Stack Overflow

COMP620

Outline

- Threat
- Problem definition
- Vulnerabilities
- Solutions

National Cyber Alert System

Technical Cyber Security Alert TA09-161A

Adobe Acrobat and Reader Vulnerabilities

Original release date: June 10, 2009
Last revised: --
Source: US-CERT

Systems Affected

*** Adobe Reader versions 9.1.1 and earlier**
*** Adobe Acrobat versions 9.1.1 and earlier**

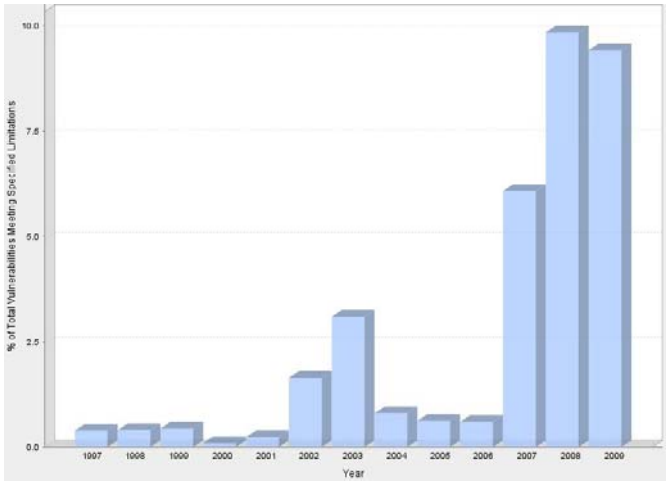
Overview

Adobe has released Security Bulletin APSB09-07, which describes several buffer overflow **vulnerabilities that could allow a remote attacker to execute arbitrary code.**

Buffer Overflows Are A Major Threat

- Buffer overflows are a major security vulnerability.
- When a security alert contains the phrase **"The most severe of these vulnerabilities allows a remote attacker to execute arbitrary code."**, the underlying problem is probably a buffer overflow.
- The Morris worm (the first Internet worm) spread in part by exploiting a stack buffer overflow in the Unix finger server.
- Many students do not know what they are.

Buffer Overflows as Percent of Total Vulnerabilities



source: DHS National Cyber Security Division/US-CERT National Vulnerability Database

What will this program do?

```
void examplefunc() {
  int stuff = 0;
  char info[4];
  int i;
  for (i = 0; i < 7; i++){
      info[i] = stuff++;
   }
}
```

1. Compiler Error
2. Run time buffer overflow error
3. Corrupt data
4. Data execute exception

Basic Buffer Overflow

```
boolean rootPriv = false;
char name[8];
cin >> name;
```

- When the program reads the name "Smith"

S	m	i	t	h				false

char name[8] rootPriv

Basic Buffer Overflow

```
boolean rootPriv = false;
char name[8];
cin >> name;
```

- When the program reads the name "Armstrong"

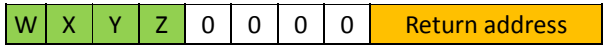
A	r	m	s	t	r	o	n	g

char name[8] rootPriv

Stack Overflow

- A stack overflow exploit occurs when a user enters data that exceeds the memory reserved for the input. The input can change adjacent data or the return address on the stack.

```
char myStuff[4];
```



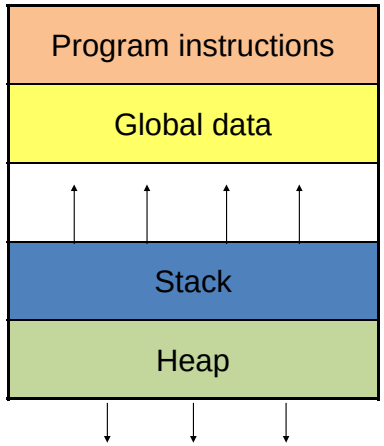
Program Stack

The Other Stack Overflow

- The phrase "***Stack Overflow***" also applies to programs whose stack grows to exceed the available memory.
- These stack overflows are often generated by runaway recursion or allocated large data structures on the stack.
- This form of stack overflow is not usually the result of a malicious attack.

