

EGI **CSIRT** – Quick and Dirty Forensics Intro

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April 24, 2012

Is this for real? – Incident triage

Look at things like:

- system logs
- command line histories
- ps
- top
- netstat
- lsof
- ...

Do *not*:

- run `rpm -Va`
- reboot the system
- kill suspect processes
- delete malicious files
- ...

Observation changes the observed object

Each time you run a command, each time you read a file, you change timestamp information. Each time you write data to disk, you might overwrite previously freed data sectors.

Do the least intrusive investigation possible.

Our goal

To get back into *secure* service we would like to know:

- How the intruders got in
- When they did so
- What they have been doing on the system
- What we can do to stop them from returning
- Which other sites that may have been hit

Make sure you are not interrupted

If possible, first check open network connections, e.g. by `netstat`. Save the output, but preferably not on the system itself; cut-and-paste it from the terminal window to a local file.

Then isolate the system. Unplug the network cable, introduce a router filter or drop a firewall in place, whatever is easiest.

Now we can start in earnest

There are various types of data in the system, with widely varying expected lifetime.

Table of Order of Volatility:

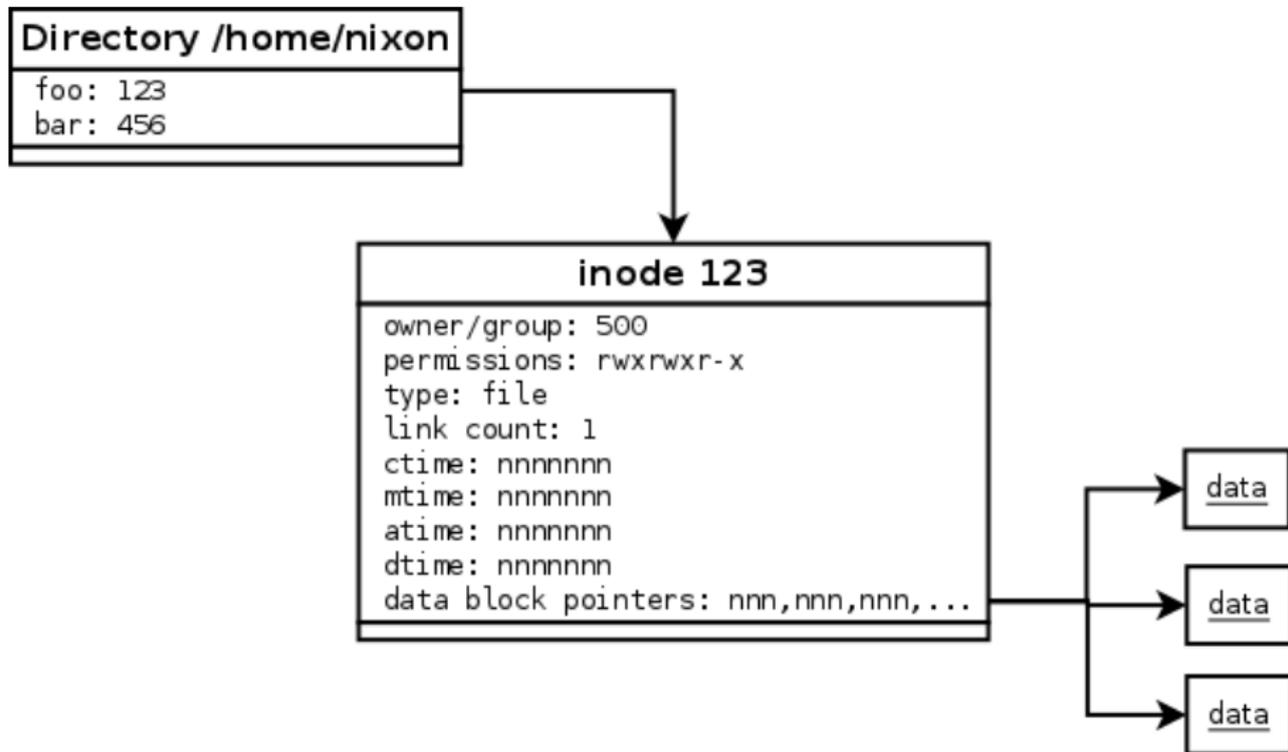
Registers, peripheral memory, caches, etc.	nanoseconds
Main memory	nanoseconds
Network state	milliseconds
Running processes	seconds
Disk	minutes
Backup media, etc.	years
Printouts, etc.	tens of years

(Table borrowed from "Forensic Discovery", Farmer & Venema, Addison-Wesley 2005). You should buy this book.)

