Cerber ransomware: new, but mature

By hasherezade

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Ransomware authors seem to love mythological creatures. We have seen Chimera, now we will take a look at Cerber. Both are named after powerful beasts and both are prepared in a professional way. As SenseCy states (source), Cerber is sold to distributors on underground Russian forums.

This malware is often distributed via Exploit Kits (read more here).

UPDATE: Checkpoint released a decryption tool working for some cases of Cerber

Analyzed samples

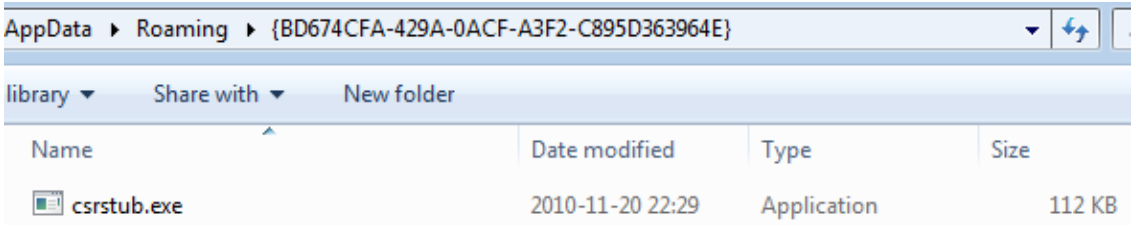
- f5146a3bbe6c71e5a0ef2f04f955b1a1
- 2f7059d7b1dda3080e391d99788fff18
  - payload: 9a7f87c91bf7e602055a5503e80e2313 <- main focus of this analysis

Behavioral analysis

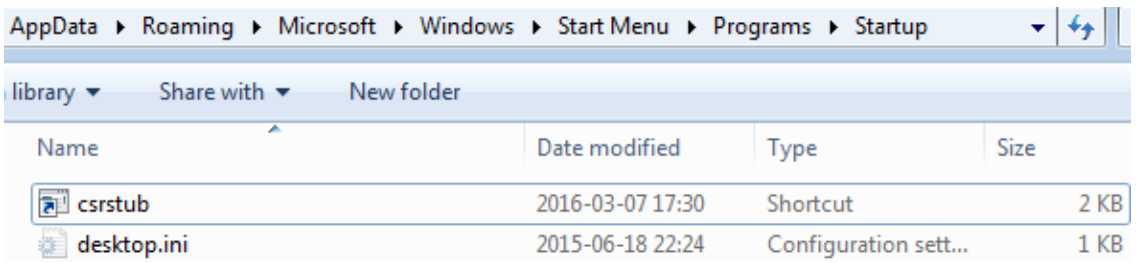
After being deployed it disappears and runs its dropped copy (renamed to [a random word].exe from the hidden folder created in **%APPDATA%**. Name of the folder is specific to a particular sample – in the analyzed one it is: **{BD674CFA-429A-0ACF-A3F2-C895D363964E}**.

Some observed file names: *csrstub.exe*, *dinotify.exe*, *ndadmin.exe*, *setx.exe*, *rasdial.exe*, *RelPost.exe*, *ntkrnlpa.exe*

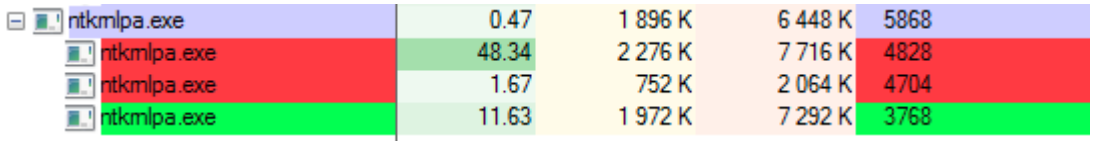
The dropped file has an edited creation timestamp.



It also creates a link to the dropped malware in: *%APPDATA%/Microsoft/Windows/Start Menu/Programs/Startup*:



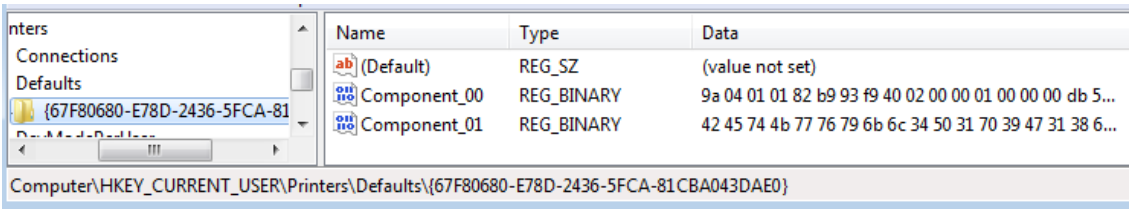
Looking via Process Explorer we can see the dropped sample deploying new instances (it is used in order to divide the work of encrypting files).



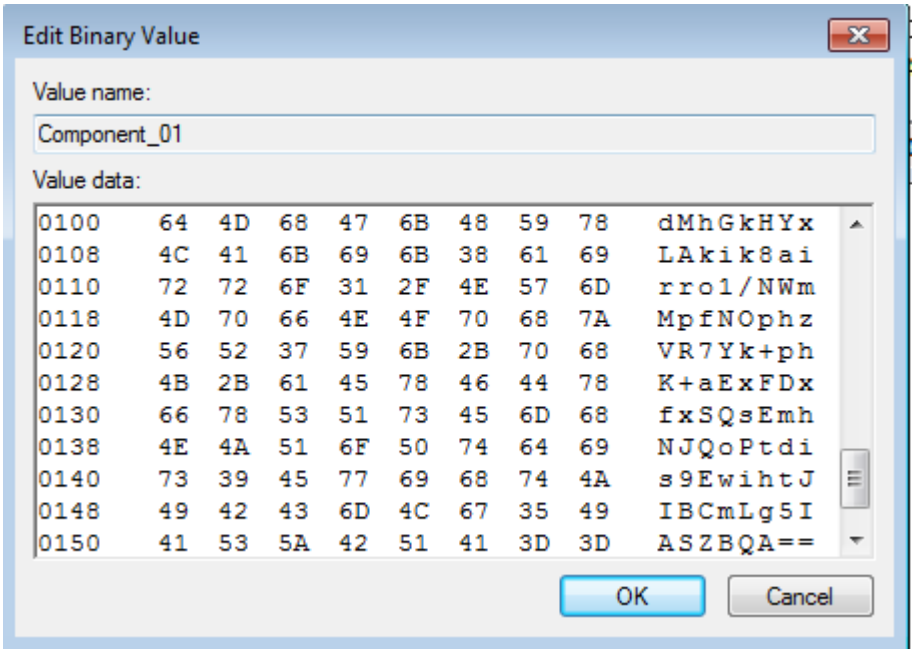
Registry keys

The malware makes changes in the Windows registry.

