Decrypting APT33’s Dropshot Malware with Radare2 and Cutter – Part 2

megabeets.net/decrypting-dropshot-with-radare2-and-cutter-part-2/

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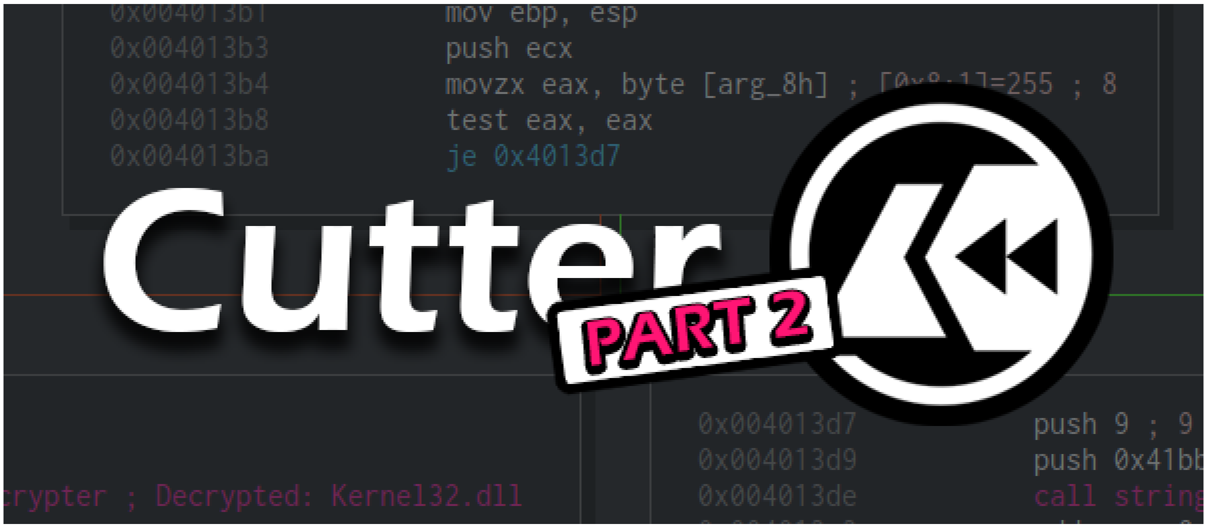
Prologue

Previously, in the first part of this article, we used Cutter, a GUI for radare2, to statically analyze APT33’s Dropshot malware. We also used radare2’s Python scripting capabilities in order to decrypt encrypted strings in Dropshot. If you didn’t read the first part yet, I suggest you do it now.

Today’s article will be shorter, now that we are familiar with cutter and r2pipe, we can quickly analyze another interesting component of Dropshot — an encrypted resource that includes Dropshot’s actual payload. So without further ado, let’s start.



Downloading and installing Cutter

Cutter is available for all platforms (Linux, OS X, Windows). You can download the latest release here. If you are using Linux, the fastest way to use Cutter is to use the AppImage file.

If you want to use the newest version available, with new features and bug fixes, you should build Cutter from source by yourself. It isn't a complicated task and it is the version I use.

First, you must clone the repository:

```
git clone --recurse-submodules https://github.com/radareorg/cutter
cd cutter
```

Building on Linux:

```
./build.sh
```

Building on Windows:

```
prepare_r2.bat
build.bat
```

If any of those do not work, check the more detailed instruction page here

Dropshot \ StoneDrill

As in the last part, we'll analyze Dropshot, which is also known by the name StoneDrill. It is a wiper malware associated with the APT33 group which targeted mostly organizations in Saudi Arabia. Dropshot is a sophisticated malware sample, that employed advanced anti-emulation techniques and has a lot of interesting functionalities. The malware is most likely related to the infamous Shamoon malware. Dropshot was analyzed thoroughly by Kaspersky and later on by FireEye. In this article, we'll focus on decrypting the encrypted resource of Dropshot which contains the actual payload of the malware.

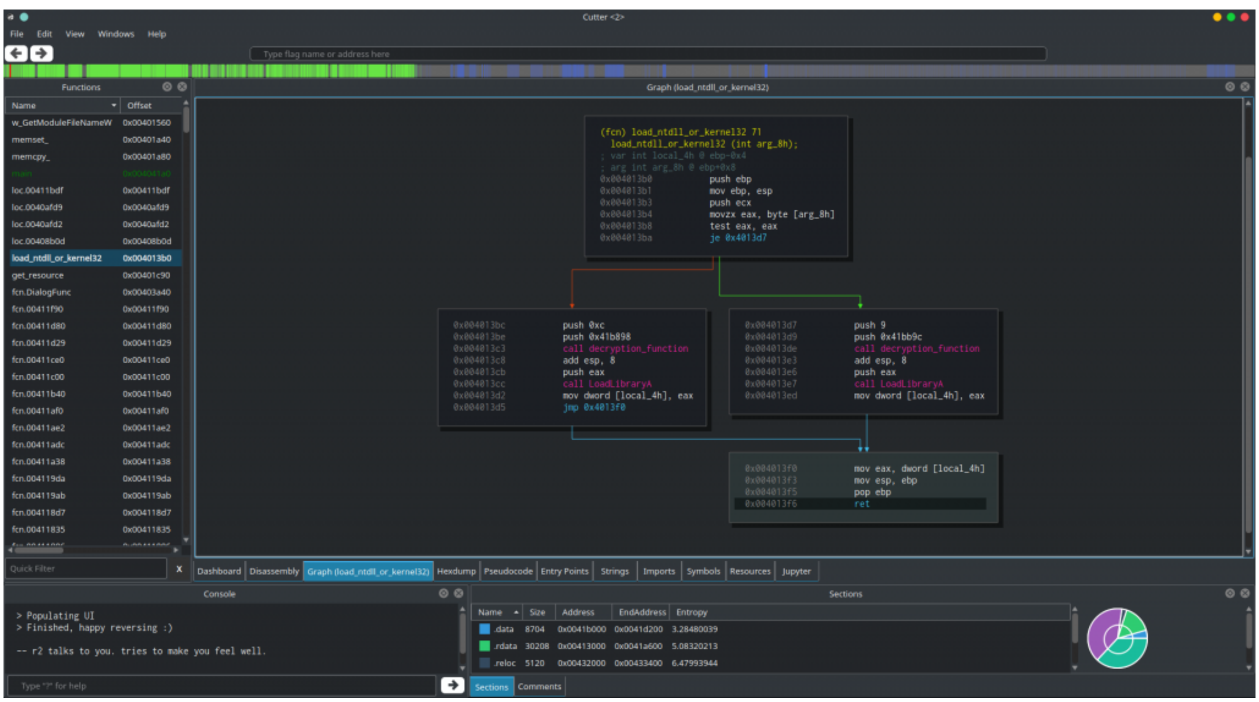
The Dropshot sample can be downloaded from here (password: *infected*). I suggest you star (★) the repository to get updates on more radare2 tutorials 🙂

Please, be careful when using this sample. It is a real malware, and more than that, a wiper! Use with caution!

Since we'll analyze Dropshot statically, you can use a Linux machine, as I did.

Getting Started

Assuming you went through the first part of the article, you are already familiar with Cutter and r2pipe. Moreover, you should already have a basic clue of how Dropshot behaves. Open the Dropshot sample in Cutter, execute in Jupyter the r2pipe script we wrote and seek to the `main` function using the "Functions" widget or the upper search bar.



A function we analyzed in the previous article | Click to enlarge

main ()

The role of the `main()` function in a program shouldn't be new to you since it is one of the fundamental concepts of programming. Using the Graph mode, we'll go thorugh `main` 's flow in order to find our target – the resource decryption routine. We can see that a function at `0x403b30` is being called at the first block of `main` .

```
(fcn) main 420
  main ();
; var int local_54h @ ebp-0x54
; var int local_38h @ ebp-0x38
; var int local_1ch @ ebp-0x1c
; var int local_18h @ ebp-0x18
; var int local_14h @ ebp-0x14
; var int local_10h @ ebp-0x10
; var int local_ch @ ebp-0xc
; var int local_8h @ ebp-0x8
; var int local_4h @ ebp-0x4
0x004041a0          push ebp
0x004041a1          mov ebp, esp
0x004041a3          sub esp, 0x54
0x004041a6          call fcn.00403b30
0x004041ab          mov eax, 1
0x004041b0          test eax, eax
0x004041b2          je 0x40429d
```

