

THE DUQU 2.0

Technical Details

Version: 2.1 (11 June 2015)

CONTENTS

EXECUTIVE SUMMARY	3
INITIAL ATTACK	4
LATERAL MOVEMENT	4
ANALYSIS OF A DUQU 2.0 MSI PACKAGE	7
File properties	7
First Layer: ActionDLL (msi.dll)	10
Second Layer: ActionData0	10
Third Layer: klif.dll	11
Attacking AVP.EXE	12
CTwoPENC.dll zero-day and K MART.dll	14
PAYOUT CONTAINERS AND MIGRATION	15
Payload type "L"	15
Payload run type "G"	16
Payload run type "I"	16
Payload run type "K"	17
Payload run type "Q"	17
PLATFORM PLUGGINABLE MODULES	17
PERSISTENCE MECHANISM	33
COMMAND AND CONTROL MECHANISMS	33
The "portserv.sys" driver analysis	35
SIMILARITIES BETWEEN DUQU AND DUQU 2.0	37
VICTIMS OF DUQU 2.0	42
ATTRIBUTION	43
CONCLUSIONS	44
REFERENCES	45

EXECUTIVE SUMMARY

Earlier this year, during a security sweep, Kaspersky Lab detected a cyber intrusion affecting several of its internal systems.

Following this finding, we launched a large-scale investigation, which led to the discovery of a new malware platform from one of the most skilled, mysterious and powerful groups in the APT world – Duqu. The Duqu threat actor went dark in 2012 and was believed to have stopped working on this project - until now. Our technical analysis indicates the new round of attacks include an updated version of the infamous ¹2011 Duqu malware, sometimes referred to as the step-brother of ²Stuxnet. We named this new malware and its associated platform "Duqu 2.0".

Victims of Duqu 2.0 have been found in several places, including western countries, the Middle East and Asia. The actor appears to compromise both final and utilitarian targets, which allow them to improve their cyber capabilities.

Most notably, some of the new 2014-2015 infections are linked to the P5+1 events and venues related to the negotiations with Iran about a nuclear deal. The threat actor behind Duqu appears to have launched attacks at the venues for some of these high level talks. In addition to the P5+1 events, the Duqu 2.0 group has launched a similar attack in relation to the ³70th anniversary event of the liberation of Auschwitz-Birkenau.

In the case of Kaspersky Lab, the attack took advantage of a zero-day (CVE-2015-2360) in the WindowsKernel, patched by Microsoft on June 9 2015 and possibly up to two other, currently patched vulnerabilities, which were zeroday at that time.

1 <https://en.wikipedia.org/wiki/Duqu>

2 http://www.kaspersky.com/about/news/virus/2011/Duqu_The_Step_Brother_of_Stuxnet

3 <http://70.auschwitz.org/index.php?lang=en>

INITIAL ATTACK

The initial attack against Kaspersky Lab began with the targeting of an employee in one of our smaller APAC offices. The original infection vector for Duqu 2.0 is currently unknown, although we suspect spear-phishing e-mails played an important role. This is because for one of the patients zero we identified had their mailbox and web browser history wiped to hide traces of the attack. Since the respective machines were fully patched, we believe a zero-day exploit was used.

In 2011, we were able to identify Duqu attacks that used Word Documents containing an exploit for a zero-day vulnerability (CVE-2011-3402) that relied on a malicious embedded TTF (True Type Font File). This exploit allowed the attackers to jump directly into Kernel mode from a Word Document, a very powerful, extremely rare, technique. A similar technique and zero-day exploit (⁴CVE-2014-4148) appeared again in June 2014, as part of an attack against a prominent international organization. The C&C server used in this 2014 attack as well as other factors have certain similarities with Duqu, however, the malware is different from both Duqu and Duqu 2.0. It is possible that this is a parallel project from the Duqu group and the same zero-day (CVE-2014-4148) might have been used to install Duqu 2.0.

Once the attackers successfully infected one machine, they moved on to the next stage.

LATERAL MOVEMENT

In general, once the attackers gain access into a network, two phases follow:

- Reconnaissance and identification of network topology
- Lateral movement

In the case of Duqu 2.0, the lateral movement technique appears to have taken advantage of another zero-day, (CVE-2014-6324) which was patched in November 2014 with ⁵MS14-068 . This exploit allows an unprivileged domain user to elevate credentials to a domain administrator account. Although we couldn't retrieve a copy of this exploit, the logged events match the Microsoft detection guidance for this attack. Malicious modules were also observed performing a "pass the hash" attack inside the local network, effectively giving the attackers many different ways to do lateral movement.

Once the attackers gained domain administrator privileges, they can use these permissions to infect other computers in the domain.

To infect other computers in the domain, the attackers use few different strategies. In most of the attacks we monitored, they prepare Microsoft Windows Installer Packages (MSI) and then deploy them remotely to other machines. To launch them, the attackers create a service on the target machine with the following command line:

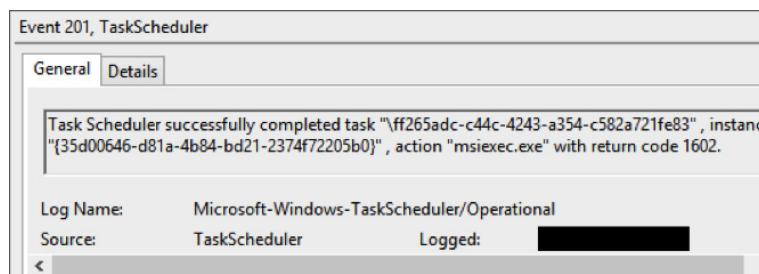
```
msiexec.exe /i "C:\\[...]\\tmp8585e3d6.tmp" /q PROP=9c3c7076-d79f-4c
```

4 <https://www.fireeye.com/blog/threat-research/2014/10/two-targeted-attacks-two-new-zero-days.html>

5 <https://technet.microsoft.com/library/security/MS14-068>

The PROP value above is set to a random 56-bit encryption key that is required to decrypt the main payload from the package. Other known names for this parameter observed in the attacks are "HASHVA" and "CKEY". The folder where the package is deployed can be different from case to case, depending on what the attackers can access on the remote machine.

In addition to creating services to infect other computers in the LAN, attackers can also use the Task Scheduler to start "msiexec.exe" remotely. The usage of Task Scheduler during Duqu infections for lateral movement was also observed with the 2011 version and was described by ⁶Symantec in their technical analysis.



“msiexec.exe” - Task Scheduler trace in the logs

The MSI files used in the attacks contain a malicious stub inside which serves as a loader. The stub loads the other malware resources right from the MSI file and decrypts them, before passing execution to the decrypted code in memory.

Malicious stub with query to load the other resources from the MSI file highlighted.

The encryption algorithms used for these packages differ from case to case. It's important to point out that the attackers were careful enough to implement unique methods, encryption algorithms and names (such as file names) for each attack, as a method to escape detection from security products and limit the ability of an antivirus company to find other infections once one of them has been identified.

So far, we've seen the following encryption algorithms used by the attackers:

- Camellia
 - AES

⁶ http://www.symantec.com/content/en/us/enterprise/media/security_response/whitepapers/w32_duqu_the_precursor_to_the_next_stuxnet.pdf

- XTEA
- RC4
- Different multibyte XOR-based encryption

For compression algorithms, we've seen the following:

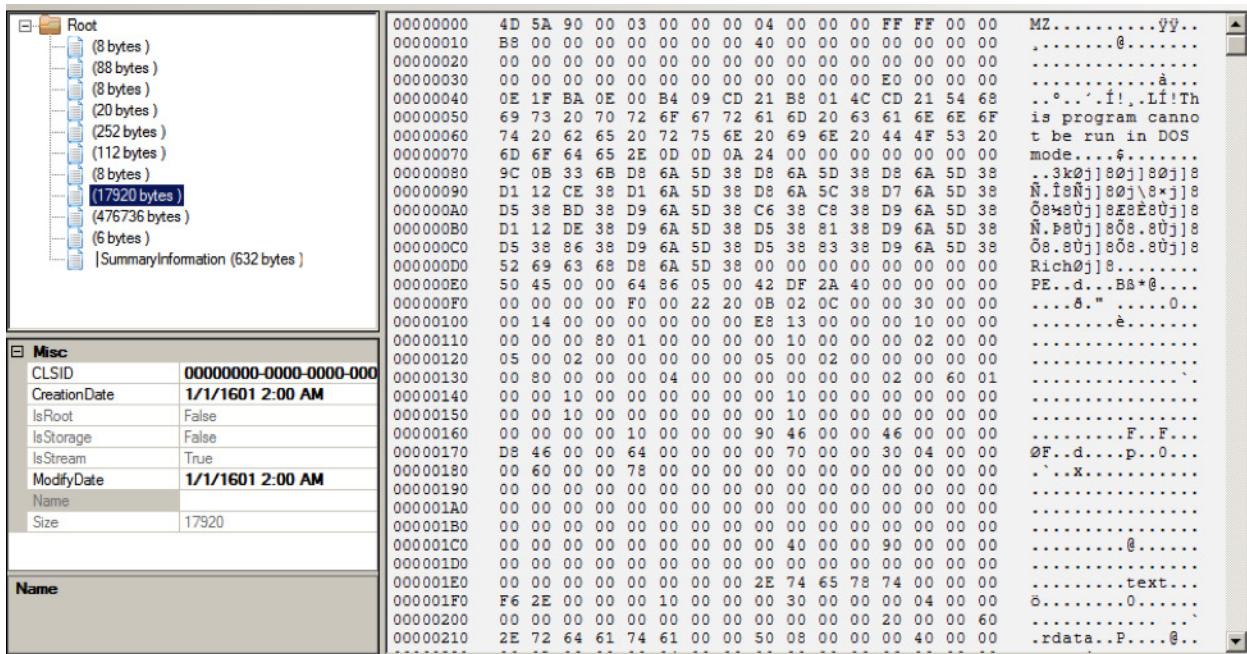
- LZJB
- LZF
- FastLZ
- LZO

In essence, each compiled attack platform uses a unique combination of algorithms that make it very difficult to detect.

The attackers can deploy two types of packages to their victims:

- "Basic", in-memory remote backdoor (~500K)
- Fully featured, C&C-capable, in-memory espionage platform (18MB)

These have similar structures and look like the following:



Malicious Duqu 2.0 MSI package.

In the screenshot above, one can see the loader (ActionDll: 17,920 bytes) and the main payload (ActionData0: 476,736 bytes). Upon execution, ActionDll is loaded and control is passed to its only export, StartAction.

The "basic" in-memory remote backdoor is pushed to computers inside the domain by the Domain Controller on a regular basis – almost like a worm infection. This gives the attackers an entry into most of the machines from the domain and if further access is needed, they can upload a more sophisticated MSI file that deploys tens of different plugins to harvest information.

A thorough description of the malware loading mechanism from the "basic" remove backdoor MSI can be found below.

ANALYSIS OF A DUQU 2.0 MSI PACKAGE

Filename: random / varies from case to case

MD5 (example, can vary): 14712103ddf9f6e77fa5c9a3288bd5ee

Size: 503,296 bytes

File properties

The MSI file has the following general properties:

- Composite Document File V2 Document
- Little Endian
- OS: Windows, Version 6.1
- Code page: 1252
- Title: {7080A304-67F9-4363-BBEB-4CD7DB43E19D} (randomly generated GUIDs)
- Subject: {7080A304-67F9-4363-BBEB-4CD7DB43E19D}
- Author: {7080A304-67F9-4363-BBEB-4CD7DB43E19D}
- Keywords: {7080A304-67F9-4363-BBEB-4CD7DB43E19D}
- Comments: {7080A304-67F9-4363-BBEB-4CD7DB43E19D}
- Template: Intel;1033
- Last Saved By: {7080A304-67F9-4363-BBEB-4CD7DB43E19D}
- Revision Number: {4ADA4205-2E5B-45B8-AAC2-D11CFD1B7266}
- Number of Pages: 100
- Number of Words: 8
- Name of Creating Application: Windows Installer XML (3.0.5419.0)
- Security: 4

It should be noted that MSI files used in other attacks can have different other properties. For example, we observed several other fields:

- Vendor: Microsoft or InstallShield
- Version: 1.0.0.0 or 1.1.2.0 or 2.0.0.0

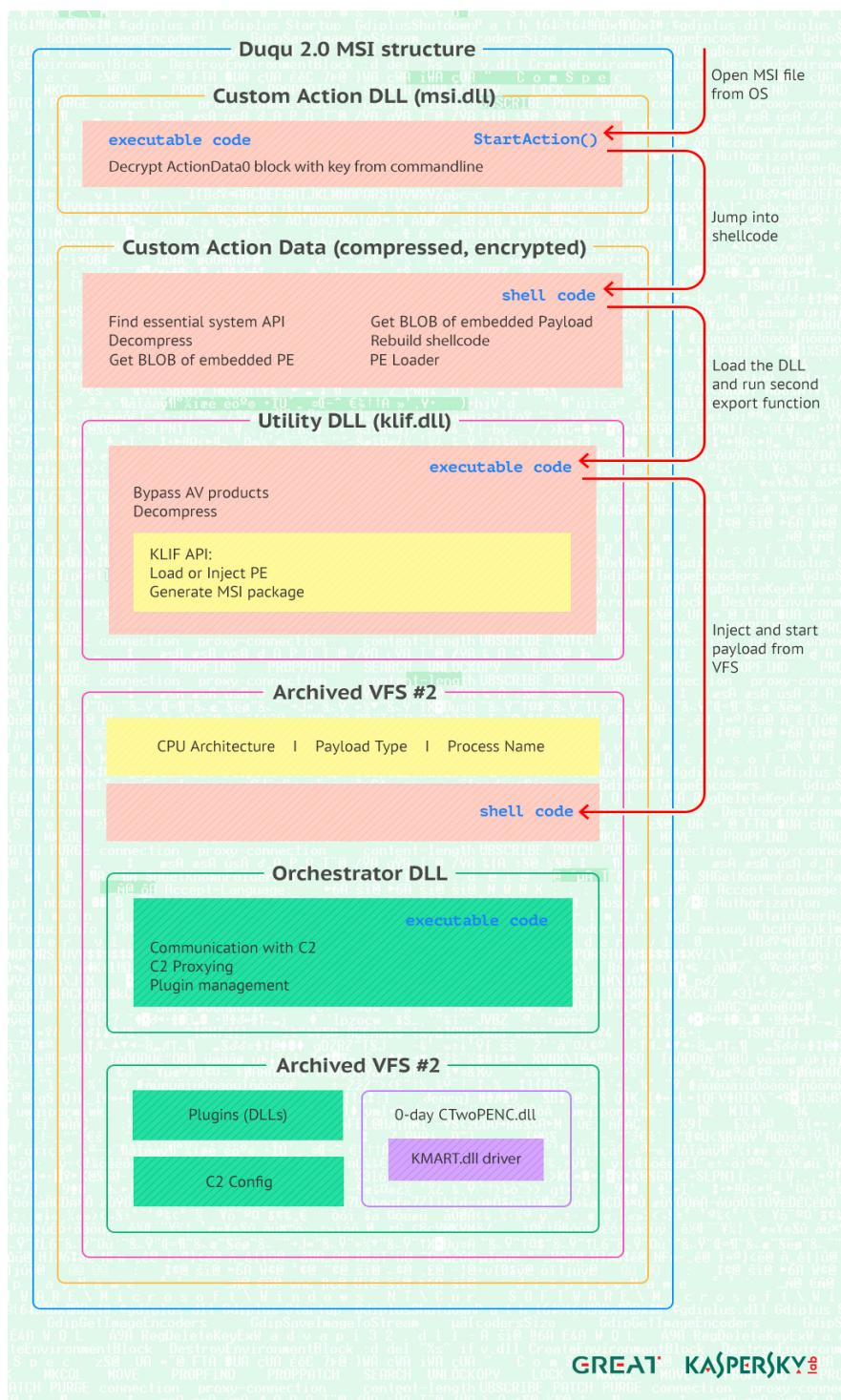
Some of these are visible via the Windows Explorer file properties dialog box:

Property	Value
Description	
Title	{7080A304-67F9-4363-BBEB-4CD7DB43
Subject	{7080A304-67F9-4363-BBEB-4CD7DB43
Categories	
Tags	{7080A304-67F9-4363-BBEB-4CD7DB43
Comments	{7080A304-67F9-4363-BBEB-4CD7DB43
Origin	
Authors	{7080A304-67F9-4363-BBEB-4CD7DB43
Revision number	{4ADA4205-2E5B-45B8-AAC2-D11CFD1E
Content created	
Program name	Windows Installer XML (3.0.5419.0)
File	
Name	
Item type	Windows Installer Package
Folder path	
Date created	
Date modified	

There are two binary blocks inside this MSI package:

Tables	Name	Data
Binary	ActionDII	[Binary Data]
CustomAction	ActionData0	[Binary Data]
InstallExecuteSequence		
Property		

The first binary, called ActionDll, is in fact a Windows PE DLL file, while the other one is a Camellia-encrypted and LZJB-compressed data payload (the encryption and compression algorithm vary from case to case). In fact, there are several layers of executable code embedded one into another as compressed or encrypted binary blocks. Here's a look at a Duqu 2.0 MSI package, with all its internal payloads:



We describe these components in more detail below.

