Dancing With Shellcodes: Cracking the latest version of Guloader

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Guloader is a downloader that has been active since 2019. It is known to deliver various malware, more notably: Agent-Tesla, Netwire, FormBook, Nanocore, and Parallax RAT.

The malware architecture consists of a VB wrapper and a shellcode that does all the malicious activities of Guloader. Although many malware use crypters that have shellcode in their initial droppers, the Guloader shellcode is notorious for its anti-analysis capabilities; thus making the unpacking mechanism of Guloader much more challenging.

The majority of the anti-analysis functionality of Guloader is already published by several security researchers. However, for researchers who are not 100% familiar with the Guloader shellcode, it could be challenging to predict where these features are located, which might lead to failure in analysis.

In this article, I will present a step-by-step dynamic analysis of Guloader. As well, the malware anti-analysis functions, and how to overcome them.
Also, I will demonstrate the malware's main objectives.

Note- Guloader heavily uses time checks and other traditional anti-analysis techniques. Therefore, to save time, in this analysis I will use the ScyllaHide plugin.

Also, several of the Guloader's anti-analysis techniques are impossible to evade without manual intervention. So I will mainly (but not only) focus on them.

File metadata

Hash: d55259bcf47af7e645ab7b003aa2cd4071cb36c6

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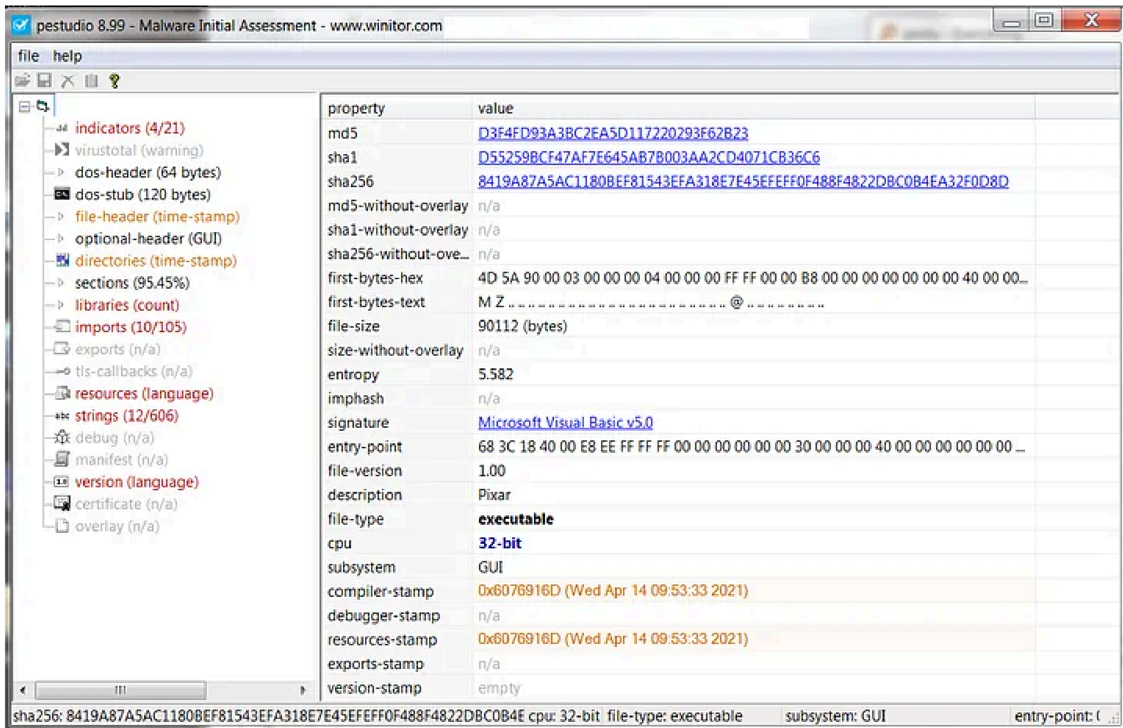

Sample metadata in Pestudio

Getting into the shellcode

In its initial state, Guloader is wrapped with a VB. To overcome it, we'll first reach the entry point and then set a breakpoint on VirtualAlloc. Next, we will click Run 12 times (the VB wrapper calls several times to VirtualAlloc, but we only care about the 12th time).

As we return to user code from the 12th VirtualAlloc, we will see the next image

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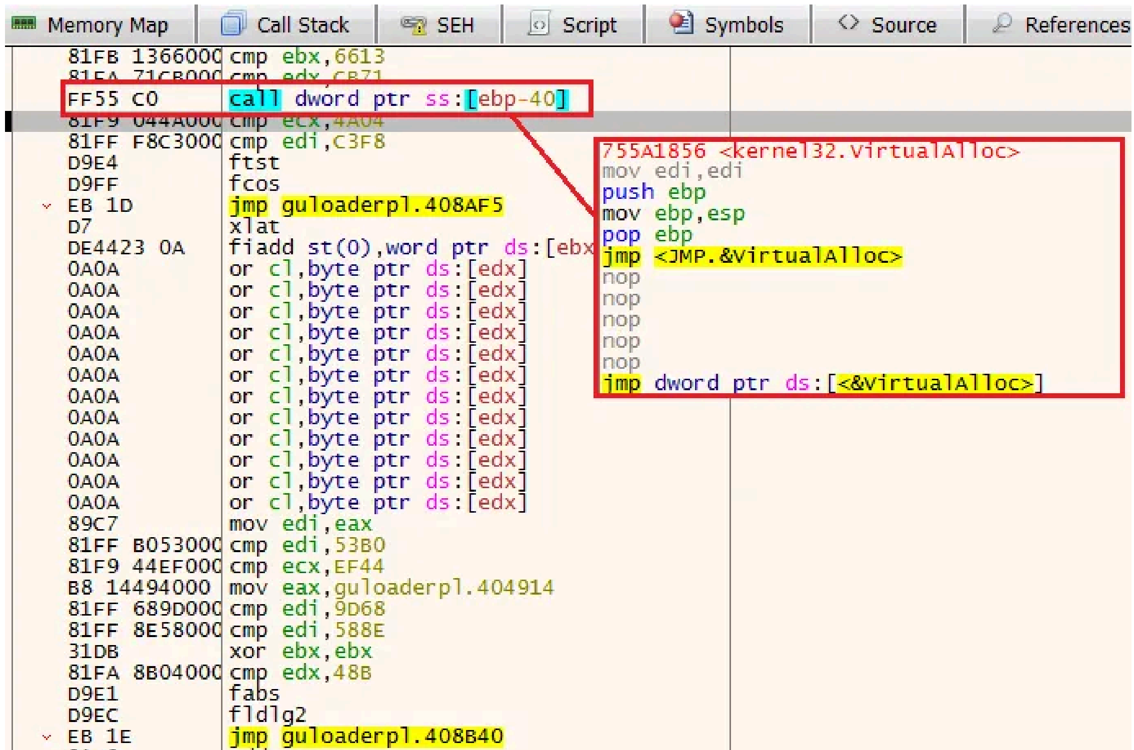
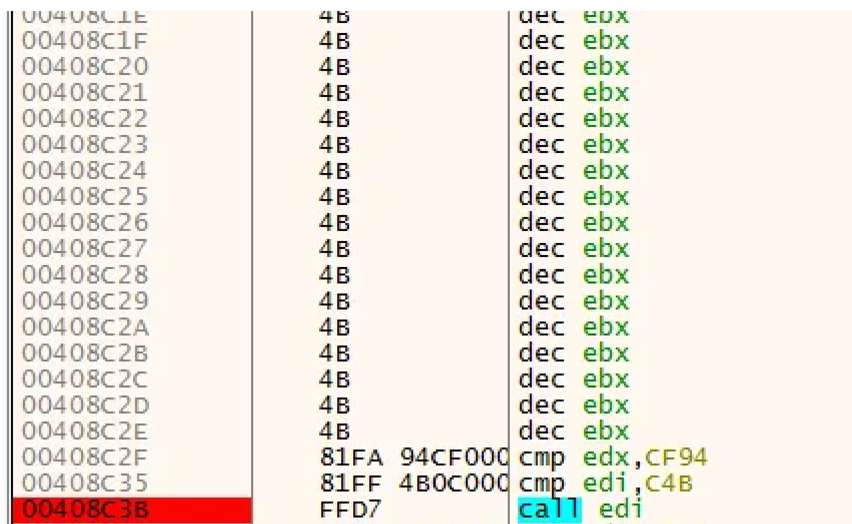


