Windows Antivirus Evasion Techniques: How to Stay Ahead of the Hooks

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Abstract
The practice of API hooking in user-space is a common technique used by antivirus (AV) and endpoint detection and response (EDR) software to monitor and control software execution on Windows systems. This method of detection allows for the interception and examination of interactions between processes and operating system services, making it a potential target for both simulated penetration testing and malicious attacks. After an extensive analysis on how commercial antivirus software do implement hooking techniques, this paper introduces a new approach, named `Whisper2Shout`, which enables users to bypass API hooking in user-space. Unlike established unhooking methods, `Whisper2Shout` does not rely on any operating system service monitored by antivirus or endpoint detection and response software. We compare the advantages and disadvantages of `Whisper2Shout` with respect to similar tools and we evaluate the effectiveness of `Whisper2Shout` by circumventing hooks on 16 commercial antivirus programs and 4 endpoint detection and response software.

Keywords
windows evasion, api hooking, user-space unhooking

1. Introduction

API hooking [1] is a technique in computer programming that allows modification of the behavior of an application by intercepting its function calls to certain APIs[1]. This technique is used by a variety of software, including *Antivirus* (AV) and *Endpoint Detection and Response* (EDR) programs, to monitor the behavior of suspicious processes and detect malicious activities [2]. AV and EDR software utilize API hooking to keep track of both API and system calls made by an application, allowing them to detect any suspicious behavior that might indicate malware or other security threats. By hooking the APIs used by a process, the software can monitor the data being passed to and from the API, and take appropriate actions based on the information collected. This provides a powerful tool for security software to detect and respond to potential threats in real-time, and helps to keep systems protected from malicious actors. API hooking is

ITASEC 2023: The Italian Conference on CyberSecurity, May 03–05, 2023, Bari, Italy
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[1]Application Programming Interfaces

a remarkably effective method of detection, as it allows to take actions based on real-time events that could trigger the identification of malicious software after it has started its execution.

From the perspective of an attacker, a way to evade these security products is to try to remove the hooking. There are numerous documented techniques to remove user-space hooking (refer to Section 2 for more details), though the sheer majority of them result in some *Indicator Of Compromise* (IoC) [2] that could alert the AV/EDR.

In this paper we present `Whisper2Shout`, a novel unhooking technique which does not require knowledge of the original (unhooked) library. This paper expands on our previous work [3] by looking into a more comprehensive analysis of hooking techniques implemented by AV/EDR and providing a detailed examination of the inner workings of our approach.

The idea behind our strategy is that even if an AV/EDR employs hooking in user-space, it must save all the information about the original code of the hooked APIs in memory. This is because if a process is considered not suspicious, the AV/EDR should allow transparent access to the APIs without interfering with the execution of legitimate applications. The technique focuses on identifying the memory location where this information is stored, and utilizing it to retrieve the original bytes of the hooked APIs. Moreover, these operations should be executed without alerting the AV/EDR. In summary, the contribution and novelties of this paper are:

- via an extensive analysis carried out on 16 AVs and 4 EDRs, we identify and classify hooking techniques used by real world Windows AV/EDRs;
- we devise `Whisper2Shout`, a novel unhooking technique which does not rely on any monitored OS service, and allows to selectively remove hooks on user-defined APIs;

The remainder of this paper is organized as follows: Section 2 highlights differences between `Whisper2Shout` and other existing techniques, Section 3 discusses how hooking is employed in the commercial AV/EDRs analyzed, Section 4 explains how our technique has been devised and implemented; its effectiveness is assessed in Section 5, and Section 6 concludes this paper.

2. Related Work

Since *API hooking* is a technique commonly used by security software to detect suspicious processes [2], there are various documented methods for the circumvention of user-space hooking, such as those cited in [4], [5], [6], and [7]. However, these techniques need to retrieve the unaltered library file (*Dynamic Link Library* - DLL) either by reading it from the disk or from the memory of a remote process before the security software places the hooks. The detection of such techniques is commonly facilitated by the Windows kernel via the deployment of minifilter drivers [8]. Anti-malware software can register callbacks for a variety of system events, such as file operations and process creation, through Windows [9], which notifies the AV and prompts a deeper analysis that may result in detection. For instance, reading of the `ntdll.dll` file, which should only be loaded at the time of process creation, is deemed suspicious and could trigger detection.

