[QuickNote] Analysis of Pandora ransomware

kienmanowar.wordpress.com/2022/03/21/quicknote-analysis-of-pandora-ransomware/

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FOREWORD:

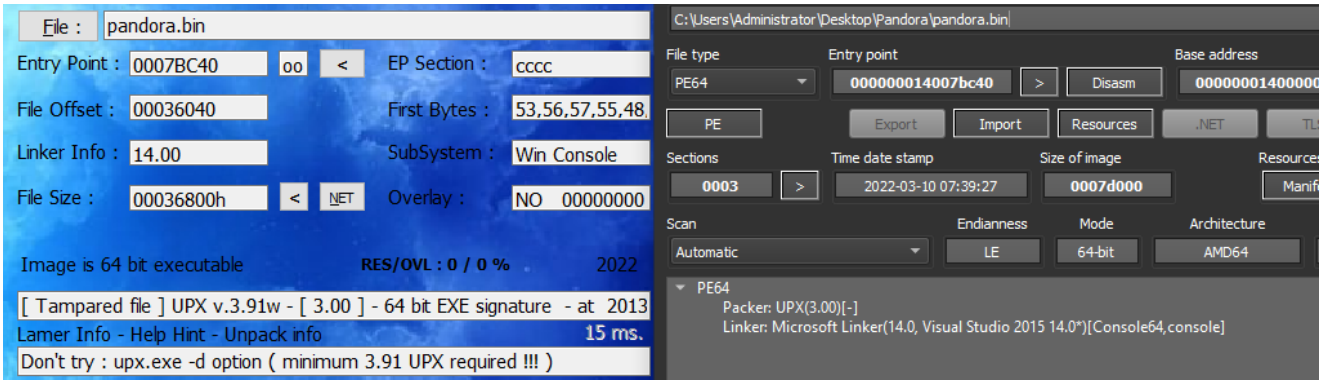
- *Pandora's code looks very weird and obfuscate complicated, so this analysis does not cover all its functions.*
- *I'm not a crypto expert, so I won't dive into Pandora's function like generating encryption key, process of creating threads to do its main task of encrypting files, writing file footer,..*
- *During malware code analysis, I found that **Pandora** and **Rook** ransomware (https://chuongdong.com/reverse%20engineering/2022/01/06/RookRansomware) shared a lot of similarities.*

1. Pandora sample

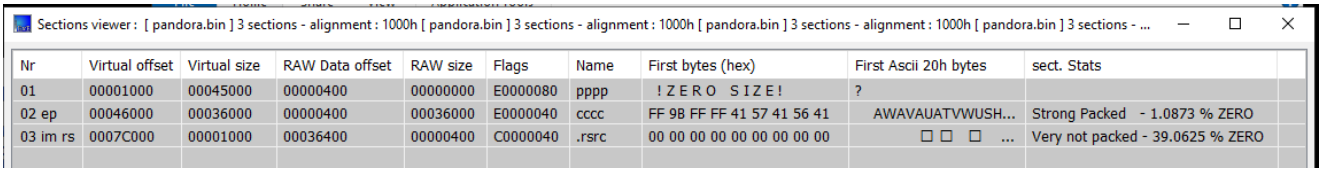
The analyzed sample is a 64-bit executable: 0c4a84b66832a08dccc42b478d9d5e1b

2. Manual unpacking

Quick check the sample with some tools like **ExeInfo PE**, **DiE**, all results show that this sample is packed by **UPX**.



Checking more information about sections shows that the names of sections have been changed, not **UPX0**, **UPX1**, it changed to **pppp** and **cccc**.



Additionally, the information behind the **3.00 UPX!** strings were stripped by the attacker:

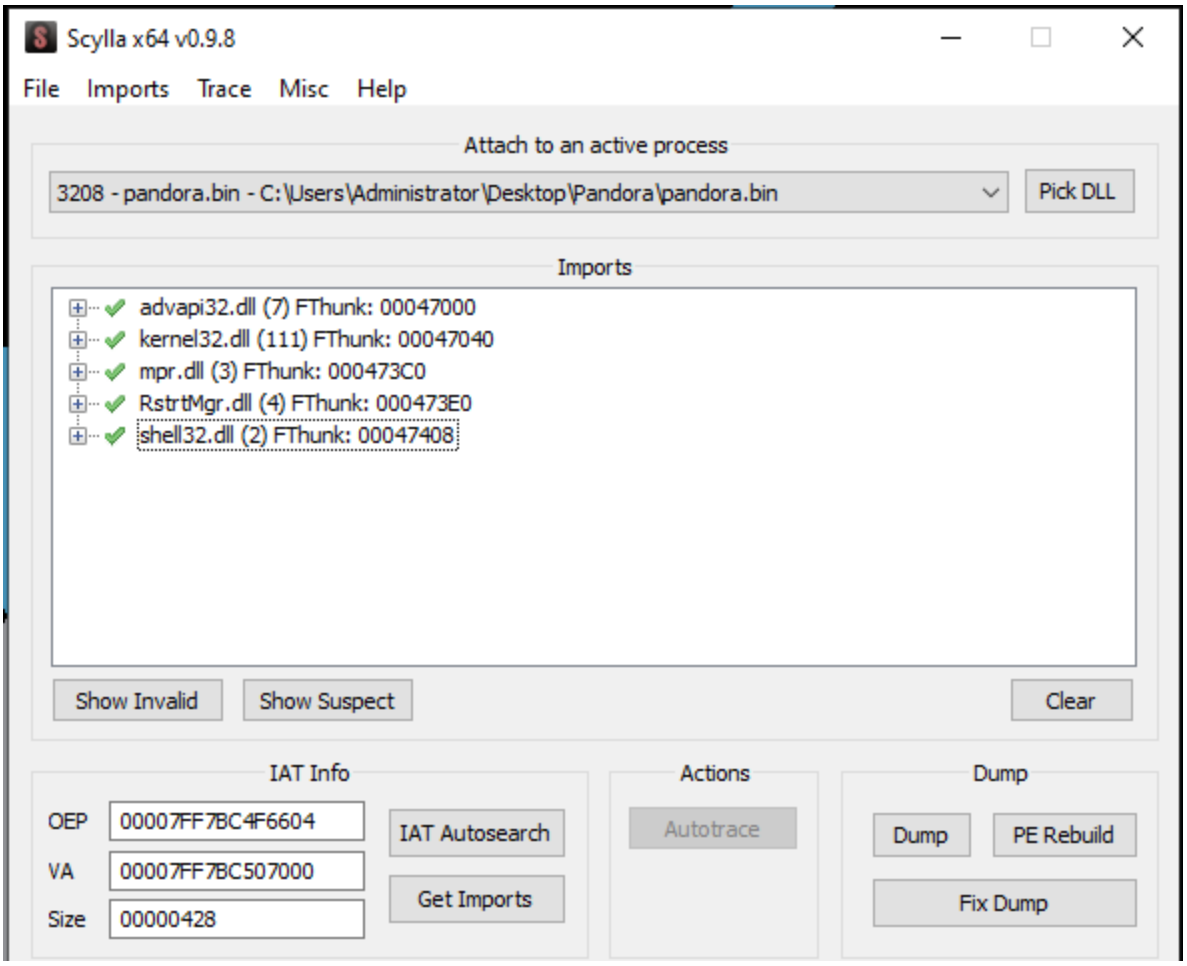
pandora.bin

```
Offset(h)  00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F  Decoded text
00000360   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000370   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000380   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000390   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000003A0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000003B0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000003C0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
000003D0   00 00 00 00 00 00 00 00 00 00 00 33 2E 30 30 00  ...........3.00.
000003E0   55 50 58 21 A1 D8 D0 D5 00 00 00 00 00 00 00 00  UPX!¡ØÐÕ........
000003F0   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 2D  ...............-
00000400   FF 9B FF FF 41 57 41 56 41 55 41 54 56 57 55 53  ÿ›ÿÿAWAVAUATVWUS
00000410   48 81 EC E8 00 C7 44 24 50 D4 93 D6 B5 48 8D 6F  H.ìè.ÇD$PÔ"ÖµH.o
```

Therefore, we can not use the `upx -d` command to auto unpack this sample:

```
C:\Users\Administrator\Desktop\Pandora>upx -d pandora.bin
                       Ultimate Packer for eXecutables
                          Copyright (C) 1996 - 2018
UPX 3.95w       Markus Oberhumer, Laszlo Molnar & John Reiser   Aug 26th 2018

        File size         Ratio      Format      Name
   --------------------   ------   -----------   -----------
upx: pandora.bin: CantUnpackException: file is possibly modified/hacked/protected; take care!

Unpacked 0 files.

C:\Users\Administrator\Desktop\Pandora>upx -d "pandora - fix_UPX_name.bin"
                       Ultimate Packer for eXecutables
                          Copyright (C) 1996 - 2018
UPX 3.95w       Markus Oberhumer, Laszlo Molnar & John Reiser   Aug 26th 2018

        File size         Ratio      Format      Name
   --------------------   ------   -----------   -----------
upx: pandora - fix_UPX_name.bin: CantUnpackException: header corrupted 4

Unpacked 0 files.
```

For manually unpacking, I used **x64dbg** to find OEP and **Scylla** to dump the file and fix the IAT:



Here is the unpacked file that can run normally: 1497ac198a13de8c4e6d1a1e73eaa50f

3. Pandora Code Obfuscation

Pandora developer makes it very difficult for static analysis, its code uses indirect calls through registers `rax, rdx, rbp`, etc. Important strings such as ***Mutex name, Dll Name, PUBLIC KEY info, Ransom note,*** are already encrypted and decrypted when the malicious code executes.