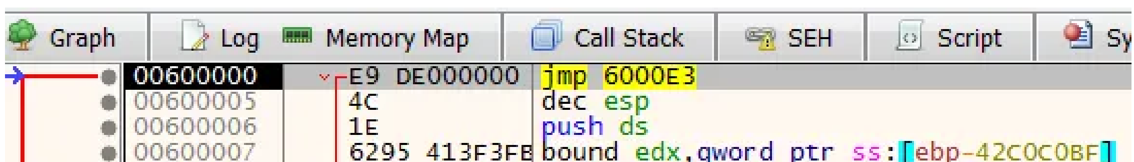
12th VirtualAlloc

Now, Guloader will write the shellcode to this newly allocated memory - The process consists of several JMP instructions. Scroll down until you'll see a CALL to the register EDI (the place where the shellcode is eventually stored). Taking this CALL will lead us to the shellcode itself.



Call the shellcode

Immediately after taking the CALL to EDI, we'll see a jump to another location. Take this jump as well.



Take the jump

The shellcode

After taking the initial jump, we see three different functions. For our unpacking tutorial, we can skip them and go straight to the JMP 602766, located at the end.

```
Graph | Log | Notes | Breakpoints | Memory Map | Call Stack
006000E3   66:39C9         cmp cx,cx
006000E6   A9 5EE65AC0     test eax,C05AE65E
006000EB   81EC 0002000    sub esp,200
006000F1   F6C6 95         test dh,95
006000F4   55              push ebp
006000F5   38E5            cmp ch,ah
006000F7   F6C7 8A         test bh,8A
006000FA   89E5            mov ebp,esp
006000FC   66:39C3         cmp bx,ax
006000FF   84FD            test ch,bh
00600101   66:F7C6 7C23    test si,237C
00600106   38C2            cmp dl,al
00600108   E8 00000000     call 60010D                      call $0
0060010D   66:39C8         cmp ax,cx
00600110   F7C1 69335D2    test ecx,2F5D3369
00600116   8F45 44         pop dword ptr ss:[ebp+44]
00600119   85C8            test eax,ecx
0060011B   81FA CAA40F8    cmp edx,810FA4CA
00600121   FF75 44         push dword ptr ss:[ebp+44]
00600124   90              nop
00600125   E8 381D0000     call 601E62
0060012A   8945 44         mov dword ptr ss:[ebp+44],eax
0060012D   D9D0            fnop
0060012F   84C3            test bl,al
00600131   66:F7C1 79C3    test cx,C379
00600136   E8 71360000     call 6037AC
0060013B   38E5            cmp ch,ah
0060013D   85D8            test eax,ebx
0060013F   E9 22260000     jmp 602766
```

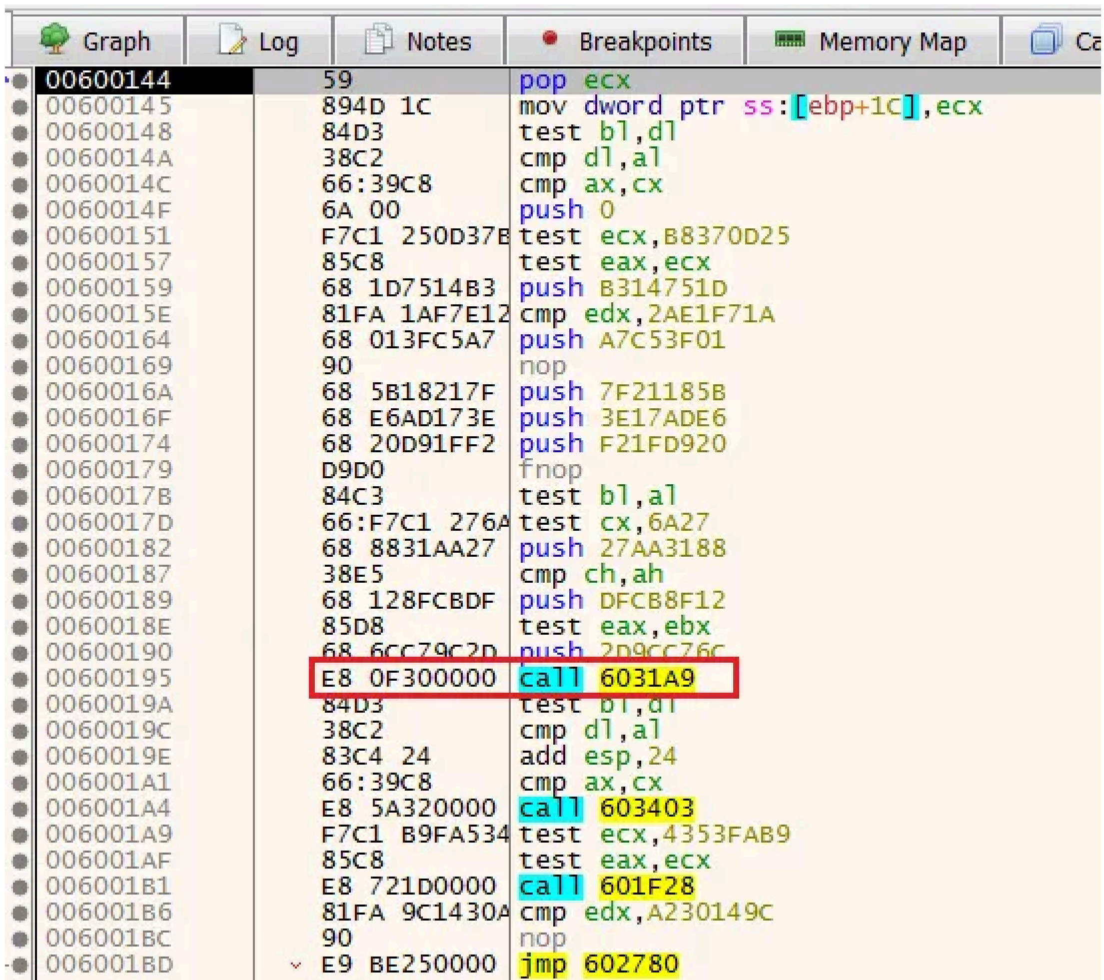
Take the jump

After taking the jump, we see an immediate CALL to 600144, step into it.

```
Graph | Log | Notes | Breakpoints | Memory Map
00602766   E8 D9D9FFFF     call 600144
0060276B   0E              outsb
0060276C   74 64           je 6027D2
0060276E   6C              insb
0060276F   6C              insb
```

Step into

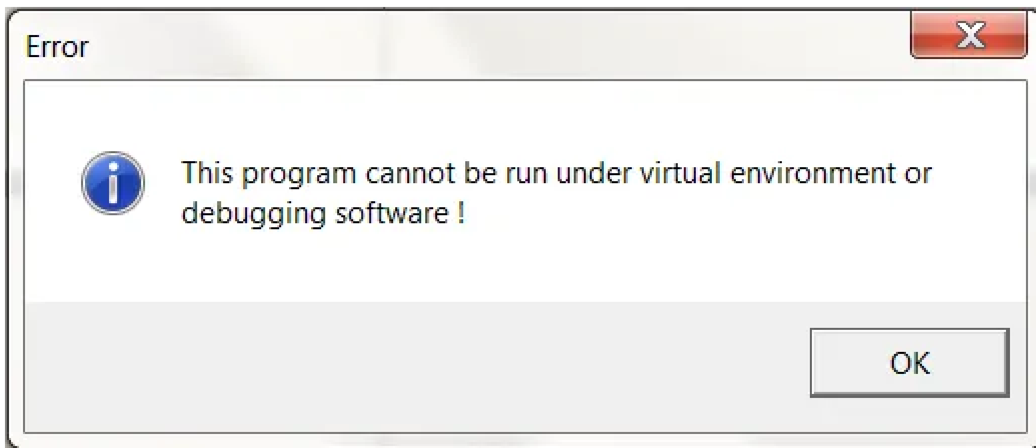
Now, we see several functions and a JMP at the end. Also, we see that the first function is 6013A9.