Shellycoat [10] is a renowned technique that un-hooks a hooked DLL by loading an unaltered version from disk. This technique employs the syscalls `NtCreateFile`, `NtCreateSection`,

[2]https://www.trendmicro.com/vinfo/us/security/definition/indicators-of-compromise

and `NtMapViewOfSection` to i) load a fresh copy of the DLL in the process' address space, ii) copy the original bytes of its text section to the text section of the hooked DLL, and finally iii) call `NtUnmapViewOfSection` to unload the previously loaded library.

However this technique, as well as all the aforementioned existing ones, could be detected because of three main reasons:

1. `NtCreateFile` is called to open a system-reserved `DLL` that is not usually accessed by user-space programs
2. `NtMapViewOfSection` is called to map a `DLL` that is already loaded in the process address space (i.e. `ntdll.dll` is always loaded by the OS)
3. There is a (small) amount of time in which the `DLL` is mapped twice in the process address space

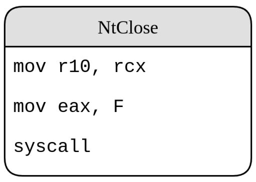
Perun's Fart [7] is another unhooking technique which does not require reading the clean `DLL` from disk, and its main steps are:

- Spawn a new process in suspended state.
- Read memory from the new spawned process, at which point the target `DLL` has not been tampered yet, so the bytes of the functions to be unhooked can be copied.
- Resume/kill the suspended process

Such a technique could trigger an IoC, i.e. reading the contents of the `ntdll.dll` file from a suspended target process, which would be considered an abnormal and suspicious operation by AVs and EDRs.

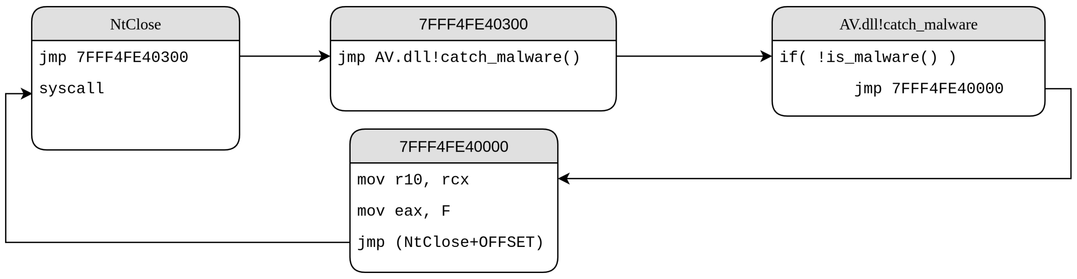
There are alternative means of covertly invoking API calls on Windows, as referenced by [11] and [12]. However, their aim is not solely to evade hooking, but rather to develop more comprehensive functionalities that can bypass antivirus software. Additionally, other strategies for monitoring APIs, such as [13] and [14], exist. Nevertheless, our study concentrates on the hooking methods utilized by commercial AV/EDR software, which are analyzed in greater depth in Section 3.

The `Whisper2Shout` technique distinguishes itself from the previously documented methods in that it does not require any syscall or API monitored in kernel-space to execute the unhooking process. In contrast, all of these techniques necessitate, at some point, the ability to read the contents of a *fresh* version of the `DLL` to be unhooked, whether it be by reading it from the disk or another process' memory, a task which involves the utilization of either APIs or system calls. `Whisper2Shout` only requires the capability to traverse a series of pointers and the capability to retrieve metadata about a memory region, abilities that are enabled by default for all processes on Windows. Additionally, `Whisper2Shout` is resilient against hook monitoring. The previous unhooking techniques remove the hooks from the original `DLL` and presume that the AV/EDR will not interfere with its memory again. However, as we will explain later in Section 4, certain AVs periodically verify if their hooks are in place and restore them if they are not. `Whisper2Shout` circumvents this mechanism by misleading the AV during its hook check. Lastly, it is worth to mention that all previously documented techniques aim to remove all hooks within a specific `DLL` whereas `Whisper2Shout` enables selective removal of certain hooks, a concept that will be made clearer in the following sections.



```
mov r10, rcx
mov eax, F
syscall
```

Figure 1: Layout of the `NtClose` function before being hooked.



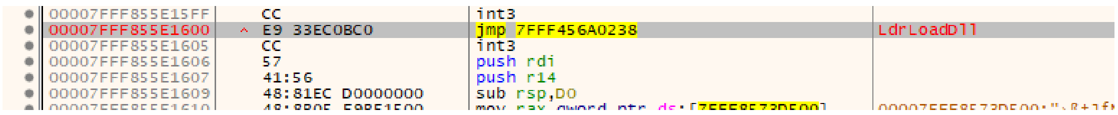
```
NtClose:
jmp 7FFF4FE40300
syscall

7FFF4FE40300:
jmp AV.dll!catch_malware()

AV.dll!catch_malware:
if( !is_malware() )
        jmp 7FFF4FE40000

7FFF4FE40000:
mov r10, rcx
mov eax, F
jmp (NtClose+OFFSET)
```

Figure 2: Layout of the `NtClose` function after being hooked.