First Layer: ActionDLL (msi.dll)

Original filename: msi.dll

MD5: e8eaec1f021a564b82b824af1dbe6c4d

Size: 17'920 bytes

Link time: 2004.02.12 02:04:50 (GMT)

Type: 64-bit PE32+ executable DLL for MS Windows

This DLL has only one export name called StartAction, which is called in the context of msiexec.exe process. When this function is called, it retrieves an MSI property called PROP and uses it as a decryption key for the bundled ActionData0 package:

```
mov    [rsp+hInstall], ecx
sub   rsp, 58h
mov    [rsp+58h+pcchValueBuf], 11h
lea    r9, [rsp+58h+pcchValueBuf] ; pcchValueBuf
lea    r8, [rsp+58h+szValueBuf] ; szValueBuf
lea    rdx, szName      : "PROP"
mov    ecx, [rsp+58h+hInstall] ; hInstall
call   MsiGetPropertyW
test  eax, eax
jz    short loc_180003BD2
xor   eax, eax
jmp   short loc_180003C49
```

Next, the code iterates over 12 possible payloads that have to be decrypted and started. The payloads are part of the MSI and may have the following names: ActionData0, ActionData1, ActionData2, etc.

The package described here contains only one payload named "ActionData0".

Second Layer: ActionData0

```
0000 AppClass      struc ;
0000 dwMagic       dd ? ; 0x72384263
0004 field_4        dd ?
0008 lstrcmpiw     dq ?
0010 VirtualQuery   dq ?
0018 RtlAnsiStringToUnicodeString dq ?
0020 field_20       dq ?
0028 VirtualProtect  dq ?
0030 VirtualAlloc    dq ?
0038 GetProcAddress  dq ?
0040 RtlFreeUnicodeString dq ?
0048 MapViewOfFile   dq ?
0050 FlushInstructionCache dq ?
0058 VirtualFree     dq ?
0060 LdrLoadDll      dq ?
0068 ZwCreateSection   dq ?
0070 ZwMapViewOfSection dq ?
0078 ZwUnmapViewOfSection dq ?
0080 FreeLibrary     dq ?
0088 CreateThread     dq ?
0090 WaitForSingleObject dq ?
0098 ZwClose         dq ?
00A0 GetSystemDirectoryW dq ?
00A8 ZwOpenSection    dq ?
00B0 GetExitCodeThread dq ?
00B8 ZwQuerySystemInformation dq ?
00C0 CreateFileW      dq ?
00C8 GetTickCount     dq ?
00D0 GetCurrentProcessId dq ?
00D8 GetCurrentProcess  dq ?
00E0 ReadProcessMemory dq ?
00E8 DeviceIoControl  dq ?
00F0 GetCurrentThreadId dq ?
00F8 GetModuleHandleW dq ?
0100 LdrUnlockLoaderLock dq ?
0108 LdrLockLoaderLock dq ?
0110 wsprintfw       dq ?
```

This binary chunk contains the main code, in compressed and encrypted format. It represents a composition of executable, position-independent code blocks mixed with embedded data objects. The code seems to be based on a framework and heavily uses helper structures that contain pointers to a set of system APIs and offsets to internal data blocks. Such structures are definitely a trademark of the developer. When they are initialized, one field (usually the first 4 bytes) contains a magic value that identifies the state and type of the structure.

Another trademark of the coder is the way to import system API by module and export name hashes. The hashing algorithm was found all over this and other layers of executable code. It's easily recognizable by two DWORD constants: **0x8A20C27** and **0x67F84FC6**.

Basically, the code in ActionData0 passes execution to an embedded executable, which we will refer by its internal name: "klif.dll". The execution is passed to the second exported function in table of exports of this DLL file. This disregards the export name and relies only on the order of functions in the table of PE export ordinals.

When this export function is called, a next stage helper structure pointer is passed to it, so that it can use some of the values set on the upper layer.

However, before passing execution to klif.dll, the code attempts alternative routes. First, it attempts to find the name of the following format “**api-ms-win-shell-XXXX.dll**”, where “X” can be any decimal number. The name is valid if there is no module with such filename loaded into current process. The code attempts to iteratively find such name starting from api-ms-win-shell-0000.dll, api-ms-win-shell-0001.dll, api-ms-win-shell-0002.dll and so on. This may be a dependency to the Duqu platform component that is yet to be discovered.

Right after this, if the name was found, the code attempts to map a section kernel object by name, which is generated using a PRNG-based algorithm. The name of the section has the following template: “**\BaseNamedObjects\{XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXX}**”, where “X” is any hexadecimal digit that is generated based on current system boot time. So far, the name of the section is “machine/boot time” dependent, which makes it unique but allows other processes of modules to locate such section if they use the same name generation algorithm. This section is accessed in different other parts of the code and modules. Lets refer to this section as OSBoot-section from now. Once the section name is generated the code tries to open such section and, if it is found, it takes some values from it and attempts to open a specific device and issue a number of IOCTL codes to the driver. The name of the driver device as well as IOCTL codes are located inside a section of the kernel mode driver KMART.dll that is described below.

The code developer has a preference for using sections to any other ways to access data. Another use of sections appears to be in mapping the part of code/data where klif.dll is embedded and then finding that section using a hardcoded magic QWORD number: **0xA1B5F8FC0C2E1064**. Once the section is found in address space of current process the code attempts to pass execution to it. This alternative execution route is not applicable to current MSI file package but simply exists in the code probably due to common code template used for building current MSI package. It may also be an indicator of another Duqu platform component that wasn’t used in the attacks that we observed.

Third Layer: klif.dll

Original filename: klif.dll

MD5: 3fde1bbf3330e0bd0952077a390cef72

Size: 196'096 bytes

Link time: 2014.07.06 08:36:50 (GMT)

Type: 64-bit PE32+ executable DLL for MS Windows

Apparently, this file attempts to mimic some of legitimate names of Kaspersky Lab product components: “klif.sys”. Although there is neither similarity in code nor in file information, the module uses Kaspersky Lab acronym in its export names: KLInit and KLDone.

When this DLL is loaded into a new process, it simply initializes internal structures, such as those providing pointers to the required system API.

The real payload of this module is located in the KLDone export function, which is second in the list of the export table. This export function is called from the previous code layer.

First, it makes sure that global application structure is initialized with essential functions from ntdll.dll, kernel32.dll and user32.dll. System API functions are imported using hashes of export names. The hashing algorithm is identical to the one described one layer above and uses the same magic constants: **0x8A20C27** and **0x67F84FC6**.

Next the code iterates through the list of running processes and hashes lowercase name of each process. The hash is compared to a hardcoded value of 0x3E3021CB, which is a hash for the “**avp.exe**” string.

Attacking AVP.EXE

If the “avp.exe” process is running, the module attempts to open the OSBoot-section as described before and tries to attack the avp.exe process. The attack starts from identifying the exact path to the installed Kaspersky Lab product by iterating through an array of hardcoded registry keys and values for the following products:

KES12	AVP15	AVP10	AVP8
KES11	AVP14.0.0	KES9	AVP7
KES10	AVP14	KES8	AVP6
AVP16.0.0	AVP13	AVP80	
AVP16	AVP12	AVP90	
AVP15.0.0	AVP11	AVP9	

The registry values queried by the module contain a filesystem path to the root directory where the corresponding product is installed. For example: “**C:\Program Files\Kaspersky Lab\Kaspersky Internet Security 15.0.0**”

Once the registry key and value is found, the module confirms that avp.exe file is located in that directory. It does some basic file availability checks as well: makes sure that environment variables are resolved and the file can be opened for reading and it begins with 0x5A4D (magic “MZ” value of Windows executables).

After that, the module creates a new section and maps avp.exe as a file view to this section. To allow code execution, the attributes of this memory region are also changed accordingly. This allows the module to change bytes from the mapped avp.exe in memory. The module applies two patches to the mapped avp.exe in a quite unusual way using SSE2 CPU extensions. In fact, it patches just the old DOS PE header (less than 120 bytes). The patches are simple callback mechanisms that call arbitrary function passed as an argument.

Right after this, the module attempts to start a new thread that begins with one of the patched locations. So far, it looks like the new thread begins with a call originating from avp.exe module that does some other calls, i.e. jumping back to klif.dll. Apparently, this

attack was introduced to trick the avp.exe process into believing that further calls will be safe and trusted as the root of the call stack is coming from the legitimate avp.exe module. This is what we see further down in the code: the new thread instantly jumps from avp.exe back to klif.dll and tries to communicate with the Kaspersky Lab product minifilter driver, known as klif.sys.

In fact, just before communicating with klif.sys, it opens OSBoot-section and gets an IOCTL code as well as the driver device name to send this IOCTL code to. The section and corresponding driver (KMART.dll) provide certain support to the current module. The code hashes current process name and verifies if it falls down into one of three hashes: **0x3E3021CB (avp.exe), 0xDE6D4DA0 (msiexec.exe), 0xB915B2D8 (rundll32.exe)**.

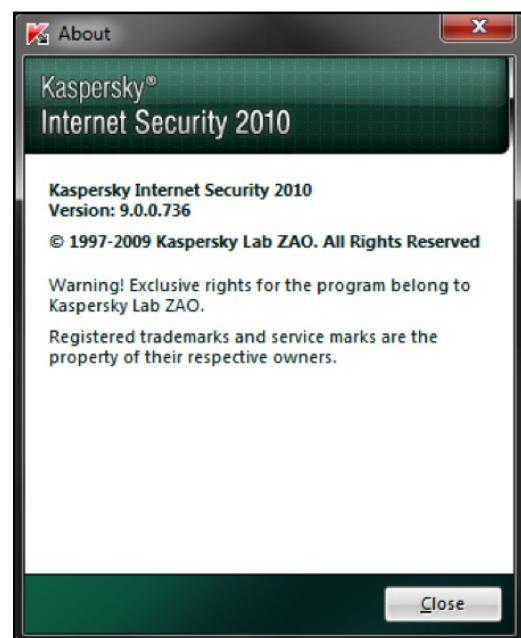
If current process name hash is recognized, the module communicates with klif.sys by opening \KlifComm minifilter communication port and sending series of driver communication messages. According to analysis of the messages, this technique makes process or thread operations “invisible” to the klif interceptor. Such registered entity is considered to be trusted and its activity is removed from AV-scanning, process monitoring, firewall and other defense engines that are subscribed to intercepted events. In addition, the module requests support of the self-defense feature of Kaspersky Lab product, which is normally used to protect the software from aggressive malware which kills the security software processes using a number of techniques available from the OS. This of course guarantees that even a user with administrative privileges cannot stop such process.

Considering that this seemed to be an attack against Kaspersky Lab products, we did some additional tests of the products and found that current products verify the caller process by checking its custom digital signature. So far, without additional driver support, this technique should fail. Verification of the digital signature of the process that opened \KlifComm minifilter communication port was implemented in all Kaspersky Lab products since 2010. So far, this could affect only older products such as KIS2010, which was released by Kaspersky Lab in 2009 ►

It doesn't look realistic now that the attackers started implementing tricks against Kaspersky Lab products in 2009 or earlier. So we looked for another rational explanation and seem to have found it.

Such an attack doesn't normally work against our products because they verify that the caller process is legitimate by checking its custom digital signature. To bypass this, the Duqu 2.0 component named “KMART.dll” patches “klif.sys” in memory to bypass this check. The attack works because the attacker's “KMART.dll” is already running in kernel mode due to a vulnerability in the Windows kernel.

After sending the codes, the module proceeds to the next stage, which is process migration, described further below.



CTwoPENC.dll zero-day and KMART.dll

The third layer klif.dll performs a multitude of functions in order to ensure the survival of the malware in memory and bypass antivirus detections.

One important step is to get kernel level access. On 64-bit systems, one cannot simply load and run kernel mode code without a signed driver. While other attackers such as Equation or Turla chose to piggyback on third-party signed drivers, the Duqu 2.0 platform relies on a much more cunning trick.

One of the payloads bundled together with "klif.dll" is called "CTwoPENC.dll". This is a Windows kernel mode exploit (CVE-2015-2360) that allows them to run code with the highest privileges in the system. We recovered several versions of "CTwoPENC.dll", both for 32-bit and 64-bit versions of Windows, with the following compilation timestamps:

- 2014.08.25 01:20:04 (GMT)
- 2014.08.25 01:19:03 (GMT)
- 2014.07.06 09:17:03 (GMT)

Unlike other Duqu 2.0 modules, these timestamps appear to be legitimate. The reason for this remains unknown – perhaps the Duqu platform developers got this module from somebody else and forgot to patch its compilation timestamp.

"CTwoPENC.DLL" exploits a zero-day vulnerability in "win32k.sys" to gain kernel privileges while being run as an unprivileged user. It creates several windows with classes named "CPer", "Zero", "CTwo", "Vero" in several threads and manipulates the callback pointers.

```
' v0 = GetProcessHeap();
v29 = HeapAlloc(v0, 8u, 0x8000u);
if ( v29 )
{
    v1 = GetProcessHeap();
    lpMem = HeapAlloc(v1, 8u, 0x4000u);
    if ( lpMem )
    {
        WndClass.lpfnWndProc = DefWindowProcA;
        WndClass.lpszClassName = "CPer";
        if ( RegisterClassA(&WndClass) )
        {
            hWndNewParent = CreateWindowExA(0, "CPer", 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0);
            if ( hWndNewParent )
            {
                WndClass.lpszClassName = &ClassName;
                v9 = 0;
                do
                {
                    v25 = v9 + 1;
                    sub_100037FE(&ClassName, "%d%s%d", v9);
                    v10 = RegisterClassA(&WndClass);
                    *(_WORD *)lpMem + v9) = v10;
                    if ( !v10 )
                        break;
                    v11 = CreateWindowExA(0, &ClassName, &ClassName, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0);
                    v12 = (char *)v29 + 4 * v9;
                    *(_DWORD *)v12 = v11;
                    if ( !v11 || sub_100035AB(v11, &hWnd, 0) )
                        break;
                    v14 = *(_DWORD *)v12;
                    if ( Check64(v13) )
                }
            }
        }
    }
}
```

Part of the exploit code that registers window classes and creates new windows.