This is a problem for another day.

Program Memory Organization



Intel method

Stack Review

- Consider the function

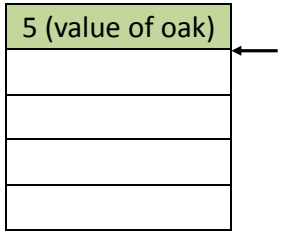
```
void thefunc( float &dog, int cat ){
     char cow[4];
}
```

- that is called by the main program

```
int oak = 5;
float  pine = 7.0;
float *birch = &pine;
thefunc( birch, oak );
```

Stack for Call

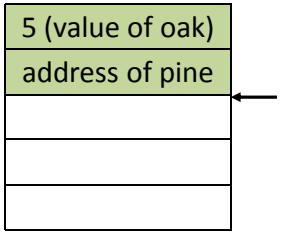
- push oak




```
thefunc( birch, oak );
```

Stack for Call

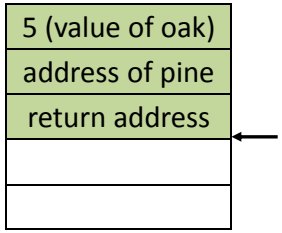
- push oak
- push birch




```
thefunc( birch, oak );
```

Stack for Call

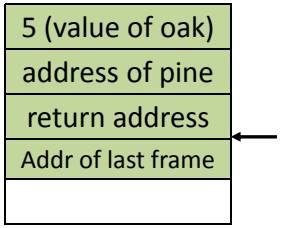
- push oak
- push birch
- push return address




```
thefunc( birch, oak );
```

Stack for Call

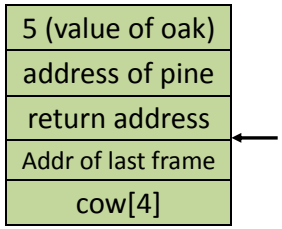
- push oak
- push birch
- push return address
- push frame pointer




```
thefunc( birch, oak );
```

Stack for Call

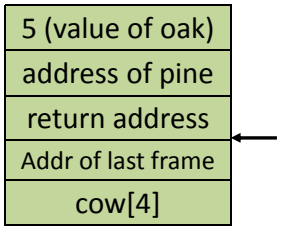
- push oak
- push birch
- push return address
- push frame pointer
- Allocate space for local variable, cow[4]




```
thefunc( birch, oak );
```

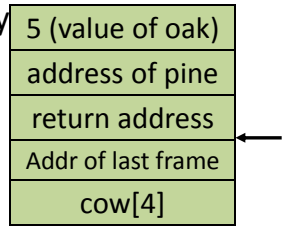
Overflowing Local Variables

- On an Intel processor *(and many others)* the stack is extended to lower addresses
- If you address beyond a local variable, you will overwrite the return address.



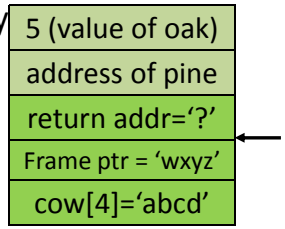
Hacking the Stack

- If a program does not properly check array bounds, it may be possible to give the program specially crafted input that overwrites the return address with a binary value.
- `cow[8]` to `cow[11]` are the return address



Hacking the Stack

- If a program does not properly check array bounds, it may be possible to give the program specially crafted input that overwrites the return address with a binary value.
- The return address can be changed to the address of a function in the program.
- Function parameters can also be put on the stack



Loading Malicious Code

- A long input to a short buffer might also contain binary machine language.
- The return address can be overwritten to cause the program to jump to the newly loaded machine language when it returns.

What is the most evil thing a stack overflow exploit can do?

