
- Chain together sequences ending in RET
  - Build together "gadgets" for arbitrary computation
  - Buffer overflow contains a sequence of addresses that direct each successive RET instruction
- It is possible for an attacker to use ROP to execute arbitrary algorithms without injecting new code into an application
  - Removing dangerous functions, such as *system*, is ineffective
  - Make attacking easier: use a compiler that generates gadgets!
    - Example: ROPC – a Turing complete compiler, https://github.com/pakt/ropc

Dealing with buffer overflows & ROP: ASLR

Address Space Layout Randomization

- Dynamically-loaded libraries used to be loaded in the same place each time, as was the stack & memory-mapped files
- Well-known locations make them branch targets in a buffer overflow attack
- Position stack and memory-mapped files to random locations
- Position libraries at random locations
  - Libraries must be compiled to produce position independent code
- Implemented in
  - OpenBSD, Windows ≥Vista, Windows Server ≥2008, Linux ≥2.6.15, macOS, Android ≥4.1, iOS ≥4.3
- But … not all libraries (modules) can use ASLR
  - And it makes debugging difficult

Address Space Layout Randomization

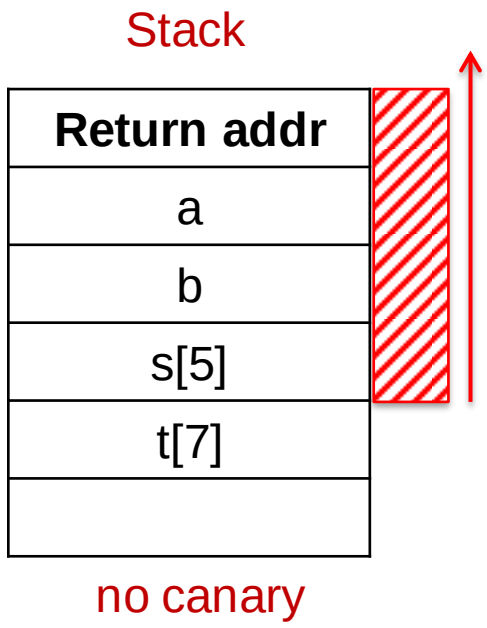
- Entropy
  - How random is the placement of memory regions?
- Examples
  - Linux Exec Shield patch
    - 19 bits of stack entropy, 16-byte alignment > 500K positions
    - Kernel ASLD added in 3.14 (2014)
  - Windows 7
    - 8 bits of randomness for DLLs
      - Aligned to 64K page in a 16MB region: 256 choices
  - Windows 8
    - 24 bits for randomness on 64-bit processors: >16M choices

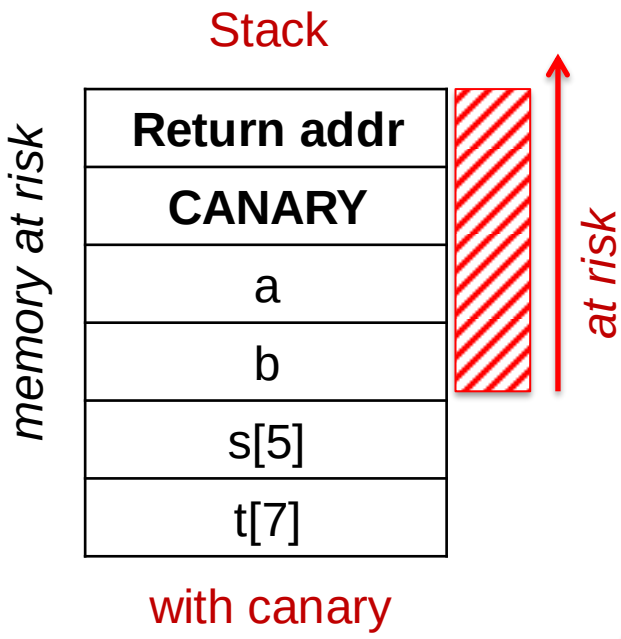
Dealing with buffer overflows: Canaries

Stack canaries

- Place a random integer before the return address on the stack
- Before a return, check that the integer is there and not overwritten: a buffer overflow attack will likely overwrite it

```
int a, b=999;
char s[5], t[7];

gets(s);
```