Related to indirect calls, it can be seen as follows:

> The calls to the decrypt string function will take the `rdx` and `rcx` registers as parameters. The `rdx` register will point to the memory area containing the encrypted string. The `rcx` register will point to the memory area containing the decoded string.

```
0014000673A 48 8B 05 6F 33 06 00          mov     rax, cs:qword_140069AB0
00140006741 48 C7 C7 BC CA F7 AA          mov     rdi, 0FFFFFFFFAAF7CABCh
00140006748 48 8B 80 E4 B2 0B 26          mov     rax, [rax+260BB2E4h]
0014000674F 48 01 F8                      add     rax, rdi
00140006752 BE E4 B2 0B 26                mov     esi, 260BB2E4h
00140006757 48 8B 0D 5A 33 06 00          mov     rcx, cs:qword_140069AB8
0014000675E 48 01 F1                      add     rcx, rsi
00140006761 BD FD B8 0B 26                mov     ebp, 260BB8FDh
00140006766 48 8B 15 53 33 06 00          mov     rdx, cs:qword_140069AC0
0014000676D 48 01 EA                      add     rdx, rbp
00140006770 FF D0                         call    rax
```

The calls to the API functions or Pandora's function should look like this:

```
00140006772 4C 8B 05 3F 33 06 00          mov     r8, cs:qword_140069AB8
00140006779 49 01 F0                      add     r8, rsi
0014000677C 48 8B 05 2D 33 06 00          mov     rax, cs:qword_140069AB0
00140006783 48 8B 80 EC B2 0B 26          mov     rax, [rax+260BB2ECh]
0014000678A 48 01 F8                      add     rax, rdi
0014000678D B9 01 00 1F 00                mov     ecx, 1F0001h
00140006792 31 D2                         xor     edx, edx
00140006794 FF D0                         call    rax
```

```
UPX0:0000000140006C85 48 8B 0D 4C 2E 06 00          mov     rcx, cs:qword_140069AD8
UPX0:0000000140006C8C 48 89 81 E4 B2 0B 26          mov     [rcx+260BB2E4h], rax
UPX0:0000000140006C93 48 8B 05 16 2E 06 00          mov     rax, cs:g_119FAE64Ch
UPX0:0000000140006C9A 48 8B 80 5C B3 0B 26          mov     rax, [rax+260BB35Ch]
UPX0:0000000140006CA1 48 01 F8                      add     rax, rdi
UPX0:0000000140006CA4 FF D0                         call    rax
```

Besides, Pandora also applies control flow obfuscation technique. For example, the pseudo-code of function that decrypt the string is as follows:

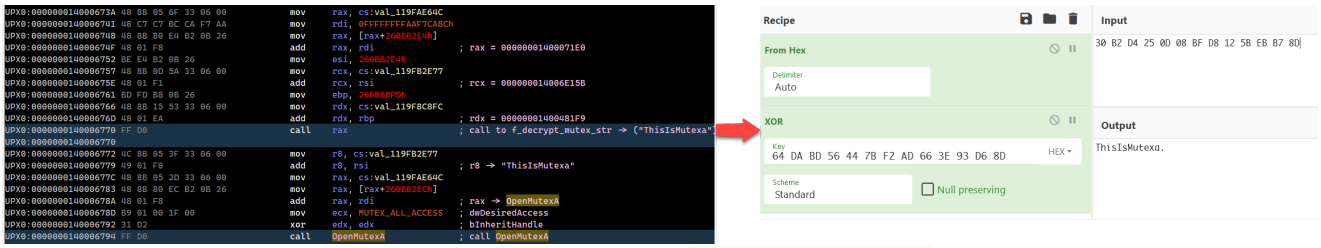
```
byte_flag = byte_14006E168;
control_var = 0x89A158FAi64;
while ( 1 )
{
  while ( control_var < 0x381B68E6 )
  {
    if ( control_var >= 0xA188260E )
    {
      byte_14006E168 = 1;
      control_var = 0x381B68E6i64;
    }
    else
    {
      control_var = 0x69EBE42Fi64;
      if ( byte_flag == 1 )
      {
        control_var = 0x381B68E6i64;
      }
      idx = 0;
    }
  }
  if ( control_var < 0x69EBE42F )
  {
    break;
  }
  decString[idx] = encString[idx + 0x10] ^ encString[idx & 0xF];
  ++idx;
  control_var = 0x69EBE42Fi64;
  if ( idx == 0xD )
  {
    control_var = 0xA188260Ei64;
  }
}
return control_var;
}
```

4. Analyze some of the main functions of Pandora

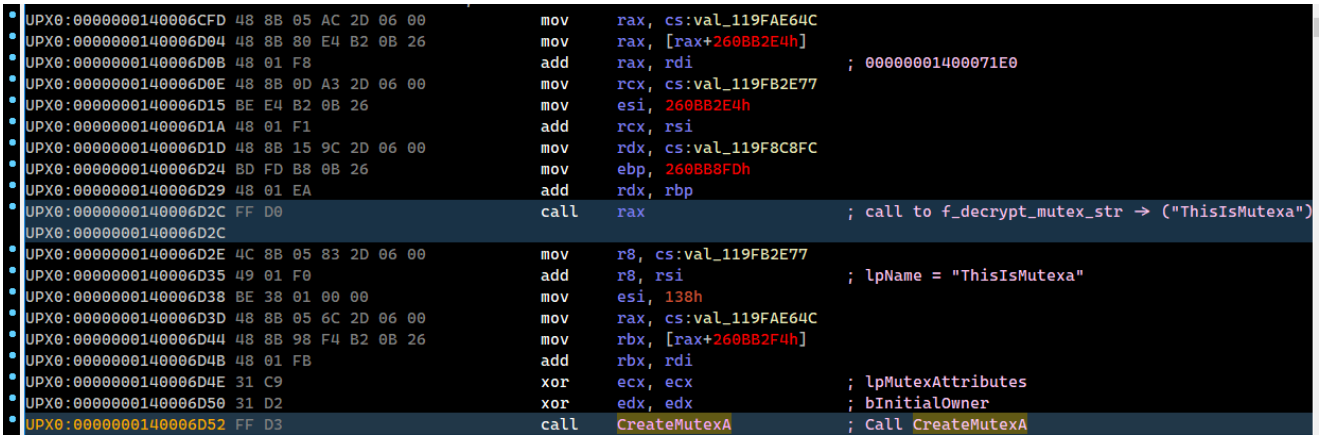
To be able to analyze, I use IDA in combination with **Bochs debugger**.

4.1. Create Mutex

First, Pandora decrypts the mutex name is “ `ThisIsMutexa` ”, then call the `OpenMutexA` function to check the existence of this mutex.

