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Analysis of an Unknown Binary

SANS GCFA Practical Assignment v.1.2 Part 1

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Syntax Conventions

The text of the document is in 12 point Arial font

Commands executed at the shell, the output of commands, and references to files, directories or system binaries are all in 10 or 12 point Courier New font.

Part 1: Analyze an Unknown binary

Introduction

The security of one of my employer's systems was compromised recently. The system administrator who responded to the incident found an unknown binary named atd that was installed by the intruders. The system administrator created an MD5 checksum of the binary and stored it in a file named atd.md5. The binary and associated md5 checksum file were then zipped into a file named binary_v1.2.zip and given to me for analysis.

I analyzed and identified the purpose of the binary using the forensic and reverse engineering techniques and tools described below.

I set up a PC running RedHat Linux 7.1 to perform the analysis. I connected the analysis system's network card to another Linux system via a 10Base-T cross over cable to monitor network traffic originating from the analysis systems with the Snort package during the analysis process. I assigned IP addresses in the private 192.168.100.0/24 range on both the analysis and monitoring hosts.

Binary Details

The first step in the analysis process was to extract the binary from the zip file. I used the command unzip -x to extract the files. This command extracts the files in the zip archive and preserves their original user and group (UID/GID) information.

Figure 1-1: Unzipping the archive

```
# unzip -X binary_v1.2.zip
Archive: binary_v1.2.zip
inflating: atd.md5
inflating: atd
```

The next step in analyzing the unknown binary was to gather basic information about the binary such as the MAC times (the date and time the file was last Modified, Accessed or Changed), file size, owner, and permissions.

debugfs is a Linux utility that can examine and edit an ext2 filesystem. I used this utility to gather the unknown binary's size, owner, permissions, and MAC times as shown in Figure 1-2. I accomplished this by first running ls -i atd which shows me the inode associated with the file. (See part1 for inode description). I then used debugfs to display the contents of the inode structure of the inode (34756) associated with the file using the command debugfs -R "stat <34756>" /dev/had1

Figure	1-2:	debugfs	output
<u> </u>		<u> </u>	

```
# ls -i atd
    34756 atd
# debugfs -R "stat <34756>" /dev/hda1
debugfs 1.27 (8-Mar-2002)
Inode: 34756 Type: regular Mode: 0644 Flags: 0x0 Version: 1
User: 0 Group: 0 Size: 15348
File ACL: 0 Directory ACL: 0
Links: 1 Blockcount: 32
Fragment: Address: 0 Number: 0 Size: 0
ctime: 0x3e314e73 -- Fri Jan 24 09:32:19 2003
atime: 0x3d653432 -- Thu Aug 22 14:57:54 2002
mtime: 0x3d653432 -- Thu Aug 22 14:57:54 2002
BLOCKS:
196931 196932 196933 196934 196935 196936 196937 196938 196939 196940
196941 196942 196943 196944 196945 196946
TOTAL: 16
```

The output from debugfs provided me with the following relevant information about the unknown binary. (bolded in Figure 1-2)

- The ctime (create time) of the binary is: Fri Jan 24 09:32:19 2003 This reflects when the binary was created (unzipped from the zipfile) on my system.
- The atime (last access time) of the binary is: Thu Aug 22 14:57:54 2002 This represents the last time the file was accessed. The time could indicate when the intruder accessed the file, or when the sys-admin accessed it to zip it.
- The mtime (last modify time) of the binary is: Thu Aug 22 14:57:54 2002 The represents when the file was last modified. The time could indicate when the intruder accessed the file, or when the sys-admin accessed it to zip it.
- The unknown binary, atd, is 15348 bytes in size
- The binary is owned by User 0 (root) and group 0 (root)

 The file permissions of the atd binary are 0644. UNIX file's permissions contain three attributes.
 r – read permission – Allows the user to read the file
 w – write permission – Allows the user to write to the file
 x – execute permission – Allows the user to execute the file.
 There are three categories of users on the system. The user (owner), users who belong to the same pre-defined group (group) and all other users on the system (other). Each of these three attributes can be set for each of the three categories of users. The three permission attributes can be represented as letters (r,w,x) or as octal digits (shown below).

Octal: Attribute:

- 1 = execute only
- 2 = write only
- 3 = write and execute
- 4 = read only
- 5 = read and execute
- 6 = read and write
- 7 = read and write and execute

The unknown binary file permissions (0644) show that it is read-able and writeable by the user who owns the file, but is read-only for the group and all other users.

To ensure that the checksum process didn't alter the MAC times of the unknown binary, I verified the MD5 checksum of the binary after gathering MAC time information with debugfs.

I performed the MD5 checksum of the binary using the /usr/bin/md5sum program and verified that the value obtained matched the MD5 signature stored in the atd.md5 file that was packaged with the atd binary. (See Figure 1-3) This indicates that my analysis so far had not changed the binary.

Figure 1-3: md5sum output

md5sum atd
48e8eed3052cbf637e638fa82bdc566 atd
cat atd.md5
48e8eed3052cbf637e638fa82bdc566 atd

md5sum calculates a hash of binary data using the MD5 hashing algorithm (as described in RFC 1321). This MD5 hash or checksum of the data is unique only to that data. If the data is modified, the MD5 calculation will not match the previous one. For all intents and purposes it is impossible for two different pieces of data or files to have the same MD5 checksum. Consistently reproducing the same MD5 checksum for the same piece of data proves that the data has not

been modified. This concept is extremely important in the field of computer forensics, and is used to prove the integrity of evidence.

Next, I ran /usr/bin/file on the binary, as shown in Figure 1-4 to determine the file type.

Figure 1-4 out of file command

file atd

```
atd: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), dynamically linked (uses shared libs), stripped
```

The output of file in Figure 1-4 shows the unknown binary is a 32-bit ELF executable compiled for the Intel 80386 architecture. This also shows the binary is dynamically linked and stripped. A dynamically linked binary contains references to external shared libraries, and accesses code within these shared libraries when it is executed. A stripped binary is one that has had the symbol table removed. ELF binaries are only supported on UNIX systems, so I knew I was not dealing with a DOS/Window's binary.

After determining the binary was an ELF executable, it seemed odd to me that the execute permission bits were not set on the file, meaning the file could not be executed. I decided to determine if the system administrator who zipped the binary changed the file permissions. To do this, I ran <code>zipinfo -v</code> on binary_v1.2.zip to see what type of system the zipfile was created on. There was a lot of output generated from the command, but the significant piece of information about the zipfile is that it was created on a MS-DOS or NT FAT system. (Shown in Figure 1-5)

Figure 1-5: Output of zipinfo

```
# zipinfo -v binary_v1.2.zip
....
File system or operating system of origin: MS-DOS, OS/2 or NT FAT
....
```

The zipfile binary_v1.2.zip was created on an MS-DOS based system so the original UNIX file permissions were not preserved and it also means that the MAC times on the unknown binary had been modified by the MS-DOS system.

To prove this I ran debugfs –R "stat <34755>" /dev/hda1 to get the inode contents of the atd.md5 file that the system administrator included with the unknown binary.

The atime and mtime of the atd.md5 file are both Thu Aug 22 14:58:08, which is 15 seconds later than the atime and mtime of the unknown binary, atd. This proves that the MAC times of the unknown binary were modified by the system administrator who created the zipfile, and do not represent the MAC times of the binary as it existed on the compromised system.

The next step was to run /usr/bin/strings on the binary in order to determine what the binary contains for ASCII string data. The strings command parses a file and shows any ASCII text strings such as comments in the code, error messages, passwords, author information, and sometimes library information if the file is dynamically linked. I ran strings with the command line option -n 1, which prints all string data greater than 1 character in length, rather than the default length of 4 characters.

Figure 1-6 contains a portion of the strings output containing keywords that were helpful in determining the function of the unknown binary, and my interpretation of the meaning of the string data. The strings data was produced by running the command: /usr/bin/strings -n 1 atd

String data found in binary	My interpretation of the string
/lib/ld-linux.so.1	The binary uses Id-linux.so.1 shared library indicating it was compiled on a Linux system
libc.so.5	The binary is compiled against libc.so.5 shared library - indicates it was compiled on an older Libc5 version of Linux. More recent versions of Linux use Libc6
lokid: Client database full	status message from daemon, indicates it's lokid
2.0 Iokid version: %s	Indicates the binary is lokid version (2.0)
XOR active cryptography: %s	Indicates that it uses XOR cryptography in the communications
lokid: inactive client <%d> expired from list [%d]	status message from daemon, indicates it's lokid
lokid -p (i u) [-v (0 1)]	"help" instructions on command line options. Indicates it's lokid
LOKI2 route [(c) 1997 guild corporation worldwide]	Comment in source code: copyright statement by the author "route"
lokid: server is currently at capacity. Try again later	status message from daemon, indicates it's lokid
lokid: Cannot add key	status message from daemon, indicates it's lokid
lokid: popen	status message from daemon, indicates it's lokid compiled to use popen() to fork a process.
lokid: client <%d> requested an all kill	status message from daemon, indicates it's lokid
lokid: clean exit (killed at client request)	status message from daemon, indicates it's lokid
lokid: cannot locate client entry in database	status message from daemon, indicates it's lokid
lokid: client <%d> freed from list [%d]	status message from daemon, indicates it's lokid
lokid: unsupported or unknown command string	status message from daemon, indicates it's lokid
lokid: client <%d> requested a protocol swap	status message from daemon, indicates it's lokid
lokid: transport protocol changed to %s	status message from daemon, indicates it's lokid

Figure 1-6: Significant strings output

The text from the strings output indicates to me that the unknown binary is the LOKI daemon, which is a well known "covert channel" backdoor program used by intruders to covertly log into compromised systems. (See Phrack Magazine, Issue 51)

It has previously been shown that the atime, mtime, owner and group information is not indicative of the values the binary had on the compromised system. The process used to retrieve and package the atd and atd.md5 files into the zip file altered them, so it's impossible to determine when the binary was last executed. The strings data found in the file (Shown in Figure 1-6) indicate the binary is version 2.0 of the LOKI daemon. Figure 1-7 contains a summary of basic information I gathered about the unknown binary using the methods demonstrated above.

File Attribute	Value
Name	Atd 🗸
File Size:	15348 bytes
File Permissions:	0644
Ctime	Fri Jan 24 09:32:19 2003
Atime	Thu Aug 22 14:57:54 2002
Mtime	Thu Aug 22 14:57:54 2002
Owner	0 (root)
Group	0 (root)
Md5 checksum:	48e8e8ed3052cbf637e638fa82bdc566
Keywords found in file:	(See Figure 1-6)
Filetype:	ELF 32-bit LSB executable, Intel 80386,
	version 1 (SYSV), dynamically linked,
5	stripped. Compiled on a Linux system
	with libc5.

F igure	1 7. Cumanaa	n , of Dinor	, Dataila
rigure	I-7: Summa	y or Binar	y Details

Program Description and Forensic Details:

So far in my investigation I have gathered basic information about the binary. The next part of the investigation is to identify exactly how the binary behaves. The unknown binary is a dynamically linked, stripped ELF binary compiled on a Linux system that uses libc version 5.

I used the 1dd command to identify all the shared libraries the binary has been linked against as shown in Figure 1-8.

Figure 1-8: Output of Idd command

The output of ldd confirms that the binary is linked against the /lib/libc.so.5 shared library. Libc version 5 was used in older versions of Linux. The current versions of Linux now use Libc version 6.

The ELF binary contains many different sections that are relevant to the structure and execution of the binary. The .comment section of the ELF binary usually contains information about the compiler used to compile it. Dumping the .comment section of the unknown binary using the command objdump -j .comment -s atd reveals that the binary atd was compiled using the GNU GCC compiler version 2.7.2.1 as shown in Figure 1-9.

Figure	1-9: ou	tput of	objdump
--------	---------	---------	---------

This is an older version of the GCC compiler indicating the unknown binary may have been compiled on a system with an old operating system. This is consistent with the hypothesis that it was compiled on an older operating system because the binary is linked against libc5.

All programs have a unique "footprint" when they are executed on a system. This "footprint" of the execution of a binary has several characteristics including:

- The system calls that the process executes.
- The signals sent/received by the process.
- The files, file descriptors and system devices used by the process.

The program strace in Linux executes a given binary and displays these characteristics. It is an invaluable tool for investigating the behavior of a running process.

Before running strace on the binary I had to make the file executable by setting the execute bits using the command chmod +x atd. I ran strace with the command line options -ff which creates individual output files for each forked process. Figure 1-10 shows the output of running the command: strace -o atd-strace,out -ff atd

Function Call from execution of unknown binary.	Description of Call
execve("./atd", ["./atd"], [/* 28 vars */]) = 0	call execve to execute the program
mmap(0, 4096, PROT_READ PROT_WRITE, MAP_PRIVATE MAP_ANONYMOUS, -1, 0) = 0x40007000	map file descriptor to memory
mprotect(0x40000000, 21025, PROT_READ PROT_WRITE PROT_EXEC) = 0	set read,write,execute access to mapped memory
mprotect(0x8048000, 13604, PROT_READ PROT_WRITE PROT_EXEC) = 0	set read,write,execute access to mapped memory
stat("/etc/ld.so.cache", {st_mode=S_IFREG 0644, st_size=7473,}) = 0	get file status of /etc/ld.so.cache
open("/etc/ld.so.cache", O_RDONLY) = 3	open /etc/ld.so.cache (file descriptor 3)
mmap(0, 7473, PROT_READ, MAP_SHARED, 3, 0) = 0x40008000	map file descriptor 3 to memory (ld.so.cache)
close(3) = 0	close file descriptor 3 (ld.so.cache)
stat("/etc/ld.so.preload", 0xbffff9e8) = -1 ENOENT (No such file or directory)	get file status of /etc/ld.so.preload (doesn't exist)
open("/usr/local/qt/lib/libc.so.5", O_RDONLY) = -1 ENOENT (No such file or directory)	open /usr/local/qt/lib/libc.so.5 (doesn't exist)
open("/lib/libc.so.5", O_RDONLY) = 3	open /lib/libc.so.5 (file descriptor 3)
read(3, "\177ELF\1\1\1\0\0\0\0\0\0\0\0\3", 4096) = 4096	read from the file descriptor (3)
mmap(0, 786432, PROT_NONE, MAP_PRIVATE MAP_ANONYMOUS, -1, 0) = 0x4000a000	map info from file descriptor to memory
mmap(0x4000a000, 555135, PROT_READ PROT_EXEC, MAP_PRIVATE MAP_FIXED, 3, 0) = 0x4000a000	map info from file descriptor to memory
mmap(0x40092000, 21344, PROT_READ PROT_WRITE, MAP_PRIVATE MAP_FIXED, 3, 0x87000) = 0x40092000	map info from file descriptor to memory
mmap(0x40098000, 204364, PROT_READ PROT_WRITE, MAP_PRIVATE MAP_FIXED MAP_ANONYMOUS, -1, 0) = 0x40098000	map info from file descriptor to memory
close(3) = 0	close filehandle 3 - libc.so.5

Figure 1-10: Output of main process strace

mprotect(0x4000a000, 555135, PROT_READ PROT_WRITE PROT_EXEC) = 0	set read, write, execute access to mapped memory
munmap(0x40008000, 7473) = 0	unmap memeory at location 0x40008000 (/etc/ld.so.cache)
mprotect(0x8048000, 13604, PROT_READ PROT_EXEC) = 0	set read, execute access to mapped memory
mprotect(0x4000a000, 555135, PROT_READ PROT_EXEC) = 0	set read, execute access to mapped memory
mprotect(0x40000000, 21025, PROT_READ PROT_EXEC) = 0	set read,execute access to mapped memory
personality(PER_LINUX) = 0	set "execution domain". The man page states"personality is Linux-specific and should not be used in programs intended to be portable". This is further proof that the binary was built on and for a LiNUX SYSTEM.
geteuid() = 0	get the process owner's effective identity
getuid() = 0	get the process owner's UID
getgid() = 0	get the process owner's group ID
getegid() = 0	get the process owner's effective group ID
aeteuid() = 0	get the process owner's effective identity
aetuid() = 0	get the process owner's UID
brk(0x804c820) = 0x804c820	sets end of data segment in memory
brk(0x804d000) = 0x804d000	sets end of data segment in memory
stat("/etc/locale/C/libc.cat", 0xbffff520) = -1 ENOENT (No such file or directory)	get file status of /etc/locale/C/libc.cat
stat("/usr/share/locale/C/libc.cat", 0xbffff520) = -1 ENOENT (No such file or directory)	get file status of /usr/share/locale/C/libc.cat
stat("/usr/share/locale/libc/C", 0xbffff520) = -1 ENOENT (No such file or directory)	get file status of /usr/share/locale/libc/C
stat("/usr/share/locale/C/libc.cat", 0xbffff520) = -1 ENOENT (No such file or directory)	get file status of /usr/share/locale/C/libc.cat
stat("/usr/local/share/locale/C/libc.cat", 0xbffff520) = -1 ENOENT (No such file or directory)	get file status of /usr/local/share/locale/C/libc.cat
socket(PF_INET, SOCK_RAW, IPPROTO_ICMP) = 3	open raw socket for ICMP protocol (file descriptor 3)
sigaction(SIGUSR1, {0x804a6b0, [], SA_INTERRUPT SA_NOMASK SA_ONESHOT}, {SIG_DFL}) = 0	define action upon receipt of signal
socket(PF_INET, SOCK_RAW, IPPROTO_RAW) = 4	open raw socket for IP protocol (file descriptor 4)
setsockopt(4, IPPROTO_IP3, [1], 4) = 0	set options on the previously defined socket (fd4)
getpid() = 25965	get PID of current process
getpid() = 25965	get PID of current process
shmget(26207, 240, IPC_CREAT(0) = 5	allocate a shared memory segment
semget(26389, 1, IPC_CREATI0x18010600) = 4	initialize a semaphore
shmat(5, 0, 0) = $0x40008000$	attach the shared memory segment to the address space of the calling process.
write(2 "\nl OKI2\troute [(c) 1997 guild c" 52	writes text "LOKI2 route [© 1997 guild corporation worldwide]" to STDOUT
I OKI2 route [(c) 1997 guild corporation worldwide]	
1 - 52	
y = 52 time/[10/3/26226]) = 10/2/26226	aets time in seconds since the enoch
1116(10+3+20220) = 10+3+20220	gete time in seconds direc the open

close(0) = 0	close filehandle 0
sigaction(SIGTTOU, {SIG_IGN}, {SIG_DFL}) = 0	define action upon receipt of signal
sigaction(SIGTTIN, {SIG_IGN}, {SIG_DFL}) = 0	define action upon receipt of signal
sigaction(SIGTSTP, {SIG_IGN}, {SIG_DFL}) = 0	define action upon receipt of signal
fork() = 25966	fork off a child process to run as daemon (child inherits parent's info including shared memeory segments)
close(4) = 0	close file descriptor 4 (raw IP socket)
close(3) = 0	close file descriptor 3 (ICMP socket)
semop(0x4, 0x2, 0, 0xbfff9a4) = 0	set options for semaphore (4)
Shmdt(0x40008000) = 0	detatches shared memory space from calling program
semop(0x4, 0x1, 0, 0xbfff9a4) = 0	set options for semaphore (4)
_exit(0) = ?	exit the parent process which forked the child

The fork() system call in the execution of the atd binary creates a child process that inherits the environment and memory of the parent process and listens for incoming connections on a network socket (file descriptor) created by the parent process. The strace of the child process forked off by the atd program is listed in Figure 1-11.