3. Hooking

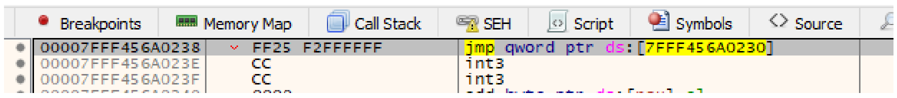
The `Whisper2Shout` method was developed through an exploration of various commercial AV/EDR programs with the aim of evaluating their utilization of API hooking and the way in which it was executed. The research analyzed the contents of several Windows `DLLs` stored in RAM to determine *if* and *how* the execution flow for each API was being redirected to a location outside of the same `DLL`.

In general, API hooking is implemented by AVs/EDRs by injecting a custom library (`DLL`) into the address space of a new process. The purpose of this library is to install hooks within `DLLs` which contain critical APIs and/or syscalls. Let's take as an example the `NtClose` API contained in `ntdll.dll` and which is a simple wrapper for a syscall on Windows. The layout of this API, and its corresponding assembly instructions, are shown in Figure 1. The insertion of the hook occurs by overwriting the initial assembly instructions with a `JMP` [15] instruction, redirecting the execution flow to a memory region dynamically allocated by the AV `DLL` and classified as *private*. This memory region acts as a *trampoline* between the hooked API and the `DLL` injected by the AV/EDR. As a matter of fact, this memory region often contains a `JMP` to the AV `DLL`, which contains the code to determine whether the API invocation can be deemed suspicious or not. If the invocation is not considered suspicious, the execution will proceed running the original API instructions. However, if the invocation triggers an alarm, the execution will be diverted to somewhere else, in a memory area controlled by the security product. This layout is depicted in Figure 2, which shows how the execution flow of `NtClose` is altered after the AV placed its hook.



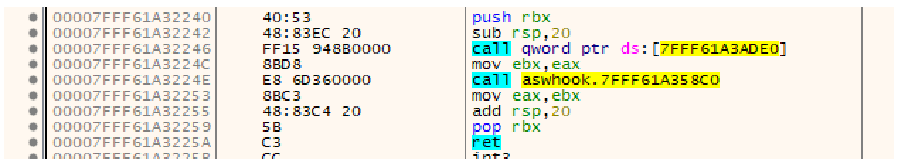
```
00007FFF855E15FF    CC                  int3
00007FFF855E1600  ^ E9 33EC0BC0         jmp 7FFF456A0238                     LdrLoadDll
00007FFF855E1605    CC                  int3
00007FFF855E1606    57                  push rdi
00007FFF855E1607    41:56               push r14
00007FFF855E1609    48:81EC D0000000    sub rsp,D0
```

Figure 3: `NTDLL.LdrLoadDll` hooked by *AVG* using inline hooking



```
00007FFF456A0238  ˅ FF25 F2FFFFFF       jmp qword ptr ds:[7FFF456A0230]
00007FFF456A023E    CC                  int3
00007FFF456A023F    CC                  int3
```

Figure 4: Trampoline for jumping to *AVG* DLL



```
00007FFF61A32240    40:53               push rbx
00007FFF61A32242    48:83EC 20          sub rsp,20
00007FFF61A32246    FF15 948B0000       call qword ptr ds:[7FFF61A3ADE0]
00007FFF61A3224C    8BD8                mov ebx,eax
00007FFF61A3224E    E8 6D360000         call aswhook.7FFF61A358C0
00007FFF61A32253    8BC3                mov eax,ebx
00007FFF61A32255    48:83C4 20          add rsp,20
00007FFF61A32259    5B                  pop rbx
00007FFF61A3225A    C3                  ret
```

Figure 5: AV Checker function in *AVG* DLL

This analysis can be validated by looking at Figures 3, 4, 5 and 6, which show how *AVG*[3] implements user-space API hooking. In particular:

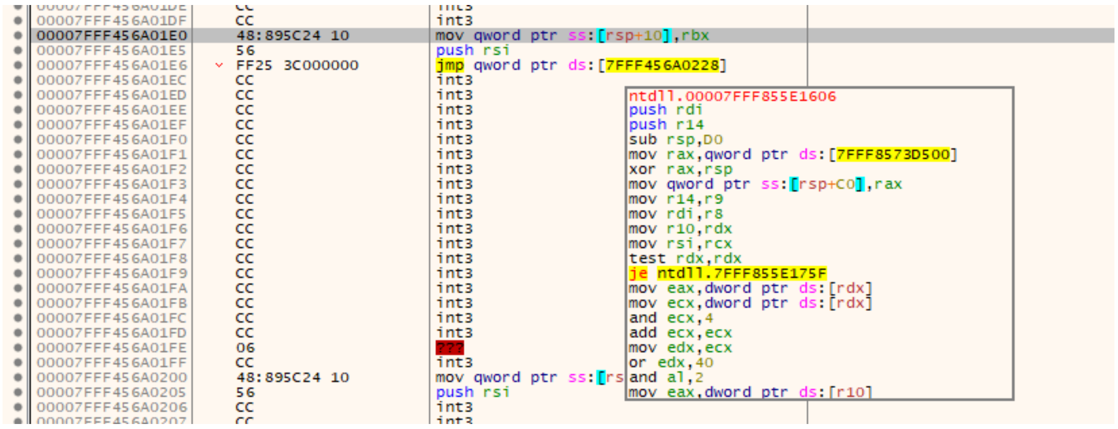
- Figure 3 shows how *AVG* overwrites the original bytes of the API `LdrLoadDll` contained in `ntdll.dll`.
- Figure 4 shows the content of the memory area which contains the *trampoline* to *AVG* DLL.
- Figure 5 shows the code of *AVG* DLL which implements the logic to determine whether the process should be classified as malicious or not.
- Figure 6 shows the *trampoline* containing the original instructions of `LdrLoadDll`, followed by a `JMP` to go back to `ntdll.dll`

In order to classify AVs and EDRs with respect to hooking, and based on the observations above, there are three main steps in which each AV/EDR can implement hooks differently from the others, i.e. there are three features that can be used to classify:

1. how the AV implements the jump to the area containing the *trampoline*
2. how the AV DLL allocates the area containing the *trampolines*
3. how the AV implements the *trampoline* back to the original API.

For the first point, we observed that only two different techniques are used by AVs/EDRs to divert execution of an API, i.e. i) a `jmp` instruction and ii) the sequence `mov eax, N; jmp rax;`. These two techniques we observed are not exhaustive, however, our research determined that these are the only techniques utilized in practice.

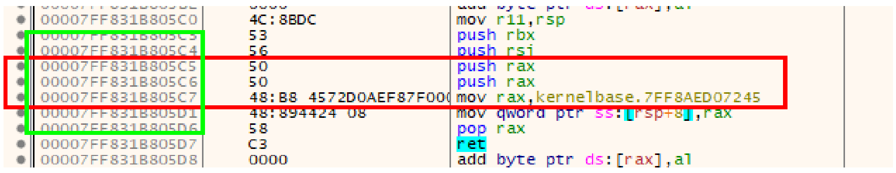
[3]https://www.avg.com/en-us/internet-security



```
00007FFF456A01DF    CC                  int3
00007FFF456A01E0    48:895C24 10        mov qword ptr ss:[rsp+10],rbx
00007FFF456A01E5    56                  push rsi
00007FFF456A01E6    FF25 3C000000       jmp qword ptr ds:[7FFF456A0228]
00007FFF456A01EC    CC                  int3
00007FFF456A01ED    CC                  int3
00007FFF456A01EE    CC                  int3
00007FFF456A01EF    CC                  int3
00007FFF456A01F0    CC                  int3
00007FFF456A01F1    CC                  int3
00007FFF456A01F2    CC                  int3
00007FFF456A01F3    CC                  int3
00007FFF456A01F4    CC                  int3
00007FFF456A01F5    CC                  int3
00007FFF456A01F6    CC                  int3
00007FFF456A01F7    CC                  int3
00007FFF456A01F8    CC                  int3
00007FFF456A01F9    CC                  int3
00007FFF456A01FA    CC                  int3
00007FFF456A01FB    CC                  int3
00007FFF456A01FC    CC                  int3
00007FFF456A01FD    CC                  int3
00007FFF456A01FE    06                  ???
00007FFF456A01FF    CC                  int3
00007FFF456A0200    48:895C24 10        mov qword ptr ss:[rs
00007FFF456A0205    56                  push rsi
00007FFF456A0206    CC                  int3
```

```
ntdll.00007FFF855E1606
push rdi
push r14
sub rsp,D0
mov rax,qword ptr ds:[7FFF8573D500]
xor rax,rsp
mov qword ptr ss:[rsp+C0],rax
mov r14,r9
mov rdi,r8
mov r10,rdx
mov rsi,rcx
test rdx,rdx
je ntdll.7FFF855E175F
mov eax,dword ptr ds:[rdx]
mov ecx,dword ptr ds:[rdx]
and ecx,4
add ecx,ecx
mov edx,ecx
or edx,40
and al,2
mov eax,dword ptr ds:[r10]
```