The main purpose of the exploit is to load a driver named "KMART.dll". If the exploit succeeds, it decompresses "KMART.dll" from the module's body and passes control

to it while running in kernel mode. Both 32-bit and 64-bit versions of the "KMART.DLL" exist. This driver implements a kernel-mode attack against the Kaspersky Lab products filter "klif.sys". It patches the import table addresses of system API functions PsGetCurrentProcessId, PsLookupProcessByProcessId and KlGetStringRef export of Kaspersky Lab's anti-virus driver klflt.sys. The intercepted functions are preceded by malicious code that impersonates the other malicious modules as coming from the process/file "avp.exe" (using the actual location of the anti-virus component), thus evading monitoring by the anti-virus software.

During testing, the zero-day exploit worked on all contemporary Windows versions (XP, Vista, 7, 8, 8.1 both 32-bit and 64-bit). This vulnerability has been patched by Microsoft on June 9, 2015."

PAYOUT CONTAINERS AND MIGRATION

The module supports a number for different payloads provided in the form of containers following klif.dll in memory (located in PE overlay).

A payload container contains a short header describing target CPU architecture, payload type and target process name or hash. When the module uses some embedded code or file there is normally at least two variants of code bundled inside: 32 and 64-bit. Each payload run type is identified by a single character. Current module supports the following 5 payload run types: **g, i, k, l, q**. Seems like the developer used ordered alphabet characters, which means that there could be other payload run types which were removed from the code at some time. Currently the container located in the overlay of subject executable contains a "l" character as a payload run type, so lets describe it first.

Payload type "L"

First, the code looks for privileges from other processes. The process handle can be hardcoded or obtained by looking for currently running processes, hashing their names and comparing them to one of known hashes. The module includes the following hardcoded process hashes:

0x31283314 (services.exe), 0x1026D1BA (lsass.exe), 0x3BD2498C (svchost.exe).

If any of the recognized processes are found, the module opens process token and verifies that the following privileges are available:

- SeDebugPrivilege
- SeTcbPrivilege
- SeAssignPrimaryTokenPrivilege
- SeIncreaseQuotaPrivilege
- SeImpersonatePrivilege
- SeRestorePrivilege

If they are available the module duplicates process token and saves it into an internal structure for future use.

The module looks for one of the available security suites installed in current system and some generic processes if nothing was found. It attempts to find executable files of the following software:

- More than 20 different Kaspersky Lab products
- McAfee VSCore, SystemCore, HIP
- Symantec Internet Security
- Bitdefender
- ESET
- H+BEDV
- TrendMicro Network Security Component
- Rising AV
- Avast
- AVG 2012/2013/2014/2015
- F-Secure
- Qihoo 360 Security
- Generic Windows Processes:
 - %ProgramFiles(x86)%\Windows Defender\MsMpEng.exe
 - %SystemRoot%\syswow64\svchost.exe
 - %SystemRoot%\system32\lsass.exe
 - %SystemRoot%\system32\svchost.exe

When such an executable is found and eventually it should (at least svchost or lsass.exe should be present), it runs a new process from discovered location and replaces its executable code with own embedded into current executable in encrypted and compressed form.

If the code manages to find a security token from one of the processes with required security privileges, it will try to use this token when creating a new process using CreateProcessAsUser API. Otherwise it simply spawns new process instance.

The new process is started in suspended and debugged state. Just before starting the new process it disables DEP for the child processes to simplify code injection and data manipulation. So far, from the outside, it may look like a security software was started, while from the inside its code is completely different from legitimate module.

Payload run type “G”

This payload is almost identical to payload L described above, but the loader is simpler – it skips hijacking of privileged token. Code injection target is selected automatically depending on the availability of known processes.

Payload run type “I”

This payload is similar to payload G, but makes the loader parse payload header a bit differently: instead of process name string it takes only 4 bytes, which are supposedly used as a process hash. This seems to be a way to hide target process name and use only hash, however this hasn't been implemented completely in the module we analyzed.

Payload run type “K”

This payload is designed to run within the context of the current process. The code simply copies the code to be executed into separate memory and runs it in a dedicated thread. It blocks until thread finishes its execution.

Payload run type “Q”

This payload is identical to payload K described above but it doesn't block execution when a new thread is started. So far, the new code runs asynchronously.

After the payload container is opened and code migrated to another process, which can be elevated and protected from security software, the real malicious code is activated. In most cases, it is simple named pipe based backdoor that listens for incoming communications from the orchestrator. In rare cases, on selected machines, it can be heavy orchestrator module that communicates with command and control server, works as a bidirectional proxy and comes with a large bundle of secondary plugins.

PLATFORM PLUGGINABLE MODULES

In addition to the basic remote backdoor, the attackers deploy more sophisticated packages to domain controllers and to the victims of interest inside the LAN. These MSI packages can contain tens of different modules designed for various cyberespionage functions.

The fully featured packages are much larger than the basic remote backdoor – 18MB vs 500KB. They follow the same structure, with ActionDll and the loader mechanism, except they contain a lot more plugins to load and run.

During our analysis, we identified more than 100 variants of such plugins. A description of these plugins follows. To separate them, we used a virtual identifier based on the first two bytes of their MD5 sum.

03B7 – The main module of Duqu 2.0, orchestrator.

Implements multiple protocol handlers for C&C communication, can start an intermediate C&C proxy server with a self-signed HTTPS certificate. Starts the plugin framework, loads and manages all additional plugins.

It works via HTTP, HTTPS, SMB network pipes or direct TCP connection using a custom, encrypted protocol. Interaction via HTTP is concealed in JPEG or GIF files, similar to the 2011 version of Duqu. Request names, URLs and User-Agent strings may vary between attacks.

Additional known variants: 3026, 4F11.

0682 – Collects basic system information:

- List of running processes
- Active desktop and terminal sessions

Collected information is then transmitted to a named pipe provided by the caller.

Additional known variants: C0B7

073C – Implements a **complete Windows socket-based transport**, both client and server side. Provides a class factory for the class that encapsulates various networking functions.

0872 – **MSI CustomAction library** that is activated when the malicious installer package is started by the Windows Installer. Loads the encrypted binary blob that contains actual malicious payload, decrypts and then executes it in memory.

The names in version information vary: **svcmisi_32.dll**, **msi3_32.dll**, **MSI.dll**, **msi4_32.dll**.

Encryption algorithms also vary: **Camellia 256**, **AES**, **XXTEA**.

The decryption key is extracted from an MSI parameter, possible names: **PROP**, **HASHVA**, **CKEY**.

The encrypted blob is searched by prefixes (can vary): ActionData, CryptHashs, CAData.

Both 32-bit and 64-bit versions are known. Additional known variants: 8D7C, 16EF, E6E5, 434C, 44BD, F708.

09A0 – 64-bit, **Exfiltrates file contents**, particularly searching for files matching these rules:

- *.inuse, *.hml
- filename contains “data.hmi” or “val.dat”
- files from the /Int/HMI/ or /LG/HM/ folders.

```

        align 10h
Hml:          ; DATA XREF: sub_18001AC58+750i
    unicode 0, <hml>,0
Data_hmi:      ; DATA XREF: sub_18001BF70:loc_18001C021i
    IO+         unicode 0, <data.hmi>,0
                align 10h
Val_dat:      ; DATA XREF: sub_18001C5BC+1Ei
    IO+         unicode 0, <val.dat>,0
IntHmi:        ; DATA XREF: sub_18001BF70+1Fi
                ; sub_18001C1F8+1Ei
                ; sub_18001C1F8:loc_18001C251i
    IO+         unicode 0, </Int/HMI/>,0
LgHm:          ; DATA XREF: sub_18001AC58+764i
    IO+         unicode 0, </LG/HM/>,0
qword_18003F988 dq 19DB1DED53E8000h ; DATA XREF: sub_180023DA0+136i
dword_18003F990 dd 1                 ; DATA XREF: sub_180023DA0+1A3i
    align 8

```

File and directory names of interest for the 09A0 plugin.

Additional known variants: 8858

0AB8 – Provides 25 **functions for manipulating files and directories**:

- List files in directories
- Upload and download arbitrary files
- Read/write file contents

In several cases, the modules are looking specifically for directories named "\int", "\lg", "\of\md", "\tl", "\ak" and files with extensions ".part", ".manual", ".inuse".

```

Alldirs      db 'allDirs',0          ; DATA XREF: sub_10003A3A+32io
Downloadable db 'Downloadable',0    ; DATA XREF: sub_10003C43+17io
              align 10h
Dlg          db 'dlg',0            ; DATA XREF: sub_1000409E+18io
Explorer_0   db 'Explorer',0       ; DATA XREF: sub_10004329+2Dio
              align 10h
asc_10017210 db '\',0           ; DATA XREF: sub_1000455A+18io sub_10(
                                ; sub_10007882+77io sub_10007882+88io
                                ; sub_10008FE8+18io
              align 10h
              dd offset Int        ; "\\int"
              dd offset Lg         ; "\\lg"
              dd offset TL         ; "\\tl"
              dd offset Ak         ; "\\ak"
              dd offset OfMd       ; "\\of\\md"
              dd offset Int        ; "\\int"
              align 10h

```

File and directory names of interest for the OAB8 plugin.

Additional known variants: A69E.

OB97 – Network transport. Implements API for connecting sockets and pipes provided by the caller. Additional variant: 56A2.

152B – Network and domain discovery.

- Enumerates all servers in the domain
- Tries to connect to remote registries and enumerate all users in "HKEY_USERS". Usernames are then converted to SIDs
- Enumerates all visible network shares

Additional known variants: A987

1C71 – In-memory storage. Receives and stores string data in file mappings.

2125 – Network infection module. Tries to acquire administrative credentials from the running processes and then connect to a target machine using Windows shares. The machine is infected with a malicious DLL backdoor, the target directory varies and may be in UPDROOT\$, ADMIN\$ or C\$. Uses custom SMB packets to identify the target OS version. The target malicious DLL is then started using a new service created with a name "**svcmci_32@**". The module communicates with the target backdoor via Windows pipes. Additional variant: **DB65**. Instead of the malicious DLL, it uploads a new MSI package and then relies on **MSIEXEC.EXE** to start the MSI via a newly created service named "**msisvc_32@**", the target MSI name is generated randomly using a template "**tmp%*x*.tmp**".

A service was installed in the system.
Service Name: svcmci_32@
Service File Name: msieexec /i %systemroot%\temp\tmp129deb0.tmp /q PROP=fa5d78ba-f17
Service Type: user mode service
Service Start Type: demand start
Service Account: LocalSystem

Example of a Windows event log (System) entry created at the moment of infection.

Administrative credentials are acquired by stealing a token from any running process that was started by a logged on user having domain administrator's rights. For that, it first

queries for the first 100 administrative usernames in the current domain directly from the domain controller.

```

        unicode 0, <\\%s>,0
        align 4
; CHAR netname[]
netname:                                ; DATA XREF: sub_1000A90A+84io SelectConnectShare+381
; SelectConnectShare:loc_1000AEB4io
; SelectConnectShare+47Aio
        unicode 0, <UPDR0OT$,0
        align 10h
SAdminSystem32Msieexec_exe:             ; DATA XREF: CheckAccessToMsieexec+59io
        unicode 0, <%s\ADMIN$\system32\msieexec.exe>,0
        align 10h
SAdminSyswow64Msieexec_exe:            ; DATA XREF: CheckAccessToMsieexec+68io
        unicode 0, <%s\ADMIN$\syswow64\msieexec.exe>,0
        align 10h
; CHAR Admin[]
Admin:                                    ; DATA XREF: SelectConnectShare+EFio
        unicode 0, <ADMIN$,0
        align 10h
; char SC[]
SC:                                         ; DATA XREF: SelectConnectShare+175io
        unicode 0, <\\%s\\c$,0
        align 4
; char C_0[]
C_0:                                       ; DATA XREF: SelectConnectShare+189io
        unicode 0, <%c$,0
; char C_1[]
C_1:                                       ; DATA XREF: SelectConnectShare+1A3io
        unicode 0, <%c:>,0
        align 4
dword_1000EA58 dd 0                      ; DATA XREF: SelectConnectShare+39Eio
; char asc_1000EA5C[]
asc_1000EA5C:                            ; DATA XREF: SelectConnectShare+432io
; NetUseAddMisc+2Dio DoNetUseEnum+3Aio
        unicode 0, <\\%s\\s>,0
; char SIpc[]
SIpc:                                     ; DATA XREF: NetUseAddIPC+36io
        unicode 0, <\\%s\IPC$,0
: wchar + Src

```

Remote locations used by the network infection module.

24B7 – Remote desktop administration. Acquires the screenshots of the desktop but also can send input to the desktop, move the mouse cursor. Both 32-bit and 64-bit variants exist. Additional known variants: 65BE, 7795, BDC8, DEE2

26D6 – Detects running network sniffers (**wireshark**, **tcpview**, **netstat**, **dumpcap**, **perfmon**); implements a **TCP server** and communicates via **network pipes**. Internal name: “P.dll”.

2829 – Collects system information

- Monitors USB device attachment
- Collects USB drive history
- Enumerates network shares, windows captions, system routing tables
- Reads/writes encrypted files

2913 - WMI data collection

- Enumerate profiles with SIDs
- For each profile, extracts information from Ink files in the profile directory
- Enumerate processes via WMI (CIMV2), including terminated processes
- Extracts user information from available remote registries

Additional known variant: C776

29D4 - Service **msisvc_32@; DLL backdoor** that is used for network infection by module **2125**. Accepts commands via named pipe “Global\{B54E3268-DE1E-4c1e-A667-2596751403AD}”. Both 32-bit and 64-bit variants exists.

Additional known variants: 6F92, A505, D242

2B46 – Extensive collection of system and user information

- Domain controller's name
- List of users in the domain
- Administrators of the domain
- Enumerates domain trusts
- TCP tables
- UDP tables
- SNMP discovery (OS, parse all replies)
- USB drive history, mounted devices
- Installed programs
- Time zone
- OS install date
- **ODBC.ini, SQL Server** instance info, **Oracle ALL_HOMES, SyBase, DB2, MS SQL, MySQL** last connections
- DHCP/routing
- Network profiles
- Zero Config parameters
- Connected printers
- MRU list for **WinRAR, WinZip, Office, IE** typed URLs, mapped network drives, **Visual Studio MRU**
- Terminal Service Client default username hint
- User Assist history
- **PuTTY** host keys and sessions
- Logged on users
- Network adapter configuration
- **VNC** clients passwords
- Scan the network and identify OS using SMB packet

```
'Hostname': ; DATA XREF: sub_10008AF1+16io
    unicode 0, <HostName>,0
    align 4
'Logfilename': ; DATA XREF: sub_10008AF1+27io
    unicode 0, <LogFileName>,0
'Portnumber': ; DATA XREF: sub_10008AF1+35io
    unicode 0, <PortNumber>,0
    align 4
'Portforwardings': ; DATA XREF: sub_10008AF1+4Aio
    unicode 0, <PortForwardings>,0
'SSUS': ; DATA XREF: sub_10008AF1+CCio
    unicode 0, <%s - %s:%u [ %s %s ]>,0
    align 4
'SoftwareSimontathamPuttySshhostkeys': ; DATA XREF: sub_10008C2B+59Cio
    unicode 0, <Software\SimonTatham\PUTTY\SshHostKeys>,0
    align 4
'SoftwareSimontathamPuttySessions': ; DATA XREF: sub_10008C2B+5BAio
    unicode 0, <Software\SimonTatham\PUTTY\Session>,0
'SoftwareMicrosoftWindowsCurrentversionExplorerComdlg32File': ; DATA XREF: sub_10008C2B+45io
    unicode 0, <Software\Microsoft\Windows\CurrentVersion\Explorer\ComDlg>
    unicode 0, <32\filemr&u>,0
'SoftwareMicrosoftWindowsCurrentversionExplorerComdlg32open': ; DATA XREF: sub_10008C2B+8Aio
    unicode 0, <Software\Microsoft\Windows\CurrentVersion\Explorer\ComDlg>
    unicode 0, <32\OpenSavePidlMRU>,0
'SoftwareMicrosoftVisualstudio9_0Filemrulist': ; DATA XREF: sub_10008C2B+D4io
    unicode 0, <Software\Microsoft\VisualStudio9.0\FileMRUList>,0
'SoftwareMicrosoftVisualstudio9_0Projectmrulist': ; DATA XREF: sub_10008C2B+11Eio
    unicode 0, <Software\Microsoft\VisualStudio9.0\ProjectMRUList>,0
```

Some of the registry locations harvested by the module.

