Syscalls - SysWhispers

Introduction

SysWhispers is a tool that evades syscalls hooking via direct syscalls. There are several versions of SysWhispers which have different features. The difference between the versions will be discussed in this module.

SysWhispers

SysWhispers generates header/ASM file implants to enable direct system calls on 64-bit systems. It supports syscalls from Windows XP to Windows 10 19042 (20H2). The supported Windows versions are limited since the syscall number (SSN) can be altered with each Windows update. Therefore, a direct syscall implementation for a particular syscall on Windows 10 1903 may not be compatible with the same syscall on Windows 10 1909, and vice versa.

Since the same syscalls may have different SSNs on different versions of Windows, SysWhispers checks the Windows version of the target system at runtime and sets the SSN manually to the correct version.

SysWhispers - NtMapViewOfSection Example

SysWhispers uses a Python script to generate two files (example). The SSNs are derived from the Windows X86-64 System Call Table and are hardcoded into the created assembly file. The assembly functions then determine which SSN to use.

SysWhispers Sample Output

The assembly functions below are derived when SysWhispers is used to generate direct syscalls for `NtMapViewOfSection`.

```
// ...

NtMapViewOfSection PROC
        mov rax, gs:[60h]                             ; Load PEB into RAX.
NtMapViewOfSection_Check_X_X_XXXX:                ; Check major version.
        cmp dword ptr [rax+118h], 5
        je  NtMapViewOfSection_SystemCall_5_X_XXXX
        cmp dword ptr [rax+118h], 6
        je  NtMapViewOfSection_Check_6_X_XXXX
        cmp dword ptr [rax+118h], 10
        je  NtMapViewOfSection_Check_10_0_XXXX
        jmp NtMapViewOfSection_SystemCall_Unknown
NtMapViewOfSection_Check_6_X_XXXX:               ; Check minor version for
```

```
Windows Vista/7/8.
        cmp dword ptr [rax+11ch], 0
        je  NtMapViewOfSection_Check_6_0_XXXX
        cmp dword ptr [rax+11ch], 1
        je  NtMapViewOfSection_Check_6_1_XXXX
        cmp dword ptr [rax+11ch], 2
        je  NtMapViewOfSection_SystemCall_6_2_XXXX
        cmp dword ptr [rax+11ch], 2
        je  NtMapViewOfSection_SystemCall_6_3_XXXX
        jmp NtMapViewOfSection_SystemCall_Unknown
NtMapViewOfSection_Check_6_0_XXXX:               ; Check build number for
Windows Vista.
        cmp dword ptr [rax+120h], 6000
        je  NtMapViewOfSection_SystemCall_6_0_6000
        cmp dword ptr [rax+120h], 6001
        je  NtMapViewOfSection_SystemCall_6_0_6001
        cmp dword ptr [rax+120h], 6002
        je  NtMapViewOfSection_SystemCall_6_0_6002
        jmp NtMapViewOfSection_SystemCall_Unknown
NtMapViewOfSection_Check_6_1_XXXX:               ; Check build number for
Windows 7.
        cmp dword ptr [rax+120h], 7600
        je  NtMapViewOfSection_SystemCall_6_1_7600
        cmp dword ptr [rax+120h], 7601
        je  NtMapViewOfSection_SystemCall_6_1_7601
        jmp NtMapViewOfSection_SystemCall_Unknown
NtMapViewOfSection_Check_10_0_XXXX:              ; Check build number for
Windows 10.
        cmp dword ptr [rax+120h], 10240
        je  NtMapViewOfSection_SystemCall_10_0_10240
        cmp dword ptr [rax+120h], 10586
        je  NtMapViewOfSection_SystemCall_10_0_10586
        cmp dword ptr [rax+120h], 14393
        je  NtMapViewOfSection_SystemCall_10_0_14393
        cmp dword ptr [rax+120h], 15063
        je  NtMapViewOfSection_SystemCall_10_0_15063
        cmp dword ptr [rax+120h], 16299
        je  NtMapViewOfSection_SystemCall_10_0_16299
        cmp dword ptr [rax+120h], 17134
        je  NtMapViewOfSection_SystemCall_10_0_17134
        cmp dword ptr [rax+120h], 17763
        je  NtMapViewOfSection_SystemCall_10_0_17763
        cmp dword ptr [rax+120h], 18362
        je  NtMapViewOfSection_SystemCall_10_0_18362
        cmp dword ptr [rax+120h], 18363
        je  NtMapViewOfSection_SystemCall_10_0_18363
        jmp NtMapViewOfSection_SystemCall_Unknown
NtMapViewOfSection_SystemCall_5_X_XXXX:          ; Windows XP and Server
2003
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_0_6000:          ; Windows Vista SP0
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_0_6001:          ; Windows Vista SP1 and
Server 2008 SP0
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_0_6002:          ; Windows Vista SP2 and
Server 2008 SP2
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_1_7600:          ; Windows 7 SP0
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_1_7601:          ; Windows 7 SP1 and Server
2008 R2 SP0
        mov eax, 0025h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_2_XXXX:          ; Windows 8 and Server
2012
        mov eax, 0026h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_6_3_XXXX:          ; Windows 8.1 and Server
2012 R2
        mov eax, 0027h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_10240:        ; Windows 10.0.10240
(1507)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_10586:        ; Windows 10.0.10586
(1511)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_14393:        ; Windows 10.0.14393
(1607)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_15063:        ; Windows 10.0.15063
(1703)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_16299:        ; Windows 10.0.16299
(1709)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_17134:        ; Windows 10.0.17134
(1803)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_17763:        ; Windows 10.0.17763
(1809)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_18362:        ; Windows 10.0.18362
(1903)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_10_0_18363:        ; Windows 10.0.18363
(1909)
        mov eax, 0028h
        jmp NtMapViewOfSection_Epilogue
NtMapViewOfSection_SystemCall_Unknown:           ; Unknown/unsupported
version.
        ret
NtMapViewOfSection_Epilogue:
        mov r10, rcx
        syscall
        ret
NtMapViewOfSection ENDP

// ...
```