Figure 1-11: St	trace of child	process
-----------------	----------------	---------

Function Call	Description of Call
Setsid() = 477	creates a new session for this child process (pid 477)
open("/dev/tty", O_RDWR) = -1 ENXIO (No such device or address)	open /dev/tty
chdir("/tmp") = 0	change directory to /tmp
umask(0) = 022	set umask of 022, files will be created with permissions 0644
sigaction(SIGALRM, {0x8049218, [], SA_INTERRUPT SA_NOMASK SA_ONESHOT}, {SIG_DFL}) = 0	define SIGALARM signal actions
Alarm(3600) = 0	send SIGALARM to process after 3600 seconds
sigaction(SIGCHLD, {0x8049900, [], SA_INTERRUPT SA_NOMASK SA_ONESHOT}, {SIG_DFL}) = 0	set signal attribute to not notify when child process exits.
read(4, 0x804c78c, 84) = ? ERESTARTSYS (To be restarted)	read from filehandle (looking for loki client connect)

The strace output in Figure 1-10 and 1-11 shows the atd binary references several files (listed below) when it executes.

- Loads information from the file /etc/ld.so.cache which contains a list of directories to search for shared libraries.
- Checks /etc/ld.so.preload which is a list of libraries to load before the program
- Looks for libc.so.5 in /usr/local/qt/lib (not found) and finds it at /lib/libc.so.5

Looks for libc.cat in /etc/locale/C, /usr/share/locale/C, /usr/locale/libc/C, /usr/local/share/locale/C

The child process spawned by fork() attempts to open /dev/tty, and fails, then executes chdir (change directory) to /tmp.

My research has shown that the unknown binary is LOKID v2.0. There is not evidence of it containing any malicious code that would cause it to act differently than expected. I compiled a loki client (See section "Program Identification" for details) and attempted to connect to the atd process running on the local system using the command: lokid -d localhost to verify that the unknown binary could communicate with the loki client. The client was compiled with XOR encryption enabled to match the encryption type found in the strings output of the unknown binary.

Figure 1-12: Connecting to atd process with loki client

```
sans:~/sans/L2# ./loki -d localhost
LOKI2 route [(c) 1997 guild corporation worldwide]
loki> /stat
lokid version: 2.0
remote interface: 127.0.0.1
active transport: icmp
active cryptography: XOR
server uptime: 46.58 minutes
client ID: 25899
packets written: 5
bytes written: 5
bytes written: 420
requests: 1
loki>
```

Figure 1-12 shows the communication between the loki client and the atd binary which was running as a daemon process on the system. I sent the LOKI protocol /stat command from the client to show the status of the current session. The atd binary replied and identified itself as lokid version 2.0, using XOR encryption and ICMP as a transport protocol.

Communicating with the unknown binary using the loki client is a strong indicator that the atd binary is version 2.0 of the LOKI daemon.

The LOKI daemon (LOKID2), as described in the Phrack 51 article, is "an information tunneling program". It has the capability of tunneling UNIX "shell commands inside of ICMP_ECHO/ICMP_ECHOREPLY and DNS namelookup query/reply traffic."

ICMP (Internet Control Message Protocol) traffic can be a critical part to the operation of every IP based network. It has several purposes including determining if a particular host is able to communicate on the network or

determining if routes to hosts exist. There are 15 ICMP message types, defined in RFC 792, which serve different purposes for network devices. LOKID2 implements communication between a server daemon and a client using ICMP types 0 and 8. ICMP type 0 (ICMP_ECHOREPLY) and ICMP type 8 (ICMP_ECHO). Under normal circumstances, the ping command sends an ICMP_ECHO to a host, which upon receiving it, responds with an ICMP ECHOREPLY therefore showing it is connected and communicating on the network. The LOKID2 client, by default, uses the data portion in ICMP type 0 and 8 packets to transport shell commands, which are interpreted by the LOKID2 daemon, to the remote host running the daemon. It also has the ability to transport the covert channel communications in the data portion of a DNS reply packet. The covert channel established by LOKI can often pass traffic through firewalls undetected and gives the user of the client "back-door" access to the remote host as if they were logged on to that host with telnet/rlogin/ssh etc.

Program Identification

The evidence I gathered indicates that the unknown binary is the LOKI daemon and relies on the shared library libc.so.5, which is an older version of libc. This indicates that the binary was compiled on an older version of Linux. I downloaded the source code and documentation for LOKID2 at http://www.phrack.com/show.php?p=51&a=6.

The documentation clearly states that the LOKI 2 program is written for Linux kernel versions 2.0.x. This also indicates that the binary was compiled on an older version of Linux. Newer versions of Linux use the 2.2.x, or more recently, the 2.4.x kernels. I installed Slackware Linux 3.6 on the analysis station, which has kernel 2.0.35, libc 5.4.46 and includes GCC-2.7.2.3 as the bundled compiler. I also installed GCC version 2.7.2.1 to compile the LOKI daemon with same compiler version that compiled the atd binary.

I extracted the source code from the Phrack article using the extract utility provided by Phrack as shown below:

- Dowloaded gzipped Phrack issue 51, unzipped and un-tarred it. This created a directory named "phrack" with all the articles as separate files. # gunzip -dc phrack51.tar,gz | tar xvf -
- Copied and pasted the extract utility source code from the Phrack issue into the file extract.c. and compiled extract.c: gcc -o extract extract.c
- The LOKI 2 source code was contained in Article 6 of Phrack 51, so I extracted the source code from the Article 6 file using the extract utility. # ./extract p51-6

This created a directory "L2" with the LOIKD2 source code in it.

I then looked at the Makefile included with the source code to see what compile options were available. LOKI 2 has the option of being compiled with various type of encryption to encrypt the network traffic. In addition the Makefile has the option of selecting to use popen() or open an pty to execute commands. Both XOR and the popen() option is also present in the strings output of the atd daemon in Figure 1-6, so I editied the Makefile as shown below to compile the source code with XOR encryption and using popen() to match the unknown binary.

CRYPTO_TYPE	=	WEAK_CRYPTO	#XOR
SPAWN TYPE	=	POPEN	

I then compiled the LOKI 2 binaries for Linux using the following command: # /usr/bin/make linux

This compiles and strips the lokid (server daemon) and loki (client) binaries. The next step was to compare the binary that I compiled from source code with the unknown binary to confirm that the unknown binary is LOKI 2. I checked the size, file type and MD5 checksum of the lokid binary to compare it against the atd binary. (Shown below in Figure 1-13)

Figure 1-13: Gathering basic info about lokid binary.

```
# ls -al lokid
-rw-rw-r-l root other 15752 Jan 04 14:41 lokid
# file lokid
lokid: ELF 32-bit LSB executable, Intel 80386, version 1,
dynamically linked, stripped
#md5sum lokid
52aba5223634695a4332624d5815d01a lokid
# ldd lokid
libc.so.5 => /lib/libc.so.5 (0x4000040000
```

The lokid binary is a dynamically linked, stripped ELF binary, which matches with the file type of atd, however, lokid is 15752 bytes is size, which is slightly larger than the atd binary. As expected the MD5 sum of lokid does not match the MD5 sum of the atd binary because of the file size difference. The ldd output shows that lokid is only linked against the shared library libc.so.5 which is consistent with the atd binary.

I compared the strings output of the two binaries to determine if atd contained the same strings data as the lokid binary I compiled. The strings output of the two binaries was very similar. There were additional lines of binary data in the strings output of the atd binary, which I found by piping the strings output to wc -1 to count the number of lines. (Shown in Figure 1-14)

Figure 1-14: Counting lines in strings output

```
# strings atd | wc -l
157
# strings lokid | wc -l
153
```

To further prove that the atd binary is the LOKID v2.0 daemon, I compared the output of strace that I performed on atd and lokid. using the diff command. diff compares the two files and outputs the lines (and line numbers) of the differences between the two file.

Figure 1-15 shown the steps taken to generate and compare the output, and the differences between the resulting files.

The comparison of these two files shows that there is no difference between the function calls executed by the atd and lokid processes.

The differences shown in the diff output in Figure 1-15 are all related to the fact that the two processes have different process id numbers (PIDs) and allocate different memory locations for themselves during execution.

Figure 1-15: Comparison of strace output

```
# strace -o atd-strace.out -ff ./atd
# strace -o lokid-strace.out -ff ./lokid
# diff atd-strace.out lokid-strace.out
1c1
< execve("./atd", ["./atd"], [/* 29 vars */]) = 0
> execve("./lokid", ["./lokid"], [/* 28 vars */]) = 0
4c4
< mprotect(0x8048000, 13604, PROT READ|PROT WRITE|PROT EXEC) = 0
___
> mprotect(0x8048000, 13956, PROT READ|PROT WRITE|PROT EXEC) = 0
9c9
< stat("/etc/ld.so.preload", 0xbffff9d4) = -1 ENOENT (No such file or
directory)
> stat("/etc/ld.so.preload", 0xbffff9e8) = -1 ENOENT (No such file or
directory)
20c20
< mprotect(0x8048000, 13604, PROT READ|PROT EXEC) = 0
> mprotect(0x8048000, 13956, PROT READ|PROT EXEC) = 0
```

```
30c30
< brk(0x804c820)
                                           = 0x804c820
> brk(0x804c9a0)
                                           = 0 \times 804 c 9 a 0
32,36c32,36
< stat("/etc/locale/C/libc.cat", 0xbffff50c) = -1 ENOENT (No such file
or directory)
< stat("/usr/share/locale/C/libc.cat", 0xbffff50c) = -1 ENOENT (No such
file or directory)
< stat("/usr/share/locale/libc/C", 0xbffff50c) = -1 ENCENT (No such
file or directory)
< stat("/usr/share/locale/C/libc.cat", 0xbffff50c) = -1 ENOENT (No such
file or directory)
< stat("/usr/local/share/locale/C/libc.cat", 0xbffff50c) = -1 ENOENT
(No such file or directory)
___
> stat("/etc/locale/C/libc.cat", 0xbffff51c) = -1 ENOENT (No such file
or directory)
> stat("/usr/share/locale/C/libc.cat", 0xbffff51c) = -1 ENOENT (No such
file or directory)
> stat("/usr/share/locale/libc/C", 0xbffff51c) = -1 ENOENT (No such
file or directory)
> stat("/usr/share/locale/C/libc.cat", 0xbffff51c) = -1 ENOENT (No such
file or directory)
> stat("/usr/local/share/locale/C/libc.cat", 0xbffff51c) = -1 ENOENT
(No such file or directory)
38c38
< sigaction(SIGUSR1, {0x804a6b0, [],
SA INTERRUPT | SA NOMASK | SA ONESHOT }, {SIG DFL}) = 0
> sigaction(SIGUSR1, {0x804a810, [],
SA INTERRUPT | SA NOMASK | SA ONESHOT }, {SIG DFL}) = 0
41,45c41,45
< getpid()
                                           = 476
                                           = 476
< getpid()
< shmget(718, 240, IPC CREAT | 0)
                                           = 13
< semget(900, 1, IPC CREAT|0x180|0600)
                                           = 12
                                           = 0 \times 40008000
< shmat(13, 0, 0)
___
                                           = 3242
> getpid()
> getpid()
                                           = 3242
> shmget(3484, 240, IPC CREAT | 0)
                                           = 16
> semget(3666, 1, IPC_CREAT|0x180|0600)
                                           = 15
                                           = 0x40008000
> shmat(16, 0, 0)
47c47
< time([1043673566])
                                           = 1043673566
> time([1043777010])
                                           = 1043777010
52c52
< fork()
                                           = 477
> fork()
                                           = 3243
55c55
< semop(0xc, 0x2, 0, 0xbffff990)
                                                            = 0
> semop(0xf, 0x2, 0, 0xbffff9a0)
                                                             = 0
```

```
57c57
< semop(0xc, 0x1, 0, 0xbffff990) = 0
---
> semop(0xf, 0x1, 0, 0xbffff9a0) = 0
```

An analysis of the child processes also revealed that processes forked off by atd execute the same system calls as the processes forked by lokid. The system calls executed by the child processes of both daemons are shown in Figure 1-11.

The next step, after having proved that the binaries execute identical system calls, was to test if they had the same command line options and behave similarly when a client connects. I parsed the source code for lokid to determine the command line options. The snippet of source code that defines the command line arguments is shown in Figure 1-16.

Figure 1-16:lokid source code with command line args.

```
while ((c = getopt(argc, argv, "v:p:")) != EOF)
 {
    switch (c)
    {
      case 'v':
                      /* change verbosity */
        verbose = atoi(optarg);
        break:
      case 'p':
                       /* choose transport protocol */
        switch (optarg[0])
        {
           case 'i':
                        /* ICMP ECHO / ICMP ECHOREPLY */
             prot = IPPROTO_ICMP;
             break:
           case 'u':
                         /* DNS query / reply */
             prot = IPPROTO_UDP;
             break:
```

According to the source code, the loki daemon has two command line arguments.

- -v (1|0) Specifying this option and the number 1 or 0 gives more or less verbose output when the daemon is running
- -p Specifies which transport protocol to use for client/server communication
 - -i use ICMP (ECHO/ECHO_REPLY packets)
 - –u use UDP (DNS query reply packet)

I ran the atd binary with a command line option of "-h" to see if it printed out its command line options. (shown in Figure 1-17)

Figure 1-17: running atd with –h command line argument

```
#./atd -h
    ./atd: illegal option -- h
    lokid -p (i|u) [ -v (0|1) ]
```

The atd binary prints out the available command line arguments that are expected from the lokid binary as seen in the source code in Figure 1-16. It also states that the name of the program is lokid when displaying the command line arguments.

The atd and lokid binaries require that they be run as root. Root, also known as "Super User" is the highest privilege of user on a UNIX system and is used as an administrative account to run and control all system processes. The root account will always have a UID of 0. Line 50 of lokid.c contains the code below that checks if the UID and EUID of the user is 0.

if (geteuid() || getuid()) err exit(0, 1, 1, L MSG NOPRIV);

The error message returned when a non-root user executes it is defined on line 239 the loki.h header file shown below.

```
#define L_MSG_NOPRIV "\n[fatal] invalid user identification
value"
```

This is an important point because the intruder would have needed root privileges to start the atd program. Both atd and lokid produced the same error when I attempted to run them as a non-root user (shown in Figure 1-18)

Figure 1-18: Attempting to run atd and lokid as non-root user

```
# ./atd
[fatal] invalid user identification value: Success
```

I then started the atd process using the command line arguments to enable verbose output (-v) and UDP transport (-p u), and connected to the daemon using the loki client. (See Figure 1-17). From the client, I sent the /stat LOKI protocol command to get a status of the connection. The /stat confirmed that the loki client was communicating with the atd process using UDP transport and XOR encryption.

Figure 1-17: Client connect to atd running w/UDP transport

```
Localhost:# ./atd -v 1 -p u
localhost:# loki -d localhost -v 1 -p u
LOKI2 route [(c) 1997 guild corporation worldwide]
loki> /stat
lokid version: 2.0
remote interface: 127.0.0.1
active transport: udp
active cryptography: XOR
server uptime: 1.58 minutes
client ID: 7977
packets written: 5
bytes written: 5
bytes written: 420
requests: 1
loki> /quit
```

To further determine if the atd and lokid processes behaved identically, I compared the output of netstat and lsof when each of the programs was running. The netstat command shows the status of network connections and listening sockets. The lsof utility lists open files and sockets that specific processes are accessing. By comparing the output of these utilities, I was able to determine that the lokid and atd processes both referenced and opened the same raw sockets as shown in Figure 1-18 and 1-19. Figure 1-18 shows the raw sockets both processes opened when running with ICMP as the transport protocol (using netstat). Figure 1-19 shows the raw sockets both processes opened when running with the UDP transport protocol (using netstat).

Figure 1-18: netstat output with atd and lokid running (ICMP)

# netst	at -a			
 raw	0	0 *:255	*:*	
raw	0	0 *:1	* • *	
.				

Figure 1-19: netstat output with atd and lokid running (UDP)

raw	0	0 *:17	* :*

The output of the lsof command related to the atd and lokid binaries running (shown in Figures 1-20 and 1-21) also show that the two daemons execute identically and reference the same raw sockets.

lokid	3196	root	cwd	DIR	3,1	1024	77521	
lokid	3196	root	rtd	DIR	3,1	1024	2	
[0301] lokid	3196	root	txt	REG	3,1	15784	77561	
[0301] lokid	3196	root	1u	CHR	4,1		6358	
[0301] lokid	3196	root	2u	CHR	4,1		6358	
[0301] lokid	3196	root	311	raw			205621	
00000000:00	001->000 3196	000000 root	:0000	st=07			205622	
00000000:00)FF->00	000000	:0000	st=07			203022	

Figure 1-20 lsof output with atd and lokid

Figure 1-21: I	sof output with	atd running.
----------------	-----------------	--------------

atd	3085	root	cwd	DIR	3,1	1024	77521	
atd	3085	root	rtd	DIR	3,1	1024	2	
[0301] atd	3085	root	txt	REG	3,1	15348	48981	
[0301] atd	3085	root	1u	CHR	4,1		6358	
[0301] atd	3085	root	2u	CHR	4,1		6358	
[0301] atd	3085	root	311	raw			204804	
00000000:0	001->00	000000	:0000	st=07			201001	
ata 00000000:0	3085)0FF->0(root)000000	4u :0000	raw st=07			204805	

The ELF binary structure has several sections (See the document "Tool interface Standards, Portable Formats Specification, Ver 1.1. "Executable and Linking Format (ELF)" for specific details.) Every ELF binary begins with a header that contains information about the binary including the byte order, entry point, and location of section header table etc. (see Appendix 1-1 for specific header) The entry point is the virtual address in the binary where the system transfers control to upon execution of the binary. The section header contains the byte offset within the file of each of the internal sections. These sections each contain information for different functions within the ELF binary. The .comments section for example, contains information about the compiler used to compile the binary (See Figure 1-9). The .dynsym section contains information about dynamic linking objects, for example information about how to resolve references (to local or global functions). By comparing the contents of

the sections of the atd and lokid binaries, I was able to gather more evidence proving that the two binaries were functionally identical.

