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Part 1, option 2 – Perform a Forensic Tool Validation – Process Accounting Records

Motivation

When computer security professionals discuss forensic investigation, much of the focus is on imaging disks and extracting what information can be found from the disk in the form of MACTime data (MAC here refers to the modification, access, and change time captured about every file on the disk in the inode structures). Another useful avenue for investigation can broadly be described as log file analysis. Modern computer systems can be configured to capture a great deal of information about what happens on the system in various types of log files. Unfortunately, there is no consistency to the format or types of data captured. There are numerous types of logs that can provide useful data to the investigator in her/his search to understand what happened and how it happened, this paper will primarily address one. The forensic investigator is charged with determining what happened and the extent of any damage. A timeline can be a crucial tool in developing this understanding.

Many modern operating systems now have the ability to generate audit data from the kernel (also known as C2 audit data, referring to the level in the “Orange Book” Department of Defense hierarchy that mandated audit trail). Unfortunately, on any moderately busy system, the volume of this data can quickly become overwhelming. Furthermore, there is a definite performance penalty in generating audit data on (potentially) every system call made by every process running on the system. This data, when it exists, is a forensic analyst’s dream. However, because of these difficulties, this auditing is rarely enabled outside of the Defense Department or contractors where it is required. A similar but often-overlooked source of forensic data (at least on Unix and Unix-like systems, including Linux) is process accounting data. While process accounting was originally used in time-sharing environments to charge users for the amount of CPU time or disk they used, it is now more often used for security purposes because it imposes much less of a performance penalty (our experience has been on the order of 2-3%) than auditing while still providing a reasonable amount of data.

Process accounting records are given very little coverage in some of the better books on Unix/Linux security, incident handling, and forensics. For example, Garfinkel and Spafford’s excellent book, Practical Unix & Internet Security, devotes 2 pages, Mandia and Prosise’s Incident Response: Investigating

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1 See the discussion on the loganalysis mailing list [https://lists.shmoo.com/mailman/listinfo/loganalysis](https://lists.shmoo.com/mailman/listinfo/loganalysis) and web site [http://www.counterpane.com/log-analysis.html](http://www.counterpane.com/log-analysis.html)

Computer Crime\textsuperscript{3} and Kruse and Heiser’s Computer Forensics: Incident Response Essentials\textsuperscript{4} each devote 2 paragraphs, and Romig’s article in Handbook of Computer Crime Investigation: Forensic Tools and Technology\textsuperscript{5} gives process accounting 1 paragraph, though Romig has used process accounting data in some of his investigations. Perhaps, the reason that process accounting is so often overlooked is a lack of tools. We\textsuperscript{6} will examine an existing tool to assist in our analysis of process accounting records for forensic purposes. We will also introduce two new tools that can make the data more useful and address some of the problems with process accounting data (see the Analysis and Presentation sections below).

Before we begin looking at the tool, we need to first take a quick look at what process accounting does and does not provide. The standard data found in the process accounting data file (usually named either acct or pacct, depending on whether the system was derived from BSD or System V) includes the name of the process (often truncated to eight or sixteen characters and settable by the process itself), the uid and gid under which the process was run, flags (the most often seen being fork and setuid), process start time, system CPU time, user CPU time, elapsed time, and tty (if the process had a controlling tty). Optionally, it may also contain memory usage, I/O counts, page faults, swap counts, and/or exit status.

Our analysis will concentrate on only a few pieces of information provided by the process accounting log. In particular, we are most interested in uid, gid, process start time, and elapsed time as these are the most useful in determining a time line for the incident being investigated. The process name, as discussed below, is not as useful as one might hope since it does not provide full path or inode information on the binary that was executed. The next most useful items provided by process accounting would be the flags (especially the setuid flag and, if available, the coredump and terminated on signal flag), the controlling tty (for noting interactive usage) and exit status, if available. The CPU time and I/O data are more useful for determining anomalous behavior, as are the memory, page fault, and swap statistics.

As mentioned previously, the original intent of process accounting was chargeback. All operating systems that provide process accounting provide some tools for displaying the data. Unfortunately, there is no standard format for displaying the data, each tool on each operating system provides the data in a different manner. The inconsistent formats are one reason for examining the tool we have chosen for this exercise. There are also some definite weaknesses with


\textsuperscript{6} The author apologizes for his use of the royal ‘we’ throughout the rest of this document. This is all the work of one person, but he is uncomfortable writing so much in the first person, and ‘we’ did not grate on the ear as much as ‘I’.
process accounting data that must be taken into account if this data is going to be used in prosecution, but as long as they are understood they should not prevent its usage.

**Problems**

Some of the major limitations to the use of process accounting data include the following:

- **Name information.** As mentioned above, the name information in the process accounting record is a fixed size string (generally eight characters, but sometimes sixteen) and the name can be set by the process itself. That means the process can call itself anything it wants. This means the name cannot be relied on, by itself, to tell us what binary was executed, but it will tell us that *something* was executed. When combined with MACTime data, however, this may provide us with extremely useful clues.

- **Ordering.** The data in the process accounting file is ordered by the time the process ended. These means a sequential look at the logs usually just causes confusion. While this problem can usually be overcome, it does need to be taken into account. More problematic is that processes that are still running do not appear in the accounting log at all, while long-running processes will appear in the logs far from other processes that were started with them.

- **Timing granularity.** While the CPU times and elapsed time have much finer granularity, the start time only has one second granularity. This means calculated end times could be off by ±1 second. Our tool follows the same convention as the native tools provided by the operating systems we tested of rounding fractions down.

- **Vulnerability of the log.** The accounting log itself is vulnerable to deletion (or potentially modification, though we are not aware of any tools at this time that modify process accounting records). We will present another tool to address this issue.

**The main tool—lastcomm**

The primary tool we will discuss is lastcomm from Venema & Farmer’s *The Coroner’s Toolkit*, (TCT) version 1.09 (the current version as of this writing). Our first reason for choosing this tool is that this version will run SunOS 4, SunOS 5 (Solaris), FreeBSD, OpenBSD, BSDi, and many Linux distributions. It should be possible to port to most, if not all, operating systems that TCT supports. The second reason for choosing this tool is that one option for output format is time-machine format which will ease the development of one of the new tools we will present later.

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7 [http://www.porcupine.org/forensics/tct.html](http://www.porcupine.org/forensics/tct.html)
Scope

Since process accounting is used for billing purposes, we will not invest any time in proving the accuracy of the data produced by the accounting system in the kernel. While this might be an avenue for challenge in court, it is well beyond the scope of our efforts in this paper. Since the tool we are examining is essentially a log analysis tool, our testing concentrates on establishing that our tool accurately represents the data in the log. As programmers, we could turn this paper into a code review, but instead, we will restrict ourselves to showing that this tool, lastcomm, reports the same information as the standard tools provided by the operating system. If we can show this, then a defendant would likely have to challenge the security of the logs or the accuracy of the entire accounting system, which would be a much greater effort than simply attacking this tool. We will then examine how the tool can be used for forensic purposes and some techniques that can be used to overcome some of the problems noted above.

Tool Description

As noted above, we will be examining lastcomm as provided in TCT, version 1.09 available from http://www.porcupine.org/forensics/tct.html. The tool was adapted by Wietse Venema from BSD source (in particular, it appears to have been taken from a FreeBSD release). The tool will read a process accounting log from a victim machine. This file is usually named either acct or pacct and can be located in any number of places based on the operating system or package version. Some of the common places are /var/adm/pacct (the usual Solaris location), /var/log/pacct (used by many Linux distributions), and /var/account/acct (the usual BSD location). It can take a command line argument giving the file name to read, so it can be used on accounting logs copied from victim machines. This tool can be run on images or live on a victim system. Note that running it on a live system will not change any old data, but will cause the log to change as entries are added for the tool being run. The tool can provide the investigator with information about the start/end time (indirectly, via start and elapsed time), name (see limitation above), uid and gid of processes run on the system. This information, when combined with MACTime data, can provide a timeline of activities taking place on a victim system. lastcomm can be statically compiled, but must be separately compiled for each type of system being investigated since it relies on layout of the accounting logs which can and do change periodically (the layout is found in /usr/include/sys/acct.h on most systems). We may attempt to create a version of the tool that will be able to read multiple formats of accounting logs based on a command line switch at some point in the future. The tool can (and has been) run from CD-ROM, it is run as part of grave-robber and obviously can be used independently.

Test Apparatus

For the purpose of this paper, we shall test the tool on the following platforms:
• Sun Sparc Ultra-2 running SunOS 5.6 (also known as Solaris 2.6) with current recommended patch cluster as of 15 Aug 2002.
• Sun Sparc Ultra-2 running SunOS 5.7 (a.k.a. Solaris7) with current recommended patch cluster as of 15 Aug 2002.
• Sun Sparc Ultra-2 running SunOS 5.8 (a.k.a Solaris8) with current recommended patch cluster as of 15 Aug 2002.
• Sun Sparc Ultra-2 running SunOS 5.9 (a.k.a. Solaris9) with current recommended patch cluster as of 15 Aug 2002.
• Compaq Presario desktop system running SuSE Linux 7.3 with accounting package acct-6.3.5-217.
• Sony Vaio laptop running Red Hat 7.2 with accounting package psacct-6.3.2-9.

We will refer the the Sun systems as SunOS 5.x in the discussion that follows, rather than Solaris x, since this is what `uname(1)` returns.

Environmental Conditions
During these tests, the tester will be the only interactive user on the system which will be on a closed network. We will be running the tests as an unprivileged user on a copy an accounting log that was taken live from the system. There are no outside forces that could influence the results of the tests.

Description of the Procedure
For each of the six test environments the following steps will be taken.

1) Ensure that the process accounting package was appropriately installed on the test system.
2) Verify that the process accounting package is, in fact, running (executing `/etc/init.d/acct start` or its equivalent).
3) Ensure that we have sufficient data logged to the acct or pacct file (file size > 5,000 bytes was deemed sufficient for this test since each record is on the order of 40 to 64 bytes).
4) Copy the acct/pacct file to our test directory.
5) Run the native utility for examining the accounting logs and save the ASCII output to a file.
6) Run `lastcomm` with the `-t` switch on the acct/pacct file to produce a version of the accounting log in time-machine format. Note, we previously compiled `lastcomm` on each of our six test systems.
7) Run a perl script of our own design on the output of `lastcomm -t` to reformat the time-machine format data into the same format as that produced by the native tool.
8) Finally, we run `diff(1)` on the two files and analyze any differences.

To verify that this is a valid test, we will examine the perl scripts that transform the output carefully, to ensure that the transformations are valid, in particular, we need...
to carefully any calculations that may be performed beyond simple formatting. Since our test systems fall into two families, the Sun Solaris servers and the Intel Linux servers, we shall see analysis of these scripts below for each family of operating systems.

Criteria for approval

Our approval criteria are actually quite simple. Ideally, there should be no difference between the output of the native tool and our reformatted output from lastcomm. Since it is unlikely that the output will be identical, we shall examine each difference and determine if the difference is substantive or merely cosmetic. In particular, given our previous discussion of the most important fields, we are most concerned with start time, end time (see granularity discussion to see why we are more concerned with end time than with elapsed time), uid, and process name.

Data and Results

For the SunOS systems that we examined, we used the native utility, acctcom(1) to print out the accounting records in a human readable form. We created a perl script, tm2acctcom.pl, to take the time-machine output of lastcomm –t and convert it to something close to the format produced by acctcom. We include the script here with some explanation.

```
#!/usr/local/bin/perl
#
# $RCSfile: tm2acctcom.pl,v $  
# $Revision: 1.4 $          
# Author: Jim Clausing <clausing@computer.org>  
# $Date: 2002/09/16 00:58:10 $  
#
# Purpose: Converts time-machine format output from tct-1.09's
# version of lastcomm and reformats in same format as
# Solaris acctcom(1) command run with -btfi switches
# then truncated to 96 chars (see note below).
# Note, the version of lastcomm in tct-1.09 does not
# keep exit status, the author will submit a patch
# to Venema & Farmer to capture that information.
# $Log: tm2acctcom.pl,v $  
# Revision 1.4  2002/09/15 20:58:10  jac  
# cosmetic clean up  
# Revision 1.3  2002/08/29 20:25:16  jac  
# use different format for really big integers  
# Revision 1.2  2002/08/29 20:14:19  jac  
# put RCS stuff in the header  
#  
# use POSIX qw(strftime);
#
# The bizzare format2 comes from peculiarities noted in the 5.8 version
```
# of acctcom, this resulted in fewer differences.
#
$format = "%-9s %-9s %-12s %8s %8s %7.2f %7.2f %7.2f %7d %7d %3d\n";
$format2 = "%-9s %-9s %-12s %8s %8s %7.2f %7.2f %7.2f %7d %7d %3d\n";

open (INPUT, "$ARGV[0]");
$junk = <INPUT>;
$junk = <INPUT>;
($junk,$junk,$start_date) = split(/\|\|/, $junk);
print "ACCOUNTING RECORDS FROM: ", scalar localtime($start_date), "\n"

COMMAND START END REAL CPU (SECS)
CHARS BLOCKS
NAME USER TTYNAME TIME TIME (SECS) SYS USER TRNSFD READ F
"

$junk = <INPUT>;

while(<INPUT>) {
  ($name,$flags,$uid,$gid,$tty,$ucpu,$cpu,$start,$elapse,$mem,$char,$io_blk) =
  split (/\|\|/,$_);
  if ($tty =~ /,/) {
    ($foo,$bar) = split(/,/,$tty);
    $tty = 'pts/' . $bar;
  } else {
    $tty = '?';
  }
  $fl = 40;
  $fl += 1 if ($flags =~ /F/);
  if ($flags =~ /S/) {
    $fl += 2;
    $name = '#' . $name;
  }

  if ($char <= 99999999) {
    printf $format, $name,$user,$tty,$start,$end,$elapse,$cpu,$ucpu,$char,$io_blk,$fl;
  } else {
    printf $format2, $name,$user,$tty,$start,$end,$elapse,$cpu,$ucpu,$char,$io_blk,$fl;
  }
}

The script is relatively straight-forward, but we shall point out a few features of the script. First, note the lines that read $junk = <INPUT>;. These statements read the first three lines in the time-machine format output. The print statement generates the four header lines to match the output of acctcom less the exit status field noted in the comments. Next, we take note of the section that sets up the $tty variable. This worked for the machines we tested on, but we actually would prefer to leave things in the time-machine format of major and minor device numbers. We cheated a little on this one since the ptys that we were using were all
in /dev/pts. Similarly, we are not sure why an entry with no flags set resulted in a value of 40 in the flag field of acctcom, but it does and the setuid and fork flags, set the bits shown above, so we just add them. We then did a lookup of username given uid and truncated the result to eight characters since we noted the problem below with long usernames. We used the strftime function to get start and end times in the same (short) format used by acctcom. Finally, we made our best guess as to when acctcom would do strange things with the formatting of their output. This was close but not perfect, as we will see below.

Our first test subject was a SunOS 5.6 system. This system is a relatively busy ftp server, but the subnet was disconnected from the outside world while running this test. The usernames have been changed below to protect the guilty (er, make that the innocent).

```
jac@hobbes[539] cp /var/adm/pacct32 ./pacct-5.6
jac@hobbes[540] acctcom -bfti ./pacct-5.6 | cut -c1-96 > pacct-5.6.acctcom.out
jac@hobbes[541] ~/src/tct/tct-1.09/bin/lastcomm -t -f ./pacct-5.6 > pacct-5.6.tm
jac@hobbes[542] ./tm2acctcom.pl pacct-5.6.tm > tm2a.out-5.6
jac@hobbes[543] wc -l tm2a.out-5.6
9606
jac@hobbes[544] diff pacct-5.6.acctcom.out tm2a.out-5.6
67c67
< #sh        test0323_ ?            14:00:01 14:00:02     1.77    0.02    0.01
22992       0  42
---
> #sh        test0323 ?            14:00:01 14:00:02     1.77    0.02    0.01
22992       0  42
77c77
< #sh        smithneph ?            14:00:02 14:00:02     0.21    0.01    0.01
22992       0  42
---
> #sh        smithnep ?            14:00:02 14:00:02     0.20    0.01    0.01
22992       0  42
```

We shall take a moment and examine these first few differences. We note here that acctcom is actually a little inconsistent. This system uses usernames that can be up to ten characters in length, acctcom sometimes truncates the username to eight characters, at other times nine. We do not consider these differences significant.
Here we note a peculiarity which appears consistently in our tests on Sun machines and probably warrants further investigation. There are a number of processes where `lastcomm` gave an elapsed time of 0.00 seconds. In every single case, `acctcom` gave an elapsed time of 0.01 seconds for the same process. We note again, that since the granularity of the start time is at the 1-second level, in either case the start time and end time will be the same. We intend to investigate the cause of this difference further at some point in the future, but for now we again conclude that these differences are insignificant to our test.

While there were a total of 290 differences between the two files (out of a total of 9602 records – the 9606 lines minus the four lines of header, or 3.02%), all of them fell into one of the two categories noted above, either a username truncation (67 of the differences) or a very short duration process (223 times).

Next, we examine a SunOS 5.7 system, this system is not quite as busy as the 5.6 system we just examined. This system serves primarily as a console server. Again, we will use the same process as above and examine each difference as we encounter it.
In this case, we note a rather disappointing feature of acctcom under SunOS 5.7, it appears (at least at the patchlevel we tested) to not properly report tty, even though that data is in the log. This problem does not seem to occur on 5.6, 5.8, or 5.9, but all of the 5.7 systems we tested (granted, this was a relatively small sample) provided incorrect output for the tty in one fashion or another (some gave console for pts/0, others showed the results we see above). We consider this a bug in the native utility and not a problem with the tool we are examining.

Here we again see the problem we noted in the SunOS 5.6 results, where for very short-lived processes, lastcomm reports an elapsed time of 0.00 seconds, while acctcom reports an elapsed time of 0.01 seconds. As with the results from SunOS 5.6, we do not consider these differences significant for the purposes of this test.