Explanation

The PEB structure contains three members that can be used to determine the Windows OS version:

- `OSBuildNumber`
- `OSMajorVersion`
- `OSMinorVersion`

The 64-bit assembly functions generated by SysWhispers use these members to jump to the location where the correct SSN is located as a hardcoded value. The logic being utilized is essentially several if & else if statements. For example, if the target machine is Windows 10 1809 then the following logic occurs:

1. Since the *major version* member of the PEB is equal to 10, the `NtMapViewOfSection_Check_10_0_XXXX` label is executed.

2. This label then checks the *build number* of the system. In this example, that number is 1809 which makes it jump to the `NtMapViewOfSection_SystemCall_10_0_17763` label.

3. The SSN is then set to `0028h`

4. A final jump happens to the `NtMapViewOfSection_Epilogue` label where the remaining syscall instructions are executed. Recall that a syscall function has the following format:

```
mov r10, rcx
mov eax, SSN
syscall
ret
```

SysWhispers2

SysWhispers2 shares the same concept as its previous version with the main difference being that SysWhispers2 does not require the user to specify which Windows versions to support in the Python generator. This is because SysWhispers2 no longer relies on the Windows X86-64 System Call Table for the SSNs and instead uses a method called *Sorting By System Call Address*. This method eliminates the need to have the assembly instructions manually choose the SSN at runtime, resulting in smaller syscalls stubs.

Sorting By System Call Address

Sorting by system call address is a method to retrieve the SSN of a syscall during runtime. This is done by finding all syscalls starting with `Zw` and then saving their address in an array and sorting them in ascending order (smallest to biggest addresses). The SSN will become the index of the system call stored in the array.