I ran the readelf -a command to dump the information stored in all sections both binaries. (The full output of readelf -a atd is shown in Appendix 1-1). Upon comparing the output of the readelf command on each of the two binaries, I determined that they contained the same sections, and the references stored in the all the sections were identical, proving that the binaries were functionally identical.

There were some notable differences between the two binaries shown in Figure 1-22 (not a complete list of differences, just representative of all the key differences)

```
Figure 1-22: Notable differences in readelf output
```

```
atd bianry:
    Entry point address: 0x8048db0
    Start of section headers: 14508 (bytes into file)
    Dynamic segment at offset 0x3644
Lokid binary:
    Entry point address: 0x8048d90
    Start of section headers: 14944 (bytes into file)
    Dynamic segment at offset 0x36bc
```

The entry points were slightly different, and the offset locations of the internal sections were at different locations within each of the files. Both of these are acceptable differences and don't negate the conclusion that the binaries are functionally identical based on the following facts:

- The Whirlwind Tutorial on Creating Really Teensy ELF Executables for Linux" document states ".....Almost any [entry] address can be used as long as it's above 0x00000000, below 0x80000000 and page aligned."
- The "Executable and Linking Format(ELF)" document states "sections and segments have no specified order. Only the ELF header has a fixed position in the file."

These differences in the binaries could have been caused by differences in the compiler, linker or assembler used to compile them both.

Program Identification Summary:

Through the previous analysis, I have determined that the <code>atd</code> binary that was retrieved from the compromised system is LOKID v2.0. I was unable to compile the LOKID v2.0 daemon from source code and match the file size and MD5 checksum of the <code>atd</code> binary. I installed the same version of the compiler that was used to compile the <code>atd</code> binary, and I was still unable to match my compiled

version to the file size. This slight difference in size may be attributed to compiling the source with a different version of the libc5 library than was used to compile atd.

Although I was unable to compile the LOKID source and match the file size of atd, I am able to prove that the atd binary behaves exactly as the lokid binary does in the following ways:

- The binaries are both 32-bit ELF executable compiled for the Intel 80386 architecture, dynamically linked, and stripped
- They are both only linked against the /lib/libc.so.5 shared library
- They contain nearly identical strings data.
- The system calls executed by the binaries are identical
- The system calls executed by the child processes of the binaries are identical.
- The binaries have the same command line arguments, and the atd process identifies itself as lokid when querying the command line arguments.
- Both the atd and lokid process must be run as root user (UID 0), and give the same error when run as non-privileged user.
- The loki client communicates with the atd daemon process with both ICMP and UDP as it were the loki daemon.
- The output of the netstat command shows identical open raw sockets.
- The output of the lsof command shows identical process and open socket information
- readelf shows identical information in all sections of the ELF binary (except for noted acceptable differences)

Legal Implications:

In my forensic analysis I was unable to get forensic information from the compromised system that would have shown that the unknown binary had been executed on that system. The process of zipping them up for my analysis altered the MAC times of the binary, which can sometimes be used to determine if/when the binary was executed. I was able to prove that the binary is the LOKID2 "covert channel" backdoor, which allows unauthorized access to the system and I was able to prove that a user needs root privileges to run the daemon. Executing the binary on the compromised system, could have been a violation of the Computer Fraud and Abuse Act (18 U.S.C §1030), which criminalizes "unauthorized access" or "damage" to a "protected computer".

A protected computer is defined in §1030(e)(2) as computers:

- "Exclusively for the use of a financial institution or the United States Government"
- "used in interstate or foreign commerce or communication"

Essentially every computer connected to the Internet in the U.S. is considered a protected computer. The compromised system is not a U.S.

government system, so in order for the binary running on the compromised system to be considered a crime under §1030, the intruder would have had to have done one of the following:

- caused damage in excess of \$5,000 dollars in a 1 year period (can be aggregated to include damage to other systems by same intruder),
- caused impairment of medical records
- caused physical injury to a person
- posed a threat to public safety

Other evidence would have to be gained to determine if the intruder was in violation of §1030, the presence of the binary on the system is not enough to prove it.

If the intruder was found to be in violation of §1030 one of the penalties listed in §1030 (c) would apply. The penalties range from 1 year imprisonment and a fine, all the way up to a fine and 20 years imprisonment depending on the severity and number of violations.

The compromised system resides at my employer's location in Massachusetts, therefore Massachusetts computer crime laws apply as well. The individual who installed and ran the LOKI daemon binary would be in violation of Massachusetts General Law (M.G.L) 266 §120F, which states: "Whoever, without authorization, knowingly accesses a computer system by any means, or after gaining access to a computer system by any means knows that such access is not authorized and fails to terminate such access, shall be punished by imprisonment in the house of correction for not more than thirty days or by a fine of not more than one thousand dollars, or both. The requirement of a password or other authentication to gain access shall constitute notice that access is limited to authorized users."

The intruder would also be in violation of M.G.L 226 §33A, which states: "Whoever, with intent to defraud, obtains, or attempts to obtain, or aids or abets another in obtaining, any commercial computer service by false representation, false statement, unauthorized charging to the account of another, by installing or tampering with any facilities or equipment or by any other means, shall be punished by imprisonment in the house of correction for not more than two and one-half years or by a fine of not more than three thousand dollars, or both. As used in this section, the words ""commercial computer service" shall mean the use of computers, computer systems, computer programs or computer networks, or the access to or copying of the data, where such use, access or copying is offered by the proprietor or operator of the computer, system, program, network or data to others on a subscription or other basis for monetary consideration."

Based on my research it would be easier to prove that the individual who installed the atd binary on the system was in violation of M.G.L 226 §33a and §120F than it would be to prove they were in violation of U.S.C §1030.

The atd binary allows unauthenticated, unauthorized remote access to the host computer. In addition, the user has to run the atd program as root, indicating that they exceeded their privileges on the system and would therefore be in violation of state law, but none of the criteria for a Federal violation can be proven.

Interview questions:

As part of my job, I occasionally interview students who have violated our Computer and Network Acceptable Use Policies as part of the University's disciplinary process. Experience from these interviews has taught me that people respond differently to the interview process and it's important to be prepared and well informed before the interview. Furthermore, it's important to have a plan for dealing with different scenarios that may come up during the course of the interview.

In the process of interviewing the individual who installed LOKID2 on the system, I would take the following approach:

I start the interview off by taking a moment to look over my notes and the printouts of evidence such as logfiles etc. The interviewees are not allowed to see the contents of the notes or evidence, but it gives them the sense that I have concrete evidence against them. I begin by asking simple questions, for example:

What type of computer is your personal system?,

What operating system are you running on your personal computer? These questions give me a sense of their level of knowledge and a sense of how they might react to the situation. Their answers to the simple questions help me gauge if they are going to be arrogant, talkative, defensive, combative or helpful and willing to cooperate. I take different approaches to the interviews depending on how they respond.

The next step I usually take is to ask an open-ended question such as, "why do you think I have asked to speak with you today?" Some interviewees know why they are being interviewed, think I have undisputable evidence against them, tell me everything, apologize and swear it will never happen again. Those interviews are easy, but they seldom go that way. When they claim to not know why they are being interviewed, I often take the approach of: "I have some evidence here indicating that you have been involved in an incident on one of our computer systems and I'd like to speak with you to see if perhaps we've misinterpreted this incident. I appreciate any information you may be able to give me to help sort this out. Right now it looks pretty bad, but I'm hoping that we can resolve this issue here so it doesn't have to go before the Dean of Students Judicial Board or the University Police."

This gives the interviewee the sense that it's bad, and I am there to help. It perhaps gives them a chance to explain to someone who is willing to listen and understand.

I would then proceed to throw out a little information that I know and give the interviewee a chance to explain. "*I found an interesting program in your home directory, could you please explain why it's there?*" The intention with that question is to see if the interviewee will tell you he/she owns the binary and if he/she ran the binary.

Another approach is to say "*I've found a backdoor program in your home directory, could you please not run it anymore, it's causing problems on the system.*" This sets the stage for the interviewee to confirm that he/she ran the backdoor program.

Some of the more arrogant interviewees have the need to prove their computer skills, so questions such as "*That back door was easy to spot, did you think we wouldn't notice? Is that the best you could do?*" Sometimes in defending their knowledge of computers they admit to running the program and may also tell why.

The key things to keep in mind when interviewing are that you're going to have to find the angle to coerce information from the subject. Sometimes it is a matter of acting understanding as an interviewer, or insist that they can help by telling you everything, and sometimes you can gain information by making the subject defensive. It varies depending on the interview subject and it's important to be prepared for whatever information may come out of the interview.

Additional information:

I used several online resources to research reverse engineering techniques and tools that I used to analyze the unknown binary. I found the following URLs, which describe reverse engineering techniques in detail, on the Honeynet Reverse Challenge page.

http://www.honeynet.org/reverse/sol/sol-06/analysis.html http://www.honeynet.org/reverse/sol/sol-21/analysis.html

The following references give great insight into the format of the ELF binary. Tool interface Standards, Portable Formats Specification, Ver 1.1. "Executable and Linking Format (ELF)" http://www.skyfree.org/linux/references/ELF_FORMAT.pdf

Raiter, Brian. "A Whirlwind Tutorial on Creating Teensy ELF Executables for Linux" 21 Jan 2003 http://www.muppetlabs.com/~breadbox/software/tiny/teensy.html

See the References section below for a full listing of sources to gather more information.

References:

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18 U.S.C §1030 http://www4.law.cornell.edu/uscode/18/1030.html

And the state of t Zalewski, Michal. 29 Nov 2002 http://lcamtuf.coredump.cx/fenris/reverse.txt

Appendix 1-1: readelf output of unknown binary

ELF Header:									
Magic: 7f 45 4c 46 0	1 01 01 00 0	00 00 00 00 00	00 00 0	00					
Class:		ELF32							
Data:		2's complement, little endian							
OG/ART.		I (Current)	n 77						
ABI:		ONIX - Syster	ll V						
ABI VEISION.		U EVEC (Evocut:	blo fi	10)					
Type. Machine:		Thtol 00206	ADIE II.	TC)					
Machine.		111LEI 00300 0v1							
Entry point address.		0x1 0x8048db0							
Start of program heade	re•	52 (bytes int	to file)					
Start of section heade	rs.	14508 (bytes	into f	, ile)					
Flags.	10.	0x0	11100 11	110)					
Size of this header		52 (bytes)							
Size of program header	s:	32 (bytes)							
Number of program head	ers:	5							
Size of section header	s:	40 (bytes)							
Number of section head	ers:	21							
Section header string	table index:	20							
Section Headers:									
[Nr] Name	Туре	Addr	Off	Size	ΕS	Flg			
Lk Inf Al									
[0]	NULL	00000000	000000	000000	00				
0 0 0									
[1] .interp	PROGBITS	080480d4	0000d4	000013	00	A			
					~ •	_			
[2].hash	HASH	080480e8	0000e8	0001a4	04	A			
3 0 4	DVMOVM	0004000-	00000-	000400	10	7			
	DINSIM	U8U4828C	000280	000420	ΤŪ	А			
[4] dynstr	פייסשאם	08048620	000620	000210	00	7			
	SIRIAD	000400ac	0000ac	000210	00	Л			
[5] rel bss	REI.	080488bc	0008bc	000020	0.8	Δ			
3 11 4		000100000	0000000	000020	00	11			
[6].rel.plt	REL	080488dc	0008dc	000190	08	А			
3 8 4									
[7].init	PROGBITS	08048a70	000a70	000008	00	AX			
0 0 16									
[8] .plt	PROGBITS	08048a78	000a78	000330	04	AX			
0 0 4									
[9] .text	PROGBITS	08048db0	000db0	001b28	00	AX			
0 0 16									
[10] .fini	PROGBITS	0804a8e0	0028e0	000008	00	AX			
0 0 16									
[11] .rodata	PROGBITS	0804a8e8	0028e8	000c3c	00	A			
0 0 4									
[12] .data	PROGBITS	0804c528	003528	000038	00	WA			
0 0 4									
[13] .ctors	PROGBITS	0804c560	003560	000008	00	WA			
0 0 4									

PROGBITS 0804c568 003568 000008 00 WA [14] .dtors 0 0 4 0804c570 003570 0000d4 04 WA [15] .got PROGBITS 0 0 4 DYNAMIC 0804c644 003644 000088 08 WA [16] .dynamic 4 0 4 [17] .bss NOBITS 0804c6cc 0036cc 00012c 00 WA 0 0 8 [18] .comment PROGBITS 0000000 0036cc 0000a0 00 \cap 0 1 [19] .note NOTE 000000a0 00376c 0000a0 00 0 0 1 [20] .shstrtab STRTAB 00000000 00380c 0000a0 00 0 0 1 Key to Flags: W (write), A (alloc), X (execute), M (merge), S (strings) I (info), L (link order), G (group), x (unknown) O (extra OS processing required) o (OS specific), p (processor specific) Program Headers: Type Offset VirtAddr PhysAddr FileSiz MemSiz Flq Aliqn 0x000034 0x08048034 0x08048034 0x000a0 0x000a0 R E 0x4 PHDR INTERP 0x0000d4 0x080480d4 0x080480d4 0x00013 0x00013 R 0x1 [Requesting program interpreter: /lib/ld-linux.so.1] LOAD 0x000000 0x08048000 0x08048000 0x03524 0x03524 R E 0x1000 0x003528 0x0804c528 0x0804c528 0x001a4 0x002d0 RW LOAD 0x1000 0x003644 0x0804c644 0x0804c644 0x00088 0x00088 RW 0x4 DYNAMIC Section to Segment mapping: Segment Sections... 00 01 .interp 02 .interp .hash .dynsym .dynstr .rel.bss .rel.plt .init .plt .text .fini .rodata 03 .data .ctors .dtors .got .dynamic .bss 04 .dynamic Dynamic segment at offset 0x3644 contains 17 entries: Taq Type Name/Value 0x0000001 (NEEDED) Shared library: [libc.so.5] 0x000000c (INIT) 0x8048a70 0x000000d (FINI) 0x804a8e0 0x0000004 (HASH) 0x80480e8 0x0000005 (STRTAB) 0x80486ac 0x0000006 (SYMTAB) 0x804828c 0x0000000a (STRSZ) 528 (bytes) 0x000000b (SYMENT) 16 (bytes) 0x0000015 (DEBUG) 0x0 0x0000003 (PLTGOT) 0x804c570 0x0000002 (PLTRELSZ) 400 (bytes) 0x00000014 (PLTREL) REL 0x0000017 (JMPREL) 0x80488dc 0x00000011 (REL) 0x80488bc

0x000000	12 (RELSZ	32 (bytes)							
0x000000	1.3 (RELEN'	(RELENT) 8 (bytes)							
0x000000	00 (NULL)	- /		0×0					
07000000				0210					
Relocatio	n section	'.rel.bss'	at off:	set 0x8bc	contains 4 entries:				
Offset	Info	Туре		Sym.Value	Sym. Name				
0804c6d8	00001005	R 386 COPY		0804c6d8	IO stderr				
0804c72c	00001405	R 386 COPY		0804c72c	optarg –				
0804c730	00002205	R 386 COPY		0804c730	fpu control				
0804c6d0	00003d05	R 386 COPY		0804c6d0	errno				
Relocatio	n section	'.rel.plt'	at off:	set 0x8dc	contains 50 entries:				
Offset	Info	Туре		Sym.Value	Sym. Name				
0804c57c	00000107	R_386_JUMP	SLOT	08048a88	longjmp				
0804c580	00000207	R_386_JUMP	SLOT	08048a98	strcpy				
0804c584	00000307	R 386 JUMP	SLOT	08048aa8	ioctl				
0804c588	00000407	R 386 JUMP	SLOT	08048ab8	popen				
0804c58c	00000507	R 386 JUMP	SLOT	08048ac8	shmctl				
0804c590	00000607	R 386 JUMP	SLOT	08048ad8	geteuid				
0804c594	00000807	R 386 JUMP	SLOT	08048ae8	🔍 getprotobynumber				
0804c598	00000a07	R 386 JUMP	SLOT	08048af8	strtol internal				
0804c59c	00000b07	R 386 JUMP	SLOT	08048b08	usleep				
0804c5a0	00000c07	R 386 JUMP	SLOT	08048b18	semget				
0804c5a4	00000d07	R 386 JUMP	- SLOT	08048b28	getpid				
0804c5a8	00000e07	R 386 JUMP	SLOT	08048b38	faets				
0804c5ac	00000f07	R 386 JUMP	SLOT	08048b48	shmat				
0804c5b0	00001107	R 386 JUMP	SLOT	08048558	perror				
0804c5b4	00001207	R 386 JUMP	SLOT	0804868	getuid				
0804c5b8	00001207	R 386 TIMP		08048b78	semati				
0804c5bc	00001507	D 386 TIMD		08048588	sockot				
08040500	00001307	D 386 TIMD	_STOT	08048598	bzoro				
08040500	00001707	D 386 TIMD	STOT	08048658	alarm				
08040504	00001907	P 386 TIMP	STOT TOTC	08040Da0	liba init				
08040508	00001a07			000000000					
08040500	00001207	R_386_JUMP		08048008					
08040500	00001007	R_386_JUMP	_SLOT	08048008					
08040504	00001607	R_386_JUMP	_SLOT	08048068	inet_addr				
08040508	00001107	R_386_JUMP	_SLOT	08048018	chair				
0804C5aC	00002007	R_386_JUMP	SLOT	08048C08	shmat				
0804c5e0	00002107	R_386_JUMP	_SLOT	08048c18	setsockopt				
0804c5e4	00002307	R_386_JUMP	SLOT	08048C28	snmget				
0804c5e8	00002407	R_386_JUMP	_SLOT	08048c38	walt				
0804c5ec	00002507	R_386_JUMP	_SLOT	08048c48	umask				
0804c510	00002607	R_386_JUMP	_SLOT	08048c58	signal				
0804c5f4	00002707	R_386_JUMP	_SLOT	08048c68	read				
0804c5f8	00002807	R_386_JUMP	_SLOT	08048c78	strncmp				
0804c5fc	00002907	R_386_JUMP	SLOT	08048c88	sendto				
0804c600	00002a07	R_386_JUMP	SLOT	08048c98	bcopy				
0804c604	00002b07	R_386_JUMP	SLOT	08048ca8	fork				
0804c608	00002c07	R_386_JUMP	SLOT	08048cb8	strdup				
0804c60c	00002d07	R_386_JUMP	SLOT	08048cc8	getopt				
0804c610	00002e07	R_386_JUMP	SLOT	08048cd8	inet_ntoa				
0804c614	00002f07	R_386_JUMP	SLOT	08048ce8	getppid				
0804c618	00003007	R_386_JUMP	SLOT	08048cf8	time				
0804c61c	00003107	R 386 JUMP	SLOT	08048d08	gethostbyname				
0804c620	00003307	R 386 JUMP	SLOT	08048d18	sprintf				
0804c624	00003407	R 386 JUMP	SLOT	08048d28	difftime				
0804c628	00003507	R_386_JUMP	SLOT	08048d38	atexit				

