### **Advanced Format String Attacks** Presented by Paul Haas





### Contents

- Background
- Abstract
- Definition
- Context
- Technique

- How-to
- Tools
- Exploits
- Conclusion
- Q&A

### Background

- Lead Web Application Security Engineer at Redspin, Inc with over 4 years experience in hundreds of audits.
- This talk is not associated with my company
- Defcon 13 CTF winner (Shellphish 2005)
- Alumni of UCSB's Computer Security Group
- Mario Kart DS: Rob in Tank on Rainbow Road

#include <stdio.h>
int main(int argc, char \*\*argv){
 printf(argv[1]);
}



Reading arbitrary locations Writing arbitrary locations Executing arbitrary code Get a shell





### **RTFM and Writing it yourself!**

## Without

# Format String Attack

- Software vulnerability in certain C functions that perform string formating leading to the potential to write arbitrary data to arbitrary locations
- Despite easy solutions, vulnerabilities and ignorance of issue still exist, hence the talk
- Common in hackademic exercises
- Talk assumes you have a basic idea of the attack (%x, %s, %n)
- Talk details technique but tools do not require it



- 1990: csh "Interaction Effect" crash: !o%8f
- 1999-09-17: proftpd 1.2.0pre6 "Argument attack/" snprintf Vulnerability" (BID 650)
- 2000-06-22: wu-ftpd 2.6.0 Remote Format String Stack Overwrite Vulnerability (BID 1387)
- 2000-09-09: "Format String Attacks" whitepaper by Tim Newsham
- 2010-06-30: KVIrc DCC Directory Traversal and Multiple Format String Vulnerabilities (BID 40746)



# Old Technique

- Manual popping up of stack using string of '%x's
- Get overwrite address using other technique
- Search for shellcode in core after SEGFAULT
- Characters written using long value in %x or %c
- Final write to address using %n
- Frequent RTFM
- Write once, use once

of '%x's ique ULT

# **Current Technique**

- %p gives detailed information of stack location
- •%s allows us to view known stack addresses as strings
- %NNc controls number of bytes written
- %hhn allows single byte writes
- Direct parameter access shortens format string:

 $5^n = p^p p^p p^p p^n$ 

# New Technique

- Format String Attack allows us to dump stack
- Stack contains interesting information:
  - data, code pointers, stack addresses
  - our format string, format string's address
  - stack offset location of all of the above
- •Knowledge of this gives us the address of any value on the stack
- These values are enough to write our exploit

# Our Vulnerable Code

#include <stdio.h>

### int main(int argc, char \*\*argv){ printf(argv[1]); } # Compile and setup insecure environment

gcc printf.c -w -OO -ggdb -std=c99 -static -D\_FORTIFY\_ SOURCE=0 -fno-pie -Wno-format -Wno-format-security -fno-stack-protector -z norelro -z execstack -o printf

sudo sysctl -w kernel.randomize va space=0



# **Exploit Steps**

- Dump stack values until format string is found
- Locate pointer address of format string
- Choose our overwrite address on the stack
- Point format string at overwrite address and write address of shellcode to end of string
- Adjust offsets for 'chicken and egg' problem:
  - Address of format string based on its length
  - Format string needs its own address to reference

• Method 1: Pass a long string of %p's

./printf`perl -E 'say "%p"x200``

• Method 2: Execute binary in loop with %NNN\$p

for i in {001..200}; do echo -n "\$i = "; ./printf "%\$i\\$p"; echo; done

Search for hex representation of string

= 0x24, % = 0x25, p = 0x70

Result will be stack offset of format string

### Stack Dump



# Format String Address

- Execute binary in loop with sequential %NNN\$s
  - Will cause SEGFAULTS, may trip any IDS systems
  - for i in {001..100}; do echo -n "i = "; ./printf "%i = "; ./printf "%i = "; ./printf
- Create format string only comprising of addresses obtained from stack dump
  - Single execution/string prevents SEGFAULT
  - Much more elegant, verifies constant stack

## Offset + Address = WIN

Matching up an offset to a stack address allows us to learn the address of any location on the stack

**Example:** 

Offset 100 (0xBFFFF100): Our format string sizeof(pointer) = 4 bytes \* 100 pointers = 400 Offset 1 = 0xBFFFF100 + 400 = 0xBFFFF290



# **Overwrite Location**

- Common exploit locations require binary examination tools: PLT, DTORS, LIBC
- Advance format string attack could extract these from known binary headers (difficult)
- Return addresses are stored on the stack
  - We know the stack address of each value
- Overwrite these locations to point to shellcode



- Different format strings lengths effect stack addresses, yet we assume stack is constant
  - Keep all strings to same modulus of sizeof(pointer)
- Format string may not align with stack address
  - Keep padding requirement when addressing string
- Even with the correct modulus and pad, our string offset may be off

Verify our exploit before we attempt it by reading rather than writing to our overwrite location

### ssues

- It is possible to create a format string exploit using only 2 executions of the vulnerable program with no program exceptions
- Math only, no bruteforcing necessary
- Incorporate shellcode as part of format string
- Smaller format string buffers are also possible
  - 8 bytes to examine a stack address
  - Format string as small as 68 bytes + shellcode

### Result

### Format String Auto Exploitation

- Proof of concept tool in Python
- Instructions for running on Backtrack 4
- Multiple exploit and overwrite options
- Missing some useful features:
  - Separate execution of independent steps
  - Architectures independent (x86 & 64)
  - Read arbitrary locations rather than write
  - Finer control over exploit

# Metasploit Integration

- Control each step of the exploit individually or automate entire process
- Use as payload generator
- Uses Metasploit payload library for shellcode
- Integrates into other modules and injection functionality
- Functionality will be demonstrated during Defcon

### Demonstrations

- Testing Code
- OverTheWire
- •Known exploit •0-Day?



- The output from format string attacks gives you everything you need to know to go from discovery to compromise
- The exploitation process can be automated from start to finish
- Format string attacks are easy to fix, and now are easy to exploit as well
- There are plenty of vulnerable programs out there to discover and exploit





## **Questions?**



- The most recent version of this presentation and associated tools can be found on www.redspin.com and www.defcon.org
- Look for the incorporation of the tools in this talk in Metasploit in the near future
- Any follow-up questions can be addressed to phaas AT redspin DOT com
- Shouts to the Shellphish, G. Vigna "zanardi" and the Goats at Redspin {ap3r, jhaddix, fulg0re, D3, OwNpile, Yimmy & b3tty}

### Thanks