Figure 6: Trampoline created by *AVG* to execute back the hooked function



```
00007FF831B805C0    4C:8BDC                 mov r11,rsp
00007FF831B805C3    53                      push rbx
00007FF831B805C4    56                      push rsi
00007FF831B805C5    50                      push rax
00007FF831B805C6    50                      push rax
00007FF831B805C7    48:B8 4572D0AEF87F00    mov rax,kernelbase.7FF8AED07245
00007FF831B805D1    48:894424 08            mov qword ptr ss:[rsp+8],rax
00007FF831B805D6    58                      pop rax
00007FF831B805D7    C3                      ret
00007FF831B805D8    0000                    add byte ptr ds:[rax],al
```

Figure 7: *BitDefender* trampoline to execute back the hooked function

For the second point, our research uncovered a recurring pattern with respect to memory allocation to store pointers and trampolines essential for hooking. We discovered that the memory type of all regions holding relevant information regarding hooks was designated as *Private* (namely, `MEMORY_BASIC_INFORMATION.Type == MEM_PRIVATE`) [16].

For the third and last point, we identified the following two distinct techniques to execute the original function from the hook: i) a `jmp` instruction that jumps back to the original function (employed by the `Detours` hooking library [17]) and ii) the `double-push` technique [18]. An example of hooking using the first of these two techniques is shown in Figure 6 (*AVG*); the second one is shown in Figure 7 (*Bitdefender*[4]).

Our analysis was based on 16 commercial AV products and 4 commercial EDR software. The results are shown in Table 1: for each AV/EDR we identified how they implement the three main steps of hooking i.e. i) how they jump to the trampoline area ii) how they allocate the trampoline area and iii) how they jump back to the original API.

4. Unhooking

The `Whisper2Shout` technique is based upon the aforementioned observations aimed at restoring the preamble of hooked functions to their original state, without the requirement of retrieving the content of the original library. To understand the techniques utilized, we

[4]https://www.bitdefender.com/

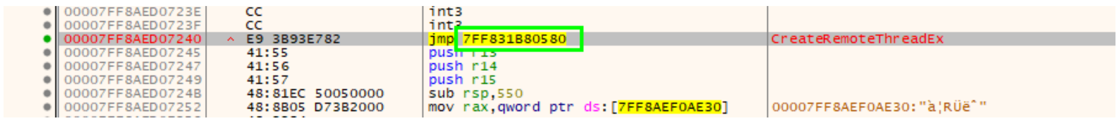
Table 1
Comparison of how API hooking is employed by different AV and EDR software.

Antivirus/EDR	jmp to trampoline	private area	trampoline back
AVG	`jmp`	✓	`long jmp`
Avast	`jmp`	✓	`long jmp`
BitDefender	`jmp`	✓	`double push`
Comodo	`jmp`	✓	`long jmp`
MalwareBytes	`jmp`	✓	`jmp`
ESET Internet Security	`jmp`	✓	`long jmp`
Sophos Home 3.0	`jmp`	✓	`long jmp`
Norton 360	`jmp`	✓	`long jmp`
Trend Micro	`jmp`	✓	`jmp`
Dr. Web	`mov eax, N; jmp rax;`	✓	`jmp`
Windows Defender	✗	✗	✗
Kaspersky	✗	✗	✗
Avira Prime	✗	✗	✗
McAfee Total Protection	✗	✗	✗
Webroot	✗	✗	✗
Qihoo 360	✗	✗	✗
SentinelOne *EDR*	`jmp`	✓	`long jmp`
CrowdStrike *EDR*	`jmp`	✓	`jmp`
Cortex *EDR*	✗	✗	✗
Sophos *EDR*	✗	✗	✗

analyzed prior research on the topic [18] and the AVs/EDRs of Table 1, and thus devised a general unhooking technique that can be applied to each identified hooking method. At its core, the `Whisper2Shout` approach is to trace the arrows as depicted in Figure 2, traverse the *trampoline* area, the AV `DLL` and the hooked `DLL` in order to locate the original instructions of the hooked API and ultimately restore these instructions without alerting the AV/EDR.