The differences here were a result of spacing anomalies from acctcom, it was inconsistent in its formatting of the character I/O field when the value became large. The missing 40 on the end of the acctcom output was a result of our passing the results of acctcom through the cut(1) command to cut off the exit status field since this version of lastcomm does not capture that information for Solaris (we will be submitting a patch to the maintainers of TCT, which will allow lastcomm to capture Solaris exit status values). We went back and examined
these lines without `cut`-ing the `acctcom` output and the flag fields matched. Again, these differences are insignificant to our test. There are no users on this system with usernames longer than eight characters, so we did not encounter that particular anomaly on our SunOS 5.7 system. There were a total 302 differences out of a total of 5254 entries in the log (or 5.75%), of these differences 156 were the tty display issue, 2 were the large character I/O field formatting, and the remainder (144) were the very short duration processes.

Our third test system, was a SunOS 5.8 system which runs a web server and monitors the status of some network devices via SNMP.

```
jac@newmozart[509]  acctcom -bfti ./pacct-5.8 | cut -c1-96 > pacct-5.8.acctcom.out
jac@newmozart[510] ~/src/tct/tct-1.09/bin/lastcomm -t -f ./pacct-5.8 > pacct-5.8.tm
jac@newmozart[511] ./tm2acctcom.pl ./pacct-5.8.tm > tm2a.out-5.8
jac@newmozart[512]  wc -l tm2a.out-5.8
                    2806 tm2a.out-5.8
jac@newmozart[513]  diff pacct-5.8.acctcom.out tm2a.out-5.8
179c179
<  ssh        jac       pts/26       09:32:27 13:15:51 1568604.16 0.15 0.81
274432      50
---
>  ssh        jac       pts/26       09:32:27 13:15:51 1568604.16 0.15 0.81
274432      50
```

Here we see another problem with our use of `cut`, in this case it is because the elapsed time overflowed the space allocated. In this case, we see the termination of an `ssh` process that had been running for almost three weeks. As we did with the `tripwire` entry on the previous system, we did examine the flag field from `acctcom` (without piping it through `cut`) and they matched, so again these differences are not significant for the purpose of our test.

```
240c240
<  gethosti  root      ?            13:05:01 13:05:01    0.01    0.00    0.00
11       0  41
---
>  gethosti  root      ?            13:05:01 13:05:01    0.00    0.00    0.00
11       0  41
```

As with the previous versions, we see the same problem with very short-lived processes.

```
1184c1184
<  tripwire  root      ?           10:00:00 10:14:29  869.12  91.04 250.24-2069889024
110912
---
>  tripwire  root      ?           10:00:00 10:14:29  869.12  91.04 250.24
2225078272 110912  40
```

In this case, it looks like we may have a case of `acctcom` treating the character I/O field as a signed, rather than an unsigned integer and again, we see the formatting issues when certain of the fields are larger than the default sizes. In this test, there were a total of 61 differences out of a total of 2802 records (or 2.18%).
Of these, 34 were due to the two different formatting issues noted, the remaining 27 were the extremely short duration processes.

Our fourth test system was a workstation running SunOS 5.9. In this case we had a much smaller log to examine, but there were sufficient different types of entries that we deemed it representative for the purposes of this test.

```
jac@Scheduler[51] acctcom -bfti ./pacct-5.9 | cut -c1-96 > pacct-5.9acctcom.out
jac@Scheduler[52] ~/src/tct/tct-1.09/bin/lastcomm -t -f ./pacct-5.9 > pacct-5.9.tm
jac@Scheduler[57] ./tm2acctcom.pl ./pacct-5.9.tm > tm2a.out-5.9
jac@Scheduler[58] wc -l tm2a.out-5.9
   267 tm2a.out-5.9
jac@Scheduler[59] diff pacct-5.9acctcom.out tm2a.out-5.9
24c24
< postfix     root      pts/11       13:25:43 13:25:43     0.01    0.00    0.00
  44       0  41
---
> postfix     root      pts/11       13:25:43 13:25:43     0.00    0.00    0.00
  44       0  41
```

As we have seen with all of the other SunOS versions, this version also suffers from the problem of very short duration processes.

```
165c165
163840000     557
---
163840000     557  42
```

This version also suffers from the same formatting issues when one of the fields exceeds its default size. Of the 262 entries in the accounting log, 13 of them (4.96%) were different and of those 12 were the very short duration processes and the other was the formatting issue.

We next moved on to a pair of Linux systems. For examining the Linux output, we noted that the native version of lastcomm has a switch (--debug) which provides much of the data found in the accounting record in a format that is quite similar to the time-machine format from TCT's lastcomm. We wrote another perl script, tm2lin-debug.pl, to give us a format similar to the output from the native Linux lastcomm run with the --debug option. We shall examine that script now. We should note, however that the native Linux version outputs quite a few lines of debugging information mapping numbers to device names. We deleted all of these lines before doing the diff's below.

```
#!/usr/local/bin/perl
#
# $RCSfile: tm2lin-debug.pl,v $
# $Revision: 1.2 $
# Author:       Jim Clausing <clausing@computer.org>
# $Date: 2002/09/15 20:51:19 $
#```
# Purpose: Converts time-machine format output from tct-1.09's
# version of lastcomm and reformats in same format as
# Linux's lastcomm(1) run with the --debug switch
#
# $Log: tm2lin-debug.pl,v $
# Revision 1.2  2002/09/15 20:51:19  jac
# Put RCS stuff in header
#
# use Getopt::Std;
use POSIX qw(strftime);
getopts('s');
$str1 = "-----------------------------------------------------------------------------

$format = "CURRENT REC: %s|%6.1f|%6.1f|%6.1f|%5d|%5d|%6.1f|%s\n"
$format2 = "%s %5s %8s %8s %6.2f secs %s\n"

open (INPUT, "tail +4 $ARGV[0]\n");
while(<INPUT>) {
  ($name,$flags,$uid,$gid,$tty,$ucpu,$cpu,$start,$elapse,$mem,$char,$io_blk,
   $maj_pflt,$min_pflt,$exit_stat,$swap)
    = split(/\|/,$_);
  ($foo,$bar) = split(\,\,\$tty);
  if ($foo != 0) {
    $tty = $opt_s?'pts/':'tty' . $bar;
  } else {
    $tty = '??';
  }
  $fl1 = $fl2 = $fl3 = $fl4 = $fl5 = ' '; $fl = $fl1 . $fl2 . $fl3 . $fl4 . $fl5 ;
  $user = getpwuid($uid);
  $start_str = scalar localtime($start);
  $short_date = strftime("%a %b %e %H:%M",localtime($start));
  print $str1;
  printf $format, $name,$ucpu*100.0,$cpu*100.0,$elapse*100.0,$mem,$char,$io_blk,
    $maj_pflt,$min_pflt,$exit_stat,$swap,scalar localtime($start);
  printf $format2,$name,$fl,$user,$tty,$cpu+$ucpu,$short_date
}

This script is actually simpler than the SunOS one. We first skip over the three
header lines in the time-machine format. Next, we have some inconsistencies in
the way ttys are displayed between SuSE and Red Hat (the two Linux systems that
we tested) and even that depends on whether we run the test from the same pts as
the original process, we shall explain that when we encounter it below. Further, we
note that the native lastcomm on our SuSE system did not print out the flag
information even though it was contained in the log, so we used our SuSE switch
(-s) to turn off output of the flags. We finally note that in time-machine format the
TCT version of lastcomm has already converted from ticks to seconds, we need
to undo this conversion to get back to what the native `lastcomm` outputs, thus the multiplication by 100.0 in the `printf` command above.

Our fifth test system is a desktop system running SuSE Linux version 7.3, with the accounting package acct-6.3.5-217 installed.

The first thing we note on this system is that the accounting log is located in `/var/account`. We also had to change ownership or permissions so that it could be read by the unprivileged account running this test. Also, note that we cheated here a little bit and in another window figured out that there were 1551 lines of device mapping info at the top of the file that needed to be removed before we ran `diff`. Next, we see that the native version outputs debugging information everytime it extracts another 256 records from the file. This difference between the two files is not significant to our test.

Of the 2168 records (6504 lines divided by three lines per record), there were 429 differences all of which were the tty naming (there were also eight instances of the debugging messages in the `pacct-suse-7.3.lc.out2` file).

The final system we examined was a laptop running Red Hat 7.2 with the psacct-6.3.2-9 package installed. From the version numbers, it appears that the SuSE and Red Hat systems should be very similar as they appear to be based on the same original source tree.
As was the case with SuSE, we see the debugging output from the native version of lastcomm. We also note that the native version outputs the flag indicating the process was terminated by a signal, but the TCT version does not. It turns out the reason for this is the version of the accounting header file (<sys/acct.h> versus <linux/acct.h>) used to build the TCT version of lastcomm. These are, in fact, the only differences between the files. Again, these differences are not considered significant to this test.

So, now that we have completed the six tests, what can we conclude? Not surprisingly, the version of lastcomm distributed in version 1.09 of The Coroner’s Toolkit, accurately renders the contents of the process accounting logs in a standard format. Well, this result should be expected. The format of the process accounting record is recorded in a header file for each operating system (in most cases, <sys/acct.h>, though as noted, on Red Hat <linux/acct.h> is probably a better choice), so the tool does not have to do anything particularly special. We then conclude that the tool has passed our test by providing essentially the same information as the native tools provided with the operating system.

**Analysis**

If the tool we have been examining does not have to do anything special, why does the forensic investigator care about it? As noted above, the data provided by the accounting logs are most useful for creating a timeline of an event. In particular, we note that with MACTime analysis, we only know the last time that a particular file was accessed. The process accounting logs provide us with information on which users were running processes during an event. This can provide data that may fill in some of the holes in the MACTime data.

We have previously noted, however, that there are some problems with process accounting data. One of those problems is the fact that the log exists only on the host system. The logs are therefore vulnerable to deletion or modification by an
attacker. To address this issue, we were inspired by a tool called loginlog⁸, written by mark@netsys.com in 1994. This tool constantly watches the wtmp file and when it sees a new entry, sends that information to syslog. At the time this tool was written attackers were regularly running tools to erase their tracks including deleting entries in the wtmp file. We wanted to create a tool that would do something similar for process accounting records, so we have written a tool called acctlog which constantly watches the current process accounting log and when a new entry is written, sends a message to syslog. We include the source code in Appendix A and will make it available on the Internet when we can find a web site to serve as its permanent home.

**Presentation**

The version of lastcomm that we have been examining has a number of different options for displaying output. We have noted the time-machine format in our testing and this has worked out to be a reasonable format for storing and manipulating the process accounting records. We like the basic format of the output of mactime, also part of tct-1.09, so we have created another perl script (which we are calling acctime.pl, the code is included in Appendix B and, as with acctlog, we hope to have this available from a web site on the Internet in the near future) to output the process accounting data in a similar format. We anticipate at some point creating a script to produce a unified timeline combining the output of mactime and our new script. An example of the output of our script is shown below.

```
jac@newmozart[509] ./accttime.pl -f pacct-5.7.tm "Sep 15 13:13" 2002-09-151319
2002-09-15 13:13:47 <> root  other  mount  —  0.02 (21100027-0)
2002-09-15 13:13:48 <> root  other  mount  —  0.13 (21100028-0)
2002-09-15 13:13:49 <> root  other  mount  —  0.03 (21100028-1)
2002-09-15 13:13:50 <> root  other  mount  —  0.05 (21100028-2)
2002-09-15 13:13:51 <> root  other  mount  —  0.04 (21100028-3)
2002-09-15 13:13:52 <> root  other  mount  —  0.11 (21100030-0)
2002-09-15 13:13:53 <> root  other  mount  —  0.04 (21100030-1)
2002-09-15 13:13:54 <> root  other  mount  —  0.04 (21100030-2)
2002-09-15 13:13:55 <> root  other  mount  —  0.04 (21100030-3)
>  root  other  sh  —  590.56 (2109440-0)
>  root  other  cfexecd —  590.56 (2109440-1)
>  root  other  cfagent  —  587.28 (2109444-0)
2002-09-15 13:14:45 <  jac  sysadmin  ls  0,3  1.37 (2110085-0)
2002-09-15 13:14:46 >  jac  sysadmin  ls  0,3  1.37 (2110085-0)
2002-09-15 13:16:04 <> root  other  netstat  —  0.03 (2110164-0)
<> root  other  ps  —  0.06 (2110164-1)
```

This example shows some, but not all, of the power of our script. First note that thanks to the perl module Date::Manip, we can specify start and end dates very flexibly. Also, note we output a date and time stamp (we use strftime to format

---

this, so the format can be changed relatively easily), the next two characters signify
the start (<) and end (>) time of the process. If the process took less than one
second to execute you see both together. Next, we see the username and group
name that the process was executed under (give the \( \text{--n} \) switch on the command
line and it will leave these as numeric values, \( \text{--p} \) allows specification of an
alternate passwd file, \( \text{--g} \) allows specification of an alternate group file). After this,
we see the process name, followed by tty, elapsed time and a pseudo-processid
so that we can match up process starts with the corresponding process ends. The
script also provides for a \( \text{--u} \) switch to select only the process executed by a
particular user. The passwd and group lookups use the same routines (written by
Steve Romig over ten years ago, thanks Steve) that are included in the tct-1.09
distribution (though we have created our own \texttt{paths.pl} file which is also shown
in Appendix B).

Conclusions
We have taken this opportunity to examine an often-overlooked avenue for
collecting forensic data, the process accounting records. We performed tests on
variants of two major operating systems (SunOS 5, a.k.a Solaris, and 2 relatively
closely related Linux distributions, SuSE and Red Hat) and determined that the tool
from The Coroner's Toolkit provided essentially the same data as the native tools
for examining the process accounting data. This data can be quite useful for the
investigator in trying to build a timeline of an event and can help fill in some of the
gaps in MACTime analysis. The analysis can be run on a system image or run
from a CD-ROM with the results sent off the server. Running the tool may result in
additional data being appended to the process accounting log, but will not alter old
data from the event being investigated. We also introduced another tool that can
be used to send much of this accounting data off the server to a central log server
in real-time. We have finally provided another new tool that formats the process
accounting data in a format similar to the popular \texttt{mactime} tool and we have
begun considering how both types of data might be combined in one more
comprehensive overall timeline for investigation of an event.

Additional Information
- Loganalysis mailing list - \texttt{https://lists.shmoo.com/mailman/listinfo/loganalysis}
- Loganalysis web site - \texttt{http://www.counterpane.com/log-analysis.html}
Addison-Wesley, 2002.
- The Coroner's Toolkit - \texttt{http://www.porcupine.org/forensics/tct.html}

• Old version of loginlog – Note this is a good site for many useful security tools. [ftp://ftp.cerias.purdue.edu/pub/tools/unix/logutils/loginlog/loginlog.c](ftp://ftp.cerias.purdue.edu/pub/tools/unix/logutils/loginlog/loginlog.c)
Appendix A – acctlog.c

/*
 * $Revision: 1.2 $
 * $Date: 2002/09/15 19:37:36 $
 * $Author: clausings@computer.org $
 * Purpose: This program was inspired by loginlog v1.7 by mark@netsys.com.
 * The purpose of this program is to monitor the process accounting file (acct or pacct) and when new entries are written to it, send the data to syslog.
 * $Log: acctlog.c,v $
 * Revision 1.2  2002/09/15 19:37:36  jac
 * Add RCS stuff to header. --jac
 */

#include "sys_defs.h"        /* borrowed from Wietse's lastcomm.c port */
#ifdef USE_SYSMACROS_H
#include  <sys/sysmacros.h>
#endif

#include <sys/param.h>
#include <sys/stat.h>
#include <sys/acct.h>
#include <stdio.h>
#include <ctype.h>
#include <errno.h>
#include <syslog.h>
#include <fcntl.h>
#include <string.h>
#include "struct.h"
#include <utmp.h>
#include <unistd.h>

#define FACILITY    LOG_LOCAL0
#define SEVERITY    LOG_DEBUG
#define AC_HZ       ((double)AHZ)

void reopen(char *, int  *, struct stat *, struct stat *); 
char *flagbits(int);
char *getdev(dev_t);

int main(int argc,char **argv) {
    register int  n;
    char *progname;
    struct acct acct_entry;
    struct stat old_stat, curr_stat;
    int  fd;
    off_t  size;
    time_t  t;
    int  ch, rc, end;
    char  *acct_file;
    int  time = 0;
    char  format[160];
```c
char          start_time[20], end_time[20];
#endif

if (fork()) exit(0);    /* orphan ourselves and let init take us */
if ((fd = open(_PATH_ACCT,O_RDONLY|O_LARGEFILE)) != 0 ||
    stat(_PATH_ACCT, &old_stat)) {
    perror(_PATH_ACCT);
    exit(1);
}
(void)close(1);
(void)close(2);
if ((progname = (char *)strrchr(argv[0], '/')) == NULL) { /* kill path */
    progname = argv[0];
} else {
    progname++;
}

format[0] = '\0';
(void)strcat(format, "command = %s, flags = %s, uid = %lu, gid = %lu, ");
(void)strcat(format, "tty = %s, start = %s, end = %s, user = %8.3f, ");
(void)strcat(format, "system = %8.3f, elapsed = %8.3f"ROM);
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```
#endif

void reopen (s,fd,old,curr)
  char *s;
  int  *fd;
  struct stat *old,*curr;
{
  struct stat new_stat;
  
  (void)close(*fd);
  if ((fd = open(_PATH_ACCT,O_RDONLY|O_LARGEFILE)) != 0 ||
      stat(_PATH_ACCT, &new_stat)) { 
    perror(_PATH_ACCT);
    exit(1);
  }
  (void)memcpy(old,&new_stat,sizeof(struct acct));
}

/*
 * Borrowed from lastcomm.c from tct-1.09
 *
*/
char *flagbits(f)
    register int f;
{
  static char flags[20] = "-";
  char *p;

#define BIT(flag, ch)  if (f & flag) *p++ = ch

  p = flags + 1;
  BIT(ASU, 'S');
  BIT(AFORK, 'F');

#define ACOMPAT
  BIT(ACOMPAT, 'C');
#endif

#define ACORE
  BIT(ACORE, 'D');
#endif

#define AXSIG
  BIT(AXSIG, 'X');
#endif

  *p = '\0';
  return (flags);
}

/*
 * Also borrowed and slightly modified from lastcomm.c in tct-1.09
 * We use / rather than , to separate the major & minor device numbers
 *
*/
char *getdev(dev)
    dev_t dev;
{
  static char lastname[BUFSIZ];

  if (dev == NODEV)
Note, we have added a line to the sys_defs.h, struct.h taken from tct-1.09.

```diff
jac@newmozart[507] /usr/local/bin/diff -u ../tct-1.09/src/lastcomm/sys_defs.h sys_defs.h
@@ -38,6 +38,7 @@
 #define HAVE_COMP_BLOCK_RW_COUNT
 #define HAVE_COMP_CHAR_IO_COUNT
 #define HAVE_COMP_MEMORY_USAGE
+#define HAVE_CFTIME
 #endif

 #ifdef SUNOS4

 #ifdef SUNOS4
```
Appendix B – accttime.pl