Anti VM function

Anti-Analysis 1: Anti-VM

To our surprise, when we will try to step over the CALL to function 6031A9 we encounter the following message box.



Gotcha

Why did it happen?

Without paying attention, the shellcode pushed 8 pre-computed hashes into the stack, in the following order:

push 0xB314751D

push 0xA7C53F01

push 0x7F21185B

push 0x3E17ADE6

push 0xF21FD920

push 0x27AA3188

push 0xDFCB8F12

push 0x2D9CC76C

These hashes will be used by the function 6031A9 in the following manner:

1) The function will use the API call ZwQueryVirtualMemory (the kernel equivalent of VirtualQuery) to scan the process's memory.

2) The pre-computed hashes will be calculated using the djb2 algorithm. Each one of them will represent a string that is related to a Virtual Machine product (for example *0xB314751D* represents "vmtoolsdControlWndClass").

3) If one of these strings will be found by the ZwQueryVirtualMemory, the process will create the previously mentioned message box.

How we overcome this anti-VM technique?

There are three different approaches we can take:

1) The first approach is to change the pre-computed hashes on the stack before the call to 6031A9.

2) Fill the CALL line with no operation (NOP)

3) Change the control flow by redirecting the EIP register to contain the address of the next instruction (after the CALL to 6031A9)

For this example, I took the first approach and changed the hashes suffix to "22".

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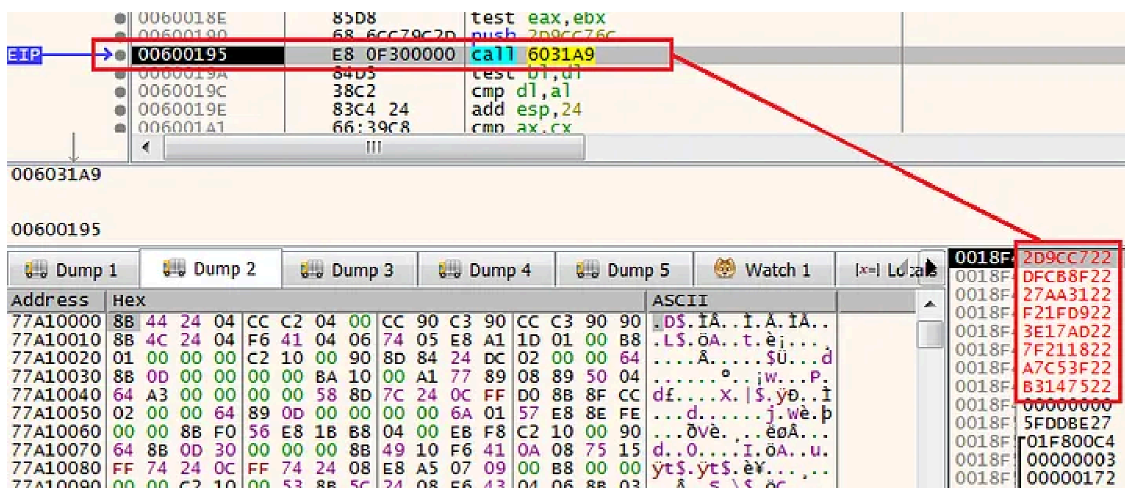


Changing the hashes on the stack

As we continue to step over to the next functions, we encounter the function 601F28, which is 2 functions below 6031A9 (the anti-VM function).

Anti-Analysis 2: Time checks & CPUID

If we will try to step over this function, we'll see that we are stuck and can't move forward.

```
00600195  E8 0F300000   call 6031A9
0060019A  84D3          test bl,dl
0060019C  38C2          cmp dl,al
0060019E  83C4 24       add esp,24
006001A1  66:39C8       cmp ax,cx
006001A4  E8 5A320000   call 603403
006001A9  F7C1 B9FA534  test ecx,4353FAB9
006001AF  85C8          test eax,ecx
006001B1  E8 721D0000   call 601F28
```

Anti-Analysis function

Why did it happen?

Inside the function 601F28, there is another routine that consists of two anti-analysis mechanisms. Time cheks using RDTSC (Read Time-Stamp Counter), and anti-VM using CPUID.

```
01CF1ED8  66:39D9       cmp cx,bx
01CF1EDB  80FF 8B       cmp bh,8B
01CF1EDE  51            push ecx
01CF1EDF  E8 1F000000   call 1CF1F03
01CF1EE4  F7C1 233D764  test ecx,46763D23
01CF1EEA  59            pop ecx
01CF1EEB  85C8          test eax,ecx
01CF1EED  01D7          add edi,edx
01CF1EEF  49            dec ecx
01CF1EF0  83F9 00       cmp ecx,0
01CF1EF3  75 E6         jne 1CF1EDB
01CF1EF5  81FF C0E1E40  cmp edi,E4E1C0
01CF1EFB  7D D1         jge 1CF1ECE
01CF1EFD  38D2          cmp dl,dl
01CF1EFF  C3            ret
01CF1F00  66:85CA       test dx,cx
01CF1F03  E8 13000000   call 1CF1F1B
01CF1F08  89D6          mov esi,edx
01CF1F0A  60            pushad
01CF1F0B  0F31          rdtsc
01CF1F0D  31C0          xor eax,eax
01CF1F0F  40            inc eax
01CF1F10  0FA2          cpuid
01CF1F12  61            popad
01CF1F13  E8 03000000   call 1CF1F1B
01CF1F18  29F2          sub edx,esi
01CF1F1A  C3            ret
```

Anti-Analysis function

How we overcome this anti-analysis?

Similar to the first anti-VM, we can change the control flow with the EIP register, or fill the line of the CALL to 601F28 with NOPS.

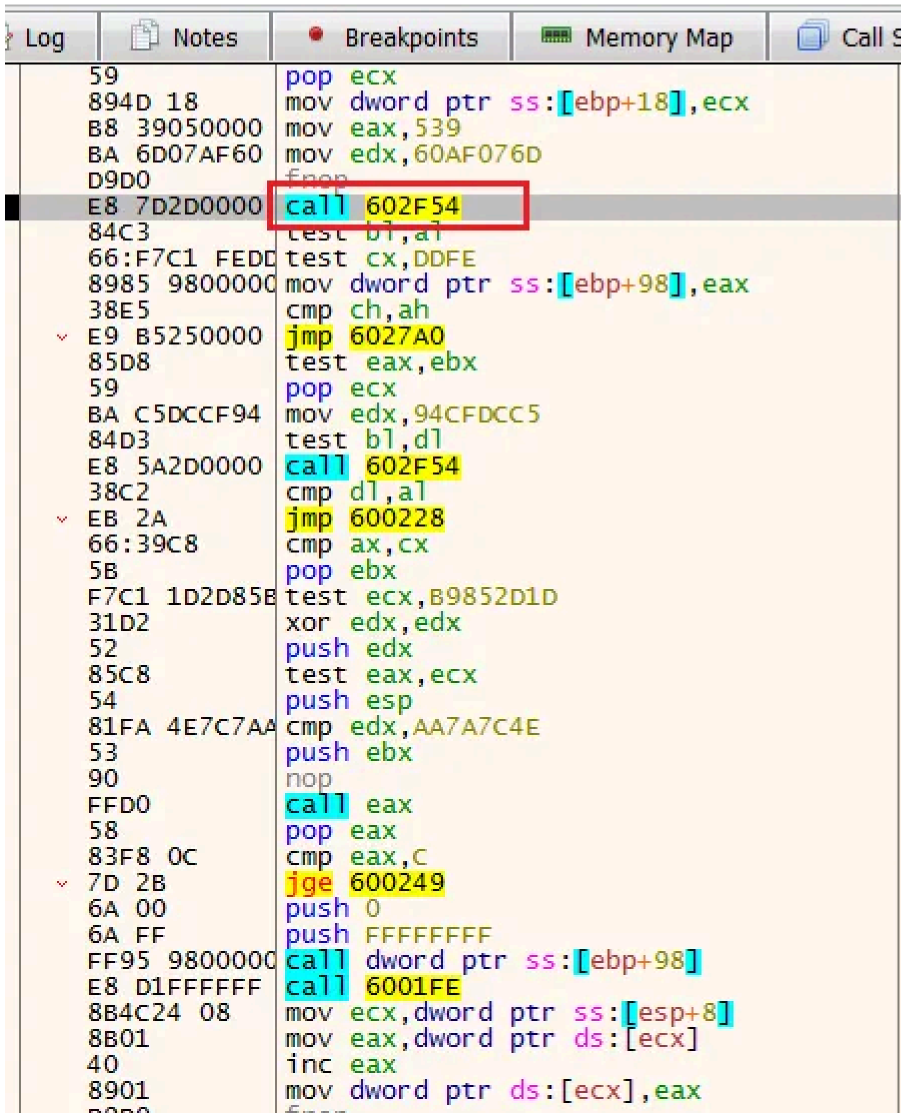
After choosing our preferred method, we can go to the next JMP instruction.