Additional known variants: A7F8

2BF7 - Utility DLL. Provides basic API for creating new MSI packages, loading and injecting arbitrary PE modules. Also responsible for loading the first level of the VFS inside the malicious MSI files. Both 32-bit and 64-bit versions exist.

Known names: "ntdll.dll", "klif.dll", "apiSet.dll".

Additional known variants: 6DA1, 32DB, 8304, 9931, 9E60, A2D4, ABA9, B3BB, DC5F, DD32, F7BB

3395 – MS SQL discovery module. Module can send ARP packets to network and discover MS SQL Server ports. Additional functions are responsible for connecting and reading of remote registry contents.

35E9 – File system discovery.

- Enumerate network shares
- Enumerate local disks
- Traverse file system hierarchy and enumerate files; identify reparse points

3F45 – Pipe backdoor. Opens a new globally visible named Windows pipe, receives and executes encrypted commands. The “magic” string that identifies the encrypted protocol is “ttttttt”.

- Enumerates running processes
- Loads and executes arbitrary PE files

Both 32-bit and 64-bit versions exist.

Known pipe names:

- \\.\pipe\{AAFFC4F0-E04B-4C7C-B40A-B45DE971E81E} \\.\pipe\{AB6172ED-8105-4996-9D2A-597B5F827501}
- \\.\pipe\{0710880F-3A55-4A2D-AA67-1123384FD859} \\.\pipe\{6C51A4DB-E3DE-4FEB-86A4-32F7F8E73B99}
- \\.\pipe\{7F9BCFC0-B36B-45EC-B377-D88597BE5D78}, \\.\pipe\{57D2DE92-CE17-4A57-BFD7-CD3C6E965C6A}

Additional known variants: 6364, 3F8B, 5926, A90A, DDF0, A717, A36F, 8816, E85E, E927

4160 - Password stealer

- Extracts Google Chrome and Firefox login data
- LSA credentials

```

Localappdata: align 4
0+      unicode 0, <localappdata>,0 ; DATA XREF: sub_1000401A+2E1o
0+      align 4
Local:   align 4
0+      unicode 0, <local>,0 ; DATA XREF: sub_1000401A:loc_100040871o
0+      align 8
SGoogleChromeUserDataDefaultLoginData: ; DATA XREF: sub_1000401A+BD1o
0+      unicode 0, <s\Google\Chrome\User Data\Default\Login Data>,0
E+SelectUsername_valuePassword_valueOrigin_urlFromLogins db 'SELECT username_value,password_value,origin_url FROM logins',0
1+      ; DATA XREF: sub_10004158+591o
; _MEDIA_TYPE Unknown
Unknown:   ; DATA XREF: sub_10004511:loc_100045A91o
0+      dw 3Ch
unicode 0, <Unknown>
        ; DATA XREF: sub_10004511

```

Data used to locate Chrome saved logins.

Additional known variants: B656

41E2 – Password stealer. 64-bit module. Extracts:

- IE IntelliForms history
- POP3/HTTP/IMAP passwords
- TightVNC, RealVNC, WinVNC3/4 passwords
- Outlook settings
- SAM, LSASS cache
- Windows Live, .Net Passport passwords

```

; CHAR Credenumerate[]
+Credenumerate  db 'CredEnumerateW',0 ; DATA XREF: sub_BD6588+2E1o
                align 10h
; CHAR Credfree[]
Credfree     db 'CredFree',0 ; DATA XREF: sub_BD6588+3E1o
                align 20h
Microsoft_wininet: ; DATA XREF: sub_BD6588+C31o
+    unicode 0, <Microsoft_WinInet>,0
+    align 10h
+Abe2869f9b474cd9A358C22904dba7f7 db 'abe2869f-9b47-4cd9-a358-c22904dba7f7',0
+    ; DATA XREF: sub_BD6588+D31o
+    align 20h
WindowsliveName: ; DATA XREF: sub_BD6588+F61o
+    unicode 0, <WindowsLive:name>,0
+    align 10h
_netPassport: ; DATA XREF: sub_BD6588+A61o
+    unicode 0, <.Net Passport>,0
+    align 10h
+_82bd0e679fea47488672D5efe5b779b0 db '82BD0E67-9FEA-4748-8672-D5EFE5B779B0',0
+    ; DATA XREF: sub_BD6588+B61o
+    align 20h
A           db 'A',0 ; DATA XREF: sub_BD69C0+261o sub_BD69C0+
+           align 10h
dword_BE1430 dd 20000010h ; DATA XREF: sub_BD84CC+1211r sub_BD84CC
db 0
        ; DATA XREF: sub_BD84CC+1211r sub_BD84CC

```

References to information collected by the module.

Additional known variants: 992E, AF68, D49F

482F – Collects system information.

- Enumerates disk drives
- Gets list of running processes
- Extensive process information including uptime

- Memory information
- SID information

Additional known variants: F3F4

559B – Active Directory survey.

- Connects to the Active Directory Global Catalog ("GC:") using ADSI
- Enumerates all objects in AD
- Presents every entry in a human-readable format

```

v6 = ADsOpenObject(L"GC:", v5, v3, lu, &stru_100030C8, &ppObject);
*a3 = v6;
if ( v6 >= 0 )
{
    v7 = ADsBuildEnumerator((IADsContainer *)ppObject, &ppEnumVariant);
    *a3 = v7;
    if ( v7 >= 0 )
    {
        VariantInit(&pvarg);
        v8 = ADsEnumerateNext(ppEnumVariant, lu, &pvarg, &pcElementsFetched);
        *a3 = v8;
        if ( v8 < 0 || pcElementsFetched != 1 )
        {
            *v4 = -16;
        }
        else
        {
            *a3 = (**(int (__stdcall **)(LONG, IID *, int *))pvarg.lVal)(pvarg);
            VariantClear(&pvarg);
            if ( *a3 < 0 )
                *v4 = -17;
        }
    }
    else
    {
        *v4 = -15;
    }
    else
    {
        *v4 = -14;
    }
    if ( ppEnumVariant )
        ADsFreeEnumerator(ppEnumVariant);
}

```

Active Directory enumeration routine.

580C - Collects system and network information.

- Retrieves the domain controller name
- Enumerates all users and groups in the domain
- Collects Task Scheduler logs
- Collects disk information, removable device history
- Retrieves firewall policies
- Enumerates all named system objects
- Enumerates all system services

5B78 - Collects system information and utilities. One of the two exported functions has a name "GetReport".

- Enumerate running processes, extract tokens and SIDs, collect timing information
- Logon users using explicit credentials
- Impersonate users of running processes
- Build new 32-bit and 64-bit shellcode stubs using a hardcoded template

Both 32-bit and 64-bit versions exist.

Additional known variants: E8C7, EE6E.

5C66 – Encrypted file I/O, utilities

- File I/O operations: open/seek/read/write
- Manages compressed and encrypted temporary files

622B - Generate XML report about system using unique schema

- Computer name
- Windows directory
- Enumerates all logical drives
- Lists all files
- OS serial number
- Domain name
- Network adapter configuration: IP addresses, MAC, MTU, adapter list

```

S_info_xml:          ; DATA XREF: sub_1000B5DE+6Dio
    unicode 0, <S_info.xml>,0
GatherMetadataError: ; DATA XREF: sub_1000B5DE:loc_1000B71Cio
    unicode 0, <Gather metadata error>,0
ArchiveErrorWriteFailed: ; DATA XREF: sub_1000B5DE+123io
    unicode 0, <Archive error: write failed>,0
ArchiveErrorEndFileFailed: ; DATA XREF: sub_1000B5DE:loc_1000B746io
    unicode 0, <Archive error: end file failed>,0
    align 4
unk_1000E1DC db 0FFh           ; DATA XREF: sub_1000B7F1+9io
    db 0FEh ; |
?xmlVersion1_0?:      dw 3Ch
    unicode 0, <?xml version="1.0" ?>
    dw 3Eh, 0Ah, 0
    db 0
    db 0
SurveyresultXsiHttpWww_w3_org2001XmlschemaInstan: ; DATA XREF: sub_1000B7F1+1Aio
    dw 3Ch
    unicode 0, <SurveyResult xmlns:xsi="http://www.w3.org/2001/XMLSchema->
    unicode 0, <instance" xmlns:xsd="http://www.w3.org/2001/XMLSchema">
    dw 3Eh, 0Ah, 0
    align 4
UniqueidCompnameSBootosserial08xUniqueIdS: ; DATA XREF: sub_1000B7F1+35io
    unicode 0, < >
    dw 3Ch
    unicode 0, <UniqueID compname="%s" bootOsSerial="%08X" uniqueid="%s" >
    unicode 0, </>
    dw 3Eh, 0Ah, 0
Surveyresult:          ; DATA XREF: sub_1000B5DE+EBio
    dw 3Ch
    unicode 0, </SurveyResult>
    dw 3Eh, 0Ah, 0
    align 4
True_0:                ; DATA XREF: sub_1000B843+2Aio sub_1000B843+AFio
    unicode 0, <true>,0
    align 4
; _BoolValue False
False:                 ; DATA XREF: sub_1000B843+22io sub_1000B843+B4io
    unicode 0, <false>,0
    align 8
ParametersDirsonlySMMaxdepthU: ; DATA XREF: sub_1000B843+33io
    unicode 0, < >
    dw 3Ch
    unicode 0, <Parameters DirsOnly="%s" MaxDepth="%u" >
    dw 3Eh, 0Ah, 0
    align 10h
TimefilterS:           ; DATA XREF: sub_1000B843+50io
    unicode 0, < >
    dw 3Ch
    unicode 0, <TimeFilter %s />
    dw 3Eh, 0Ah, 0

```

XML tags used to generate the system report.

6302 - Utilities. Has internal name "d3dx9_27.dll". Executes timer-based events.

Additional known variants: FA84

669D – Utilities. Given a list of file names and directories, checks if they exist.

Additional known variants: 880B

6914 - Sniffer-based network attacks. Uses a legitimate WinPcap driver “npf.sys”. Detects NBNS (NetBIOS protocol) requests of interest and sends its own responses:

- Responds to WPAD requests (“FHFAEBE” in NBNS packets)
- Sends responses to HTTP GET requests

The network filter is based on the BPF library. The payloads for the HTTP and WPAD responses are provided externally.

```

Str2      db 'GET ',0           ; DATA XREF: sub_1000565E+901o
          align 4
DetectedGetRequestFromSToS:        ; DATA XREF: sub_1000565E+F71o
+     unicode 0, <Detected GET request from %s to %s>,0
          align 10h
NoMoreAttacksLeftNotResponding__: ; DATA XREF: sub_1000565E+11C1o
+     unicode 0, <No more attacks left, not responding..>,0
          align 10h
SentResponsePacketToSForSAttacksLeftU: ; DATA XREF: sub_1000565E+21A1o
+     unicode 0, <Sent response packet to %s  for %s (attacks left = %u)>,0
          align 10h
; char SubStr[]
SubStr    db 'User-Agent: ',0       ; DATA XREF: sub_10005890+11o
          align 10h
·Http1_12000kContentTypeTextHtmlConnectionCloseCon db 'HTTP/1.1 200 OK',0Dh,0Ah
+     ; DATA XREF: sub_100058E2+F61o
+     db 'Content-Type: text/html',0Dh,0Ah
+     db 'Connection: Close',0Dh,0Ah
+     db 'Content-Length: %d',0Dh,0Ah
+     db 'Accept-Ranges: none',0Dh,0Ah
+     db 'Cache-Control: no-cache, no-store, must-revalidate',0Dh,0Ah
+     db 'Pragma: no-cache',0Dh,0Ah
+     db 'Expires: Wed, 21 Jan 1995 11:56:08 GMT',0Dh,0Ah
+     db 0Dh,0Ah,0
          align 4
NotWpadRequest:                  ; DATA XREF: sub_10005B52:loc_10005CBA1o
+     unicode 0, <Not WPAD request>,0
          align 10h
DetectedWpadRequestFromSToS:      ; DATA XREF: sub_10005B52+C01o
+     unicode 0, <Detected WPAD request from %s to %s>,0
SentResponsePacket:               ; DATA XREF: sub_10005B52+1501o
+     unicode 0, <Sent response packet>,0

```

Fake HTTP response and related status messages.

6FAC - File API

- Get file size, attributes
- Securely delete a file
- Open/close/read/write file contents

Additional known variants: A7EE

7BDA – Collects system information

- Current state of AV and firewall protection using wscapi.dll API
- Detect if “sqlservr.exe” is running
- Computer name
- Workgroup info
- Domain controller name
- Network adapter configuration
- Time and time zone information
- CPU frequency

Additional known variants: EF2E

7C23 – Extracts metadata from documents and collects system information

- Computer name
- System volume serial
- Complete file API as in 6FAC

Searches for documents and archives and implements routines to extract all valuable information from them:

- E-mail messages: eml, msg
- Image files: jpg, jpe, jpeg, tif, tiff, bmp, png
- Multimedia files: wmv, avi, mpeg, mpg, m4a, mp4, mkv, wav, aac, ac3, dv, flac, flv, h264, mov, 3gp, 3g2, mj2, mp3, mpegs, ogg, asf. These are re-encoded with libffmpeg.
- Contents from PDF documents
- Microsoft Office: doc, docx, xlsx, pptx. Dedicated routines are called accordingly: "OfficeRipDoc", "OfficeRipDocx", "OfficeRipXlsx", "OfficeRipPptx". PPT slides are extracted and converted to a HTML digest of the presentation.
- Archives: gz, gzip, gzX3, zip, rar

Creates temporary files with extension ".fg4".

Additional known variants: EB18, C091

```

'_docx':           -          ; DATA XREF: 100105081o
'_pptx':          unicode 0, <.pptx>,0      ; DATA XREF: 100105141o
'_xlsx':          unicode 0, <.xlsx>,0      ; DATA XREF: 100105201o
'_zip':            unicode 0, <.zip>,0      ; DATA XREF: 1001052C1o
'_rar':            unicode 0, <.rar>,0      ; DATA XREF: 100105381o
               align 4
; const WCHAR Gdiplus_dll_0
Gdiplus_dll_0:    -          ; DATA XREF: sub_1000AAC0
               unicode 0, <GdiPlus.dll>,0
; const WCHAR ImageJpeg
ImageJpeg:         -          ; DATA XREF: sub_1000A8D0
               unicode 0, <image/jpeg>,0
               align 4
asc_10013978:     unicode 0, <%s\%s>,0      ; DATA XREF: sub_1000AD7C
GatheringRarS:    unicode 0, <Gathering Rar:>,0      ; DATA XREF: sub_1000AD7C
Rar:               unicode 0, <Rar>,0      ; DATA XREF: sub_1000AD7C
Rar_error_D:       unicode 0, <RAR_ERROR_%d>,0      ; DATA XREF: sub_1000AD7C
               align 4
; const WCHAR Ooxml
Ooxml:             -          ; DATA XREF: sub_1000B250
               unicode 0, <OOXML>,0
; const WCHAR String
String:            -          ; DATA XREF: sub_1000B310
               unicode 0, <\>,0      ; sub_1000B310+8D1o sub_1
               ; sub_1000B310+11F1o sub_
; const WCHAR Image
Image:             -          ; DATA XREF: sub_1000B8AC
               unicode 0, <Image>,0
; const WCHAR Ffmpeg
Ffmpeg:            -          ; DATA XREF: sub_1000B9BC
               unicode 0, <ffmpeg>,0
               align 4
RunningLibffmpegS: -          ; DATA XREF: sub_1000B9BC
               unicode 0, <Running libffmpeg:>

```

Part of the list of file extensions of interest and corresponding status messages.