#!/usr/local/bin/perl
#
# $RCSfile: accttime.pl,v $  
# $Revision: 1.2 $  
# Author:       Jim Clausing <clausing@computer.org>  
# $Date: 2002/09/15 20:40:38 $  
#
# Purpose:      Take time-machine format lastcomm output and  
#               present it in a format similar to what mactime  
#               does with MACTimes from the body file.  
#
# Switches & arguments:  
# -h           - usage message  
# -n           - numeric uid/gid  
# -d           - debug  
# -f file      - acct/pacct file to use, otherwise stdin  
# -g grpfile   - alternate group file to use (default /etc/group)  
# -p pwdfile   - alternate passwd file to use (default /etc/passwd)  
# -u user      - select records of a particular user (use numeric with -n)  
#               time [time2]      - optional start and end time to search  
#
# $Log: accttime.pl,v $  
# Revision 1.2  2002/09/15 20:40:38  jac  
# Put RCS stuff in headers  
#  
# use POSIX qw(strftime);  
use Getopt::Std;  
use Date::Manip;  
require "pass.cache.pl";

$debug = 0;  
$usage = " usage: $0 [-hnd] [-f file] [-g grpfile] [-p pwdfile] [-u user] [time [time2]]\n";  
getopts('f:g:hnp:u:') || die $usage;  
die $usage if ($opt_h||$#ARGV>1);  

$debug = 1 if ($opt_d);  
select(STDOUT); $|=1;  

$PASSWD = ($opt_p?$opt_p:"/etc/passwd");  
$GROUP = ($opt_g?$opt_g:"/etc/group");  

if (!$opt_n) {  
  &'load_passwd_info(0,$PASSWD);  
  &'load_group_info(0,$GROUP);  
}  

if ($opt_f) {  
  close(STDIN);  
  open(STDIN,"$opt_f");  
}  

$time_one = shift @ARGV if ($#ARGV>0);  
$time_two = shift @ARGV if ($#ARGV>0);  

$time_one = &ParseDate($time_one);  
$time_two = &ParseDate($time_two);
if (defined($time_one)) {
    $start_seconds = &UnixDate($time_one,"%s");
} else {
    $start_seconds = 0;
}
if (defined($time_two)) {
    $end_seconds = &UnixDate($time_two,"%s");
} else {
    $end_seconds = time();
}

for $i ( 0..2 ) {
    $junk = <STDIN>;
}

@names = split /
|/,$junk;
push @names,"end_time";

while (<STDIN>) {
    $k++;
    print "." if ($k%20 == 0 && !opt_d);
    $newrec = {};
    @vals = split /
|/;
    for $i ( 0 .. $#vals ) {
        $newrec->{$names[$i]} = $vals[$i];
    }
    if ($opt_u) {
        $flag = 0;
        $flag = 1 if ($opt_u && ($opt_u == $newrec->{uid}));
        $flag = 1 if (!$opt_n && ($opt_u eq $uid2names{$newrec->{uid}}));
        next if !$flag;
    }
    $newrec->{end_time} = int($newrec->{start_time} + $newrec->{elapsed_time});
    $newrec->{pseudoid} = substr($newrec->{start_time},7,7) . '-' . base62($#{$starts{$newrec->{start_time}}} + 1);
    push @records, $newrec;
    push @{$starts{$newrec->{start_time}}}, $newrec;
    push @{$ends{$newrec->{end_time}}}, $newrec;
    $time_exists{$newrec->{start_time}} = 1;
    $time_exists{$newrec->{end_time}} = 1;
}

@list = sort( keys %starts );
for $i ( sort keys %time_exists ) {
    next if $i < $start_seconds;
    exit if $i > $end_seconds;
    $date_string = strftime("%Y-%m-%d %H:%M:%S",localtime($i));
    if (defined($starts{$i})) {
        for $j ( 0..$#{$starts{$i}} ) {
            $r = @{$starts{$i}};
            $sc = ($r->[j]->{elapsed_time}<1.0) ? ':' : ''; 
            if (!$opt_n) {
                printf "%-21s <%s  %8d %8d %16s %6s %8.2f (%8s)\n",
                        $date_string,$c,$uid2names{$r->[j]->{uid}},
                        $gid2names{$r->[j]->{gid}},
                        $r->[j]->{command},
                        $r->[j]->{tty},$r->[j]->{elapsed_time},$r->[j]->{pseudoid};
            } else {
                printf "%-21s %8s %8s %8d %8s %8s %8s %8.2f %8s\n",
                        $date_string,$c,$r->[j]->{uid},
                        $r->[j]->{gid}, $r->[j]->{command},
                        $r->[j]->{tty},$r->[j]->{elapsed_time},$r->[j]->{pseudoid};
            }
        } }
And our version of paths.pl

```perl
# If you add anything to this file, add it to reconfig!
#
# No format required, try to keep things alphabetical at top, platform
# specific next, then our internal TCT commands last for sheer readability.
#
1;
```
Part 2 – Analyze an Unknown Binary

Binary Details

Name
We have been given a zip file, sn.zip, which contains an unknown program. Unfortunately, the process of zip-ing the file for distribution has cost us some important data, as we shall see below. The zip archive contains two files, sn.dat and sn.md5. The name of the file does not provide us any useful information; the .dat extension is probably intended as misinformation and it is too soon to tell if sn is meaningful. Next, we shall run the file(1) command and see if this yields any useful information.

This does provide some useful information, we now know that this is an x86 executable binary, so we shall eventually move further analysis from our Sparc Solaris machine to an x86 Linux machine, but we shall gather a little more data before we do that. We further note that the binary is statically linked, so it won’t rely on any shared libraries being present on the machine on which it is eventually installed and it is stripped, so symbol table information has been removed. We shall return to this as we analyze the binary.

File/MACTime information
We shall use some of the tools that we discussed in the course to gather the MACTime information.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>User</th>
<th>Group</th>
<th>Permission</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 11 2002 09:29:52</td>
<td>37 ma. -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.md5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 11 2002 09:29:58</td>
<td>399124 ma. -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.dat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 19 2002 14:11:44</td>
<td>175185 m. -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.zip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 19 2002 14:12:17</td>
<td>175185 ..c -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.zip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 19 2002 14:12:20</td>
<td>399124 ..c -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.dat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 30 2002 12:48:23</td>
<td>175185 .a. -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.zip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr 30 2002 12:48:23</td>
<td>175185 .a. -rw-r--r--</td>
<td>jac sysadmin</td>
<td>./sn.zip</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We now have a bit more information, the sn.dat file, was modified and accessed at 09:29:58 on 11 April 2002 (14:29:58 GMT if the clock on the original victim machine was accurate, the analysis machine is configured for US/Eastern
timezone). 19 April was when the zip archive was downloaded from the GIAC web site and unzipped it on the Solaris analysis machine.

**File ownership**

The files have user and group ownership by the id that downloaded and unzipped the file. The permissions also appear to be based on the umask of the user who unzipped the file. This is unfortunate, it appears that the process of moving the data from the victim machine to the analysis machine has cost us some critical data. We shall examine the zip file a bit more to see if there is anymore useful information in the archive. To accomplish this we execute the `zipinfo(1)` command on the archive.

```
jac@newmozart[525] $ zipinfo -v sn.zip
Archive: sn.zip  175185 bytes  2 files

End-of-central-directory record:
--------------------------------
          Actual offset of end-of-central-dir record:  175163 (0002AC3Bh)
Expected offset of end-of-central-dir record:       175163 (0002AC3Bh)
(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 2 entries. The central directory is 104 (00000068h) bytes long, and its (expected) offset in bytes from the beginning of the zipfile is 175059 (0002ABD3h).

There is no zipfile comment.

Central directory entry #0:
----------------------------

sn.dat

offset of local header from start of archive:           0 (00000000h) bytes
file system or operating system of origin:             MS-DOS, OS/2 or NT FAT
version of encoding software:                          2.0
minimum file system compatibility required:            MS-DOS, OS/2 or NT FAT
minimum software version required to extract:          2.0
compression method:                                    deflate
compression sub-type (deflation):                     normal
file security status:                                  not encrypted
extended local header:                                 no
file last modified on (DOS date/time):                 2002 Apr 11 09:29:58
32-bit CRC value (hex):                                d80a22be
compressed size:                                      174950 bytes
uncompressed size:                                    399124 bytes
length of filename:                                   6 characters
length of extra field:                                0 bytes
length of file comment:                               0 characters
disk number on which file begins:                      disk 1
apparent file type:                                   binary
```
non-MSDOS external file attributes: 81B600 hex
MS-DOS file attributes (20 hex): arc

There is no file comment.

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

sn.md5

offset of local header from start of archive: 174986 (0002AB8Ah) bytes
file system or operating system of origin: MS-DOS, OS/2 or NT FAT
version of encoding software: 2.0
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): 2002 Apr 11 09:29:52
32-bit CRC value (hex): 0b9f9462
compressed size: 37 bytes
uncompressed size: 37 bytes
length of filename: 6 characters
length of extra field: 0 bytes
length of file comment: 0 characters
disk number on which file begins: disk 1
apparent file type: text
non-MSDOS external file attributes: 81B600 hex
MS-DOS file attributes (20 hex): arc

There is no file comment.

This tells us that the archive was actually created on a Windows machine (see file system or operating system of origin) and not on the machine where the actual compromise took place (since as we will show below that the binary is actually a Linux binary and not a Windows binary). We thus conclude the access and modification times from the MACTime section above are probably the time when the binary was copied to the Windows machine where the zip archive was created.

**File size**

As we can see from both the `zipinfo` output and the MACTime information above, the binary in question is 399124 bytes in size.

**MD5 hash**

In order to ensure that we have correctly extracted the file, we will generate an MD5 hash of the file and compare that with the MD5 hash contained in the zip archive.
jac@newmozart[529] md5 sn.dat
MD5 (sn.dat) = 0e954f43fd73f56e812a7285f32e41d3
jac@newmozart[530] cat sn.md5
0e954f43fd73f56e812a7285f32e41d3  sn

The hashes match, so our extraction was correct.

Keywords
Next, we examine the binary for keywords and interesting strings. This is accomplished by running the strings(1) command on the binary. Since this is still the preliminary examination of the binary and we are still working on a Solaris analysis machine, we will run the stock Solaris version of strings first. We shall examine the results of that in a moment. Then, just for the heck of it, since we also have the GNU version of strings (version 2.11.2) on our analysis machine, we will run it as well. The two versions provide us with roughly the same information. We will then re-run both versions with the -a switch to examine the whole binary, not just the initialized and loaded sections (see man page for strings(1)). This provides us with a key piece of additional information. The extracts below is from the output of the Solaris version run with the -a switch. We shall address some of the important features as we encounter them.

```c
---=[ %s:%i -->
%s:%i ]=--
DUMP STRUCT = NUMBER %i
*sip -> %*s
*sport -> %i*
*dip -> %s*
*dport -> %i*
*data -> %s
*---------*
\* The END *

priv 1.0
ADMsniff %s <device> [HEADERSIZE] [DEBUG]
ex : admsniff le0
..ooOO The ADM Crew OOoo..
cant open pcap device :
init_pcap : Unknown device type!
ADMsniff %s in libpcap we trust !
credits: ADM, mel , ^pretty^ for the mail she sent me
The _l0gz
@(#) $Header: pcap-linux.c,v 1.15 97/10/02 22:39:37 leres Exp $ (LBL)
@(#) $Header: pcap.c,v 1.29 98/07/12 13:15:39 leres Exp $ (LBL)
@(#) $Header: savefile.c,v 1.37 97/10/15 21:58:58 leres Exp $ (LBL)
@(#) $Header: bpf_filter.c,v 1.33 97/04/26 13:37:18 leres Exp $ (LBL)
/lib/
/usr/lib/
undefined symbol:
```
Right at the beginning, we have a few very important pieces of data. We see what appear to be credits in the program. The program purports to be ADMsniff, a libpcap-based packet sniffer available from a number of websites on the internet (see program identification section below). In addition, the pcap-linux header string is an indicator that the binary in question is a Linux binary. At this point, we also surmise that the sn part of the name was actually a clue that the binary is a sniffer, but of course, more analysis is still required to verify this. These strings could be meant to mislead, or the program could have been modified from its original purpose.

```
linux socket: %s
linux SIOCSIFFLAGS: %s
```

More indicators that this is a Linux binary.

```
/etc/ld.so.cache
  search cache=%s
ld.so-1.7.0
 glibc-ld.so.cachel.1
```

Still more indication that this is a Linux binary. This could also provide more information on which version of Linux the binary was built on.

```
GCC: (GNU) 2.96 20000731 (Red Hat Linux 7.1 2.96-97)
GCC: (GNU) 2.96 20000731 (Red Hat Linux 7.1 2.96-97)
GCC: (GNU) 2.96 20000731 (Red Hat Linux 7.1 2.96-98)
GCC: (GNU) 2.96 20000731 (Red Hat Linux 7.1 2.96-98)
GCC: (GNU) 2.96 20000731 (Red Hat Linux 7.1 2.96-98)
```

Here we have a very significant piece of information. The binary and/or some of the library routines that were statically linked into the binary were compiled by gcc version 2.96 on a Red Hat Linux 7.x system (the version of gcc that ships with Red Hat 7.2 on CD-ROM is 2.96 and matches the '98' signatures above, see below in the program identification section). This seems to confirm definitively that this is a Linux binary. For the remainder of our analysis we will move to a Linux machine.

**Program Description**

Judging from the strings in the binary, this would appear to be ADMsniff, a libpcap-based packet sniffer. Also, as noted above, the process of packaging the binary up for distribution to us has removed the key MACTime data on when the binary was last used on the victim machine. We shall now analyze the binary, including executing it on a machine on an isolated network, to attempt to determine just what it does.

The machine used for the rest of the analysis is a laptop running Red Hat 7.2 current on all patches through mid-May 2002. We begin the analysis of the
runtime characteristics, by using the `strace(1)` command to trace the system calls made by the binary as it executes.

```
$ strace sn.dat
execve("./sn.dat", ["./sn.dat"], /* 46 vars */) = 0
fcntl64(0, 0x1, 0, 0xbffff7a4) = 0
fcntl64(0x1, 0x1, 0, 0xbffff7a4) = 0
fcntl64(0x2, 0x1, 0, 0xbffff7a4) = 0
uname({sys="Linux", node="Gazelle", ...}) = 0
geteuid32() = 500
getuid32() = 500
getegid32() = 500
getgid32() = 500
brk(0) = 0x80ab488
brk(0x80ab4a8) = 0x80ab4a8
brk(0x80ac000) = 0x80ac000
fcntl64(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 6), ...}) = 0
old_mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x40000000
write(1, "ADMsniff priv 1.0 <device> [HEAD"..., 49
write(1, "ex   : admsniff le0\n", 20
write(1, " ..ooOO The ADM Crew OOoo.. \n", 29
munmap(0x40000000, 4096) = 0
_exit(-1) = ?
```

The binary almost immediately exited since it was missing a required command-line parameter. Fortunately, the authors were kind enough to tell us that the missing parameter was the interface to be sniffed (see bold text above). We will try again with the additional parameter.

```
$ strace ./sn.dat eth0
execve("./sn.dat", ["./sn.dat", "eth0"], /* 46 vars */) = 0
fcntl64(0, 0x1, 0, 0xbffff794) = 0
fcntl64(0x1, 0x1, 0, 0xbffff794) = 0
fcntl64(0x2, 0x1, 0, 0xbffff794) = 0
uname({sys="Linux", node="Gazelle", ...}) = 0
geteuid32() = 500
getuid32() = 500
getegid32() = 500
getgid32() = 500
brk(0) = 0x80ab488
brk(0x80ab4a8) = 0x80ab4a8
brk(0x80ac000) = 0x80ac000
socket(PF_INET, SOCK_PACKET, 0x300 /* IPPROTO_??? */) = -1 EPERM
(failed to bind to socket)
fcntl64(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 6), ...}) = 0
old_mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x40000000
write(1, "cant open pcap device :<\n", 25
```

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This time we proceeded a little further, but also failed, this time because it could not open a raw socket. We shall try again, this time running a root, rather than an unprivileged user.

Success! There are a few things to take note of here. First, we successfully opened the socket, next we did a bind to that socket. The interesting data are the port (25972) and IP address (104.84.0.0) used in the bind call. We will have to investigate this more closely in the forensic details section below. The next item of interest is that we have opened a file for writing named The_10gz in the current...
directory (we shall return to this shortly). Finally, we note that the program is sniffing the traffic on the socket (see the recvfrom(3,...) call). It appears that the interface has been placed in promiscuous mode, since it appears to be reading data, while snort(8) running on the system simultaneously shows no traffic to or from the IP address of the virtual Red Hat machine, we'll run ifconfig(8) below to verify this (after killing snort, so that it does not skew the results). At this point, the binary in question appears to be passive, i.e., there has not, yet, been any attempt to initiate outbound communication. The file, The_l0gz, is empty, probably because there was no significant traffic on the network during this run. We have not yet let the program run for an extended period of time to see if, after some period of time or some amount of data has been collected, the program attempts to “phone home.” Running ifconfig and lsof(8), we see the following.

```
jac@Gazelle[516]$ ifconfig eth0
eth0 Link encap:Ethernet  HWaddr xx:xx:xx:xx:xx:xx
    inet addr:10.18.2.35  Bcast:10.18.2.255  Mask:255.255.255.0
    UP  BROADCAST  NOTRAILERS  RUNNING  PROMISC   MTU:1500  Metric:1
    RX packets:10723  errors:0  dropped:0  overruns:0  frame:0
    TX packets:5439  errors:0  dropped:0  overruns:0  carrier:0
    collisions:1  txqueuelen:100
    RX bytes:1470520 (1.4 Mb)  TX bytes:484154 (472.8 Kb)
    Interrupt:9  Base address:0x9000
jac@Gazelle[517]$ lsof -p 3194
COMMAND    PID USER   FD   TYPE DEVICE SIZE NODE NAME
sn.dat  3194 root  cwd    DIR    3,7  1024 1978369 /home/jac/giac/gcfa
sn.dat  3194 root  rtd    DIR    3,6  1024       2 /
sn.dat  3194 root  txt    REG    3,7 399124 1978371 /home/jac/giac/gcfa/sn.dat
sn.dat  3194 root  0u   CHR  136,6              8 /dev/pts/6
sn.dat  3194 root  1u   CHR  136,6              8 /dev/pts/6
sn.dat  3194 root  2u   CHR  136,6              8 /dev/pts/6
sn.dat  3194 root  3u sock  0,0              5917 can't identify protocol
sn.dat  3194 root  4w   RGB  3,7      0 1978380 /home/jac/giac/gcfa/The_l0gz
```

The binary has put the interface in promiscuous mode, as we see when we run ifconfig again after we kill the program the PROMISC flag is no longer present.

```
jac@Gazelle[521]$ ifconfig eth0
eth0 Link encap:Ethernet  HWaddr xx:xx:xx:xx:xx:xx
    inet addr:10.18.2.35  Bcast:10.18.2.255  Mask:255.255.255.0
    UP  BROADCAST  NOTRAILERS  RUNNING  MTU:1500  Metric:1
    RX packets:10741  errors:0  dropped:0  overruns:0  frame:0
    TX packets:5439  errors:0  dropped:0  overruns:0  carrier:0
    collisions:1  txqueuelen:100
    RX bytes:1473494 (1.4 Mb)  TX bytes:484154 (472.8 Kb)
    Interrupt:9  Base address:0x9000
```
Forensic Details

Now that we have the program running, we shall examine the footprints it leaves behind. The first piece of evidence we have is the network interface being placed in promiscuous mode. A program such as ifstatus\(^9\) can be used in many circumstances to alert administrators or security officers when a system’s network interface has been changed to promiscuous mode unexpectedly.