NOP the function

After taking the jump, we immediately find ourselves in another CALL to a function called 6001C2, step into it.

Step Into

Next, we see a function named 602F54 that will take a big role in the main functionality of the shellcode.
This function is responsible for accessing the process environment block (PEB) and returning an API call.
We also see a direct call to the register EAX - something that is always interesting to inspect when we are dealing with shellcodes.



Resolving API Calls

When we step over 602F54, we see that it returns the API call TerminateProcess. Then, we'll take a jump to 6027A0.

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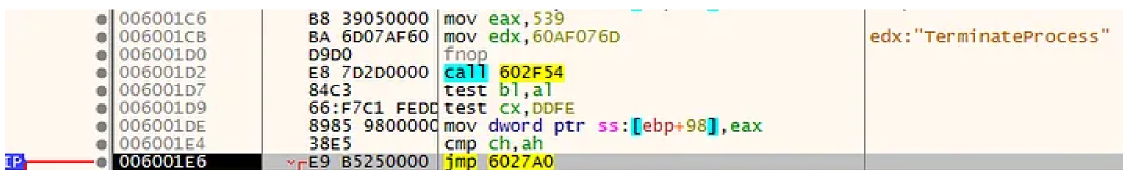
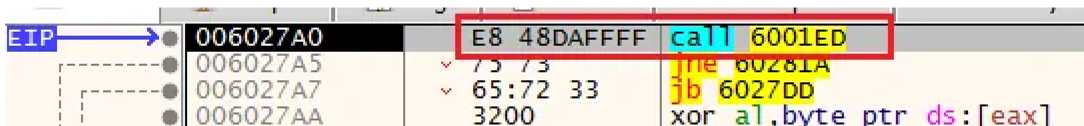


Take the jump

After taking the jump, we find ourselves in a call to the function 6001ED.



Step Into

After stepping into this function, we see that we in a location that will call directly to the register EAX. Now, this register holds the API call EnumWindows (Enumerates all top-level windows on the screen).

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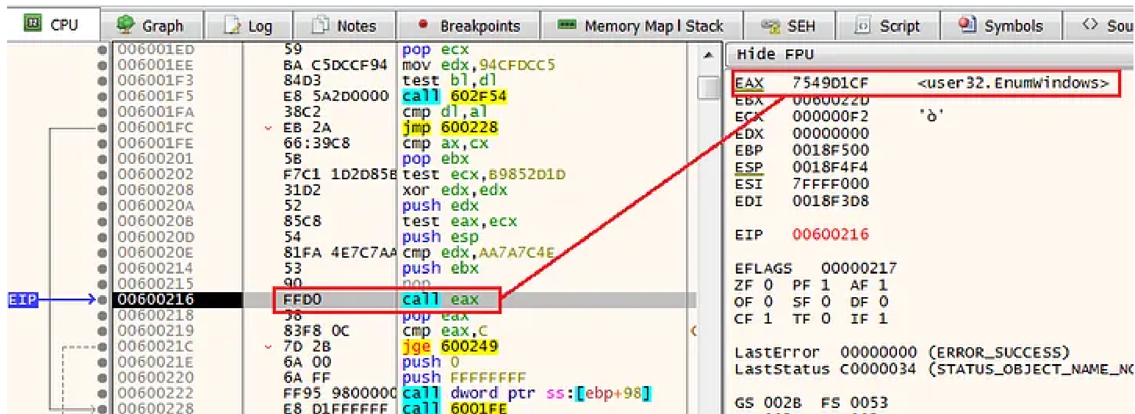
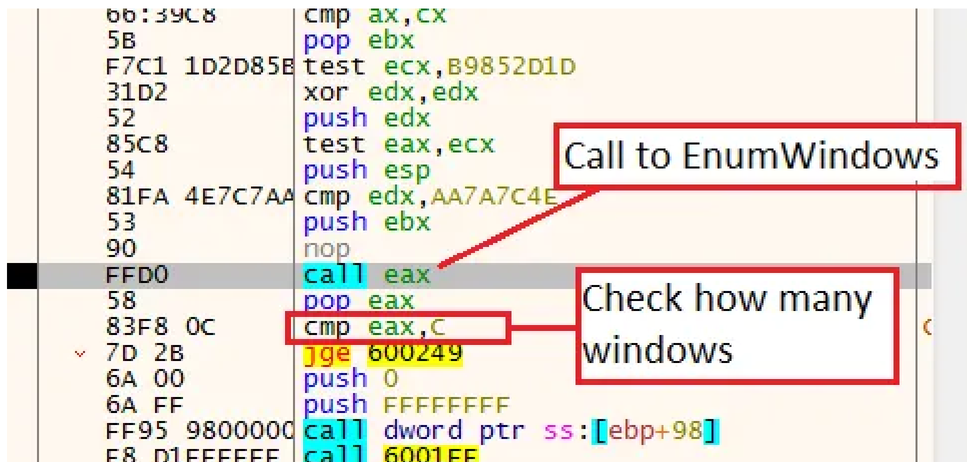


EnumWindows

Anti-Analysis 3: Anti-VM\Anti-Sandbox

After we step over the call to *EnumWindows*, we see the line: *cmp eax,c*.
Using this line the shellcode determines if there are at least 12 (C in hexadecimal) windows in the machine. If not, the process will be terminated using the previously mentioned API call - TerminateProcess.



Check for at least 12 windows

How we overcome this anti-sandbox?

Switch the flag in the JGE jump if necessary, however, I did not have any issues with it.

As we continue with the normal execution of the shellcode, we see more instances of the function 602F54, one of these instances resolves the function *ZwProtectVirtualMemory* (the kernel equivalent of *VirtualProtect*).
Right after, we'll see multiple Push 0 instructions and a CALL to the function 6034F4.

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Getting into the Anti-breakpoint function

Anti-Analysis 4: Anti breakpoints

When we step into this function, we observe an interesting anti-debugging technique. In its first lines, the shellcode gets the function DbgBreakPoint and store it on esp+18.

```
mov ecx,dword ptr ss:[ebp+1C]      [ebp+1C]:"ntdll"
mov edx,321C9581                   edx:"DbgBreakPoint"
cmp cx,bx
call 292F54
test bx,bx
mov dword ptr ss:[esp+18],eax
```

Getting DbgBreakPoint

Then, it gets the function DbgUiRemoteBreaking, and store its address in esp+1C

```
mov ecx,dword ptr ss:[ebp+1C]      [ebp+1C]:"ntdll"
mov edx,6F0BDB18                   edx:"DbgUiRemoteBreakin"
call 292F54
cmp dx,713C
mov dword ptr ss:[esp+1C],eax
```

Getting DbgUiRemoteBreakin

Next, the shellcode gets the address of DbgBreakingPoint (esp+18) moves it to the EAX register, and writes the byte 90 into it.
As we remember, 90 represent NOP, which means that each time a breakpoint will occur it will not break because of the NOP.