The Order of Volatility

Basically, you should follow the order of volatility when collecting data. With one exception: filesystem timestamp data. This is often the most important data, and you want to capture it early in the investigation.

Something about filesystems



Types of timestamps

mtime – modification time; the last time the *contents* (data blocks) of a file changed

atime – access time; the last time the file was read

ctime – change time; the last time one of the attributes in the inode changed

dtime – deletion time; recorded in deleted inodes (*extnfs*)

crttime – creation time; *ext4fs* only

Trustworthiness of timestamps

The `mtime` and `atime` can easily be set to arbitrary values (using `touch`, but *not* the `ctime`). This is sometimes very important.

(It *is* possible to change the `ctime` by directly modifying the on-disk file system with `fsdebug`, but this is a bit tricky, especially if the file system is mounted.)

Generating timelines from timestamps

By collecting and sorting timestamp data from the entire filesystem, you can sometimes gain surprising insights into past activities.

There are two basic ways to collect the data, each with their own (dis)advantages:

- 1 `stat` every file in the mounted filesystem
- 2 bypass the filesystem and dig it out directly from the device or an image using specialized tools

Generating timelines the quick and dirty way

Collecting data from the mounted filesystem is a simple one-liner.
Generating the timeline is almost as easy.

```
find / -xdev -print0 | xargs -0 stat -c "%Y %X %Z %A %U %G %n" >> timestamps.dat  
timeline-decorator.py < timestamps.dat | sort -n > timeline.txt
```

Generating timelines the quick and dirty way

timeline-decorator.py:

```
#!/usr/bin/python

import sys, time

def print_line(flags, t, mode, user, group, name):
    print t, time.ctime(float(t)), flags, mode, user, group, name

for line in sys.stdin:
    line = line[:-1]
    (m, a, c, mode, user, group, name) = line.split(" ", 6)
    if m == a:
        if m == c:
            print_line("mac", m, mode, user, group, name)
        else:
            print_line("ma-", m, mode, user, group, name)
            print_line("--c", c, mode, user, group, name)
    else:
        if m == c:
            print_line("m-c", m, mode, user, group, name)
            print_line("-a-", a, mode, user, group, name)
        else:
            print_line("m--", m, mode, user, group, name)
            print_line("-a-", a, mode, user, group, name)
            print_line("--c", c, mode, user, group, name)
```

Generating timelines the quick and dirty way

Doing it this way is very easy, which is good if you are working with an inexperienced admin.

However, you will be messing up the atimes on every directory, and you will miss information about deleted files.

If you are not careful about where you store the output data, it may overwrite important deleted data blocks on the system.

Also, if the system is rootkitted, you will miss any hidden files.

Slightly slower and cleaner timelines

Alternatively, you can use The Sleuth Kit¹, TSK, to generate timelines.

TSK is an open source toolkit that, among other things, can generate timelines by reading the raw disk device (or a disk image).

TSK finds deleted inodes and directory entries.

¹<http://www.sleuthkit.org/>

TSK timelines

```
fls -r -m / /dev/sda1 > rootfs.body
```

```
mactime -b rootfs.body > rootfs.timeline
```

TSK timelines

With TSK you bypass the kernel filesystem code and any rootkits, revealing any hidden files. You also see deleted directory entries.

However, you have to somehow either make the TSK binaries available on the system (compile them in place, transfer them to from another system or mount some filesystem (NFS, USB stick. . .)), or make an image of the disk and transfer it somewhere else.