Next, we shall examine the file that we noted above as being opened for writing. At this point in our examination, the file, The_l0gz, is empty. Next, while running the target binary, we initiated a connection to the analysis system via ssh. The file remains 0 bytes. So, we enabled telnet and created a sacrificial account named fred with password flintstone. When we then connected to the system via telnet, we see that the file has increased in size. Apparently, the program looks for certain cleartext protocols to capture. Examining the contents of the file, we see that the username and password can be found in the log, as can the commands typed and the results returned. By taking a little time to study and understand how this program logs the sessions, harvesting username/password pairs (including possibly administrator/superuser passwords) is not too difficult.

Our experiment thus far suggests that encrypting the traffic is a defense against this particular sniffer.

\(^9\) [http://www.cymru.com/Tools/ifstatus-4.0.tar.gz](http://www.cymru.com/Tools/ifstatus-4.0.tar.gz)
Let us briefly examine that IP address again. A quick check of ARIN reveals that this address range, 104.48.0.0/16, has not yet been assigned.

```
jac@Gazelle[531]$ whois -h whois.arin.net 104.48.0.0
[whois.arin.net]
OrgName:    IANA
OrgID:      IANA-2
NetRange:   96.0.0.0 - 126.255.255.255
CIDR:       96.0.0.0/4, 112.0.0.0/5, 120.0.0.0/6, 124.0.0.0/7, 126.0.0.0/8
NetName:    RESERVED-0
NetHandle:  NET-96-0-0-0-1
Parent:     
NetType:    Direct Assignment
Comment:    
RegDate:    1998-11-03
Updated:    1998-11-03
TechHandle: IANA-ARIN
TechName:   Internet Corporation for Assigned Names and Number
TechPhone:  +1-310-823-9358
TechEmail:  res-ip@iana.org
```

This suggests a number of possibilities. One, that this was put in the binary as a distraction. The second possibility is that the binary was built on a network that was using address space that they did not own. Some of our customers have been known to use a similar plan to number the WAN, but things start to break down when IANA does start distributing the addresses, that previously only existed in our network, out into the cruel internet resulting in conflicts. The third possibility is that this is a red herring. Similarly, a search for port 25972 has yielded no useful data.

**Program Identification**

Given the hints found in the `strings` output, we did a quick search on our favorite meta-search engine, Dogpile\(^1\), and discovered the source code for ADMsniff at [http://www.freelsd.net/ADM/ADMsniff.tar.gz](http://www.freelsd.net/ADM/ADMsniff.tar.gz). We downloaded the archive onto our analysis machine and we will build it to see if we can tell if the binary we found has been altered.

```
jac@Gazelle[525]$ tar xzvf ADMsniff.tar.gz
ADMsniff/
ADMsniff/ip.h
ADMsniff/tcp.h
ADMsniff/bpf.h
ADMsniff/pcap.h
```

\(^1\) [http://www.dogpile.com](http://www.dogpile.com)
Examining the source file, "thesniff.c", we note that there is a list of cool ports that probably explains why it took no note of our ssh connection earlier. It appears to only be looking for ftp, telnet, pop2, pop3, imap, the Berkeley r-commands, Oracle, and BackOrifice. All of these are protocols that (can) send passwords in the clear, or do not require a password at all.

```c
u_short coolport[] =
{21, 23, 109, 110, 143, 512, 513, 514, 1521, 31337};
```

Next, we shall actually compile the source that we have downloaded. We first run `gcc -v` to note the version of the compiler we are running (which conveniently appears to be the same version used on our target binary).

```
jac@Gazelle[526]$ gcc -v
Reading specs from /usr/lib/gcc-lib/i386-redhat-linux/2.96/specs
gcc version 2.96 20000731 (Red Hat Linux 7.1 2.96-98)
jac@Gazelle[527]$ cd ADMsniff
jac@Gazelle[528]$ make
.makefile ADMsniff private 1.0 beta 0 0000..
libpcap-0.4/CHANGES
libpcap-0.4/FILES
libpcap-0.4/INSTALL
libpcap-0.4/Makefile.in
libpcap-0.4/README
...
ar rc libpcap.a pcap-linux.o pcap.o inet.o gencode.o optimize.o
    nametodaddr.o etherent.o savefile.o bpf_filter.o bpf_image.o scanner.o
    grammar.o version.o
ranlib libpcap.a
make[1]: Leaving directory `/home/jac/giac/gcfa/source/ADMsniff/libpcap-0.4'
compiling ADMsniff...
gcc -I. -L. thesniff.c -lpcap -lz -o ./ADMsniff
Done!
```

We have cut out some of the extraneous stuff above. Typing `make` caused source for `libpcap` to be untarred, configured, and built, ending with the creation of the `libpcap.a` library archive above. Then, `thesniff.c` was compiled and linked with `libpcap.a` and `libz` (we shall return to this briefly below) creating the binary named `ADMsniff-1`. We now examine the binary created to see if it matches our mystery binary.

```
jac@Gazelle[529]$ md5sum ADMsniff-1
07210c66577d70b2d6d4e6b48ee498dd  ADMsniff-1
```

matches our mystery binary.
We obviously made a mistake here, the binary we built is not statically linked, is much smaller, and does not match the MD5 hash of our target. We will edit the Makefile to have it build a statically linked binary and try again. To do this, we add --static to the CFLAGS line in the Makefile, then delete ADMsniff-1, and run make again. After doing this we see the following.

We are closer, but the file is now too big and not stripped. We will take care of that next, but we will save this version of the executable, it will be useful in our analysis.

This binary is much closer in size, it is only 1900 bytes larger than our target binary. Since the sizes are different, obviously, the MD5 hashes will differ, but we include it here for completeness. Does this mean that we have the wrong source? Not necessarily. Clearly, we have not exactly duplicated the conditions under which the original binary was built, but the differences could simply be some of the other libraries that were statically linked into the final binary. We still have some additional analysis we can do. The original binary was stripped, either to reduce the size of the binary, hide information by removing the symbol table, or, perhaps, both. The information in the symbol table would be extremely useful to us if we could recreate it. Fortunately, we can restore at least part of it. During the Honeynet Project’s Reverse Challenge\textsuperscript{11} in May of 2002, there were several postings to various mailing lists that mentioned tools that might be of assistance to participants. One of those mentioned was a tool called fenris, available from

\textsuperscript{11}http://projects.honeynet.org/reverse/
Bindview\textsuperscript{12}. Fenris is written and maintained by Michal Zalewski\textsuperscript{13}, who has links to other similar tools on his own website\textsuperscript{14}. Included with the fenris (we used version 0.03b which was current when we began this analysis, there have been several updates since then), is a utility called dress which is intended as the opposite of strip(1) that can restore at least part of the symbol table. This is accomplished by looking for library routines in a stripped binary, comparing hashes calculated from the object code with those in a database built from several versions of standard libraries and, based on matches, determining the name of the library routine. The package also includes instructions on adding new signatures to the database, so we added signatures from the libraries on our analysis system before taking the further steps below. In a previous life, we wrote commercial C compilers, so for determining functional equivalence, our first inclination is to disassemble and look at the generated code. To do that here, we are going to run dress on the target binary and then disassemble both it and the version of ADMsniff that we have compiled and saved above to see if where the differences lie. Our guess, at this point, is that that the differences in size (and signature) are due to our analysis system having different (probably newer) libraries than the machine on which our target binary was built.

```
jac@Gazelle[548]$ dress sn.dat sn.dat.dress
dress - stripped static binary recovery tool by <lcamtuf@coredump.cx>
[+] Loaded 59411 fingerprints...
[+] Code section at 0x080480e0 - 0x08090160, offset 224 in the file.
[*] For your initial breakpoint, use *0x80480e0
[+] Locating CALLs... 417 found.
[+] Matching fingerprints...
[*] Writing new ELF file:
[+] Cloning general ELF data...
[+] Setting up sections: .init .text .fini .rodata .data .eh_frame .ctors .dtors .got .sbss .bss .comment .note.ABI-tag .note
[+] Preparing new symbol tables...
[+] Copying all sections: .init .text .fini .rodata .data .eh_frame .ctors .dtors .got .sbss .bss .comment .note.ABI-tag .note
[+] All set. Detected fingerprints for 342 of 417 functions.
jac@Gazelle[549]$ objdump -xD sn.dat.dress > sn.dat.dress.objdump
jac@Gazelle[550]$ objdump -xD ADMsniff-1.save > ADMsniff-1.objdump
```

Examination of thesniff.c shows us that it contains the following routines: myinet_ntoa, goodstr, flushstruct, dumpstruct, newstruct, Log, and main. If compiled with \texttt{-DCOMPRESS}, it will also have the routines hup_handler and term_handler. The target version, however, appears not to have been compiled with the COMPRESS flag, because if it had been, it would have printed two additional lines when it was executed (see below), so we will limit our examination to the seven routines listed above. This suggests that libz above is not actually linked in.

\textsuperscript{12}http://razor.bindview.com/tools/fenris/
\textsuperscript{13}lcamtuf@bos.bindview.com
\textsuperscript{14}http://lcamtuf.coredump.cx/fenris/other.txt
printf ("ADMsniff %s in libpcap we trust !\n", VERSION);
printf ("credits: ADM, mel , ^pretty^ for the mail she sent me\n");
#endif

The following comparison was actually performed using sdiff(1) on a 150 column xterm. That format, however, does not transfer to paper too well, so in the analysis that follows we will first show the source code from the archive we downloaded. Then we will show the disassembled object code. For the first (two) routine(s) we examine, we will show both versions (the disassembled object code for the unstripped binary we built above and then the equivalent section for the dressed version of the target binary) and thereafter we will show the excerpt only from our unstripped binary and highlight (and explain) any differences between it and the dressed version of the target binary. We chose the dressed version rather than the original to save ourselves the effort of running down some of the library routines if dress is able to determine which library routine it was. The only differences between the dressed and stripped versions for the routines in question are the names of the routines between the <>s. We have also gotten a great deal of useful information in other investigations using the Reverse Engineering Compiler from Backer Street Software\(^\text{15}\), but we will stick with examining the disassembled machine code for this examination.

Let us begin our examination with the myinet_ntoa routine. We note that this is a very simple routine, and therefore generates relatively little object code. Unfortunately, some of the routines that we examine later will be larger and result in more generated code.

```c
char *
myinet_ntoa (u_long theipofthedeath)
{
  struct in_addr in;
  in.s_addr = theipofthedeath;
  return (inet_ntoa (in));
}
```

Here we see the routine from the unstripped version we built earlier.

```
080481e0 <myinet_ntoa>:
80481e0: 55        push  %ebp
80481e1: 89 e5     mov   %esp,%ebp
80481e3: 83 ec 08  sub   $0x8,%esp
80481e6: 8b 45 08  mov   0x8(%ebp),%eax
80481e9: 89 45 fc  mov   %eax,0xfffffffffc(%ebp)
80481ec: 83 ec 0c  sub   $0xc,%esp
```

\(^\text{15}\) [http://www.backerstreet.com/rec/rec.htm](http://www.backerstreet.com/rec/rec.htm)
Now, we examine the same routine from our dressed version of the mystery binary.

We see, the only differences in the routines are the address of the call. So, we will examine this and see if those are, in fact, the same library call. Notice that dress could not determine the name of the library routine and came up with just socket+0x30. This is not necessarily significant. We also note that the addresses of the called routine differ between the two binaries by 0x10, this will turn out to be a recurring theme. Since the names do not match, we will examine the called library routine to see if they are, in fact, the same routine. In cases where dress determined the routine name to be the same, we will skip this step. Again, we first look at the unstripped binary that we built and then compare it with the dressed version.
8053d60: 89 c3           mov    %eax, %ebx
8053d62: 50            push   %eax
8053d63: 0f b6 45 0b    movzbl 0xb(%ebp), %eax
8053d67: 50            push   %eax
8053d68: 0f b6 45 0a    movzbl 0xa(%ebp), %eax
8053d6c: 50            push   %eax
8053d6d: 0f b6 45 09    movzbl 0x9(%ebp), %eax
8053d71: 50            push   %eax
8053d72: 0f b6 45 08    movzbl 0x8(%ebp), %eax
8053d76: 50            push   %eax
8053d77: 68 28 05 0a 08 push    $0x80a0528
8053d7c: 6a 12          push    $0x12
8053d7e: 53            push   %ebx
8053d7f: e8 54 97 01 00 call    0x806d4d <__snprintf>
8053d84: 83 c4 20      add    %esp, %esp
8053d87: 89 d8         mov    %ebx, %eax
8053d89: 8b 5d fc       mov    0xf8ffffffc(%ebp), %ebx
8053d8c: c9            leave
8053d8d: c3            ret
8053d8e: 89 f6         mov    %esi, %esi
8053d90: b8 00 00 00 00 mov    $0x0, %eax
8053d95: 85 c0         test   %eax, %eax
8053d97: 74 53         je     8053dec <inet_ntoa+0xbc>
8053d99: 83 ec 0c       sub    %esp, %esp
8053d9c: ff 35 7c 6f 0a 08 pushl   0x80a6f7c
8053da2: e8 59 c2 fa f7 call    0 <__libc_malloc>
8053da7: 83 c4 10      add    %esp, %esp
8053daa: 89 c3         mov    %eax, %ebx
8053dab: 85 db         test   %ebx, %ebx
8053dace: 75 b2        jne    8053d62 <inet_ntoa+0x32>
8053db0: 83 ec 0c       sub    %esp, %esp
8053db3: 6a 12         push    $0x12
8053db5: e8 ca b4 ff ff call    804f284 <__libc malloc>
8053db8: 83 c4 10      add    %esp, %esp
8053dbb: 85 db         test   %ebx, %ebx
8053dcd: 74 1d         je     8053de0 <inet_ntoa+0xc3>
8053dc5: be 00 00 00 00 mov    $0x0, %eax
8053dc8: 85 c0         test   %eax, %eax
8053dce: 74 96         je     8053d4b <inet_ntoa+0x7c>
8053dd0: ff 35 7c 6f 0a 08 pushl   0x80a6f7c
8053dd6: e8 25 c2 fa f7 call    0 <__init+0x8048048>
8053dd9: 83 c4 10      add    %esp, %esp
8053dde: eb 82         jmp    8053d62 <inet_ntoa+0x32>
8053dee: bb 80 6f 0a 08 mov     $0x80a6f80, %ebx
8053ded: e9 78 ff ff ff  jmp    8053d62 <inet_ntoa+0x32>
8053def: 89 f6         mov    %esi, %esi
8053dec: 31 db         xor    %ebx, %ebx
8053dee: eb bc         jmp    8053dac <inet_ntoa+0x7c>
8053df0: 8b 15 78 6f 0a 08 mov     $0x80a6f78, %edx
8053df6: 85 d2         test   %edx, %edx
8053df8: 0f 85 59 ff ff  jmp    8053d57 <inet_ntoa+0x27>
8053dfb: e8 11 00 00 00 movl    $0x1, 0x80a6f78
The address of the routine differs between the two files by 0x10 (16 decimal). This is important because the addresses in all of the `jmp` and `call` instructions differ by the same amount except for the call to `snprintf`, but `dress` has determined that those routines are the same, so we will not pursue that any further other than to note that the addresses of the `snprintf` routines differ by 0x60 (96 decimal). Also, we note the `pushl` instruction at the beginning of the routine where we have italicized the address. That address is the address of the next routine (identified as `init` in our unstripped binary) and this address also differs between the two by 0x10. Next, note the address in italics at offset 0x8053d77 (0x80a0528). The corresponding address from the target binary is 0x809fe48, which is an argument passed to the `snprintf` call just below. These addresses are in the initialized portion of memory and in both cases the address pointed to contains the data 0x25642e25. Since the values are identical, we conclude that they are pointing to the same initialized variables, we conclude that they are pointing to the same format strings. We will see this pattern repeated with all of the `snprintf` calls.

That leaves those addresses highlighted in bold in the listing above. The highlighted addresses differ between the two versions by 0x6c0 (1728 decimal). These addresses are the addresses of memory locations used for local variables in this routine. The addresses are consistent between the two executables. That is, everywhere that 0x80a6f78, for example, appears in the unstripped binary, 0x80a68b8 appears in the dressed binary (see the table below, rather than waste two pages to reproduce the entire routine again, we will just show the address from the unstripped binary we built and the corresponding address from the dressed version of the target binary). Since this is all uninitialized memory, we again assume that the differences are related to different version of other library routines between our analysis system and the one where the target binary was built. We therefore conclude that the routine called by `myinet_ntoa` is the same library routine (`inet_ntoa`) in both versions.