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```
test dh,20
pushad
lfence
rdtsc
lfence
shl edx,20
or edx,eax
popad
mov eax,dword ptr ss:[esp+18]
mov byte ptr ds:[eax],90
test dl,dl
cmp eax,ebx
cmp ecx,eax
mov eax,dword ptr s
cmp bh,ah
```

Moving DbgBreakPoint address to the eax register

Patch DbgBreakPoint to start with NOP

Patching DbgBreakPoint

Then, the shellcode will do the same with DbgUiRemoteBreaking. However, it will patch its beginning with 6A, 0, B8, and then add the function ExitProcess after. So every time a breakpoint will be happening the process will be terminated.

Funny enough, this anti-breakpoint mechanism is under another Anti-analysis mechanism using the RDTSC time checks.

```
rdtsc
lfence
shl edx,20
or edx,eax
popad
mov eax,dword ptr ss:[e
mov byte ptr ds:[eax],9
test dl,dl
cmp eax,ebx
cmp ecx,eax
mov eax,dword ptr ss:[esp+1C]
cmp bh,ah
mov byte ptr ds:[eax],6A
mov byte ptr ds:[eax+1],0
mov byte ptr ds:[eax+2],B8
mov edx,dword ptr ss:
test cx,dx
mov dword ptr ds:[eax
cmp dh,C6
mov byte ptr ds:[eax+
test cl,al
mov byte ptr ds:[eax+
mov byte ptr ds:[eax+9],C2
mov byte ptr ds:[eax+A],4
mov byte ptr ds:[eax+B],0
pushad
mov ebx,6
rdtsc
```

Moving DbgUiRemoteBreaking address to the eax register

Patch DbgUiRemoteBreaking to start with 6A,0,B8

Patching DbgUiRemoteBreakin

In the end, from the disassembler point of view, the changes will look like this:

DbgBreakingPoint

```
CC        int3                  DbgBreakPoint
C3        ret          Before
90        nop
90        nop
```

```
90        nop                   DbgBreakPoint
C3        ret          After
90        nop
90        nop
```

DbgUiRemoteBreakin

```
6A 08            push 8                     DbgUiRemoteBreakin
68 60BAA277      push ntdll.77A2BA60
E8 EEE5F8FF      call ntdll.77A2DEE4     Before
```

```
6A 00            push 0                                  DbgUiRemoteBreakin
B8 F8795A75      mov eax,&lt;kernel32.ExitProcess&gt;
FFD0             call eax                                After
C2 0400          ret 4
```

Before and after patch

How we overcome this anti-breakpoint?

The best way is to bypass the function that responsible for this anti-analysis mechanism, which is 6034F4. Either NOP or Control flow solutions are fine here.

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```
0060029A   84F7    test bh,dh
0060029C   6A 00   push 0
0060029E   6A 00   push 0
006002A0   6A 00   push 0
006002A2   6A 00   push 0
006002A4   90      nop
006002A5   90      nop      NOP instead of 6034F4
006002A6   90      nop
006002A7   90      nop
006002A8   90      nop
006002A9   60      pushad
006002AA   B0 BC   mov al,BC
006002AC   3C BC   cmp al,BC
```

NOP Anti-Analysis function

Anti-Analysis 5: Anti-VM

Next, we see the function 602038, if we step over it and we’ll see the string “*C:\Program Files\qqa\qqa.exe*”. This is because 602038 functionality is to search whether the Qemu gues agent is located on the machine. This is another anti-VM feature of Guloader.

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Qemu gues agent

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In the next two calls, we see a call to 602F54 which resolves *NtSetInformationThread.* This API call will be stored in the EAX register and will be executed several instructions later. However, in this case, we need to pay attention to the argument *NtSetInformationThread* gets.

Anti-Analysis 6: *NtSetInformationThread*

The second argument is ThreadHideFromDebugger (11), which in this case will cause the process to crash if it's working under a debugger.

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NtSetInformationThread Anti-Analysis

How we overcome this anti-debugger technique?

ScyllaHide covers this technique, however, we can just change the control flow or insert NOPs.

After bypassing *NtSetInformationThread*, we will keep step-over until we will reach a JMP at the end of this large routine, In my case, it is 602773

Take the jump

Right after we took the jump, we see a call to another function, step into it.

Step into

After stepping into the function, we found ourselves in a unique location. Using other pre-computed hashes, the shellcode searches for installed products with the API *MsiEnumProducA* and *MsiGetProductInfo* (again with the djb2 algorithm).
I will not focus on this technique, but it is explained in detail [here](#).

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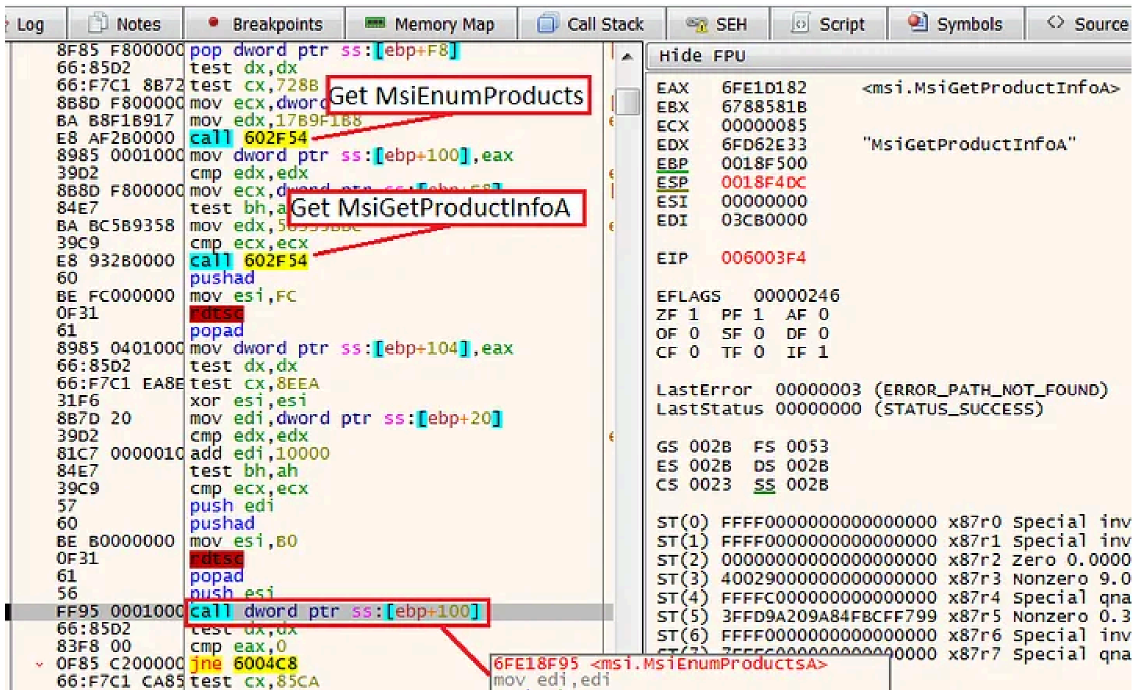

MsiEnumProducA and MsiGetProductInfo

After the execution of MsiEnumProductsA, we see the instruction JNE 6004C8, by default we will not take this jump, but for the sake of bypassing this anti-analysis, we will change the ZF (zero flag) from 1 to 0, and take the jump.