Double-clicking this line will take us to the graph of `fcn.00403b30`, a rather big function. Going through this function, we'll see some non-sense Windows API calls with invalid arguments. When describing Dropshot, I said that it uses anti-emulation heavily – this function, for example, performs anti-emulation.

```
0x00404064          push 0
0x00404066          call GetStockObject
0x0040406c          push 0
0x0040406e          push 0
0x00404070          call GetCurrentObject
0x00404076          push 0
0x00404078          push 0
0x0040407a          push 0
0x0040407c          call GetBitmapBits
0x00404082          push 0
0x00404084          push 0
0x00404086          push 0
0x00404088          call SetBitmapBits
0x0040408e          push 0
0x00404090          push 0
0x00404092          push 0
0x00404094          push 0
0x00404096          push 0
0x00404098          call CreateBitmap
0x0040409e          push 0
0x004040a0          push 0
0x004040a2          push 0
0x004040a4          push 0
0x004040a6          push 0
0x004040a8          push 0
0x004040aa          push 0
0x004040ac          call GetDIBits
0x004040b2          push 0
0x004040b4          push 0
0x004040b6          push 0
0x004040b8          push 0
0x004040ba          call SetPixelV
```

Click to enlarge

Anti-Emulation

Anti-emulation techniques are used to fool the emulators of anti-malware products. The emulators are one of the most important components of many security products. Among others, they are used to analyze the behavior of malware, unpack samples and to analyze shellcode. It is doing this by emulating the program's workflow by mimicking the target architecture's instruction set, as well as the running environment, and dozens or even hundreds of popular API functions. All this is done in order to make a malware 'think' it has been executed in a real environment by a victim user.

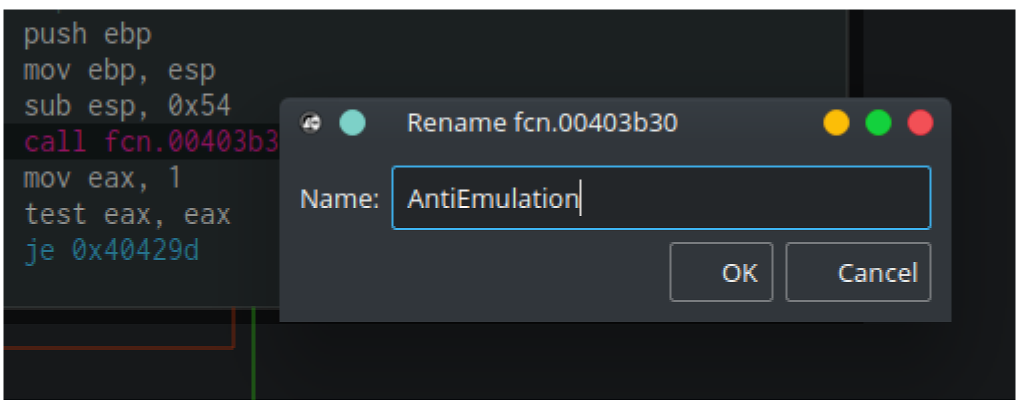
The emulator engine is mimicking the API or the system calls that are offered by the actual operating systems. Usually, it will implement popular API functions from libraries such as *user32.dll*, *kernel32.dll*, and *ntdll.dll*. Most of the times this will be a dummy implementation where the fake functions won't really do anything except returning a successful return value.

By using different anti-emulation techniques, malware authors are trying to fool a generic or even a specific emulator. The most common technique, which is also implemented in Dropshot's `fcn.00403b30`, is the use of uncommon or undocumented API calls. This technique can be improved by using incorrect arguments (like *NULL*) to a certain API function which should cause an Access Violation exception in a real environment.

In our case, Dropshot is calling some esoteric functions as well as passing non-sense arguments to different API functions.

More information about emulation and anti-emulation mechanisms are available in the following, highly recommended, book: The Antivirus Hacker's Handbook

Now that we know all this, we can rename this function from `fcn.00403b30` to a more meaningful name. I used "AntiEmulation" but you can choose whatever name you want, as long as it is meaningful to you. Clicking the call instruction and then pressing Shift+N will open the Rename dialog box. Right-clicking the row and choosing "Rename" will do the job as well.



After `main` is calling to the AntiEmulation function, we are facing a branch. Here's the assembly, copied from Cutter's Disassembly widget:

```
|           0x004041a6          call AntiEmulation
|           0x004041ab          mov eax, 1
|           0x004041b0          test eax, eax
|       ,=< 0x004041b2          je 0x40429d
|       |   0x004041b8          push 4
```

As you can see, the code would never branch to `0x40429d` since this `test eax, eax` followed by `je ...` is basically checking whether `eax` equals 0. One instruction before, the program moved the value 1 to `eax`, thus `0x40429d` would be The Road Not Taken.

We'll skip the next block which is responsible for creating temporary files and take a look at the block starting at `0x4041f9`. In this block, we'll see that Dropshot is creating a modeless Dialog box using `CreateDialogParamA` with the following parameters: `CreateDialogParamA(0, 0x410, 0, DialogFunc, 0);` .

```
0x004041f9          mov dword [local_14h], 0
0x00404200          mov dword [local_10h], 0
0x00404207          push 0
0x00404209          push fcn.DialogFunc
0x0040420e          mov ecx, dword [local_10h]
0x00404211          push ecx
0x00404212          push 0x410
0x00404217          mov edx, dword [local_14h]
0x0040421a          push edx
0x0040421b          call CreateDialogParamA
0x00404221          mov dword [0x41dbe4], eax
0x00404226          push 5
0x00404228          mov eax, dword [0x41dbe4]
0x0040422d          push eax
0x0040422e          call ShowWindow
0x00404234          mov byte [0x41dbe0], 1
```

The DialogPrc callback which is passed to `CreateDialogParamA` is recognized by radare2 and shown by Cutter as `fcn.DialogFunc` . This function contains the main logic of the dropper and this is the function that we'll focus on. Later in this block, `ShowWindow` is being called in order to "show" the window. Obviously, this is a dummy window which would never be shown since the malware author doesn't want any artifact to be shown to the victim. `ShowWindow` will trigger the execution of `fcn.DialogFunc` .

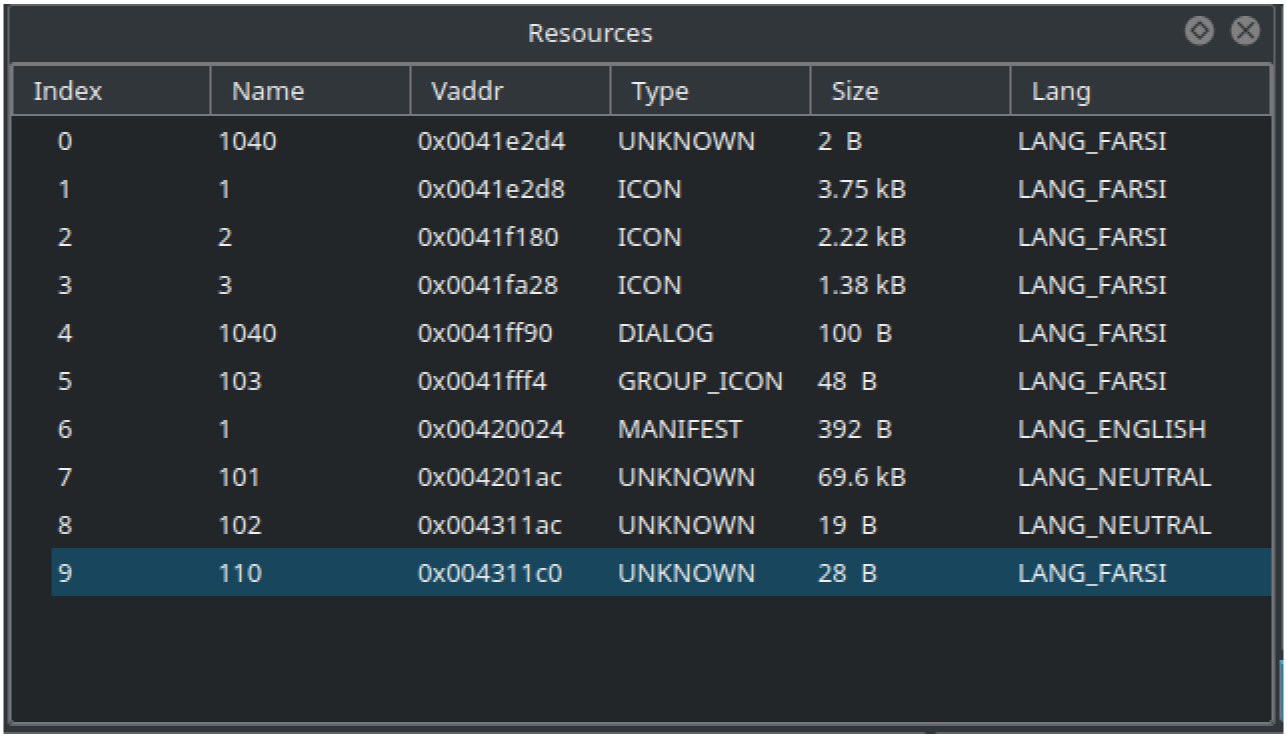
Double-clikcing on `fcn.DialogFunc` will take us to the function itself. We can see that it is performing several comparisons for the messages it receives and then is calling to a very interesting function `fcn.00403240` .