<table>
<thead>
<tr>
<th>Address from our binary</th>
<th>Address from target binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x80a6f78</td>
<td>0x80a68b8</td>
</tr>
<tr>
<td>0x80a6f94</td>
<td>0x80a68d4</td>
</tr>
<tr>
<td>0x80a6f7c</td>
<td>0x80a68bc</td>
</tr>
<tr>
<td>0x80a6f80</td>
<td>0x80a68c0</td>
</tr>
</tbody>
</table>

Next, we examine the routine `goodstr`.

```c
void
goodstr (char *src, char *dst, int size)
{
  int i;
  for (i = 0; i < size; i++)
    if (isprint (src[i]))
      dst[i] = src[i];
```
else if (dst[i] == '\r' || dst[i] == '\n')
    dst[i] = '\n';
else
    dst[i] = '.';

The corresponding code from our unstripped binary is shown below.

```
08048200 <goodstr>:
   08048200:      55                      push   %ebp
   08048201:      89 e5                   mov    %esp,%ebp
   08048203:      8b 45 04                mov    %esi,%esi
   08048206:      8b 45 fc                mov    0xfffffffc(%ebp),%eax
0804820e:      3b 45 10                cmp    0x10(%ebp),%eax
   08048213:      7c 04                   jl     0804821c <goodstr+0x1c>
   08048218:      eb 6a                   jmp    08048284 <goodstr+0x84>
   0804821a:      89 f6                   mov    %esi,%esi
   0804821c:      8b 45 fc                mov    0xfffffffc(%ebp),%eax
   0804821f:      03 45 08                add    0x8(%ebp),%eax
   08048222:      0f be 00                movsbl (%eax),%eax
   08048225:      6b d0 02                imul   $0x2,%eax,%edx
   08048228:      a1 c0 44 0a 08          mov    0x80a44c0,%eax
   0804822d:      66 8b 04 10             mov    (%eax,%edx,1),%ax
   08048231:      25 00 40 00 00          and    $0x4000,%eax
   08048236:      66 85 c0                test   %ax,%ax
   08048239:      74 15                   je     08048250 <goodstr+0x50>
   0804823b:      80 38 0d                cmpb   $0xd,(%eax)
   0804823e:      74 02                   je     08048268 <goodstr+0x68>
   08048240:      8b 45 fc                mov    0xfffffffc(%ebp),%eax
   08048244:      03 45 08                add    0x8(%ebp),%eax
   08048248:      8a 00                   mov    (%eax),%al
   0804824b:      01 c2                    add    %eax,%edx
   0804824e:      c6 00 0a                movb   $0xa,(%eax)
   08048251:      eb 0a                   jmp    0804827d <goodstr+0x7d>
   08048254:      90                      nop
   08048257:      80 38 0d                cmpb   $0xd,(%eax)
   0804825a:      74 02                   je     08048268 <goodstr+0x68>
   0804825c:      8b 45 fc                mov    0xfffffffc(%ebp),%eax
   08048260:      03 45 0c                add    0x8(%ebp),%eax
   08048264:      88 02                   mov    %eax,(%edx)
   08048266:      c6 00 2e                movb   $0x2e,(%eax)
   08048269:      8d 45 fc                lea    0xfffffffc(%ebp),%eax
```
This routine is actually identical between the two (the jump target addresses are the same, though the labels within the <>s are different), so we will not waste anymore time analyzing this routine. Next, we move to flushstruct.

```c
int flushstruct (int i, char add) {
    if (add != 1)
        if (theipz[i]->flags != NOL0G)
            if (((theipz[i]->time + 7000) > time (NULL))
                if (strlen (theipz[i]->data) > 4011)
                    {
                        fprintf (filez, "\n--=[ %s:%i --> ", myinet_ntoa (theipz[i]->sip),
                            ntohs (theipz[i]->sport));
                        fprintf (filez, "%s:%i ]=\n", myinet_ntoa (theipz[i]->dip),
                            ntohs (theipz[i]->dport));
                        fwrite (theipz[i]->data, strlen (theipz[i]->data), 1, filez);
                        fflush (filez);
                        theipz[i]->flags = NOL0G;
                        return (0);
                    }
                if ((theipz[i]->time + 7000) < time (NULL) || add == 1)
                    {
                        if (theipz[i]->flags != NOL0G)
                            {
                                fprintf (filez, "\n--=[ %s:%i --> ", myinet_ntoa (theipz[i]->sip),
                                    ntohs (theipz[i]->sport));
                                fprintf (filez, "%s:%i ]=\n", myinet_ntoa (theipz[i]->dip),
                                    ntohs (theipz[i]->dport));
                                fwrite (theipz[i]->data, strlen (theipz[i]->data), 1, filez);
                                fprintf (filez, ".\n");
                                fflush (filez);
                                theipz[i]->flags = NOL0G;
                            }
                        free (theipz[i]);
                        theipz[i] = NULL;
                        return (0);
                    }
            return (0);
        }
}
```

We have taken a few liberties in the presentation of the code above. We have removed the #ifndef's and only included the code that was actually compiled into our version of the binary since we did not enable compression. We have also eliminated some blank lines to get it all to fit together in less space. The code generated for this routine is shown below.

```
08048288 <flushstruct>:
```
8048288: 55          push %ebp
8048289: 89 e5       mov %esp,%ebp
804828b: 53          push %ebx
804828c: 83 ec 04    sub $0x4,%esp
804828f: 8b 45 0c    mov 0xc(%ebp),%eax
8048292: 88 45 fb    mov %al,0xffffffffb(%ebp)
8048295: 80 7d fb 01  cmpb $0x1,0xffffffffb(%ebp)
8048299: 0f 84 d5 01 00 00  je 8048474 <flushstruct+0x1ec>
804829f: 8b 45 08    mov 0x8(%ebp),%eax
80482a2: 89 c0       mov %eax,%eax
80482a4: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
80482a8: b8 00 77 0a 08 mov $0x80a7700,%eax
80482ae: 8b 04 02    mov (%eax,%edx,1),%eax
80482b4: 8b 58 0c    mov 0xc(%eax),%ebx
80482b9: 81 c3 58 1b 00 00 add $0x1b58,%ebx
80482c5: 83 ec 0c    sub $0xc,%esp
80482c8: 6a 00       push %edx
80482cb: e8 59 b3 00 00 call 8053640 <time>
80482d8: 83 c4 10    add $0x10,%esp
80482da: 89 c0       mov %eax,%eax
80482db: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
80482e2: b8 00 77 0a 08 mov $0x80a7700,%eax
80482e8: 8b 04 02    mov (%eax,%edx,1),%eax
80482f4: 8b 58 0c    mov 0xc(%eax),%ebx
80482f9: 81 c3 58 1b 00 00 add $0x1b58,%ebx
8048301: 83 ec 0c    sub $0xc,%esp
8048303: 6a 00       push %edx
8048306: e8 48 ad 00 00 call 805305c <strlen>
8048312: 83 c4 10    add $0x10,%esp
8048314: 89 c0       mov %eax,%eax
8048316: 89 c0       mov %eax,%eax
8048318: 3d ab 0f 00 00 cmp $0xfab,%eax
8048321: 0f 86 80 01 00 00 jbe 8048474 <flushstruct+0x1ec>
8048326: b8 00 77 0a 08 mov $0x80a7700,%eax
804832c: 8b 04 02    mov (%eax,%edx,1),%eax
8048331: 89 c0       mov %eax,%eax
8048333: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
8048338: b8 00 77 0a 08 mov $0x80a7700,%eax
804833e: 8b 04 02    mov (%edx,%eax,1),%eax
8048343: 89 c0       mov %eax,%eax
8048345: 0f b7 40 08 movzwl 0x8(%eax),%eax
804834b: 83 ec 0c    sub $0xc,%esp
804834d: 50          push %eax
8048351: e8 d9 b9 00 00 call 8053d20 <htons>
804835d: 83 c4 10    add $0x10,%esp
8048361: 89 c0       mov %eax,%eax
8048363: 89 c0       mov %eax,%eax
8048365: 0f b7 c0    movzwl %eax,%eax
804836b: 50          push %eax
8048352:  83 ec 08         sub $0x8,%esp
8048355:  8b 45 08         mov 0x8(%ebp),%eax
8048358:  89 c0          mov %eax,%eax
804835a:  8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
8048361:  b8 00 77 0a 08         mov $0x80a7700,%eax
8048366:  8b 04 02         mov (%edx,%eax,1),%eax
8048369:  ff 30          pushl (%eax)
804836b:  e8 70 fe ff ff   call 80481e0 <myinet_ntoa>
8048370:  83 c4 0c       add $0xc,%esp
8048373:  89 c0          mov %eax,%eax
8048375:  50             push %eax
8048376:  68 80 08 09 08   push $0x8090880
804837b:  ff 35 b4 b5 0a 08   pushl 0x80ab5b4
8048381:  e8 1e 24 00 00  call 804a7a4 <printf>
8048386:  83 c4 10     add $0x10,%esp
8048389:  8b 45 08     mov 0x8(%ebp),%eax
804838c:  89 c0      mov %eax,%eax
804838e:  8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
8048395:  b8 00 77 0a 08         mov $0x80a7700,%eax
804839a:  8b 04 02     mov (%edx,%eax,1),%eax
804839d:  0f b7 c0          movzwl 0xa(%eax),%eax
80483a1:  83 ec 0c     sub $0xc,%esp
80483a4:  50          push %eax
80483a5:  e8 76 b9 00 00  call 8053d20 <htons>
80483aa:  83 c4 10     add $0x10,%esp
80483ad:  89 c0      mov %eax,%eax
80483af:  89 c0      mov %eax,%eax
80483b1:  0f b7 c0          movzwl %ax,%eax
80483b4:  50          push %eax
80483b5:  83 ec 08     sub $0x8,%esp
80483b8:  8b 45 08     mov 0x8(%ebp),%eax
80483bb:  89 c0      mov %eax,%eax
80483bd:  8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
80483c4:  b8 00 77 0a 08         mov $0x80a7700,%eax
80483c9:  8b 04 02     mov (%edx,%eax,1),%eax
80483cc:  ff 70 04          pushl 0x4(%eax)
80483cf:  e8 0c fe ff ff   call 80481e0 <myinet_ntoa>
80483d4:  83 c4 0c     add $0xc,%esp
80483d7:  89 c0      mov %eax,%eax
80483d9:  50          push %eax
80483da:  68 91 08 09 08   push $0x8090891
80483df:  ff 35 b4 b5 0a 08   pushl 0x80ab5b4
80483e5:  e8 ba 23 00 00  call 804a7a4 <printf>
80483ea:  83 c4 10     add $0x10,%esp
80483ed:  ff 35 b4 b5 0a 08   pushl 0x80ab5b4
80483f3:  6a 01          push $0x1
80483f5:  8b 45 08     mov 0x8(%ebp),%eax
80483f8:  89 c0      mov %eax,%eax
80483fa:  8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
8048401:  b8 00 77 0a 08         mov $0x80a7700,%eax
8048406:  8b 04 02     mov (%edx,%eax,1),%eax
8048409:  83 c0 10     add $0x10,%eax
804840c:  83 ec 04     sub $0x4,%esp
804840f:  50          push %eax
8048410:  e8 47 ac 00 00  call 805305c <strlen>
8048415:  83 c4 08     add $0x8,%esp
8048418:  89 c0      mov %eax,%eax
804841a: 89 c0 mov %eax, %eax
804841c: 50 push %eax
804841d: 8b 45 08 mov 0x8(%ebp), %eax
8048420: 89 c0 mov %eax, %eax
8048422: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
8048429: b8 00 77 0a 08 mov $0x80a7700, %eax
804842e: 8b 04 02 mov (%edx, %eax, 1), %eax
8048431: 83 c0 10 add $0x10, %eax
8048434: 50 push %eax
8048435: e8 36 27 00 00 call 804ab70 <_IO_fwrite>
804843a: 83 c4 10 add $0x10, %esp
804843d: 8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
8048445: b8 00 77 0a 08 mov $0x80a7700, %eax
804844e: 8b 04 02 mov 0x8(%ebp), %eax
8048451: 89 c0 mov %eax, %eax
8048453: 8b 04 02 mov (%edx, %eax, 1), %eax
804845a: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
804845f: 8b 04 02 mov (%edx, %eax, 1), %eax
8048462: c6 80 c0 0f 00 00 03 movb $0x3, 0xf0(%eax)
8048469: b8 00 00 00 00 mov $0x0, %eax
804846e: e9 fa 01 00 00 jmp 804866d <flushstruct+0x3e5>
8048473: 90 nop
8048474: 8b 45 08 mov 0x8(%ebp), %eax
8048477: 89 c0 mov %eax, %eax
8048479: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
8048480: b8 00 77 0a 08 mov $0x80a7700, %eax
8048485: 8b 04 02 mov (%edx, %eax, 1), %eax
8048488: 8b 04 02 mov 0xc(%eax), %ebx
804848b: 81 c3 58 1b 00 00 add $0x1b58, %ebx
8048491: 83 ec 0c sub $0xc, %esp
8048494: ff 35 b4 b5 0a 08 pushl 0x80ab5b4
8048496: e8 05 25 00 00 call 804a950 <_IO_fflush>
804849b: 83 c4 10 add $0x10, %esp
804849e: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
80484a0: 80 b8 c0 0f 00 00 03 cmpb $0x3, 0xfc0(%eax)
80484a5: 0f b7 40 08 movzb %eax
80484ab: 90 nop
80484b0: 8b 45 08 mov 0x8(%ebp), %eax
80484b3: 89 c0 mov %eax, %eax
80484b5: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
80484bc: b8 00 77 0a 08 mov $0x80a7700, %eax
80484c1: 8b 04 02 mov (%edx, %eax, 1), %eax
80484c4: 80 b8 c0 0f 00 00 03 cmpb $0x3, 0xfc0(%eax)
80484cb: 0f 84 59 01 00 00 je 804862a <flushstruct+0x3a2>
80484d1: 8b 45 08 mov 0x8(%ebp), %eax
80484d4: 89 c0 mov %eax, %eax
80484d6: 8d 14 85 00 00 00 00 00 lea 0x0(%eax, 4), %edx
80484dd: b8 00 77 0a 08 mov $0x80a7700, %eax
80484e2: 8b 04 02 mov (%edx, %eax, 1), %eax
80484e5: 0f b7 40 08 movzw %eax
80484e9: 83 ec 0c sub $0xc, %esp
80484ec: 50 push %eax
80484ed: e8 2e b8 00 00 00 call 8053d20 <htons>
80484f2: 83 c4 10 add $0x10,%esp
80484f5: 89 c0 mov %eax,%eax
80484f7: 89 c0 mov %eax,%eax
80484f9: 0f b7 c0 movzwl %ax,%eax
80484fc: 50 push %eax
80484fd: 83 ec 08 sub $0x8,%esp
8048500: 8b 45 08 mov 0x8(%ebp),%eax
8048503: 89 c0 mov %eax,%eax
8048505: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
804850c: b8 00 77 0a 08 mov $0x80a7700,%eax
8048511: 8b 04 02 mov (%edx,%eax,1),%eax
8048514: ff 30 pushl (%eax)
8048516: e8 c5 fc ff ff call 80481e0 <myinet_ntoa>
804851b: 83 c4 0c add $0xc,%esp
804851e: 89 c0 mov %eax,%eax
8048520: 50 push %eax
8048521: 68 80 08 09 08 push $0x8090880
8048526: ff 35 b4 b5 0a 08 pushl 0x80ab5b4
8048555: 89 c4 10 add $0x10,%esp
8048558: 89 c0 mov %eax,%eax
804855a: 89 c0 mov %eax,%eax
804855c: 0f b7 c0 movzwl %ax,%eax
804855f: 50 push %eax
8048560: 83 ec 08 sub $0x8,%esp
8048563: 8b 45 08 mov 0x8(%ebp),%eax
8048566: 89 c0 mov %eax,%eax
8048568: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
804856f: b8 00 77 0a 08 mov $0x80a7700,%eax
8048574: 8b 04 02 mov (%edx,%eax,1),%eax
8048577: ff 70 04 pushl 0x4(%eax)
804857a: e8 61 fc ff ff call 80481e0 <myinet_ntoa>
804857f: 83 c4 0c add $0xc,%esp
8048582: 89 c0 mov %eax,%eax
8048584: 50 push %eax
8048585: 68 91 08 09 08 push $0x8090891
804858a: ff 35 b4 b5 0a 08 pushl 0x80ab5b4
8048590: e8 0f 22 00 00 call 804a7a4 <fprintf>
8048595: 83 c4 10 add $0x10,%esp
8048598: ff 35 b4 b5 0a 08 pushl 0x80ab5b4
804859e: 6a 01 push $0x1
80485a0: 8b 45 08 mov 0x8(%ebp),%eax
80485a3: 89 c0 mov %eax,%eax
80485a5: 8d 14 85 00 00 00 00 lea 0x0(%eax,4),%edx
80485ac: b8 00 77 0a 08 mov $0x80a7700,%eax
80485b1: 8b 04 02 mov (%edx,%eax,1),%eax
All of the differences are bolded above. The first differences we note between the two executables are the addresses for `ipz` (0x80a7700), `filez` (0x80ab5b4),
and the addresses of the strings that represent the formats for the fprintfs (which are in the range 0x8090880-0x809089d). The first two addresses differ between the two binaries by the same 0x6c0 as we noted previously and the format strings differ by 0x6e0 (1760 decimal). We further note that the addresses of the time and htons routines differ between the two by 0x10 and the addresses of the strlen and free routines differ by four. All the other jump and call target addresses are identical between the two versions. Since dress identified all of the calls as being the same library routines we see in our binary, we conclude that this routine is functionally equivalent between ours and the target binary.