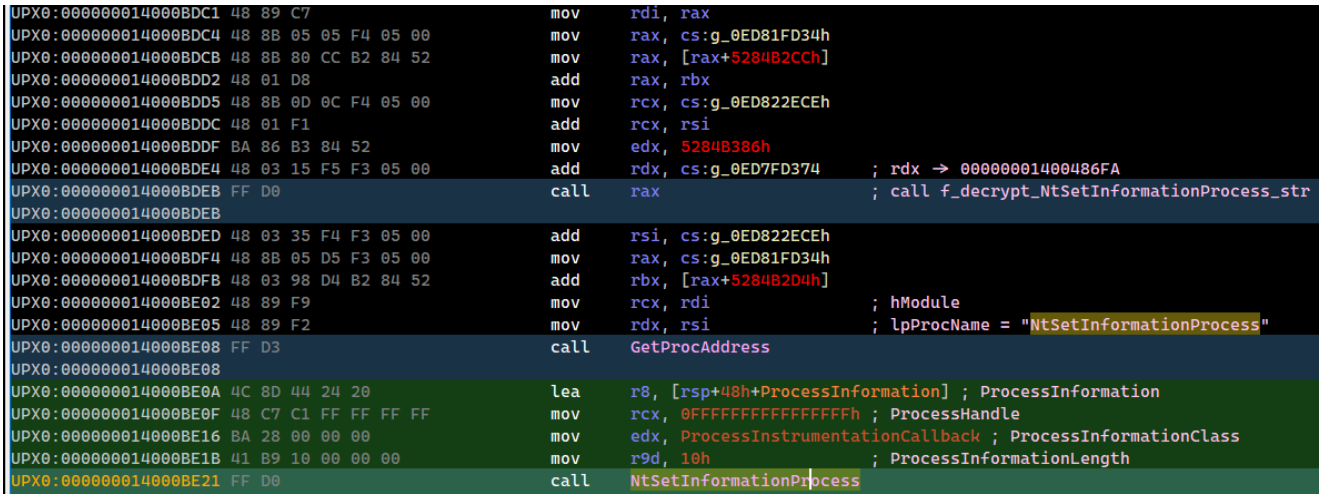


If the mutex has not been created, call the `CreateMutexA` function to create the mutex to ensure that only one instance of the malware is running in the system.



4.2. Call NtSetInformationProcess

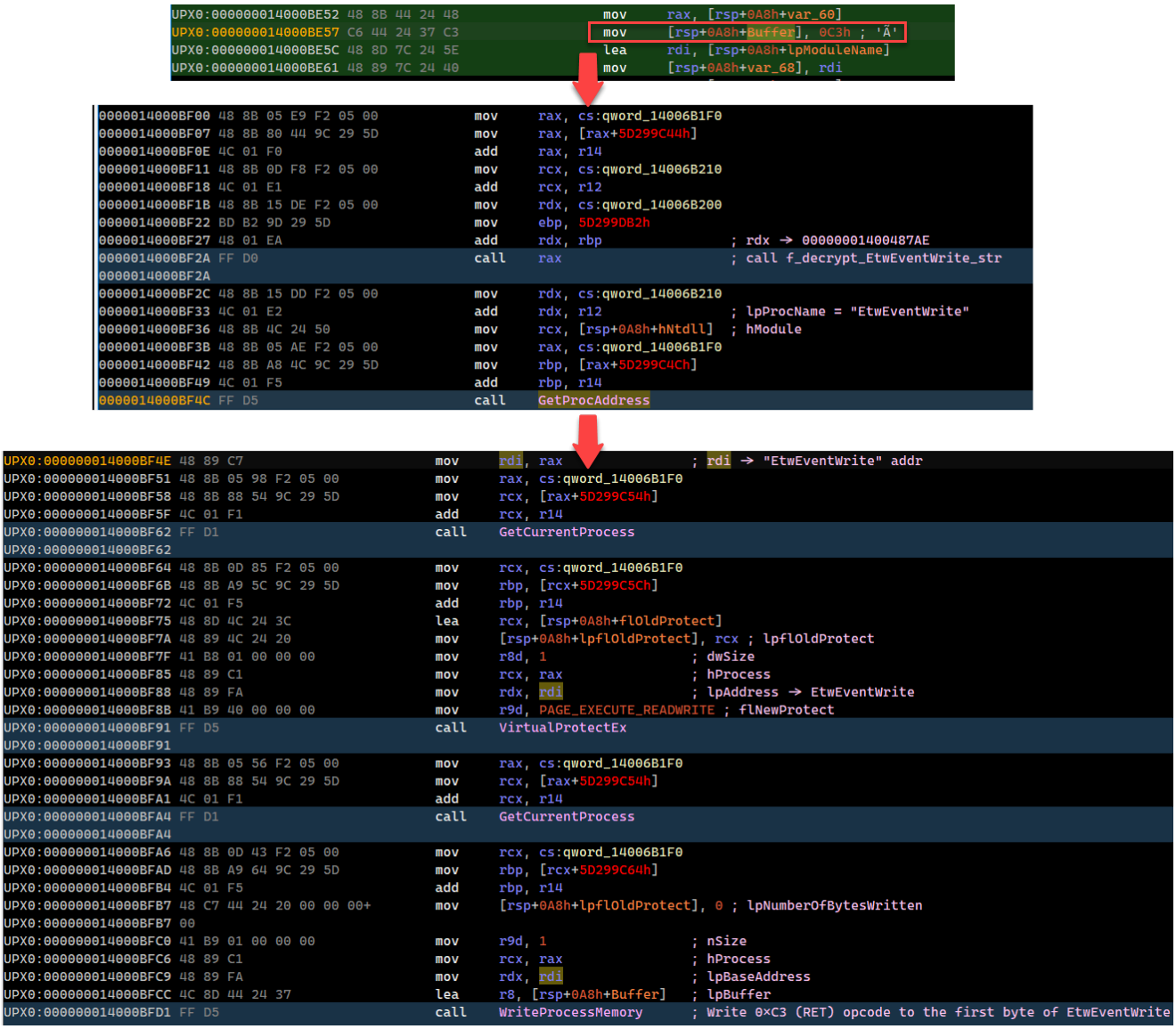
Pandora decrypts the string "`NtSetInformationProcess`", calls the `GetProcAddress` function to retrieve the address. Then call the function `NtSetInformationProcess` with the `ProcessInformationClass` parameter passed as "`ProcessInstrumentationCallback`":



I still do not know the purpose of using this function of Pandora.

4.3. Patching EtwEventWrite function

To disable ETW logging, Pandora decrypts the string "`EtwEventWrite`" and uses `GetProcAddress` to get the address of the function. Then use `WriteProcessMemory` to replace the first byte of the `EtwEventWrite` function with the opcode `0xC3` for the purpose to return immediately stopping the user-mode loggers.



4.4. Defeat AmsiScanBuffer function

Pandora decrypts the string “ `amsi.dll` ” and calls the `GetModuleHandleA` function to get the `amsi` handle.

```
UPX0:000000014000C14B 48 8B 05 CE F0 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C152 49 C7 C7 98 F7 B9 93          mov     r15, 0FFFFFFFF93B9F798h
UPX0:000000014000C159 48 8B 80 E8 A5 5E 4B          mov     rax, [rax+4B5EA5E8h]
UPX0:000000014000C160 4C 01 F8                      add     rax, r15
UPX0:000000014000C163 BA E8 A5 5E 4B                mov     edx, 4B5EA5E8h
UPX0:000000014000C168 48 8B 0D B9 F0 05 00          mov     rcx, cs:qword_14006B228
UPX0:000000014000C16F 48 01 D1                      add     rcx, rdx
UPX0:000000014000C172 BA A5 A7 5E 4B                mov     edx, 4B5EA7A5h
UPX0:000000014000C177 48 03 15 B2 F0 05 00          add     rdx, cs:qword_14006B230 ; rdx → 00000001400487ED
UPX0:000000014000C17E FF D0                         call    rax                     ; call f_decrypt_amsi_dll_str
UPX0:000000014000C17E
UPX0:000000014000C180 48 8B 05 A1 F0 05 00          mov     rax, cs:qword_14006B228
UPX0:000000014000C187 48 8B 4C 24 40                mov     rcx, [rsp+0A8h+var_68]
UPX0:000000014000C18C 8A 90 F0 A5 5E 4B             mov     dl, [rax+4B5EA5F0h]
UPX0:000000014000C192 88 51 08                      mov     [rcx+8], dl
UPX0:000000014000C195 48 8B 80 E8 A5 5E 4B          mov     rax, [rax+4B5EA5E8h]
UPX0:000000014000C19C 48 89 01                      mov     [rcx], rax
UPX0:000000014000C19F 48 8B 05 7A F0 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C1A6 48 8B 80 F0 A5 5E 4B          mov     rax, [rax+4B5EA5F0h]
UPX0:000000014000C1AD 4C 01 F8                      add     rax, r15
UPX0:000000014000C1B0 48 89 F1                      mov     rcx, rsi                ; lpModuleName = "amsi.dll"
UPX0:000000014000C1B3 FF D0                         call    GetModuleHandleA
```