Handling the Resources

The first block of `fcn.00403240` is pretty straightforward. Dropshot is getting a handle to itself using `GetModuleHandleA` . Then, by using `FindResourceA` , it is locating a resource with a dummy type 0x67 (Decimal: 111) and a name 0x6e (Decimal: 110). Finally, it is loading a resource with this name using `LoadResource` .

```
0x00403240    push ebp
0x00403241    mov ebp, esp
0x00403243    sub esp, 0x68
0x00403246    push 0
0x00403248    call GetModuleHandleA
0x0040324e    mov dword [local_40h], eax
0x00403251    push 0x6f
0x00403253    push 0x6e
0x00403255    mov eax, dword [local_40h]
0x00403258    push eax
0x00403259    call FindResourceA
0x0040325f    mov dword [local_48h], eax
0x00403262    mov ecx, dword [local_48h]
0x00403265    push ecx
0x00403266    mov edx, dword [local_40h]
0x00403269    push edx
0x0040326a    call LoadResource
0x00403270    mov dword [local_60h], eax
0x00403273    mov eax, dword [local_48h]
0x00403276    push eax
0x00403277    mov ecx, dword [local_40h]
0x0040327a    push ecx
0x0040327b    call SizeofResource
0x00403281    mov dword [local_5ch], eax
0x00403284    mov dword [local_8h], 0
0x0040328b    mov dword [local_14h], 0
0x00403292    mov dword [local_2ch], 0
0x00403299    jmp 0x4032a4
```

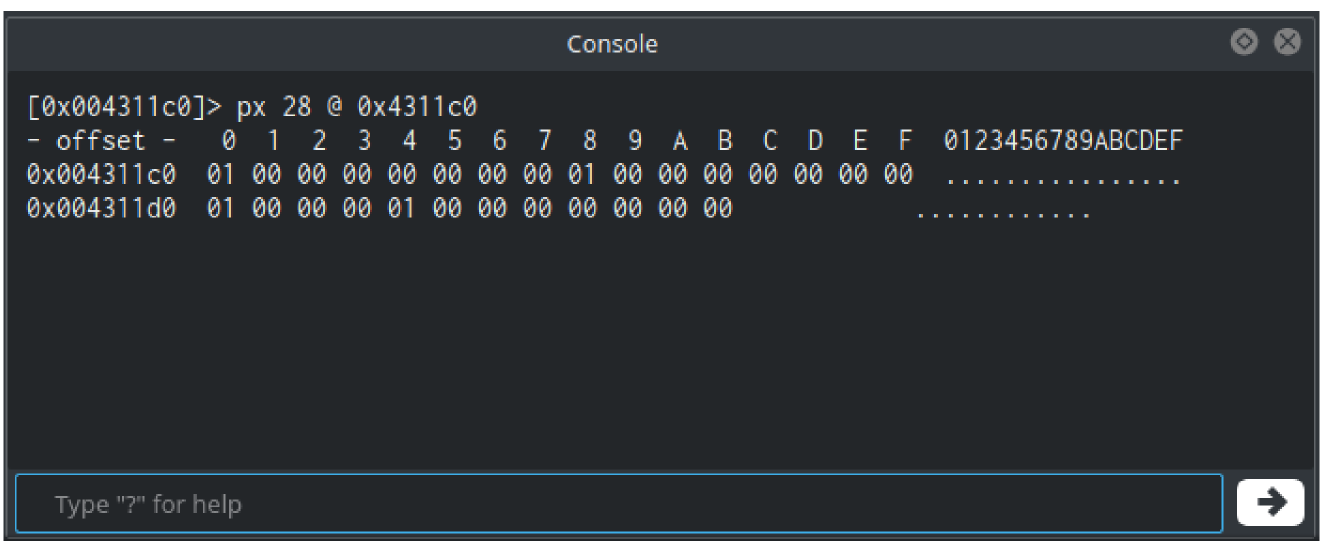
Using Cutter, we can see the content of this resource. Simply go to the Resources widget and locate the resource with the name “110”.



Index	Name	Vaddr	Type	Size	Lang
0	1040	0x0041e2d4	UNKNOWN	2 B	LANG_FARSI
1	1	0x0041e2d8	ICON	3.75 kB	LANG_FARSI
2	2	0x0041f180	ICON	2.22 kB	LANG_FARSI
3	3	0x0041fa28	ICON	1.38 kB	LANG_FARSI
4	1040	0x0041ff90	DIALOG	100 B	LANG_FARSI
5	103	0x0041fff4	GROUP_ICON	48 B	LANG_FARSI
6	1	0x00420024	MANIFEST	392 B	LANG_ENGLISH
7	101	0x004201ac	UNKNOWN	69.6 kB	LANG_NEUTRAL
8	102	0x004311ac	UNKNOWN	19 B	LANG_NEUTRAL
9	110	0x004311c0	UNKNOWN	28 B	LANG_FARSI

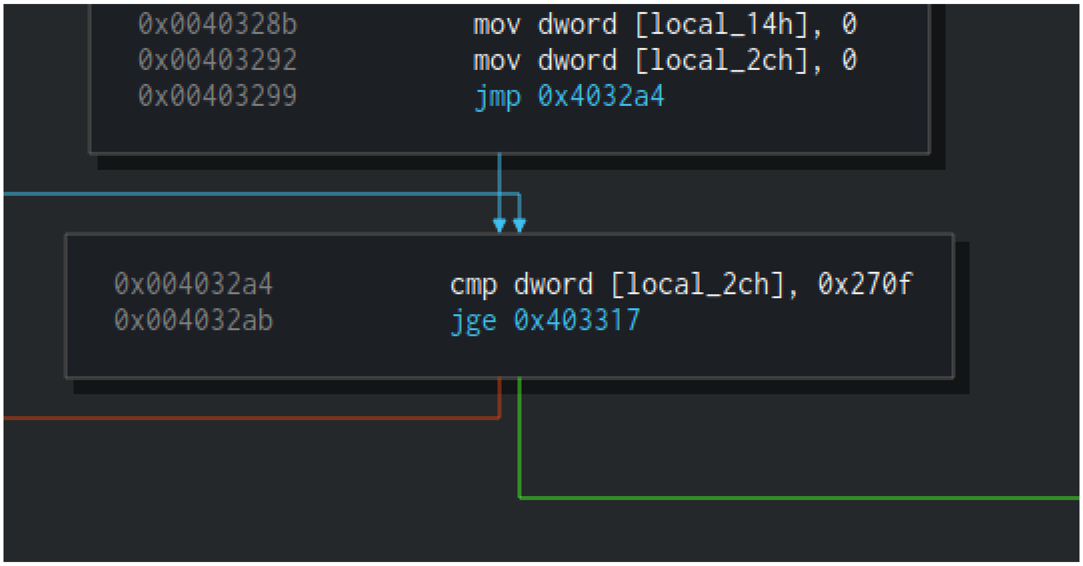
As you can see in the screenshot above, the size of the resource is 28 Bytes and its Lang is Farsi which might hint us about the threat actor behind Dropshot.

Double-clicking the resource will take us to the resource's address. Let's click on the Hexdump widget to see its data. In the hexdump we can see that this resource contains the following bytes: `01 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 01 00 00 00 01 00 00 00 00 00 00 00`. Those of you who are familiar with radare2 may use the Console widget in the bottom left to do this quickly with `px`:



This resource will be used later but we won't be getting into it since it is out of the scope of this post.