The next routine we will examine is dumpstruct.

```c
void dumpstruct()
{
    int i;
    for (i = 0; i < 4012; i++)
        if (theipz[i] != NULL)
            {
                printf("DUMP STRUCT = NUMBER %i\n", i);
                printf("*sip -> %s*", myinet_ntoa(theipz[i]->sip));
                printf("*sport -> %i*", htons(theipz[i]->sport));
                printf("*dip -> %s*", myinet_ntoa(theipz[i]->dip));
                printf("*dport -> %i*", htons(theipz[i]->dport));
                printf("*data -> %s", theipz[i]->data);
                printf("*---------*\n");
            }
    printf("\*\* The END\*\*/\n");
}
```

Which gives us the following object code.

```
08048674 <dumpstruct>:
  8048674:      55                      push   %ebp
  8048675:      89 e5                   mov    %esp,%ebp
  8048677:      83 ec 08                sub    $0x8,%esp
  804867a:      90                      nop
  804867b:      c7 45 fc 00 00 00 00    movl   $0x0,0xfffffffc(%ebp)
  8048682:      89 f6                   mov    %esi,%esi
  8048684:      81 7d fc ab 0f 00 00    cmpl   $0xfab,0xfffffffc(%ebp)
  804868b:      7e 07                   jle    8048694 <dumpstruct+0x20>
  804868d:      e9 56 01 00 00          jmp    80487e8 <dumpstruct+0x174>
  8048692:      89 f6                   mov    %esi,%esi
  8048694:      c7 45 fc 00 00 00 00    movl   $0x0,0xfffffffc(%ebp)
  804869b:      89 c0                   mov    %eax,%eax
  804869d:      8d 14 85 00 00 00 00    lea    0x0(%eax,4),%edx
  80486a0:      8b 00 77 0a 08          movb   $0x80a7700,%eax
  80486a5:      83 c0 02 00            mov    $0x0,(%edx,%eax,1)
  80486a9:      0f 84 2c 01 00 00      je     80487db <dumpstruct+0x167>
  80486af:      83 ec 08                sub    $0x8,%esp
  80486b2:      ff 75 fc                pushl  0xfffffffc(%ebp)
  80486b5:      68 a0 08 09 08          push   $0x80908a0
```
<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>80486ba:</td>
<td>e8 01 21 00 00</td>
<td>call 804a7c0 &lt;_IO_printf&gt;</td>
</tr>
<tr>
<td>80486bf:</td>
<td>83 c4 10</td>
<td>add $0x10, %esp</td>
</tr>
<tr>
<td>80486c2:</td>
<td>83 ec 08</td>
<td>sub $0x8, %esp</td>
</tr>
<tr>
<td>80486c5:</td>
<td>83 ec 04</td>
<td>sub $0x4, %esp</td>
</tr>
<tr>
<td>80486c8:</td>
<td>8b 45 fc</td>
<td>mov $fffffffc(%ebp), %eax</td>
</tr>
<tr>
<td>80486cb:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>80486cd:</td>
<td>ff 30</td>
<td>pushl (%eax)</td>
</tr>
<tr>
<td>80486de:</td>
<td>e8 fd fa ff ff</td>
<td>call 80481e0 &lt;myinet_ntoa&gt;</td>
</tr>
<tr>
<td>80486e3:</td>
<td>83 c4 08</td>
<td>add $0x8, %esp</td>
</tr>
<tr>
<td>80486e6:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>80486e8:</td>
<td>50</td>
<td>push %eax</td>
</tr>
<tr>
<td>80486e9:</td>
<td>68 b9 08 09 08</td>
<td>push $0x80908b9</td>
</tr>
<tr>
<td>80486ee:</td>
<td>e8 cd 20 00 00</td>
<td>call 804a7c0 &lt;_IO_printf&gt;</td>
</tr>
<tr>
<td>80486f3:</td>
<td>83 c4 10</td>
<td>add $0x10, %esp</td>
</tr>
<tr>
<td>80486f6:</td>
<td>83 ec 08</td>
<td>sub $0x8, %esp</td>
</tr>
<tr>
<td>80486f9:</td>
<td>8b 45 fc</td>
<td>mov $fffffffc(%ebp), %eax</td>
</tr>
<tr>
<td>80486fc:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>80486fe:</td>
<td>8d 14 85 00 00 00 00</td>
<td>lea 0x0(%eax, %edx, 1), %eax</td>
</tr>
<tr>
<td>8048705:</td>
<td>b8 00 77 0a 08</td>
<td>mov $0x80a7700, %eax</td>
</tr>
<tr>
<td>804870a:</td>
<td>8b 04 02</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804870d:</td>
<td>0b f7 40 08</td>
<td>movzwl %eax, %eax</td>
</tr>
<tr>
<td>8048711:</td>
<td>83 ec 04</td>
<td>sub $0x4, %esp</td>
</tr>
<tr>
<td>8048714:</td>
<td>50</td>
<td>push %eax</td>
</tr>
<tr>
<td>8048715:</td>
<td>e8 06 b6 00 00</td>
<td>call 8053d20 &lt;htons&gt;</td>
</tr>
<tr>
<td>804871a:</td>
<td>83 c4 08</td>
<td>add $0x8, %esp</td>
</tr>
<tr>
<td>804871d:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804871f:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>8048721:</td>
<td>0f b7 c0</td>
<td>movzwl %eax, %eax</td>
</tr>
<tr>
<td>8048724:</td>
<td>50</td>
<td>push %eax</td>
</tr>
<tr>
<td>8048725:</td>
<td>68 c6 08 09 08</td>
<td>push $0x80908c6</td>
</tr>
<tr>
<td>804872a:</td>
<td>e8 91 20 00 00</td>
<td>call 804a7c0 &lt;_IO_printf&gt;</td>
</tr>
<tr>
<td>804872f:</td>
<td>83 c4 10</td>
<td>add $0x10, %esp</td>
</tr>
<tr>
<td>8048732:</td>
<td>83 ec 08</td>
<td>sub $0x8, %esp</td>
</tr>
<tr>
<td>8048735:</td>
<td>83 ec 04</td>
<td>sub $0x4, %esp</td>
</tr>
<tr>
<td>8048738:</td>
<td>8b 45 fc</td>
<td>mov $fffffffc(%ebp), %eax</td>
</tr>
<tr>
<td>804873b:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804873d:</td>
<td>8d 14 85 00 00 00 00</td>
<td>lea 0x0(%eax, %edx, 1), %eax</td>
</tr>
<tr>
<td>8048744:</td>
<td>b8 00 77 0a 08</td>
<td>mov $0x80a7700, %eax</td>
</tr>
<tr>
<td>8048749:</td>
<td>8b 04 02</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804874c:</td>
<td>ff 70 04</td>
<td>pushl %eax</td>
</tr>
<tr>
<td>804874f:</td>
<td>e8 8c fa ff ff</td>
<td>call 80481e0 &lt;myinet_ntoa&gt;</td>
</tr>
<tr>
<td>8048754:</td>
<td>83 c4 08</td>
<td>add $0x8, %esp</td>
</tr>
<tr>
<td>8048757:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>8048759:</td>
<td>50</td>
<td>push %eax</td>
</tr>
<tr>
<td>804875a:</td>
<td>68 d5 08 09 08</td>
<td>push $0x80908d5</td>
</tr>
<tr>
<td>804875f:</td>
<td>e8 5c 20 00 00</td>
<td>call 804a7c0 &lt;_IO_printf&gt;</td>
</tr>
<tr>
<td>8048764:</td>
<td>83 c4 10</td>
<td>add $0x10, %esp</td>
</tr>
<tr>
<td>8048767:</td>
<td>83 ec 08</td>
<td>sub $0x8, %esp</td>
</tr>
<tr>
<td>804876a:</td>
<td>8b 45 fc</td>
<td>mov $fffffffc(%ebp), %eax</td>
</tr>
<tr>
<td>804876d:</td>
<td>89 c0</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804876f:</td>
<td>8d 14 85 00 00 00 00</td>
<td>lea 0x0(%eax, %edx, 1), %eax</td>
</tr>
<tr>
<td>8048776:</td>
<td>b8 00 77 0a 08</td>
<td>mov $0x80a7700, %eax</td>
</tr>
<tr>
<td>804877b:</td>
<td>8b 04 02</td>
<td>mov $eax, %eax</td>
</tr>
<tr>
<td>804877e:</td>
<td>0f b7 40 0a</td>
<td>movzwl 0xa(%eax), %eax</td>
</tr>
</tbody>
</table>
Here we see use of the same variable, theipz, as was used in the previous routine (0x80a7700), more calls to htons, and printf format strings (addresses ranging from 0x8090880-0x8090920).

The next routine for us to examine is newstruct.

```c
int
ewstruct (u_long sip, u_long dip, u_short sport, u_short dport)
{
    int i = -1;

    /* Debug only   dumpstruct (); */ */

    for (i = 0; i < 4012; i++)
        if (theipz[i] != NULL)
            {
```
This routine gives us the following object code.

```
if (sip == theipz[i]->sip)
  if (dip == theipz[i]->dip)
    if (sport == theipz[i]->sport)
      if (dport == theipz[i]->dport)
        return (i);
  
for (i = 0; i < 4012; i++)
  if (theipz[i] == NULL)
    {
    theipz[i] = calloc (1, sizeof (struct the_ip));
    theipz[i]->sip = sip;
    theipz[i]->dip = dip;
    theipz[i]->sport = sport;
    theipz[i]->dport = dport;
    theipz[i]->time = time (NULL);
    theipz[i]->size = 0;
    memset (theipz[i]->data, 0, 4012);
    return (i);
  }

return (-1);
```
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8048939:   b8 00 77 0a 08   mov $0x80a7700, %eax
804893d:   8b 14 02       mov (%edx, %eax, 1), %edx
8048941:   8b 45 08       mov 0x8(%ebp), %eax
8048944:   89 02       mov %eax, (%edx)
8048946:   8b 45 f8       mov 0xfffffffff8(%ebp), %eax
8048949:   89 c0       mov %eax, %eax
804894b:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
8048952:   b8 00 77 0a 08 mov $0x80a7700, %eax
8048957:   8b 14 02       mov (%edx, %eax, 1), %edx
804895a:   8b 45 0c       mov 0xc(%ebp), %eax
804895d:   89 42 04       mov %eax, 0x4(%edx)
8048960:   8b 45 f8       mov 0xfffffffff8(%ebp), %eax
8048963:   89 c0       mov %eax, %eax
8048965:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
804896c:   b8 00 77 0a 08 mov $0x80a7700, %eax
8048971:   8b 14 02       mov (%edx, %eax, 1), %edx
8048974:   66 8b 45 fe mov 0xffffffffe(%ebp), %ax
8048978:   86 89 42 08 mov %ax, 0x8(%edx)
804897c:   8b 45 f8       mov 0xfffffffff8(%ebp), %eax
804897f:   89 c0       mov %eax, %eax
8048981:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
8048988:   b8 00 77 0a 08 mov $0x80a7700, %eax
804898d:   8b 14 02 mov (%edx, %eax, 1), %edx
8048990:   8b 45 fc mov 0xfffffffff(%ebp), %eax
8048993:   66 89 42 0a mov %eax, 0xa(%edx)
8048997:   83 ec 0c sub $0xc, %eax
804899a:   6a 00   push $0x0
804899c:   e8 9f ac 00 00 call 8053640 <time>
80489a1:   83 c4 10  add $0x10, %esp
80489a4:   89 c1       mov %eax, %ecx
80489a6:   8b 45 f8 mov 0xfffffffff(%ebp), %eax
80489a9:   89 c0 mov %eax, %eax
80489ab:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
80489b2:   b8 00 77 0a 08 mov $0x80a7700, %eax
80489b7:   8b 04 02 mov (%edx, %eax, 1), %eax
80489ba:   89 48 0c mov %ecx, 0xc(%eax)
80489bd:   8b 45 f8 mov 0xfffffffff8(%ebp), %eax
80489c0:   89 c0 mov %eax, %eax
80489c2:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
80489c9:   b8 00 77 0a 08 mov $0x80a7700, %eax
80489ce:   8b 04 02 mov (%edx, %eax, 1), %eax
80489d1:   89 c0 10 add $0x10, %eax
80489d4:   50 push %eax
80489d6:   e8 6a a7 00 00 call 805316c <memset>
80489de:   6b ac 0f 00 00 push $0xac
80489e3:   6a 00   push $0x0
80489e4:   8b 45 f8 mov 0xfffffffff8(%ebp), %eax
80489e6:   89 c0 mov %eax, %eax
80489ea:   8d 14 85 00 00 00 00 lea 0x0(%eax, 4), %edx
80489f0:   b8 00 77 0a 08 mov $0x80a7700, %eax
80489f4:   8b 04 02 mov (%edx, %eax, 1), %eax
80489f9:   83 c0 10 add $0x10, %eax
80489ff:   50 push %eax
8048a02:   e8 6a a7 00 00 call 805316c <memset>
8048a09:   8b 04 02 mov (%edx, %eax, 1), %eax
8048a0d:   8b 45 f8 mov 0xfffffffff8(%ebp), %eax
8048a0f:   89 c0 mov %eax, %eax
The only new things to note in this routine are the addresses of `calloc` (0x8050a60 which differs between the two versions by 4) and `memset` (0x805316c, which also differs between the two versions by 4).

The sixth of the seven routines we will examine is `Log`.

```c
int Log ()
{
    int i;
    char buffer[8012];
    LOG = 0;
    ip = (struct iphdr *) (buf + ETHHDRSIZE);
    tcp = (struct tcphdr *) (buf +IPHDRSIZE + ETHHDRSIZE);
    for (i = 0; i < sizeof (logname); i++)
    logname[i] = 0;
    for (i = 0; i < sizeof (tmp); i++)
    tmp[i] = 0;
    for (i = 0; i < sizeof (sip); i++)
    sip[i] = 0;
    for (i = 0; i < sizeof (dip); i++)
    dip[i] = 0;
    switch (ip->protocol)
    {
    case IPPROTO_TCP:
        if ((h.len - (IPHDRSIZE + TCPHDRSIZE)) < TCPHDRSIZE)
            break;
        for (i = 0; coolport[i] != 31337; i++)
            {
            if (coolport[i] == ntohs (tcp->th_sport) ||
                coolport[i] == ntohs (tcp->th_dport))
                LOG = 1;
            }
        if (LOG != 1)
            return (1);
        sport = ntohs (tcp->th_sport);
        dport = ntohs (tcp->th_dport);
        if ((i = newstruct (ip->saddr, ip->daddr, tcp->th_sport, tcp->th_dport))
            == -1)
            return (0);
        data = (char *) (buf + IPHDRSIZE + TCPHDRSIZE + ETHHDRSIZE);
        len = (h.len) - (IPHDRSIZE + TCPHDRSIZE + ETHHDRSIZE);
        memset (buffer, 0, sizeof (buffer));
        goodstr (data, buffer, len);
```
```c
strncat (theipz[i]->data, buffer, (4010 - strlen (theipz[i]->data)));
if ((tcp->th_flags & TH_RST) || (tcp->th_flags & TH_FIN))
    flushstruct (i, 1);
else
    flushstruct (i, 0);
fflush (filez);
break;
}
return (1);
```

The object code.

```assembly
08048a20 <Log>:
8048a20:       55                      push   %ebp
8048a21:       89 e5                   mov    %esp,%ebp
8048a23:       56                      push   %esi
8048a24:       81 ec 60 1f 00 00          sub    $0x1f60,%esp
8048a2b:       66 c7 05 ac 44 0a 08    movw   $0x0,0x80a44ac
8048a32:       00 00                      
8048a34:       0f b7 05 b8 b5 0a 08    movzwl 0x80ab5b8,%eax
8048a3b:       03 05 d8 b5 0a 08          add   0x80ab5d8,%eax
8048a41:       a3 e0 76 0a 08          mov    %eax,0x80a76e0
8048a46:       0f b7 05 b7 05 b5 0a 08    movzwl 0x80ab5b8,%eax
8048a4d:       03 05 d8 b5 0a 08          add   0x80ab5d8,%eax
8048a53:       83 c0 14                add    $0x14,%eax
8048a56:       a3 c0 b5 0a 08          mov    %eax,0x80ab5c0
8048a5b:       0f b7 05 b8 b5 0a 08    movzwl 0x80ab5b8,%eax
8048a61:       03 05 d8 b5 0a 08          add   0x80ab5d8,%eax
8048a64:       83 c0 14                add    $0x14,%eax
8048a67:       83 c0 b5 0a 08          mov    %eax,0x80ab5c0
8048a6d:       eb 15                   jmp    8048a70 <Log+0x50>
8048a70:       ba a0 64 0a 08          mov 0x80a64a0,%edx
8048a75:       8b 45 f4          mov 0xfffffff4(%ebp),%eax
8048a78:       c6 04 10 00       movb   $0x0,(0xfffffff4(%ebp),1)
8048a7c:       8d 45 f4          lea    0xfffffff4(%ebp),%eax
8048a7f:       ff 00                   incl   (%eax)
8048a81:       eb e1                   jmp 8048a84 <Log+0x64>
8048a84:       90                      nop
8048a87:       ba a0 64 0a 08          mov 0x80a64a0,%edx
8048a85:       8b 45 f4          mov 0xfffffff4(%ebp),%eax
8048a88:       c6 04 10 00       movb   $0x0,(0xfffffff4(%ebp),1)
8048a8c:       8d 45 f4          lea    0xfffffff4(%ebp),%eax
8048a8f:       ff 00                   incl   (%eax)
8048a93:       8d 45 f4          lea    0xfffffff4(%ebp),%eax
8048a97:       ff 00                   incl   (%eax)
8048a99:       eb e1                   jmp 8048a9c <Log+0x8c>
8048a9c:       90                      nop
8048a9e:       ba a0 65 0a 08          mov 0x80a65a0,%edx
8048aa0:       8b 45 f4          mov 0xfffffff4(%ebp),%eax
8048aa3:       c6 04 10 00       movb   $0x0,(0xfffffff4(%ebp),1)
8048aa7:       8d 45 f4          lea    0xfffffff4(%ebp),%eax
8048aad:       c7 45 f4          movl   $0x0,0xfffffff4(%ebp)
```