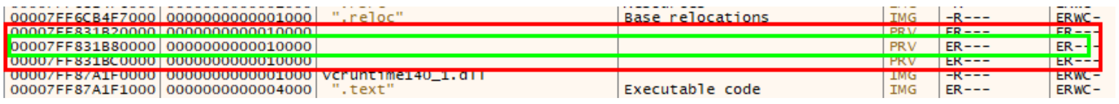
The observation made in the previous section about the recurring pattern with respect to memory allocation constitutes the fundamental block of our unhooking technique, as that *private* memory regions contain all the necessary information for the unhooking process. Figures 3, 4, 5, 6 illustrate the blocks utilized by *AVG Internet Security* to hook the function `NTDLL.LdrLoadDll`. When a function is hooked, the pointer to the symbol within the the *Export Directory*[5] of the `DLL` is diverted to either a jump instruction or a sequence of well-known instructions that redirect execution to a designated address located within a private memory region - namely, `short jmp` or `mov eax, N; jmp rax;` - as demonstrated in Figures 8 and 9 for the case of the *BitDefender* antivirus. This *private* memory region contains the trampolines both to the hooking `DLL`, which serves to divert the execution to the anti-malware software, and to the original, hooked `DLL`, which will be utilized if the call is deemed legitimate by the anti-malware software and the execution must proceed as intended. By accessing the destination address of the jump located at the symbol address (i.e. the first arrow of Figure 2),

[5]https://learn.microsoft.com/en-us/windows/win32/debug/pe-format



```
00007FF8AED0723E      CC                int3
00007FF8AED0723F      CC                int3
00007FF8AED07240   ^  E9 3B93E782       jmp 7FF831B80580                        CreateRemoteThreadEx
00007FF8AED07245      41:55             push r13
00007FF8AED07247      41:56             push r14
00007FF8AED07249      41:57             push r15
00007FF8AED0724B      48:81EC 50050000  sub rsp,550
00007FF8AED07252      48:8B05 D73B2000  mov rax,qword ptr ds:[7FF8AEF0AE30]     00007FF8AEF0AE30:"à¦RÜë˘"
```

Figure 8: `CreateRemoteThreadEx` hooked by *BitDefender*



```
00007FF6CB4F7000 0000000000001000  ".reloc"            Base relocations  IMG  -R---  ERWC-
00007FF831B20000 0000000000010000                                        PRV  ER---  ER---
00007FF831B80000 0000000000010000                                        PRV  ER---  ER---
00007FF831BC0000 0000000000010000                                        PRV  ER---  ER---
00007FF87A1F0000 0000000000001000 vcruntime140_1.dll                     IMG  -R---  ERWC-
00007FF87A1F1000 0000000000004000  ".text"             Executable code   IMG  ER---  ERWC-
```

Figure 9: *BitDefender* private memory region (highlighted in red) where the trampoline of `CreateRemoteThreadEx` resides (highlighted in green)

we can call `VirtualQuery`[6] to obtain the base address of the memory region that stores the original prologue of the hooked function (Figure 8 shows the destination address of the jump, Figure 9 depicts the *private* memory region containing that address and Figure 7 shows that the *trampoline* to return back to the hooked function resides within the *private* area). It should be noted that some security solutions might use different memory spaces to store the trampoline containing the original function prologue. In the event the trampoline cannot be located in the same memory area, it is necessary to scan all the *Private* memory regions in the address space using multiple calls to `VirtualQuery`.

Once the memory region has been identified, it is necessary to examine it in search of trampolines that facilitate a return to the original function. Each trampoline will comprise the original prologue of a hooked function, as well as a pointer to an area located near to the hooked function location - just a few bytes past its first instructions. Figures 1 and 2 display the structure of the `NtClose` function before and after being hooked, respectively.

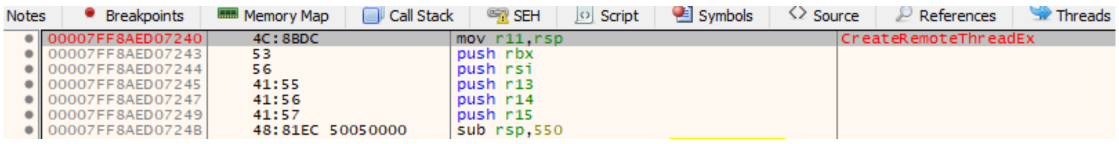
At this stage, the steps required to be taken diverge, as the method of determining whether the trampoline leads to the desired unhooked function depends on the hooking technique employed, i.e. a `jump` and the `double-push` technique.