After loading the resource, in the next block we can see the start of a loop:

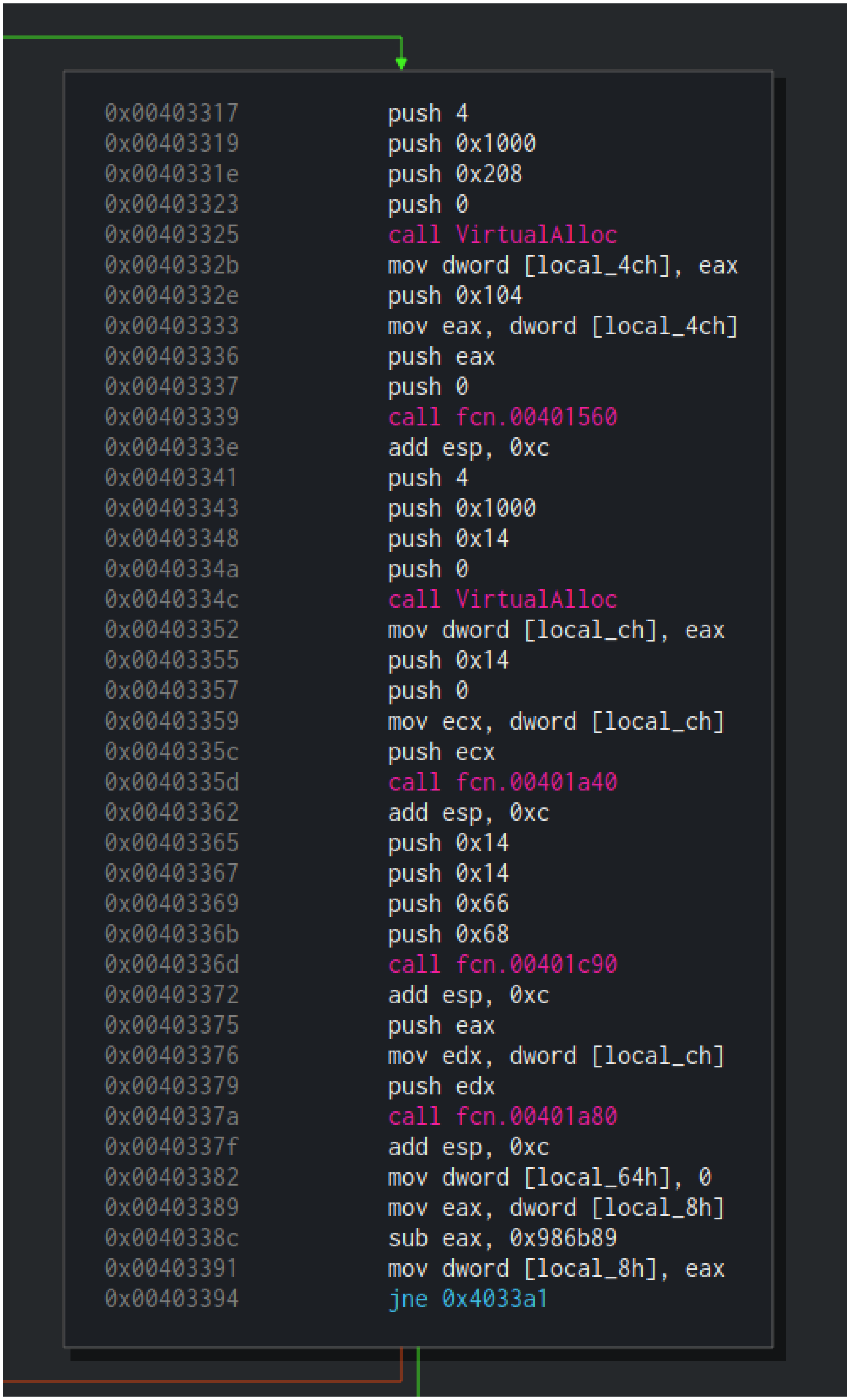


This loop is checking if `local_2ch` equals to 0x270f (Decimal: 9999) and if yes it exits from the loop. Inside this loop, there will be another loop of 999 iterations. So basically, this is how this nested loop looks like:

```
for ( i = 0; i < 9999; ++i )
{
  for ( j = 0; j < 999; ++j )
  {
      dummy_code;
  }
}
```

This is just another anti-emulation\analysis technique which is basically doing nothing. This is another example of the heavy use of anti-emulation by Dropshot.

After this loop, the right branch is taken and this is an interesting one.



Click to enlarge

At first, `VirutalAlloc` in the size of 512 bytes is being called. Next, `fcn.00401560` is called with 3 arguments. Let's enter this function and see what's in there:

```
(fcn) fcn.00401560 61
  fcn.00401560 (int arg_8h, int arg_ch, int arg_10h);
; arg int arg_8h @ ebp+0x8
; arg int arg_ch @ ebp+0xc
; arg int arg_10h @ ebp+0x10
0x00401560      push ebp
0x00401561      mov ebp, esp
0x00401563      push 0x12                                   ; 18
0x00401565      push 0x41bc88
0x0040156a      call decryption_function                    ; Decrypted: GetModuleFileNameW
0x0040156f      add esp, 8
0x00401572      push eax
0x00401573      push 1                                      ; 1
0x00401575      call load_ntdll_or_kernel32
0x0040157a      add esp, 4
0x0040157d      push eax
0x0040157e      call GetProcAddress ; 0x413164 ; "T\x99\x01"
0x00401584      mov dword [0x41dc04], eax                   ; [0x41dc04:4]=0
0x00401589      mov eax, dword [arg_10h]                    ; [0x10:4]=-1 ; 16
0x0040158c      push eax
0x0040158d      mov ecx, dword [arg_ch]                     ; [0xc:4]=-1 ; 12
0x00401590      push ecx
0x00401591      mov edx, dword [arg_8h]                     ; [0x8:4]=-1 ; 8
0x00401594      push edx
0x00401595      call dword [0x41dc04]
0x0040159b      pop ebp
0x0040159c      ret
```

Click to enlarge

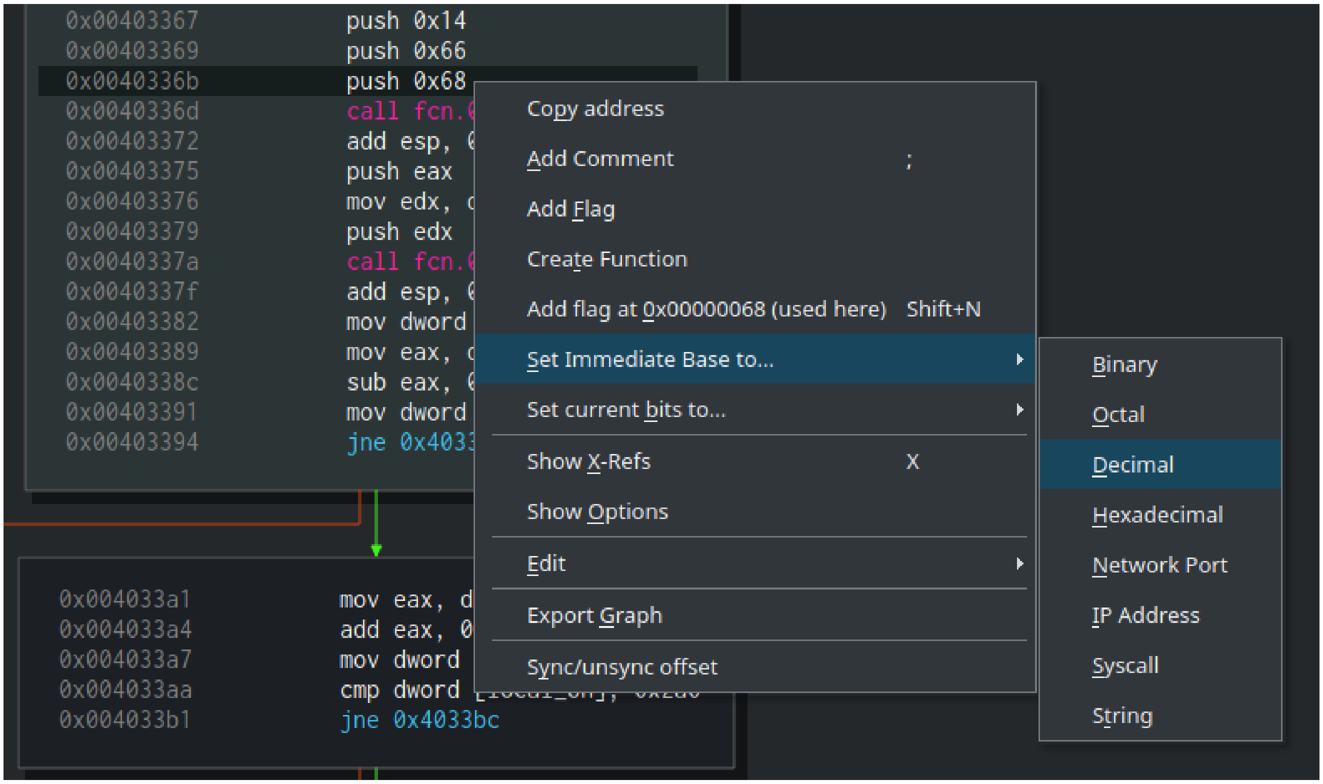
Hey! Look who's back! We can see the 2 functions we analyzed in the previous article: `decryption_function` and `load_ntdll_or_kernel32` . That's great! Also, you can notice the comment on `call decryption_function` which is telling us that the decrypted string is `GetModuleFileNameW` . This comment is the result of the r2pipe script we wrote.

