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

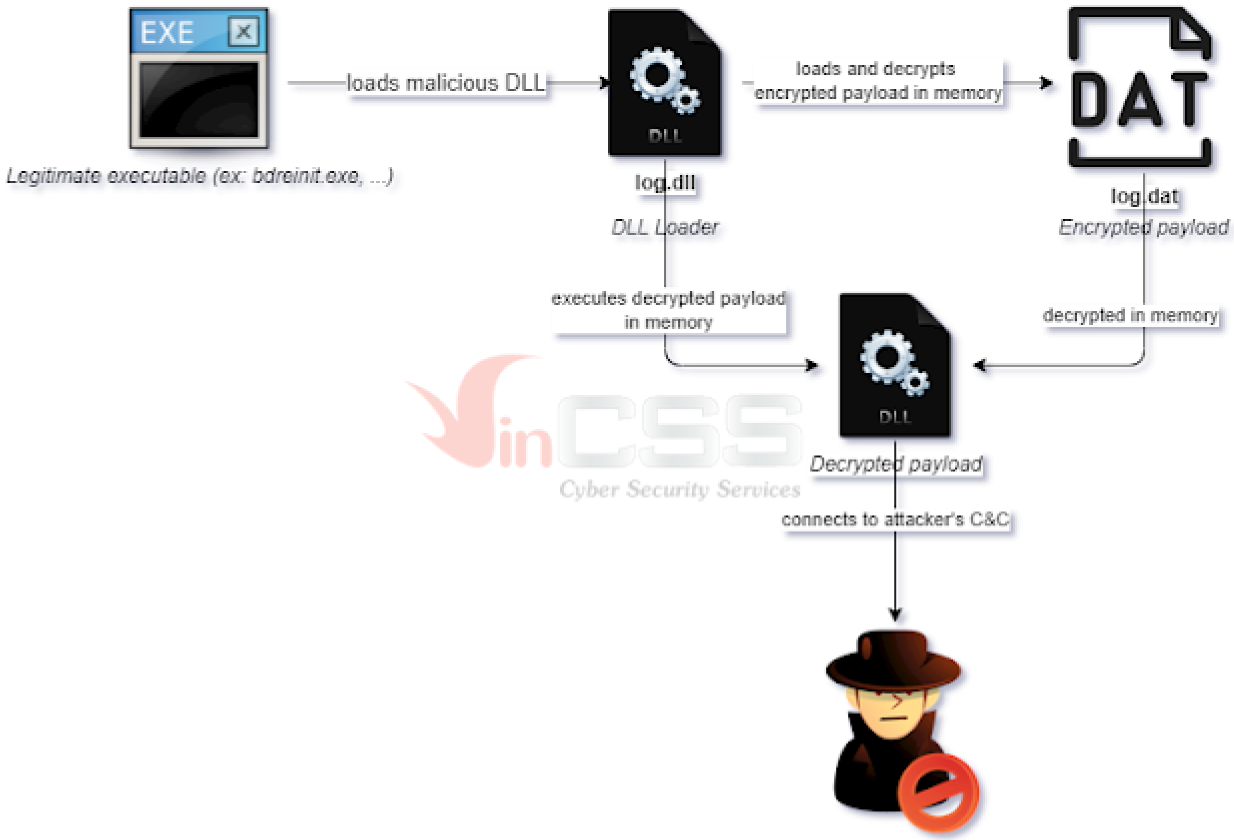
1. Executive Summary

At VinCSS, through continuous cyber security monitoring, hunting malware samples and evaluate them to determine the potential risks, especially malware samples targeting Vietnam. Recently, during hunting on VirusTotal's platform, performing scan for specific byte patterns related to the **Mustang Panda (PlugX)**, we discovered a series of malware samples that we suspect have a relationship with this group were uploaded from Vietnam.

All of these samples share the same name as "**log.dll**" and have a rather low detection rate.

Based on the above information, we believe that there is a possibility that malware has been installed in a few orgs in Vietnam, so we decided to analyze these samples. During the analysis, based on the detected indicators, we continue to hunt for the missing data to add a more complete picture for the analysis.

A general overview of the execution flow looks like this:



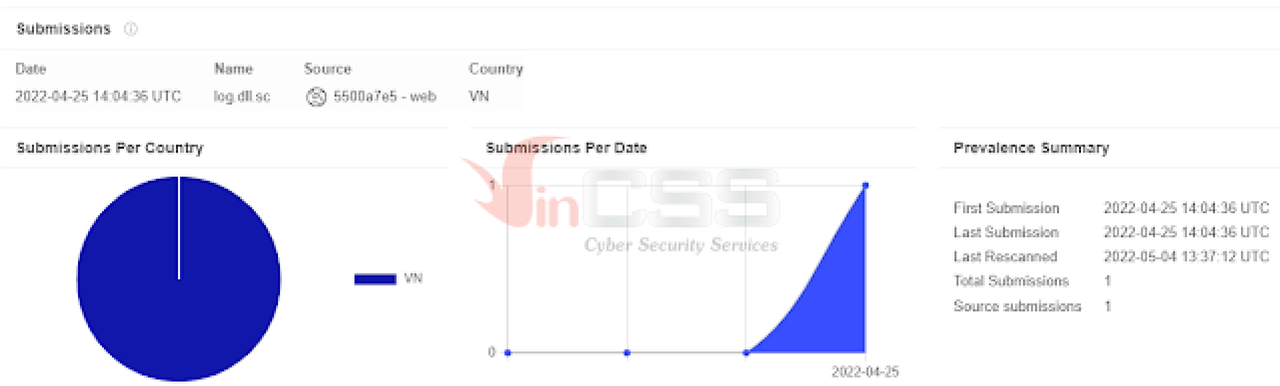
Our blog includes:

- Technical analysis of the **log.dll** file.
- Technical analysis of shellcode decrypted from **log.dat**.
- Analyze **PlugX Dll** as well as decrypt PlugX configuration information.

2. Analyze the log.dll

In the list of hunted samples above, we choose the one with hash:
3171285c4a846368937968bf53bc48ae5c980fe32b0de10cf0226b9122576f4e

This sample was submitted to VirusTotal from **Vietnam** on **2022-04-25 14:04:36 UTC**



The information from the Rich Header suggests that it is likely compiled with **Visual Studio 2012/2013**:

product-id (8)	build-id (4)
Implib1100	Visual Studio 2012 - 11.0
Import	Visual Studio
Utc1800_CPP	Visual Studio 2013 - 12.0
Masm1200	Visual Studio 2013 - 12.0
Utc1800_C	Visual Studio 2013 - 12.0
Import (old)	Visual Studio
Export1200	Visual Studio 2013 - 12.0 RTM
Linker1200	Visual Studio 2013 - 12.0 RTM

By checking the sections information, we can see that it is packed or the code is obfuscated:

Nr	Virtual offset	Virtual size	RAW Data offset	RAW size	Flags	Name	First bytes (hex)	First Ascii 20h bytes	sect. Stats
01 ep	00001000	000577C6	00000400	00057800	60000020	.text	55 53 57 56 83 ...	USWV 0 □□1 D...	Strong Packed - 2.2743 % ZERO
02 im	00059000	000046F4	00057C00	00004800	40000040	.rdata	20 02 05 00 34 ...	□ 4 □ F □ T □ ...	Very not packed - 43.6306 % ZERO
03	0005E000	00002FA0	0005C400	00001200	C0000040	.data	4E E6 40 BB B1 ...	N @ □ D ...	Very not packed - 64.3012 % ZERO
04	00061000	00000ED4	0005D600	00001000	42000040	.reloc	00 10 00 00 0C ...	□ ♠ □0□0 ...	Not packed - 16.6992 % ZERO

Sample has the original name **ljAt.dll**, and it exports two functions **LogFree** and **LogInit**:

5d7db86620f99cdb2002d8f78847761a2_log_dll.bin

Offset	Name	Value	Meaning
5BC90	Characteristics	0	
5BC94	TimeDateStamp	622DA6ED	Sunday, 13.03.2022 08:10:21 UTC
5BC98	MajorVersion	0	
5BC9A	MinorVersion	0	
5BC9C	Name	5D0CC	ljAt.dll
5BCA0	Base	1	
5BCA4	NumberOfFunctions	2	
5BCA8	NumberOfNames	2	
5BCAC	AddressOfFunctions	5D0B8	
5BCB0	AddressOfNames	5D0C0	
5BCB4	AddressOfNameOrdinals	5D0C8	

Exported Functions [2 entries]

Offset	Ordinal	Function RVA	Name RVA	Name	Forwarder
5BCB8	1	1000	5D0D5	LogFree	
5BCBC	2	4E5E0	5D0DD	LogInit	

Load sample into IDA, analyze the code of the two functions above:

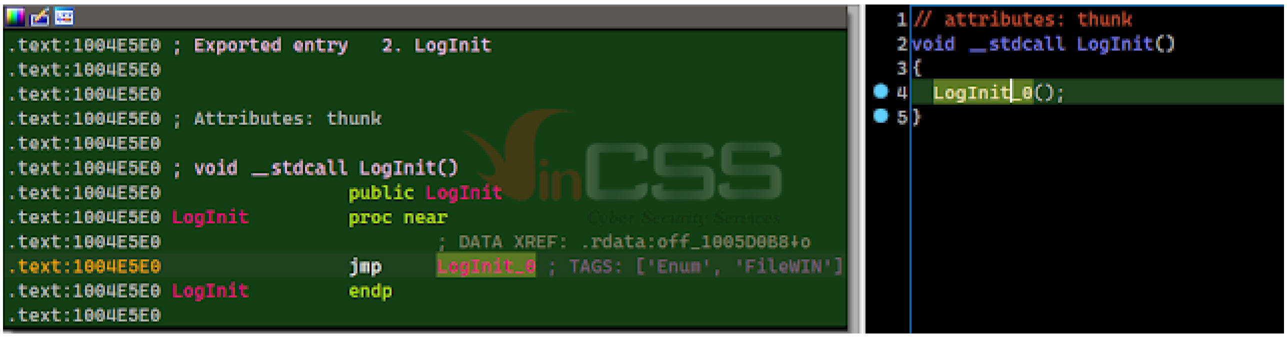
- **LogFree** function:

Looking at this function, it can be seen that its code has been completely obfuscated by Obfuscator-LLVM, using the Control Flow Flattening technique:

After further analysis, I found that this function has no special task.