When a `jump` is employed to return to the hooked function (as in the first hooking approach), it becomes necessary to locate all jumps within that memory region, so as to evaluate the destination of each jump and locate the memory region that houses the original function. Our research has revealed that there exist two `jump` patterns utilized in assembly by anti-virus programs, namely `long` and `short` jumps. In particular, we examine the *private* memory sector searching for:

- long jumps (utilized by the e.g. *Detours* library) with opcode `0xFF25`
- short jumps (employed by e.g. *MalwareBytes* [7]) with opcode `0xE9`.

In the case of the second technique (`double-push`), it is necessary to locate all sequences of `push rax; push rax; mov rax, addr` in order to extract the destination address and confirm that it points to the hooked function.

[6]https://learn.microsoft.com/en-us/windows/win32/api/memoryapi/nf-memoryapi-virtualquery
[7]https://www.malwarebytes.com/



```
00007FF8AED07240   4C:8BDC            mov r11,rsp      CreateRemoteThreadEx
00007FF8AED07243   53                 push rbx
00007FF8AED07244   56                 push rsi
00007FF8AED07245   41:55              push r13
00007FF8AED07247   41:56              push r14
00007FF8AED07249   41:57              push r15
00007FF8AED0724B   48:81EC 50050000   sub rsp,550
```

Figure 10: `CreateRemoteThreadEx` unhooked

Once the trampoline has been correctly located, the bytes that precede the aforementioned stub are the original bytes that were overwritten by the initial hook, and they must be rewritten to the original symbol address in order to unhook the function.

First version of `Whisper2Shout`: Initially, we carried out the unhooking idea by iterating over each hooked `DLL` and executing the following procedures:

1. Employ a direct system call to `NtProtectVirtualMemory` to adjust the memory permissions of the `.text` section to `RW`
2. Unhook the functions by writing each original stub at the corresponding symbol address
3. Call `NtProtectVirtualMemory` to restore the original memory permissions (`RX`)

The conclusive results are shown in Figure 10 for `CreateRemoteThreadEx`.

Final version of `Whisper2Shout`: During the evaluation of the initial version of our unhooking technique, we were met with a challenge posed by security products that employed a more sophisticated technique and monitored the stability of their hooks, thereby nullifying our modifications. To address this issue, we adjusted our strategy by opting to overwrite the AV hooking trampoline with a jump to the original prologue function instead of overwriting the hooks at the symbol address (as we previously did).

As a result, when the AV inspects its hooks, all the original jumps will remain unaltered, directing towards the same locations where the AV positioned the hooking trampolines. However, the instructions there will no longer divert the execution towards the AV `DLL`. Essentially, we have circumvented the hooking trampoline, guaranteeing the seamless execution of the function as if no hooks were present, even in the presence of a jump at the symbol address. Figure 11 depicts the layout of the `NtClose` function after being unhooked in this manner.

It is worth mentioning that all previous observations are still valid and allow us to traverse the process address space and retrieve all original stubs in a clever way.

We have all the information that is necessary to restore the original execution path:

- we know the destination address of each jump located at the symbol address
- we have knowledge of the location of the original function stub.

After collecting all this information, we can initiate the unhooking process:

- Use a direct system call to `NtProtectVirtualMemory` to adjust the protection of the memory region that stores the stub to `RW`.
- Add a short jump instruction - opcode `0xe9` - to jump to the original prologue.

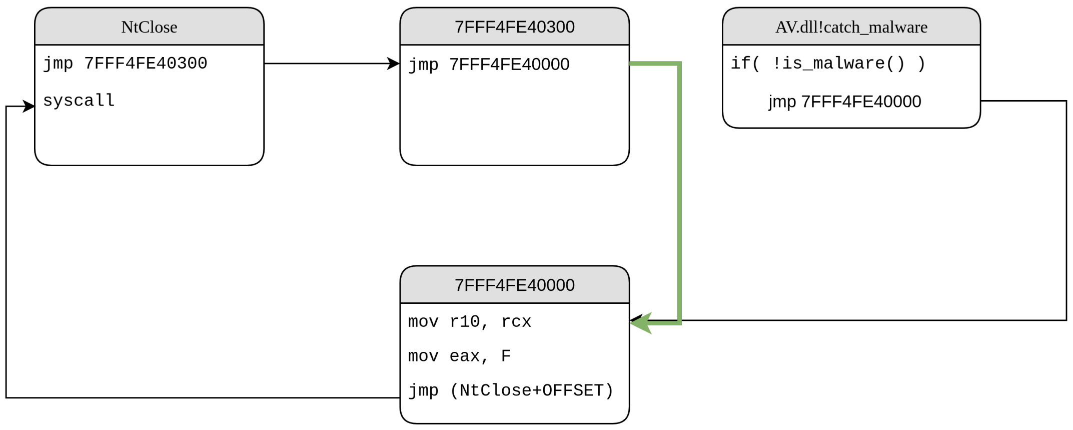


Figure 11: Layout of the `NtClose` function after being unhooked.