Two entries (Component_00, Component_01) are dropped in PrintersDefaults:



Compont_01 contains some binary data in base64:



Registry keys for the persistance are added in various places, i.e:

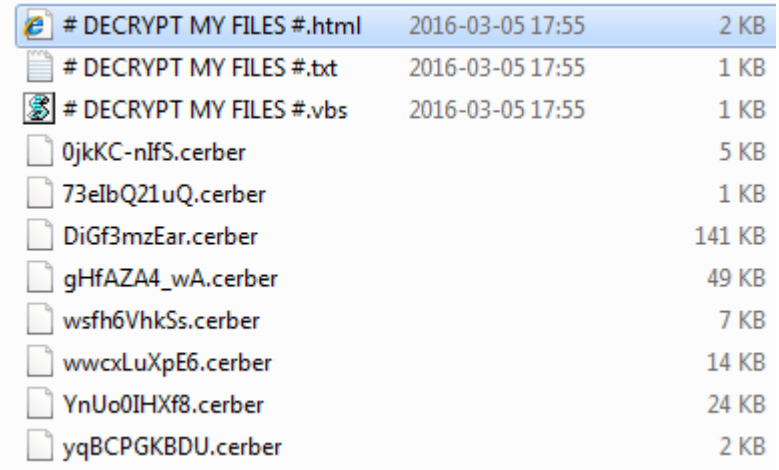
HKEY_USERS -> [current user's SID]:

- "Software\Microsoft\Windows\CurrentVersion\Run"
- "Software\Microsoft\Windows\CurrentVersion\RunOnce"
- "Software\Microsoft\Windows\CurrentVersion\Policies\Explorer" -> "Run"
- "Software\Microsoft\Command Processor" -> "AutoRun"

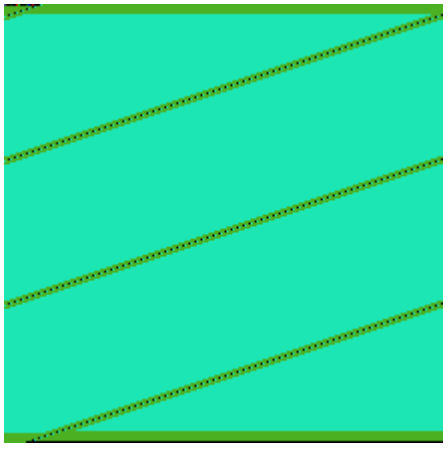
However, when the encryption finishes successfully, the dropped sample is deleted.

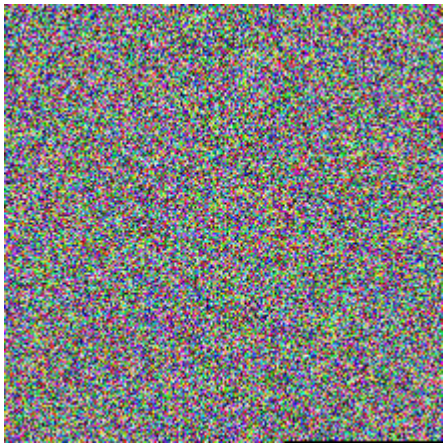
Encryption process

Cerber can encrypt files in offline mode – it means it doesn't need to fetch the key from the CnC server. Files that have been encrypted are fully renamed and appended with the extension typical for this ransomware: **.cerber**. Pattern of the name: **[0-9a-zA-Z_-]{10}.cerber**



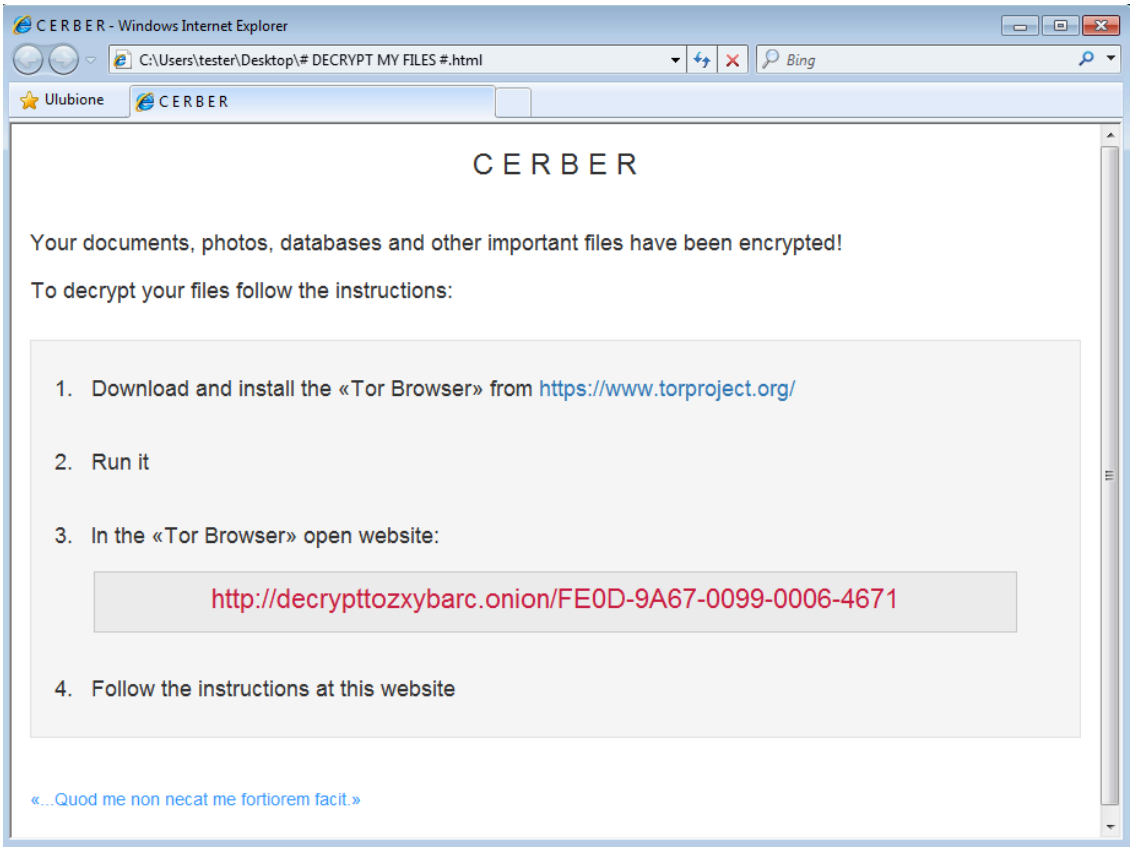
The encrypted content has a high level of entropy and no patterns are visible. Below: visualization of bytes of ***square.bmp*** : left – original, right encrypted with Cerber:





Content of the encrypted file is different on every encryption – probably keys are dynamically generated. After encryption size of the file content is increased about 384 bytes* – it may suggest, that the RSA encrypted AES key is appended to the file (*depending on the file this value may vary a bit, probably because of various padding).