In this function, `GetModuleFileNameW` will be decrypted, then Kernel32.dll will be loaded and `GetProcAddress` will be called to get the address of `GetModuleFileNameW` and then it will move it to `[0x41dc04]` . Later in this function, `[0x41dc04]` will be called.

Basically, this function is wrapper around `GetModuleFileNameW` , something which is common in Dropshot's code. Let's rename this function to `w_GetModuleFileNameW` where "w_" stands for "wrapper". Of course, you can choose whatever naming convention you prefer.

Right after the call to `w_GetModuleFileNameW` , Dropshot is using VirtualAlloc to allocate 20 (0x14) bytes, then there is a call to `fcn.00401a40` which is a function quite similar to memset, it is given with 3 arguments (*address, value* and *size*), just like `memset` and it is responsible to fill the range from `address` to `address+size` with the given `value` . Usually, along the program, this function is used to fill an allocated buffer with zeroes. This is quite strange to me, since VirtualAlloc is already "initializes the memory it allocates to zero". Let's name this function to `memset_` using Shift+N or via right click and move on.

Right after the program is zeroing-out the allocated memory, we see a call to another function – `fcn.00401c90`. We can see 3 arguments which are being passed to it, 0x14, 0x66, and 0x68. Since sometimes we prefer to see decimal numbers and not hex, let's use another useful trick of Cutter. Right-click on any of these hex numbers and choose "Set Immediate Base to…" and then select "Decimal".



Now we can see that the values which are being passed to `fcn.00401c90` are 20, 102 and 104. Looks familiar? 20 was the size of the buffer that was just allocated. 102 and 104 remind us the Resource name and type that used before (110 and 111). Are we dealing with resources here? Let's see.

Moving to the Resources widget again, we can see that there's indeed a resource named "102" which "104" is its type. And yes, it is 19B long, close enough 😉

`fcn.00401c90` is one of the key functions involved in the dropper functionality of Dropshot. The thing is, that this function is rather big and quite complicated when you don't know how to look at it. We'll get back to it in one minute but before that, I want to show you an approach I use while reverse engineering some pieces of code and while facing a chain of calls to functions which are probably related to each other.

First, we saw that 20 bytes were allocated by `VirtualAlloc` and the pointer to the allocated memory was moved to `[local_ch]`. Right after that, `memset_` was called in order to zero-out 20 bytes at `[local_ch]`, i.e to zero-out the allocated buffer. Immediately after, `fcn.00401c90` was called and 3 arguments were passed to it – 104, 102 and our beloved 20. We know that 102 is a name of a resource and its size is almost 20. We don't know yet what this function is doing but we know that its return value(`eax`) is being passed along with 2 more arguments to another function, `fcn.00401a80` . The other arguments are, you guessed right, 20 and the allocated buffer. A quick look at `fcn.00401a80` , which is a really tiny function, will reveal us that this function is copying a buffer to the allocated memory. This function is quite similar to memcpy so we'll rename it to `memcpy_` . So now we can do an educated guess and say that `fcn.00401c90` is reading a resource to a buffer and returns a pointer to it.

Using this approach, we can understand (or at least guess) a complicated function without even analyzing it. Just by looking at a programs chain of function calls, we can build the puzzle and save us important time.

That said, we'll still give this function a quick analysis because we want to be sure that we guessed right, and more importantly — because this is an interesting function.

Resource Parser

The next part is where things are getting more complicated. We'll start by going over `fcn.00401c90` pretty fast so try to follow. Also, you may want to make sure you fasten yourself since we are going on a rollercoaster ride through the PE structure.

Take a look at the first block of this function. You'll see one `call` and a lot of `mov` , `add` and calculation of offsets. This is how a typical PE parsing looks like.

```
/ (fcn) fcn.00401c90 468
|   fcn.00401c90 (int arg_8h, int arg_ch, int arg_10h);
|           0x00401c90          push ebp
|           0x00401c91          mov ebp, esp
|           0x00401c93          sub esp, 0x44
|           0x00401c96          mov dword [local_40h], 0
|           0x00401c9d          push 0
|           0x00401c9f          call GetModuleHandleW
|           0x00401ca5          mov dword [local_34h], eax
|           0x00401ca8          mov eax, dword [local_34h]
|           0x00401cab          mov dword [local_20h], eax
|           0x00401cae          mov ecx, dword [local_20h]
|           0x00401cb1          mov dword [local_24h], ecx
|           0x00401cb4          mov edx, dword [local_24h]
|           0x00401cb7          mov eax, dword [edx + 0x3c]
|           0x00401cba          add eax, dword [local_24h]
|           0x00401cbd          mov dword [local_38h], eax
|           0x00401cc0          mov ecx, dword [local_38h]
|           0x00401cc3          add ecx, 0x18
|           0x00401cc6          mov dword [local_3ch], ecx
|           0x00401cc9          mov edx, dword [local_3ch]
|           0x00401ccc          add edx, 0x60
|           0x00401ccf          mov dword [local_28h], edx
|           0x00401cd2          mov eax, 8
|           0x00401cd7          shl eax, 1
|           0x00401cd9          mov ecx, dword [local_28h]
|           0x00401cdc          mov edx, dword [ecx + eax]
|           0x00401cdf          mov dword [local_44h], edx
|           0x00401ce2          mov eax, 8
|           0x00401ce7          shl eax, 1
|           0x00401ce9          mov ecx, dword [local_28h]
|           0x00401cec          mov edx, dword [local_20h]
|           0x00401cef          add edx, dword [ecx + eax]
|           0x00401cf2          mov dword [local_10h], edx
|           0x00401cf5          mov eax, dword [local_10h]
|           0x00401cf8          mov dword [local_4h], eax
|           0x00401cfb          mov ecx, dword [local_4h]
|           0x00401cfe          movzx edx, word [ecx + 0xe]
|           0x00401d02          mov eax, dword [local_4h]
|           0x00401d05          movzx ecx, word [eax + 0xc]
|           0x00401d09          add edx, ecx
|           0x00401d0b          mov dword [local_ch], edx
|           0x00401d0e          mov dword [local_14h], 0
|       ,=< 0x00401d15          jmp 0x401d20
...
...
```

At first, a handle to the current process is received using `GetModuleHandleW`. Then, the handle (`eax`) is being moved to a variety of local variables. First, it is being moved to `[local_34h]` at `0x00401ca5`. Then you can see `eax` moved to `[local_20h]` which is later being moved to `[local_24h]` using `ecx`.

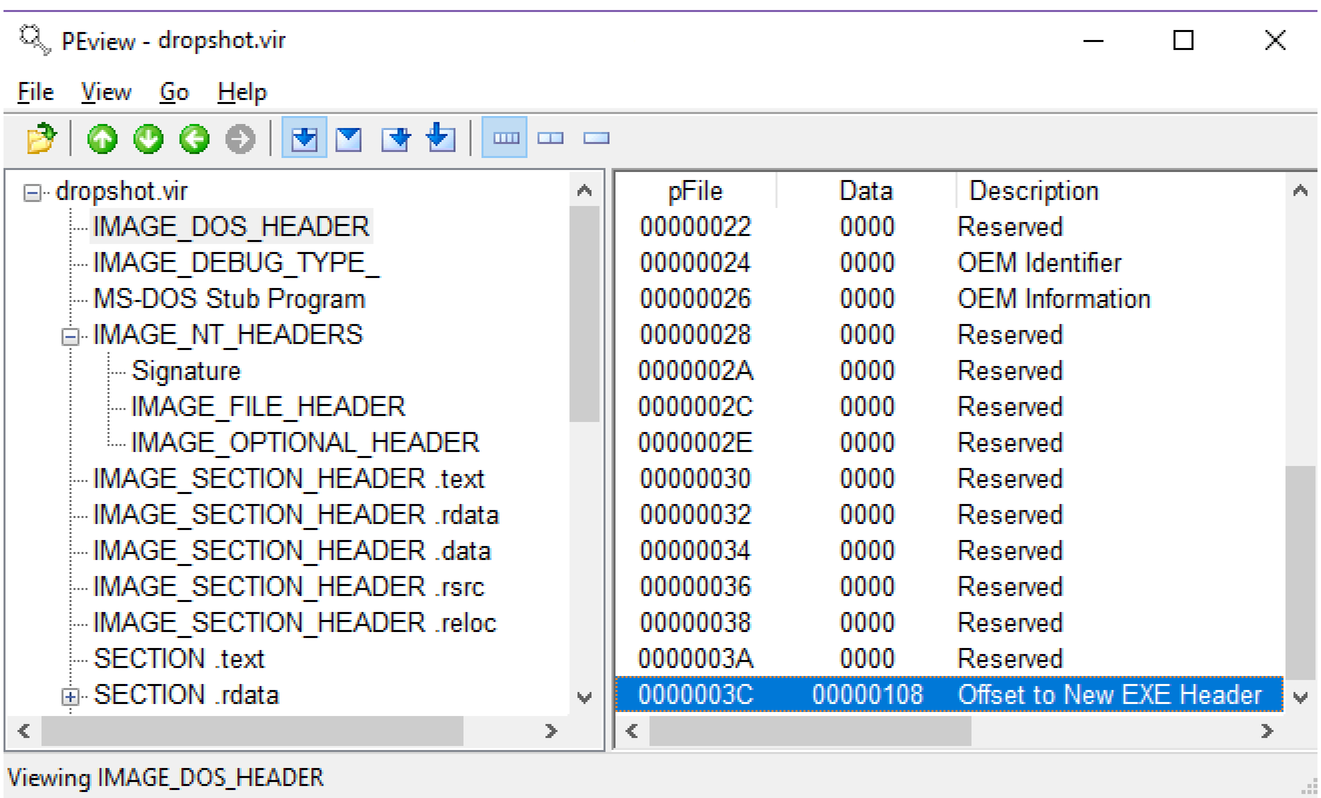
So basically we have a bunch of local variables that currently hold the handle `hmodule`. We can rename all three variables to `[hmodule_x]` so it'll be easier to keep track of all the reference to `hmodule`. To rename flags you can use the Console widget and just execute `afvn old_name new_name`. For example, I executed: `afvn local_34h hmodule_1; afvn local_20h hmodule_2; afvn local_24h hmodule_3`.