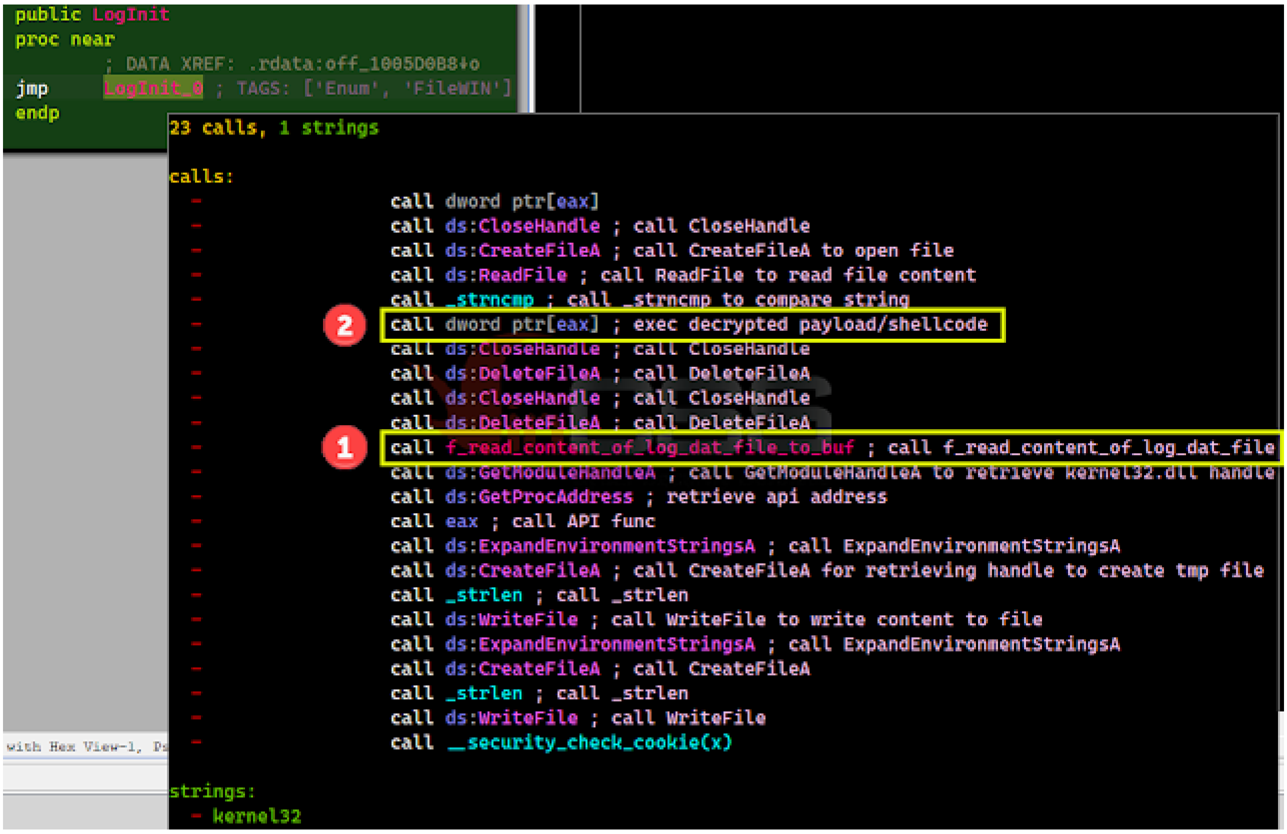
- **LogInit** function:

This function will call the **LogInit_0** function:

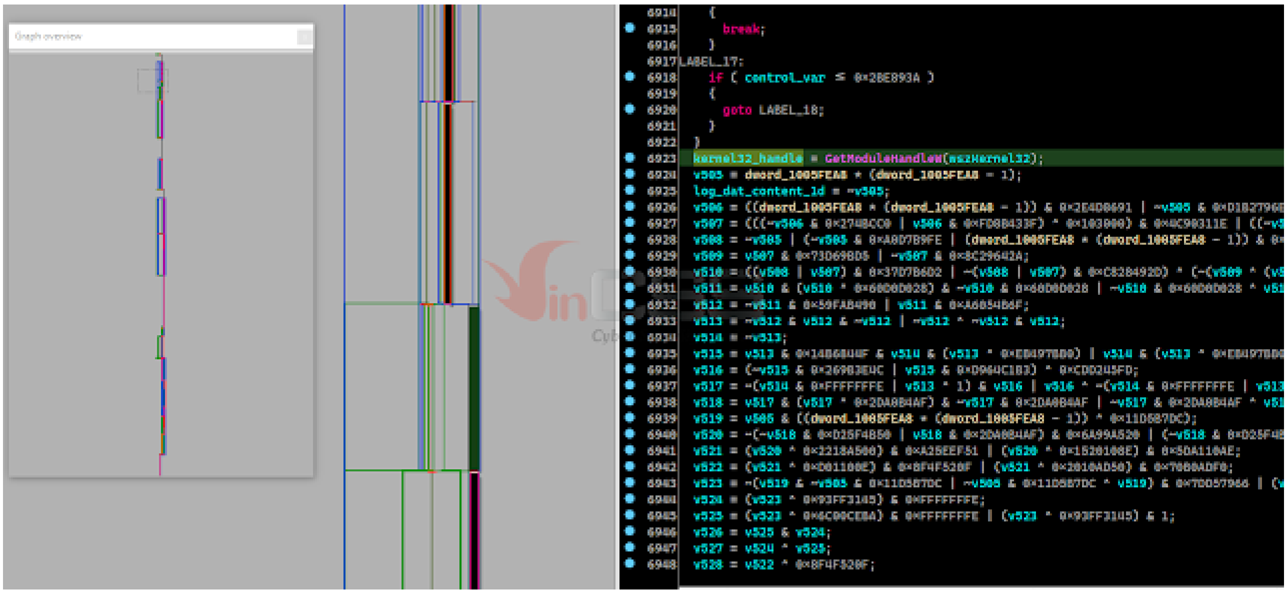


Similar to the above, the code at the **LogInit_0** function has also been completely obfuscated, it takes a long time for IDA to decompile the code of this function:

The primary task of the **LogInit_0** function is to call the function **f_read_content_of_log_dat_file_to_buf** for reading the content of **log.dat** file and execute the decrypted shellcode:

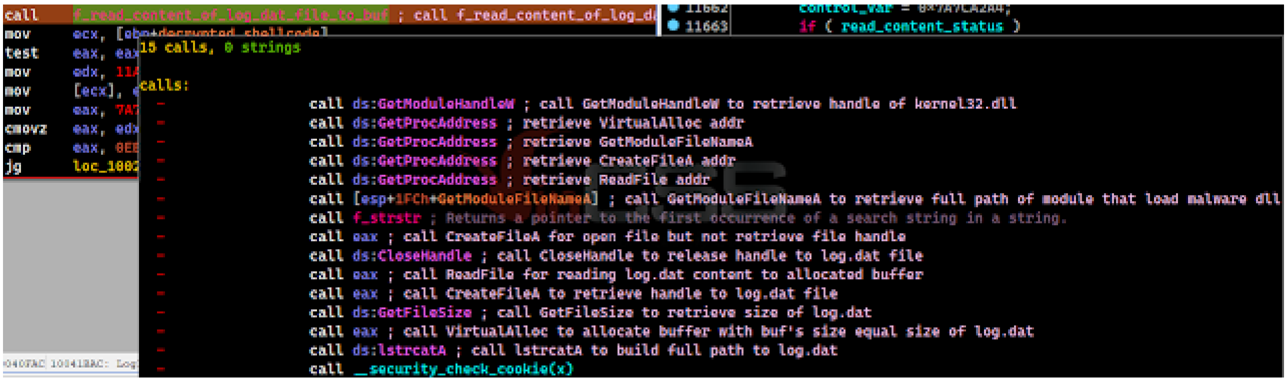


f_read_content_of_log_dat_file_to_buf'scode is also completely obfuscated:

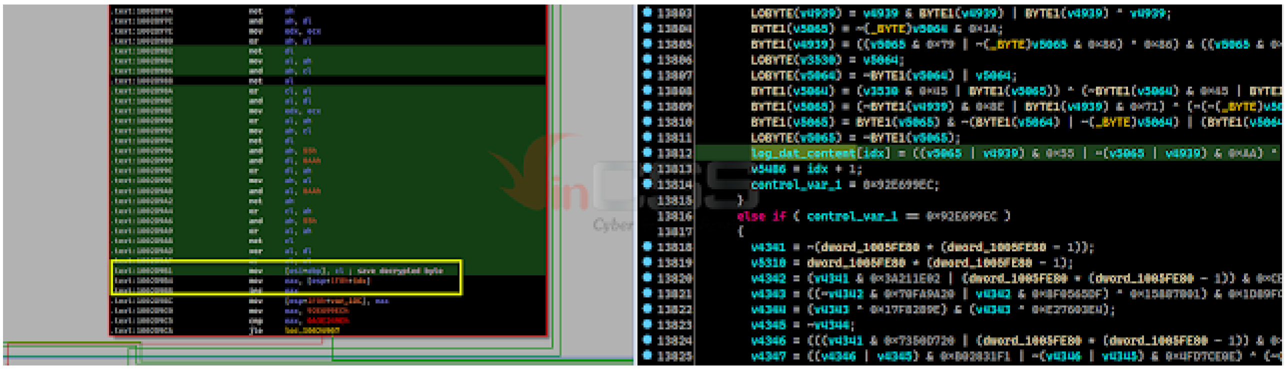


The major task of this function as the following:

- Call the **GetModuleHandleW** function to retrieve the handle of **kernel32.dll**.
- Call the **GetProcAddress** function to get the addresses of the APIs: **VirtualAlloc**, **GetModuleFileNameA**, **CreateFileA**, **ReadFile**.
- Use the above APIs to retrieve the path to the **log.dat** file and read the contents of this file into the allocated memory.



- Decode the contents of **log.dat** into shellcode so that this shellcode is then executed by the call from the **LogInit_0** function.

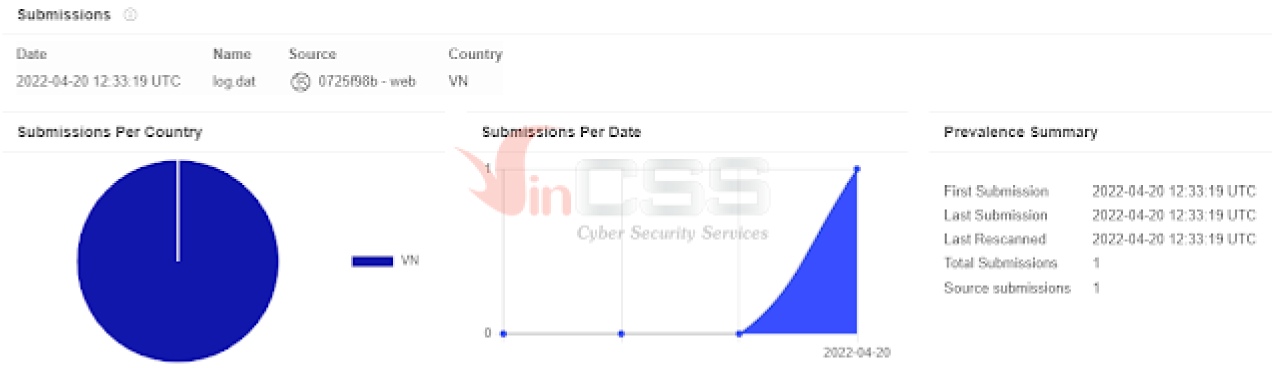


3. Shellcode analysis

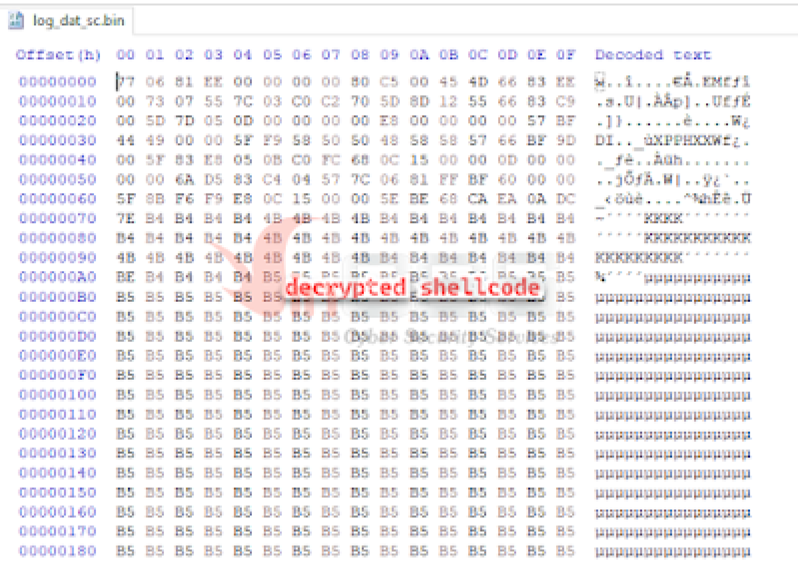
Based on the information analyzed above, we know that the **log.dll** file will read the content from the **log.dat** file and decrypt it into shellcode for further execution. Relying on this indicator, we continue to hunt **log.dat** file on VirusTotal which restrict the scope of submission source from Vietnam.

The results are following:

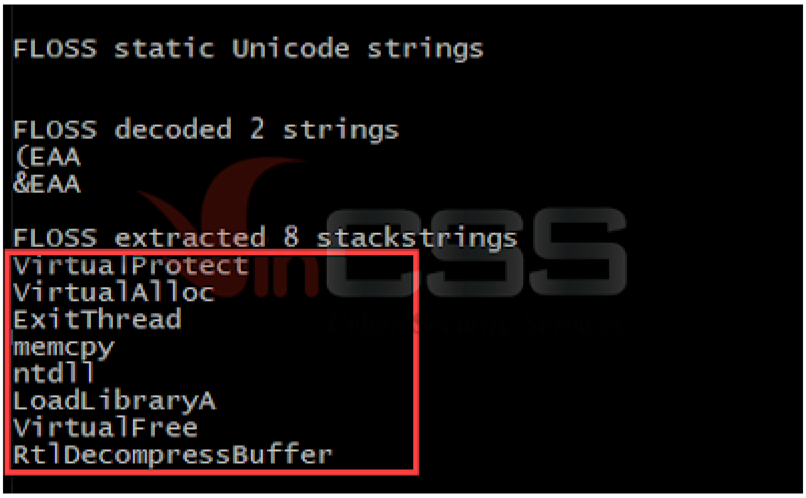
With the above results, at the time of analysis, we selected the **log.dat** file (2de77804e2bd9b843a826f194389c2605cfc17fd2fafde1b8eb2f819fc6c0c84) was submitted to VirusTotal on **2022-04-20 12:33:19 UTC** (5 days before the above **log.dll** file).

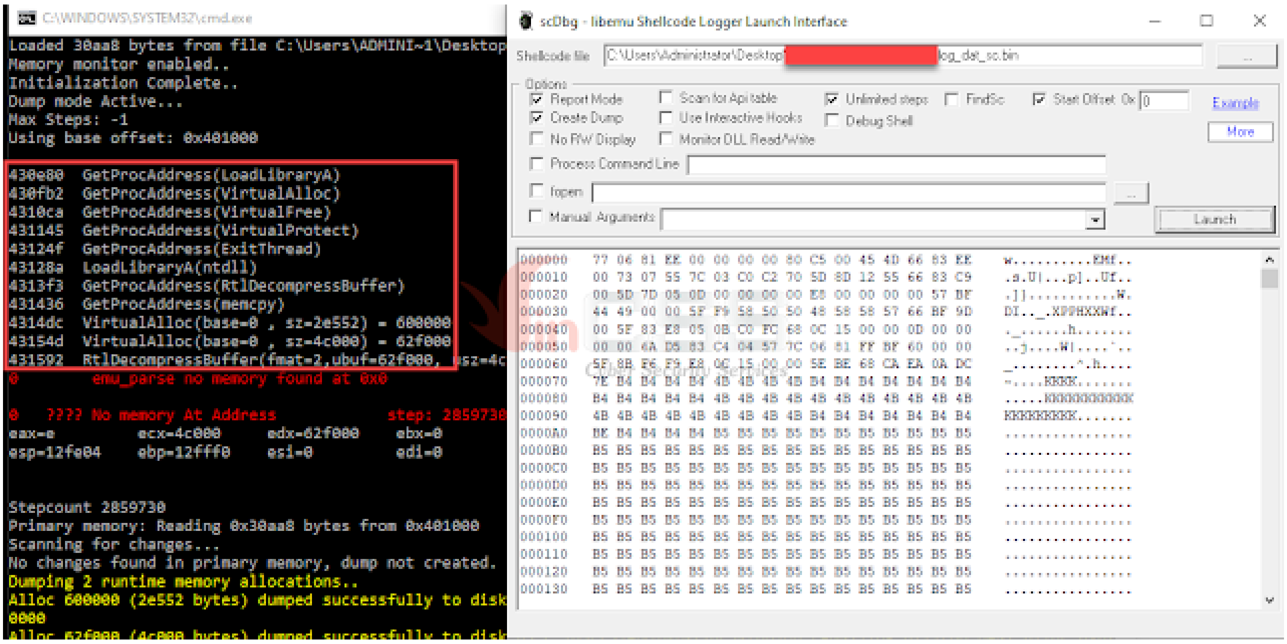


Debugging and dump the decrypted shellcode look like this:



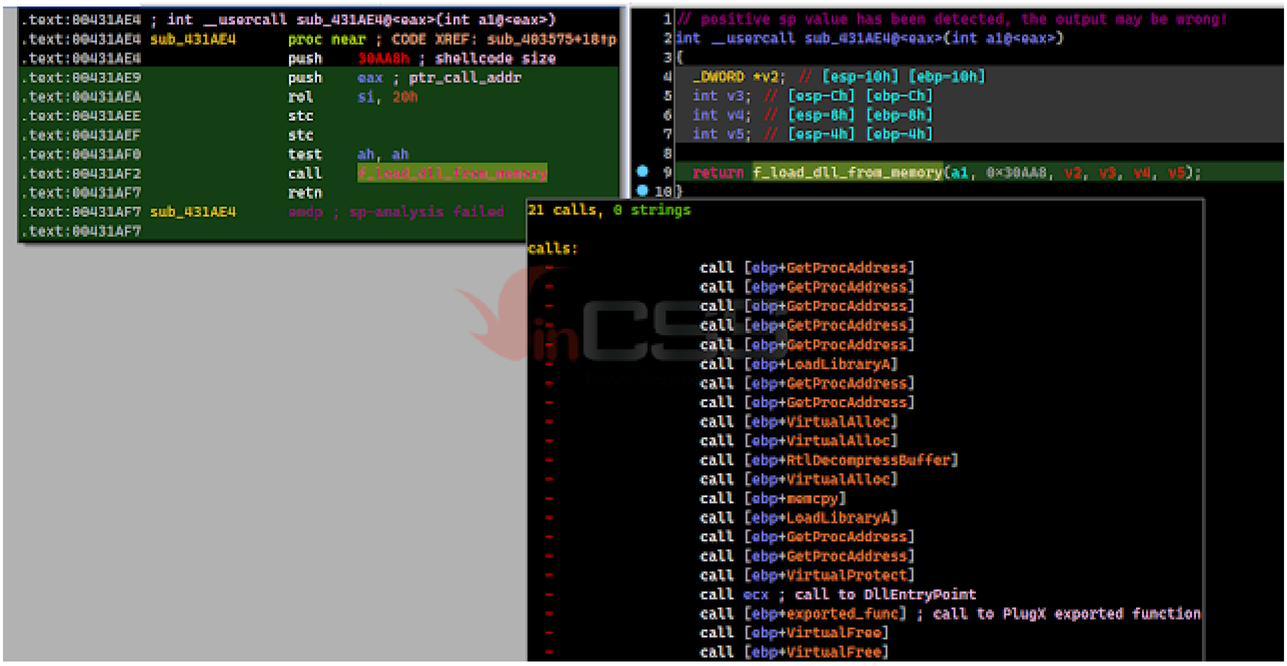
I use two tools, FLOSS and scdbg to get an overview of this shellcode. The results can be seen in the screenshots below:





With the results obtained above, it can be seen that this shellcode will perform memory allocation and then call the **RtlDecompressBuffer** function to decompress the data with the compression format is **COMPRESSION_FORMAT_LZNT1**.

By using IDA to analyze this shellcode, its main task is to decompress a Dll into memory and call the exported function of this Dll to execute. The function that does this task is named **f_load_dll_from_memory**:



The code in this function will first get the base address of **kernel32.dll** based on the pre-calculated hash value is **0x6A4ABC5B**. This hash value has also been mentioned by us in this analysis.

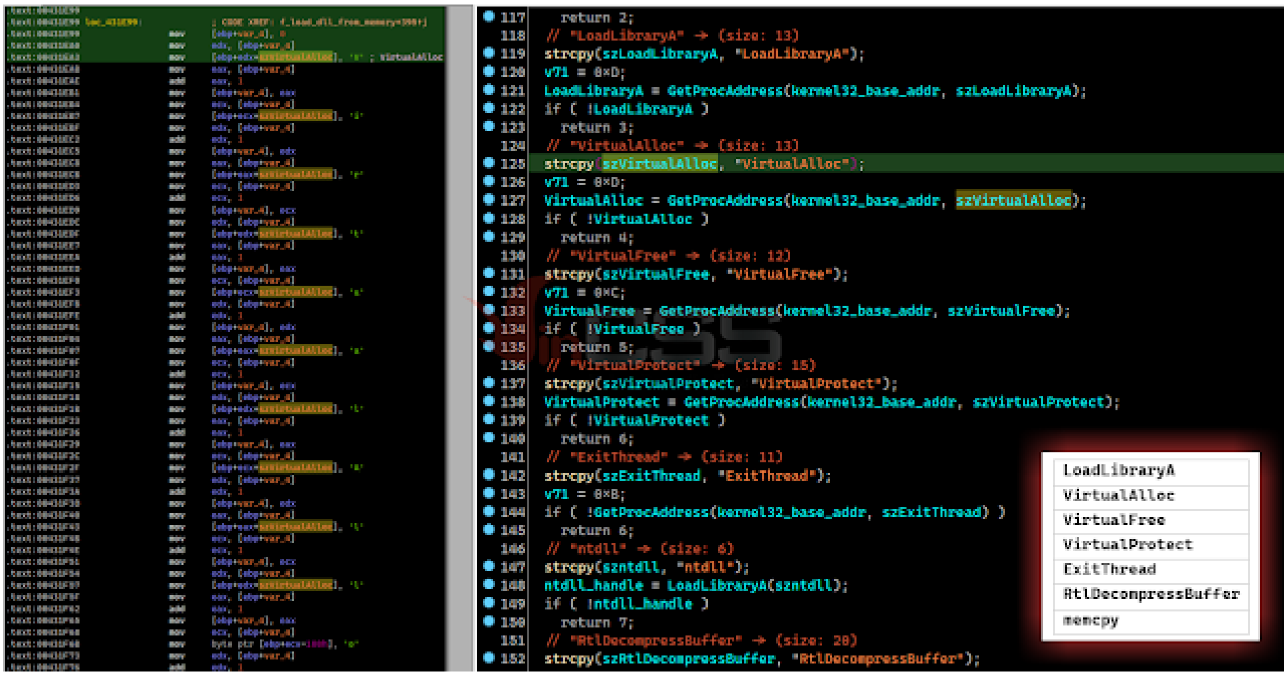
```
kernel32_base_addr = 0;
GetProcAddress = 0;
pLdr = NtCurrentPeb()->Ldr;
for ( ldr_entry = pLdr->InMemoryOrderModuleList.Flink; ldr_entry; ldr_entry = ADJ(ldr_entry)->InMemoryOrderLinks.Flink )
{
  wszDllName = ADJ(ldr_entry)->BaseDllName.Buffer;
  dll_name_length = ADJ(ldr_entry)->BaseDllName.Length;
  calced_hash = 0;
  do
  {
    calced_hash = __ROR4__(calced_hash, 13);
    if ( *wszDllName < 'a' )
      calced_hash += *wszDllName;             // calced_hash + letter
    else
      calced_hash = calced_hash + *wszDllName - 0x20;    // calced_hash + upper_letter
    wszDllName = (wszDllName + 1);
    --dll_name_length;
  }
  while ( dll_name_length );
  if ( calced_hash == 0x6A4ABC5B )            // kernel32.dll's hash
  {
    kernel32_base_addr = ADJ(ldr_entry)->DllBase;
    break;
  }
}
if ( !kernel32_base_addr )
  return 1;

// python .\brute_force_Dll_name.py
// Found dll kernel32.dll of 0x6a4abc5b
// Found dll ntdll.dll of 0x3cfa685d
```

Next it will retrieve the address of **GetProcAddress**:

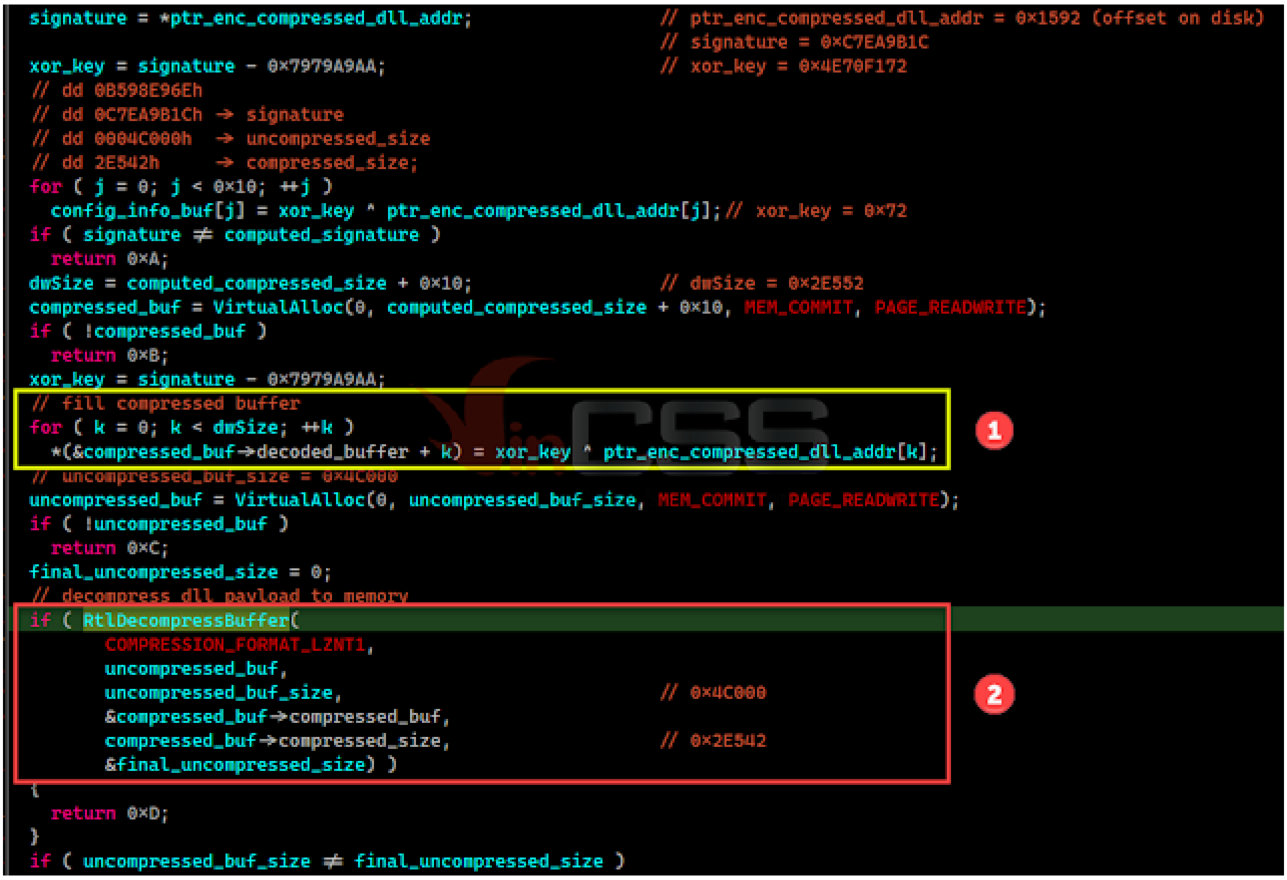
```
for ( i = 0; i < export_dir_va->NumberOfNames; ++i )
{
  szAPIName = kernel32_base_addr + pFuncsNamesAddr[i];
  if ( *szAPIName == 'G'
    && szAPIName[1] == 'e'
    && szAPIName[2] == 't'
    && szAPIName[3] == 'P'
    && szAPIName[4] == 'r'
    && szAPIName[5] == 'o'
    && szAPIName[6] == 'c'
    && szAPIName[7] == 'A'
    && szAPIName[8] == 'd'
    && szAPIName[9] == 'd' )
  {
    GetProcAddress = (kernel32_base_addr
                    + *(kernel32_base_addr
                      + 4 * *(kernel32_base_addr + 2 * i + export_dir_va->AddressOfNameOrdinals)
                      + export_dir_va->AddressOfFunctions));
    break;
  }
}
if ( !GetProcAddress )
  return 2;
```

By using the stackstring technique, the shellcode constructs the names of the APIs and gets the addresses of the following API functions:



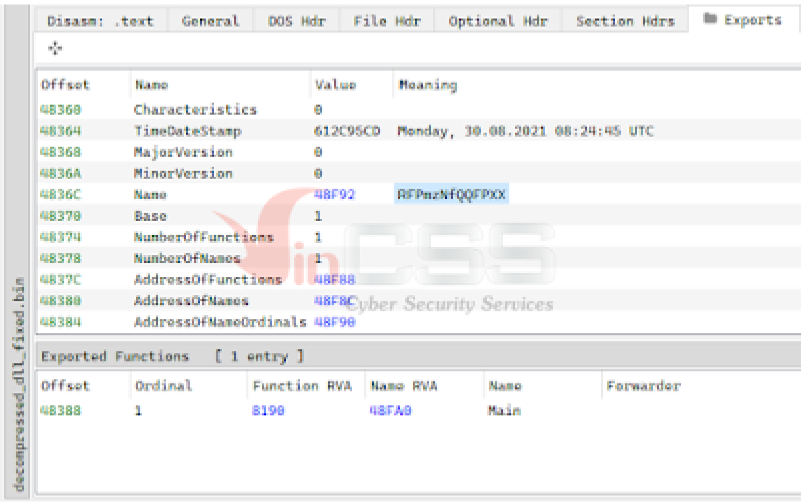
Next, the shellcode performs a memory allocation (**compressed_buf**) of size **0x2E552**, then reads data from offset **0x1592** (on disk) and executes an xor loop with a key is **0x72** to fill data into the **compressed_buf**. In fact, the size of **compressed_buf** is **0x2E542**, but its first 16 bytes are used to store information about **signature**, **uncompressed_size**, **compressed_size**, so **0x10** is added.

Shellcode continues to allocate memory (**uncompressed_buf**) of size **0x4C000** and calls the **RtlDecompressBuffer** function to decompress the data at the **compressed_buf** into **uncompressed_buf** with the compression format is **COMPRESSION_FORMAT_LZNT1**.

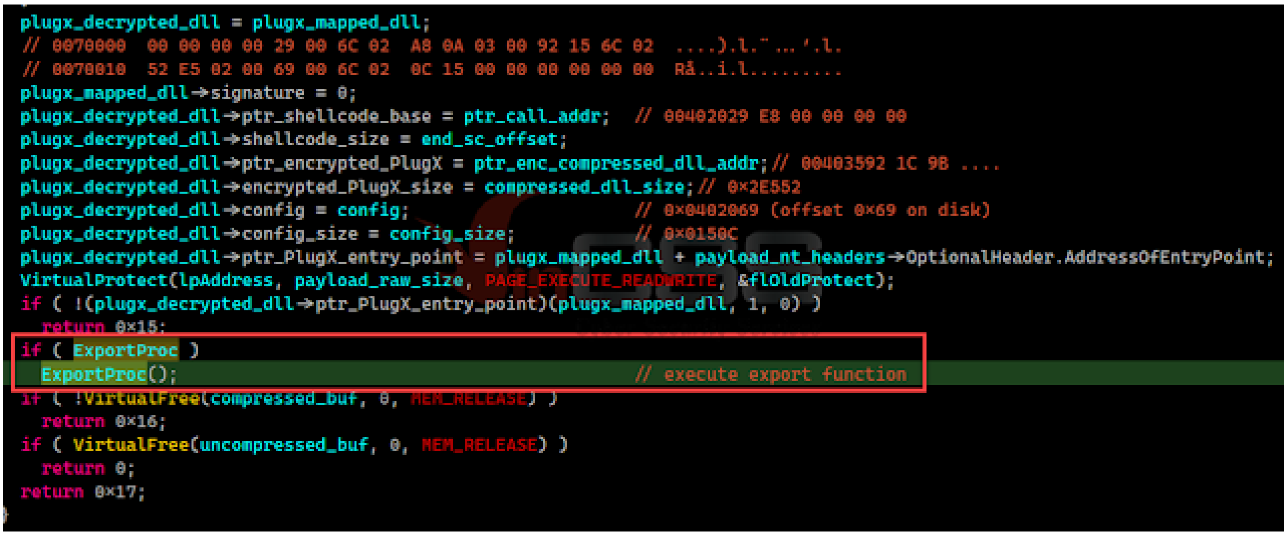


Based on the above analysis results, it is easy to get the extracted Dll file (however, the file header information was destroyed):

Fix the header information and check with PE-bear, this Dll has the original name is **RFPmzNfQQFPXX** and only exports one function named **Main**:



Back to the shellcode, after decompressing the Dll into memory, it will perform the task of a loader to map this Dll into a new memory region. Then, call to the exported function (here is the **Main** function) to perform the the main task of malware:



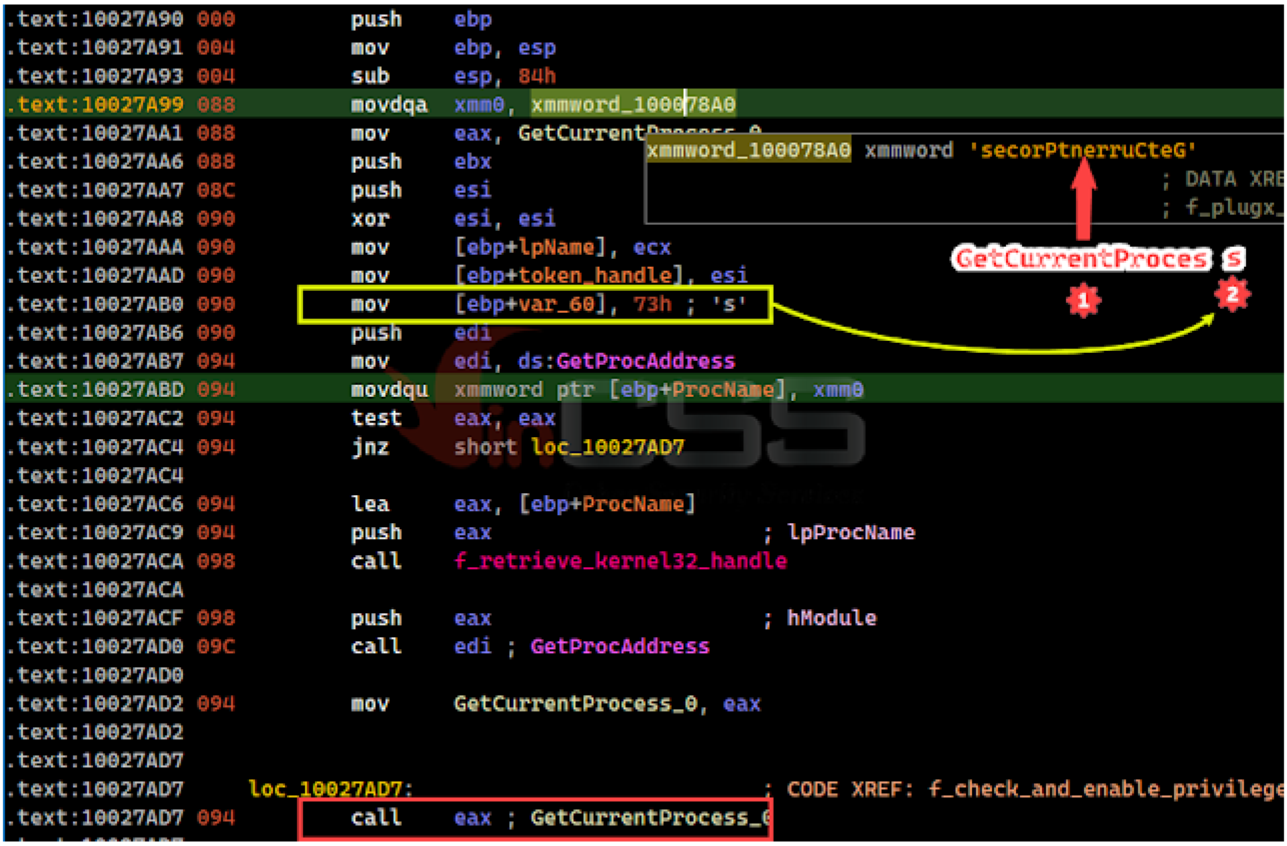
***<u>Note</u>**: At the time of analyzing this shellcode, we have not yet confirmed it is a variant of the PlugX malware, but only raised doubts about the relationship. It was only when we analyzed the above extracted Dll, then we confirmed for sure that this was a variant of PlugX and renamed the fields in the struct for understandable reasons as screenshot above.*

4. Analyze the extracted Dll

We will not go into detailed analysis of this Dll, but only provide the necessary information to prove that this is a PlugX variant as well as the process of decrypting the configuration information that the malware will use.

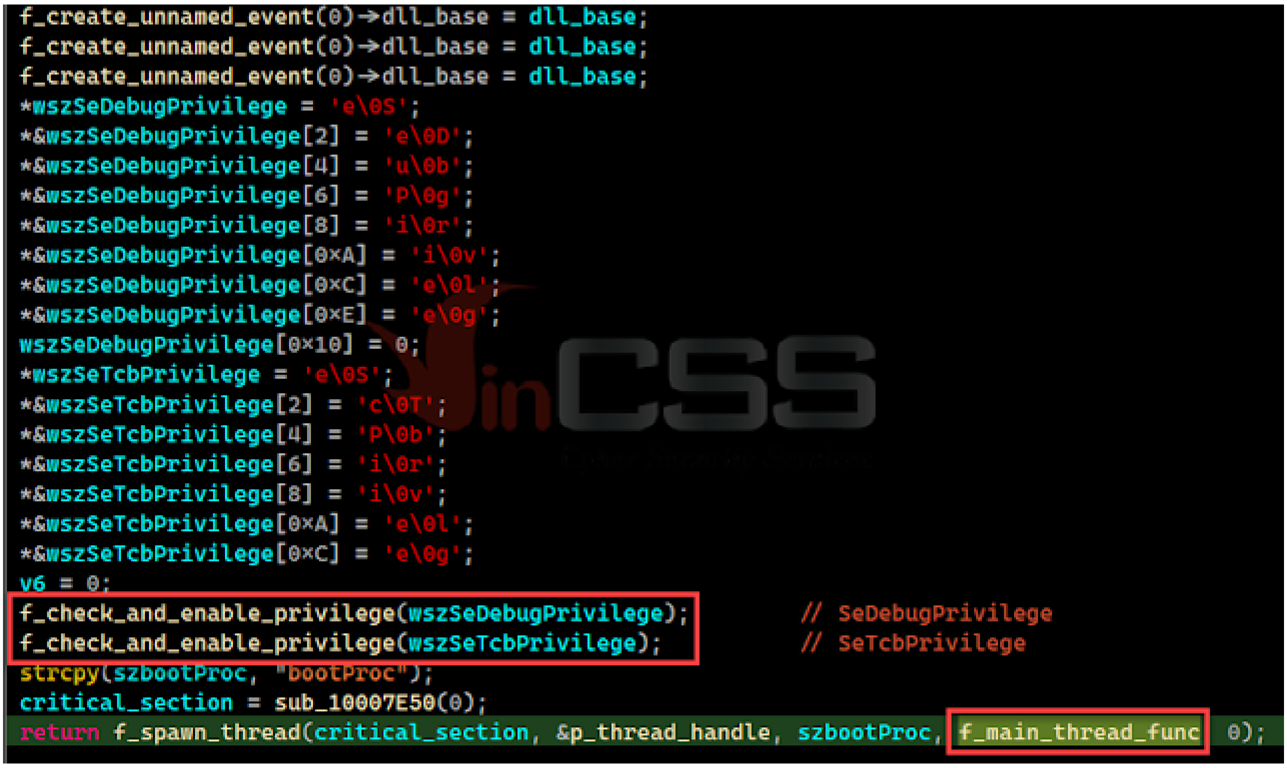
4.1. How PlugX calls an API function

In this variant, information about API functions is stored in **xmmword**, then loaded into the **xmm0** (128-bit) register, the missing part of the function name will be loaded through the stack. The malicious code gets the handle of the Dll corresponding to these API functions, then uses **GetProcAddress** function to retrieve the address of the specified API function to use later:



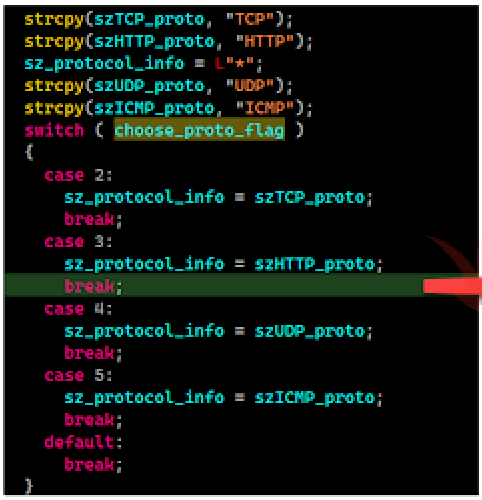
4.2. Create main thread to execute

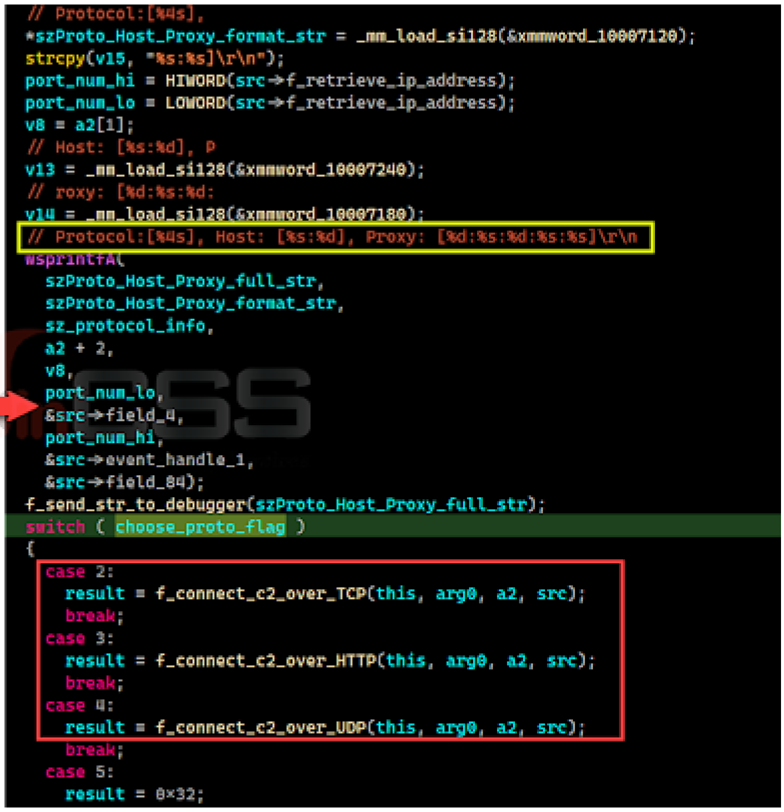
The malware adjusts the **SeDebugPrivilege** and **SeTcbPrivilege** tokens of its own process in order to gain full access to system processes. Then it creates its main thread, which is named “**bootProc**”:



4.3. Communicating with C2

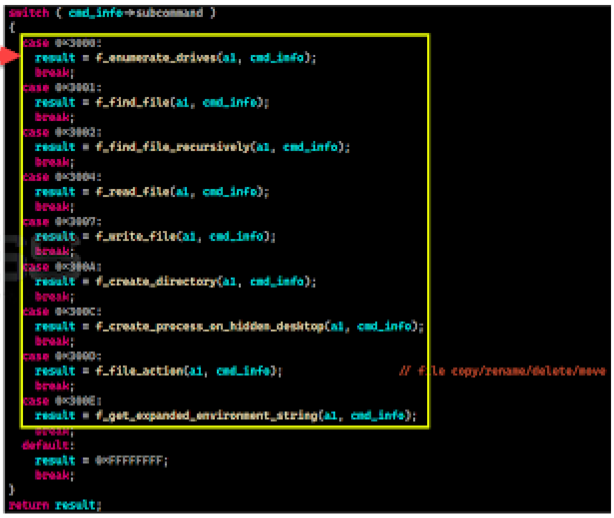
The malware can communicate with C2 via TCP, HTTP or UDP protocols:





4.4. Implemented commands

The malware will receive commands from the attacker to execute the corresponding functions related to *Disk*, *Network*, *Process*, *Registry*, etc.