0804c62c	00003707	/ R 38	36 JUMP :	SLOT	08048d48	ser	nop
0804c630	00003807	' R 38	36 JUMP	SLOT	08048d58	ex	it
0804c634	00003907	' R 38	36 JUMP	SLOT	08048d68	5	setfpucw
0804c638	00003a07	' R 38	36 JUMP	SLOT	08048d78	 ope	en
0804c63c	00003b07	7 R 38	36 JUMP	SLOT	08048d88	set	tsid
0804c640	00003c07	7 R 38	36 JUMP	SLOT	08048d98	cld	ose
		—					
There are	e no unwir	nd sea	ctions in	n this	file.		
Symbol t	able ' dvr	svm'	contain	s 66 en	tries.		
Num:	Value	Size	Type	Bind	Vis	Ndx	Name
0.	00000000	0	NOTYPE	LOCAL	DEFAILT	UND	Traine S
1.	08048a88	0 0	FUNC	GLOBAL	DEFAULT	UND	longimp
2.	08048a98	30	FUNC	GLOBAL	DEFAILT	UND	strony
2.	08048aa8	0	FUNC	MEVK	DEFAILT	UND	ioctl
3 . 4 •	08048ab8	0	FUNC	WEAK	DEFAILT	UND	popen
5.	08048ac8	42	FUNC	GLOBAL	DEFAILT	UND	shmct1
5. 6.	08048ad8	12	FUNC	MEVK	DEFAILT	UND	geteuid
7.	08040644	0	OBJECT	GLOBAL	DEFAILT	ABS	DVNAMIC
, . 8 .	08048208	292	FUNC	CIOBAI		LIND	
0. Q.	080404640	292 1	NOTVET	GLODAL		17	orrno
9. 10.	08042040	1132	FUNC				errico intornal
11.	00040410	1132	FUNC	CIODAL	DEFAULI	UND	
12.	00040000	10	FUNC	GLODAL	DEFAULI	UND	usieep
12:	08048018	42	FUNC	GLOBAL	DEFAULT	UND	sengel
13:	08048028	0	FUNC	WEAK	DEFAULT	UND	gelpia facto
14:	08048038	0	FUNC	WEAK	DEFAULT	UND	Igets
15:	08048648	59	FUNC	GLOBAL	DEFAULT	UND	shmat
16:	0804668	84	OBJECT	GLOBAL	DEFAULT	/ ⊥	_10_stderr_
1/:	08048658	0	FUNC	WEAK	DEFAULT	UND	perror
18:	08048668	0	FUNC	WEAK	DEFAULT	UND	getuid
19:	08048678	4 /	FUNC	GLOBAL	DEFAULT	UND	semctl
20:	0804c72c	4	OBJECT	GLOBAL	DEFAULT	17	optarg
21:	08048688	94	FUNC	WEAK	DEFAULT	UND	socket
22:	0804c528	4	OBJECT	GLOBAL	DEFAULT	12	environ
23:	08048b98	54	FUNC	GLOBAL	DEFAULT	UND	bzero
24:	08048a70	0	FUNC	GLOBAL	DEFAULT	7	_init
25:	08048ba8	0	FUNC	WEAK	DEFAULT	UND	alarm
26:	08048bb8	70	FUNC	GLOBAL	DEFAULT	UND	libc_init
27:	0804c528	4	NOTYPE	WEAK	DEFAULT	12	environ
28:	08048bc8	0	FUNC	WEAK	DEFAULT	UND	fprintf
29:	08048bd8	0	FUNC	WEAK	DEFAULT	UND	kill
30:	08048be8	57	FUNC	GLOBAL	DEFAULT	UND	inet_addr
31:	08048bf8	0	FUNC	WEAK	DEFAULT	UND	chdir
32:	08048c08	36	FUNC	GLOBAL	DEFAULT	UND	shmdt
33:	08048c18	111	FUNC	WEAK	DEFAULT	UND	setsockopt
34:	0804c730	2	OBJECT	GLOBAL	DEFAULT	17	fpu_control
35:	08048c28	42	FUNC	GLOBAL	DEFAULT	UND	shmget
36:	08048c38	0	FUNC	WEAK	DEFAULT	UND	wait
37:	08048c48	0	FUNC	WEAK	DEFAULT	UND	umask
38:	08048c58	84	FUNC	GLOBAL	DEFAULT	UND	signal
39:	08048c68	0	FUNC	WEAK	DEFAULT	UND	read
40:	08048c78	38	FUNC	GLOBAL	DEFAULT	UND	strncmp
41:	08048c88	124	FUNC	WEAK	DEFAULT	UND	sendto
42:	08048c98	146	FUNC	GLOBAL	DEFAULT	UND	bcopy
43:	08048ca8	0	FUNC	WEAK	DEFAULT	UND	fork
44:	08048cb8	79	FUNC	GLOBAL	DEFAULT	UND	strdup
45:	08048cc8	44	FUNC	GLOBAL	DEFAULT	UND	getopt

46:	08048cd8	67	FUNC	GLOBAL	DEFAULT	UND	inet_ntoa
47:	08048ce8	0	FUNC	WEAK	DEFAULT	UND	getppid
48:	08048cf8	0	FUNC	WEAK	DEFAULT	UND	time
49:	08048d08	292	FUNC	GLOBAL	DEFAULT	UND	gethostbyname
50:	0804a8e0	0	FUNC	GLOBAL	DEFAULT	10	fini
51:	08048d18	38	FUNC	WEAK	DEFAULT	UND	sprintf
52:	08048d28	16	FUNC	GLOBAL	DEFAULT	UND	difftime
53:	08048d38	52	FUNC	GLOBAL	DEFAULT	UND	atexit
54:	0804c570	0	OBJECT	GLOBAL	DEFAULT	ABS	
_GLOBAL	OFFSET_TA	ABLE_					
55:	08048d48	42	FUNC	GLOBAL	DEFAULT	UND	semop
56:	08048d58	128	FUNC	GLOBAL	DEFAULT	UND	exit
57:	08048d68	62	FUNC	GLOBAL	DEFAULT	UND	setfpucw
58:	08048d78	0	FUNC	WEAK	DEFAULT	UND	open
59:	08048d88	0	FUNC	WEAK	DEFAULT	UND	setsid
60:	08048d98	0	FUNC	WEAK	DEFAULT	UND	close
61:	0804c6d0	4	OBJECT	GLOBAL	DEFAULT	17	errno
62:	0804a8d8	0	OBJECT	GLOBAL	DEFAULT	ABS	etext
63:	0804c6cc	0	OBJECT	GLOBAL	DEFAULT	ABS	edata
64:	0804c6cc	0	OBJECT	GLOBAL	DEFAULT	ABS	bss_start
65 :	0804c7f8	0	OBJECT	GLOBAL	DEFAULT	ABS	end
							_
Histogra	am for buc	cket l:	ist leng	th (tota	al of 37	bucke	ets):
Length	Number	%	of total	Covera	age		
0	9	(2	24.3%)				
1	8	(2	21.6%)	12.39	20		
2	10	(2	27.0%)	43.19	00		
3	4	(1	10.8%)	61.5	20		
4	5	(1	13.5%)	92.39	20		
5	1	(2.7%)	100.09	20		
No vers	ion inform	nation	found i	n this :	file.		

Forensic Analysis of Compromised Linux Host

SANS GCFA Practical Assignment v.1.2 Part 2 - Option 1

Jacob Cunningham

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Syntax Conventions

The text of the document is in 12 point Arial font

Commands executed at the shell, the output of commands, and references to files, directories or system binaries are all in 10 or 12 point Courier New font.

Part 2 – Option 1: Perform Forensic Analysis of a System

Introduction

This section of the paper is a write-up of the results of an in depth analysis of a Linux system that has been compromised. This analysis focuses on using forensic techniques to image the evidence media, and recovering evidence of the intrusion using the TASK and Autopsy forensic tools. Some familiarity with UNIX on the part of the reader is assumed.

Synopsis of Case Facts

The University's network consists of approximately 25,000 nodes connected to the Internet via 355mb/s leased circuit. The residential network accounts for about 50% of the total nodes connected to the campus network. It's somewhat rare for us to get contacted by students who think their systems have been compromised. We, in the networking department often find the compromised systems first when they start scanning for vulnerabilities or attempt a denial of service attack.

A user of the University's residential network contacted me on Oct 10, 2002 because he noticed user accounts on his personal Linux system that he had not created and suspected it had been hacked. The user who contacted me was not very computer savvy, but was observant enough to realize that something odd was happening on his system.

Upon finding the system may have been hacked, the user shut the system down and contacted me. If given a choice I would have preferred to gather some vital information about open network ports, running processes, and the contents of memory on the system before the user shut the system down, but there was still a plethora of forensic evidence to be gathered from the hard disk. I was concerned that the shutdown process may have been trojaned to cover the intruder's tracks.
After speaking to me, the user brought his computer system to my office where I inventoried it, tagged all the components as evidence (See Figure 2-1) and removed the hard disk for imaging.

Evidence Tag #	Description
2002-10-10-1	"Home Built" Generic ATX PC 500 Mhz computer system (no case serial number) with Maxtor 20GB internal hard drive, 3.5" floppy drive, Mitsumi CDROM drive, 3Com 3c905b PCI Ethernet card, ATI Mach 64 PCI video card.
2002-10-10-2	Maxtor 541DX 20GB Ultra ATA/100 – 5400RPM Hard Drive S/N 2B020H1110511
2002-10-10-3	Mitsumi CRMC-FX810S CROM Drive S/N: DPU010136
2002-10-10-4	3Com 3c509b Ethernet card - MAC: 00:10:5a:e5:b4:fa
2002-10-10-5	ATI Mach 64 video card
2002-10-10-6	3.5" floppy

Figure 2-1: Evidence listing and description

The potentially compromised system is a "home built" generic ATX 500MHZ Pentium II PC that was running RedHat Linux 7.0. The user explained that he set the system up to learn more about Linux and do some programming for a class he was taking. He also said he had installed RedHat Linux 7.0 on it, configured it to obtain an IP address via DHCP, and had it connected to the University Ethernet network in his room for only a few days before finding the unknown accounts and suspecting it was compromised. During the course of my investigation I discovered it was a default installation of RedHat 7.0 using kernel version 2.2.16-22. The system had been running several default exploitable daemons and services such as FTP (wu-ftpd-2.6.1), Telnet, rsh, rlogin, portmap and statd.

Imaging the Evidence Disk

The system I created to do the forensic analysis is a PC running RedHat Linux 7.3. I performed a fresh install of the OS on a pristine disk to ensure the security and integrity of the OS before imaging and analyzing the evidence disk. This system has never been connected to the network, and to further ensure the security of the forensic system, no network card was installed. All software was transferred to the system via a known-clean CDROM.

The forensics system has an internal hard disk, a CDROM drive and two removable hard drive bays in the following configuration:

- hda boot disk (primary IDE Master)
- hdb CDROM (primary IDE slave)
- hdc removable drive bay (secondary IDE Master)
- hdd removable drive bay (secondary IDE slave)

The two removable hard drive bays attached to the secondary IDE controller are used to hold the image storage and evidence drives.

I performed the following tasks on the forensic system to create an image of the compromised system for analysis.

- Verified that hdc and hdd did not appear in /etc/fstab on the forensic system, so evidence and storage disks wouldn't be mounted at boot time.
- Placed a single partition 40gb drive with an ext2 filesystem in hdc removable drive bay. This hard drive was then sanitized using the command: # dd if=/dev/zero of=/dev/hdc1
- Set the evidence disk jumper to be a slave and placed the drive in the hdd removable drive bay. I had already confirmed the filesystem would not be mounted, therefore minimizing the risk of it getting altered.
- Booted the forensic system with all the disks installed.
- Generated an MD5 signature of the evidence partitions to compare against the MD5 signature of the resulting images. md5sum calculates a hash of binary data using the MD5 hashing algorithm (as described in RFC 1321). This MD5 hash or checksum of the data is unique only to that data. If the data is modified, the MD5 calculation will not match the previous one. For all practical purposes it is impossible for two different pieces of data or files to have the same MD5 checksum. Consistently reproducing the same MD5 checksum for the same piece of data proves that the data has not been modified. It is important to create the md5 checksum before performing any operations on the evidence. Verifying matching MD5 checksums prove that the operations performed to image the media did not alter the original evidence in any way.

md5sum /dev/hdd6
691560c798eb212ec5e750af5753c788 /dev/hdd6
md5sum /dev/hdd5
835ba3f211ede3e529634997aafc7afe /dev/hdd5

- Mounted the sanitized image storage disk. This makes the hdc1 evidence storage partition available to the filesystem in the directory /images.
 # mount /dev/hdc1 /images
- Obtained a partition listing of evidence disk using /sbin/fdisk. This command provides information about the layout and type of the disk partitions without altering the contents of the disk. The evidence disk is a 20GB Maxtor hard drive (show in Figure 2-2 as hdd) with one large partition for the OS and a smaller one for swap space.

Figure 2-2: fdisk output

```
# fdisk -l /dev/hdd
Disk /dev/hdd: 255 heads, 63 sectors, 2491 cylinders
Units = cylinders of 16065 * 512 bytes
Device Boot Start End Blocks Id System
/dev/hdd2 4 2491 19984860 5 Extended
/dev/hdd5 2338 2370 265041 82 Linux swap
/dev/hd6 4 2337 18747792 83 Linux
```

- Imaged main partition and swap space of the evidence disk to a file on storage disk using dd. dd is a Unix command used to copy or convert files from one location or device to another.
 - # dd if=/dev/hdd6 of=/images/sans-hdd6.img
 # dd if=/dev/hdd5 of=/images/sans-hdd5-swap.img
- Generated an MD5 signature of evidence image file and compared the hash of the image against the original. The md5 checksums match proving the image is identical to the original partition.

```
# md5sum /images/sans-hda6.img
691560c798eb212ec5e750af5753c788 sans-hda6.img
# md5sum /images/sans-hdd5-swap.img
```

835ba3f211ede3e529634997aafc7afe sans-hdd5-swap.img

• I shutdown the forensics system and removed the evidence disk to minimize chance of corrupting or writing to the original evidence disk and then rebooted the forensics system to begin the analysis.

To protect the evidence hard drive, I placed it in an anti-static bag, and tagged the outside of the bag with the same evidence number that was on the drive (2002-10-10-2) with my signature and the date. I then locked the hard drive in my media safe, which is only accessible to my department's security officer and myself, and signed and dated the log book which is used for tracking all the items that are housed in the safe. The security officer and I have a clearly established protocol for adding and removing items from the safe, which includes tracking the location of the item in the log book. Maintaining this chain of custody ensured that the evidence disk did not get tampered with and its location was always known. This is one important piece of maintaining the integrity of the original evidence if it is questioned in a court of law.

Analyzing the Image with TASK and Autopsy

For the analysis of this potentially compromised system, I downloaded and compiled the latest version of forensics tools that I prefer to use.

Autopsy Forensic Browser v1.62 http://www.atstake.com/research/tools/autopsy/

TASK – The @Stake Sleuth Kit v1.52 http://www.atstake.com/research/tools/task/

The Coroner's Toolkit (TCT) is a package used for analyzing filesystems, file system images and recovering deleted files. Although TASK (The @Stake Sleuth Kit) is built upon TCT, I prefer to use TASK because of the added functionality it has over TCT. Specifically it has support for analyzing the Windows filesystems (FAT, NTFS) as well as UFS and ext2, this gives the examiner the advantage of using the same tools regardless of the filesystem type being analyzed. The Autopsy Forensic Browser is an HTML based front-end which employs the web browser as an interface to the TASK tools.

The evidence system disk had been formatted with an ext2 filesystems, which is common for that version of Linux. In an ext2 filesystem, files on the disk are described by inodes and the data is stored on the disk in data blocks. A general overview of inodes is best described by the document "Design and Implementation of the Second Extended Filesystem" found at http://e2fsprogs.sourceforge.net/ext2intro.html

This document states:

"Each file is represented by a structure, called an inode. Each inode contains the description of the file: file type, access rights, owners, timestamps, size, pointers to data blocks. The addresses of data blocks allocated to a file are stored in its inode. When a user requests an I/O operation on the file, the kernel code converts the current offset to a block number, uses this number as an index in the block addresses table and reads or writes the physical block."