Example

```
Tue Aug 16 2011 14:03:15 .a. r-xr-xr-x root    root    /usr/bin/w
Tue Aug 16 2011 14:03:28 .a. rwxr-xr-x root    root    /usr/bin/curl
Tue Aug 16 2011 14:03:36 .a. rwxr-xr-x root    root    /usr/bin/bzip2
Tue Aug 16 2011 14:04:41 .a. rwxr-xr-x root    root    /usr/bin/shred
Tue Aug 16 2011 14:06:26 .a. rw-r--r-- root    root    /usr/include/crypt.h
Tue Aug 16 2011 14:07:25 m.. rwxrwxr-x x_lenix  x_lenix  /var/tmp/...
Tue Aug 16 2011 14:08:01 m.c rw-r--r-- root    root    /var/tmp/.../openssh-5.2p1.tar.bz2 (delet
Tue Aug 16 2011 14:08:01 m.c rw-r--r-- root    root    /var/tmp/.../openssh-5.2p1 (deleted-reall
```

What does the timeline tell us?

ctime often tells us when files were created

atime can tell us when files were read and binaries executed

mtime can be useful *because* they can be modified

mtime preservation

Many commands preserve mtimes (and atimes) when they copy files.

```
[nixon@host1]$ stat fie
  File: 'fie'
  Size: 0          Blocks: 0          IO Block: 4096   regular empty file
Device: fd01h/64769d Inode: 314704      Links: 1
Access: (0664/-rw-rw-r--)  Uid: ( 500/   nixon)   Gid: ( 500/   nixon)
Access: 2012-04-19 13:39:29.311321819 +0200
Modify: 2012-04-19 13:39:29.311321819 +0200
Change: 2012-04-19 13:39:29.311321819 +0200
 Birth: -
```

```
[nixon@host1 foo]$ scp -p fie host2:
```

```
[nixon@host2 foo]$ stat fie
  File: 'fie'
  Size: 0          Blocks: 0          IO Block: 4096   regular empty file
Device: ca10h/51728d Inode: 2013283013  Links: 1
Access: (0664/-rw-rw-r--)  Uid: ( 7090/   nixon)   Gid: ( 7090/   nixon)
Access: 2012-04-19 13:39:29.000000000 +0200
Modify: 2012-04-19 13:39:29.000000000 +0200
Change: 2012-04-19 14:15:50.905321991 +0200
```

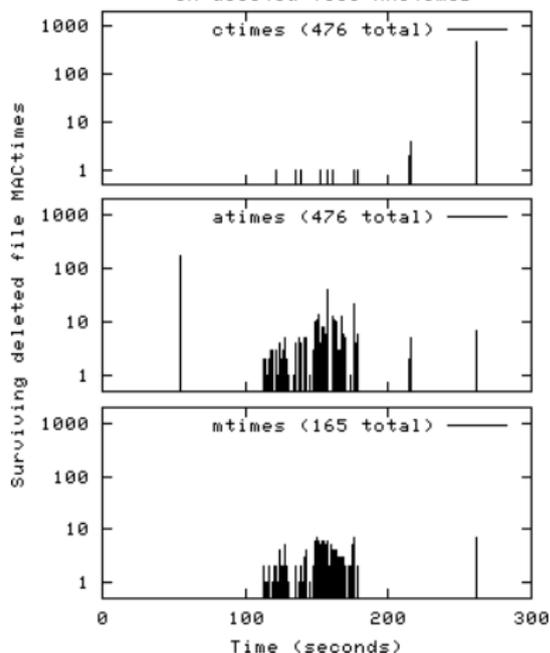
Traps and complicating factors

- You only see the last timestamp – surprisingly easy to forget!
- Prelinking
- `updatedb`
- `tmpwatch`
- `makewhatis`

Signs of modifications

Has something interesting happened to this filesystem?

Rootkit activity signature
in deleted file MACtimes



```
ls -i
12982 fileA
34919 fileB
12984 fileC
12985 fileD
```

Looking at deleted data

When a file is deleted, it is of course not actually removed from the disk. In ext3:

- The directory entry is marked as deleted, the directory list pointers are updated to skip over the deleted entry, but the entry remains in place on the disk.

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- The data blocks are marked as available, but their content remain in place until overwritten.

Looking at deleted data

TSK can display deleted directory entries and inodes.

Retrieving the contents of deleted files is harder. If a file was deleted sufficiently recently that the inode contents remain in the file system journal, it can be recovered using `extundelete`.

Otherwise, your best bet is simply grepping through the whole image.

```
strings sda.img | grep "sshd.*Accepted "
```

Looking at deleted data

Since disk space is allocated in chunks of (typically) 4096 bytes – data blocks – there will be some unused space in the last data block if the file size is not a multiple of 4096. This unused space is called *slack space*.