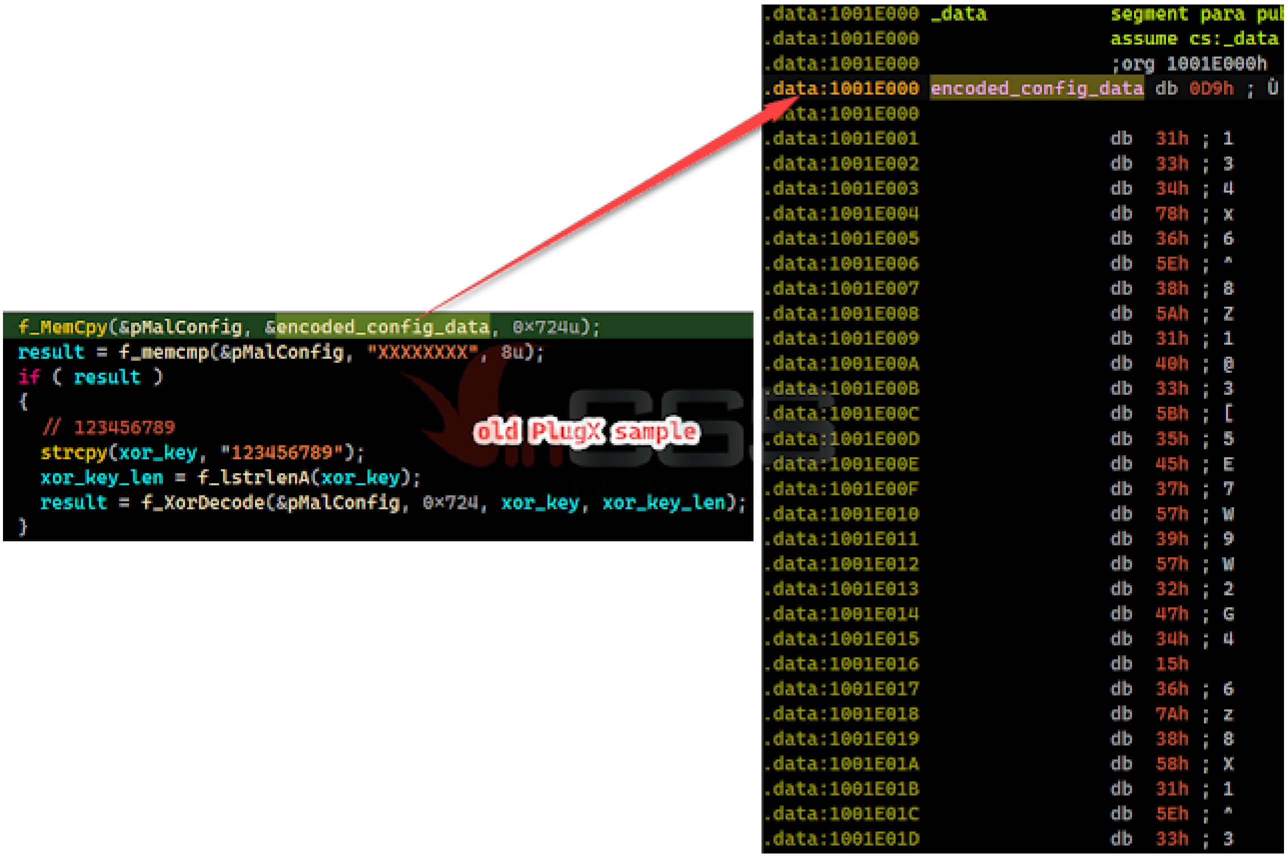
The entire list of commands as shown in the table below that the attacker can execute through this malware sample:

Command Group	Sub-command	Description
Disk	0x3000	Get information about the drives (type, free space)
	0x3001	Find file

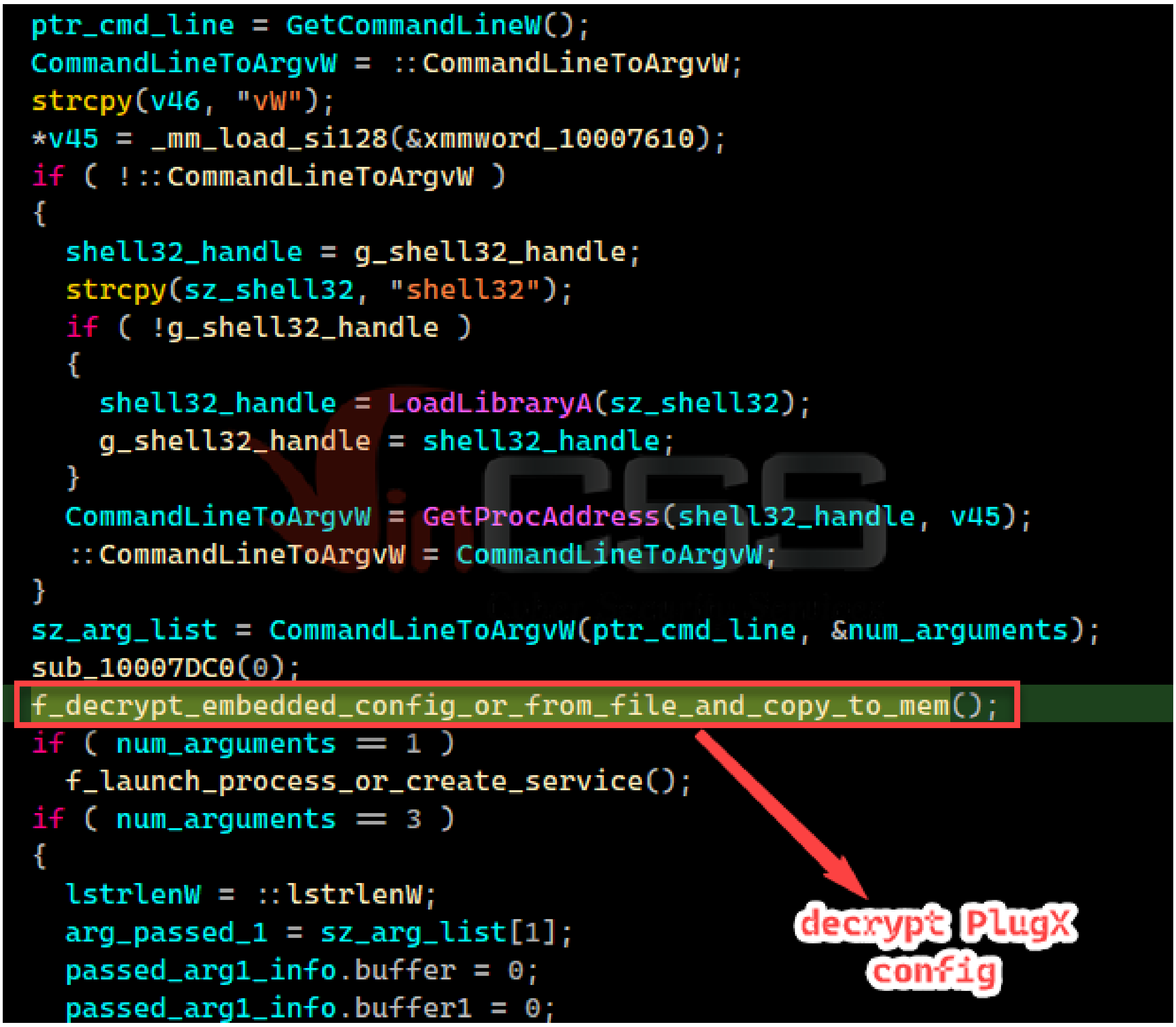
	0x3002	Find file recursively
	0x3004	Read data from the specified file
	0x3007	Write data to the specified file
	0x300A	Create a new directory
	0x300C	Create a new process on hidden desktop
	0x300D	File action (file copy/rename/delete/move)
	0x300E	Expand environment-variable strings
Nethood	0xA000	Enumeration of network resources
Netstat	0xD000	Retrieve a table that contains a list of TCP endpoints
	0xD001	Retrieve a table that contains a list of UDP endpoints
	0xD002	Set the state of a TCP connection
Option	0x2000	Lock the workstation's display
	0x2001	Force shut down the system
	0x2002	Restart the system
	0x2003	Shut down the system safety
	0x2005	Display massage box
PortMap	0xB000	Perform port mapping
Process	0x5000	Retrieve processes info
	0x5001	Retrieve modules info
	0x5002	Terminate specified process
RegEdit	0x9000	Enumerate registry
	0x9001	Create registry
	0x9002	Delete registry
	0x9003	Copy registry
	0x9004	Enumerates the values of the specified open registry key
	0x9005	Sets the data and type of a specified value under a registry key
	0x9006	Deletes a named value from the specified registry key
	0x9007	Retrieves a registry value
Service	0x6000	Retrieves the configuration parameters of the specified service
	0x6001	Changes the configuration parameters of a service
	0x6002	Starts a service
	0x6003	Sends a control code to a service
	0x6004	Delete service
Shell	0x7002	Create pipe and execute command line
SQL	0xC000	Get SQL data sources
	0xC001	Lists SQL drivers
	0xC002	Executes SQL statement
Telnet	0x7100	Start telnet server
Screen	0x4000	simulate working over the RDP Protocol
	0x4100	Take screenshot
KeyLog	0xE000	Perform key logger function, log keystrokes to file "**%allusersprofile%\MSDN\6.0\USER.DAT**"

4.5. Decrypt PlugX configuration

As analyzed above, the malware will connect to the C2 address via HTTP, TCP or UDP protocols depending on the specified configuration. So where is this config stored? With the old malware samples that we have analyzed (1, 2, 3, 4), the PlugX configuration is usually stored in the **.data** section with the size of **0x724 (1828)** bytes.