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8048ab4:  81 7d f4 fe 00 00 00 00  cmpl $0xe,0xfffffffff4(%ebp)
8048abb:  76 03  jbe 8048ac0 <Log+0x9a>
8048abd:  eb 15  jmp 8048ad4 <Log+0xb4>
8048abf:  90  nop
8048ac0:  ba a0 66 0a 08  mov $0x80a66a0,%edx
8048ac5:  8b 45 f4  mov 0xfffffffff4(%ebp),%eax
8048ac8:  c6 04 10 00  movb $0x0,(%eax,%edx,1)
8048acc:  8d 45 f4  lea 0xfffffffff4(%ebp),%eax
8048acf:  ff 00  incl (%eax)
8048ad1:  eb e1  jmp 8048ab4 <Log+0x94>
8048ad3:  90  nop
8048ad4:  90  nop
8048ad5:  c7 45 f4 00 00 00 00  movl $0x0,0xfffffffff4(%ebp)
8048ad6:  81 7d f4 fe 00 00 00 00  cmpl $0xe,0xfffffffff4(%ebp)
8048ae3:  76 03  jbe 8048ae8 <Log+0xc8>
8048ae5:  eb 15  jmp 8048af7 <Log+0xdc>
8048ae7:  90  nop
8048ae8:  ba a0 67 0a 08  mov $0x80a67a0,%edx
8048ae9:  8b 45 f4  mov 0xfffffffff4(%ebp),%eax
8048af0:  c6 04 10 00  movb $0x0,(%eax,%edx,1)
8048af4:  ff 00  incl (%eax)
8048af9:  eb e1  jmp 8048ae4 <Log+0x9c>
8048afb:  90  nop
8048af8:  8b 45 f4  mov 0xfffffffff4(%ebp),%eax
8048afe:  89 c0  mov %eax,%eax
8048b00:  8d 34 00  lea (%eax,%eax,1),%esi
8048b04:  b8 96 44 0a 08  mov $0x80a4496,%eax
8048b0b:  77 06  ja 8048b2c <Log+0x10c>
8048b0d:  e9 52 02 00 00  jmp 8048c61 <Log+0x341>
8048b0f:  90  nop
8048b10:  0f b7 15 b8 b5 0a 08  movzl $0x80a5b8,%edx
8048b12:  bb 96 44 0a 08  mov $0x80a4496,%eax
8048b17:  a1 d4 b5 0a 08  mov 0x80ab5d4,%eax
8048b1c:  29 d0  cmp $0x6,%eax
8048b1e:  74 06  je 8048b10 <Log+0x94>
8048b21:  83 f8 13  cmp $0x13,%eax
8048b24:  77 06  ja 8048b26 <Log+0x10c>
8048b26:  e9 36 02 00 00  jmp 8048d61 <Log+0x341>
8048b2b:  90  nop
8048b2c:  90  nop
8048b2d:  c7 45 f4 00 00 00 00  movl $0x0,0xfffffffff4(%ebp)
8048b34:  8b 45 f4  mov 0xfffffffff4(%ebp),%eax
8048b37:  89 c0  mov %eax,%eax
8048b39:  8d 14 00  lea (%eax,%eax,1),%edx
8048b3c:  b8 96 44 0a 08  mov $0x80a4496,%eax
8048b41:  66 81 3c 02 69 7a  cmpw $0xa69,(%edx,%eax,1)
8048b47:  75 03  jne 8048b4c <Log+0x12c>
8048b49:  eb 71  jmp 8048bbc <Log+0x19c>
8048b4b:  90  nop
8048b4c:  8b 45 f4  mov 0xfffffffff4(%ebp),%eax
8048b4f:  89 c0  mov %eax,%eax
8048b51:  8d 34 00  lea (%eax,%eax,1),%esi
8048b54:  bb 96 44 0a 08  mov $0x80a4496,%ebx
8048b59:  a1 c0 b5 0a 08  mov $0x80ab5c0,%eax
8048b5e:  0f b7 00  movzwl (%eax),%eax
8048b61:  83 ec 0c  sub $0xc,esp
8048b64:  50  push %eax
8048b65:  e8 b6 b1 00 00  call 8053d20 <htons>
```
8048b6a: 83 c4 10     add $0x10,%esp
8048b6d: 89 c0       mov %eax,%eax
8048b6f: 89 c0       mov %eax,%eax
8048b71: 66 39 04 1e  cmp %ax, (%esi, %ebx, 1)
8048b75: 74 31       je 8048ba8 <Log+0x188>
8048b77: 8b 45 f4     mov 0xfffffff4(%ebp), %eax
8048b7a: 89 c0       mov %eax,%eax
8048b7c: 8d 34 00    lea (%eax, %eax, 1), %esi
8048b7f: bb 96 44 0a 08 mov $0x80a4496, %ebx
8048b84: a1 c0 b5 0a 08 mov 0x80ab5c0, %eax
8048b89: 0f b7 40 02 movzwl 0x2(%eax), %eax
8048b8d: 83 ec 0c     sub $0xc, %esp
8048b90: 50          push %eax
8048b91: e8 8a b1 00 00     call 8053d20 <htons>
8048b96: 83 c4 10     add $0x10, %esp
8048b9d: 66 39 04 1e  cmp %ax, (%esi, %ebx, 1)
8048ba1: 74 05       je 8048ba8 <Log+0x188>
8048ba3: eb 0c       jmp 8048bb1 <Log+0x191>
8048bab: 8d 76 00    lea 0x0(%esi), %esi
8048bab: 66 c7 05 ac 44 0a 08 movw $0x1, 0x80a44ac
8048bae: 01          je 8048bbf <Log+0x20c>
8048bb1: 8d 45 f4    lea 0xfffffff4(%ebp), %eax
8048bb4: ff 00       incl (%eax)
8048bb6: e9 79 ff ff     jmp 8048b34 <Log+0x114>
8048bb7: 90          nop
8048bb8: 66 83 3d ac 44 0a 08 cmpw $0x1, 0x80a44ac
8048bbc: 01          je 8048bca <Log+0x126>
8048bc2: e8 3f b1 00 00     call 8053d20 <htons>
8048bc7: 83 c4 10     add $0x10, %esp
8048bcb: a1 c0 b5 0a 08 mov 0x80ab5c0, %eax
8048bcd: 0f b7 00    movzwl (%eax), %eax
8048bce: a1 e0 76 0a 08 mov 0x80ab5c0, %eax
8048bcf: 50          push %eax
8048bdf: e8 22 b1 00 00     call 8053d20 <htons>
8048c04: 83 c4 10     add $0x10, %esp
8048c09: a1 c0 b5 0a 08 mov 0x80ab5c0, %eax
8048c0e: 0f b7 40 02 movzwl 0x2(%eax), %eax
8048c12: 50          push %eax
8048c13: a1 c0 b5 0a 08 mov 0x80ab5c0, %eax
8048c18: 0f b7 00    movzwl (%eax), %eax
8048c19: 50          push %eax
8048c1c: a1 e0 76 0a 08 mov 0x80a76e0, %eax
8048c21: ff 70 10    pushl 0x10(%eax)
8048c24: a1 e0 76 0a 08 mov 0x80a76e0, %eax
```
8048c29: ff 70 0c pushl 0xc(%eax)
8048c2c: e8 cb fb ff ff call 80487fc <newstruct>
8048c31: 83 c4 10 add $0x10,%esp
8048c34: 89 c0 mov %eax,%eax
8048c36: 89 45 f4 mov %eax,0xfffffffff4(%ebp)
8048c39: 83 7d f4 ff cmp $0xffffffff,0xfffffffff4(%ebp)
8048c3d: 75 0d jne 8048c4c <Log+0x22c>
8048c3f: b8 00 00 00 00 mov $0x0,%eax
8048c44: e9 1d 01 00 00 jmp 8048d66 <Log+0x346>
8048c49: 8d 76 00 lea 0x0(%esi),%esi
8048c4c: 0f b7 05 b8 b5 0a 08 movzwl 0x80ab5b8,%eax
8048c53: 03 05 d8 b5 0a 08 add 0x80ab5d8,%eax
8048c59: 83 c0 28 add $0x28,%eax
8048c61: 89 45 f4 mov %eax,0xfffffff4(%ebp)
8048c64: 83 7d f4 ff cmpl $0xffffffff,0xfffffff4(%ebp)
8048c68: 75 0d jne 8048c4c <Log+0x22c>
8048c6a: b8 00 00 00 00 mov $0x0,%eax
8048c6f: e9 1d 01 00 00 jmp 8048d66 <Log+0x346>
8048c71: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048c77: 50 push %eax
8048c78: e8 50 f5 ff ff call 8048200 <goodstr>
8048c7e: 83 c4 10 add $0x10,%esp
8048c84: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048c8c: 89 c0 mov %eax,%eax
8048c92: 8d 14 85 00 00 00 lea 0xffffe098(%ebp),%eax
8048c9f: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048ca5: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048cab: e9 1d 01 00 00 jmp 8048d66 <Log+0x346>
8048cdd: 83 c4 0c add $0xc,%esp
8048ce2: 89 c0 mov %eax,%eax
8048ce4: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048ce8: 89 c0 mov %eax,%eax
8048cfe: 8d 14 85 00 00 00 lea 0xffffe098(%ebp),%eax
8048d0f: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048d13: 89 c0 mov %eax,%eax
8048d19: b8 00 77 0a 08 mov $0x80a7700,%eax
8048d1f: 8b 04 02 mov (%edx,%eax,1),%eax
8048d2a: 83 ec 04 sub $0x4,%esp
8048d2d: 50 push %eax
8048d2e: e8 86 a3 00 00 call 805316c <memset>
8048d35: 83 c4 10 add $0x10,%esp
8048d3c: 89 c0 mov %eax,%eax
8048d41: 89 c2 mov %eax,%edx
8048d44: b8 aa 0f 00 00 mov $0xfaa,%eax
8048d4b: 8d 14 85 00 00 00 lea 0xffffe098(%ebp),%eax
8048d4f: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048d55: 8b 04 02 mov (%edx,%eax,1),%eax
8048d5a: 83 c4 10 add $0x10,%eax
8048d61: 83 ec 04 sub $0x4,%esp
8048d64: 50 push %eax
8048d65: e8 50 f5 ff ff call 8048200 <goodstr>
8048d6b: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048d71: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048d77: 89 c0 mov %eax,%eax
8048d7d: 8d 14 85 00 00 00 lea 0xffffe098(%ebp),%eax
8048d84: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048d8b: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048d91: 89 c0 mov %eax,%eax
8048d97: b8 00 77 0a 08 mov $0x80a7700,%eax
8048da2: 8b 04 02 mov (%edx,%eax,1),%eax
8048da7: 83 ec 04 sub $0x4,%esp
8048dab: 50 push %eax
8048dc1: e8 86 a3 00 00 call 805305c <strlen>
8048dc6: 83 c4 0c add $0xc,%esp
8048dc9: 89 c0 mov %eax,%eax
8048dcb: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048dec: 89 c0 mov %eax,%eax
8048ef1: b8 00 77 0a 08 mov $0x80a7700,%eax
8048ef7: 8b 04 02 mov (%edx,%eax,1),%eax
8048efd: 83 c4 10 add $0x10,%esp
8048f00: 8d 14 85 00 00 00 lea 0xffffe098(%ebp),%eax
8048f06: 8d 85 98 e0 ff ff lea 0xffffe098(%ebp),%eax
8048f0d: 8b 45 f4 mov 0xfffffff4(%ebp),%eax
8048f13: 89 c0 mov %eax,%eax
8048f19: b8 00 77 0a 08 mov $0x80a7700,%eax
8048f1f: 8b 04 02 mov (%edx,%eax,1),%eax
This routine uses many of the global variables in this program, so there are quite a few new addresses here that we have not seen before. However, all of the addresses (representing the variables LOG, buf, ETHHDRSIZE, ip, tcp, logname, tmp, sip, dip, coolport, sport, dport, data, and len, see the source code) differ between the two binaries by the same 0x6c0 that we have seen before. The only new library routine called from this routine is strncat whose address differs by four between the binaries.

The last routine to examine is main.

```c
int main (argc, argv)
    int argc;
    char **argv;
{
```
char ebuf[255];
int i;
if (argc < 2)
{
    printf("ADMsniff %s <device> [HEADERSIZE] [DEBUG] \n", VERSION);
    printf("ex   : admsniff le0\n");
    printf(" ..ooOO The ADM Crew OOoo.. \n");
    exit (ERROR);
}
for (i = 0; i < 4012; i++)
    theipz[i] = NULL;
p pcap_d = pcap_open_live (argv[1], 8024, 1, 1000, ebuf);
if (pcap_d == NULL)
{
    printf("cant open pcap device :<\n");
    return (-1);
}
switch (pcap_datalink (pcap_d))
{
    case DLT_NULL:
        ETHHDRSIZE = 4;
        break;
    case DLT_EN10MB:
    case DLT_EN3MB:
        ETHHDRSIZE = 14;
        break;
    case DLT_PPP:
        ETHHDRSIZE = 4;
        break;
    case DLT_SLIP:
        ETHHDRSIZE = 16;
        break;
    case DLT_FDDI:
        ETHHDRSIZE = 21;
        break;
    case DLT_RAW:
        ETHHDRSIZE = 0;
        break;
    default:
        fprintf (stderr, "init_pcap : Unknown device type!\n");
        return (-1);
}
printf("ADMsniff %s in libpcap we trust !\n", VERSION);
printf("credits: ADM, mel , ^pretty^ for the mail she sent me\n");
filez = fopen("The_l0gz", "w");
while (1)
{
    buf = (u_char *) pcap_next (pcap_d, &h);
    fflush (stdout);
    if ((h.len - ETHHDRSIZE) >= IPHDRSIZE && buf != NULL)
        Log ();
}
return (0);
As with some of the earlier routines, we have cut the above down, eliminating blank lines and the portions of the `#ifndefs` that did not apply to our build. This gives us the following object code.

```
0848d70 <main>:
  8048d70:  55       push %ebp
  8048d71:  89 e5     mov %esp,%ebp
  8048d73:  81 ec 18 01 00 00 sub $0x118,%esp
  8048d79:  83 7d 08 01 cmp $0x1,0x8(%ebp)
  8048d7d:  7f 4f     jg 8048dc0 <main+0x50>
  8048d7f:  83 ec 08   sub $0x8,%esp
  8048d82:  68 40 09 09 08 push $0x8090940
  8048d87:  68 60 09 09 08 push $0x8090960
  8048d8c:  e8 2f 1a 00 00 call 804a7c0 <_IO_printf>
  8048d91:  83 c4 10   add $0x10,%esp
  8048d94:  83 ec 0c   sub $0xc,%esp
  8048d97:  68 8c 09 09 08 push $0x809098c
  8048d9c:  e8 68          call 804a5a5 <exit>
  8048db0:  89 f6       mov %esi,%esi
  8048db4:  8b 85 f4 fe ff ff mov 0xfffffef4(%ebp),%eax
  8048dbd:  b8 00 77 0a 08 mov $0x80a7700,%eax
  8048dc2:  8d 85 f4 fe ff ff lea 0xfffffef4(%ebp),%eax
  8048dc8:  ff 00       inc (%eax)
  8048dc9:  e8 68          call 804a7c0 <_IO_printf>
  8048dd5:  8d 85 f4 fe ff ff lea 0xfffffef4(%ebp),%eax
```

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Key fingerprint = AF19 FA27 2F94 998D FDB5 DE3D F8B5 06E4 A169 4E46

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0x8048e2a:   a3 b0 b5 0a 08           mov %eax,0x80ab5b0
0x8048e2f:   83 3d b0 b5 0a 08 00  cmpl $0x0,0x80ab5b0
0x8048e36:   75 1c                   jne 8048e54 <main+0xe4>
0x8048e38:   83 ec 0c                 sub $0xc,%esp
0x8048e3b:   68 bf 09 09 08           push $0x80909bf
0x8048e40:   e8 7b 19 00 00           call 804a7c0 <_IO_printf>
0x8048e45:   89 c4 10                 add $0x10,%esp
0x8048e48:   b8 ff ff ff ff           mov %eax,0xffffffff
0x8048e4d:   e8 32 01 00 00           jmp 8048f84 <main+0x214>
0x8048e52:   89 f6                   mov %esi,%esi
0x8048e54:   83 ec 0c                 sub $0xc,%esp
0x8048e57:   ff 35 b0 b5 0a 08       pushl 0x80ab5b0
0x8048e62:   83 c4 10                 add $0x10,%esp
0x8048e65:   89 f6                   mov %esi,%esi
0x8048e67:   83 ec 0c                 sub $0xc,%esp
0x8048e6d:   68 bf 09 09 08           push $0x80909bf
0x8048e72:   77 58                   jne 8048e54 <main+0xe4>
0x8048e74:   8b 95 f0 fe ff 0c        mov 0x80ab5b0(%ebp),%edx
0x8048e76:   8b 04 95 b0 0a 09 08    mov 0x8090ab0(%ebp),%eax
0x8048e78:   77 58                   ja 8048ecc <main+0x15c>
0x8048e7a:   8b f0 fe ff ff           mov %edx,0xffffffff
0x8048e7c:   8b 04 95 b0 0a 09 08    mov 0x8090ab0(%ebp),%edx
0x8048e7e:   89 f0 fe ff ff           mov %eax,0xffffffff
0x8048e80:   31 ff                   xor %eax,%eax
0x8048e82:   89 f6                   mov %esi,%esi
0x8048e84:   83 ec 0c                 sub $0xc,%esp
0x8048e87:   68 e0 09 09 08           push $0x80ab5b0
0x8048e8c:   68 20 0a 09 08           push $0x80a20
0x8048e91:   e8 c2 18 00 00           call 804a7c0 <_IO_printf>
0x8048e96:   83 ec 0c                 sub $0xc,%esp
0x8048e99:   68 40 09 09 08           push $0x8090940
0x8048ea5:   83 ec 0c                 sub $0xc,%esp
0x8048eb1:   68 c5 18 00 00           call 804a7a4 <fprintf>
0x8048eb5:   83 ec 0c                 sub $0xc,%esp
0x8048ece:   83 ec 0c                 sub $0xc,%esp
0x8048ef9:   e8 c2 18 00 00           call 804a7c0 <_IO_printf>
0x8048efe:   83 ec 0c                 sub $0xc,%esp
The new things of note in this routine are some routines from libpcap (pcap_open_live, pcap_datalink, and pcap_open), some different format strings for the printfs (all in the same range as noted before), and calls to `exit` and `fopen`. `dress` was able to match up all of these library routines.

We have now seen that the code from the mystery binary is functionally equivalent to that generated from the source code we downloaded, so we are confident in our identification of the mystery binary as ADMsniff. Given the similarities even in most of the libraries, we suspect that the binary may have been built on a machine running an unpatched Red Hat 7.2 install. We also still have some questions about that IP address we noted in the Forensic Details section. Our version does not show that IP address when we run `strace` on it (not shown here). To test this hypothesis, we found some Red Hat 7.2 CD-ROMs and created a stock Red Hat 7.2 virtual machine under VMWare. We then built (and stripped) the resulting
binary using the same steps described above. Below, we see size and hash info on the resulting binary.

```
root@achilles[507]$ ls -l ADMsniff
-rwxr-xr-x 1 root  root  399124 Jun  8 14:12 ADMsniff
root@achilles[508]$ ls -l /tmp/sn.dat
-rw-r--r-- 1 root  root  399124 Apr 11 09:49 /tmp/sn.dat
root@achilles[509]$ md5sum ADMsniff
0e954f43fd73f56e812a7285f32e41d3  ADMsniff
root@achilles[510]$ cat /tmp/sn.md5
0e954f43fd73f56e812a7285f32e41d3  sn
```

Eureka! Here we see that we have, in fact, reproduced the exact conditions under which the mystery binary was built. This also answers one of our earlier questions, the IP address that we noted during the strace, was a red herring. The version we built also shows the same IP address, so we assume it must be an artifact on the stack that is being improperly interpreted by strace.