Decrypts the string “ `AmsiScanBuffer` ” and get the address of the function. Then use `VirtualProtectEx` to change the protection at the `AmsiScanBuffer` .

```
UPX0:000000014000C28D 48 8B 05 8C EF 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C294 48 8B 80 F8 A5 5E 4B          mov     rax, [rax+4B5EA5F8h]
UPX0:000000014000C29B 4C 01 F8                      add     rax, r15
UPX0:000000014000C29E 48 8B 0D 9B EF 05 00          mov     rcx, cs:qword_14006B240
UPX0:000000014000C2A5 BE E8 A5 5E 4B                mov     esi, 4B5EA5E8h
UPX0:000000014000C2AA 48 01 F1                      add     rcx, rsi
UPX0:000000014000C2AD 48 8B 15 7C EF 05 00          mov     rdx, cs:qword_14006B230
UPX0:000000014000C2B4 4C 01 DA                      add     rdx, r11                ; rdx → 0000000140048820
UPX0:000000014000C2B7 FF D0                         call    rax                     ; call f_decrypt_AmsiScanBuffer_str
UPX0:000000014000C2B7
UPX0:000000014000C2B9 48 8B 15 80 EF 05 00          mov     rdx, cs:qword_14006B240
UPX0:000000014000C2C0 48 01 F2                      add     rdx, rsi                ; lpProcName = "AmsiScanBuffer"
UPX0:000000014000C2C3 48 8B 4C 24 50                mov     rcx, [rsp+0A8h+hamsi]   ; hModule
UPX0:000000014000C2C8 48 8B 05 51 EF 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C2CF 48 8B A8 00 A6 5E 4B          mov     rbp, [rax+4B5EA600h]
UPX0:000000014000C2D6 4C 01 FD                      add     rbp, r15
UPX0:000000014000C2D9 FF D5                         call    GetProcAddress
UPX0:000000014000C2D9
UPX0:000000014000C2DB 48 89 C7                      mov     rdi, rax                ; rdi → AmsiScanBuffer addr
UPX0:000000014000C2DE 48 8B 05 3B EF 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C2E5 48 8B 88 08 A6 5E 4B          mov     rcx, [rax+4B5EA608h]
UPX0:000000014000C2EC 4C 01 F9                      add     rcx, r15
UPX0:000000014000C2EF FF D1                         call    GetCurrentProcess
```

```
UPX0:000000014000C2F1 48 8B 0D 28 EF 05 00          mov     rcx, cs:qword_14006B220
UPX0:000000014000C2F8 48 8B A9 10 A6 5E 4B          mov     rbp, [rcx+4B5EA610h]
UPX0:000000014000C2FF 4C 01 FD                      add     rbp, r15
UPX0:000000014000C302 48 8D 4C 24 3C                lea     rcx, [rsp+0A8h+dwSize+5]
UPX0:000000014000C307 48 89 4C 24 20                mov     [rsp+0A8h+lpflOldProtect], rcx ; lpflOldProtect
UPX0:000000014000C30C 41 B8 01 00 00 00             mov     r8d, 1                  ; dwSize
UPX0:000000014000C312 48 89 C1                      mov     rcx, rax                ; hProcess
UPX0:000000014000C315 48 89 FA                      mov     rdx, rdi                ; lpAddress
UPX0:000000014000C318 41 B9 40 00 00 00             mov     r9d, PAGE_EXECUTE_READWRITE ; flNewProtect
UPX0:000000014000C31E FF D5                         call    VirtualProtectEx
UPX0:000000014000C31E
UPX0:000000014000C320 48 8B 05 F9 EE 05 00          mov     rax, cs:qword_14006B220
UPX0:000000014000C327 48 8B 88 08 A6 5E 4B          mov     rcx, [rax+4B5EA608h]
UPX0:000000014000C32E 4C 01 F9                      add     rcx, r15
UPX0:000000014000C331 FF D1                         call    GetCurrentProcess
UPX0:000000014000C331
UPX0:000000014000C333 48 8B 0D E6 EE 05 00          mov     rcx, cs:qword_14006B220
UPX0:000000014000C33A 48 8B A9 18 A6 5E 4B          mov     rbp, [rcx+4B5EA618h]
UPX0:000000014000C341 4C 01 FD                      add     rbp, r15
UPX0:000000014000C344 48 C7 44 24 20 00 00 00+      mov     [rsp+0A8h+lpflOldProtect], 0 ; lpflOldProtect
UPX0:000000014000C344 00
UPX0:000000014000C34D 41 B9 01 00 00 00             mov     r9d, PAGE_NOACCESS      ; flNewProtect
UPX0:000000014000C353 48 89 C1                      mov     rcx, rax                ; hProcess
UPX0:000000014000C356 48 89 FA                      mov     rdx, rdi                ; lpAddress
UPX0:000000014000C359 4C 8D 44 24 37                lea     r8, [rsp+0A8h+dwSize]   ; dwSize
UPX0:000000014000C35E FF D5                         call    VirtualProtectEx
```

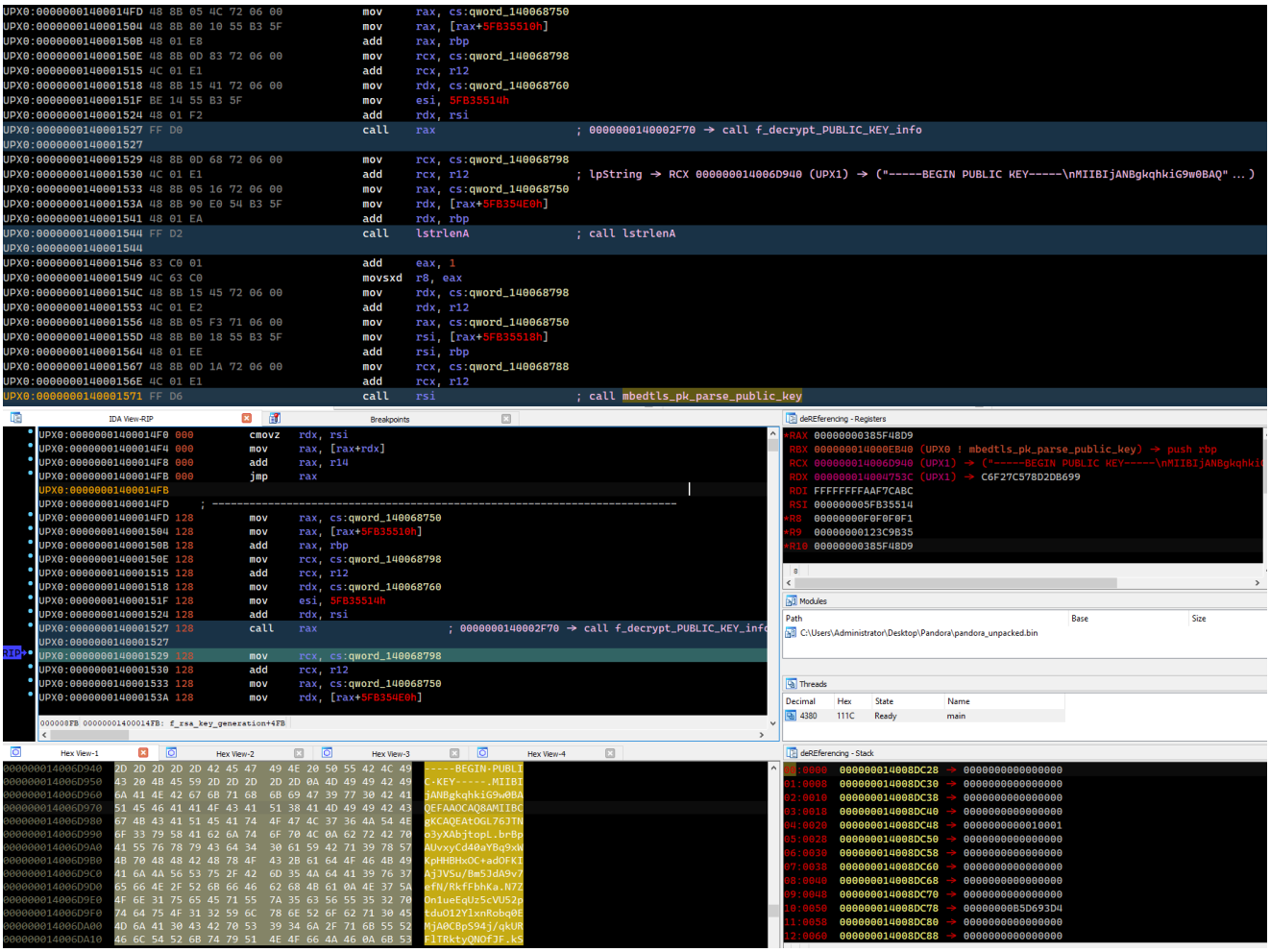
4.5. Generate RSA key

Pandora decrypts the string “ `fast_test` “, then uses the `CryptAcquireContext` , `CryptGenRandom` functions to generate a random bytes buffer:

```
UPX0:0000000140001028 48 8B 05 1C 77 06 00          mov     rax, cs:qword_140068750
UPX0:000000014000102F 48 C7 C5 B0 44 52 C5          mov     rbp, 0FFFFFFFFC55244B0h
UPX0:0000000140001036 48 8B 80 C8 54 B3 5F          mov     rax, [rax+5FB354C8h]
UPX0:000000014000103D 48 01 E8                      add     rax, rbp
UPX0:0000000140001040 41 BC C8 54 B3 5F             mov     r12d, 5FB354C8h
UPX0:0000000140001046 48 8B 0D 06 77 06 00          mov     rcx, cs:qword_140068758
UPX0:000000014000104D 4C 01 E1                      add     rcx, r12                ; decString
UPX0:0000000140001050 BA DB 54 B3 5F                mov     edx, 5FB354DBh
UPX0:0000000140001055 48 03 15 FF 76 06 00          add     rdx, cs:qword_140068760 ; encString
UPX0:000000014000105C FF D0                         call    f_decrypt_fast_test_str ; call 0000000140002E90 → "fast_test"
UPX0:000000014000105C
```

```
v4 = a4;
*a4 = 0i64;
if ( !CryptAcquireContextW(&phProv, 0i64, 0i64, PROV_RSA_FULL, CRYPT_VERIFYCONTEXT) )
{
  return 0xFFFFFFC4i64;
}
if ( !CryptGenRandom(phProv, dwLen, pbRandomBytesBuf) )
{
  CryptReleaseContext(phProv, 0);
  return 0xFFFFFFC4i64;
}
CryptReleaseContext(phProv, 0);
result = 0i64;
*v4 = dwLen;
return result;
```