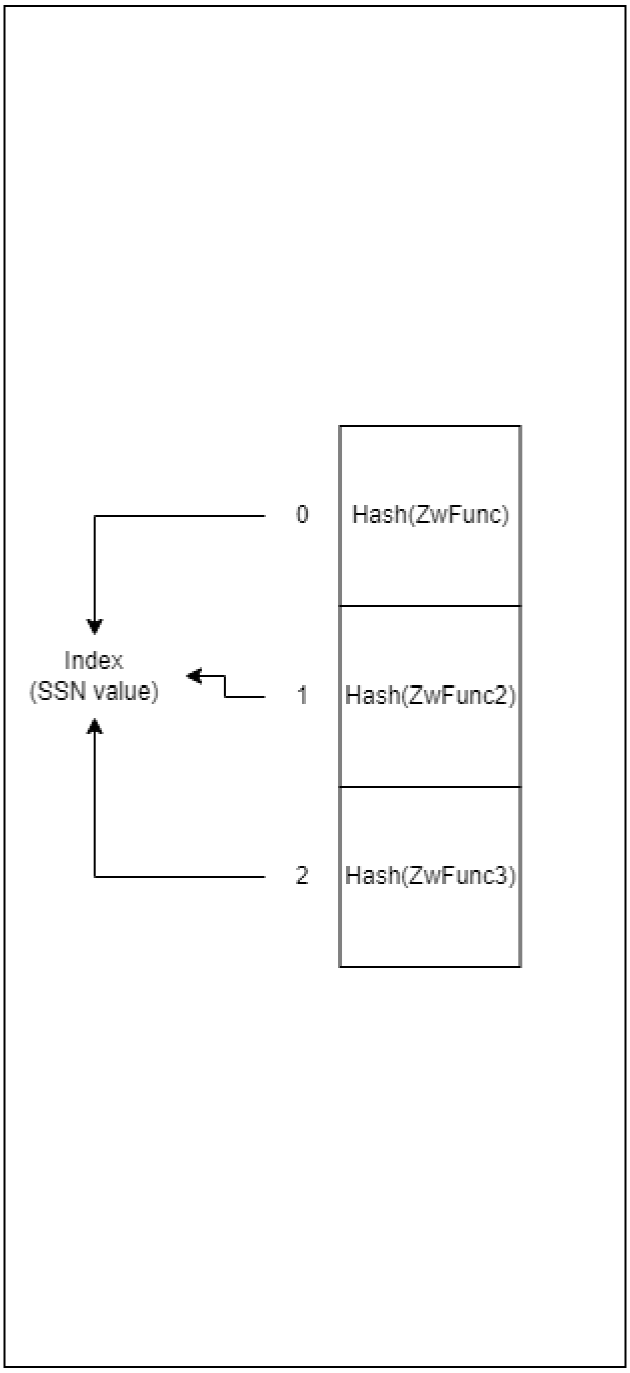
SysWhispers2 Implementation

Sorting by system call address is done via Syswhispers2's SW2_PopulateSyscallList function which fetches NTDLL's base address and its export directory. Using that information it calculates the VAs of the exported functions (addresses, names, ordinals). Recall the *IAT Hiding & Obfuscation - Replacing GetProcAddress* module where this was performed.

Next, SysWhispers2 checks the exported function names for ones prefixed with `Zw`. Those function names are hashed and saved into an array along with their addresses. After that, `SW2_PopulateSyscallList` sorts the addresses collected in ascending order.

To find a syscall's SSN, the SW2_GetSyscallNumber function takes the hash of the target syscall name and returns the index where this syscall hash is found in the array. The index value is the SSN of the syscall.

A visual example of the implementation is shown below.



SysWhispers2 Sample Output

SysWhispers2 is used to generate a direct syscall for `NtMapViewOfSection`.

```
.data
currentHash DWORD 0

.code
```

```
EXTERN SW2_GetSyscallNumber: PROC

WhisperMain PROC
    pop rax
    mov [rsp+ 8], rcx              ; Save registers.
    mov [rsp+16], rdx
    mov [rsp+24], r8
    mov [rsp+32], r9
    sub rsp, 28h
    mov ecx, currentHash
    call SW2_GetSyscallNumber
    add rsp, 28h
    mov rcx, [rsp+ 8]              ; Restore registers.
    mov rdx, [rsp+16]
    mov r8, [rsp+24]
    mov r9, [rsp+32]
    mov r10, rcx
    syscall                        ; Issue syscall
    ret
WhisperMain ENDP

NtMapViewOfSection PROC
    mov currentHash, 060C9AE95h    ; Load function hash into global
variable.
    call WhisperMain               ; Resolve function hash into syscall
number and make the call
NtMapViewOfSection ENDP

end
```