Going back to the sample we are analyzing, we see that before the step of checking the parameters passed when the malware executes, it will call the function that performs the task of decrypting the configuration:

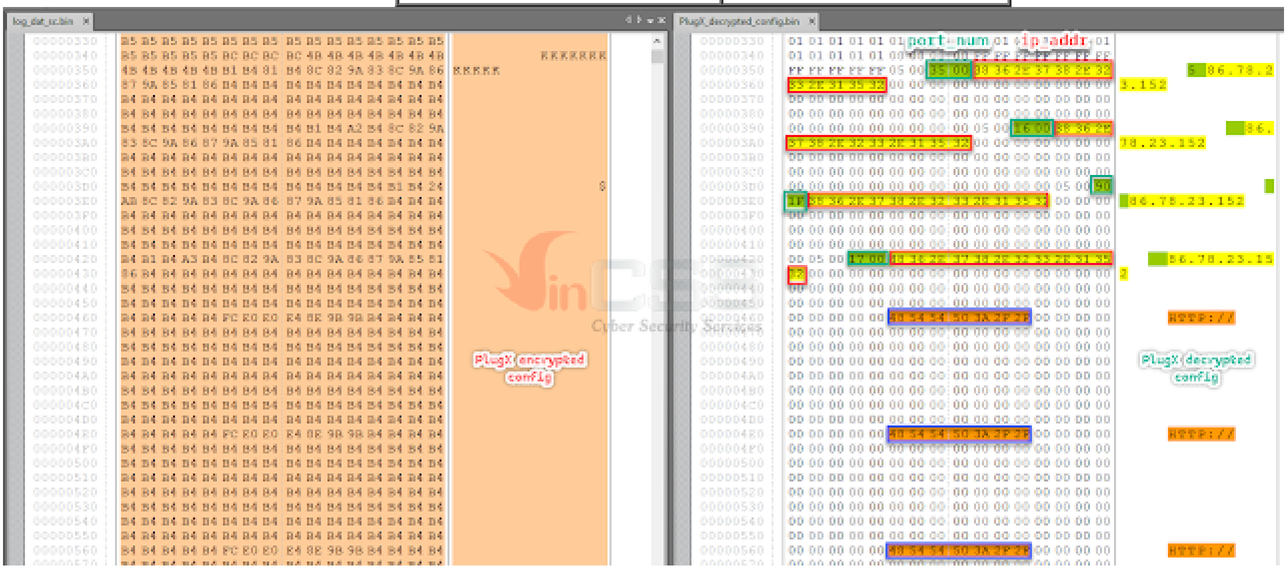


Diving into this function, combined with additional debugging from shellcode, renaming the fields in the generated struct, we get the following information:

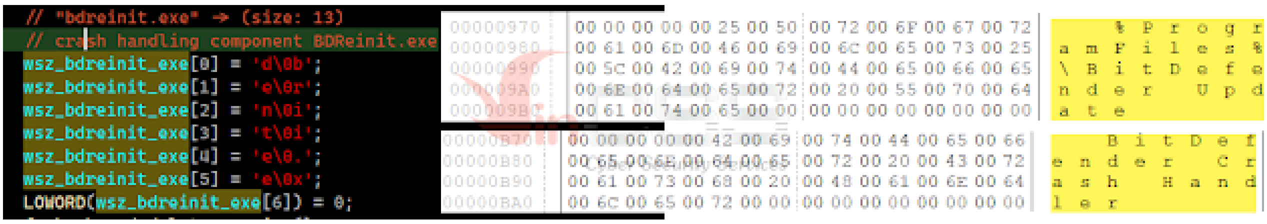
- PlugX's configuration is embedded in shellcode and starts at offset **0x69**.
- The size of the configuration is **0x0150C** (**5388**) bytes.
- Decryption key is **0xB4.**

With all the complete information as above, it is possible to recover the configuration information easily:

IP	Port
86.78.23.152	53
86.78.23.152	22
86.78.23.152	8080
86.78.23.152	23



In addition to the list of C2 addresses above, there is additional information related to the directory created on the victim machine to contain malware files as well as the name of the service that can be created:



To make our life easier, I wrote a python script to automatically extract configuration information for this variant. The output after running the script is as follows:

```
$ python plugx_extract_config.py plugx_decrypted_config.bin

[+] Config file: plugx_decrypted_config.bin
[+] Config size: 5388 bytes
[+] Folder name: %ProgramFiles%\BitDefender Update
[+] Service name: BitDefender Crash Handler
[+] Proto info: HTTP://
[+] C2 servers:
        86.78.23.152:53
        86.78.23.152:22
        86.78.23.152:8080
        86.78.23.152:23
[+] Campaign ID: 1234
```

5. Conclusion

CrowdStrike researchers first published information on Mustang Panda in June 2018, after approximately one year of observing malicious activities that shared unique Tactics, Techniques, and Procedures (TTPs). However, according to research and collect from many different cybersecurity companies, this group of APTs has existed for more than a decade with different variants found around the world. Mustang Panda, believed to be a APT group based in China, is evaluated as one of the highly motivated APT groups, applying sophisticated techniques to infect and install malware, aims to gain as much long-term access as possible to conduct espionage and information theft.

In this blog we have analyzed the different steps the infamous PlugX RAT follows to start execution and avoid detection. Thereby, it can be seen that this APT group is still active and constantly looking for ways to improve and upgrade techniques. VinCSS will continue to search for additional samples and variants that may be associated with this PlugX variant that we analyzed in this article.

6. References

7. Indicators of Compromise

log.dll - db0c90da56ad338fa48c720d001f8ed240d545b032b2c2135b87eb9a56b07721
log.dll - 84893f36dac3bba6bf09ea04da5d7b9608b892f76a7c25143deebe50ecbbdc5d
log.dll - 3171285c4a846368937968bf53bc48ae5c980fe32b0de10cf0226b9122576f4e
log.dll - 604b202cbe5e97c7c8a74a12e1f08e843c08ae08be34dc60b8518b9417c133a9
log.dll - da28eb4f4a66c2561ce1b9e827cb7c0e4b10afe0ee3efd82e3cc2110178c9b7a
log.dat - 2de77804e2bd9b843a826f194389c2605cfc17fd2fafde1b8eb2f819fc6c0c84 Decrypted config: [+] Folder name: %ProgramFiles%\BitDefender Update [+] Service name: BitDefender Crash Handler [+] Proto info: HTTP:// [+] C2 servers: 86.78.23.152:53 86.78.23.152:22

86.78.23.152:8080 86.78.23.152:23 [+] Campaign ID: 1234
log.dat - 0e9e270244371a51fbb0991ee246ef34775787132822d85da0c99f10b17539c0 Decrypted config: [+] Folder name: %ProgramFiles%\BitDefender Update [+] Service name: BitDefender Crash Handler [+] Proto info: HTTP:// [+] C2 servers: 86.79.75.55:80 86.79.75.55:53 86.79.75.46:80 86.79.75.46:53 [+] Campaign ID: 1234
log.dat - 3268dc1cd5c629209df16b120e22f601a7642a85628b82c4715fe2b9fbc19eb0 Decrypted config: [+] Folder name: %ProgramFiles%\Common Files\ARO 2012 [+] Service name: BitDefender Crash Handler [+] Proto info: HTTP:// [+] C2 servers: 86.78.23.152:23 86.78.23.152:22 86.78.23.152:8080 86.78.23.152:53 [+] Campaign ID: 1234
log.dat - 02a9b3beaa34a75a4e2788e0f7038aaf2b9c633a6bdbfe771882b4b7330fa0c5 (THOR PlugX) Decrypted config: [+] Folder name: %ProgramFiles%\BitDefender Handler [+] Service name: BitDefender Update Handler [+] Proto info: HTTP://

[+] C2 servers:

www.locvnpt.com:443

www.locvnpt.com:8080

www.locvnpt.com:80

www.locvnpt.com:53

[+] Campaign ID: 1234

Click here for Vietnamese version.

Dang Dinh Phuong – Threat Hunter

Tran Trung Kien (aka m4n0w4r) - Malware Analysis Expert

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