- Revert the memory back to `RX` using another direct system call to `NtProtectVirtualMemory`

The aforementioned operations can be executed to successfully unhook one API. At this stage, we may opt to either i) indiscriminately apply this technique to all APIs within a user-defined `DLL`, or ii) methodically iterate over all APIs, or a selected subset of user-defined APIs, and remove the hook only if it is present.

To summarize, the final unhooking process of Whisper2Shout involves iterating the following steps for each API the user desires to unhook:

- verify if the API has been hooked
- obtain the pointers to the *hooking* and *original* stubs
- overwrite the *hooking* stub with a jump to the *original* stub

5. Results

The efficacy of `Whisper2Shout` was tested against the antivirus software and endpoint detection and response systems listed in Table 1.

The testing process was executed in several steps. Initially, an anti-virus or endpoint detection and response system was installed, followed by the creation of a test program using the C programming language, for instance a simple "Hello World" program. The unhooking code was then added to the program, which was opened in a debugger. Prior to executing the unhooking code, it was verified that certain APIs were hooked, such as the `LdrLoadDll` API. Finally, after executing the unhooking code, the same APIs were verified to be unhooked by walking through the pointers in the debugger's graphical user interface.

The number of hooked APIs goes up to approximately 90 in `ntdll.dll` and approximately 20 in `kernel32.dll`. A comprehensive list of hooked APIs for EDRs is provided in [19]. As previously mentioned, it is worth to mention that `Whisper2Shout` can be configured to either unhook all APIs within the memory space of a given process or methodically unhook a subset of user-defined APIs. In the results provided in this paper the first option was adopted, in order to obtain a more comprehensive analysis on the capabilities of our technique.

It was noted that not all of the anti-virus programs listed in the study employed API hooking. However, for those that did, `Whisper2Shout` was able to successfully remove the hooks, and we validated this result by analyzing the hooked APIs of each DLL and verifying that the hooks set by the AVs/EDRs were no longer present.

As a demonstration of its potential, `Whisper2Shout` was utilized to pack a Cobalt Strike beacon shellcode and several other payloads that were detected as malicious. The technique was able to effectively bypass the security products that rely on API hooking, showcasing its efficacy as a tool for evading detection.

6. Conclusions

The technique discussed in this paper allows to bypass user-space API hooking in a universal way. The core of this mechanism lies in the observation that memory allocated by AVs/EDRs is designated as *Private* in all products analyzed. This makes identifying the stub effortless, as it cannot be mistaken for any other central libraries in memory, enabling us to pinpoint the memory area assigned by the anti-virus `Dll` to accommodate the stubs. The steps taken to acquire the necessary information are executed in a stealth manner as they only require reading memory and following pointers within our own process address space. Moreover, calls to `NtProtectVirtualMemory` are kept to a bare minimum, as we only use the system call twice per *Private* memory area, once to set the region to `RW` and again to set it back to `RX`. However, `Whisper2Shout` still suffers from the following two limitations:

- calls to `NtProtectVirtualMemory`, although kept to a bare minimum, can still alert some AV/EDR
- the scanning technique itself could still be detected, for example, by setting a GUARD page bit [20] on the memory of the trampolines and validate from the exception handler what is the address of the offending instruction with respect to the return address on stack.

From a defensive viewpoint, user-space hooking is a crucial mechanism, and though bypasses may be feasible, its utilization as part of a defense-in-depth strategy is imperative. Furthermore, security products that monitor hook integrity are preferable, as they render attacker's efforts more arduous, increasing the likelihood of detection.

Finally, it is important to emphasize that anti-malware solutions are not impenetrable security mechanisms that can guarantee protection against every possible threat, they are tools that defenders can utilize to identify anomalies in monitored systems. Proper setup and tuning of security software are crucial steps when installing a new anti-virus program in a network. The ability to receive meaningful alerts would facilitate defenders in detecting and responding to stealth attacks that may not be automatically identified as malicious but appear suspicious.

7. Acknowledgments

This work was partially supported by the project SERICS**0** (PE00000014) under the NRRP MUR program funded by the EU - NGEU.

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