`GetModuleHandle` returns a handle to a mapped module, this basically means that our `hmodule`s point to our binary's base address. In line `0x00401cb4` we can see that `[hmodule_3]` is moved to `edx`, then the value at `[edx + 0x3c]` is being moved to `eax` and `[hmodule_3]` is added to it at `0x00401cba`. Finally, `eax` is moved to `[local_38h]`. To put it simply, we can use the following pseudo-code:

```
[local_38h] = (BYTE*)hmodule + *(hmodule + 0x3c)
```

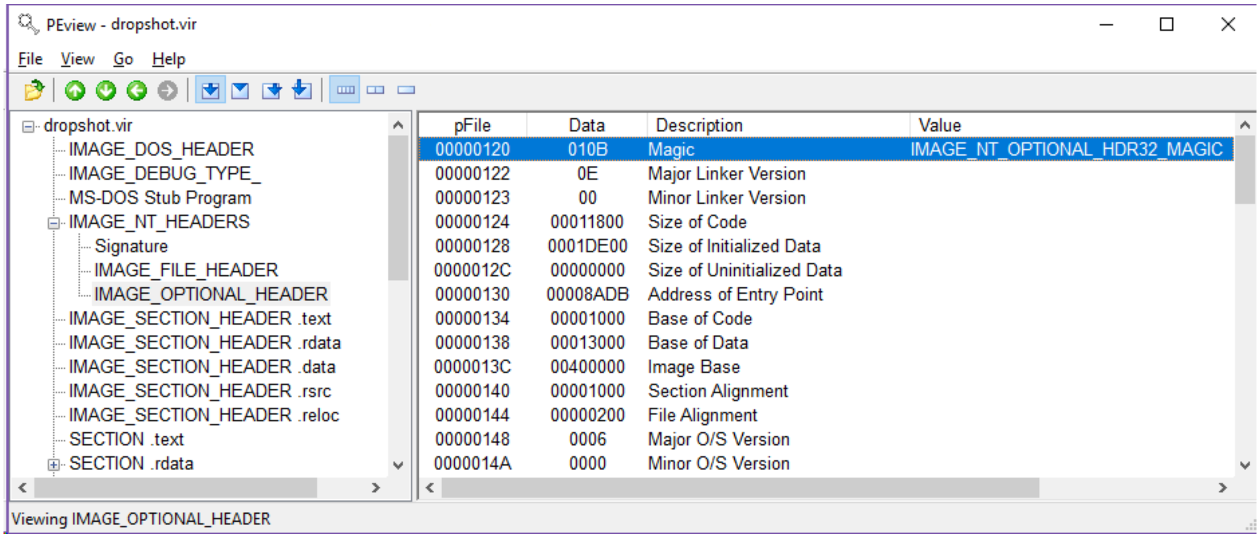
So what's in this address? Use your favorite binary structure viewer to find out. In this example, I'll use PEview but you can use any other program you prefer – including the binary structure parsing feature of radare2, if you're already a radare2 pro (see `pf?`).

Open Dropshot in PEview and inspect the DOS Header:



As you can see, in offset `0x3c` there is a pointer (0x108) to the offset to the new EXE Header which is basically the IMAGE_NT_HEADER. Awesome! So `[local_38h]` holds the address of the NT Header. Let's rename it to `NT_HEADER` and move on.

At address `0x00401cc0` we can see that `NT_HEADER` is moved to `ecx` and then the program is adding 0x18 to `ecx`. Last, the value in `ecx` is moved to `[local_3ch]`. Just as before, let's open again our PE parser and check what is in `NT_HEADER + 0x18`. Adding 0x18 to 0x108 will give us 0x120. Let's see what is in this offset:

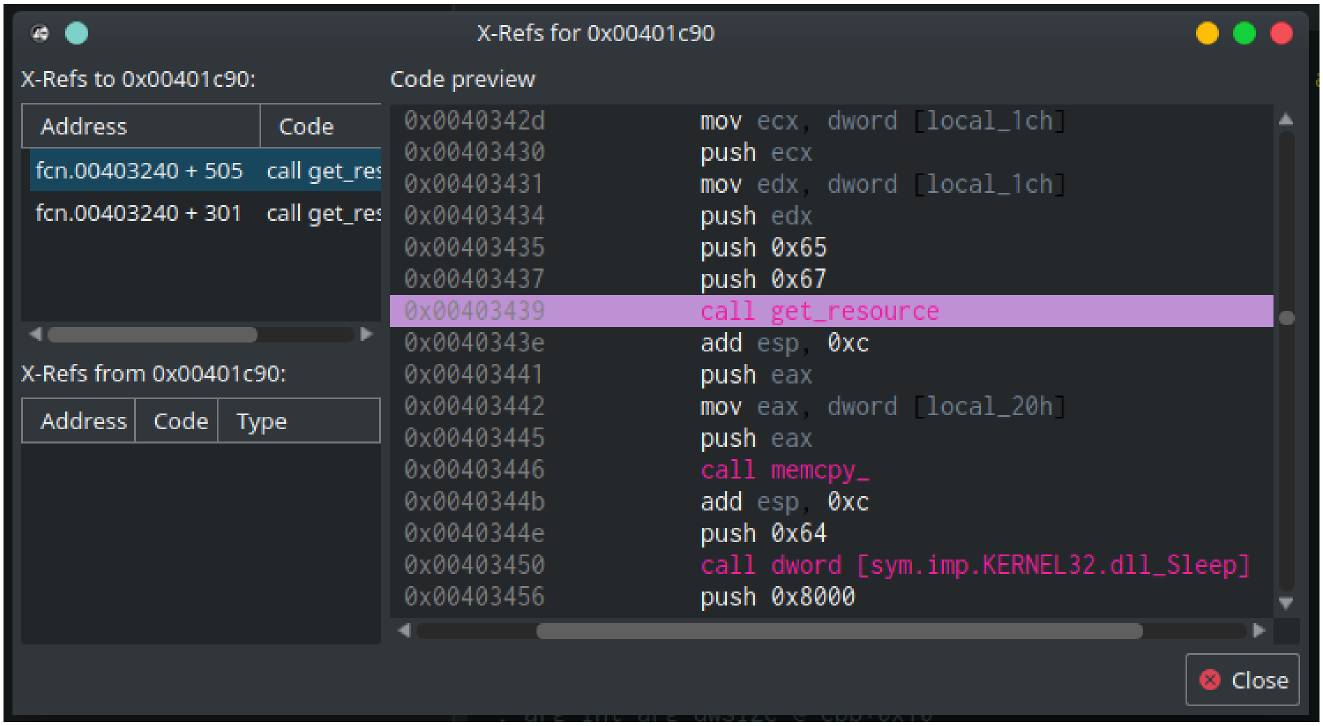


Click to enlarge

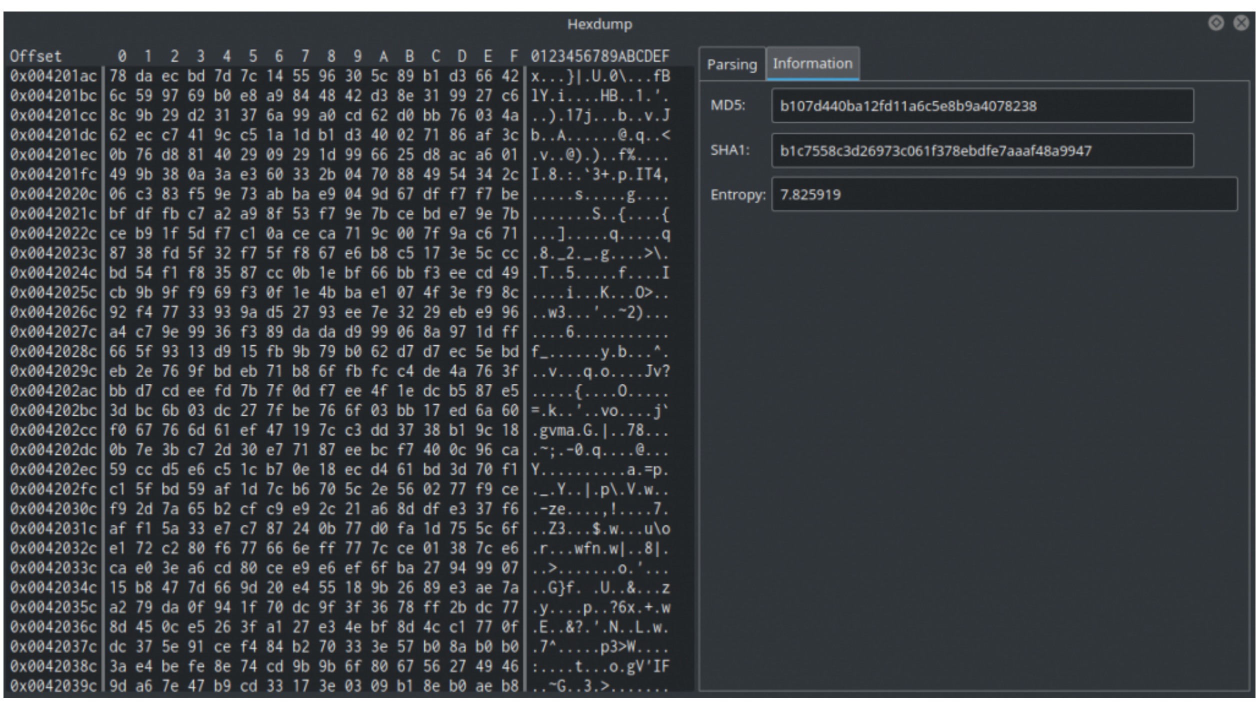
Nice! 0x120 is the offset of the IMAGE_OPTIONAL_HEADER as can be seen in the image above. Let's rename `local_3ch` to `OPTIONAL_HEADER`. To cut a *long story short*, Dropshot is then parsing the IMAGE_DATA_DIRECTORY structure (OPTIONAL_HEADER + 0x60), the RESOURCE_TABLE, and last it iterates through the different resources and compares the resource type and the resource name to the function's arguments. Finally, it uses `memcpy_` to copy the content of the required resource to a variable and returns this variable.

Now we can rename the function to `get_resource` and the arguments to the corresponding meaning of them by executing `afvn arg_8h arg_rsrc_type; afvn arg_ch arg_rsrc_name; afvn arg_10h arg_dwsize`.

Now that we are sure about what this function does, we can see where else it is referenced. Right-click on the function and choosing "Show X-Refs" (or simply pressing 'x') will take us to the X-Refs window. We can see that `get_resource` is being called from two locations. One (`0x0040336d`) is already familiar to us, it is called to get resource "102". The second call (at `0x00403439`), a few instructions later, is new to us — it is called to get the content of another resource, named "101" (0x65).



Remember the screenshot of the Resources widget from before? We can see there the resource named “101”. What makes “101” so interesting is that it is **much** bigger than the other — its size is 69.6 KB! This is Dropshot’s payload. By going to the Resources widget and double-clicking “101” will take us to the resource’s offset in the binary. In the Hexdump widget, we can see that the content of this resource makes no sense and has a really high entropy (7.8 out of the maximum 8):



Click to enlarge

This data is compressed/encrypted somehow so we need to decrypt it. Let's continue our analysis to find out how.

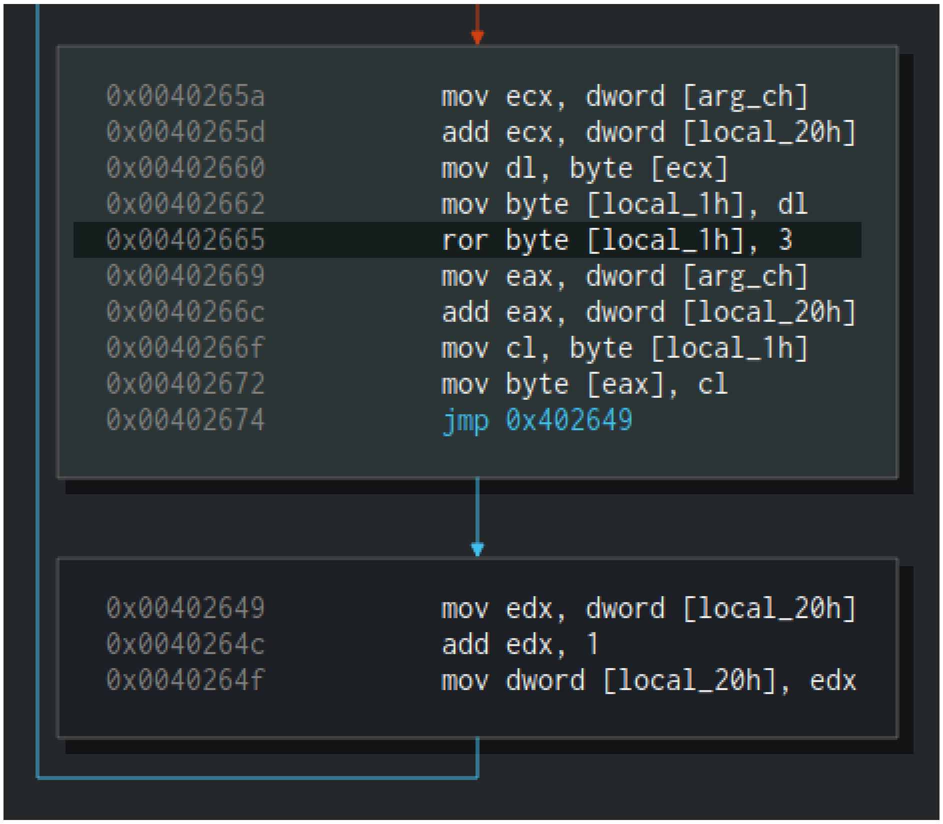
How To Decrypt The Resource

In order to decrypt the resource, we should follow the program's flow to see how and where the payload is being used. Right after `get_resource` is being called with "101" and "103", the resource is copied to `[local_20h]` using `memcpy_` (at `0x00403446`). Let's call it `compressed_payload`. The compressed buffer is then passed to `fcn.00401e70` which is a function that performs dummy math calculations on the resource's data. Probably another Anti-Emulation technique or simply a way to waste our time. I'll rename it to `dummy_math`. Next, `compressed_payload` is being passed to `fcn.00401ef0` along with another buffer `[local_54h]`.

The analysis of this function is out of the scope of this article but this function is responsible to decompress a buffer using zlib and put the decompressed buffer in `[local_54h]`. You can see, for example, that `fcn.00401ef0` is calling to `fcn.004072f0` which contains strings like "unknown compression method" and "invalid window size" which can be found in the file inflate.c in the zlib repository. I renamed `fcn.00401ef0` to `zlib_decompress` and `local_54h` to `decompressed_payload`.

I'll tell you now that simply a decompression of the buffer isn't enough since there's still another simple decryption to do. Straight after the decompressing, we can see more of the Anti-Emulation which we are already familiar with. Finally, our decompressed buffer is being passed to `fcn.00402620`. This function is responsible for the last decryption of the resource and then it performs a notorious technique known as "Process Hollowing" or "RunPE" in order to execute the decrypted payload.

So how `fcn.00402620` decrypts the decompressed payload? Simply, it uses `ror 3` to rotate-right each byte in the decompressed buffer. 3 stands for the number of bits to rotate.



The rest of this function is interesting as well but it has nothing to do with decrypting the resource so I'll leave it to you.

To sum things up, and before we adding the logic for the resource decryption inside the script we wrote in the previous article – let's sketch how the decryption function should look like. It should be something like this:

```
rsrc_101 = get_resource("101")

decompressed_payload = decompress(rsrc_101)

decrypted_payload = []

for b in decompressed_payload:
   decrypted_payload.append(ror3(b))
```

Scripting time! Decrypting the resource

Scripting radare2 is really easy thanks to r2pipe. It is the best programming interface for radare2.