Slack space is mainly interesting for two reasons; it can sometimes contain data from old deleted files, and it can be used by an intruder to hide data on the disk.

Similarly to deleted data, slack space data can be found by grepping through the disk image.

Working with disk images

Grabbing a disk image is easy enough. To get the whole disk:

```
dd if=/dev/sda of=sda.img bs=512
```

Just a specific partition:

```
dd if=/dev/sda1 of=sda1.img bs=512
```

Caution: if disk is mounted at the time, the resulting image will be inconsistent and probably not mountable. Still, TSK will be able to work with it.

Working with disk images

Listing and extracting partitions with TSK:

```
$ mmls -a sda.img
DOS Partition Table
Offset Sector: 0
Units are in 512-byte sectors

   Slot   Start          End          Length      Description
02: 00:00  0000002048  0000022527  0000020480  Linux (0x83)
06: 01:00  0000024576  0000126975  0000102400  Linux (0x83)
10: 02:00  0000129024  0000169983  0000040960  Linux Swap / Solaris x86 (0x82)
14: 03:00  0000172032  0000262143  0000090112  Linux (0x83)

$ mmcat sda.img 6 > sda2.img

$ ls -lh
total 51M
-rw-rw-r-- 1 nixon nixon  50M Apr 22 12:36 sda2.img
-rw-rw-r-- 1 nixon nixon 129M Apr 22 12:32 sda.img
```

Working with disk images

Images can be loopback-mounted for easy access:

```
mount -o loop,ro sda2-copy.img mnt
```

Sometimes this will fail; this can be because the image is corrupted, or simply because you have to replay the journal by briefly mounting the image read-write:

```
mount -o loop sda2-copy.img mnt  
umount mnt
```

```
mount -o loop,ro sda2-copy.img mnt
```

Working with disk images

To avoid time- and space-consuming copy operations, you can work with partitions in-place:

```
fls -o 245762 -r -m / sda.img > rootfs.body
```

```
mount -o ro,loop,offset=125829123 sda-copy.img mnt
```

²Offset in sectors, as reported by `mmls`

³Offset in bytes, e.g. 24576×512

Looking at other data

Of course, we must also look at other data sources on the running system. However, if the system is root compromised, it might be lying to us.

We might gain some confidence in the system by verifying system binaries by running e.g. `rpm -Va`⁴.

If we find that e.g. the `ps` binary has been replaced, perhaps we can copy a fresh binary from another system, or simply use `ps tree` or `top` instead.

⁴ *Don't* do this before you have gathered timestamps, since it will zap all atimes!

Looking at processes

Once we think that we might be getting reliable data, look at the running processes. Remember that malicious processes can change their name to masquerade as, say, an extra `init` process.

Look for anomalies like duplicate system processes or strange inheritances (`ping` should not have a `bash` child process, for example).

Also look at pid numbers; system processes usually have pids in a narrow range. Something that looks like a system process but has a much higher pid might be suspicious.

Looking at open files and sockets

Use `netstat` and `lsof` to check open files and sockets. This can help identifying evil processes.

Looking at memory

If you find a malicious process, its memory may contain important information. You can use e.g. `gcore` to generate a core dump for the process. Running `strings` on this can often reveal stuff like IP addresses and passwords.

It may also be interesting to dump the entire RAM of the system. Unfortunately, doing this can be less than trivial in modern kernels – see e.g.

<http://www.digitalbenji.com/scripts/fmem-notes.txt>
for one method.

Quick and dirty malware analysis

If you find a malicious binary, running `strings -a` on it can yield interesting results.

You can also try to execute the binary under `strace` and `ltrace` to see in greater detail what it is doing. *This must be done very carefully*, preferably on an isolated host (like e.g. a VM without network access).

Quick and dirty malware analysis

ltrace and strace of a suspect sshd binary when logging in as myuser:mypassword:

```
:
:
3348 strcmp("mypassword", ".ssh/authorized_keys2 ") = 1
3348 memset(0x7fff24742210, '\000', 2048)      = 0x7fff24742210
3348 memset(0x7fff24742c10, '\000', 512)      = 0x7fff24742c10
3348 memset(0x7fff24742a10, '\000', 512)      = 0x7fff24742a10
3348 strcat("SR: '", "myuser")                = "SR: 'myuser"
3348 strcat("SR: 'myuser' '", "mypassword")   = "SR: 'myuser' 'mypassword"
:
:
:
:
3318 <... read resumed> "\n\0\0\0\6mypassword", 11) = 11
3321 read(4, <unfinished ...>
3318 open("/usr/share/kbd/keymaps/i386/azerty/c1", O_RDWR|O_CREAT|O_APPEND, 0666) = 3
3318 getuid()                                     = 0
:
:
```

Obfuscated data

Often, trojans will obfuscate strings (e.g. filenames) in the binary and data in log files. This is almost, almost always done by xor:ing the data with a single byte.