After executing it displays a ransom note in two forms: HTML and TXT. The note is available only in English. Example below:




```
C E R B E R

Your documents, photos, databases and other important files have been encrypted!
```

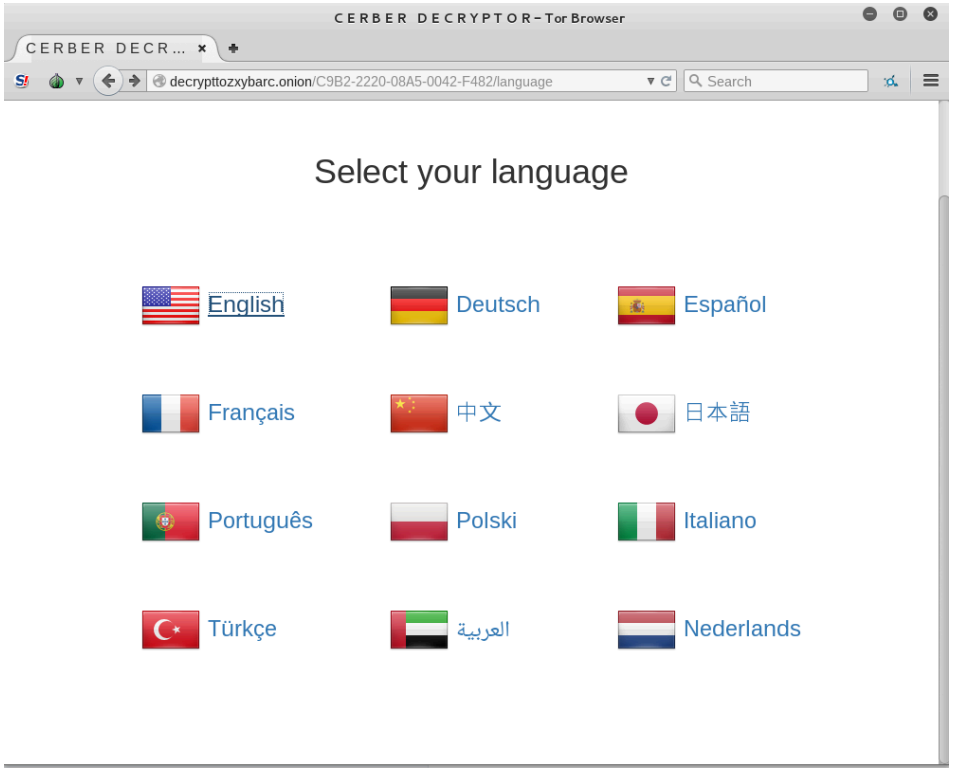
At the bottom of the ransom note attackers added a quote in Latin: «…Quod me non necat me fortiorem facit.» (“What doesn’t kill me, makes me stronger”). We can only speculate what they wanted to convey – to share their own motto, or to console the victim of the attack?

It comes also with a VB macro that is supposed to speak up the message with the help of a local text-to-speech emulator:

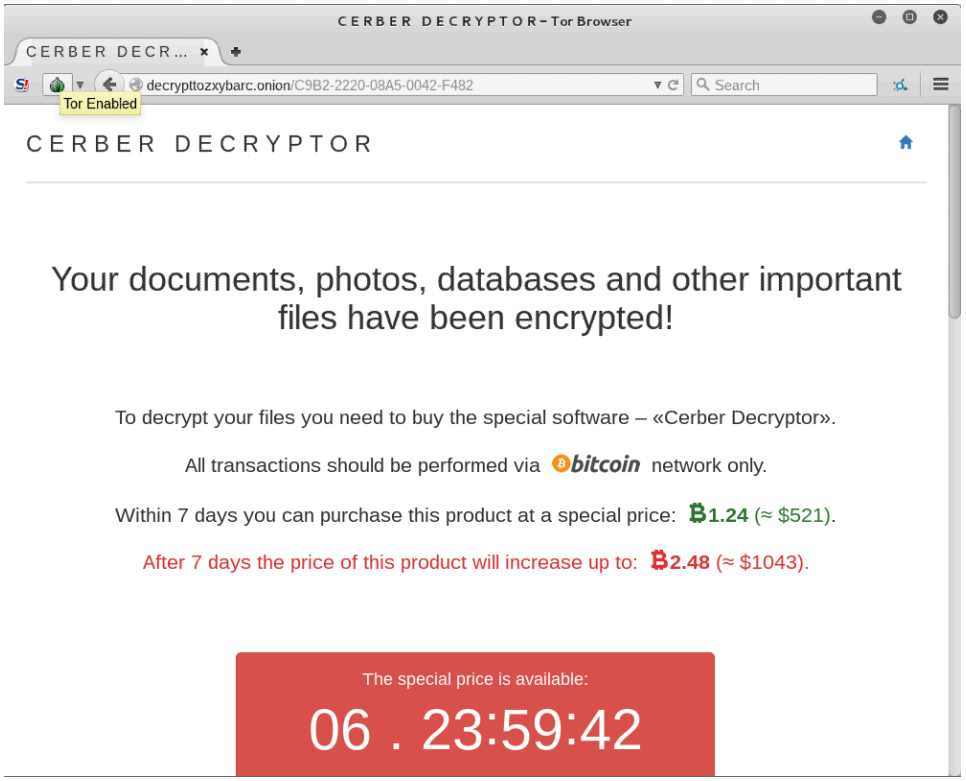
```
Set SAPI = CreateObject("SAPI.SpVoice") SAPI.Speak "Attention! Attention! Attention!" For i = 1 to 5
```

Website for the victim

Each victim has a Web page that can be accessed via Tor. Although the ransom note is available only in English, the Tor website can be customized to several languages:



These pages contain further instructions to the victim and support for managing payments. The time to an increase in the ransom price is counted from the first access to this website.



```
To decrypt your files you need to buy the special software - <>.
```

Network communication

Cerber can manage well without CnC and accomplish its task offline. However, if given opportunity, it can communicate with CnC in order to send statistics from encryption process.