Pandora calls the function to decrypt the RSA public key. Then call the `mbedtls_pk_parse_public_key` function to parse this public key:



The decrypted content of the Public key is as follows:

```
-----BEGIN PUBLIC KEY-----
MIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAtOGL76JTNo3yXAbjtopL
brBpAUvxyCd40aYBq9xWKpHHBHxOC+adOFKIAjJVSu/Bm5JdA9v7efN/RkfFbhKa
N7ZOn1ueEqUz5cVU52ptduO12YlxnRobq0EMjA0CBpS94j/qkURFlTRktyQNOfJF
kSPd497k2xqkq5fXqJYftwXky7nJeXyji+mIyhMFQFS9Uq2mI7plnRAVJIE1LASH
D1tAg9SNIA0SsyuazkWwHRefWo0z3YBBxP1r+7E/gQqMFVX8odLyq+yTIXFY0P9b
V7WnBRrBimY5KMcPRgKusLzXPTO0xA+RDxWbFkUcPmpnp498MYcfH9wBu83mHpWW
1wIDAQAB
-----END PUBLIC KEY---
```

Use the `RegCreateKeyExW` function to open the "`Software`" subkey in the `HKEY_CURRENT_USER` branch.

```
UPX0:0000000140001953 48 8D 7C 24 7C                lea     rdi, [rsp+128h+dwDisposition]
UPX0:0000000140001958 48 89 BC 24 90 00 00 00       mov     [rsp+128h+var_98], rdi
UPX0:0000000140001960 48 8B 84 24 90 00 00 00       mov     rax, [rsp+128h+var_98]
UPX0:0000000140001968 C7 44 24 7C 02 00 00 00       mov     [rsp+128h+dwDisposition], 2
UPX0:0000000140001970 48 8B 15 39 6E 06 00          mov     rdx, cs:qword_1400687B0
UPX0:0000000140001977 4C 01 E2                      add     rdx, r12                ; lpSubKey
UPX0:0000000140001977                                                               ; RDX 00000001400474C0 (UPX1 ! str.Software) → ("Software")
UPX0:000000014000197A 48 8B 05 CF 6D 06 00          mov     rax, cs:qword_140068750
UPX0:0000000140001981 48 8B B0 28 55 B3 5F          mov     rsi, [rax+5FB35528h]
UPX0:0000000140001988 48 01 EE                      add     rsi, rbp
UPX0:000000014000198B 48 89 7C 24 40                mov     [rsp+128h+lpdwDisposition], rdi ; lpdwDisposition
UPX0:0000000140001990 48 89 4C 24 38                mov     [rsp+128h+phkResult], rcx ; phkResult
UPX0:0000000140001995 48 C7 44 24 30 00 00 00+      mov     [rsp+128h+lpSecurityAttributes], 0 ; lpSecurityAttributes
UPX0:0000000140001995 00
UPX0:000000014000199E C7 44 24 28 3F 00 0F 00       mov     [rsp+128h+cbData], KEY_ALL_ACCESS ; samDesired
UPX0:00000001400019A6 C7 44 24 20 00 00 00 00       mov     dword ptr [rsp+128h+lpData], 0 ; dwOptions
UPX0:00000001400019AE 48 C7 C1 01 00 00 80          mov     rcx, HKEY_CURRENT_USER  ; hKey
UPX0:00000001400019B5 45 31 C0                      xor     r8d, r8d                ; Reserved
UPX0:00000001400019B8 45 31 C9                      xor     r9d, r9d                ; lpClass
UPX0:00000001400019BB FF D6                         call    RegCreateKeyExW         ; call RegCreateKeyExW
```

Then call the `RegQueryValueExW` function to check if the registry value "`Public`" exists in there:

```
UPX0:0000000140001C96 48 8B 4C 24 60                mov     rcx, [rsp+128h+hKey]    ; hKey
UPX0:0000000140001C9B 48 8B 15 16 6B 06 00          mov     rdx, cs:qword_1400687B8
UPX0:0000000140001CA2 4C 01 E2                      add     rdx, r12                ; lpValueName
UPX0:0000000140001CA2                                                               ; RDX 00000001400474D2 (UPX1 ! str.P) → ("Public")
UPX0:0000000140001CA5 48 8B 05 14 6B 06 00          mov     rax, cs:qword_1400687C0
UPX0:0000000140001CAC 4C 01 E0                      add     rax, r12
UPX0:0000000140001CAF 48 8B 35 9A 6A 06 00          mov     rsi, cs:qword_140068750
UPX0:0000000140001CB6 48 8B B6 30 55 B3 5F          mov     rsi, [rsi+5FB35530h]
UPX0:0000000140001CBD 48 01 EE                      add     rsi, rbp
UPX0:0000000140001CC0 48 89 7C 24 28                mov     qword ptr [rsp+128h+cbData], rdi ; lpcbData
UPX0:0000000140001CC5 48 89 44 24 20                mov     [rsp+128h+lpData], rax  ; lpData
UPX0:0000000140001CCA 45 31 C0                      xor     r8d, r8d                ; lpReserved
UPX0:0000000140001CCD 45 31 C9                      xor     r9d, r9d                ; lpType
UPX0:0000000140001CD0 FF D6                         call    RegQueryValueExW        ; call RegQueryValueExW
```

If it does not, the malware generates a public-private key pair for the victim.

```
UPX0:000000014000143F                           loc_14000143F:                      ; DATA XREF: UPX1:000000014006671C↓o
UPX0:000000014000143F 48 8B 0D 3A 73 06 00              mov     rcx, cs:qword_140068780
UPX0:0000000140001446 4C 01 E1                          add     rcx, r12
UPX0:0000000140001449 41 B8 00 08 00 00                 mov     r8d, 800h
UPX0:000000014000144F FF D6                             call    rsi                 ; call sub_1400134F0 → f_gen_my_pubic_key
UPX0:000000014000144F
UPX0:0000000140001451 48 8B 0D 70 73 06 00              mov     rcx, cs:qword_1400687C8
UPX0:0000000140001458 4C 01 E1                          add     rcx, r12            ; lpString
```

```
result = sub_1400127C0(a1, v6);
if ( result >= 0 )
{
  result = f_generate_RSA_key("-----BEGIN PUBLIC KEY-----\n", "-----END PUBLIC KEY-----\n", &v7[-result], result, a2, a3, &v8);
}
```

```
UPX0:00000001400013F7 48 8B 15 CA 73 06 00          mov     rdx, cs:qword_1400687C8
UPX0:00000001400013FE 4C 01 E2                      add     rdx, r12
UPX0:0000000140001401 48 8B 05 48 73 06 00          mov     rax, cs:qword_140068750
UPX0:0000000140001408 48 8B B0 40 55 B3 5F          mov     rsi, [rax+5FB35540h]
UPX0:000000014000140F 48 01 EE                      add     rsi, rbp
UPX0:0000000140001412 48 8B 0D 67 73 06 00          mov     rcx, cs:qword_140068780
UPX0:0000000140001419 4C 01 E1                      add     rcx, r12
UPX0:000000014000141C 41 B8 00 08 00 00             mov     r8d, 800h
UPX0:0000000140001422 FF D6                         call    rsi                     ; call sub_140013570 -> f_gen_my_private_key
```

```
rsa_ctx = *pprsa_ctx;
if ( !*pprsa_ctx )
{
  return 0xFFFFC680i64;
}
if ( rsa_ctx->ver == 1 )
{
  v9 = "-----BEGIN RSA PRIVATE KEY-----\n";
  v10 = "-----END RSA PRIVATE KEY-----\n";
  return f_generate_RSA_key(v9, v10, (&v12 - v7), v7, a2, a3, &v13);
}
if ( !rsa_ctx || rsa_ctx->ver != 2 )
{
  return 0xFFFFC680i64;
}
v9 = "-----BEGIN EC PRIVATE KEY-----\n";
v10 = "-----END EC PRIVATE KEY-----\n";
return f_generate_RSA_key(v9, v10, (&v12 - v7), v7, a2, a3, &v13);
}
```