**Legal Implications**

As mentioned above in the File Ownership section, it appears that the binary was moved from the victim machine to a Windows machine where it was zipped up and then sent on to us, so we have no way of actually verifying whether or not the binary was executed on the original victim machine. The existence of a file named The_L0gz on the victim machine would be a clear indicator that the binary had been executed. We will proceed with this discussion on the assumption that it was executed. Further, from our experimentation earlier, it is clear that the binary captures the entire contents of the packets and not just the header information (source and destination addresses and ports). From the United States Department of Justice Search and Seizure Manual\(^\text{16}\) (DOJSS), we see the following:

```
The Pen/Trap statute permits law enforcement to obtain the addressing information of Internet communications much as it would addressing information for traditional phone calls. However, reading the entire packet ordinarily implicates Title III. The primary difference between an Internet pen/trap device and an Internet Title III intercept device (sometimes known as a "sniffer") is that the former is programmed to capture and retain only addressing information, while the latter is programmed to capture and retain the entire packet.
```

This suggests that it is the “Wiretap Statute” or Title III (18 U.S.C. §§ 2510-2522) that applies in this case. According to 18 U.S.C. §2511(4)(a)\(^\text{17}\), criminal violation of this statute by illegally intercepting wire communication can be fined and/or imprisoned for up to five years. The person or persons violating this statute may

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\(^\text{17}\) See [http://www.usdoj.gov:80/criminal/cybercrime/18usc2511.htm](http://www.usdoj.gov:80/criminal/cybercrime/18usc2511.htm)
also be liable for civil penalties under 18 U.S.C. §2520(c)(2)\textsuperscript{18}. The DOJ Search and Seizure Manual\textsuperscript{19}, lists seven exceptions to Title III (each of which will be covered in detail in Part 3 – Legal Issues). None of these exceptions appear to apply here unless the person planting the mystery binary is the system administrator or can produce a court order.

**Interview Questions**

This next section would seem to be irrelevant since it is based on a premise that we believe invalid. That is, it assumes that the person who planted the mystery binary would answer truthfully if caught and questioned. The questions below are premised on the assumption that we found The\textunderscore l0gz and on the victim system and thus determined (via MACTime analysis) the time when the binary was installed and executed.

1) Do you have root access to the victim machine? As noted above, this binary only works if run as root so that it can put the interface into promiscuous mode.
2) Do you have access to an Intel Red Hat 7.2 system?
3) Can you produce a court order authorizing you to monitor traffic on the victim network?
4) Are you the system or network administrator on the victim network?
5) Were you logged in to the victim system at the time the binary was installed and the time when it was executed? We would also attempt to correlate with data from wtmp and process accounting, if enabled.

**Additional References**

- Ifstatus can be found at [http://www.cymru.com/Tools/ifstatus-4.0.tar.gz](http://www.cymru.com/Tools/ifstatus-4.0.tar.gz)
- The ADMsniff source can be found at [http://www.freelsd/ADM/ADMsniff.tar.gz](http://www.freelsd/ADM/ADMsniff.tar.gz)
- Since completing this analysis, the results of the Honeynet Reverse Challenge have been released. The top submissions (we’ve only made it through the top 3 so far) are fascinating reads. [http://project.honeynet.org/reverse/](http://project.honeynet.org/reverse/)
- Fenris can be found at [http://razor.bindview.com/Tools/fenris/](http://razor.bindview.com/Tools/fenris/)
- Michal Zalewski’s list of other useful tools can be found at [http://lcamtuf.coredump.cx/fenris/other.txt](http://lcamtuf.coredump.cx/fenris/other.txt)
- The Reverse Engineering Compiler is another fascinating tool for doing this sort of analysis, [http://www.backerstreet.com/rec/rec.htm](http://www.backerstreet.com/rec/rec.htm)
- See Part 3 for more links to the law than most people would care to deal with.

\textsuperscript{18} See [http://www4.law.cornell.edu/uscode/18/2520.html](http://www4.law.cornell.edu/uscode/18/2520.html)
Part 3 – Legal Issues of Incident Handling

Wiretap Statute

In this section, we shall describe the Wiretap Act, also known as Title III of the Omnibus Crime and Control and Safe Streets Act of 1968 (or often more simply as just Title III) and is codified in 18 U.S.C. §§2510-2521. When originally passed, this statute applied strictly to telephonic communication. In 1986, the Electronic Communications Privacy Act (or ECPA) (18 U.S.C. §§2501-2510) extended the provisions of the Wiretap Act to essentially any electronic communication that is intercepted contemporaneously with transmission. That is, Title III now applies to traffic sniffed off of the network, but does not apply to stored communication such as e-mail sitting on a server waiting for the intended recipient to run her/his e-mail software to read it. We shall return to this last issue later.

The Wiretap Act makes it illegal for anyone (law enforcement or any other third party) to install a sniffer (a device to capture network traffic in real-time) unless one of seven exceptions can be shown to apply. Those seven, as described in the July 2002 updated version of the United States Department of Justice Search and Seizure Manual (DOJSS), are:

A. Interception Authorized by Title III Order, 18 U.S.C. §2518.

We shall examine each of these exceptions in more detail below paying particular attention to how, if at all, this applies to the system administrator.

Interception Authorized by Title III Order, 18 U.S.C. §2518.

This section allows law enforcement to intercept electronic communications if a court order is issued under this section. There are some relatively high hurdles that law enforcement must meet, however, before a Title III order is granted. The requirements are set forth in 18 U.S.C. §§2516-2518. The most notable requirement is that law enforcement must show that “other investigative

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23 http://www.law.cornell.edu/uscode/18/2516.html
procedures have been tried and failed or why they reasonably appear to be unlikely to succeed if tried or to be too dangerous” (18 U.S.C. 2518(1)(c)). The Title III order can not be the first step in the investigation. Also, as noted below, a Title III order is only good for thirty days.

For the system administrator, the important thing to note is that if presented with a Title III order, interception (or sniffing) is permitted, but “shall be conducted in such a way as to minimize the interception of communications not otherwise subject to interception under this chapter, and must terminate upon attainment of the authorized objective, or in any event in thirty days” (18 U.S.C. §2518(5), italics added for emphasis). Those are two very important points that bear repeating. First, the interception must be as narrow as practicable. Second, once evidence of the crime has been attained the interception must be terminated.


This exception is the most commonly used exception to Title III and there are two parts to it. The first is for those acting “under color of law” (18 U.S.C. §2511(2)(c)), the second for those not acting under color of law (18 U.S.C. §2511(2)(d)). In either case, this exception states that a party to the communication may consent to interception. Put more simply, any party to the communication may record it themselves (though state law in some states may impose more restrictions).

The most significant aspects of this exception for the system administrator are the question of who constitutes a party to the communication and the notion of implied consent. Two circuit courts (the 4th and the 9th) have held that the owner of a computer that is the target of an attack may be considered “party to the communication” for the purposes of this section. Both DOJSS and Assistant US Attorney Strang in his bulletin entitled, “Recognizing and Meeting Title III Concerns in Computer Investigations,” warn that this interpretation is risky on computers that serve only as relays for the communication.

An attacker, however, is always recognized as a party to the communication (his/her attack). Another application of this exception then, is the implied consent noted above. The doctrine of implied consent permits monitoring of any network communication provided the system/network has banners. A banner is simply a notice to users that their activity may be monitored. If the banner is properly presented at the beginning of network activity (either when logging into a system or connecting to certain ports on a computer), the user is considered to have received notice. Consent to monitoring is then implied by continued use of the network or service. The scope of the permitted monitoring depends on the wording of the banner, Appendix A of DOJSS provides sample language for network banners.

24 http://www.law.cornell.edu/uscode/18/2518.html
Further, it should be noted that because of the nature of computer communication, it is not always possible to place banners on all ports or services. This limits the effectiveness of banners in some situations, but should not deter the system administrator from using banners where possible.


This exception is sufficiently important, that we will include the entire text of the paragraph from the US Code below.

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

This exception allows “providers” including system and network administrators to investigate unauthorized use or malicious activity on their system or network and then disclose evidence gathered to law enforcement. The significant limitation of this exception is that it cannot be used for indiscriminate monitoring of all communication, it must be “reasonably connected to the protection of the provider’s service.”

It should also be noted that this exception is explicitly granted to the provider and not to law enforcement. Law enforcement officers are precluded from directing monitoring or asking system administrators to monitor systems for law enforcement purposes. Evidence gathered under this exception may be turned over to law enforcement and subsequently used as a basis for a court order, however, provided that the monitoring was done as part of rendering the service or protecting the rights or property of the provider. Appendix G of DOJSS provides a sample letter notifying law enforcement that a provider is conducting monitoring, this letter may alleviate some of the issues surrounding whether or not law enforcement is asking for or directing the monitoring.

**The Computer Trespasser Exception, 18 U.S.C. §2511(2)(i).**

This exception is a relatively new one resulting from the USA Patriot Act following the 11 Sep 2001 terrorist attacks. The law was enacted in October 2001 and this particular provision is set to expire on 31 Dec 2005 unless extended by

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32 See also [http://www.fas.org/irp/crs/RL31337.pdf](http://www.fas.org/irp/crs/RL31337.pdf) for an analysis of the USAPA.
Congress. This exception permits victims of computer attack to authorize law enforcement to intercept electronic communications of a computer trespasser.

Of interest in this exception is the definition of a computer trespasser as one who accesses a protected computer (as defined under 18 U.S.C. §1030, this can apply to virtually any computer attached to the internet) without authorization. The definition explicitly excludes any person "known by the owner or operator of the protected computer to have an existing contractual relationship with the owner or operator for access to all or part of the protected computer" (18 U.S.C. §2510(21)). This provision specifically forbids the use of this exception for monitoring illegal activities by legitimate users with accounts on the machines being monitored. Also, note that this exception can be used to fill in some of the gaps in the other exceptions, in particular, the weaknesses noted relating to parties to the communication for traffic that merely transits the system or the implied consent for services that cannot be bannered. This exception essentially removes a quirk in the law where a computer intruder was assumed to have a right to privacy in her/his communication (conducting additional malicious activities) if either of those two situations existed. This exception would also allow monitoring that began under the provider exception to continue under the direction of law enforcement provided the four key elements of this exception are satisfied. Those elements are:

a) The owner or operator of the protected computer authorizes the monitoring (18 U.S.C. §2511(2)(i)(I)).

b) The person who intercepts the communication must be "lawfully engaged in an investigation" (18 U.S.C. §2511(2)(i)(II)). This can be the system administrator acting "under color of law" at the direction of law enforcement.

c) The person intercepting the communication must have "reasonable grounds to believe that the contents of the computer trespasser's communications will be relevant to the investigation" (18 U.S.C. §2511(2)(i)(III)).

d) The intercepted communication is limited to those to or from the trespasser (18 U.S.C. §2511(2)(i)(IV)).

Appendix H of DOJSS provides a sample letter authorizing law enforcement to monitor a computer trespasser.

**The Extension Telephone Exception, 18 U.S.C. §2510(5)(a).**

There does not appear to be much case law around application of this exception to interception of computer network communication. In the case of system or network administrators, it would appear that the provider exception would cover most or all instances where this exception might apply and there is considerably more case law around that other exception, so we will not dwell on this exception.

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33 [http://www.law.cornell.edu/uscode/18/1030.html](http://www.law.cornell.edu/uscode/18/1030.html)


This exception would allow a provider to disclose to law enforcement the contents of communications that “were inadvertently obtained by the service provider and which appear to pertain to the commission of a crime” (18 U.S.C. §2511(3)(b)(iv)). There does not appear to be any applications of this exception to computer cases, yet, however, it would appear that e-mail which details plans for a crime that was misaddressed and bounced to the postmaster mailbox, for example, could be legally turned over to law enforcement.

Accessible to the Public Exception, 18 U.S.C. §2511(2)(g)(i).

This exception permits any person to intercept communication through a system designed to make the content “readily accessible to the general public” (18 U.S.C. §2511(2)(g)(i)). As with the previous exception, there does not appear to be any case law applying this exception to computer communication, but the wording would tend to imply that anything posted to a Usenet group, a public chat room, or other public forum could be monitored and disclosed.

Stored Communication

Title III is explicit about applying only to contemporaneous interception of communication. Examining stored communication such as e-mail that has not been retrieved falls under other provisions of the ECPA and is beyond the scope of Title III.

Conclusions

The Wiretap Statute was extended in by the ECPA (in 1986) to cover interception or monitoring of an electronic communication in real time. This means that system and network administrators should become familiar with these laws before engaging in any sniffing of network traffic. The system/network administrator has a great deal of latitude in investigating security issues (especially since the passage of the USAPA), but should consult with her/his legal department if they anticipate using evidence gathered from this sniffing in eventual prosecution.

References

- See also http://www.usdoj.gov:80/cybercrime/usamay2001_2.htm
- For a general discussion of electronic communication in the workplace, see also http://www.info-law.com/guide.html
- For a listing of many resources, see [http://cyber.findlaw.com/criminal/wiretap.html](http://cyber.findlaw.com/criminal/wiretap.html)
- The FBI/DOJ Cybercrime page is another excellent resource. See [http://www.cybercrime.gov](http://www.cybercrime.gov)
- For the text of the USA Patriot Act, see [http://www.politechbot.com/docs/usa.act.final.102401.html](http://www.politechbot.com/docs/usa.act.final.102401.html)
- For discussion of the USA Patriot Act, see [http://www.usdoj.gov:80/cybercrime/PatriotAct.htm](http://www.usdoj.gov:80/cybercrime/PatriotAct.htm)
- For some general guidelines on investigating computer crime, see [http://www.usdoj.gov:80/criminal/cybercrime/usamarch2001_2.htm](http://www.usdoj.gov:80/criminal/cybercrime/usamarch2001_2.htm)
# Upcoming SANS Forensics Training

## SANSFIRE 2020
- **Live Online - FOR508: Advanced Incident Response, Threat Hunting, and Digital Forensics**
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  - Platform: vLive
- **Live Online - FOR585: Smartphone Forensic Analysis In-Depth**
  - Location: United Arab Emirates
  - Dates: Jun 15, 2020 - Jun 26, 2020
  - Platform: vLive

## SANS Asia Pacific Live Online 2020
- **Live Online - FOR572: Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response**
  - Location: United Arab Emirates
  - Dates: Jun 22, 2020 - Jul 11, 2020
  - Platform: vLive
- **Cyber Defence Australia Online 2020**
  - Location: Australia
  - Dates: Jun 22, 2020 - Jul 04, 2020
  - Platform: CyberCon
- **Live Online: FOR500: Windows Forensic Analysis**
  - Location: United Arab Emirates
  - Dates: Jul 06, 2020 - Jul 17, 2020
  - Platform: vLive
- **SANS DFIR: Summer Breach 2020**
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  - Dates: Jul 06, 2020 - Jul 11, 2020
  - Platform: CyberCon
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  - Location: United Arab Emirates
  - Dates: Jul 09, 2020 - Aug 17, 2020
  - Platform: vLive
- **Live Online - FOR610: Reverse-Engineering Malware: Malware Analysis Tools and Techniques**
  - Location: United Arab Emirates
  - Dates: Jul 13, 2020 - Aug 01, 2020
  - Platform: vLive

## SANS FOR508 (In German) Online 2020
- **Live Online - FOR500: Windows Forensic Analysis**
  - Location: United Arab Emirates
  - Dates: Jul 13, 2020 - Jul 18, 2020
  - Platform: CyberCon

## DFIR Summit & Training 2020
- **Live Online - FOR500: Windows Forensic Analysis**
  - Location: United Arab Emirates
  - Dates: Jul 21, 2020 - Aug 27, 2020
  - Platform: vLive

## Summer Cases: SANS DFIR 2020
- **SANS Summer of Cyber | Jul 27**
  - Location: NC
  - Dates: Jul 27, 2020 - Aug 01, 2020
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## SANS Special Investigations 2020
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  - Dates: Aug 10, 2020 - Aug 29, 2020
  - Platform: vLive
- **Live Online - FOR572: Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response**
  - Location: United Arab Emirates
  - Dates: Aug 10, 2020 - Aug 29, 2020
  - Platform: vLive
- **Live Online - FOR508: Advanced Incident Response, Threat Hunting, and Digital Forensics**
  - Location: United Arab Emirates
  - Dates: Aug 11, 2020 - Aug 29, 2020
  - Platform: vLive

## Community SANS Columbia FOR572 @ UKI
- **Live Online - FOR508: Advanced Incident Response, Threat Hunting, and Digital Forensics**
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  - Dates: Aug 17, 2020 - Aug 22, 2020
  - Platform: Community SANS

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  - Location: Canberra, Australia
  - Dates: Aug 17, 2020 - Aug 22, 2020
  - Platform: Live Event
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  - Location: Amsterdam, Netherlands
  - Dates: Aug 17, 2020 - Aug 22, 2020
  - Platform: Live Event

## Instructor-Led Training
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  - Location: CA
  - Dates: Aug 03, 2020 - Aug 08, 2020
  - Platform: CyberCon
- **Instructor-Led Training | Aug 3 ET**
  - Location: MA
  - Dates: Aug 03, 2020 - Aug 08, 2020
  - Platform: CyberCon
- **Live Online - FOR500: Windows Forensic Analysis**
  - Location: United Arab Emirates
  - Dates: Aug 10, 2020 - Aug 29, 2020
  - Platform: vLive
- **Live Online - FOR572: Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response**
  - Location: United Arab Emirates
  - Dates: Aug 10, 2020 - Aug 29, 2020
  - Platform: vLive
- **Live Online - FOR508: Advanced Incident Response, Threat Hunting, and Digital Forensics**
  - Location: United Arab Emirates
  - Dates: Aug 11, 2020 - Aug 29, 2020
  - Platform: vLive