First, it fetches geolocation info (in JSON format) of the local computer by querying a genuine service: http:/ipinfo.io/json

Then, we can observe sending UDP requests to a predefined range of IP addresses:

Destination	Protocol	Length	Info
87.98.128.0	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.1	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.2	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.3	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.4	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.5	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.6	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.7	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.8	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.9	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.10	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.11	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.12	UDP	68	Source port: 33919 Destination port: 6891
87.98.128.13	UDP	68	Source port: 33919 Destination port: 6891

Inside

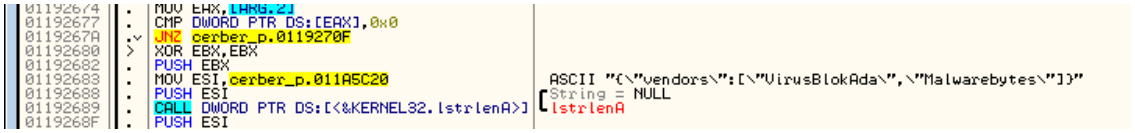
Cerber samples come packed by some crypters/FUDs, so the code is not readable at first. Even when we unpack the core (i.e. 9a7f87c91bf7e602055a5503e80e2313), only a few strings are readable. It is caused by the fact that the authors decided to encrypt the strings and decrypt them just before the usage. Example:

```
00346BED  $  PUSH EBP
00346BEE  .  MOV EBP,ESP
00346BF0  .  PUSH ECX                          cerber_p.0034B21E
00346BF1  .  PUSH ECX                          cerber_p.0034B21E
00346BF2  .  PUSH EBX
00346BF3  .  PUSH ESI
00346BF4  .  PUSH EDI
00346BF5  .  PUSH 0x1
00346BF7  .  PUSH 0xECB03F2D
00346BFC  .  PUSH 0x6
00346BFE  .  PUSH cerber_p.003565AC
00346C03  .  CALL cerber_p.0034A12A            decrypt_string
00346C08  .  PUSH EAX                          L"CERBER"

EAX=0155B0E0, (UNICODE "CERBER")

Address   Hex dump                                        ASCII
003565AC  75 D1 A7 D1 0E E5 00 00 81 51 AB FB B9 1A DD 47  uÐžÐ♫å..üQ«û╣→ÝG
003565BC  E8 33 1D 19 BE E2 9E 2C 18 50 A5 EB 2A 6E 2F CB  Φ3↔↓¥â×,↑P¤ë*n/╦
003565CC  9F A2 61 0C 5D 41 F2 E5 72 CB 00 00 EC B2 1F 6B  ƒóa♀]AòårË..ì▓▼k
003565DC  74 B7 36 41 B1 31 D7 CF C7 44 E4 EF 9A 1D 04 E2  t╖6A▒1╫╧╟Dδï▼♦Γ
003565EC  EA EB 75 CA D4 AA 51 07 4D A8 CA 66 00 00 00 00  Ωδu╩╘¬Q•M¨╩f....
```

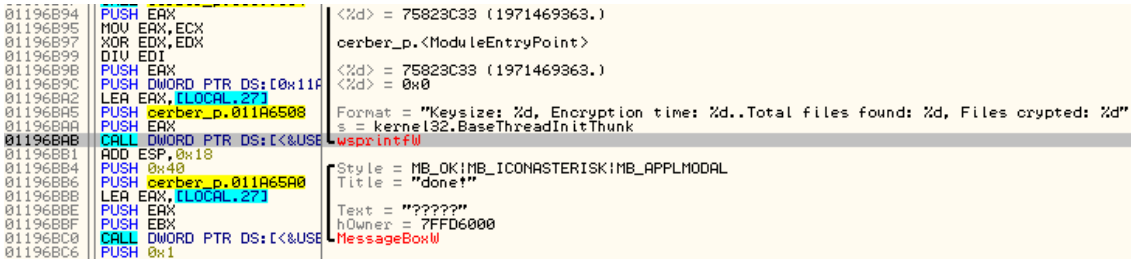
The decrypting function takes the following parameters:

```
decrypt_string(char* input_buffer, DWORD input_lenght, DWORD key, BOOL is_unicode)
```

One of the few strings that hasn't been encrypted was a check against anti-malware vendors (one of them is Malwarebytes). The list of vendors is in JSON – this format have been used extensively by Cerber.

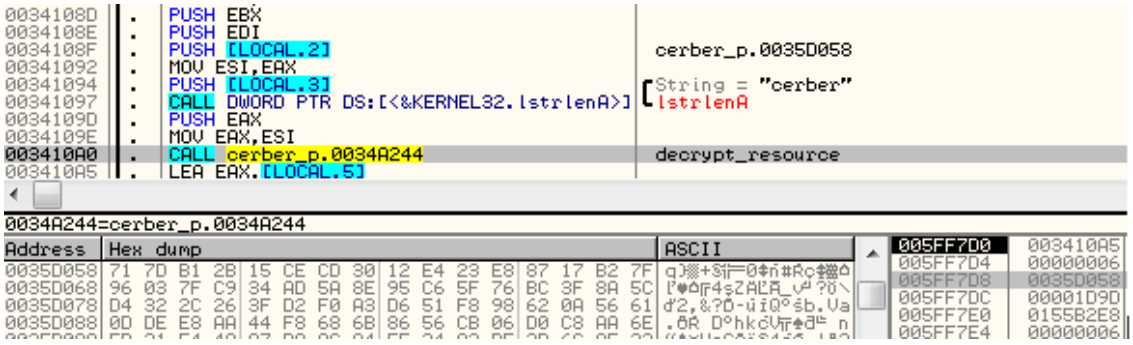


Another interesting unencrypted string was a log, showing the statistics from encryption (the feature used if the malware is deployed in the debug mode):

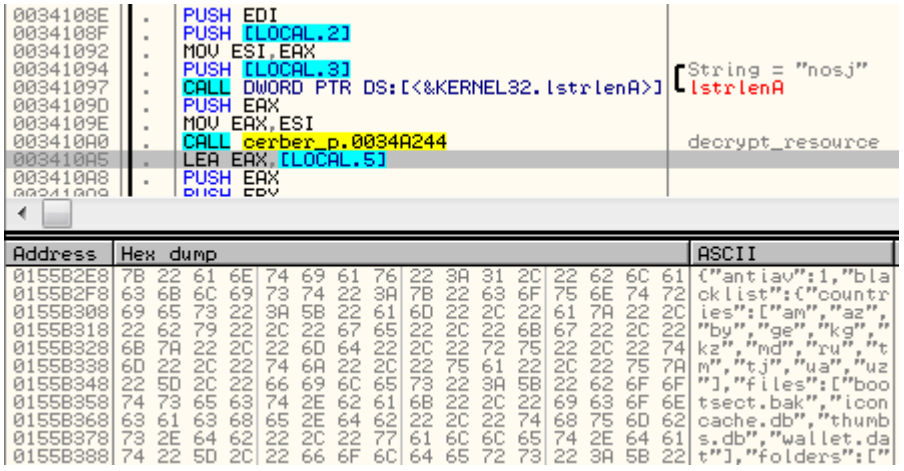


Configuration file

Cerber comes with an encrypted resource, stored as *RC Data*. It is decrypted by a dedicated function:



After decryption, it turns out to be a configuration in JSON format (you can see it full here):



Configuration is rich in options. Contains i.e:

- a blacklist used to exclude some countries, languages, file names and directories from the attack
- a list of attacked extensions
- environment checks that are enabled
- whether or not to deploy the sample in a debug mode
- encryption settings and output extension
- public RSA key in base64 (decoded).
- files with ransom note to be dropped
- list of services used to obtain geolocation
- range of IPs where to send statistics *(compare with IPs described in the section 'Network communication')*
- format of statistics to be sent

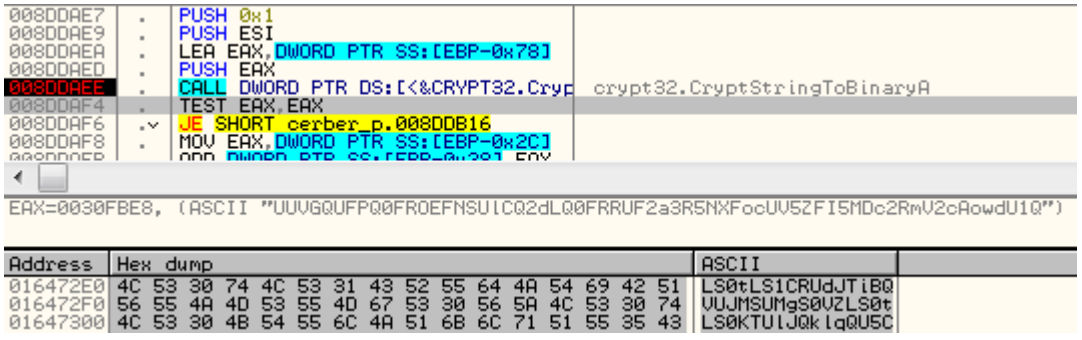
Distributors can customize many things with the help of the config file. Changing the full look-and-feel of the malware – attacked extensions, ransom note and even extension of encrypted files – can make it appear like a new product. This flexibility made me wonder if the same package is not being distributed in a different campaign – not as a Cerber, but under some other name.

The distributor of the analyzed sample decided to exclude several countries form the attack (Armenia, Azerbaijan, Belarus, Georgia, Kyrgyzstan, Kazakhstan, Moldova, Russia, Turkmenistan, Tajikistan, Ukraine, Uzbekistan). It will also spare your default Windows directories, Tor browser and Bitcoin wallet.

Loading the key

The sample comes with a public RSA key shipped in the configuration file (described in the previous section).

Below – decrypting public key from Base64:



Key is imported using function CryptImportPublicKeyInfo.

```
00404DD3 lea     eax, [ebp+pInfo]
00404DD6 push    eax             ; info
00404DD7 push    esi             ; 0
00404DD8 push    8000h           ; CRYPT_DECODE_ALLOC_FLAG
00404DDD push    [ebp+buf]       ; size = 0x126
00404DE0 mov     [ebp+pInfo], esi
00404DE3 push    edi             ; decoded_key_stage2
00404DE4 push    8               ; X509_PUBLIC_KEY_INFO
00404DE6 push    10001h          ; X509_ASN_ENCODING | PKCS_7_ASN_ENCODING
00404DEB mov     [ebp+var_10], esi
00404DEE call    ds:CryptDecodeObjectEx
00404DF4 test    eax, eax
00404DF6 jz      short loc_404E16

00404DF8 lea     eax, [ebp+phKey]
00404DFB push    eax             ; phKey
00404DFC push    [ebp+pInfo]     ; pInfo
00404DFF push    1               ; dwCertEncodingType
00404E01 push    hCryptProv      ; hCryptProv
00404E07 call    ds:CryptImportPublicKeyInfo
```

Configuration mentioned: *"rsa_key_size": 576* – but it turns out to be a 2048 bit key (BLOB size – 276 bytes)

```
BLOBHEADER {PUBLICKEYBLOB, CUR_BLOB_VERSION, 0, CALG_RSA_KEYX}
    RSAPUBKEY {"RSA1", len=2048, public_exponent=65537}

Address   Hex dump                                        ASCII
003B0CB0  06 02 00 00 00 A4 00 00 52 53 41 31 00 08 00 00  ♠☻...Ñ..RSA1.◘..
003B0CC0  01 00 01 00 9D 07 3D A8 59 DB 6B 53 48 3A 39 02  ☺.☺.¥·=¿Y■kSH:9☻
003B0CD0  3D D6 C7 C0 F6 14 2F 2D AC 12 C0 16 61 45 87 91  =ÍÃ└÷¶/-¼↕└▬aEçÆ
003B0CE0  1B 28 FF A1 9D B6 35 70 29 D8 38 04 D6 90 23 DA  ←( ¡¥Á5p)Ø8♦ÍÉ#┌
003B0CF0  2C 33 A2 BC AA A7 B4 58 36 39 B3 1F CD 99 84 38  ,3ó¼ ª§┤X69|▼═Öä8
003B0D00  C6 6E 59 B9 E6 4F 7A A3 53 42 2C CD 69 E1 5A 40  ÃnY╣µOz£SB,═ißZ@
003B0D10  AC A0 E7 30 D2 6E 28 A4 48 8E 93 9E A9 93 12 4D  ¼ á0Tn(¤HÄô×ęô‡M
003B0D20  F3 C1 55 43 E0 E9 9D 23 04 2A F9 C7 B4 10 B7 43  ˜┴UCóÚ#♦*¨ù┤►ÉC
003B0D30  DE 3C 73 AC 44 F8 BE 6E 12 65 20 94 C3 FC D4 6F  ö<s¬D°żn↕e ö├ü╘o
003B0D40  11 29 59 FB 94 A4 CE 43 EE A0 35 3D 8B 6F FC FE  ◄)Yûö¤╬Cţá5=ïoR■
003B0D50  42 CF 92 09 25 3C B0 F0 C8 A7 0D B3 35 5C 6A 9E  Bđ[.%<▒-ºž.|5\jx
003B0D60  2D 3B 8A FC 04 33 FD 50 B1 39 F6 EE F5 1C 10 19  -;ŏR♦3ŻP▒9÷ţ§└►↓
003B0D70  DC 6B 0C 9A 87 72 B6 19 64 32 DE C1 9E C6 E7 4D  ▄k.ÜçrA↓d2Ó┴×ÃšM
003B0D80  3F 87 01 98 38 7F 0A 70 E0 B5 4E 07 81 D3 5A DB  ?ç0ś8⌂.póAN·üÉZ■
003B0D90  D6 4A BF BF A0 43 AB C1 8A C1 E7 4F 4F 9C 12 84  ĺ╩┐┐áCź┴ö┴šOOŕ↕ä
003B0DA0  08 46 88 D8 66 31 E1 44 41 8F B1 03 40 CD 9A 4D  ◘Fłěf1ßDAC▒♦@═ÜM
003B0DB0  86 EC 0F E3 D2 E9 EB 15 FA 4E F7 51 27 13 6A A8  ćý*ND0Ú'8`N,Q'‼jĘ
003B0DC0  E6 72 4B BE                                     ŠrKż
```