Explanation

`060C9AE95h` is the hash value in hex for the `ZwMapViewOfSection` string. Calling `NtMapViewOfSection` will first load the hash value into the global variable `currentHash`, and call `WhisperMain`. `WhisperMain` is the function responsible for calling the previously explained `SW2_GetSyscallNumber` C function that will return the SSN using the syscall's hash value, which in this case is `currentHash`.

The `mov [rsp+XX], XXX` instructions are used to save the registers to the stack before calling `SW2_GetSyscallNumber`, and the `mov XXX, [rsp+ XX]` instructions are used to restore the registers to what they were before the `SW2_GetSyscallNumber` call. This is needed because calling `SW2_GetSyscallNumber` will change these registers' values. Finally, at the end of the `WhisperMain` function, the usual syscall instructions are there present:

```
mov r10, rcx
syscall
ret
```

Notice how the `mov eax, SSN` instruction is missing. This is because when a function is called, its returned output is stored in the `eax` register. Since `SW2_GetSyscallNumber` was called before these instructions, this means that the SSN is already stored in the `eax` register.

SysWhispers3

Recall that `syscall` is responsible for shifting the execution flow from user mode to kernel mode. Legitimate `syscall` instructions should always be executed from within the `ntdll.dll` address space. Therefore, when the `syscall` instruction is included in the binary, as was the case with SysWhispers and SysWhispers2, the `syscall` instruction occurs from outside of that address space. Therefore, a binary performing a `syscall` instruction can be an indicator of malicious intent.

The updates in Syswhispers3 are found in the SysWhispers is dead, long live SysWhispers! blog post. The summary of changes is shown below.