4.6. Update shutdown priority

Pandora calls the `SetProcessShutdownParameters` function to sets a shutdown order:

```
UPX0:00000001400006DBE 48 8B 05 EB 2C 06 00         mov     rax, cs:val_119FAE64C
UPX0:00000001400006DC5 48 8B 98 1C B3 0B 26         mov     rbx, [rax+260BB31Ch]
UPX0:00000001400006DCC 48 01 FB                     add     rbx, rdi
UPX0:00000001400006DCF 31 C9                        xor     ecx, ecx                ; dwLevel = 0
UPX0:00000001400006DD1 31 D2                        xor     edx, edx                ; dwFlags = 0
UPX0:00000001400006DD3 FF D3                        call    SetProcessShutdownParameters ; call SetProcessShutdownParameters
UPX0:00000001400006DD3                                                              ; sets a shutdown order for a process relative to the other processes in the system.
```

4.7. Empty all Recycle Bins on all drives

For empty all recycle bins, Pandora calls the function `SHEmptyRecycleBinA`:

```
UPX0:00000001400006DD5 48 8B 05 D4 2C 06 00         mov     rax, cs:val_119FAE64C
UPX0:00000001400006DDC 48 8B 98 24 B3 0B 26         mov     rbx, [rax+260BB324h]
UPX0:00000001400006DE3 48 01 FB                     add     rbx, rdi
UPX0:00000001400006DE6 31 C9                        xor     ecx, ecx                ; hwnd
UPX0:00000001400006DE8 31 D2                        xor     edx, edx                ; pszRootPath
UPX0:00000001400006DEA 41 B8 07 00 00 00            mov     r8d, SHERB_NOCONFIRMATION or SHERB_NOPROGRESSUI or SHERB_NOSOUND ; dwFlags
UPX0:00000001400006DF0 FF D3                        call    SHEmptyRecycleBinA      ; call SHEmptyRecycleBinA
```

4.8. Deleting Shadow Copies

By calling `IsWow64Process`, Pandora checks if its process is running under a 64-bit system. If it is, then it calls `Wow64DisableWow64FsRedirection` to disable file system redirection for its process. Finally, it calls `ShellExecuteW` to launch a command for deleting all shadow copies:

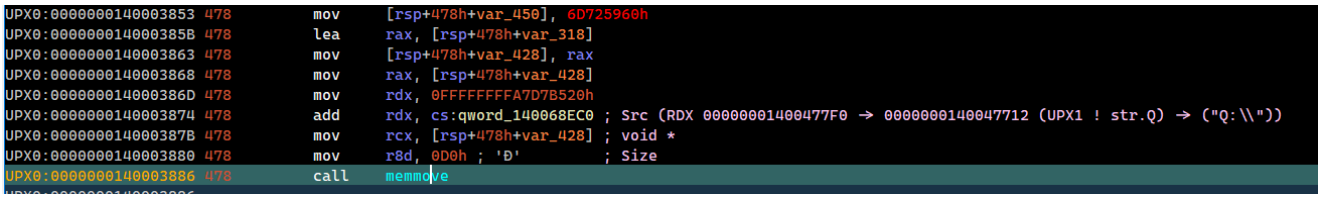
```
UPX0:00000001400045B8 48 8B 15 79 49 06 00          mov     rdx, cs:qword_140068F38
UPX0:00000001400045BF 4C 01 EA                      add     rdx, r13                ; rdx -> "open"
UPX0:00000001400045C2 4C 8B 05 77 49 06 00          mov     r8, cs:qword_140068F40
UPX0:00000001400045C9 4D 01 E8                      add     r8, r13                 ; r8 -> "cmd.exe"
UPX0:00000001400045CC 4C 8B 0D 75 49 06 00          mov     r9, cs:qword_140068F48
UPX0:00000001400045D3 4D 01 E9                      add     r9, r13                 ; r9 -> "/c vssadmin.exe delete shadows /all /quiet"
UPX0:00000001400045D6 48 8B 05 33 49 06 00          mov     rax, cs:qword_140068F10
UPX0:00000001400045DD 48 8B A8 10 8F 29 76          mov     rbp, [rax+76298F10h]
UPX0:00000001400045E4 4C 01 FD                      add     rbp, r15
UPX0:00000001400045E7 C7 44 24 28 00 00 00 00       mov     [rsp+0A8h+nShowCmd], 0  ; nShowCmd
UPX0:00000001400045EF 48 C7 44 24 20 00 00 00+      mov     [rsp+0A8h+lpDirectory], 0 ; lpDirectory
UPX0:00000001400045EF 00
UPX0:00000001400045F8 31 C9                         xor     ecx, ecx                ; hwnd
UPX0:00000001400045FA FF D5                         call    ShellExecuteW           ; call ShellExecuteW
```

The command is:

```
cmd.exe "/c vssadmin.exe delete shadows /all /quiet"
```

4.9. Manually mount drives

Pandora provides a built-in list of drive letters:



The complete list is as follows:

```
UPX1:0000000140047712     str_Q:
UPX1:0000000140047712             text "UTF-16LE", 'Q:\',0
UPX1:000000014004771A     str_W:
UPX1:000000014004771A             text "UTF-16LE", 'W:\',0
UPX1:0000000140047722     str_E:
UPX1:0000000140047722             text "UTF-16LE", 'E:\',0
UPX1:000000014004772A     str_R:
UPX1:000000014004772A             text "UTF-16LE", 'R:\',0
UPX1:0000000140047732     str_T:
UPX1:0000000140047732             text "UTF-16LE", 'T:\',0
UPX1:000000014004773A     str_Y:
UPX1:000000014004773A             text "UTF-16LE", 'Y:\',0
UPX1:0000000140047742     str_U:
UPX1:0000000140047742             text "UTF-16LE", 'U:\',0
UPX1:000000014004774A     str_I:
UPX1:000000014004774A             text "UTF-16LE", 'I:\',0
UPX1:0000000140047752     str_O_0:
UPX1:0000000140047752             text "UTF-16LE", 'O:\',0
UPX1:000000014004775A     str_P_0:
UPX1:000000014004775A             text "UTF-16LE", 'P:\',0
UPX1:0000000140047762     str_A:
UPX1:0000000140047762             text "UTF-16LE", 'A:\',0
UPX1:000000014004776A     str_S:
UPX1:000000014004776A             text "UTF-16LE", 'S:\',0
UPX1:0000000140047772     str_D:
UPX1:0000000140047772             text "UTF-16LE", 'D:\',0
UPX1:000000014004777A     str_F:
UPX1:000000014004777A             text "UTF-16LE", 'F:\',0
UPX1:0000000140047782     str_G:
UPX1:0000000140047782             text "UTF-16LE", 'G:\',0
UPX1:000000014004778A     str_H:
UPX1:000000014004778A             text "UTF-16LE", 'H:\',0
UPX1:0000000140047792     str_J:
UPX1:0000000140047792             text "UTF-16LE", 'J:\',0
UPX1:000000014004779A     str_K:
UPX1:000000014004779A             text "UTF-16LE", 'K:\',0
UPX1:00000001400477A2     str_L_0:
UPX1:00000001400477A2             text "UTF-16LE", 'L:\',0
UPX1:00000001400477AA     str_Z:
UPX1:00000001400477AA             text "UTF-16LE", 'Z:\',0
UPX1:00000001400477B2     str_X:
UPX1:00000001400477B2             text "UTF-16LE", 'X:\',0
UPX1:00000001400477BA     str_C_0:
UPX1:00000001400477BA             text "UTF-16LE", 'C:\',0
UPX1:00000001400477C2     str_V:
UPX1:00000001400477C2             text "UTF-16LE", 'V:\',0
UPX1:00000001400477CA     str_B:
UPX1:00000001400477CA             text "UTF-16LE", 'B:\',0
UPX1:00000001400477D2     str_N:
UPX1:00000001400477D2             text "UTF-16LE", 'N:\',0
UPX1:00000001400477DA     str_M_0:
UPX1:00000001400477DA             text "UTF-16LE", 'M:\',0
```