8172 - Sniffer-based network attacks. Performs NBNS (NetBIOS protocol) name resolution spoofing for:

- WPAD requests
- Names starting with "SHR"
- Names starting with "3142" (log only)

```

;-----+
DetectedShrRequestFromSToS:           ; DATA XREF: SHRRequest+91io
+     unicode 0, <Detected SHR request from %s to %s>,0
+     align 4
SentShrResponsePacket:                ; DATA XREF: SHRRequest+l22i0
+     unicode 0, <Sent SHR response packet>,0
+     align 10h
GotUnexpectedErrorWhileRunning:       ; DATA XREF: SHRRequest:loc_10006FA5i0
+     unicode 0, <Got unexpected error while running>,0
+     align 4
DetectedLog3142C:                   ; DATA XREF: Log3142+40i0
+     unicode 0, <Detected Log: 3142%C>,0
+     align 4
DetectedLogS:                       ; DATA XREF: sub_10006D77+D5i0
+     unicode 0, <Detected Log: %S>,0
+     align 4
; const WCHAR String
String:                            ; DATA XREF: sub_100072CB+E1o sub_1000
+     unicode 0, <services.exe>,0
+     align 4
; char Str2[]
Str2      db 'GET ',0           ; DATA XREF: DetectReplyGET+71i0
+     align 10h
DetectedGetRequestFromSToS:          ; DATA XREF: DetectReplyGET+E3i0
+     unicode 0, <Detected GET request from %s to %s>,0
+     align 4
NoMoreAttacksLeftNotResponding__:   ; DATA XREF: DetectReplyGET+108i0
+     unicode 0, <No more attacks left, not responding..>,0
+     align 4
SentResponsePacketToSForUriAttacksLeftU: ; DATA XREF: DetectReplyGET+213i0
+     unicode 0, <Sent response packet to >
+     dw 27h
+     unicode 0, <%s>
+     dw 27h
+     unicode 0, < for URI >
+     dw 27h
+     unicode 0, <%S>
+     dw 27h
+     unicode 0, <(attacks left = %u)>,0

```

Status messages related to the attack.

Additional feature: the module can build new shellcode blobs from hardcoded templates.

81B7 – Driver management

- Write driver to disk
- Start/stop driver
- Safely remove the driver's file from disk

Additional known variants: C1B9

8446 - Oracle DB and ADOdb client.

- Uses “oci.dll” API to access Oracle databases
- Extracts all available information from the database
- Also connects to ADOdb providers

```

Gj43k0Ddi:                                ; DATA XREF: sub_10004D26+1B1o
.     unicode 0, <GJ43K0-%dDI>,0          ; DATA XREF: sub_10005060+4A1o
Table_04d_bin:                            ; DATA XREF: sub_10005060+4A1o
.     unicode 0, <table_%04d.bin>,0
.     align 4
Table_bin:                                ; DATA XREF: sub_1000519E+8E1o
.     unicode 0, <table.bin>,0
Db:                                         ; DATA XREF: sub_10007AF0+BC1o
.     unicode 0, <DB>,0
.     align 10h
byte_100100FO db 8 dup(0)                 ; DATA XREF: sub_1000579E+421o sub_10006257+F11o
.                                         ; sub_10007AF0+231o
AlterSessionSetCursor_bind_capture_destinationOff: ; DATA XREF: sub_100059E7+591o
.     unicode 0, <alter session set cursor_bind_capture_destination = off>,0
AlterSessionSetCursor_sharingForce:        ; DATA XREF: sub_10006257+121o
.     unicode 0, <alter session set cursor_sharing = force>,0
.     align 10h
AlterSessionSetNls_date_formatDdMmYyyyHh24MiSs: ; DATA XREF: sub_10006257+341o
.     unicode 0, <alter session set nls_date_format=>
.     dw 27h
.     unicode 0, <dd/mm/yyyy hh24:mi:ss>
.     dw 27h, 0
.     align 8
BeginDbms_application_info_set_moduleSEnd: ; DATA XREF: sub_10006257+12A1o
.     unicode 0, <BEGIN dbms_application_info.set_module(>
.     dw 27h
.     unicode 0, <%s>
.     dw 27h
.     unicode 0, <, >
.     dw 27h
.     unicode 0, <%s>
.     dw 27h
.     unicode 0, <); END;>,0
.     align 10h
BeginDbms_application_info_set_client_infoSEnd: ; DATA XREF: sub_10006257+15E1o
.     unicode 0, <BEGIN dbms_application_info.set_client_info(>
.     dw 27h
.     unicode 0, <%s>
.     dw 27h
.     unicode 0, <); END;>,0
AlterSessionSetCurrent_schemaS:           ; DATA XREF: sub_10006257+19E1o
.     unicode 0, <ALTER SESSION SET CURRENT SCHEMA >,0

```

SQL queries and related data.

8912 – Encrypted file manipulation and collects system information

- Shared file mapping communication
- Write encrypted data to files
- Enumerate windows
- Enumerate network shares and local disks
- Retrieve USB device history
- Collect network routing table

Known mutex and mapping names:

- Global\{DD0FF599-FA1B-4DED-AC70-C0451F4B98F0} Global\{B12F87CA-1EBA-4365-B90C-E2A1D8911CA9},
- Global\{B03A79AD-BA3A-4BF1-9A59-A9A1C57A3034} Global\{6D2104E6-7310-4A65-9EDD-F06E91747790},
- Global\{DD0FF599-FA1B-4DED-AC70-C0451F4B98F0} Global\{B12F87CA-1EBA-4365-B90C-E2A1D8911CA9}

Additional known variants: D19F, D2EE

9224 – Run console applications. Creates processes using desktop “Default”, attaches to its console and redirects its I/O to named pipes.

92DB - Modified cmd.exe shell.

```

; wchar_t Else
Else:
    unicode 0, <ELSE>,0 ; DATA XREF: sub_410D11+108io
    align 4

; wchar_t Date
Date:
    unicode 0, <DATE>,0 ; DATA XREF: sub_406D5C:loc_406E09io 00420AC0io
    align 4
    unicode 0, <:>
asc_42050C:
    unicode 0, <\*>,0 ; DATA XREF: sub_4155FE+9io sub_4155FE:loc_415822io
    align 4

; const WCHAR Comspec
Comspec:
    ; DATA XREF: sub_408046:loc_4080C2io
    ; sub_40BD53:loc_40BE00io sub_40BD53+162io
    ; sub_40DB6D+D2io sub_41B01B+6Fio

    unicode 0, <COMSPEC>,0

; wchar_t Rem
Rem:
    unicode 0, <REM>,0 ; DATA XREF: sub_410E7C+1Eio sub_4111A7+6Bio 00420DA8io
    align 4
    Chdir_0:
        unicode 0, <CHDIR>,0 ; DATA XREF: 00420A30io

; wchar_t Cd_0
Cd_0:
    unicode 0, <CD>,0 ; DATA XREF: sub_406D5C+44io 00420A18io
    align 10h

Cmd_exe:
    ; DATA XREF: sub_40BD53+105io sub_40BD53+D1io
    ; sub_40BD53:loc_40BE7Fio 0041D71Cio
    unicode 0, <\CMD.EXE>,0 ; DATA XREF: 00420C10io
    align 4

Vol:
    unicode 0, <VOL>,0 ; DATA XREF: 00420C10io

; const WCHAR Path
Path:
    ; DATA XREF: sub_40646D+39io sub_40646D+70io
    ; sub_40646D+83io sub_408046+304io sub_40BD53+53io

    unicode 0, <PATH>,0 ; DATA XREF: sub_40646D+39io sub_40646D+70io
    align 4

; wchar_t Time
Time:
    unicode 0, <TIME>,0 ; DATA XREF: sub_406D5C:loc_406E34io 00420AD8io
    align 4

Set:
    unicode 0, <SET>,0 ; DATA XREF: 00420A90io
    align 4

```

Several CMD commands processed by the shell.

9F0D (64-bit), **D1A3**(32-bit) – **legitimate signed driver NPF.SYS** (WinPcap) distributed inside the VFS along with the plugins. It is used for sniffer-based network attacks.

A4B0 – Network survey

- Uses DHCP Server Management API (DHCPAPI.DLL) to enumerate all DHCP server's clients
- Queries all known DHCP sub-networks
- Searches for machines that have ports UDP 1434 or 137 open
- Enumerates all network servers
- Enumerates network shares
- Tries to connect to remote registries to enumerate all users in HKEY_USERS, converts them to SIDs

B6C1 - WNet API. Provides wrappers for the WnetAddConnection2 and WNetOpenEnum functions.

Additional known variants: BC4A

C25B – Sniffer based network attacks. Implements a **fake SMB server** to trick other machines to authenticate with NTLM.

- Implements basic SMB v1 commands

```
dword_10013340 dd 72h ; DATA XREF: sub_1000
off_10013344 dd offset smb_cmd_negotiate ; DATA XREF: sub_1000
dd 73h
dd offset SMB_COM_SESSION_SETUP_ANDX
dd 2Bh
dd offset SMB_COM_ECHO
dd 75h
dd offset SMB_COM_TREE_CONNECT_ANDX
dd 0A2h
dd offset SMB_COM_NT_CREATE_ANDX
dd 0A0h
dd offset SMB_COM_NT_TRANSACT
dd 32h
dd offset SMB_COM_TRANSACTION2
dd 2Eh
dd offset SMB_COM_READ_ANDX
dd 0Bh
dd offset SMB_COM_WRITE
dd 2Fh
dd offset SMB_COM_WRITE_ANDX
dd 4
dd offset SMB_COM_CLOSE
dd 71h
dd offset SMB_COM_TREE_DISCONNECT
dd 74h
dd offset SMB_COM_LOGOFF_ANDX
dd 0
```

SMB commands handled by the module

- Pretends to have IPC\$ and A: shares
- Accepts user authentication requests
- Also handles HTTP "GET /" requests

```
; char Device[]
Device db '\Device\',0 ; DATA XREF: SelectAdapter+153
align 10h
; char NtLm0_12[]
NtLm0_12 db 'NT LM 0.12',0 ; DATA XREF: smb_cmd_negotiate+9E
align 4
+challenge db 6Ch, 5Bh, 4, 86h, 0Dh, 0C2h, 0DBh, 0Eh, 0E4h, 65h, 51h, 0E5h, 0CDh, 0FEh
; DATA XREF: smb_cmd_negotiate+18F
db 4 dup(0)
db 0 ; DATA XREF: SMB_COM_SESSION_SETUP_ANDX+7B
+SMB1
Windows:
+
Windows_0:
+
Windows_0:
+
LanManager:
+
unicode 0, <Windows>
db 20h, 5, 0, 2Eh, 1, 3 dup(0)
+
unicode 0, <Windows>
db 20h, 2, 4 dup(0)
+
unicode 0, < LAN Manager>
db 0
; wchar_t Ipc
Ipc:
+
unicode 0, <IPC$>,0 ; DATA XREF: SMB_COM_TREE_CONNECT_ANDX+D5
align 10h
Ipc_0 db 'IPC:',0 ; DATA XREF: SMB_COM_TREE_CONNECT_ANDX+F0
align 4
A:
Fat:
+
unicode 0, <FAT>,0
db 0
```

NTLM challenge and SMB server data

ED92 – File system survey

- Enumerates all local drives and connected network shares
- Lists files

EF97 – Filesystem utilities

- Enumerate files
- Create and remove directories
- Copy/move/delete files and directories
- Extract version information from files
- Calculate file hashes

Additional known variants: F71E

PERSISTENCE MECHANISM

The Duqu 2.0 malware platform was designed in a way that survives almost exclusively in memory of the infected systems, without need for persistence. To achieve this, the attackers infect servers with high uptime and then re-infect any machines in the domain that get disinfected by reboots. Surviving exclusively in memory while running kernel level code through exploits is a testimony to the technical prowess of the group. In essence, the attackers were confident enough they can survive within an entire network of compromised computers without relying on any persistence mechanism at all.

The reason why there is no persistence with Duqu 2.0 is probably because the attackers wanted to stay under the radar as much as possible. Most modern anti-APT technologies can pinpoint anomalies on the disk, such as rare drivers, unsigned programs or maliciously-acting programs. Additionally, a system where the malware survives reboot can be imaged and then analyzed thoroughly at a later time. With Duqu 2.0, forensic analysis of infected systems is extremely difficult – one needs to grab memory snapshots of infected machines and then identify the infection in memory.

However, this mechanism has one weakness; in case of a massive power failure, all computers will reboot and the malware will be eradicated. To get around this problem, the attackers have another solution – they deploy drivers to a small number of computers, with direct Internet connectivity. These drivers can tunnel traffic from the outside into the network, allowing the attackers to access remote desktop sessions or to connect to servers inside the domain by using previously acquired credentials. Using these credentials, they can re-deploy the entire platform following a massive power loss.

COMMAND AND CONTROL MECHANISMS

Duqu 2.0 uses a sophisticated and highly flexible command-and-control mechanism that builds on top of the 2011 variant, with new features that appear to have been inspired by other top class malware such as Regin. This includes the usage of network pipes and mailslots, raw filtering of network traffic and masking C&C traffic inside image files.

Inside a Windows LAN, newly infected clients may not have a C&C hardcoded in their installation MSI packages. Without a C&C, they are in "dormant" state and can be activated by the attackers over SMB network pipes with a special TCP/IP packet that contains the magic string "ttttttttttttt". If a C&C is included in the configuration part of the MSI file, this can be either a local IP address, which serves as a bouncing point or an external IP address. As a general strategy for infection, the attackers identify servers with high uptime and set them as intermediary C&C points. Hence, an infected machine can jump between several internal servers in the LAN before reaching out to the Internet.