> The r2pipe APIs are based on a single r2 primitive found behind `r_core_cmd_str()` which is a function that accepts a string parameter describing the r2 command to run and returns a string with the result.

r2pipe supports many programming languages including Python, NodeJS, Rust, C, and others.

Luckily, Cutter is coming with the python bindings of `r2pipe` integrated into its Jupyter component. We'll write an r2pipe script that will do the following:

- Save the compressed resource into a variable
- Decompress the resource using zlib
- Perform ror3 on each byte in the decompressed payload
- Save the decrypted resource to a file

Just as in the previous part, let's go to the Jupyter widget and open the script we wrote when decrypted the strings (part1).

The first thing to do is to read the content of the encrypted and compressed resource to a file:

```
rsrcs = cutter.cmdj('iRj')
rsrc_101 = {}

# Locate resource 101 and dump it to an array
for rsrc in rsrcs:
    if rsrc['name'] == 101:
        rsrc_101 = cutter.cmdj("pxj %d @ %d" %
                               (rsrc['size'], rsrc['vaddr']))
```

> `iR` was used to get the list of resources and their offsets in the file. Next, we iterate through the different resources untill we find a resource named "101". Last, using `px` we are reading the resource's bytes into a varibale. We appended `j` to the commands in order to get their output as JSON.

Next, we want to decompress the buffer using zlib. Python is coming with "zlib" library by default which is great news for us. Add `import zlib` to the top of the script and use this code to decompress the buffer:

```
# Decompress the zlibbed array
decompressed_data = zlib.decompress(bytes(rsrc_101))
```

Now that our buffer is decompressed in `decompressed_data`, all we left to do is to perform right rotation on the data and save it to a file.

Define the following `ror` lambda:

```
def ror(val, r_bits, max_bits): return \
    ((val & (2**max_bits-1)) >> r_bits % max_bits) | \
    (val << (max_bits-(r_bits % max_bits)) & (2**max_bits-1))
```

And use it in your code like this:

```
decrypted_payload = []

# Decrypt the payload
for b in decompressed_data:
    decrypted_payload.append((ror(b, 3, 8)))
```

Last, save it to a file:

```
# Write the payload (a PE binary) to a file
open(r'./decrypted_rsrc.bin', 'wb').write(bytearray(decrypted_payload))
```

Now let's combine the script from the previous article to the one we created now and test it in Jupyter. The combined script should first decode the encrypted scripts, and then it should decrypt the resource and save it to the disk.

The final script can be found here.

Copy it and paste it into your Jupyter notebook. You can also execute your version of the code to see if you got it right by yourself.

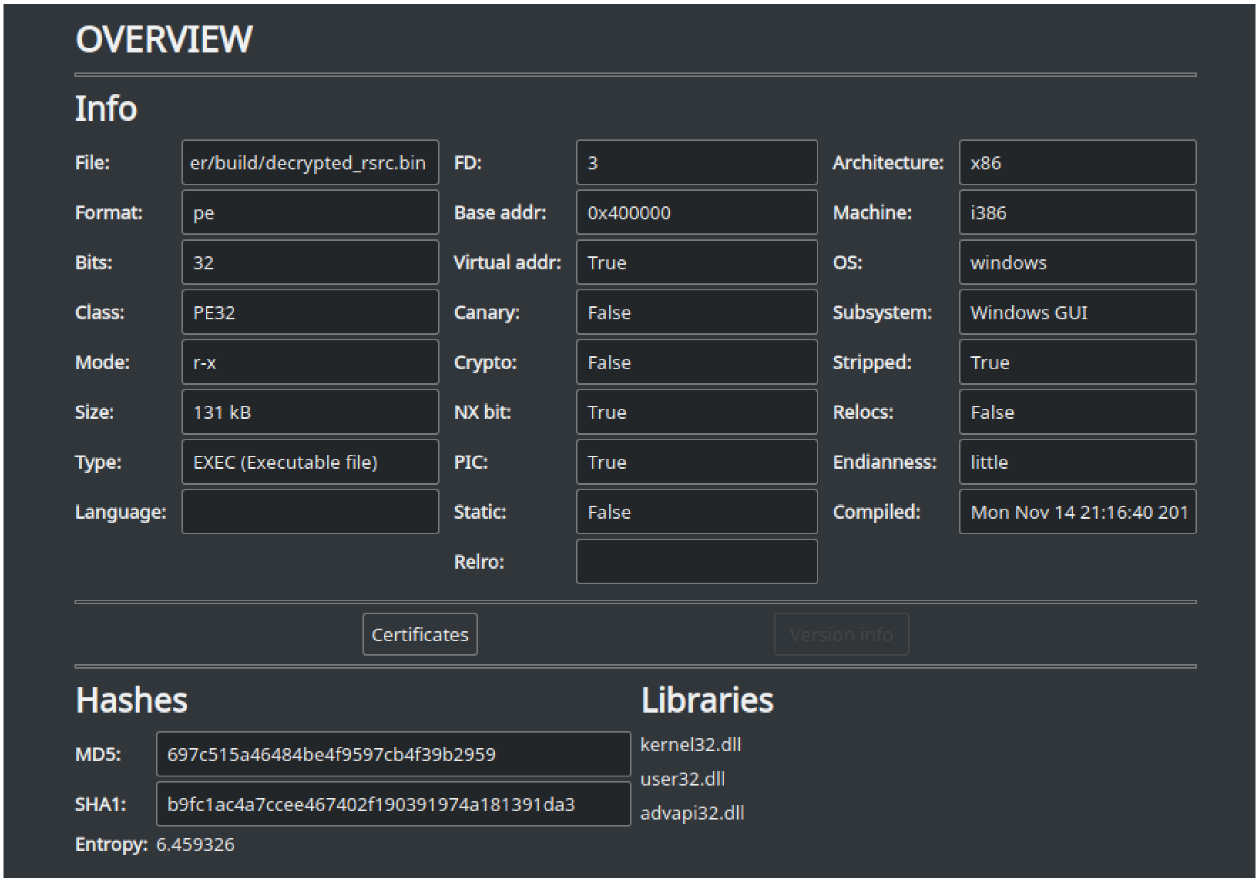
```
decode_strings()
decrypt_resource()

# Refresh the interface to load changes
cutter.refresh()
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    Starting the decode of the encrypted strings
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~


Kernel32.dll @ 0x4013c3
ntdll.dll @ 0x4013de
ZwResumeThread @ 0x40140a
ZwClose @ 0x40144a
ZwGetContextThread @ 0x40148a
NtSetContextThread @ 0x4014ca
CreateProcessW @ 0x40150a
GetModuleFileNameW @ 0x40156a
CreateFileW @ 0x4015aa
ReadFile @ 0x4015fa
WriteProcessMemory @ 0x40164a
Shell32.dll @ 0x40169b
SHGetSpecialFolderPathW @ 0x4016b4
Advapi32.dll @ 0x4016fb
RegOpenKeyW @ 0x401714
Advapi32.dll @ 0x40175b
RegCloseKey @ 0x401774
DeleteFileW @ 0x4017aa
Advapi32.dll @ 0x4017eb
RegQueryInfoKeyW @ 0x401804
Advapi32.dll @ 0x40186b
RegQueryValueExW @ 0x401884
GetTempPathW @ 0x4018ca
NtWriteVirtualMemory @ 0x40190a
WriteFile @ 0x40195a
RtlSetProcessIsCritical @ 0x4019aa
Psapi.dll @ 0x4019eb
GetModuleBaseNameA @ 0x401a04
OK @ 0x4039c7

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    Starting the decryption of the resource
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Saved the PE to ./decrypted_rsrc.bin
```

In [ ]:

Seems like our script was executed successfully and “Saved the PE to ./decrypted_rsrc.bin”. Great!

The last thing we want to do is to open `decrypted_rsrc.bin` in a new instance of Cutter in order to verify that this is indeed a PE file and that we didn't corrupt the file in some way.



Click to enlarge

Awesome! Cutter recognized the file as PE and seems like the code is correctly interpreted. This binary we just decrypted and saved is the Wiper module of Dropshot – a quite interesting piece of malware on its own. This module, just as its dropper, is using heavy anti-emulation and similar technique to decrypt its strings. You can give it a try and analyze it on your own using Cutter, radare2, and r2pipe. Good Luck!

Epilogue

Here comes to an end the second and the last part of this series about decrypting Dropshot with Cutter and r2pipe. We got familiar with Cutter, radare2 GUI, and wrote a decryption script in r2pipe's Python binding. We also analyzed some components of APT33's Dropshot, an advanced malware.

As always, please post comments to this post or message me privately if something is wrong, not accurate, needs further explanation or you simply don't get it. Don't hesitate to share your thoughts with me.

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