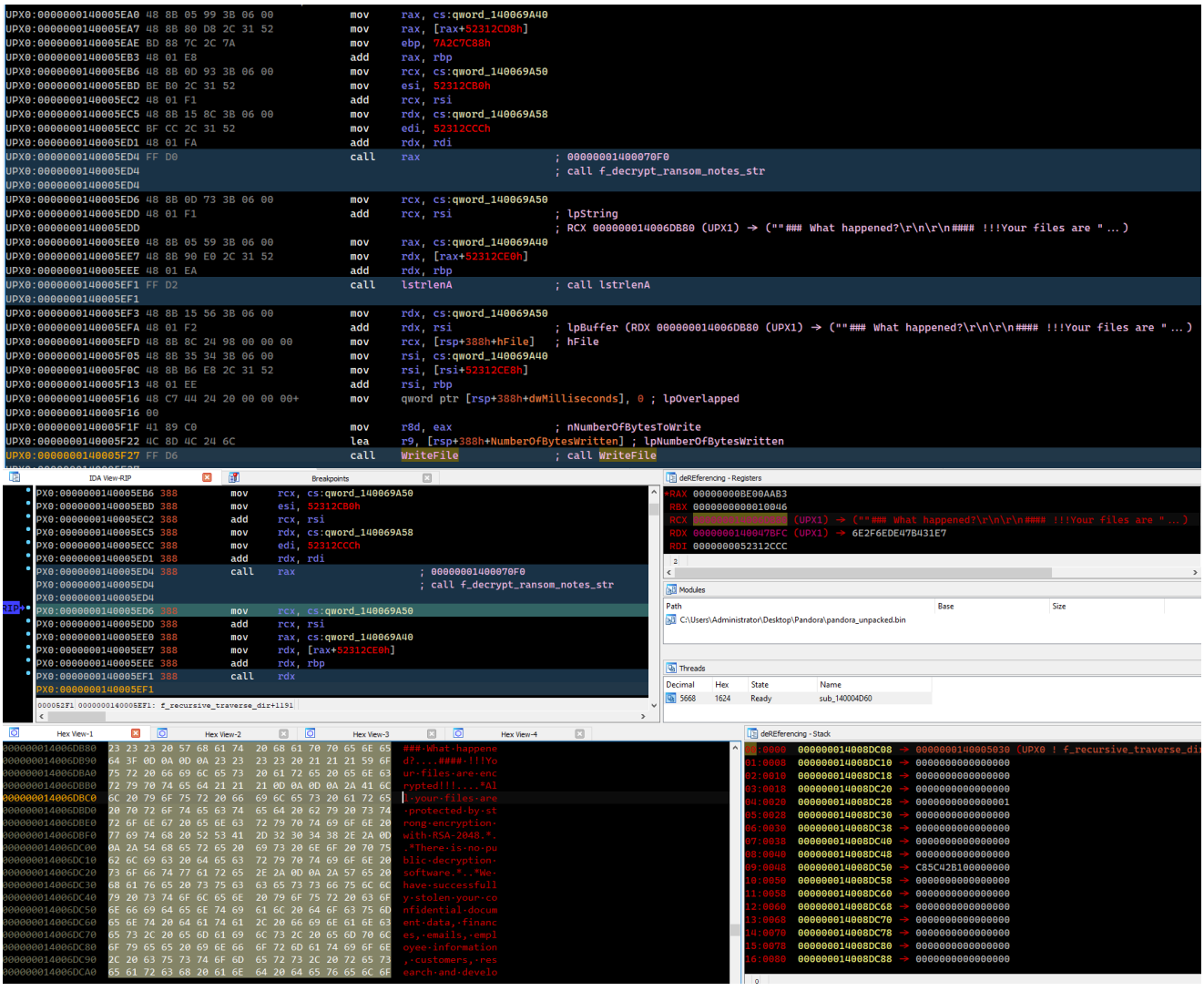
Then it uses the function `GetDriveTypeW` to find drives with type `DRIVE_NO_ROOT_DIR`.

```
UPX0:0000000140003D63 48 63 44 24 30                movsxd  rax, [rsp+478h+var_448]
UPX0:0000000140003D68 48 8D 04 C4                   lea     rax, [rsp+rax*8+478h+var_478]
UPX0:0000000140003D6C 48 05 60 01 00 00             add     rax, 160h
UPX0:0000000140003D72 48 89 44 24 78                mov     [rsp+478h+var_400], rax
UPX0:0000000140003D77 48 8B 44 24 78                mov     rax, [rsp+478h+var_400]
UPX0:0000000140003D7C 48 8B 08                      mov     rcx, [rax]              ; lpRootPathName
UPX0:0000000140003D7F 48 8B 05 4A 51 06 00          mov     rax, cs:qword_140068ED0
UPX0:0000000140003D86 48 8B 90 28 B5 D7 A7          mov     rdx, [rax-58284AD8h]
UPX0:0000000140003D8D 48 01 FA                      add     rdx, rdi
UPX0:0000000140003D90 FF D2                         call    GetDriveTypeW           ; call GetDriveTypeW
UPX0:0000000140003D90
UPX0:0000000140003D92 8B 4C 24 28                   mov     ecx, [rsp+478h+var_450]
UPX0:0000000140003D96 BA 67 0D A6 3C                mov     edx, 3CA60D67h
UPX0:0000000140003D9B 01 D1                         add     ecx, edx
UPX0:0000000140003D9D 8B 54 24 28                   mov     edx, [rsp+478h+var_450]
UPX0:0000000140003DA1 BE 5D 49 4C C1                mov     esi, 0C14C495Dh
UPX0:0000000140003DA6 01 F2                         add     edx, esi
UPX0:0000000140003DA8 83 F8 01                      cmp     eax, DRIVE_NO_ROOT_DIR
UPX0:0000000140003DAB 74 02                         jz      short loc_140003DAF
```

Next Pandora calls the `FindFirstVolumeW`, `GetVolumePathNamesForVolumeNameW`, `SetVolumeMountPointW`, `FindNextVolumeW` functions to mount the drives.

4.10. Drop ransom note

Pandora decrypts the ransom note, then writes it to a file named R`estore_My_Files.txt`:



The full content of Ransom note is as follows:

```
### What happened?
#### !!!Your files are encrypted!!!
*All your files are protected by strong encryption with RSA-2048.*
*There is no public decryption software.*
*We have successfully stolen your confidential document data, finances, emails,
employee information, customers, research and development products...*
#### What is the price?
*The price depends on how fast you can write to us.*
*After payment, we will send you the decryption tool which will decrypt all your
files.*
#### What should I do?

*There is only one way to get your files back -->>Contact us, pay and get decryption
software.*
*If you decline payment, we will share your data files with the world.*
*You can browse your data breach here:
http://vbfqeh5nugm6r2u2qvghsdxm3fotf5wbxb5ltv6vw77vus5frdpuaiid.onion*
(you should download and install TOR browser first hxxps://torproject.org)
#### !!!Decryption Guaranteed!!!
*Free decryption As a guarantee, you can send us up to 3 free decrypted files before
payment.*
#### !!!Contact us!!!
email:
contact@pandoraxyz.xyz
#### !!!Warning!!!
*Do not attempt to decrypt your data using third-party software, this may result in
permanent data loss.*
*Decrypting your files with the help of a third party may result in a price increase
(they charge us a fee), or you may fall victim to a scam.*
*Don't try to delete programs or run antivirus tools. It won't work.*
*Attempting to self-decrypt the file will result in the loss of your data.*
```

4.11. List of file extension and directories to avoid

Before performing encryption, Pandora will check if the filename is not in the list of files and directories to avoid.

```
UPX0:0000000140004C7A                         ; ---------------------------------------------------------------------------
UPX0:0000000140004C7A 44 89 74 24 2C                  mov     [rsp+88h+var_5C], r14d
UPX0:0000000140004C7F 48 63 4C 24 2C                  movsxd  rcx, [rsp+88h+var_5C]
UPX0:0000000140004C84 48 8B 54 24 40                  mov     rdx, [rsp+88h+var_48]
UPX0:0000000140004C89 48 8B 8C CA 60 4A CB 50         mov     rcx, [rdx+rcx*8+50CB4A60h]
UPX0:0000000140004C91 48 89 4C 24 30                  mov     [rsp+88h+lpAvoidList], rcx
UPX0:0000000140004C96 48 8B 4C 24 30                  mov     rcx, [rsp+88h+lpAvoidList] ; RCX → 000000014004828C (UPX1 ! str.hta) → (".hta")
UPX0:0000000140004C9B 8B 54 24 28                     mov     edx, [rsp+88h+var_60]
UPX0:0000000140004C9F BD EC 2A 80 FC                  mov     ebp, 0FC802AECh
UPX0:0000000140004CA4 01 EA                           add     edx, ebp
```