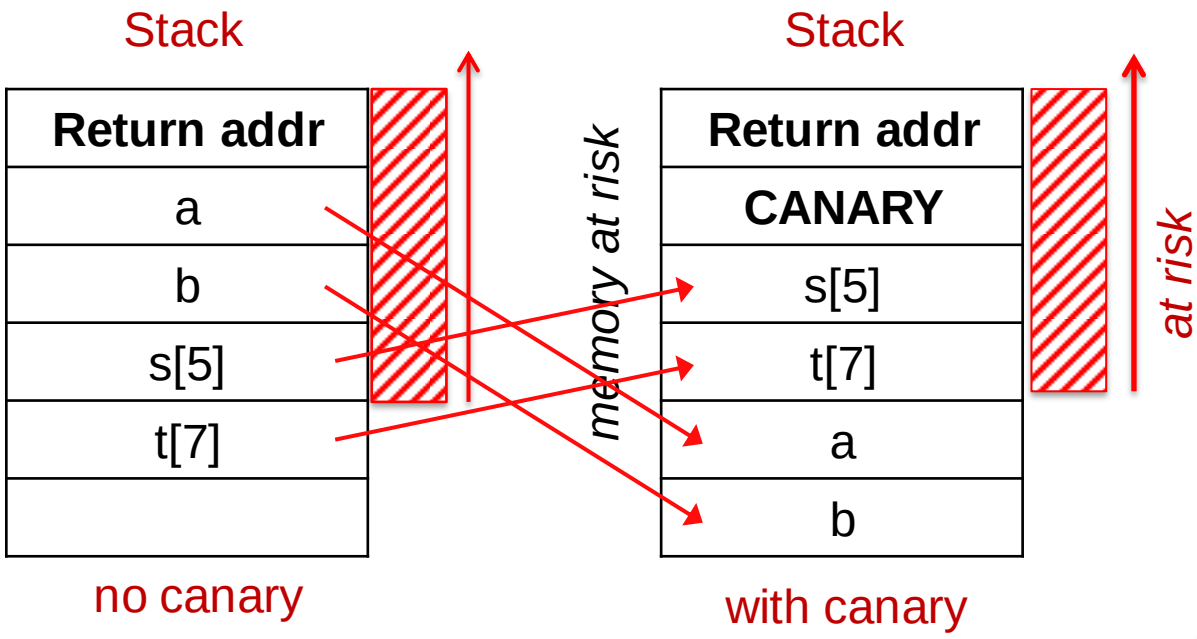


ProPolice

IBM's gcc patches

- Allocate arrays into higher memory in the stack
- Ensures that a buffer overflow attack will not clobber non-array variables

```
int a, b=999;
char s[5], t[7];

gets(s);
```



Stack canaries

- Again, not foolproof
- Heap-based attacks are still possible
- Performance impact
  - Need to generate a canary on entry to a function and check canary prior to a return
  - Minimal degradation ~8% for apache

Function pointer protection

- Encrypt function pointers
  - Example: XOR with a random value
  - Any attempt to modify them will result in invalid addresses
- Degrades performance when function pointers are used

Safer libraries

- Compilers warn against unsafe *strcpy* or *printf*
- Ideally, fix your code!
- Sometimes you can't recompile (e.g., you lost the source)
- Libsafe from Avaya Labs
  - Dynamically loaded library
  - Intercepts calls to unsafe functions
  - Validates that there is sufficient space in the current stack frame
    framepointer – destination > strlen(src)


INTERVIEW QUESTION
HOW WOULD YOU DIAGNOSE A BUFFER OVERFLOW PROBLEM?
Dilbert.com DilbertCartoonist@gmail.com
I'D PUT THE CIRCUIT BOARD IN A BUCKET OF WATER AND LOOK FOR AIR BUBBLES.
8-14-12 ©2012 Scott Adams, Inc.
THAT SOUNDS RIGHT.
I JUST DIAGNOSED A PROBLEM WITH YOUR INTERVIEW QUESTION.

The end