The tools contained in TASK can be used to view inode information for existing and deleted files and extract information from the physical disk blocks containing those existing and previously deleted files. This gives the examiner the ability to effectively un-delete and view the contents of any file and all of its attributes.

The first step in preparing the image for analysis was to mount the image to a mount point on the filesystem. To protect from modifying the evidence image and analysis system, I passed specific options to the mount command using the $-\circ$ flag (See Figure 2-3)

 \mathtt{ro} – mount the image read-only. This disallows anything from writing to the image.

loop – mounts the image as a loopback device, which allows the image to be mounted as a filesystem.

nodev – prevents character and block devices in the image from being treated as devices by the analysis system.

 ${\tt noexec}$ - disallows the execution of any binaries in the image filesystem on the analysis system.

Figure 2-3: Mounting the image

```
mkdir /mnt/image
mount -o ro,loop,nodev,noexec /images/sans-hda6.img
/mnt/image
```

The next step was to edit the fsmorgue file in the Autopsy working directory to specify the name of the image, what type of filesystem it is, where it was mounted, and the time zone the imaged system was configured to use. This prepares Autopsy for the type of image it is analyzing. Figure 2-4: fsmorge file

fsmorgue file for Autopsy Forensic Browser
sans-hda6.img linux-ext2 / EST5EDT

I then started Autopsy with the following command.

```
# usr/local/src/autopsy-1.62/autopsy -m /images 888
localhost
```

This starts autopsy listening on port 888 of the localhost and uses /images as the morgue directory where it stores the body and timeline files. The autopsy sessions was then accessed by pointing a browser at the URL autopsy generated on the localhost. Although the Autopsy process is operating on a network port (888/tcp), it is inaccessible to anyone else because there is no network card in the system.

After Autopsy was running and reading the image, the next step was to first create a timeline to see what had changed on the system since the OS was installed. The user claimed to have installed the operating system a few days before noticing the intrusion, but it was necessary to verify this and other information that the user had given me. By verifying this information, such as OS version and the installation time, I could then generate a timeline to see when the alleged intrusion occurred.

I created the timeline using the "Timeline" button on the Main Menu in Autopsy. The timeline created by Autopsy gives a chronological visual representation of when all the files on a given filesystem were modified, accessed or changed. The Timeline function of Autopsy executes the following utilities from TASK behind the scenes:

- The fls utility collects the MAC times (the date and time the file was last Modified, Accessed or Changed) of allocated and un-allocated files and writes it to the "body" file with the command:
 # fls -m / -f linux-ext2 -r sans-hda6.img > body
- Ils is then used to generate MAC time information for deleted files and appends that information to the "body" file using the command:

ils -m sans-hda6.img >> body

In Autopsy, I then selected the "Create timeline using body" function. When selecting this, Autopsy gives you the option of inserting the inode location of the /etc/password and /etc/group files so the timeline contains user/group information for files rather than just numerical Ids. I parsed the "body" file using /usr/bin/grep to locate the inodes of the /etc/password and /etc/shadow files.

Figure 2-5: Retrieving inode numbers for /etc/passwd, /etc/group from body file

```
# cat body | grep "/etc/passwd"
0|/etc/passwd|0|195932|33188|-/-rw-r-r-|1|0|0|0|939
|1034194213|1034032865|1034032865|4096|0
# cat body | grep "/etc/group"
0|/etc/group|0|195773|33152|-/-rw----1|0|0|0|492
|1034032812|1033944837|1034032813|4096|0
```

The "Specify" option was used to specify the starting time and ending time of the timeline. The user claimed to have installed the operating system on Oct 6th, and the intrusion was noticed on Oct 9th, so Oct 1st was used as the start date and the current date of Oct. 17th was used as the end of the timeline. I then selected the timezone of the imaged system ("EST") to use in Autopsy and pressed the "Create" button.

Autopsy starts the TASK mactime utility which uses the body, password and group files plus the given date range to create the chronological timeline file as shown:

```
# mactime -p 195932 -g 195773 -b /images/body
10/01/2002-10/17/2002 > timeline
```

The resulting "timeline" file, which is a chronological listing of all the files modified, accessed and changed on the image has the following format: Date/time, size (in bytes), mac (specifies which file attribute M,A,C changed), file permissions, owner, group owner, inode number, filename The example timeline entry in Figure 2-6 shows that the file /tmp/install.log: was 9829 bytes in size, was accessed on Oct 6th at 10:55:51, had UNIX file permissions "rw-r-r—" owned by user/group root/root, was referenced by inode number 162882



```
Sun Oct 6 2002 10:56:44
9829 .a. -/-rw-r--r- root/boby root 162882 /tmp/install.log
```

Before looking over the timeline in detail, I first used the "File Browsing" function of Autopsy. The "File Browsing" function of Autopsy allows the examiner to navigate the disk image as if it were a hierarchical filesystem. I was able to gather information and view the contents of specific files. My intent in browsing the filesystemn was to confirm the information the user had given me about OS version and when the OS was installed, and to gather additional information about the system that might help in the investigation. To gather this information, I examined the following files on the evidence image:

• /etc/issue - From this file I was able to verify the OS version given to me by the user was correct. It contained:

```
Red Hat Linux release 7.0 (Guinness)
Kernel 2.2.16-22 on an i686
```

/tmp/install.log – This file is written when the OS is installed. I checked the MAC times of this file and verified the operating system was installed on Oct 6th as told to me by the user.

M: 2002.10.06 11:10:26 (EDT) A: 2002.10.06 10:56:44 (EDT) C: 2002.10.06 11:10:26 (EDT)

/var/log/boot.log – This file contains information about when the operating system is booted and occasionally contains information about daemon processes. I noticed odd entries in this file about portmap and ssh daemon shutdowns. I noted the time and date that the anomalous events occurred as possible clues to the intrusion.

```
Oct 7 19:18:52 localhost portmap: portmap
shutdown succeeded
Oct 7 19:19:10 localhost sshd: sshd shutdown
succeeded
```

 /etc/passwd, /etc/shadow – This file contains user account information for the system. The owner of the system had said that he noticed a user "bobby" had been added to the system, so I checked these files and confirmed the users "bobby" and "boby" (with UID 0) exist. I also took note of the MAC times on the files as additional data points for the investigation. These files were modified approximately 2 minutes after the strange ssh and portmap daemon entries in /var/log/boot.log

/etc/passwd:

M: 2002.10.07 19:21:05 (EDT) A: 2002.10.09 16:10:13 (EDT) C: 2002.10.07 19:21:05 (EDT)

Contents:

bobby:x:501:501::/home/bobby:/bin/bash
boby:x:0:0::/root:/bin/bash

/etc/shadow:

M: 2002.10.07 19:21:05 (EDT) A: 2002.10.09 13:26:23 (EDT) C: 2002.10.07 19:21:05 (EDT)

Contents:

```
bobby:$1$.mlvYnX4$bphcZdcVh8ONBKeM8XrGw0:11967:0:
99999:7:::
boby:$1$he7ZnLoq$/zZydt8zv4ddZs18dMYI2/:11967:0:
99999:7:::
```

 /var/log/wtmp - This is a binary file that contains user login session data. I extracted the file using the "Export Contents" function in Autopsy and viewed its contents using the /usr/bin/last command. It shows users "bobby", "boby" and an anonymous FTP session logging in from webmaster.de.xxx.edu. The anonymous FTP login indicated that the intruder potentially gained access using a wu-ftpd exploit.

Figure 2-7: output of last command

```
# last -f sans-hda6.img-var.var.log.wtmp.raw
boby pts/2 webmaster.de.xxx.edu Mon Oct 7 19:46 -
19:57 (00:10)
bobby pts/2 webmaster.de.xxx.edu Mon Oct 7 19:44 -
19:46 (00:01)
ftp ftpd19543 webmaster.de.xxx.edu Mon Oct 7 19:12 -
down (1+20:57)
```

 /var/log/messages - Contains various logging information from the system and daemons. It is often a significant source of information about system events. Intruders will sometimes modify or delete this file to cover their tracks. It turned out to contain information that was key to the investigation. Figure 2-8 contains a screen shot of a portion of the file containing the most usable information.

/ on sans-hda6.in	ng - Mozilla (Build ID: 2001090111)	s ×
∑ <u>F</u> ile <u>E</u> dit <u>V</u> ie	w <u>S</u> earch <u>G</u> o <u>B</u> ookmarks <u>T</u> asks <u>H</u> elp	
Back - Porwa	ard 🔹 🏦 👪 http://localhost.888/1515220181214028856/autopsy?func=16&rdir=%2F&img=sans-hda6.ir 🚽 🜌 Search 📑 🗸 顺	0
🕺 🚮 Home 🛛 🐋 E	3ookmarks 🦧 Red Hat Network 📺 Support 📺 Shop 📹 Products 📺 Training	
Autonov		
Home File	Oct 7 23:12:24 localhost ftpd[19543]: ANONYMOUS FTP LOGIN FROM webmaster.de.xxt.edu [128.xx.18.179], mozilla@ Oct 7 19:19:52 localhost portmap: portmap shutdown succeeded Oct 7 19:19:03 localhost syslogd 1.3-3: restart.	_
Browsing	Oct / 19:19:05 localnost syslogd 1.3-3: restart. Oct 7 19:19:06 localnost syslogd 1.3-3: restart.	
Data	Oct 7 19:19:08 localhost sysloid 1.3-3: restart.	
Browsing	Oct 7 19:19:10 localhost system 1.3-3: restart.	
Inode	Oct 7 19:19:37 localhost ftpd[20821]: FTP LOGIN REFUSED (ftp in /etc/ftpusers) FROM webmaster.de.xxi.edu [128.xx].8.179], Oct 7 19:19:37 localhost ftpd[20821]: FTP secion closed	
Browsing	Oct 7 19:19:37 localhost ftpd[2023]; FTP session closed	
<u>File</u>	0ct 7 19:20:00 localhost CROMD[20825]: (root) CMD (/sbin/rumod -as) Dct 7 19:20:12 localhost adduser[20826]: new aroun: newshoby, di4501	
System	Oct 7 19:20:12 localhost adduser[20826]: new user: name=bobby, uid=501, gid=501, home=/home/bobby, shell=/bin/bash	
Keyword	Oct 7 19:20:50 Localhost adduser[20828]: new user: name=boby, und=U, grd=U, home=/root, shell=/bin/bash Oct 7 19:21:21 Localhost fud[19542]: PTP session closed	
Search	Oct 7 19:27:57 localhost kernel: write uses obsolete (PF_INET, SOCK_PACKET)	
Integrity	UCT / 19:2/:5/ Localnost Kernel: etnu: Setting promiscuous mode. Oct 7 19:27:57 Localnost Kernel: edvice etho entered promiscuous mode	
	Oct 7 19:28:02 localhost kernel: etb0: Setting promiscuous mode.	
View Notor	oct 7 19:31:43 localnost thum/2008371: FTP LOGIN REFUSED (ftp in /etc/ftpusers) FROM webmaster.de. xx.edu [128.ixc.18.179],	
INDICS	Oct 7 19:31:43 localhost ftpd(20086): FTP session closed	
l	oct 7 19:32:43 localhost rung(2006); r1 9ession closed	
File Mode	Oct 7 19:32:58 localhost thrad(937): command returned: ERROR: unable to read system id.	
Help	Oct 7 19:44:35 Localhost sshd[20391]: Accepted password for bobby from 128.xx. 18.179 port 3312 ssh2	
	0ct 7 19:44:35 localhost PAM unix[20891]: (system-auth) session opened for user bobby by (uid=0) 0ct 7 19:46:20 localhost PAM unix[20891]: (system-auth) session closed for user bobby	
<u>A11</u>	Oct 7 19 46 49 localhost schol20919]; Accepted password for ROOT from 128. xx4.18,179 port 3651 sch2	
Deleted	UCT / 19:46:49 Localnost PAM_unx[20919]: (system-auth) session opened for user boby by (uid=0) Oct 7 19:50:00 Localnost CRND[20950]: (root) CMD (/ Abin/rmmod-as)	
<u>F1165</u>	Oct 7 19:51 16 localhost modprobe: modprobe: Can't locate module net-pf-10	
	uct / 19:50:13 localnost teinetd[2095]: ttloop: peer died: EUr Oct 7 19:57:17 localnost PAM unix[20919]: (system-auth) session closed for user boby	
1	0ct 7 20:00:00 Localhost CROWD [20968]: (root) CMD (/sbir/rumod-as)	
+/lost+found	Oct 7 20:00:50 localhost sond[525]: benefating new roo bit has key.	
+/proc -	0ct 7 20:01:00 Localhost CROND[20971]: (rot) CMD (run-parts /etc/cron.hourly)	-
🌺 🆋 🗔 D	ocument: Done (0.656 secs)	đ

Figure 2-8: Screenshot of /var/log/messages file

The key items shown in Figure 2-8 are the events that happened between 19:12:24 and 19:57:17. In that time frame the system log had recorded the following suspicious events:

- An anonymous FTP login from webmaster.de.xxx.edu (also seen in wtmp file)
- Portmap daemon shutdown
- Syslogd restarted several times in quick succession
- sshd shutdown (also noted in /var/log/boot.log above)
- Attempted (refused) FTP login again from webmaster.de.xxx.edu
- Users "bobby" (with UID 0), "boby" and group "bobby" created on the system (also confirmed in /etc/passwd, /etc/shadow above)
- eth0 Network interface goes into promiscuous mode indicating a sniffer may have been started.

• Users "bobby", "boby" and "root" log into the system from 128.xxx.18.179 using ssh2 on port 3312.

These are good indicators that the system had been compromised. There was no legitimate reason for these events to have occurred on this system. The information gathered so far provided some insight into where the intruder had come from, the approximate timeframe of the intrusion, and some activities the intruder had done. It is clear from this logfile that the intruder had gained root access via FTP, created some user accounts, installed a backdoor ssh daemon on port 3312, logged in from 128.xxx.18.179, and was possibly running a network sniffer.

Initial Analysis of timeline and Recovery of Deleted files

Before turning to the timeline file to corroborate some of the information I had just gathered from /var/log/messages and gather more information the intruder's activities, I checked and noted the contents of /etc/crontab to establish when the cron daemon would run and what it would modify. Doing this allowed me to note the changes made to the system by the cron daemon and possibly eliminate it as being changes the intruder or user made.

I parsed the timeline file using /usr/bin/less. The beginning of the timeline showed the date and time of the installation of the OS which were consistent with both what the user had told me and what was found in /tmp/install.log. The first instances of suspicious behavior in the time line which weren't related to the OS install ,user or cron are shown in Figure 2-9.

root@localnost/imag	
File Edit Settings	Help
Mon Oct 07 2002 19 Mon Oct 07 2002 19	12:23 939 mrw root/boby root 276914 <sans-hda6.img-dead-276914> 12:39 4086 m.c d/drmwr-xr-x root/boby root 81855 /root/.ncftp 4096 m.c 1/drmwr-xr-x root/boby root 81855 /etc/rc.d/rc6.d/K83ypbind (del</sans-hda6.img-dead-276914>
eted-realloc)	
Mon Oct 07 2002 19	111548 .a/-rwxr-xr-x root/boby root 668586 /usr/bin/ncftpget 17:28 826817 m/-rw-rr root/boby root 1124280 /var/ftp/gold.tgz (deleted) 826817 mrw-rr root/boby root 1124290 (sans-bda6 ime-dead-1124290)
Mon Oct 07 2002 19:	17:41 826817 .a/-rw-rr root/boby root 1124290 /var/ftp/gold.tgz (deleted) 826817 .arw-rr root/boby root 1124290 <sans-hda6.img-dead-1124290></sans-hda6.img-dead-1124290>
Mon Oct 07 2002 19	17:49 826817/-rw-rr root/boby root 1124280 /var/ftp/gold.tgz (deleted) 826817rw-rr root/boby root 1124290 <sans-hda6.ing-dead-1124290></sans-hda6.ing-dead-1124290>
Yon Oct 07 2002 19:	32357 c -Hwhxhx Noot/body root 162420 (Sans-hda6.ing-dead-112420) 18151 25116 c -Hwhxh-x root/body root 167849 (Sans-hda6.ing-dead-667849) 4096 m.c d/mwh-xh-x root/body root 537505 /sbin 162437 .ac -/-nwkh-xh-x root/body root 1954971 /usr/bin/vdir 16185 m.c -/-nwkh-xh-x root/body root 293261 /bin/hostname 81017 m.c -/-nwkh-xh-x root/body root 293252 /bin/cat 56345 m.c -/-nwkh-xh-x root/body root 293224 /bin/cat 56345 m.c -/-nwkh-xh-x root/body root 293257 /bin/fgrep 4096 m.c d/nwkh-xh-x root/body root 293257 /bin/mount 62329 m.c -/-nwkh-xh-x root/body root 293257 /bin/mount 62329 m.c -/-nwkh-xh-x root/body root 293257 /bin/mount 164857 m.c -/-nwh-xh-x root/body root 293227 /bin/gauk-3.0.6

Figure 2-9: First Instance of suspicious behavior in Timeline

According to the timeline, at 19:12:23 on Oct 7th inode 276914 was modified, and at 19:12:39 ncftpget was executed by root, which created /root/.ncftp It also shows that the file /etc/rc.d/rc6.d/K83ypbind was deleted as was the file /var/log/gold.tgz a few moments later.