To connect to the C&C servers, both 2011 and 2014/2015 versions of Duqu can hide the traffic as encrypted data appended to a harmless image file. The 2011 version used a JPEG file for this; the new version can use either a GIF file or a JPEG file. Here's how these image files look like:

Duqu 2011 – JPEG	Duqu 2015 – GIF	Duqu 2015 - JPEG
	 11x11 pixels	 33x33 pixels

Another modification to the 2014/2015 variants is the addition of multiple user agent strings for the HTTP communication. The 2011 used the following user agent string:

- 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)

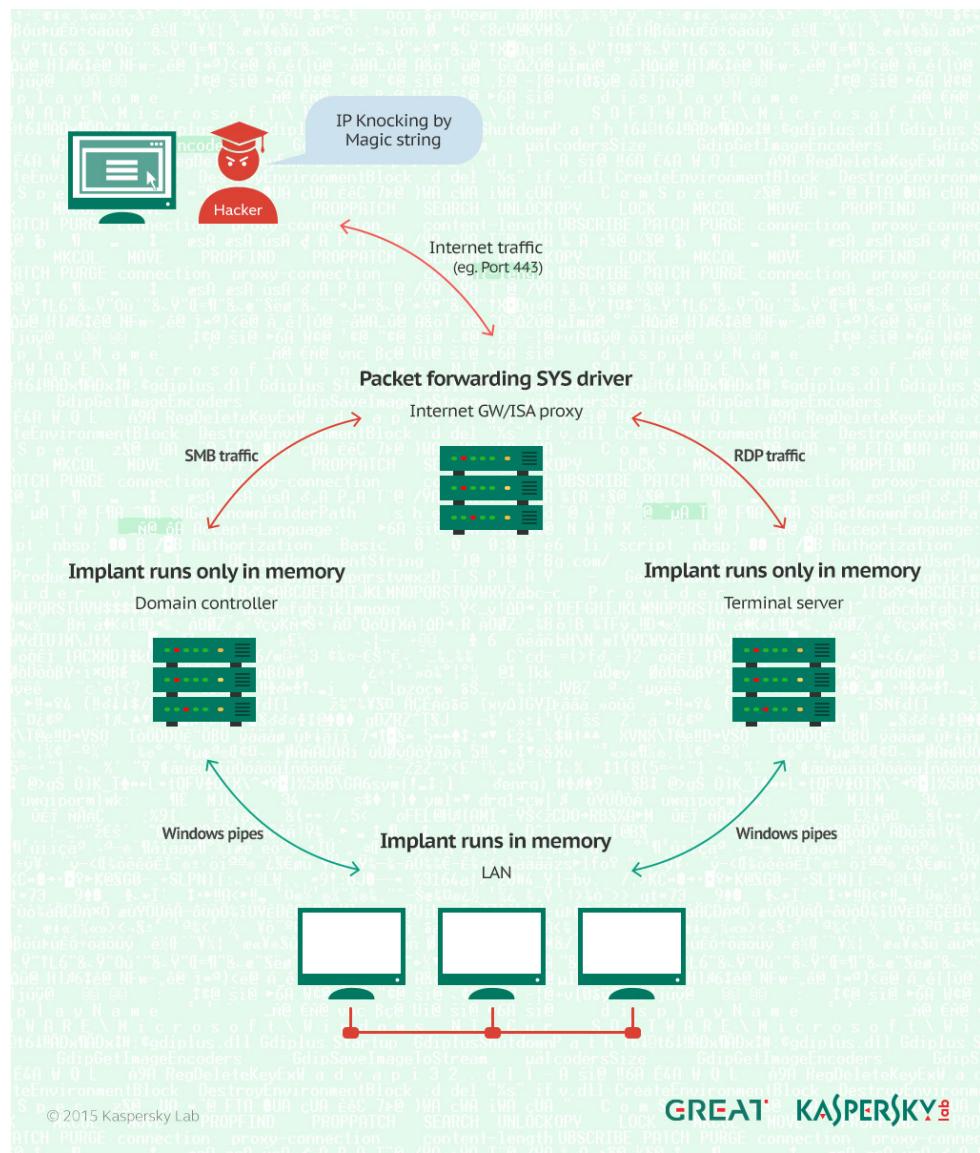
The new variants will randomly select an user agent string from a table of 53 different possible ones.

Another unusual C&C mechanism relies on driver files that are used to tunnel the C&C communications and attacker's RDP/SMB activity into the network. The attackers deploy such translation drivers on servers with direct Internet connectivity. Through a knocking mechanism, the attackers can activate the translation mechanism for their IPs and tunnel their traffic directly into the LAN. Outside the LAN, the traffic can be masked over port 443; inside the LAN, it can be either direct SMB/RDP or it can be further translated over fake TCP/IP packets to IP 8.8.8.8.

During our investigation, we observed several such drivers. A description can be found below.

The "portserv.sys" driver analysis

MD5: 2751e4b50a08eb11a84d03f8eb580a4e



Size: 14336

Compiled: Sat Feb 11 21:55:30 2006 (fake timestamp)

Internal name: termport.sys

Type: Win32 device driver (a 64 bit version is known as well)

This is a malicious NDIS filter driver designed to perform manipulation of TCP/IP packets to allow the attacker to access internal servers in the victim's infrastructure.

Upon startup, the filter driver hooks into the NDIS stack and starts processing TCP/IP packets.

To leverage the driver, the attacker first sends a special TCP/IP packet with the string "**romanian.antihacker**" to any of the hardcoded IPs belonging to infected server. In general, such servers are computers with direct Internet connectivity, such as a webserver or a proxy. The driver sees the packet, recognizes the magic string "**romanian.antihacker**" and saves the attacker's IP for later use.



```

    .aeo jjV $+00 i; |eA jeX9E-wVIE-jOPVS u@. 3Lj!!Yj-+0 it^43T≤su•|E|@ @â°▲|Bâ|L@
    uGÜ}μ]fτāu|iEΓü8@0 ü}μ]fτäu|iEΓü<@0 i@00 δεÉiH♦ëJD@0 i@ë@00 iH@9JD@0 uΓj S $@00 iMn_ ^
    B=[Φo RT+ |||; >@0 uV_ 0+ ||| i Uï=QëMnj 5g@0 5>@0 u^nha~ $-00 ||| %oo@0
    ||| %S00 ||| %@00 ||| %L00 ||| %'00 \ D o s D e v i c e s \ p o r t _ o p t
    i m i z e r \ D e v i c e \ p o r t _ o p t i m i z e r U p p e r B i n d i n g s
    romanian.antihacker iT AT IX AX
    aX nX TX @X LX @X aW L W nX RX $V JT JT ST ST TU TU jU êU @U @U
    LU U ÷U JV 6V FV ZV JV äV äV JV JV ÷V ÷V ÷V ÷V .W FW \W jW äW ÿW \W
    nT dT ZT LT 4T "T JT eS S S TS -S %S
  
```

Magic string used for knocking inside the driver.

When a packet comes from the attacker's IP (saved before), the following logic applies:

- Packet to server 1's IP on port 443, is redirected on port 445 (Samba/Windows file system)
- Packet from server 1's IP from port 445, is redirected to attacker's IP port 443
- Packet to server 2's IP on port 443 is redirected on port 3389 (Remote Desktop)
- Packet from server 2's IP from port 3389 is redirected to attacker's IP port 443

This effectively allows the attackers to tunnel SMB (remote file system access) and Remote Desktop into these two servers while making it look like SSL traffic (port 443).

These drivers allow the Duqu attackers to easily access servers inside the LAN from remote, including tunneling RDP sessions over Port 443 (normally SSL). It also gives them a persistence mechanism that allows them to return even if all the infected machines with the malware in memory are rebooted. The attackers can simply use existing credentials to log back into any of the servers that the driver is serving and can re-initialize the backdoors from there.

SIMILARITIES BETWEEN DUQU AND DUQU 2.0

The 2014/2015 Duqu 2.0 is a greatly enhanced version of the 2011 Duqu malware discovered by ⁷CrySyS Lab. It includes many new ideas from modern malware, such as Regin, but also lateral movement strategies and harvesting capabilities which surpasses commonly seen malware from other APT attacks.

Side by side:

	2011 Duqu	2014/2015 Duqu 2.0
Number of victims:	<50 (estimated)	<100 (estimated)
Persistence mechanism:	Yes	No
Loader:	SYS driver	MSI file
Zero-days used:	Yes	Yes
Main storage:	PNF (custom) files	MSI files
C&C mechanism:	HTTP/HTTPS, network pipes	HTTP/HTTPS, network pipes
Known plugins:	6	>100

There are many similarities in the code that leads us to conclusion that Duqu 2.0 was built on top of the original source code of Duqu. Those interested can read below for a technical description of these similarities.

⁷ <https://www.crysys.hu/publications/files/bencsathPBF11duqu.pdf>

One of the “trademark” features unique to the original Duqu was the set of functions that provide logging facilities. Unlike many other APTs, Duqu logs almost every important step of its activity but does it in a special way: there are no readable strings written to the log. Instead, a series of unique numbers identify every state, error, or message in the log. Comparing the functions that generate every log entry in Duqu and Duqu 2.0, we can conclude that they are almost identical:

```

0000:10015F25 arg_C      = dword ptr 14h
0000:10015F25 lpString2  = dword ptr 10h
0000:10015F25 arg_14     = byte ptr 1Ch
0000:10015F25
0000:10015F25 push    ebp
0000:10015F25 mov     ebp, esp
0000:10015F25 push    edi
0000:10015F25 call    ds:_imp__GetLastError@0 ; GetLastError()
0000:10015F2F push    [ebp+lpString2] ; lpString
0000:10015F32 mov     edi, eax
0000:10015F34 call    ds:strlenNW
0000:10015F3A cmp     eax, 400h
0000:10015F3F jb     short loc_10015F4C
0000:10015F41 push    edi
0000:10015F42 call    ds:_imp__SetLastError@4 ; SetLastError(x)
0000:10015F48 xor     eax, eax
0000:10015F4A jmp     short loc_10015FAA
0000:10015F4C ; -----
0000:10015F4C loc_10015F4C: ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015F4C push    esi
0000:10015F4D call    class17_ctor
0000:10015F4E mov     edi, eax
0000:10015F4F test   esi, esi
0000:10015F56 jnz    short loc_10015F63
0000:10015F58 push    edi
0000:10015F59 call    ds:_imp__SetLastError@4 ; SetLastError(x)
0000:10015F5F xor     eax, eax
0000:10015F61 jmp     short loc_10015FA9
0000:10015F63 ; -----
0000:10015F63 loc_10015F63: ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015F63 mov     eax, [ebp+arg_0]
0000:10015F66 mov     dword ptr ds:[_class_17.int1 - _class_17.int1][esi], eax
0000:10015F68 mov     eax, [ebp+arg_4]
0000:10015F6B mov     eax, [_class_17.int2 - _class_17.int1][esi], eax ; log entry
0000:10015F6C mov     eax, [_class_17.int3 - _class_17.int1][esi], eax ; log entry
0000:10015F71 mov     eax, [_class_17.int4 - _class_17.int1][esi], eax ; log entry
0000:10015F74 mov     eax, [ebp+arg_C]
0000:10015F77 mov     eax, [_class_17.int4 - _class_17.int1][esi], eax ; log entry
0000:10015F7A mov     al, [ebp+arg_14]
0000:10015F7D mov     byte ptr ds:[_class_17.byte - _class_17.int1][esi], al ; log entry
0000:10015F80 lea     eax, (_class_17.FileTime - _class_17.int1)[esi] ; log entry
0000:10015F86 push    eax
0000:10015F87 call    ds:GetSystemTimeAsFileTime
0000:10015F8D cmp     [ebp+lpString2], 0
0000:10015F91 jz     short loc_10015FA0
0000:10015F93 push    [ebp+lpString2] ; lpString2
0000:10015F96 lea     eax, (_class_17.string - _class_17.int1)[esi] ; log entry
0000:10015F99 push    eax
0000:10015FA0 call    ds:lstrcpyW
0000:10015FA0 loc_10015FA0: ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015FA0 push    edi
0000:10015FA1 call    ds:_imp__SetLastError@4 ; SetLastError(x)
0000:10015FA7 mov     eax, esi
0000:10015FA9 loc_10015FA9: ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015FA9 pop    esi
0000:10015FAA loc_10015FAA: ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015FAA pop    edi
0000:10015FAA pop    ebp
0000:10015FAC retn
0000:10015FAC class17_ctor_from_string_and_date endp

1002CDF5 arg_0      = dword ptr 8
1002CDF5 arg_4      = dword ptr 0Ch
1002CDF5 lpString   = dword ptr 10h
1002CDF5 arg_C      = byte ptr 14h
1002CDF6 push    ebp
1002CDF6 mov     ebp, esp
1002CDF8 push    ecx
1002CDF9 push    edi
1002CDFB mov     [ebp+var_8], edx
1002CDFE mov     [ebp+var_4], ecx
1002CE01 call    cGetLastError
1002CE07 push    [ebp+lpString] ; lpString
1002CE0A mov     edi, eax
1002CE0C call    cstrlenW
1002CE12 cmp     eax, 400h
1002CE17 jb     short loc_1002CE24
1002CE19 push    edi
1002CE1A call    cSetLastError
1002CE20 xor     eax, eax
1002CE22 jmp     short loc_1002CE82
1002CE24 ; -----
1002CE24 loc_1002CE24: ; CODE XREF: Log+22ij
1002CE24 push    esi
1002CE24 call    sub_1002CDDB
1002CE2A mov     esi, eax
1002CE2C test   esi, esi
1002CE2E jnz    short loc_1002CE3B
1002CE30 push    edi
1002CE31 call    cSetLastError
1002CE37 xor     eax, eax
1002CE39 jmp     short loc_1002CE81
1002CE3B ; -----
1002CE3B loc_1002CE3B: ; CODE XREF: Log+39ij
1002CE3B mov     eax, [ebp+var_4]
1002CE3B [esi], eax
1002CE3B mov     eax, [ebp+var_8]
1002CE3B [esi+4], eax
1002CE3B mov     eax, [ebp+arg_0]
1002CE3B [esi+8], eax
1002CE3B mov     eax, [ebp+arg_4]
1002CE3B [esi+12h], eax
1002CE3B mov     eax, [esi+81h]
1002CE3B lea     eax, [ebp+var_8]
1002CE3B push    eax
1002CE3B call    cGetSystemTimeAsFileTime
1002CE3B [ebp+lpString], 0
1002CE3B short loc_1002CE78
1002CE3B push    [ebp+lpString2] ; lpString2
1002CE3B eax, [esi+16h]
1002CE3B lea     eax, [esi+81h]
1002CE3B push    eax
1002CE3B call    cSetLastError
1002CE3B edi, eax
1002CE3B ; -----
1002CE3B loc_1002CE81: ; CODE XREF: Log+44ij
1002CE81 pop    edi
1002CE82 loc_1002CE82: ; -----
1002CE82 pop    edi
1002CE83 mov     edi, eax
1002CE85 pop    edi
1002CE86 retn
1002CE86 Log endp

Duqu 2011
Duqu 2015

```

The first generation of Duqu was also written in a very rare and unique manner. It was compiled with Visual Studio and while parts of it were definitely written in C++, the majority of its classes were not natively generated by the C++ compiler. After analyzing all the possible variants, we conclude that these classes were written in OO-C, the objective variant of the C language, and then somehow converted into a compilable C/C++ source. All these classes had a very specific feature: the virtual function table of every instance was filled “by hand” in its constructor. Interestingly, this is no longer the case for Duqu 2.0. The authors upgraded their compiler from Visual Studio 2008 (used in 2011) to Visual Studio 2013 and now use classes that look much more like native C++ ones:

```

0000:10015F06 class17_ctor proc near
0000:10015F06          ; CODE XREF: class17_ctor_from_string_and_date+14j
0000:10015F06 push    2082
0000:10015F06          ; dwBytes
0000:10015F06 call    new
0000:10015F06 pop    edi
0000:10015F06 test   eax, eax
0000:10015F06 jnz    short loc_10015F06
0000:10015F05 retn
0000:10015F05 ; -----
0000:10015F06 loc_10015F06: ; CODE XREF: class17_ctor+0i
0000:10015F06 mov     ds:[ class_17.copy_out_buffer - _class_17.int1][eax], offset class17_copy_out_buf
0000:10015F10 mov     ds:[_class_17.ctor_from_buffer - _class_17.int1][eax], offset class17_ctor_from_buf
0000:10015F14 mov     ds:[_class_17.dtor - _class_17.int1][eax], offset generic_dtor ; log entry
0000:10015F24 class17_ctor endp

1002CD04 sub_1002CD98 endp
1002CD05 ; ====== U. ROUTINE ======
1002CD05 log_item_ctor proc near
1002CD05 mov     edi, ecx, 2084
1002CD05 call    Alloc
1002CD05 test   eax, eax
1002CD05 jnz    short loc_1002CD0E
1002CD07 retn
1002CD09 ; -----
1002CD09 loc_1002CD0E: ; CODE XREF: log_item_ctor+Ci
1002CD09 mov     dword ptr [eax+820h], offset log_item_vtbl
1002CD09 retn
1002CD0A ; -----
1002CD0A log_item_vtbl dd offset copy_out_buffer
1002CD0A dd offset ctor_from_buffer DATA XREF: log_item_ctor:loc_1002CD0E
1002CD0A dd offset j Free
1002CD0A ; ----

Duqu 2011
Duqu 2015

```

*On the left: the “hand-made” or “compiler-assisted” classed of OO-C in Duqu.
On the right: the same class in Duqu 2.0 has a native Vtable similar to native C++ one, however the offset of the pointer is not zero.*

