Advanced Format String Attacks

Presented by Paul Haas



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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

ln

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

Out

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

Without

RTFM and Writing it yourself!

Format String Attack

- •Software vulnerability in certain C functions that perform string formatting 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

Brief History

- 1990: csh "Interaction Effect" crash: lo%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

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%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 -O0 -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

Stack Dump

- 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

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\$p:%$i\$s"; echo; done | grep -v ^$
```

- 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

Issues

• 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

Result

- 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

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
 Known exploit
- OverTheWireO-Day?

Summary

- 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?

Thanks

- 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}