Inode 1124290 is the same size as the deleted gold.tgz file, so using the inode browsing feature of Autopsy, I viewed the contents of the inode to determine if it contained the data of the deleted gold.tgz file. Autopsy identified the contents of inode 1124290 as "gzip compressed data, from UNIX". I then extracted the contents of inode 1124290 out to a file on the forensics box using the "Export Contents" functionality in Autopsy. After verifying that the MD5 checksum of the inode contents as reported by Autopsy matched the output of md5sum on the file that was extracted thus proving the file hadn't been modified in the extraction process, I proceeded to uncompress the file, which resulted in a "tar" file. I checked the contents and paths of the "tar" file using the tvf flags of the /usr/bin/tar command and then "untarred" it using the xvf flags so I could analyze the contents.

root@localhost~
File Edit Settings Help
[root@localhost root]# md5sum sans-hda6.img-sans-hda6.img-inode-1124290.tgz c8725eebd74cae4cde85a37579811c50 sans-hda6.img-sans-hda6.img-inode-1124290.tgz [root@localhost root]# file sans-hda6.img-sans-hda6.img-inode-1124290.tgz sans-hda6.img-sans-hda6.img-inode-1124290.tgz; gzip compressed data, deflated, 1 ast modified: Thu Sep 26 03:59:00 2002, os: Unix [root@localhost root]# gunzip sans-hda6.img-sans-hda6.img-inode-1124290.tgz
[root@localhost root]# file sans-hda6.img-sans-hda6.img-inode-1124290.tar sans-hda6.img-sans-hda6.img-inode-1124290.tar: GNU tar archive
[root@localhost root]# tar tvf sans-hda6.img-sans-hda6.img-inode-1124290.tar drwxr-xr-x root/root 0 2002-09-26 03:58:53 gold/
-rwxr-xr-x root/root 310 2002-03-03 06:23:52 gold/lg -rwxr-xr-x root/root 1112 2002-09-26 03:58:53 gold/install -rwwr-yr-y root/root 23749 2002-09-26 03:57:31 gold/gl2
-rwxr-xr-x root/root 13297 2002-09-26 03:57:31 gold/write -rwxr-xr-x root/root 11657 2002-09-26 03:57:31 gold/v
-rwxr-xr-x root/root 1187 2001-05-30 07:14:54 gold/wroot -rwxr-xr-x root/root 13313 2002-09-26 03:57:31 gold/wscan
-rwxr-xr-x root/root 4060 2001-03-08 19:01:42 gold/read -rw-rr- root/root 120 2002-03-03 06:14:21 gold/.d
-rwxr-xr-x root/root 3371 2001-12-09 13:55:55 gold/move -rwxr-xr-x root/root 3238 1998-01-26 11:01:37 gold/remove -rwwr-yr-y root/root 18445 2002-09-26 03:57:31 gold/statdy
-rwxr-xr-x root/root 10717 2002-09-26 03:57:31 gold/login -rwxr-xr-x root/root 335 2002-09-26 03:58:14 gold/mailme

Figure 2-10: Dealing with contents of Inode 1124290

Analyzing the Rootkit

"Un-tarring" the "tar" file resulted in a directory named gold being created with several files in it. It appeared to be a rootkit containing tools that were potentially used by the intruder. I ran /usr/bin/md5sum on all the files found in the rootkit to fingerprint them. I then used /usr/bin/file to determine the type of each

of the files. /usr/bin/strings provided me some insight into the binary files and I used /use/bin/less to view the text and shell script files. Figure 1-10 contains the names of the files from the rootkit and a brief explanation of the files' purposes based on the information I gathered using strings and less.

File Name	Description		
.a	a zero length file		
.c	a file containing Netblocks and domains		
.d	file containing process names		
.inetd.conf.swp	a VIM editor swap file - It's contents indicate it was editing /usr/X11R6/lib/X11/fonts/misc/ /dan/inetd.conf		
.p	contains a list of the files in the rootkit		
.sdc	sshd config file		
.shk	sshd private key file		
.x.tgz	gzipped tar file containing ADORE LKM source code (untarred into ".x" directory)		
7350wurm	7350wurm - x86/linux wuftpd <= 2.6.1 remote root (version 0.2.2) - remote root exploiter of wu- ftpd		
chattr	strings comparison shows it looks like stock chattr (used to change file attributes)		
check	shell script to unpack .x.tgz in /usr/X11R6/lib/X11/fonts/misc/" "/,compile it and run ./start		
cl	is "sauber" log cleaner		
clean	shell script which runs "cl" and passes (yahoo.com, sshd, 208.158.209.235, rotind) as args.		
dir	a version of dir		
du	a version of du		
encrypt	SOLcrypt 1.0 by sensei - to encrypt/decrypt files		
fix	may try to modify checksums		
ifconfig	a version of ifconfig - a strings comparison revealed it wouldn't show the PROMISC flag set.		
init	shell script to run [dan1,2] -p 3200 -q from /usr/X11R6/lib/X11/fonts/misc/" "/ directory Runs /usr/X11R6/lib/X11/fonts/misc/" "/ .x/start Runs /ava i `/sbin/pidof ipitd` >>/dev/null		
install	shell script to install root kit		
killall	a version of killall		
la	shell script to copy trojan version of login to /bin/login		
Libproc.so.2.0.6	2.0.6 shared library used by trojaned Isof		
login	trojaned version of login with string cocacola , references /bin/sh,/dev/mount (from login trojaning script "lg")		
logn	trojaned version of login with string "bebito", references /bin/sh,and /usr/lib/.x		
ls	a version of Is - references /tmp/extfsRNV23z		
lsof	a version of lsof		
mailme	a shell script which emails "smoke@cacanar.com" info about the compromised host		
Md5sum	a version of md5sum - references /tmp/extfsRNV23z		
move	shell script to install trojan sshd and others (see timeline)		

Figure 2-11: Contents of Root kit:

File Name	Description		
netstat	a version of netstat		
patch	shell script to patch sshd version (see timeline)		
ps	a version of ps - references /tmp/extfsRNV23z		
pstree	a version of pstree (references /tmp/extfsRNV23z)		
read	perl script to parse output of "LinSniffer"		
remove	shell script which installs some trojan binaries (see timeline)		
sc	scanning program		
scan	statd scanner (looking for vulnerable 111 ports) runs "sc \$1 111 \$2 \$3		
sl2	modifed version of "slice" flooder from Knark. "strings" shows: anti-foonet by blizzard - based on sl2 - Usage: %s srcaddr dstaddr low high. If srcaddr is 0, random addresses will be used		
ssh_host_key	host key for trojaned version of ssh		
ssh_random_see d	random seed file for trojaned ssh		
sshd	sshd trojan - references /usr/lib/.sdc, /usr/lib/.shk		
Sshd_config	sshd_config file which references /usr/lib/.shk as Hostkey and /usr/lib/.srs as Random Seed		
startfile	shell script to modify /etc/rc.d/rc.sysinit, rc.local, boot.local		
statdx	scanner to exploit vulnerable versions of statd		
top	a version of top, references /tmp/extfsRNV23z		
v	Vadim v.lbeta by Luciffer – udp flooder		
vdir	version of vdir, references /tmp/extfsRNV23z		
write	ethernet sniffer - writes to tcp.log		
wroot	shell script to start wu ftpd vulnerability scanner		
wscan	wu-ftpd vulnerability scanner		
wted	strings shows "utzap" to remove login entries from wtmp		

Included in the rootkit was a gzipped tar file .x.tgz. Unpacking the tarball and analyzing the files that were extracted from it into the directory .x revealed it was potentially the Adore Loadable Kernel Module (LKM).

I looked in all files in the .x directory for a software version number so I could download the Adore LKM source code from the Internet and compare it. The Makefile had the following entry CFLAGS+=-DCURRENT_ADORE=42 and the Changes file listed the latest version as 0.42. Both of these files indicated that it was version 0.42

A quick Google search showed I could download the adore-0.42 source code from http://packetstormsecurity.nl/groups/teso/adore-0.42.tgz

I downloded the Adore LKM source, and compared md5 sums of files found in rootkit and files downloaded from net. Figures 2-12 and 2-13 are a comparison of the files in the .x directory and the source files downloaded from the Internet.

Figure 2-12: Adore LKM files from
rootkit

Figure 2-12: Adore I KM t	files from
rootkit	
md5sum	Filename
60a6b90f32d8387457c0357ffe33605e	.x/Changelog
8b35274c9f833c760738cd5765a5c1ba	.x/LICENSE
2d0c11e5237baac55759118567901e72	.x/Makefile
e4346f1a3a5fed10786e49b65fab7e6c	.x/Makefile.gen
9d626bf8f6874e63a64403ff24757b9d	.x/README
13d8ca70a0ca77b62c44c903c7d961d4	.x/TODO
9c1b9c8551e4ccfdfe2eb66a88588f69	.x/adore.c
7ae6abeb0db8e2ac4cb8f7b46613c8cf	.x/adore.h
a8af09fd53d76d218b3fadeb70d1fc09	.x/ava.c
3cb6c54561a78dd9c555cc3cbbf95ebc	.x/cleaner.c
03e0e705646ba77d7a399d952f15d6a6	.x/configure
ca37049245b51319ddc068f23882c3f9	.x/dummy.c
26e38f23062df4037a287303ea021484	.x/libinvisible.c
8af11813c20a544a60d2ba2d9f8f3f67	.x/libinvisible.h
158e51f5f2ceb287a4658257c9895f40	.x/rename.c
3de6dd6e7688f525e21d951fdf300e80	.x/start

Figure 2-13: Adore source from 'net download

<u>md5sum</u>	Filename
60a6b90f32d8387457c0357ffe33605e	adore/Changelog
8b35274c9f833c760738cd5765a5c1ba	adore/LICENSE
e4346f1a3a5fed10786e49b65fab7e6c	adore/Makefile.gen
9d626bf8f6874e63a64403ff24757b9d	adore/README
13d8ca70a0ca77b62c44c903c7d961d4	adore/TODO
4ae10ffd24d3038d555bbcd068e4db5b	adore/adore.c
b3b405ae9d97d68234208cda2f4a195b	adore/adore.h
a8af09fd53d76d218b3fadeb70d1fc09	adore/ava.c
3cb6c54561a78dd9c555cc3cbbf95ebc	adore/cleaner.c
55dbe55097ec9cbda701de95c084eec2	adore/configure
ca37049245b51319ddc068f23882c3f9	adore/dummy.c
26e38f23062df4037a287303ea021484	adore/libinvisible.c
8af11813c20a544a60d2ba2d9f8f3f67	adore/libinvisible.h
158e51f5f2ceb287a4658257c9895f40	adore/rename.c
92a334f54cf6f2ea67c3ac2c134ccef9	adore/startadore

The MD5 checksums of the files highlighted differ between the source code and the rootkit indicating that the source code of the kit on the compromised host had been modified. By using /usr/bin/diff of the files in question it was determined that the files had indeed been tailored to this particular install.

Figure 2-14: Diffs of adore.c

For this rootkit installation: line 543 of adore.c has been modified from the original to check if the process to hide matches netstat or lsof.

Figure 2-15: Diffs of adore.h

```
# diff adore.h ../.x/adore.h
83c83
< {":hell", ":2222", NULL};
---
> {":initd", ":25330", ":48744", ":xbnc", ":write", NULL};
```

Line 83 of adore.h found with the rootkit has also been modified to account for processes and ports specific to this rootkit (initd, xbnc, write and ports 25330, 48744).

Figure2-16: Diffs of configure

```
# diff configure ../.x/configure
18a19
> $pass = "electricreality";
24,30c25
< print "\n\nSince version 0.33 Adore requires 'authentication' or\n".
< "its services. You will be prompted for a password now and this\n".
< "password will be compiled into 'adore' and 'ava' so no further
    actions\n".
< "by you are required.\nThis procedure will save adore from
    scanners.\n".
< "Try to choose a unique name that won't clash with normal calls to
    mkdir(2).\n";
<
    print "Password (echoed):"; my $s = <STDIN>;
----
> print "Password (echoed):"; my $s = "electricreality";
```

In the configure script found with the rootkit, a print statement with instructions was removed and the password compiled into adore and ava was statically defined as "*electricreality*", This was most likely done so that the compile process could be automated and would not produce output or require user intervention.

```
# diff startadore ../.x/start
5d4
< # insmod adore without $0 but then its visible.
7.9d5
< insmod adore.o
< insmod cleaner.o
< rmmod cleaner
10a7.21
> if [ -f adore.o ] ;then
> mv adore.o xC.o
> fi
>
> if [ -f xC.o ] && [ -f cleaner.o ];then
>
> /sbin/insmod xC.o
> /sbin/insmod cleaner.o
> /sbin/rmmod cleaner
> ./ava i `/sbin/pidof initd`
> ./ava i `/sbin/pidof write`
> fi
```

The startup file in the rootkit was not only renamed from startadore to start, it was modified to rename the adore.o loadable module to xC.o and also automate the starting of the ava program to hide the initd and write processes.

Timeline Analysis: Tracing the path of the intruder

At this point in the investigation, I had a relative idea of when the intruder got access to the system and identified the tools that were downloaded on to the system. The next step in the investigation was to piece together specifically how and when the intruder gained access, and determine exactly what the intruder modified on the system.

Figure 2-18 contains a complete timeline of significant events and modifications that occurred on the system from October $6^{th} - 9^{th}$. I pieced together this timeline by analyzing the timeline file I generated with Autopsy, tracing through the install script included with the rootkit and correlating these sources with each other and log file entries I retrieved from the system. The Time column is the date and time the event occurred, the Timeline Entry was taken from the timeline generated by Autopsy, and the Description column is my interpretation of the specific event. (See page 7 and Figure 2-6 for an explanation of Timeline Entry syntax)

Time	Timeline Entry	Description	
	Sunday October 6 th 2002		
10:55:51 till 11:18:21	 0 mac root/boby root 1 <sans-hda6.img-alive-1></sans-hda6.img-alive-1> 16384 m.c d/drwxr-xr-x root/boby root 11 /lost+found 4096 mac d/drwxr-xr-x root/boby root 32577 /proc 9829 .a/-rw-rr- root/boby root 162882 /tmp/install.log 	Operating System installed by user (too many files accessed/created /modified to list – I've just listed the first few from the tim eline here)	
17:00:13	 46300 .a/-rwxr-xr-x root/boby root 537524 /sbin/depmod 1331 .a/-rw-rr root/boby root 211812 /etc/sysconfig/harddisks 	User boots system. User logs in and X windows starts (too many files accessed to list – I've just included the first few from the timeline here.)	
18:52:49	 3077 .a/-rw-rr root/boby root 260941 /usr/lib/linuxconf/help.eng/notices/10-welcome.help 	User starts linuxconf application (too many files accessed/changed to list them all)	
18:53:57	4096 m.c d/drwx jimmy jimmy 33001/home/jimmy	User creates valid user account "jimmy" using Linuxconf application	
	Monday October 7 th 2002		
19:12:39	 111548 .a/-rwxr-xr-x root/boby root 668586 /usr/bin/ncftpget 4096 m.c d/drwxr-xr-x root/boby root 81855 /root/.ncftp 	Intruder gains access to the system. /usr/bin/ncftp is executed to download the rootkit.	
19:17:28 till 19:17:49	 826817c -/-rw-rr root/boby root 1124290 /var/ftp/gold.tgz (deleted) 	rootkit tarball: /var/ftp/gold.tgz deleted	
19:18:51	4096 m.c d/drwxr-xr-x root/boby root 537505 /sbin	install script from rootkit run from /var/ftp/gold directory. Install runs ./remove which modified /sbin	
	• 89601 .ac -/-rwxr-xr-x root/boby root 1954978 /usr/sbin/lsof	remove script replaces lsof	
	• 37984c -/-rwxr-xr-x root/boby root 1954988 /lib/libproc.so.2.0.6	remove script replaces libproc.so.2.0.6	
	• 38425 .ac -/-rwxr-xr-x root/boby root 1954987 /usr/bin/md5sum	remove script replaces md5sum	
	• 38477 c -/-rwxr-xr-x root/boby root 1954960 /sbin/ifconfig	remove script replaces ifconfig	

Figure 2-18: Complete Timeline of significant events

Time	Timeline Entry	Description
	61125 m.c -/-rwxr-xr-x root/boby root 1954959 /bin/netstat	remove script replaces netstat
	69893 m.c -/-rwxr-xr-x root/boby root 1954957 /bin/ps	remove script replaces ps
	 40965 .ac -/-rwxr-xr-x root/boby root 1954958 /usr/bin/top 	remove script replaces top
	• 19313 .ac -/-rwxr-xr-x root/boby root 1954956 /usr/bin/pstree	remove script replaces pstree
	 46669 .ac -/-rwxr-xr-x root/boby root 1954974 /usr/bin/dir 	remove script replaces dir
	 162437 .ac -/-rwxr-xr-x root/boby root 1954971 /usr/bin/vdir 	remove script replaces vdir
	28279 c -/-rwxr-xr-x root/boby root 1954972 /usr/bin/killall	remove script replaces killall
	• 121821 .ac -/-rwxr-xr-x root/boby root 1954975 /usr/bin/du	remove script replaces du
	162435 m.c -/-rwxr-xr-x root/boby root 1954973 /bin/ls	remove script replaces Is
	 25624 .a/-rwxr-xr-x root/boby root 537508 /sbin/chkconfig 17 c l/lrwxrwxrwx root/boby root 2313169 /etc/rc.d/rc4.d/S13portmap ->/init.d/portmap (deleted) 17 c l/lrwxrwxrwx root/boby root 2182802 /etc/rc.d/rc2.d/K87portmap ->/init.d/portmap (deleted) 17 c l/lrwxrwxrwx root/boby root 2085239 /etc/rc.d/rc0.d/K87portmap ->/init.d/portmap (deleted) 17 ma. l/lrwxrwxrwx root/boby root 49243 /etc/rc.d/rc5.d/S13portmap ->/init.d/portmap (deleted) 17 c l/lrwxrwxrwx root/boby root 2247965 /etc/rc.d/rc3.d/S13 portmap ->/init.d/portmap (deleted) 17 4096 m.c l/drwxr-xr-x 30 root 81663 /etc/rc.d/rc6 d/K87portmap (deleted-realloc) 	remove script executes /sbin/chkconfigdel portmap to shutdown portmap daemon
19:18:52	250c -/-rw-rr root/boby root 1954969 /usr/include/file.h	remove script copies .p to /usr/includefile.h
	161c -/-rw-rr root/boby root 1954967 /usr/include/hosts.h	remove script copies .c to /usr/include/hosts.h
	• 120c -/-rw-rr root/boby root 1954950 /usr/include/proc.h	remove script copies .d /usr/include/proc.h
	93 m.c -/-rw root/boby root 195923 /etc/ftpusers	move script (called from install) executes: echo anonymous >> /etc/ftpusers echo ftp >> /etc/ftpusers
	• 19464c -/-rwxr-xr-x root/boby root 293292 /usr/lib/.x	/usr/lib/.x created by "Ig" script called from "move" script
	• 10717 .ac -/-rwxr-xr-x root/boby root 1954954 /bin/login	"lg" script (called from "move") replaces /bin/login
	 6 .ac -/-rw-rr jimmy jimmy 765952 /usr/X11R6/lib/X11/f onts/misc/ /.x/CVS/Repository 	install script executes: mkdir -p /usr/X11R6/lib/X11/fonts/misc/" "/
	 1345c -/-rwxr-xr-x root/boby root 1954966 /usr/X11R6/lib/X11/ fonts/misc/ /cl 13297c -/-rwxr-xr-x root/boby root 1954970 /usr/X11R6/lib/X11/ fonts/misc/ /wted 14796c -/-rw-rr root/boby root 1954989 /usr/X11R6/lib/X11/ fonts/misc/ /.x.tgz 	install script executes: • mv -f wted cl .x.tgz /usr/X11R6/lib/X11/fonts/misc/" "/