The more concrete evidence of similarity can be found if we look for functions that actually use the logging facilities. The authors kept using the same unique numbers for identification of internal states, errors and function results. Networking functions are good candidates for comparison:

```

0000:1000FD05 var_4_some_obj? = dword ptr -4
0000:1000FD05 arg_1_listen_address= dword ptr 8
0000:1000FD05 arg_accept_port = word ptr 0Ch
0000:1000FD05
    push    ebp
    mov     esp,ebp
    push    edi
    push    ebx
    push    esi
    push    edi
0000:1000FD0C mov    edi, eax
0000:1000FD0E call    do_WSASStartup
0000:1000FD13 test   eax, eax
0000:1000FD15 jz    loc_1000FDCA
0000:1000FD1B push    9Ch           ; dwBytes
0000:1000FD20 call    new
0000:1000FD25 mov    esi, eax
0000:1000FD27 pop    ecx
0000:1000FD28 test   esi, esi
0000:1000FD2A jz    loc_1000FDCA
0000:1000FD30 push    edi, [edi+class_12.make_class11] ; _DWORD
0000:1000FD31 call    [edi+class_12.make_class11]
0000:1000FD34 pop    ecx
0000:1000FD35 mov    [esi+class_18.p_class11], eax
0000:1000FD38 test   eax, eax
0000:1000FD3A jz    loc_1000FDG3
0000:1000FD40 push    1             ; char
0000:1000FD42 push    0             ; lpString2
0000:1000FD44 push    0             ; int
0000:1000FD46 push    904D0561h ; int
0000:1000FD4B push    0BB807043h ; int
0000:1000FD50 push    347DB92Ch ; int
0000:1000FD55 mov    ebx, eax
0000:1000FD57 call    class17_ctor_from_string_and_date
0000:1000FD5C push    ebx
0000:1000FD5E call    dword ptr ds:[_class_11.logger_log - _class_11.logger_log](edi)
0000:1000FD60 or    [esi+class_18.socket], 0FFFFFFFh
0000:1000FD67 add    esp, 20h
0000:1000FD6A push    [ebp+arg_listen_address]; lpString2
0000:1000FD6D lea    eax, [esi+class_18.listen_address]
0000:1000FD70 push    eax, [ebp+arg_listen_address]; lpString1
0000:1000FD71 call    doLstrcpyW
0000:1000FD77 mov    ax, [ebp+arg_accept_port]
0000:1000FD7B mov    word ptr [esi+class_18.listen_port_number], ax
0000:1000FD82 lea    eax, [esi+var_4_some_obj?]
0000:1000FD85 push    eax
0000:1000FD86 push    esi
0000:1000FD87 push    offset class18_listen_on_address
0000:1000FD8C push    edi
0000:1000FD8D mov    [esi+class_18.p_class12], edi
0000:1000FD90 call    [edi+class_12.exec_func]
0000:1000FD93 add    esp, 10h
0000:1000FD96 test   eax, eax
0000:1000FD98 jz    short loc_1000FDCA
0000:1000FD9A mov    edi, [esi+class_18.p_class11]
0000:1000FD9D push    1             ; char
0000:1000FD9F xor    ebx, ebx
0000:1000FDA1 push    ebx, [ebp+lpString2]
0000:1000FDA2 push    ebx, [ebp+lpString1]
0000:1000FDA3 push    569E0BE9h ; int
0000:1000FDA8 push    0BB807043h ; int
0000:1000FDAD push    347DB92Ch ; int
0000:1000FD92 call    class17_ctor_from_string_and_date
0000:1000FD77 push    edi
0000:1000FD89 call    [edi+class_11.logger_log]
0000:1000FD8B add    esp, 20h
0000:1000FD8C cmp    [ebp+var_4_some_obj?], ebx
0000:1000FD8E jnz    short loc_1000FDCE
0000:1000FD93 loc_1000FDCA: ; CODE XREF: class18_ctor+35fj ; class18_ctor+95j
0000:1000FD93 push    esi
0000:1000FD94 call    class18_dtor
0000:1000FD95 pop    ecx
0000:1000FD9A xor    eax, eax
0000:1000FD9C jmp    short loc_1000FDCA
0000:1000FDCE : -----;
0000:1000FDCA loc_1000FDCA: ; CODE XREF: sub_1001B054+411h
0000:1000FDCA xor    eax, eax
0000:1000FDCC jmp    short loc_1000FDCA
0000:1000FDCE : -----;
0000:F105:1000FD05: class18_ctor [Synchronized with Hex View-1]

1001B054 var_C = dword ptr -0Ch
1001B054 lpString2 = dword ptr -8
1001B054 var_2 = word ptr -2
1001B054 arg_0 = dword ptr 8
1001B054
    push    ebp
    mov    esp,ebp
    push    edi
    push    ebx
    push    esi
    push    edi
1001B055 mov    edi, eax
1001B056 call    cWSASStartup
1001B057 test   eax, eax
1001B058 jz    loc_1001B133
1001B059 mov    ebx, [ebp+arg_0]
1001B05A push    ebx
1001B05B mov    eax, [ebx+4]
1001B05C call    dword ptr [ecx+5Ch]
1001B05D mov    [edi+0Ch], eax
1001B05E pop    ecx
1001B05F test   eax, eax
1001B060 jz    loc_1001B12C
1001B061 mov    esi, [eax]
1001B062 mov    edx, 0BB07043h
1001B063 push    1
1001B064 push    0
1001B065 push    0
1001B066 push    904D0561h
1001B067 mov    ecx, 347DB92Ch
1001B068 call    Log
1001B069 push    eax
1001B06A push    dword ptr [edi+0Ch]
1001B06B call    dword ptr [esi]
1001B06C or    dword ptr [edi+94h], 0FFFFFFFh
1001B06D lea    eax, [edi+10h]
1001B06E add    esp, 18h
1001B06F push    [ebp+lpString2]; lpString2
1001B070 call    cLstrcpyW
1001B071 mov    ax, [ebp+var_2]
1001B072 lea    eax, [ebp+var_C]
1001B073 push    ecx
1001B074 mov    [edi+90h], ax
1001B075 mov    [edi+8], ebx
1001B076 mov    eax, [ebx+4]
1001B077 push    eax
1001B078 push    offset sub_1001B13C
1001B079 push    ebx
1001B07A call    dword ptr [eax+8]
1001B07B add    esp, 10h
1001B07C test   eax, eax
1001B07D jz    loc_1001B12C
1001B07E mov    esi, [edi+0Ch]
1001B07F mov    edx, 0BB07043h
1001B080 push    1
1001B081 push    0
1001B082 push    0
1001B083 mov    esi, [eax]
1001B084 mov    eax, 347DB92Ch
1001B085 push    569E0BE9h
1001B086 call    Log
1001B087 push    eax
1001B088 push    dword ptr [edi+0Ch]
1001B089 call    dword ptr [esi]
1001B08A add    esp, 10h
1001B08B test   eax, eax
1001B08C jz    loc_1001B12C
1001B08D mov    esi, [edi+0Ch]
1001B08E mov    edx, 0BB07043h
1001B08F push    1
1001B090 push    0
1001B091 push    0
1001B092 mov    esi, [eax]
1001B093 mov    eax, 347DB92Ch
1001B094 push    569E0BE9h
1001B095 call    Log
1001B096 push    eax
1001B097 add    esp, 10h
1001B098 test   eax, eax
1001B099 jz    loc_1001B12C
1001B09A mov    eax, edi
1001B09B mov    eax, [edi+10h]
1001B09C jmp    short loc_1001B135
1001B09D loc_1001B12C: ; CODE XREF: sub_1001B054+411h
1001B09D push    edi
1001B09E call    sub_1001B054
1001B09F pop    ecx
1001B0A0 add    esp, 10h
1001B0A1 test   eax, eax
1001B0A2 jz    loc_1001B133
1001B0A3 mov    ebx, [ebp+arg_0]
1001B0A4 mov    eax, [ebx+4]
1001B0A5 xor    eax, eax
1001B0A6 xor    eax, eax
1001B0A7 loc_1001B135: ; CODE XREF: sub_1001B054+6b1h
1001B0A7 xor    eax, eax

```

Implementation of the same networking function in Duqu and Duqu 2.0. Note the same unique numbers (in red rectangles) PUSHed as parameters to the logging function.

```
0000:10010733 push ebx
0000:10010734 push edi
0000:10010735 push 0 ; flags
0000:10010737 push eax ; len
0000:10010738 les esp, [ebp+buf]
0000:1001073E push eax ; buf
0000:1001073F push [esi+class_19_socket] ; s
0000:10010740 call ds:recv
0000:10010741 add esp, 4
0000:10010742 test ebx, ebx
0000:10010743 jnz short loc_1001071B
0000:10010744 add edi, [esi+class_19_p_class11]
0000:10010745 push eax ; char
0000:10010753 push eax ; lpString2
0000:10010754 push eax ; int
0000:10010755 push 0F04E80Ah ; int
0000:1001075A loc_1001075A: ; CODE XREF: class19_recv+9Aj
0000:1001075A push 0BB07043h ; int
0000:1001075F push 347DB92Ch ; int
0000:10010760 call ds:__class19_ctor_for_string_and_date
0000:10010769 push eax
0000:1001076A push edi
0000:1001076B call [edi+class_11_logger_log]
0000:10010770 add esp, 4
0000:10010770 jmp short loc_100107E5
0000:10010772 ; 
0000:10010772 loc_10010772: ; CODE XREF: class19_recv+1Cj
0000:10010772 mov eax, [esi+class_19_p_class8_input]
0000:10010775 push eax
0000:10010776 call [eax+class_8_get_available_size]
0000:10010777 pop eax
0000:1001077A test eax, eax
0000:1001077B jnz short loc_10010738
0000:1001077C inc eax
0000:1001077F leave
0000:10010780 retb
0000:10010781 ; 
0000:10010781 loc_10010781: ; CODE XREF: class19_recv+39j
0000:10010781 cmp ebx, -1 ; CODE XREF: class19_recv+39j
0000:10010784 jnz short loc_100107AE
0000:10010785 mov ebx, ds:WSAGetLastError
0000:10010786 call ds:WSAGetLastError
0000:1001078E cmp eax, 2738h
0000:10010793 jz short loc_100107E6
0000:10010795 call ds:WSAGetLastError
0000:10010797 cmp eax, 2749h
0000:1001079C jz short loc_100107E6
0000:1001079E mov edi, [esi+class_19_p_class11]
0000:100107A1 push 10h
0000:100107A3 push eax
0000:100107A5 call ebx ; WSAGetLastError
0000:100107A7 push eax
0000:100107A8 push 0784005h
0000:100107AD jmp short loc_1001075A
0000:100107AF ; 
0000:100107AF loc_100107AF: ; CODE XREF: class19_recv+71j
0000:100107AF mov edi, [esi+class_19_p_class11]
0000:100107B2 push 1 ; char
0000:100107B4 push 0 ; lpString2
0000:100107B6 push eax ; int
0000:100107B7 push 0FCE109h ; int
0000:100107BC push 0BB07043h ; int
0000:100107D0 push 347DB92Ch ; int
0000:100107D6 call ds:__class19_ctor_for_string_and_date
0000:100107CB push eax
0000:100107CC push edi
0000:100107CD call [edi+class_11_logger_log]
0000:100107D0 mov eax, [esi+class_19_p_class8_input]
0000:100107D2 push ebx
0000:100107D3 lea ecx, [ebp+buf]
0000:100107D4 push ecx
0000:100107D5 push eax
0000:100107D6 call [eax+class_8_write_no_class7]
0000:100107D7 add esp, 2Ch
0000:100107D9 test eax, eax
0000:100107E0 jnz short loc_100107EE
0000:100107E5 loc_100107E5: ; CODE XREF: class19_

```

```
001BBC02 push ebx
001BBC03 push esi
001BBC04 push 0 ; flags
001BBC05 push eax ; ten
001BBC06 test eax, [ebp+buf]
001BBC07 push 0 ; buf
001BBC08 push dword ptr [edi+30h] ; s
001BBC09 call ds:_recv
001BBC0A mov ebx, eax
001BBC0B test eax, eax
001BBC0C jnz short loc_1001BBCF5
001BBC0D mov eax, [edi+2Ch]
001BBC0E push 4
001BBC0F push ebx
001BBC10 push ebx
001BBC11 mov esi, [eax]
001BBC12 push 0F04EEB0Ah ; CODE XREF: sub_1001BBCB2+A14}
001BBC13 mov ebx, 0B007043h
001BBC14 mov ecx, 3470B952h
001BBC15 call _WSAGetLastError
001BBC16 cmp ebx, 20000000h
001BBC17 push eax
001BBC18 push dword ptr [edi+2Ch]
001BBC19 call dword ptr [esi]
001BBC1A add esp, 4
001BBC1B jnp short loc_1001BC61
001BBC1C mov eax, 0
001BBC1D push 0
001BBC1E push eax
001BBC1F push 0 ; flags
001BBC20 push eax ; ten
001BBC21 push 0 ; buf
001BBC22 push dword ptr [edi+30h] ; s
001BBC23 call ds:_WSAGetLastError
001BBC24 cmp ebx, 0FFFFFFFFFFh ; CODE XREF: sub_1001BBCB2+491}
001BBC25 jnz short loc_1001BC25
001BBC26 mov ebx, ds:_WSAGetLastError
001BBC27 call _WSAGetLastError
001BBC28 cmp ebx, 20000000h
001BBC29 push eax
001BBC30 jnp short loc_1001BC6C
001BBC31 push 0 ; flags
001BBC32 push eax ; ten
001BBC33 mov ebx, 0B007043h
001BBC34 mov ecx, 3470B952h
001BBC35 push 7FC1E09h
001BBC36 call _Log
001BBC37 push eax
001BBC38 push 0 ; flags
001BBC39 push dword ptr [edi+2Ch]
001BBC40 call dword ptr [esi]
001BBC41 add esp, 4
001BBC42 push 0 ; flags
001BBC43 lea edi, [ebp+buf]
001BBC44 push ebx
001BBC45 push edx
001BBC46 push eax
001BBC47 push 0 ; flags
001BBC48 push dword ptr [eax+4]
001BBC49 call _WSAGetLastError
001BBC50 add esp, 4
001BBC51 jnp short loc_1001BC6C ; CODE XREF: sub_1001BBCB2+76f}
001BBC52 mov eax, [edi]
001BBC53 push eax
001BBC54 push 0 ; flags
001BBC55 mov ecx, [eax+Ch]
001BBC56 call dword ptr [ecx]
001BBC57 add esp, 24h
001BBC58 test eax, eax
001BBC59 jnz short loc_1001BC6C
001BBC60 mov eax, [edi]
001BBC61 push eax
001BBC62 push 0 ; flags
001BBC63 push eax
001BBC64 call dword ptr [eax+4]
001BBC65 pop ecx
001BBC66 xor eax, eax
001BBC67 jnp short loc_1001BC6F ; CODE XREF: sub_1001BBCB2+71f}
001BBC68 mov eax, [edi]
001BBC69 push eax
001BBC70 push 0 ; flags
001BBC71 call dword ptr [eax+4]
001BBC72 pop ecx
001BBC73 xor eax, eax
001BBC74 jnp short loc_1001BC6F ; CODE XREF: sub_1001BBCB2+71f}
001BBC75 push 0 ; flags
001BBC76 xor eax, eax
001BBC77 jnp short loc_1001BC6F ; CODE XREF: sub_1001BBCB2+71f}
```

Duqu 2011

Duqu 2015

Another networking routine: after calling recv() to receive data from network, Duqu logs the results and possible network errors (obtained via WSAGetLastError()). Unique numbers in red rectangles are used to identify the current state of the networking routine.