Here is the complete avoid list:

```
UPX1:000000014004828C 2E 00 68 00 74 00 61 00+        text "UTF-16LE", '.hta',0
UPX1:0000000140048296                           str_exe:
UPX1:0000000140048296 2E 00 65 00 78 00 65 00+        text "UTF-16LE", '.exe',0
UPX1:00000001400482A0                           str_dll:
UPX1:00000001400482A0 2E 00 64 00 6C 00 6C 00+        text "UTF-16LE", '.dll',0
UPX1:00000001400482AA                           str_cpl:
UPX1:00000001400482AA 2E 00 63 00 70 00 6C 00+        text "UTF-16LE", '.cpl',0
UPX1:00000001400482B4                           str_ini:
UPX1:00000001400482B4 2E 00 69 00 6E 00 69 00+        text "UTF-16LE", '.ini',0
UPX1:00000001400482BE                           str_cab:
UPX1:00000001400482BE 2E 00 63 00 61 00 62 00+        text "UTF-16LE", '.cab',0
UPX1:00000001400482C8                           str_cur:
UPX1:00000001400482C8 2E 00 63 00 75 00 72 00+        text "UTF-16LE", '.cur',0
UPX1:00000001400482D2                           str_drv:
UPX1:00000001400482D2 2E 00 64 00 72 00 76 00+        text "UTF-16LE", '.drv',0
UPX1:00000001400482DC                           str_hlp:
UPX1:00000001400482DC 2E 00 68 00 6C 00 70 00+        text "UTF-16LE", '.hlp',0
UPX1:00000001400482E6                           str_icl:
UPX1:00000001400482E6 2E 00 69 00 63 00 6C 00+        text "UTF-16LE", '.icl',0
UPX1:00000001400482F0                           str_icns:
UPX1:00000001400482F0 2E 00 69 00 63 00 6E 00+        text "UTF-16LE", '.icns',0
UPX1:00000001400482FC                           str_ico:
UPX1:00000001400482FC 2E 00 69 00 63 00 6F 00+        text "UTF-16LE", '.ico',0
UPX1:0000000140048306                           str_idx:
UPX1:0000000140048306 2E 00 69 00 64 00 78 00+        text "UTF-16LE", '.idx',0
UPX1:0000000140048310                           str_sys:
UPX1:0000000140048310 2E 00 73 00 79 00 73 00+        text "UTF-16LE", '.sys',0
UPX1:000000014004831A                           str_spl:
UPX1:000000014004831A 2E 00 73 00 70 00 6C 00+        text "UTF-16LE", '.spl',0
UPX1:0000000140048324                           str_ocx:
UPX1:0000000140048324 2E 00 6F 00 63 00 78 00+        text "UTF-16LE", '.ocx',0

UPX1:0000000140048334                           str_AppData:
UPX1:0000000140048334 41 00 70 00 70 00 44 00+        text "UTF-16LE", 'AppData',0
UPX1:0000000140048344                           str_Boot:
UPX1:0000000140048344 42 00 6F 00 6F 00 74 00+        text "UTF-16LE", 'Boot',0
UPX1:000000014004834E                           str_Windows:
UPX1:000000014004834E 57 00 69 00 6E 00 64 00+        text "UTF-16LE", 'Windows',0
UPX1:000000014004835E                           str_Windowsold:
UPX1:000000014004835E 57 00 69 00 6E 00 64 00+        text "UTF-16LE",
'Windows.old',0
UPX1:0000000140048376                           str_TorBrowser:
UPX1:0000000140048376 54 00 6F 00 72 00 20 00+        text "UTF-16LE", 'Tor
Browser',0
UPX1:000000014004838E                           str_InternetExplorer:
UPX1:000000014004838E 49 00 6E 00 74 00 65 00+        text "UTF-16LE", 'Internet
Explorer',0
UPX1:00000001400483B2                           str_Google:
UPX1:00000001400483B2 47 00 6F 00 6F 00 67 00+        text "UTF-16LE", 'Google',0
UPX1:00000001400483C0                           str_Opera:
UPX1:00000001400483C0 4F 00 70 00 65 00 72 00+        text "UTF-16LE", 'Opera',0
UPX1:00000001400483CC                           str_OperaSoftware:
UPX1:00000001400483CC 4F 00 70 00 65 00 72 00+        text "UTF-16LE", 'Opera
Software',0
UPX1:00000001400483EA                           str_Mozilla:
```

```
UPX1:00000001400483EA 4D 00 6F 00 7A 00 69 00+        text "UTF-16LE", 'Mozilla',0
UPX1:00000001400483FA                             str_MozillaFirefox:
UPX1:00000001400483FA 4D 00 6F 00 7A 00 69 00+        text "UTF-16LE", 'Mozilla
Firefox',0
UPX1:000000014004841A                             str_RecycleBin:
UPX1:000000014004841A 24 00 52 00 65 00 63 00+        text "UTF-16LE",
'$Recycle.Bin',0
UPX1:0000000140048434                             str_ProgramData:
UPX1:0000000140048434 50 00 72 00 6F 00 67 00+        text "UTF-16LE",
'ProgramData',0
UPX1:000000014004844C                             str_AllUsers:
UPX1:000000014004844C 41 00 6C 00 6C 00 20 00+        text "UTF-16LE", 'All Users',0
UPX1:0000000140048460                             str_autoruninf:
UPX1:0000000140048460 61 00 75 00 74 00 6F 00+        text "UTF-16LE",
'autorun.inf',0
UPX1:0000000140048478                             str_bootini:
UPX1:0000000140048478 62 00 6F 00 6F 00 74 00+        text "UTF-16LE", 'boot.ini',0
UPX1:000000014004848A                             str_bootfontbin:
UPX1:000000014004848A 62 00 6F 00 6F 00 74 00+        text "UTF-16LE",
'bootfont.bin',0
UPX1:00000001400484A4                             str_bootsectbak:
UPX1:00000001400484A4 62 00 6F 00 6F 00 74 00+        text "UTF-16LE",
'bootsect.bak',0
UPX1:00000001400484BE                             str_bootmgr:
UPX1:00000001400484BE 62 00 6F 00 6F 00 74 00+        text "UTF-16LE", 'bootmgr',0
UPX1:00000001400484CE                             str_bootmgrefi:
UPX1:00000001400484CE 62 00 6F 00 6F 00 74 00+        text "UTF-16LE",
'bootmgr.efi',0
UPX1:00000001400484E6                             str_bootmgfwefi:
UPX1:00000001400484E6 62 00 6F 00 6F 00 74 00+        text "UTF-16LE",
'bootmgfw.efi',0
UPX1:0000000140048500                             str_desktopini:
UPX1:0000000140048500 64 00 65 00 73 00 6B 00+        text "UTF-16LE",
'desktop.ini',0
UPX1:0000000140048518                             str_iconcachedb:
UPX1:0000000140048518 69 00 63 00 6F 00 6E 00+        text "UTF-16LE",
'iconcache.db',0
UPX1:0000000140048532                             str_ntldr:
UPX1:0000000140048532 6E 00 74 00 6C 00 64 00+        text "UTF-16LE", 'ntldr',0
UPX1:000000014004853E                             str_ntuserdat:
UPX1:000000014004853E 6E 00 74 00 75 00 73 00+        text "UTF-16LE", 'ntuser.dat',0
UPX1:0000000140048554                             str_ntuserdatlog:
UPX1:0000000140048554 6E 00 74 00 75 00 73 00+        text "UTF-16LE",
'ntuser.dat.log',0
UPX1:0000000140048572                             str_ntuserini:
UPX1:0000000140048572 6E 00 74 00 75 00 73 00+        text "UTF-16LE", 'ntuser.ini',0
UPX1:0000000140048588                             str_thumbsdb:
UPX1:0000000140048588 74 00 68 00 75 00 6D 00+        text "UTF-16LE", 'thumbs.db',0
UPX1:000000014004859C                             str_ProgramFiles:
UPX1:000000014004859C 50 00 72 00 6F 00 67 00+        text "UTF-16LE", 'Program
Files',0
UPX1:00000001400485B8                             str_ProgramFilesx86:
UPX1:00000001400485B8 50 00 72 00 6F 00 67 00+        text "UTF-16LE", 'Program Files
(x86)',0
UPX1:00000001400485E0                             str_recycle:
```

```
UPX1:00000001400485E0 23 00 72 00 65 00 63 00+        text "UTF-16LE", '#recycle',0
UPX1:00000001400485F2 2E 00 2E 00 00 00               text "UTF-16LE", '..',0
UPX1:00000001400485F8 2E 00 00 00                     text "UTF-16LE", '.',0
```

Source: vx-underground (@vxunderground)

End.

m4n0w4r