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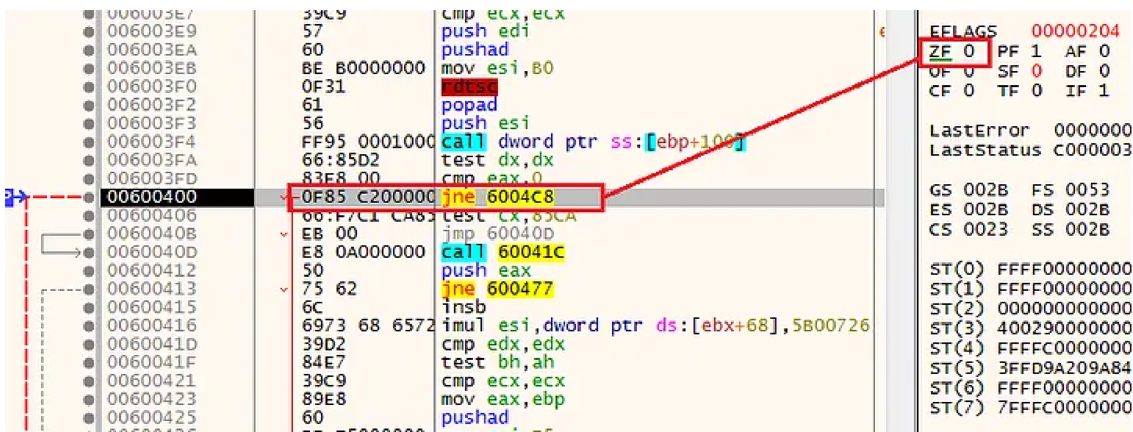

Change the flag

Shellcode main function

Once we took the jump, we will reach one of the most important functions in the shellcode. This function will mainly consist of two important functions.

The first one is the already mentioned 602F54 which will resolve API calls. The second one is 603B93 which will be responsible to execute them (except few cases). This function will be the main execution function, where the most important API calls will be executed.

These two functions will be used multiple times during the final stages of the shellcode. Set a breakpoint on 603B93 and step into it.

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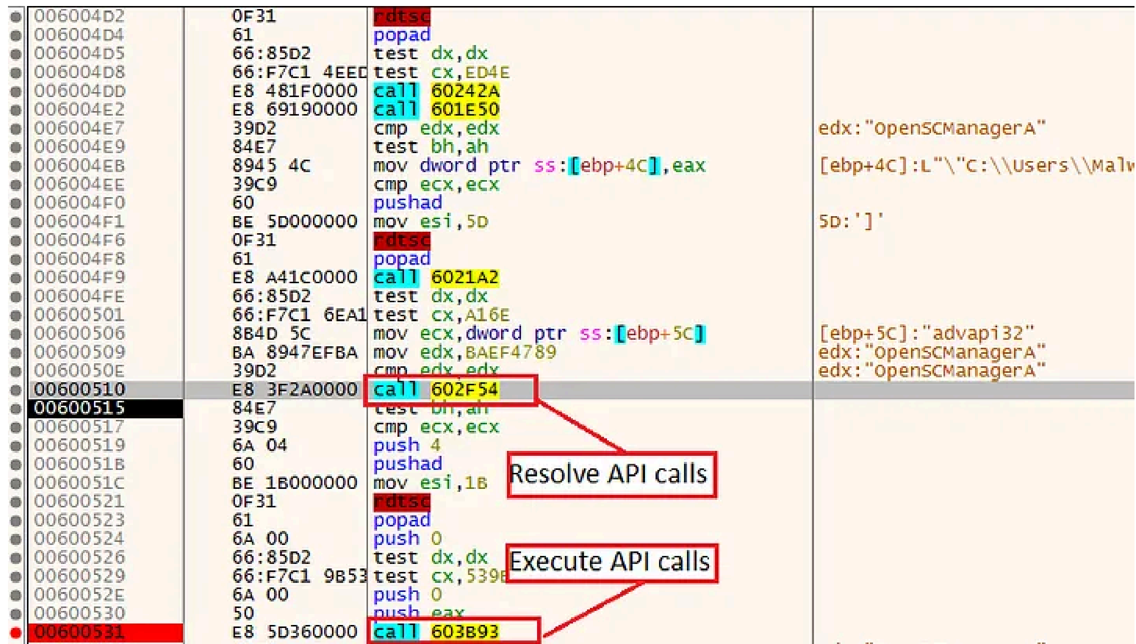

Two important functions

Because of the fact that this function will be responsible for the majority of the API calls execution, we’ll want to set a breakpoint in strategic locations so we’ll have the option to hit Run and speed things up.
My preferred locations are the call to EAX, which is the location when the API call will be executed, and JMP ECX, which is the location where the function will return to the core parent function.
However, before we’ll reach these important functions we need to bypass multiple anti-analysis checks that happened right before.

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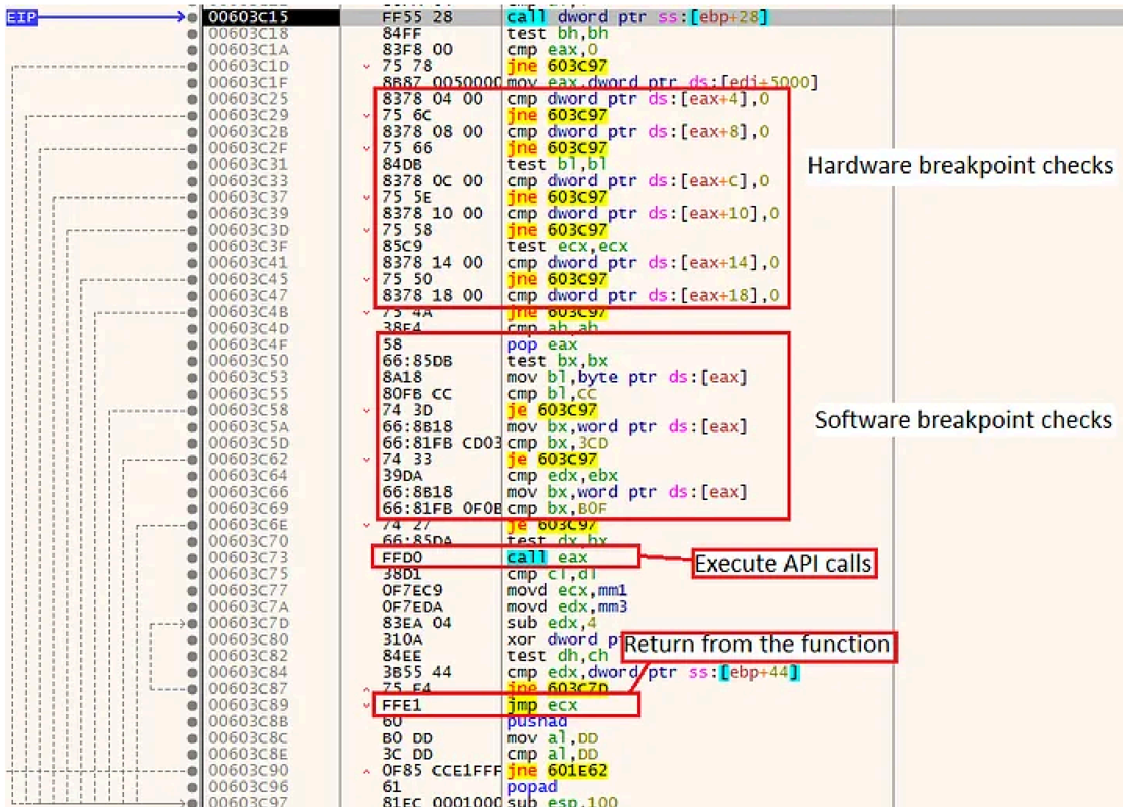

Execution function architecture

Anti-analysis 7: Hardware breakpoints

The DR (debug registers) are located in the following locations:

[eax+4] = DR 0

[eax+8] = DR 1

[eax+C] = DR 2

[eax+10] = DR 3

[eax+14] = DR 4

[eax+18] = DR 5

The shellcode will compare any of these registers to the number 0, if one of them is not 0 that means there is a hardware breakpoint. In this case, the shellcode will jump using the JNE 603C97 and the process will be terminated.