Installation

A file name of the dropped sample is created in a pretty interesting way. It is not fully random, but based on name of some file existing in the system, that is searched in the system using a random filter (format: "[random char]* [random char]. exe", i.e "p*h.exe"):

```
010F6189  .  LEA EAX,[LOCAL.411]
010F618F  .  PUSH EAX                          pFindFileData = 0038E718
010F6190  .  LEA EAX,[LOCAL.263]
010F6196  .  PUSH EAX                          FileName = "C:\\Windows\\system32\\p*h.exe"
010F6197  .  CALL DWORD PTR DS:[<&KERNEL32.FindFirstF FindFirstFileW
010F619D  .  CMP EAX,-0x1
010F61A0  .^ JE SHORT cerber_p.010F6144
```

The found file is compared with some built-in blacklist. When it pass the check, it is chosen as the new name of the dropped copy of the malware.

In order to prevent user from finding the malicious file by its creation timestamp it is changed to the timestamp of *kernel32.dll* existing on the local system.

After the successful installation, the initial malware sample terminates and deploys the dropped copy instead.

```
010F661B  CALL to CreateProcessW from cerber_p.010F6615
00976EB0  ModuleFileName = "C:\\Users\\tester\\AppData\\Roaming\\{BD674CFA-429A-0ACF-A3F2-C895D363964E}\\csrstub.exe"
00000000  CommandLine = NULL
00000000  pProcessSecurity = NULL
00000000  pThreadSecurity = NULL
00000000  InheritHandles = FALSE
01000000  CreationFlags = 1000000
00000000  pEnvironment = NULL
00000000  CurrentDir = NULL
0038EB68  pStartupInfo = 0038EB68
0038EB58  pProcessInfo = 0038EB58
```

UAC Bypass

Cerber uses tricks to bypass Windows User Account Controll (UAC) and deploy itself with elevated privileges. It is achieved by the following steps:

1. Search an executable in C:Windowssystem32, that can auto elevate it's privileges.
2. Search in it's import table a DLL that can be hijacked
3. Copy the DLL into %TEMP% folder and patch it – add a code in a new section and patch entry point in order to redirect execution there. It will be used in order to run the cerber sample with elevated privileges. It uses: WinExec("[cerber_path] **-eval 2524**", SW_SHOWNORMAL)
4. Inject the code into explorer.exe – it is responsible for executing the UAC bypass. Creates a new folder in C:Windowssystem32 and copy there both files – an EXE and the patched DLL – under original names, then it deploys the EXE causing DLL to load and execute the malicious code.
5. When the UAC bypass is executed successfully, it is signalized to the original cerber sample by setting a property **cerber_uac_status** – added to a Shell_TrayWnd. Then, the original sample deletes dropped files and exits. Otherwise, it tries the same trick with different pair of EXE + DLL.

See below how it looks in action:

First, it searches an application that can be used to elevate privileges. The check is based on the fields in application manifest:

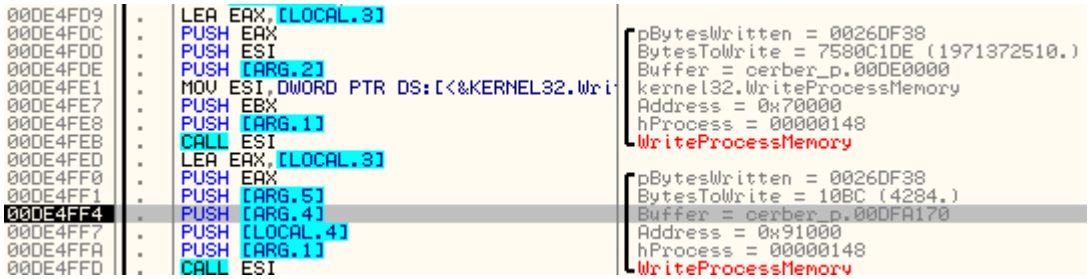
```
true
```

Among it's imported DLLs it searches a candidate suitable to be hijacked. This DLL is copied into *%TEMP%* folder

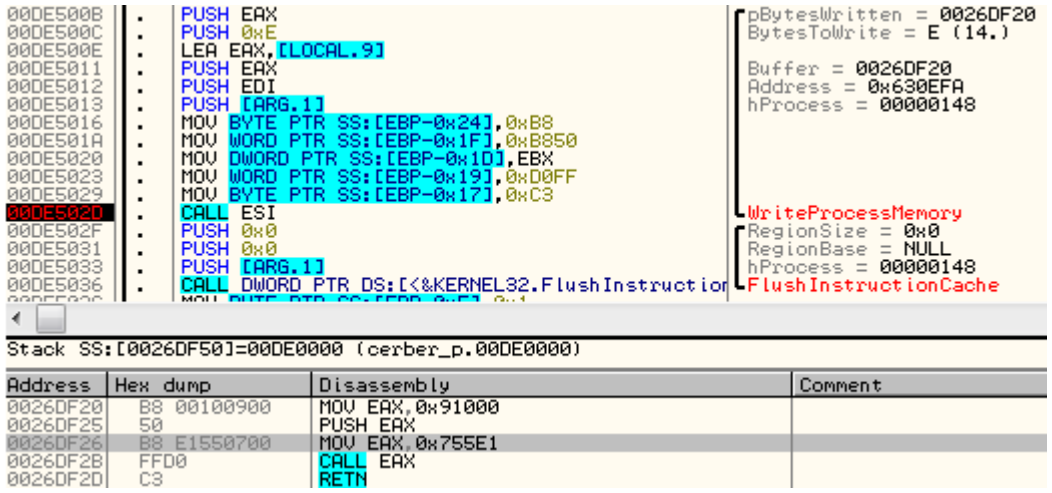
```
00DE57C2  .  LEA EAX,[LOCAL.131]
00DE57C8  .  PUSH EAX                          NewFileName = "C:\\Users\\tester\\AppData\\Local\\Temp\\1443.tmp"
00DE57C9  .  PUSH [ARG.2]                      ExistingFileName = "C:\\Windows\\system32\\d3d9.dll"
00DE57CC  .  CALL DWORD PTR DS:[<&KERNEL32.CopyFileW>]  CopyFileW
00DE57D2  .  LEA EAX,[LOCAL.131]
00DE57D8  .  PUSH EAX
00DE57D9  .  CALL cerber_p.00DE53FC
```