Time	Timeline Entry	Description
	 18445c -/-rwxr-xr-x root/boby root 1954953 /usr/X11R6/lib/X11/fonts/misc/ /statdx 13297c -/-rwxr-xr-x root/boby root 1954945 /usr/X11R6/lib/X11/fonts/misc/ /write 982c -/-rwxr-xr-x root/boby root 1954962 /usr/X11R6/lib/X11/ fonts/misc/ /scan 11657c -/-rwxr-xr-x root/boby root 1954946 /usr/X11R6/lib/X11/ fonts/misc/ /v 4060c -/-rwxr-xr-x root/boby root 1954949 /usr/X11R6/lib/X11/ fonts/misc/ /read 13505c -/-rwxr-xr-x root/boby root 1954963 /usr/X11R6/lib/X11/ fonts/misc/ /sc 1187c -/-rwxr-xr-x root/boby root 1954947 /usr/X11R6/lib/X11/ fonts/misc/ /wroot 13313c -/-rwxr-xr-x root/boby root 1954948 /usr/X11R6/lib/X11/ fonts/misc/ /wscan 23749c -/-rwxr-xr-x root/boby root 1954944 /usr/X11R6/lib/X11/ 	 mv -f statdx write scan sc sl2 wroot wscan v read /usr/X11R6/lib/X11/fonts/misc/ " "/
	fonts/misc/ /sl2 716993 m.c -/-rwxr-xr-x root/boby root 2117771 /usr/X11R6/lib/X11/fonts/misc/ /dan1 716993 m.c -/-rwxr-xr-x root/boby root 2117772 /usr/X11R6/lib/X11/fonts/misc/ /dan2	install script executes: cp -f sshd /usr/X11R6/lib/X11/fonts/misc/" "/dan1 install script executes: cp -f sshd /usr/X11R6/lib/X11/fonts/misc/"
	 998c -/-rw-rr root/boby root 1954983 /usr/lib/.sdc 541 .oo / rw/ root/boby root 105 4081 /usr/lib/.sbk 	Install script executes:
	 541.ac -/-rw root/boby root 1954981 /usr/lib/.shk2 523 m.c -/-rw root/boby root 749927 /usr/lib/.shk2 	Install script executes:
	512 mac -/-rw root/boby root 749928 /usr/lib/.srs	Install script executes:
	 121180 .a/-rwxr-xr-x root/boby root 668500 /usr/bin/make 307 .a/-rwxr-xr-x root/boby root 81873 /usr/X11R6/lib/X11/fonts/misc/ /.x/start 	The install script executes "check" script which unzips .x.tgz, and compiles it. There's too many files created and accessed to list here. I've shown make being invoked and the "start" script to load Adore LKM from the check script: make >> /dev/null ./start >> /dev/null The make process takes until 19:19:11 when the Adore LKM "start" script is run
19:18:57	• 306c -/-rwxr-xr-x root/boby root 1954976 /etc/rc.d/init.d/init	install script calls "startfile" script to copy init file from rootkit to /etc/rc.d/init.d/init to activate LKM and start Trojan ssh daemons at boot

Time	Timeline Entry	Description
19:19:01	• 401748 .a/-r-sr-xr-x root/boby root 1140314 /usr/sbin/sendmail	"mailme" script is executed by "install" It gathers information about the system from ifconfig, hostname,w, /proc/meminfo, route -n ,/proc/cpuinfo and emails it to smoke@cacanar.com
	3777 mac -/-rw root/boby root 1661574 /var/spool/mail/root	The email sent from the "mailme" script is bounced back to root since sendmail is not configured correctly
	945 m/-rw-rr root/boby root 2117778 /var/log/maillog	/var/log/mail.log is updated to report bounced mail
19:19:09	 38651 .a/-rw-rr- root/boby root 2117775 /var/log/cron 2880 .a/-rw-rr- root/boby root 2117776 /var/log/secure 3394 .ac -/-rw-rr- root/boby root 2117776 /var/log/dmesg 4941 .a/-rw-rr- root/boby root 2117774 /var/log/boot.log 0 .ac -/-rw-rr- root/boby root 2117781 /var/log/htmlaccess.log 945 .ac -/-rw-rr- root/boby root 2117778 /var/log/maillog 81072 .a/-rw-rr- root/boby root 2117784 /var/log/messages 282 .ac -/-rw-rr- root/boby root 2117784 /var/log/netconf.log 0 .ac -/-rw-rr- root/boby root 2117787 /var/log/spooler 0 .ac -/-rw-rr- root/boby root 2117787 /var/log/spooler 0 .ac -/-rw-rr- root/boby root 2117787 /var/log/spooler 	install calls "clean" shell script which runs "cl" with args to attempt to clean log files in /var/log
19:19:10	40028 .a/-rwxr-xr-x root/boby root 537567 /sbin/ipchains	install calls "clean" which shuts
19:19:11	716993 mac -/-rwxr-xr-x root/boby root 1140266 /usr/sbin/sshd	install calls "clean" which replaces the sshd and restarts the new daemon
	• 0 mac d/drwxr-xr-x root/boby root 1954941 /var/ftp/gold (deleted)	install script executes: rm -rf gold*
19:20:12	 4096 m.c d/drwxr-xr-x root/boby root 374625 /home 4096 m.c d/drwx bobby bobby 146960 /home/bobby 	User bobby created by intruder
	 4096 m.c d/drwx bobby bobby 146960 /var/log/sa (deleted -realloc) 	/var/log/sa which was deleted by "patch" script gets reallocated to /home/bobby
19:20:50	 688 m.c -/-rw-rr root/boby root 521616 /root/.emacs 24 m.c -/-rw-rr root/boby root 521424 /root/.bash_logout 	user boby created with uid 0 and /root as home dir
19:20:56	 13536 .a/-r-sx root/boby root 668868 /usr/bin/passwd 	/usr/bin/password executed to set password for user bobby
19:27:57	(see /var/log/messages file)	eth0 put in promiscuous mode
19:46:49	 (see /var/log/messages) 146584 m.c -/-rw-rr- root/boby root 276898 /var/log/lastlog 	user root logs in from webmaster.de.psu.edu
19:47:59	64604 .a/-rwxr-xr-x root/boby root 668167 /usr/bin/ftp	/usr/bin/ftp executed to download psyBNC source code
19:50:36	 224 .ac -/-rw-rw-r root/boby root 1987406 /usr/X11R6/lib/X11/fonts/misc/ / /xbnc/ 	/usr/X11R6/lib/X11/fonts/misc/ / /xbnc/ directory created when psybnc kit is untarred into this directory - too many files created to list here.

Time	Timeline Entry	Description		
19:51:16	 524596 .a/-rwxr-xr-x root/boby root 1726721 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/xbnc 524596 .a/-rwxr-xr-x root/boby root 1726721 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/psybnc (deleted-realloc) 	psybnc program renamed to xbnc		
	 2075 .a/-rw root/boby root 2199405 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/log/psybnc.log 6 mac -/-rw root/boby root 1726723 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/psybnc.pid 	xbnc program started creating psybnc.pid and psybnc.log		
19:52:24	 4096 m.c d/drwxrwxr-x root/boby root 2199403 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/log 	Intruder logs into IRC as "andrei" from 81.196.65.132		
19:55:41	• 37884 .a/-rwxr-xr-x root/boby root 1140325 /usr/sbin/in.telnetd	telnet connection attempted to host		
20:07:42	(see psybnc.log)	User andrei logged off IRCfrom 81.196.65.132		
	Tuesday October 8 th 2002			
2:52:59	 4096 m.c d/drwxrwxr-x root/boby root 1319728 /usr/X11R6/lib/X11/ fonts/misc/ / /xbnc/motd 	/usr/X11R6/lib/X11/fonts/misc/ / /xbnc/motd/USER1.MOTD changed by IRC user.		
4:20:13	 13297 .a/-rwxr-xr-x root/boby root 1954945 /usr/X11R6/lib/X11/fonts/misc/ /write 	write program (sniffer) is accessed		
05:46: 25	(see psybnc.log)	Failed Authentification for ravens from host 62.231.98.76 via IRC		
5:50:22	 3651 .a/-rw-rr bobby bobby 147118 /home/bobby/.screenrc 230 .a/-rw-rr bobby bobby 147115 /home/bobby/.bash_profile 124 .a/-rw-rr bobby bobby 147116 /home/bobby/.bashrc 24 .a/-rw-rr bobby bobby 147114 /home/bobby/.bash_logout 	Intruder logs in as bobby		
Wednesday October 9 th 2002				
13:25:43	 70216 .a/-rwxr-xr-x root/boby root 668310 /usr/bin/gnome- linuxconf 	User - who is logged in ran linuxconf – sees user "bobby", "boby" – suspicious someone has hacked in		
16:10:11	• 14460 .a/-rwxr-xr-x root/boby root 537556 /sbin/shutdown	User initiated shutdown		

In the process of compiling the complete timeline shown in Figure 2-18, I came across additional evidence related to the intruder's activities on the system. Specifically, I discovered a bounced email message and that the user was using an IRC bouncer.

Using Autopsy's "File Browsing" function, I recovered the email that the mailme script (called from the rootkit install script) attempted to send. This email, shown in Figure 2-19 was intended to provide the recipient smoke@cacanar.com information about the system that had been compromised.

The email, however, was never sent because sendmail wasn't configured on the system. Instead, the it bounced back to root's inbox

/var/spool/mail/root from which I extracted it using Autopsy.

Figure 2-19: Contents of Email sent by intruder (full email headers not shown)

From: root <root> Message-Id: <200210072319.g97NJ1i19847@localhost.localdomain> To: smoke@cacanar.com : 501.143:localhost.localdomain Subject: root:cpu MHz inet addr:128.119.x.xx Bcast:128.119.x.xx Mask:255.255.255.x inet addr:127.0.0.1 Mask:255.0.0.0 localhost.localdomain Linux localhost.localdomain 2.2.16-22 #1 Tue Aug 22 16:49:06 EDT 2000 i686 unknown 7:18pm up 1 day, 2:19, 2 users, load average: 0.39, 0.08, 0.03 USER TTY FROM LOGIN@ IDLE JCPU PCPU WHAT _ Sun 6pm 25:05m 1.11s 0.03s sh root tty1 /usr/X11R6/b pts/0 :0 Sun 6pm 24:24m 0.04s 0.04s bash root total: used: free: shared: buffers: cached: Mem: 263716864 133496832 130220032 157261824 35594240 42483712 Swap: 271392768 0 271392768 MemTotal: 257536 kB MemFree: 127168 kB MemShared: 153576 kB Buffers: 34760 kB Cached: 41488 kB BigTotal: 0 kB BigFree: 0 kB SwapTotal: 265032 kB SwapFree: 265032 kB PING yahoo.com (66.218.71.198) from 128.119.x.xx : 56(84) bytes of data. 64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198): icmp seq=0 ttl=244 time=84.765 msec 64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198): icmp seq=1 ttl=244 time=84.673 msec --- yahoo.com ping statistics ---2 packets transmitted, 2 packets received, 0% packet loss round-trip min/avg/max/mdev = 84.673/84.719/84.765/0.046 ms Kernel IP routing table Destination Gateway Genmask Flags Metric Ref Use Iface 128.119.xx.xx 0.0.0.0 255.255.255.0 U 0 0 0 eth0 127.0.0.0 0.0.0.0 255.0.0.0 U 0 0 Ω lo 0.0.0.0 128.119.x.xx 0.0.0.0 UG O 0 0 eth0 --g97NJ1h19875.1034032741/localhost.localdomain--

I also discovered that at 19:47:59 on Oct 7th the intruder had run /usr/bin/ftp on the system to download the psyBNC IRC bouncer into the directory /usr/X11R6/lib/X11/fonts/misc / /psybnc I concluded by looking at the directory /usr/X11R6/lib/X11/fonts/misc

/ / with Autopsy that the psybnc directory had been renamed to xbnc. The psybnc directory was marked as (deleted-realloc) and it shared the same inode as the xbnc directory. In addition, the binary psybnc was also marked as (deleted-realloc), was the same size (524596 bytes) and shared the same inode (1726721) and the same MD5 checksum as the xbnc binary indicating the program itself had been renamed from psybnc to xbnc.

The intruder likely renamed it because xbnc is one of the processes that appeared in .x/adore.h for the Adore LKM to hide.

After parsing several of the source code files in the xbnc directory, I determined it was the psyBNC IRC bouncer version 2.3 source code. Using Google, I was able to find and download the source code to psyBNC v2.3 from

http://www.psychoid.lam3rz.de/psyBNC2.3.tar.gz and compared it to the source code the intruder left behind. Goolge also referred me to

<u>http://www.netknowledgebase.com/tutorials/psybnc.html</u>, which is a great tutorial on psyBNC. Essentially psyBNC allows IRC users to "bounce" through a host system (in this case the compromised box) and hide their real IP address from other IRC users.

To gather more clues about the IRC habits of the user I extracted the psybnc.conf file, which configures the IRC Bouncer, from /usr/X11R6/lib/X11/fonts/misc / /

Using <u>http://www.netknowledgebase.com/tutorials/psybnc.html</u> as a reference for interpreting psybnc.conf, I was able to determine information about the IRC configuration outlined in Figure 2-20.

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Figure 2-20: Contents of psybnc.conf (My notes included with arrows)

PSYBNC.SYSTEM.PORT1=40401 PSYBNC.SYSTEM.HOST1=* PSYBNC.HOSTALLOWS.ENTRY0=*:*	>	xbnc process operates on port 40401
USER1.USER.LOGIN=andrei	>	intruder's IRC name is
USERI.USER.USER=Mr.BIG	Υ.	"andrei"
USERI.USER.PASS==0z0t Q K0v0e'4'Y h	→	Encrypted password for user
USER1.USER.RIGHTS=1		
USER1.USER.VLINK=0		
USER1.USER.PPORT=0		
USER1.USER.PARENT=0		
USER1.USER.QUITTED=0		
USER1.USER.DCCENABLED=1		
USER1.USER.AUTOGETDCC=0		
USER1.USER.AIDLE=0		
USER1.USER.LEAVEQUIT=0		
USER1.USER.AUTOREJOIN=1	→	If the user is kicked off
USER1.USER.SYSMSG=1		the IRC channel, it will
USER1.USER.LASTLOG=0		log back in automatically
USER1.USER.NICK=andrei		
USER1.SERVERS.PORT1=6667	→	port 6667 on IRC server
USER1.SERVERS.SERVER1=Oslo1.NO.EU.und	dernet.org $ \rightarrow$	IRC server
USER1.SERVERS.SPASS1=6667	→	Password to join channels
USER1.CHANNELS.ENTRY1=#Slick		
USER1.CHANNELS.ENTRY0=#gold		Channels intruder joins

The logfile psybnc.log, shown in Figure 2-21 that I extracted from

/usr/X11R6/lib/X11/fonts/misc / /xbnc/log/ contains a history of the intruder's IRC activity. This confirms the date and time the xbnc process was started, which I had already seen in the timeline generated by Autopsy. This also showed that the intruder "andrei" was logging in via IRC from 81.xxx.65.132 (and several failed attempts by user "ravens" from 62.xxx.98.76). I'm unable to tell from this whether those IPs are other bounce point the intruder is using, or their originating IP addresses. psyBNC does have the ability to be one of many hops in an IRC bounce.

```
Mon Oct 7 19:51:16 :Listener created :0.0.0.0 port 40401
Mon Oct 7 19:51:16 :Error Creating Socket
Mon Oct 7 19:51:16 :Can't create listening sock on host * port 40401
Mon Oct 7 19:51:16 :Loading all Users..
Mon Oct 7 19:51:16 :No Users found.
Mon Oct 7 19:51:16 :psyBNC2.3-cBtITLdDMSNp started (PID :20963)
Mon Oct 7 19:52:24 :connect from 81.xxx.65.132
Mon Oct 7 19:52:25 :New User:andrei (andrei) added by andrei
Mon Oct 7 19:52:34 :User andrei () has no server added
Mon Oct 7 19:54:22 :User andrei () has no server added
Mon Oct 7 19:54:40 :User andrei () trying Oslo1.NO.EU.undernet.org port 6667 ().
Mon Oct 7 19:54:41 :User andrei () connected to Oslo1.NO.EU.undernet.org:6667 ()
Mon Oct 7 19:56:30 :Hop requested by andrei. Quitting.
Mon Oct 7 19:56:30 :User andrei got disconnected from server.
Mon Oct 7 19:56:45 :User andrei () trying Oslo1.NO.EU.undernet.org port 6667 ().
Mon Oct 7 19:56:45 :User andrei () connected to Oslo1.NO.EU.undernet.org:6667 ()
Mon Oct 7 20:07:42 :User andrei quitted (from 81.xxx.65.132)
Tue Oct 8 02:52:52 :User andrei () got disconnected (from Oslo1.NO.EU.undernet.
org) Reason: Closing Link: dick-66 by Oslo1.NO.EU.undernet.org (Ping timeout)
Tue Oct 8 02:52:55 :User andrei () trying Oslo1.NO.EU.undernet.org port 6667().
Tue Oct 8 02:52:56 :User andrei () connected to Oslo1.NO.EU.undernet.org:6667 ().
Tue Oct 8 05:46:25 :connect from 62.xxx.98.76
Tue Oct 8 05:46:25 :Failed Authentification for ravens from host 62.xxx.98.76
Tue Oct 8 05:46:25 :Lost Connection from 62.xxx.98.76 (ravens)
Tue Oct 8 05:46:28 :connect from 62.xxx.98.76
Tue Oct 8 05:46:29 :Failed Authentification for ravens from host 62.xxx.98.76
Tue Oct 8 05:46:29 :Lost Connection from 62.xxx.98.76 (ravens)
Tue Oct 8 05:46:32 :connect from 62.xxx.98.76
Tue Oct 8 05:46:32 :Failed Authentification for ravens from host 62.xxx.98.76
Tue Oct 8 05:46:32 :Lost Connection from 62.xxx.98.76 (ravens)
Wed Oct 9 16:10:28 :Program Context : src/p socket.c/socketdriver Line 1229
Wed Oct 9 16:10:28 :Received TERMINATE signal from terminal
```

Throughout the course of the investigation I had recovered several deleted files with Autopsy which were significant pieces of evidence. Using the "Show All deleted" function on Autopsy I was able to generate a list of all the deleted files found on the evidence image. At this point in the investigation I had already found and recovered all the significant deleted data. The only other deleted files that Autopsy turned up when I listed them all were files deleted and reallocated by cron jobs. As stated earlier the user performed a clean shutdown before notifying me the system was compromised. As a result, the /proc filesystem was cleared of all information (the /proc filesystem exists only in memory, not on disk).