The code of the orchestrator evolved in many aspects since 2011. One of the notable differences is a huge list of HTTP User-Agent strings that are now used instead of a single hard-coded one:

0000:0008008 aContentType_2 db 'Content-Type',0 ; DATA XREF: class25+10000000000000000000000000000000
0000:000800C aChar_imageJpeg_01 db 'image/jpeg',0 ; DATA XREF: class25+10000000000000000000000000000000
0000:000800D aPost db 'POST',0 ; DATA XREF: http_ac+10000000000000000000000000000000
0000:000800E aGet db 'GET',0 ; DATA XREF: http_accept_request+5A0
0000:000800F alGet 0
0000:00080E4 : char_asc_1003B0E4[1] 0
0000:00080E4 asc_1003B0E4 db '/',0 ; DATA XREF: http_accept_request+BFIo
0000:00080E8 aChar.userAgent! 0
0000:00080E9 aUserAgent db 'User-Agent',0 ; DATA XREF: http_accept_request:loc_100007CE10
0000:00080E9 aMozilla_01 db 'Mozilla/5.0',0
0000:00080F9 Mozilla_5_Wind db 'Mozilla/5.0 (Windows; U; Windows NT 6.0; en-US; rv:1.9.2.9) Gecko' ; DATA XREF: http_accept_request+E40
0000:00080F9 Mozilla_5_Wind db '/Firefox/3.6.9 (.NET CLR 9.5.30729)',0 ; DATA XREF: http_accept_request+E40
0000:0008166 aChar_aCookie! 0
0000:0008166 db 'Cookie',0 ; DATA XREF: http_accept_request:loc_100007F10
0000:000816F aChar_aConnection! 0
0000:0008170 db 'Connection',0 ; DATA XREF: HTTP_server_on_data_available+810
0000:0008178 aContentLength db 'Content-Length',0 ; DATA XREF: HTTP_server_on_data_available+1810
0000:0008188 aContentType db 'Content-Type',0 ; DATA XREF: HTTP_server_on_data_available+2710
0000:0008199 aTransferEncod db 'Transfer-Encoding',0 ; DATA XREF: HTTP_server_on_data_available+3610
0000:00081AE aCookie_0 db 'Cookie',0 ; DATA XREF: HTTP_server_on_data_available+4510
0000:00081B7 aChar_String2! 0
0000:00081B7 db ' ',0 ; DATA XREF: HTTP_server_on_data_available+7510
0000:00081BA aChar_aPost_01! 0
0000:00081BC aPost_01 db 'POST',0 ; DATA XREF: HTTP_server_on_data_available+8610
0000:00081C1 aChar_aGet_01! 0
0000:00081C4 aGet_01 db 'GET',0 ; DATA XREF: HTTP_server_on_data_available:loc_100000A35
0000:00081CB aOk! 0
0000:00081CC db 'OK',0 ; DATA XREF: HTTP_server_on_data_available+1080
0000:00081D1 aKeepAlive! 0
0000:00081D1 db 'Keep-Alive',0 ; DATA XREF: HTTP_server_on_data_available+1610
0000:00081D8 aKeepAlive_0 db 'Keep-Alive',0 ; DATA XREF: HTTP_server_on_data_available+17210
0000:00081E3 aChar_aConnection! 0
0000:00081E4 aConnection db 'Connection',0 ; DATA XREF: HTTP_server_on_data_available+17E10
0000:00081F0 aClose db 'Close',0 ; DATA XREF: HTTP_server_on_data_available+1810
0000:00081F1 aChar_aContentLength_01! 0
0000:00081F8 aConnection_L1 db 'Connection',0 ; DATA XREF: HTTP_server_on_data_available+18A10
0000:0008200 aChar_aContentLength_04! 0
0000:0008200 db '0',0 ; DATA XREF: HTTP_server_on_data_available+1A110
0000:0008200 aChar_aContentLength_01! 0

Duqu 2015

Duqu 2011

Duqu 2015

The authors also modified the “magic” two-byte value that identifies encrypted network traffic: “SH” was replaced with a more neutral and harder to trace “WW”:

```
0000:1001F76C mov    [esi+class_43.class6_input], cl
0000:1001F76E push   cl
0000:1001F76F push   eax
0000:1001F770 lea    [eax+class_header]
0000:1001F771 push   eax
0000:1001F772 call   [eax+class_6.read_and_cut_data]
0000:1001F775 mov    eax, 'HS'
0000:1001F778 add    esp, 10h
0000:1001F77B cmp    word ptr [ebp+cmd_header], ax
0000:1001F77C jnz    [esi]
0000:1001F77D mov    ecx, dword ptr [ebp+cmd_header+2]
0000:1001F77E lea    [eax+class_43.cmd]
0000:1001F77F xor    eax, ecx
0000:1001F780 xor    [ebp+cmd_header+6], cl
0000:1001F781 push   eax
0000:1001F782 push   [esi+class_43.class6_input]
0000:1001F783 selloop ?
```

Duqu 2011

```
002B67D5 push    u
002B67D7 push    OCh
002B67D9 push    edx
002B67D9 mov     ecx, [eax+20h]
002B67D9 push    eax
002B67D9 push    call    dword ptr [ecx]
002B67E0 mov     eax, _W
002B67E5 add     esp, 10h
002B67E8 cmp     [ebp+var_C], ax
002B67EC jnh     short loc_1002B851
002B67EE mov     eax, [ebp+var_A]
002B67F1
002B67F4
002B67F8
002B67FA
002B67FC
002B67FE
```

Duqu 2015

Code that verifies the “magic” value in network traffic

The chars are swapped due to little-endianness of data in x86/64 architectures.

Both Duqu and Duqu 2.0 use special structures to identify the interfaces of their plugins. The orchestrator also has one for the “core” plugin that is compiled in its code. The newer version has a slightly bigger table, hence more functions, and a different notation for describing the plugin features. Special strings (i.e. “A888A8>@”) describe each function’s signature. The older Duqu had contained similar strings in binary (unreadable) form.

*Data structure that describes the “core” plugin of Duqu and two different version of Duqu 2.0.
Note the same constants and similar functions.*



The Duqu C&C code makes use of small image files to hide its communications over unencrypted channels, i.e. HTTP. The original Duqu used a JPEG file, and known versions of Duqu 2.0 use a similar JPEG file as well as a new, larger GIF file. Also, the layout of the data section did not change much: the image data is preceded by short AES encryption keys (string "sh123456" in Duqu, two binary DWORDs in Duqu 2.0) followed by the LZO version string "2 03".

Duqu 2011

Duqu 2015

Duqu 2015

The large number of similarities between the Duqu 2011 code and the new Duqu 2.0 samples indicates that the new code represents a new iteration of the malware platform. The new version could not have been built without access to the 2011 Duqu source code. Hence, we conclude that the authors are the same or working together.

VICTIMS OF DUQU 2.0

Victims of Duqu 2.0 were found in several places, including western countries, the Middle East and Asia. The actor appears to compromise both final and utilitarian targets, which allow them to improve their cyber capabilities.

Most of the final targets appear to be similar to their 2011 goals – which is to spy on Iran’s nuclear program. Some of the new 2014-2015 infections are linked to the P5+1 events and venues related to the negotiations with Iran about a nuclear deal. The threat actor behind Duqu appears to have launched attacks at the venues for some of these high level talks. In addition to the P5+1 events, the Duqu 2.0 group has launched a similar attack in relation to the ⁸70th anniversary event of the liberation of Auschwitz-Birkenau.

The other type of targets for the new attacks are what we call “utilitarian” targets. These are companies that the attackers compromise to improve their cyber capabilities. For instance, in 2011, the attackers compromised a certificate authority in Hungary; obviously, this would allow them to generate digital certificates, which can be further used to sign malware samples. The same pattern can be seen with the Duqu 2.0 infections. Some of the companies infected with Duqu 2.0 operate in the sector of Industrial Control Systems as well as industrial computers.

ATTRIBUTION

As usual, attribution of cyberattacks over the Internet is a difficult task. In the case of Duqu, the attackers use multiple proxies and jumping points to mask their connections. This makes tracking an extremely complex problem.

Additionally, the attackers have tried to include several false flags throughout the code, designed to send researchers in the wrong direction. For instance, one of the drivers contains the string “ugly.gorilla”, which obviously refers to ⁹Wang Dong, a Chinese hacker believed to be associated with the APT1/Comment Crew. The usage of the Camellia cypher in the MSI VFSes, previously seen in APT1-associated Poison Ivy samples is another false flag planted by the attackers to make researchers believe they are dealing with APT1 related malware. The “romanian.antihacker” string used in the “portserv.sys” driver is probably designed to mimic “w00tw00t.at.blackhats.romanian.anti-sec” requests that are often seen in server logs or simply point to an alleged Romanian origin of the attack. The usage of rare compression algorithms can also deceptive. For instance, the LZJB algorithm used in some of the samples is rarely seen in malware samples; it has been used by MiniDuke which we reported in early 2013.

Nevertheless, such false flags are relatively easy to spot, especially when the attacker is extremely careful not to make any other mistakes.

During our 2011 analysis, we noticed that the logs collected from some of the proxies indicated the attackers appear to work less on Fridays and didn’t appear to work at all on Saturdays, with their regular work week starting on Sunday. They also compiled binaries on January 1st, indicating it was probably a normal work day for them. The compilation timestamps in the binaries seemed to suggest a time zone of GMT+2 or GMT+3. Finally, their attacks would normally occur on Wednesdays, which is why we originally called them the “Wednesday Gang”. While the 2014 attack against Kaspersky Lab also took place on a Wednesday, the gang made huge OPSEC improvements compared to their older 2011 operations, including faking all the timestamps in PE files, removing the debug paths and internal module names for all plugins.

The 2014 Duqu 2.0 binaries contain several strings in almost perfect English but one of them has a minor mistake indicating the involvement of non-native speakers. The usage of “Excceeded” instead of “Exceeded” in the file-harvesting module of Duqu 2.0 is the only language mistake we observed.

⁹ <http://www.fbi.gov/wanted/cyber/wang-dong/view>

```

000000000000000000000000` ▼♦♦♦•♦○♦♂○◀!!♀←▼#+3;CScsf£Ää
@0  ►►►◀◀↑↓!!§§§--♀↑↑↓→→◀◀LL++@@^0 0 b8k5
C:\ntdll.dll %SystemRoot%\system32\kernel
32.dll NtQueryInformationFile NtSetInformationFile \?\A:\%08X
%explorer.exe Aborted. Blacklisted %d files out of %d No entries found. Optimizing entry ordering ... %uMB %uKR Gathering %u files totaling %s ... Exceeded maximum output size. Exceeded maximum configuration output size. Scanning '%s' [md=%u] A:\ Completed: Matched 0 entries (Blacklisted %d files out of %d) Completed: Matched %u entries in %u seconds Exceeded maximum file count. Could not access file. Error Success Could not process file. Could not read file. *

```

The screenshot shows a command-line log from the Duqu 2.0 malware. Several instances of the word 'Exceeded' are highlighted with red boxes. One instance is in the middle of a sentence, and another is at the end of a line where it appears to be a misspelling of 'maximum'.

Misspelling of the word "Exceeded" in Duqu 2.0.

Most interesting, one of the victims appear to have been infected both by the Equation Group and by the Duqu group at the same time; this suggests the two entities are different and competing with each other to obtain information from this victim.

CONCLUSIONS

During the 2011 Duqu attacks, we concluded that its main purpose could have been to spy on Iran's nuclear program. Some of the victims appear to have been "utility", such as one certificate authority in Hungary, which was compromised by Duqu and ultimately that led to its discovery. The group behind Duqu hacks these "utility" victims in order to gain certain technical abilities such as signing their malware with trusted certificates or to serve as platforms for further attacks.

The 2014/2015 Duqu 2.0 appears to be a massive improvement over the older "Tilded" platform, although the main orchestrator and C&C core remains largely unchanged. Back in 2011 we pointed out to the usage of ¹⁰Object Oriented C as an unusual programming technique. The 2014 version maintains the same core, although some new objects in C++ have been added. The compiler used in the 2014 is newer and it results in different code optimizations. Nevertheless, the core remains the same in functionality and it is our belief it could not have been created by anyone without access to the original Duqu source code. Since these have never been made public and considering the main interest appears to have remained the same, we conclude the attackers behind Duqu and Duqu 2.0 are the same.

The targeting of Kaspersky Lab represents a huge step for the attackers and an indicator of how quick the cyber-arms race is escalating. Back in 2011 and 2013 respectively, ¹¹RSA and ¹²Bit9, were hacked by Chinese-language APT groups, however, such incidents were considered rare. In general, an attacker risks a lot targeting a security company – because they can get caught and exposed. The exact reason why Kaspersky Lab was targeted is still not clear – although the attackers did seem to focus on obtaining information about Kaspersky's future technologies, Secure OS, anti-APT solutions, KSN and APT research.

¹⁰ <https://securelist.com/blog/research/32354/the-mystery-of-duqu-framework-solved-7/>

¹¹ <https://blogs.rsa.com/anatomy-of-an-attack/>

¹² <https://blog.bit9.com/2013/02/08/bit9-and-our-customers-security/>

From a threat actor point of view, the decision to target a world-class security company must be quite difficult. On one hand, it almost surely means the attack will be exposed – it's very unlikely that the attack will go unnoticed. So the targeting of security companies indicates that either they are very confident they won't get caught, or perhaps they don't care much if they are discovered and exposed. By targeting Kaspersky Lab, the Duqu attackers have probably taken a huge bet hoping they'd remain undiscovered; and lost.

For a security company, one of the most difficult things is to admit falling victim to a malware attack. At Kaspersky Lab, we strongly believe in transparency, which is why we are publishing the information herein. For us, the security of our users remains the most important thing – and we will continue to work hard to maintain your trust and confidence.

REFERENCES

1. Duqu: A Stuxnet-like malware found in the wild <https://www.crysys.hu/publications/files/bencsathPBF11duqu.pdf>
2. Duqu: The Precursor to the next Stuxnet http://www.symantec.com/content/en/us/enterprise/media/security_response/whitepapers/w32_duqu_the_precursor_to_the_next_stuxnet.pdf
3. The Mystery of Duqu: Part One <https://securelist.com/blog/incidents/31177/the-mystery-of-duqu-part-one-5/>
4. The Mystery of Duqu: Part Two <https://securelist.com/blog/incidents/31445/the-mystery-of-duqu-part-two-23/>
5. The Mystery of Duqu: Part Three <https://securelist.com/blog/incidents/31486/the-mystery-of-duqu-part-three-9/>
6. The Mystery of Duqu: Part Five <https://securelist.com/blog/incidents/31208/the-mystery-of-duqu-part-five-6/>
7. The Mystery of Duqu: Part Six (The Command and Control Servers) <https://securelist.com/blog/incidents/31863/the-mystery-of-duqu-part-six-the-command-and-control-servers-36/>
8. The Mystery of Duqu: Part Ten <https://securelist.com/blog/incidents/32668/the-mystery-of-duqu-part-ten-18/>
9. The Mystery of Duqu Framework Solved <https://securelist.com/blog/research/32354/the-mystery-of-duqu-framework-solved-7/>
10. The Duqu Saga Continues <https://securelist.com/blog/incidents/31442/the-duqu-saga-continues-enter-mr-b-jason-and-tvs-dexter-22/>
11. CrySyS Blog: Duqu 2.0 <http://blog.crysys.hu/2015/06/duqu-2-0/>



[Securelist](#), the ressource
for Kaspersky Lab experts'
technical research, analysis
and thoughts



[Kaspersky Lab B2C Blog](#)



[Kaspersky Lab security news
service](#)



[Eugene Kaspersky Blog](#)



[Kaspersky Lab
B2B Blog](#)



[Kaspersky Lab Academy](#)

Kaspersky Lab, Moscow, Russia
www.kaspersky.com

All about Internet security:
www.securelist.com

Find a partner near you:
www.kaspersky.com/buyoffline

Kaspersky Lab HQ

39A/3 Leningradskoe Shosse
Moscow, 125212
Russian Federation

[More contact details](#)

Tel: +7-495-797-8700
Fax: +7-495-7978709

Follow us



Twitter.com/Kaspersky



Facebook.com/Kaspersky



Youtube.com/Kaspersky