Then, it creates a suspended process of ***explorer.exe***, allocates memory in it's context and injects there own code. Details given below.

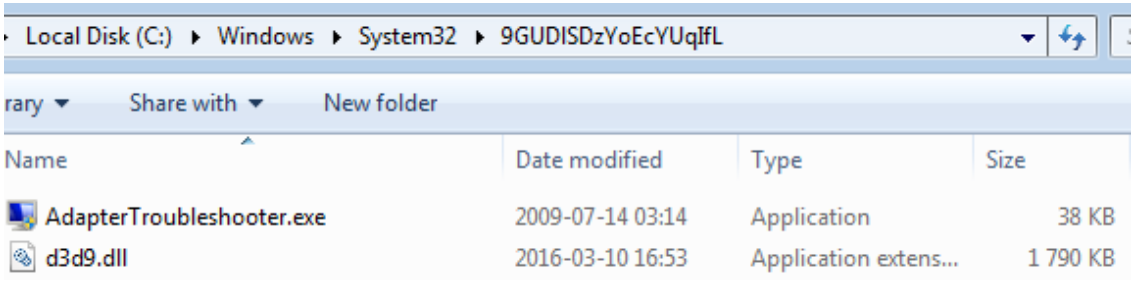
Injection into explorer is performed in several steps. First – malware is coping memory from the context of current process into the context of ***explorer.exe***. Current image of Cerber sample is replicated into a memory allocated in explorer at 0x70000. Similarly, the page containing filled data is copied at offset 0x91000 in explorer.



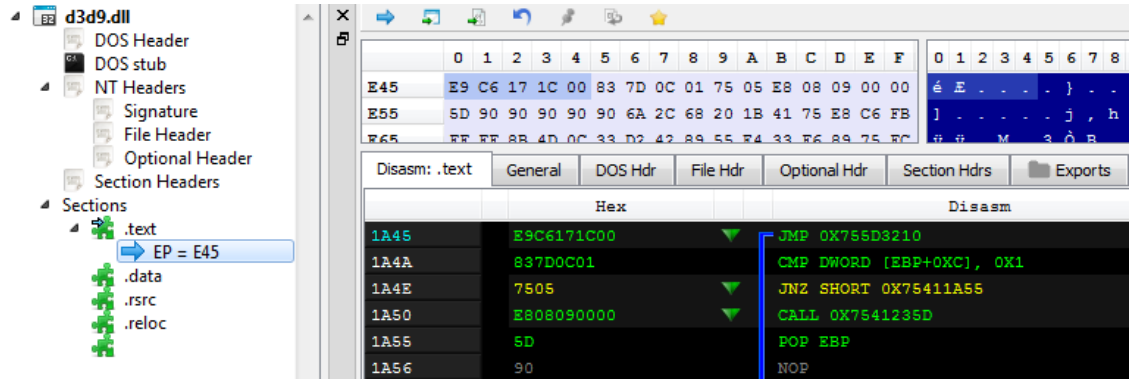
In order to run the injected code when the explorer.exe is resumed, malware performs patching of the carrier's Entry Point:



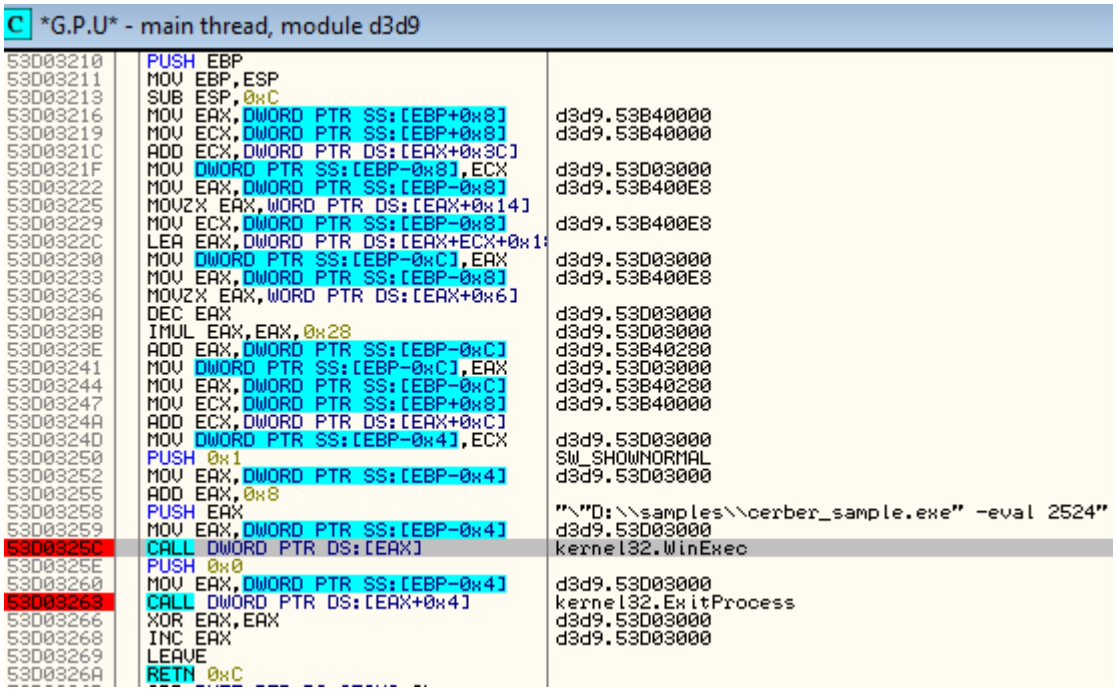
Now, Explorer's execution starts from the call to injected code. It is a function of Cerber sample – at RVA 0x55E1, called with a parameter 0x91000 – pointer to the memory page containing various dynamically loaded data, like function's handlers, paths of the files to be used, etc. From inside this code injected to explorer, the DLL patched for UAC bypass is copied under the original name – along with the appropriate EXE. The executable is deployed (using ShellExecuteExW) and along with it, the patched DLL also runs.