If we want to observe how this anti-analysis mechanism works, we can click “follow in dump” on one of these DR locations (for example eax+4), and see it has the same address of the chronological number we set the hardware breakpoint.

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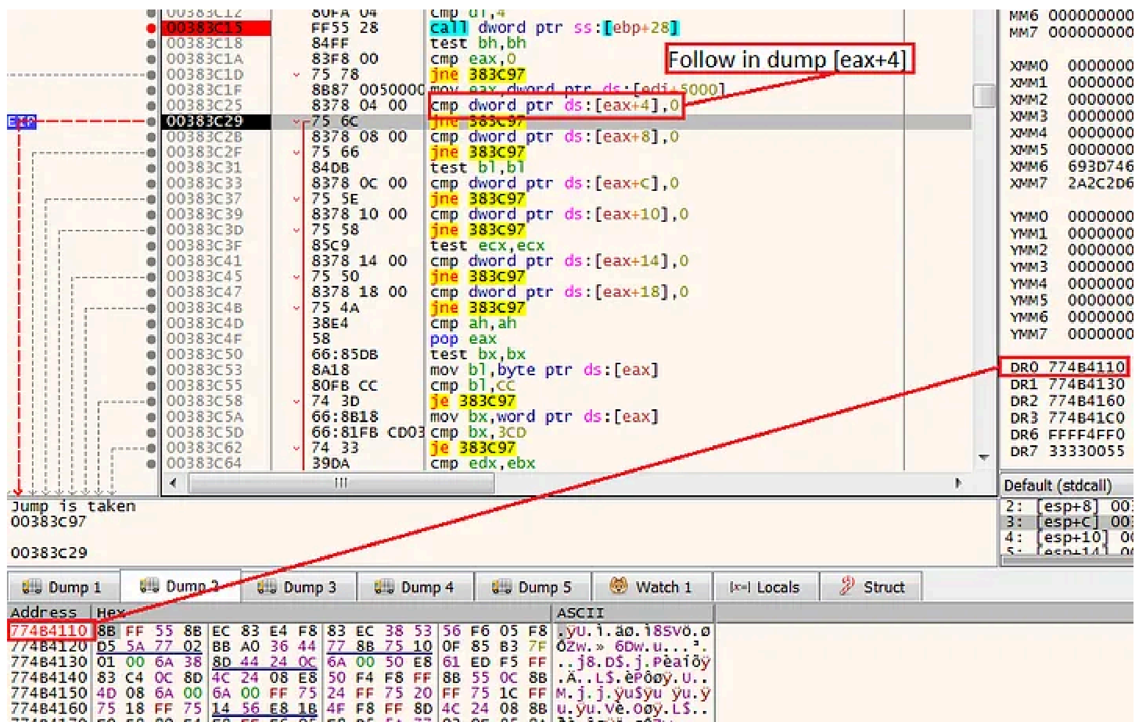

Hardware breakpoint example

How we overcome this technique?

If you set a hardware breakpoint, you can change the flag so the JNE jump will not be taken.
The easiest solution will be to use the ScyllaHide plugin.

Anti-analysis 8: Software breakpoints

In this technique, the shellcode will get the API call to be executed from the EAX register, move one byte to the bl portion of the EBX register, and will inspect if any software breakpoints assign to it.
If it has any software breakpoint, it will have one of the breakpoint opcodes(for example, 0xCC which means INT 3, and as we know, the INT 3 opcode represents a software breakpoint).

Software breakpoint example

As expected, if a software breakpoint is present, the shellcode will go to the location that will terminate the process.

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Software breakpoint example

How we overcome this technique?

Change the ZF to be 0, or change the instruction to be NOP. As mentioned before, the easiest solution is the ScyllaHide plugin.

Finally, we bypass all of the anti-analysis mechanisms and we can focus on Guloader's main goal. Because we already set a breakpoint on the call to EAX, and JMP ECX we can click Run, and observe the functions that bein executed.

The first API call that is interesting for us is *CreateProcessInternalW* (which is the kernel equivalent to *CreateProcessA*). In this case, the process to be created is RegAsm.exe, this is also a hint for us that the malware to be downloaded will probably be written in .NET (In this case, it's Agent-Tesla).

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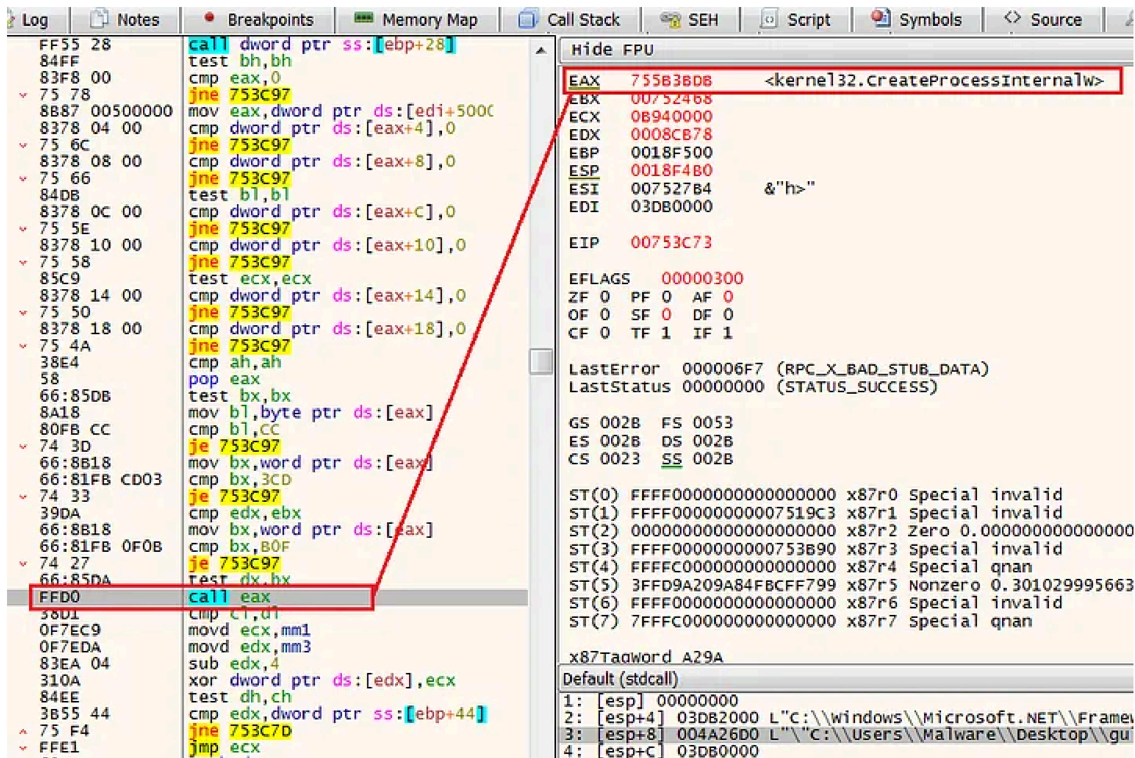
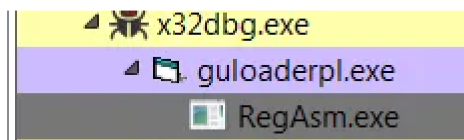


Creating process

The RegAsm process will be spawned in a suspend mode which indicates process hollowing injection, this variation of process hollowing is a bit unique, but because we only care about unpacking the final payload I will not cover it here, however, you can read here for more details.



RegAsm in suspend state

As we continue to observe the API calls that being executed, we see *NtMapViewOfSection.* When we encounter this function, click step over on JMP ECX, to return to the parent function. Then, continue to step over instructions manually until you see an instruction that calls for a function stored in the location [ebp+30]. This line will execute the API call *NtWriteVirtualMemory* (which is the kernel equivalent to *WriteProcessMemory*). This instruction will write a second shellcode to the RegAsm process.