Strings Search

The swap partition on the disk contains the all that remains of what was in the memory of the system. The swap space contained on disk contains data that was

paged out from memory, and the data is not in any logical order. Parsing the image with strings command is the most efficient way to view its contents. The file is about 265 MB so I used the command fgrep -f GREPFILE to match specific patterns, contained in GREPFILE, which appeared in other evidence I had gathered from the system.

GREPFILE contains the strings:

bobby,boby,psybnc,andrei,xbnc,ftp,gold,xC,ava,cleaner,initd
,write,PROMISC,webmaster.de.xxx.edu,62.xxx.98.76,81.xxx.65.132,r
avens

Figure 2-22: strings of swap image

```
# strings sans-hdd5-swap.img | fgrep -f GREPFILE | less
```

This strings search matched some data that was on the swap partition, but nothing that was related to the intrusion, or the trojaned processes running on the system. I ran strings again without piping to the pattern matching "fgrep", so that I could parse the output by hand. This also didn't turn up any additional info related to the intrusion.

Autopsy has a "String Search" functionality build in that allowed me to enter some search criteria and a regular expression to match on the Linux filesystem image. I was able to search in both the allocated files and un-allocated files (deleted files) using the same patterns I entered in GREPFILE. The Autopsy "String Search" generates the output such that you can see the pattern matched and the inode/disk block that it appeared in. I reviewed the contents of all the inodes and disk blocks returned by Autopsy and didn't find any additional information.

Conclusion:

I was able to determine that the host had been broken into on Oct 7th 2002 at 19:12:24 from webmaster.de.xxx.edu. The intruder most likely used the wu-ftpd file globbing heap corruption vulnerability exploit to gain entry and leverage root privileges. I arrived at this conclusion based on the fact that the system was running a version of wu-ftpd (2.6.1) that was vulnerable only to the file globbing exploit, and the first sign of attack was an anonymous FTP login with root privileges. Once the intruder gained root access to the system via FTP, he/she immediately downloaded a rootkit into /var/ftp, which is the FTP user's home directory.

The rootkit installed by the attacker contained several trojaned versions of system binaries and daemons, programs to gather information about the current system, utilities to hide their presence on the system and tools to attack other systems. The attacker also installed the psyBNC IRC bouncer for communicating via IRC.

I can only speculate as to the intention of the intruder. The installed rootkit included tools to scan and compromise other systems via statd or wu-ftpd exploits, and perform Denial of Service attacks. Though there is no evidence that these tools were actually used on this system, it is likely that the intruder intended on using them. The intruder achieved minimum success by gaining access to this system though his ultimate goals were most likely halted by the quick response of the user who found the intrusion early on and removed the system from the network.

I reported my findings to the owners of the IP addresses from which the intruder accessed this system and asked that they secure their systems. I notified the user that his system had indeed been compromised and recommended that he format the hard drive, re-install a newer version of the the OS, apply the most recent security patches and disable unnecessary services (such as FTP) before connecting it to the University network again.

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Legal Issues of Incident Handling

SANS GCFA Practical Assignment v.1.2 Part 3

Jacob Cunningham

Part 3: Legal Implications

Recently a law enforcement officer contacted me and informed me that an account on a system in my administrative domain was used to hack into a government computer. On the phone he asked me to verify the activity by reviewing the log files on the system and determine if the logs indicate the activity was initiated by the user on my system or from an upstream provider. I was able to determine from the log files that a valid user had logged in a dialup account during the period of suspicious activity. I have a pre-existing relationship with the law enforcement officer, so I have already verified his credentials and I'm sure that this is not an instance of social engineering.

When given this situation, I would immediately seek the advise of the company's legal counsel to protect my rights, the company's, and the rights of the subscriber. Without having done so, I've stated my opinion below of how I would handle the situation based on research that I have done.

There are several state and federal laws that apply to fraudulent and illegal activities on computers and computer networks. Most unauthorized "cracking" activities on computers and networks tend to be in violation of Federal Law under the Computer Fraud and Abuse Act (Title 18 U.S.C. §1030), the Wiretap Act (18 U.S.C. §2511), or the Electronic Communications Privacy Act (18 U.S.C. §2701).

The Electronic Communications Privacy Act (ECPA) 18 U.S.C §2702(a) outlines among other things, the privacy rights for customers of Internet service providers and dictates what information and under what circumstances ISPs can turn over information to law enforcement.

The ECPA distinguishes between two types of Internet service providers, public and private. The following definition of public and non-public providers as outlined in the ECPA is provided in Section III B of the Department of Justice document "Searching and Seizing Computers and Obtaining Electronic Evidence in Criminal Investigations":

"Services are available to the public if they are available to any member of the general population who complies with the requisite procedures and pays any requisite fees. For example, America Online is a provider to the public: anyone can obtain an AOL account.

(It may seem odd at first that a service can charge a fee but still be considered available "to the public," but this mirrors commercial relationships in the physical world. For example, movie theaters are open "to the public" because anyone can buy a ticket and see a show, even though tickets are not free.) In contrast, providers whose services are open only to those with a special relationship with the provider are not available to the public. For example, employers may offer network accounts only to employees. See Andersen Consulting LLP v. UOP, 991 F. Supp. 1041, 1043 (N.D. III. 1998) (interpreting the "providing . . . to the public" clause in § 2702(a) to exclude an internal e-mail system that was made available to a hired contractor but was not available to "any member of the community at large").

There are different limitations around what public and private providers can disclose to law enforcement. The restrictions the ECPA places on the disclosure of information to law enforcement for the most part do not apply to non-public providers. The company that I work for is a public Internet service provider therefore certain statutory exceptions from 18 U.S.C §2702(b) must be met before I can disclose certain information to law enforcement officials.

The ECPA also defines several different types of information that Internet Service providers may possess and law enforcement may request relating to customers or subscribers.

- Transactional data from §2703(c)(1): "record or other information pertaining to a subscriber". This has been interpreted to include "a log identifying the date, time, user, and detailed internet address of sites accessed" in H.R. Rep. No. 103-827, at 10, 17, 31 (1994), reprinted in 1994 U.S.C.C.A.N. 3489, 3490, 3497, 3511; United States v. Allen, 53 M.J. 402, 409 (C.A.A.F. 2000)
- Subscriber, billing and session specific information from §2703(c)(2): "name, address...telephone number or other subscriber number or identity and length of service of a subscriber to customer of such service and the types of services the subscriber or customer utilized"
- Stored content of communications that is defined in 18 U.S.C § 2510(8)

In my initial conversations with the law enforcement officer, I am able to confirm that my employer is a public Internet Service provider and disclose information about the company's operational practices such as what sort of transactional and system logging is performed, and how long the logfiles are kept. In order for me to legally disclose subscriber information or transactional data contained in logfiles to the law enforcement officer about a customer or subscriber, one of the following exceptions stated in 18 U.S.C §2702(c) or 18 U.S.C §2702(b) must apply to the situation. 18 U.S.C §2702(c) provides exceptions for the disclosure of contents and 18 U.S.C §2702 (c) provides exceptions for the disclosure of other non-content customer records.

• Under §2702(c)(2) records can be disclosed: "with lawful consent of the customer or subscriber." Login banners and user agreements have been considered legitimate consent by the user.

- Under §2702(c)(3) records can be disclosed for: "the protection of the rights or property of the provider of that service"
- Under §2702(c)(4) records can be disclosed: "if the provider reasonably believes that an emergency involving immediate danger of death or serious physical injury to any person justifies disclosure of the information"

In this situation, none of the exceptions allowed in §2702(b-c) apply. The law enforcement officer did not feel that there is the threat of death or serious injury, my company's user policy didn't provide me the authority to disclose their information, and the log files did not indicate that there was any threat to my company. The law enforcement officer must get the required legal authority before I can provide him with subscriber information or log files. If the officer is unable to get the documents for legal authority in a timely manner, during the phone call or subsequent phone calls the law enforcement officer can request me to "freeze" stored records and communications as outlined in 18 U.S.C §2703(f)(1) which states:

"A provider of wire or electronic communication service or a remote computing service, upon the request of a government entity, shall take all necessary steps to preserve records and other evidence in its possession pending the issuance of a court order or other process"

Section 2703 (f)(2) mandates that when the law enforcement officer issues a 2703f freeze order, the records he requested "shall be retained for a period of 90 days, which shall be extended for an additional 90-day period upon a renewed request by the government entity."

There are no provisions governing how effectively the ISP logs user activities or how effectively the ISP complies with the §2703(f) order. One limitation of the §2703(f) request discussed in the document "Searching and Seizing Computers and Obtaining Electronic Evidence in Criminal Investigations" is that it "cannot order providers to preserve records not yet made. If agents want providers to record information about future electronic communications, they must comply with electronic surveillance statutes".

As stated above, in order for me to send the law enforcement officer my secured log files related to this particular incident, the officer must get legal authority requesting the information as mandated in 18 U.S.C §2703(d): "A court order for disclosure under subsection (b) or (c) may be issued by any court that is a court of competent jurisdiction described in section 3127(2)(A) and shall issue only if the government entity offers specific and articulable facts showing that there are reasonable grounds to believe that the contents of the wire or electronic communication, or the records or other information sought, are relevant and material to an ongoing criminal investigation."

The document "Searching and Seizing Computers and Obtaining Electronic Evidence in Criminal Investigations" list the following options for legal authority to request information:

- Subpoena:
 "Investigators can subpoena basic subscriber information". The scope of "basic subscriber information" is listed in §2703(c)(2).
- Subpoena with prior notice to the subscriber or customer "Agents who obtain a subpoena, and <u>either</u> give prior notice to the subscriber <u>or</u> comply with the delayed notice provisions of § 2705(a), may obtain:
- 1) everything that can be obtained using a subpoena without notice;
- "the contents of any wire or electronic communication" held by a provider of remote computing service "on behalf of . . . a subscriber or customer of such remote computing service." 18 U.S.C. § 2703(b)(1)(B)(i), § 2703(b)(2); and
- 3) "the contents of a wire or electronic communication that has been in electronic storage in an electronic communications system for more than one hundred and eighty days." 18 U.S.C. § 2703(a).
- §2703(d) court order

Law enforcement agents who possess an order under 18 U.S.C §2703(d) can get access to:

"1) anything that can be obtained using a subpoena without notice; and 2) all "record[s] or other information pertaining to a subscriber to or customer of such service (not including the contents of communications [held by providers of electronic communications service and remote computing service])." 18 U.S.C. § 2703(c)(1)."

- §2703(d) Order with prior notice to the subscriber or customer: "Agents who obtain a court order under 18 U.S.C. § 2703(d), and either give prior notice to the subscriber or else comply with the delayed notice provisions of § 2705(a), may obtain:
 - everything that can be obtained using a § 2703(d) court order without notice;
 - 2) "the contents of any wire or electronic communication" held by a provider of remote computing service "on behalf of . . . a subscriber or customer of such remote computing service," 18 U.S.C.
 § 2703(b)(1)(B)(ii), § 2703(b)(2); and
 - "the contents of a wire or electronic communication that has been in electronic storage in an electronic communications system for more than one hundred and eighty days." 18 U.S.C. § 2703(a). ""
- Search warrant:

"Investigators can obtain the full contents of an account with a search warrant. ECPA does not require the government to notify the customer or subscriber when it obtains information from a provider using a search warrant."

After the law enforcement officer contacted me and notified me that a customer or subscriber may have been involved in criminal activity, I reviewed the relevant logs on the system to determine it was a valid user who logged in via a dialup account. Upon reviewing the log files, I did not find any evidence that the user was doing anything wrong. Because there was no evidence that the user was doing anything wrong, in accordance with the law, I as the system administrator cannot monitor the activities of that user to find proof of wrongdoing based solely on suspicion or curiosity. The user's rights pertaining to being monitored in real-time are protected by the Wiretap Act (18 U.S.C. §2511), which prohibits, among other things, the interception and monitoring of computer communications unless a specific exception applies to the situation. There are several exceptions stated in §2511 that permit the interception and monitoring of computer communications. The exceptions that pertain most to system administrators are:

§2511(2)(a)(i) is referred to as the "provider exception":
 "It shall not be unlawful under this chapter for an operator of a switchboard, or an officer, employee, or agent of a provider of wire or electronic communication service, whose facilities are used in the transmission of a wire or electronic communication, to intercept, disclose, or use that communication in the normal course of his employment while engaged in any activity which is a necessary incident to the rendition of his service or to the protection of the rights or property of the provider of that service, except that a provider of wire communication service to the public shall not utilize service observing or random monitoring except for mechanical or service quality control checks."

• §2511(2)(c) is referred to as the "consent exception":

"It shall not be unlawful under this chapter for a person acting under color of law to intercept a wire, oral, or electronic communication, where such person is a party to the communication or one of the parties to the communication has given prior consent to such interception."

• §2511(2)(i) is referred to as the "computer trespasser exception":

If the logs disclosed that the hacker had gained unauthorized access to my system, created an account and used that unauthorized account to hack into the government computer, then a few of the exceptions apply and I would legally be able to monitor the activities of the user. The provider exception §2511(2)(a)(i) allows the system administrator to investigate the matter to protect the provider's

assets and prevent "theft-of-service" The D.O.J document "Searching and Seizing Computers and Obtaining Electronic Evidence in Criminal Investigations" states: "...system administrators can track hackers within their networks in order to prevent further damage. <u>Cf. Mullins</u>, 992 F.2d at 1478 (concluding that need to monitor misuse of computer system justified interception of electronic communications pursuant to § 2511(2)(a)(i))United Sates vs. McLaren, 957 F. Supp. 215, 219 (M.D. Fla. 1997) determined there must be a "substantial nexus" between the monitoring and the threat to the provider's rights and property."

Although I as the system administrator can monitor to protect my company's rights and assets, I cannot be asked to monitor by law enforcement for the purpose of collecting evidence for a case without the law enforcement officer having legal consent to do so. Legal consent can be in the form of the court documents listed previously, or consent may be granted through the "computer trespasser exception" in 18 U.S.C §2511(2)(i) which states: "Computer trespassers have no reasonable expectation of privacy on the systems". 18 U.S.C §2510(21) states that a computer trespasser "does not include anyone known to the provider to have an existing relationship with the provider." In this case, it is not known whether or not the user is know to have an existing relationship with my employer. Therefore the individual who set up the unauthorized account is considered a trespasser and can be monitored by the system administrator in conjunction with law enforcement under the trespasser exception as long as the following criteria are met:

- The owner or operator computer must authorize the monitoring of the trespasser's communications as stated in 18 U.S.C. § 2511(2)(i)(I)
- The person who intercepts the communications must be "lawfully engaged in an investigation." as stated in 18 U.S.C. § 2511(2)(i)(II).
- The person who intercepts the communications must have "reasonable grounds to believe that the contents of the computer trespasser's communications will be relevant to the investigation." as stated in 18 U.S.C. § 2511(2)(i)(III).
- The monitoring should only intercept communications transmitted to or from the computer trespasser as stated in 18 U.S.C. § 2511(2)(i)(IV).

The law enforcement officer and I would be able to meet all the above criteria and therefore could monitor the user under the computer trespasser exception of the Wiretap Act and any evidence gathered could be used in a court of law.

My research was focused around the Federal laws that govern the various aspects of dealing with the given situation, however there is one state law that also applies. Massachusetts General Law 272 §99 governs the "Interception of wire and oral communications." It is modeled after the federal Wiretap Act, and contains similar language for prohibiting and allowing the interception of computer communications.

The notable difference between the exceptions listed in M.G.L 272 §90 D and ECPA 2511(2)(c) is that in Massachusetts, in order for the "consent exception" to apply, both parties of the communication must consent to the interception of information. Also, in M.G.L. 272 §90(D)(c) it clearly states that intercepting communications is permitted when the investigator is in compliance with the federal wiretap laws: "for investigative and law enforcement officers of the United States of America to violate the provisions of this section if acting pursuant to authority of the laws of the United States and within the scope of their authority."

In Summary, the Electronic Communications Privacy Act (18 U.S.C. §2701) regulates what information and under what circumstances ISPs can turn over information to law enforcement. I, as an employee of a public provider, cannot disclose subscriber or customer information to law enforcement unless one or more exceptions allowed in 18 U.S.C §2702(b-c) apply. In this case, the law enforcement official would have to issue a §2703(f) freeze order on the log files and obtain a court document (subpoena, search warrant) to gain access to the customer or subscribers information and log files etc.

In order for me the system administrator or the law enforcement officer, to conduct real-time monitoring of communications, they are bound by the provisions outlined in the Wiretap Act (18 U.S.C. §2511). To legally intercept real-time computer communications, one of the many exceptions listed in §2511(2) must apply. Several exceptions are made which would allow me, the system administrator to monitor intruders on the system to protect the provider's rights and property. However when I, the system administrator am working in conjunction with law enforcement (under the color of law), I must adhere to the guidelines mandated in §2511(2)(i), which relate to monitoring computer trespassers.
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