The *d3d9.dll* is used in order to run the Cerber sample with elevated privileges. Entry Point of the DLL is patched with a jump to the new section.



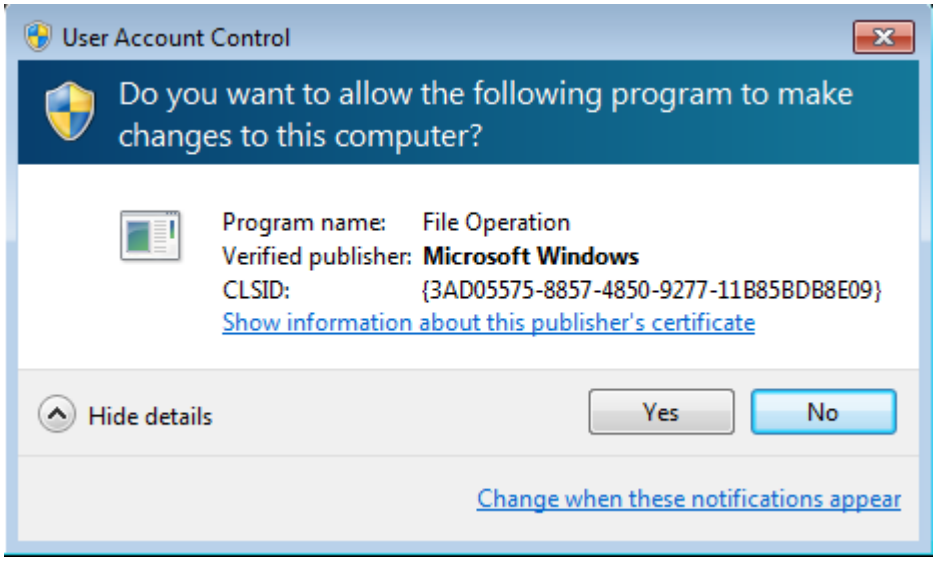
The new section contains the code that is supposed to execute the Cerber sample:



Successful UAC bypass is signalized by setting a property named "**cerber_uac_status**" in a found window of the class "*Shell_TrayWnd*". The initial Cerber sample waits for this status to change. If the timeout passed and it didn't changed it makes a new attempt of UAC bypass – using a different pair (EXE+DLL). Otherwise it cleans up the environment and terminates. Infection proceeds from inside of the elevated sample.

```
00DE570F  .   PUSH EBX                                    Title = NULL
00DE5710  .   PUSH EAX                                    Class = 00021000 ???
00DE5711  .   CALL DWORD PTR DS:[<&USER32.FindWindowW>    FindWindowW
00DE5717  .   PUSH EBX                                    hData = NULL
00DE5718  .   MOV EBP,cerber_p.00DFB024                   UNICODE "cerber_uac_status"
00DE571D  .   PUSH EBP                                    Property = "cerber_uac_status"
00DE571E  .   PUSH EAX                                    hWnd = 00021000
00DE571F  .   MOV DWORD PTR DS:[0xDFA170],EAX
00DE5724  .   CALL DWORD PTR DS:[<&USER32.SetPropW>]      SetPropW
00DE572A  .   MOV EDI,cerber_p.00DE55E1
00DE572F  .   PUSH EDI
00DE5730  .   CALL cerber_p.00DEDC6A
00DE5735  .   MOV ESI,EAX                                 image_base
00DE5737  .   CALL cerber_p.00DEDCD4
00DE573C  .   MOV DWORD PTR SS:[ESP],0x10BC
00DE5743  .   PUSH cerber_p.00DFA170                      Arg5 = 00DFA170
00DE5748  .   SUB EDI,ESI                                 cerber_p.00DE0000
00DE574A  .   PUSH EDI                                    Arg4 = 000055E1
00DE574B  .   PUSH EAX                                    Arg3 = 00021000
00DE574C  .   PUSH ESI                                    Arg2 = 00DE0000
00DE574D  .   PUSH cerber_p.00DFB230                      "C:\\Windows\\explorer.exe"
00DE5752  .   CALL cerber_p.00DE5052                      inject_into_explorer
00DE5757  .   ADD ESP,0x18
00DE575A  .   TEST EAX,EAX
00DE575C  .v  JE SHORT cerber_p.00DE5786                  cerber_p.00DE0000
00DE575E  .   XOR ESI,ESI
00DE5760  >   PUSH EBP                                    Property = "cerber_uac_status"
00DE5761  .   PUSH DWORD PTR DS:[0xDFA170]                hWnd = 0001004E (class='Shell_TrayWnd')
00DE5767  .   CALL DWORD PTR DS:[<&USER32.GetPropW>]      GetPropW
00DE576D  .   TEST EAX,EAX
00DE576F  .v  JNZ SHORT cerber_p.00DE5784                 is_uac_bypassed?
00DE5771  .   PUSH 0x3E8                                  Timeout = 1000. ms
00DE5776  .   CALL DWORD PTR DS:[<&KERNEL32.Sleep>]       Sleep
00DE577C  .   INC ESI                                     cerber_p.00DE0000
00DE577D  .   CMP ESI,0x3C
00DE5780  .^  JB SHORT cerber_p.00DE5760
00DE5782  .v  JMP SHORT cerber_p.00DE5786
00DE5784  >   MOV BL,0x1                                  success
00DE5786  >   POP EDI                                     cerber_p.00DFB230
```

In case if UAC level is set to default (or lower), Cerber can bypass it silently. However, in case if it is set to the highest, the following alert pops up:



It keeps reappearing till the user click “Yes”:

Conclusion

Cerber is a pretty powerful ransomware written with attention to details. This analysis highlighted only some of the elements. It has rich customization options and various tricks to make analysis harder. Although this product appeared recently, for sure its authors are not new in the field of malware development. We can expect it will be gaining popularity and may carry some new tricks in the future.

Appendix

- http://www.bleepingcomputer.com/forums/t/606583/cerber-ransomware-decrypt-my-files-vbs-txt-html/ – thread about Cerber on forum Bleeping Computer
- http://www.bleepingcomputer.com/news/security/the-cerber-ransomware-not-only-encrypts-your-data-but-also-speaks-to-you/

About the author

Unpacks malware with as much joy as a kid unpacking candies.