1. Change the return address to call some function
2. Load binary machine language
3. Crash the program
4. Alter data

Preventing Stack Overflow Exploits

- Better software engineering
- Avoid dangerous functions
- Language choice
- Compiler tools (Stack Guard)
- Analysis tools
- Execution Prevention

Program Errors

- Buffer overflows are primarily caused by programs which fail to properly check for invalid input, particularly longer input than expected.
- Many older library functions (such as `strcpy` or `gets`) did not check the length of the target buffer.

Good Software Engineering Practices

- Because vulnerabilities are primarily caused by unsafe programming, good software engineering principles can significantly improve a program's safety.
  - Code reviews
  - Testing with long input or too much input
  - Looking for vulnerabilities

Frequent Vulnerabilities

- Careless use of buffers without bounds checking
- Off-by-one errors
- Unsafe library function calls
- Old code used for new purposes (like UNICODE international characters)
- All sorts of other far-fetched but deadly-serious things you should think about

Off-by-one errors

- Off-by-one errors occur when a programmer takes the proper precautions in terms of bounds checking, but forgets that the last index is one less than the size.
- In C strings are terminated by a null character. Programmers often forget to reserve space for the null terminator.
- `char myString[10]` can only hold 9 printable characters, indexed from 0 to 8.

Unsafe Libraries

- The original C libraries contain several functions that do not consider the length of a target buffer.
- Many of these libraries have been superseded by safer versions that limit the target length.
- Several C++ methods still do not check the size of the target buffer.

Unsafe I/O Functions

- Avoid **gets()**. It has no way to limit input length
- Use precision specifiers with the **scanf()** family of functions (**scanf()**, **fscanf()**, **sscanf()**, etc.). Otherwise they will not do any bounds checking for you.
- **`cin >>`** `char[]` will read more characters than the length of the string.
- The **`cin.get`** and **`cin.getline`** functions allow you to specify a maximum input length.

Unsafe String Functions

- Avoid functions like **strcpy()** and **strcat()**. Use **strncpy()** and **strncat()** instead.
- Functions like **fgets()**, **strncpy()**, and **memcpy()** are safe if you make sure your buffer is the size you say it is. Be careful of off-by-one errors.
- When using **streadd()** or **strecpy()**, make sure the destination buffer is four times the size of the source buffer.

What is the proper call to read characters into a 16 byte array?

1. scanf("%s", myString);
2. scanf("%14s", myString);
3. scanf("%15s", myString);
4. scanf("%16s", myString);
5. scanf("%17s", myString);

Data Expansion

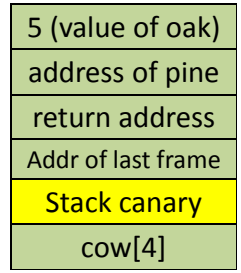
- The size in bytes of the input might not be what causes the buffer overflow, it might be the input itself.
  - For example, if you're converting a large integer to a string (maybe in binary) make sure the buffer is long enough to hold all possible outputs
  - When converting special characters for web pages (i.e. "**>**" to "**`>`**") the output can become much larger
  - Unicode is twice the size of ASCII

Safer Languages

- Several modern languages have built-in protection against stack overflow.
- Java and C# check every array reference to ensure that it is within bounds.
- Java does not allow stack violations.

Stack Canaries

- A stack canary is a random number placed on the stack between the user data and the return address.
- Overflowing the local variable and changing the return address will also change the stack canary
- Before returning, the program checks the canary value.



Data Execution Prevention

- Most newer processors have a bit in the page table that inhibits instruction fetches from that page.
- Newer operating systems can set data execution prevention for stacks.
- This prevents the program from executing machine language loaded on the stack by an exploit.
- This does **not** prevent programs from overwriting the return address.

Stack Overflow Threats

- Most students:
  - Can't recognize a buffer overflow vulnerability when they see it, so they don't even think of it when coding
  - Are not attuned into the dangers of buffer overflows
  - Do not inspect or test their code as well as you would like
  - Are often not made aware of buffer overflows by instructors or textbooks

Overflow Lab

- Run all of the simulations at

http://williams.comp.ncat.edu/overflow/Labs.html