So, if a file contains binary junk, try xor:ing it with different values until you find something interesting.

Obfuscated data

```
$ file azerty/c1
azerty/c1: data
```

```
$ xor.py azerty/c1
```

```
$ ls
0x01.out  0x21.out  0x41.out  0x61.out  0x81.out  0xa1.out  0xc1.out  0xe1.out
0x02.out  0x22.out  0x42.out  0x62.out  0x82.out  0xa2.out  0xc2.out  0xe2.out
:
:
```

```
$ grep SR: *.out
```

```
0xff.out: SR: 'myuser' 'mypassword'
```

Obfuscated data

```
#!/usr/bin/python

import sys, argparse

def xor(buf, n):
    f = open("0x%02x.out" % n, "w")
    for c in buf:
        f.write(chr(ord(c) ^ n))
    f.close()

parser = argparse.ArgumentParser(description="xor a file with one or several integer values, output")
parser.add_argument("-n", help="Integer to xor with (default: loop over 1-255)")
parser.add_argument('infile', nargs='?', type=argparse.FileType('r'),
                    default=sys.stdin, help="Input file (default: stdin)")

args = parser.parse_args()

if args.n:
    if args.n.startswith("0x"):
        n = int(args.n, 16)
    else:
        n = int(args.n)
else:
    n = None

data = args.infile.read()

if n:
    xor(data, n)
else:
    for i in range(1,256):
        xor(data, i)
```

Looking at logs

In a root intrusion, local system logs may be wiped or sanitized. Of course, this shouldn't be a problem, since you are also logging remotely to a secure central log server, *right?*

However, in the unlikely event that you don't have remote logging, remember that e.g. ssh logins will leave traces in many different places, including (on a standard RHEL5-type system):

- `/var/log/secure` – ssh logs
- `/var/log/wtmp` – binary db of terminal sessions
- `/var/log/btmp` – binary db of failed logins
- `/var/log/lastlog` – binary (sparse file) db of latest logins per user
- `/var/log/audit/audit.log` – events from the audit subsystem

Even if the intruder has tried to remove his traces, he might have missed one of these places – check them all!

A brief note on rootkits

The main problem with the quick and dirty approach to forensics is that we are placing a lot of trust in the tools on the system. If the intruder has deployed a rootkit, we may be in trouble.

User level rootkits

User level rootkits basically work by replacing key system binaries. These can often be discovered by running e.g. `rpm -Va` (this of course presumes that `rpm` itself is trustworthy – you may want to use several different methods to verify binaries).

Kernel-based rootkits

Kernel-based rootkits instead subverts the running kernel into lying about the state of the system. Kernel rootkits can typically hide the existence of certain files and processes. These rootkits can be hard to detect, but tools like `chkrootkit` and `rkhunter` can find some common kinds of rootkits.

It is also noteworthy that TSK usually can detect files hidden by kernel rootkits, since it bypasses most of the kernel filesystem stack.

A quick and dirty conclusion

We have looked at some simple methods to collect forensic data. These methods are somewhat fragile and can be fooled by a clever attacker.

However, most attackers aren't very clever, and the quick and dirty approach surprisingly often can give a surprisingly detailed picture of the intruder's actions.

All sysadmins should know some basic quick and dirty forensics methods.

Hopefully, you do so now.

Hands-on exercise!

On February 3, 2012, a system administrator discovered that sshd on one of his servers had been replaced. You will receive an image⁵ of the root filesystem of the server.

We want to know the answer to as many of these questions as possible:

- How the intruders got in
- When they did so
- What they have been doing on the system
- What we can do to stop them from returning
- Which other sites that may have been hit
- What the intruder's street address is, and what his house looks like

⁵This image is created for training purposes. While some of the data is from real incidents, much is fictitious.