Write the second shellcode

Now, we can go to the third argument of *NtWriteVirtualMemory* and click “follow in dump” to observe the new shellcode that will be written.

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Observing the second shellcode

Next, we can copy and dump the entire buffer that contains the second shellcode. In this way, we can debug it without any dependency on RegAsm.

Wrap the first shellcode

After the first shellcode creates the RegAsm process and injects a second shellcode into it, it will execute the API call *NtResumeThread* to activate the second shellcode within the RegAsm memory.

Now, we basically have two options, we can open a new debugger and attach it to RegAsm, or, we can debug the dumped second shellcode as a stand-alone shellcode using tools such as BlobRunner.

My preferred option is to debug it using the BlobRunner tool because I don't want to be dependent on RegAsm. Also, I want to have the option to debug it over and over again as quickly as possible.

For those of you who are not familiar with the BlobRunner tool, please look at the following video.

Debugging the second shellcode

When we start to debug the second shellcode, we notice that to our surprise this shellcode starts the same as the first one, In fact, this is the almost same shellcode. This resembles give us the advantage to bypass all the anti-analysis mechanism that we already see in the first shellcode.

Differences from the first shellcode

After we reach the main function we saw in the first shellcode, we will set the same breakpoints. Then, as we click Run and step over functions, we start to see indications of additional capabilities that we have not seen in the first shellcode.

First, we see a call to a location in the stack (in this case, [ebp+D8]), that will execute the function *InternetOpenUrlA*, we also see the C2 it will use.

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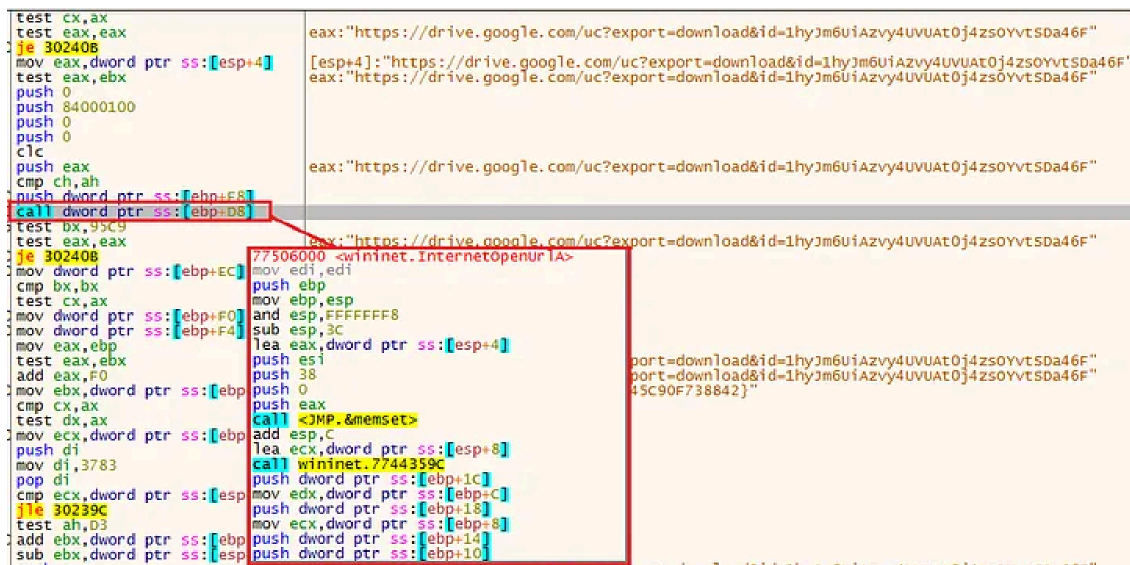
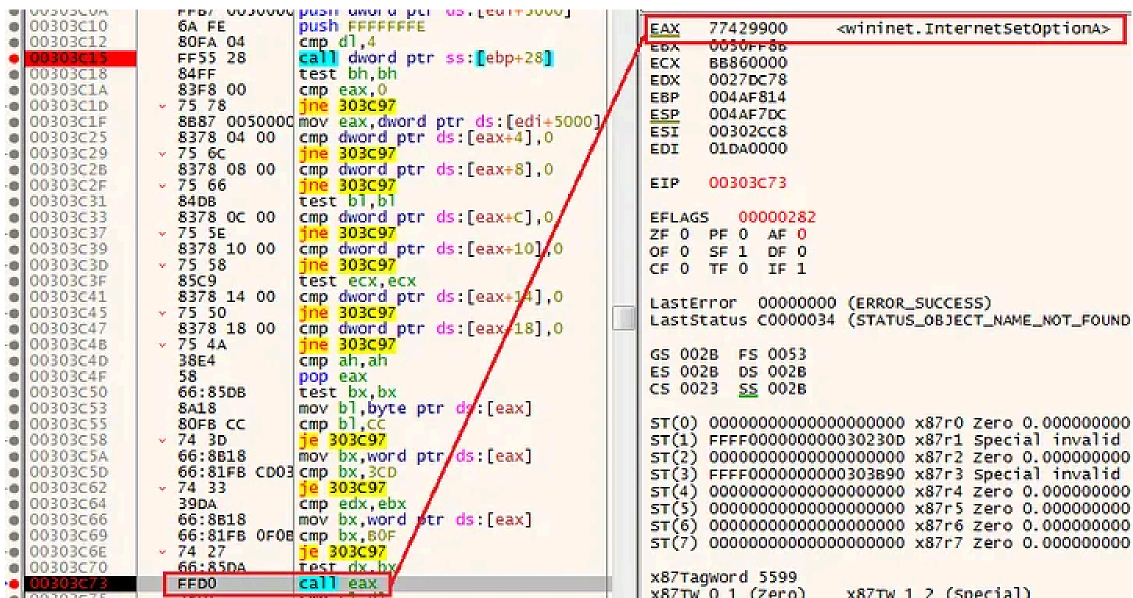


Observing the C2

Then, in the function that executes API calls, we see other wininet API calls being executed.

Press enter or click to view image in full size



Observing the C2

At this point I decided to finalize my analysis because we achieve the two goals of this article:

1) We learn how to crack the two shellcode stages of the Guloader malware.

2) We observe how to find the C2 that will be responsible for downloading the additional malware.

Recap

When we sum up the entire architecture of Guloader, we observe several stages and key features:

1) The malware initially come wrapped with a VB layer

2) After the VB part ends, the entire malware activity is executed by a shellcode.

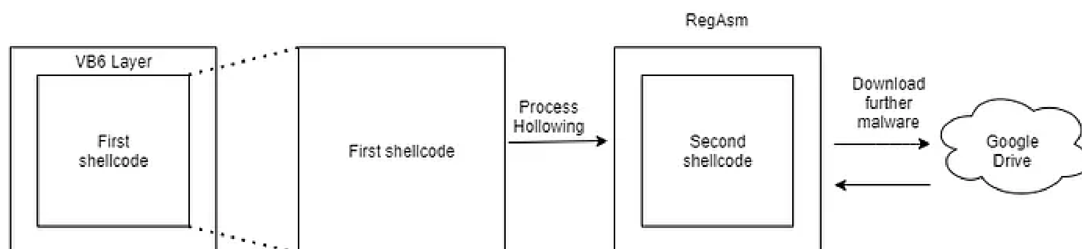
3) The shellcode contains multiple anti-analysis mechanisms, some of them are inescapable without manual intervention.

4) The shellcode creates the process RegAsm and injects a second shellcode into it with a unique variation of the Process Hollowing injection.

5) The second shellcode downloads further malware

The Guloader mechanism is depicted in the following diagram:

Press enter or click to view image in full size



Guloader architecture

Conclusion

In this article, I covered the entire process of the Guloader malware and presented several anti-analysis mechanisms from this shellcode-based downloader.

During this step-by-step observation, we saw how this malware's unique characteristic challenges security researches, and also how untraditional is Guloader in the current cybercrime landscape.

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