Changes To SysWhispers3

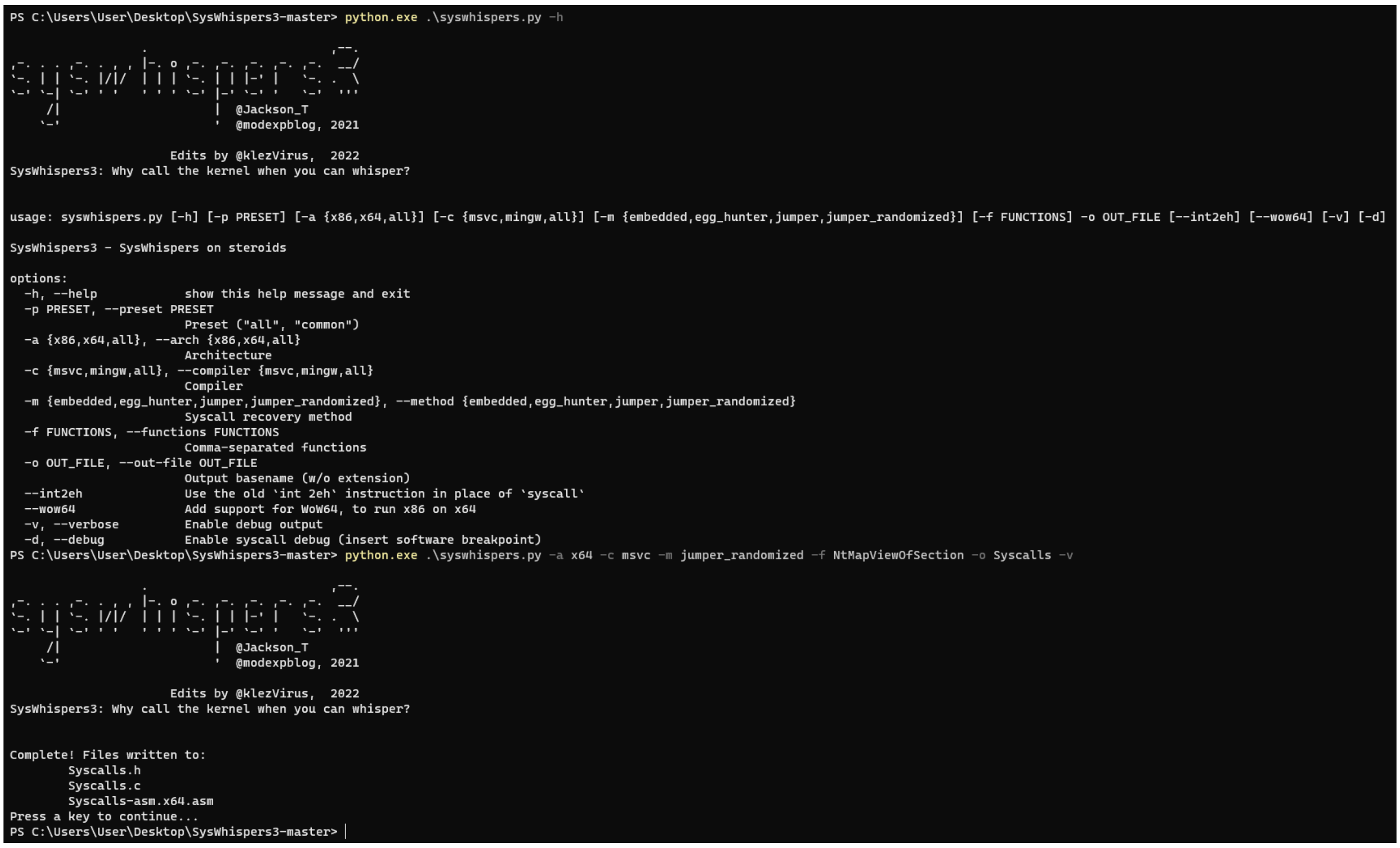
Instead of calling the `syscall` instruction directly from within the assembly functions, SysWhispers3 will search for the `syscall` instruction in `ntdll.dll`'s address space, perform a jump instruction and execute the `syscall` instruction. This method is utilizing the indirect syscall technique which is discussed later.

Furthermore, Syswhispers3 comes with a `jumper_randomized` option that will perform a jump to the `syscall` instruction that belongs to a random function. For example, when calling `NtAllocateVirtualMemory` with this option, the `syscall` instruction that will be jumped to, doesn't belong to `NtAllocateVirtualMemory` in `ntdll.dll`. Instead, the instruction belongs to another syscall like the `NtTestAlert` function.

Similar to the previous version, Syswhispers3 uses the sorting by system call address method to find a syscall.

SysWhispers3 Sample Output

SysWhispers3 is used to generate a syscall calling stub for the `NtMapViewOfSection` function. `Syswhispers3` output looks similar to `Syswhispers2` with the main difference being the additional `SW3_GetRandomSyscallAddress` and `SW3_GetSyscallNumber` function calls, which are shown and explained below.



```
PS C:\Users\User\Desktop\SysWhispers3-master> python.exe .\syswhispers.py -h

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     /|                     |  @Jackson_T
    `-'                     '  @modexpblog, 2021

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SysWhispers3: Why call the kernel when you can whisper?


usage: syswhispers.py [-h] [-p PRESET] [-a {x86,x64,all}] [-c {msvc,mingw,all}] [-m {embedded,egg_hunter,jumper,jumper_randomized}] [-f FUNCTIONS] -o OUT_FILE [--int2eh] [--wow64] [-v] [-d]

SysWhispers3 - SysWhispers on steroids

options:
  -h, --help            show this help message and exit
  -p PRESET, --preset PRESET
                        Preset ("all", "common")
  -a {x86,x64,all}, --arch {x86,x64,all}
                        Architecture
  -c {msvc,mingw,all}, --compiler {msvc,mingw,all}
                        Compiler
  -m {embedded,egg_hunter,jumper,jumper_randomized}, --method {embedded,egg_hunter,jumper,jumper_randomized}
                        Syscall recovery method
  -f FUNCTIONS, --functions FUNCTIONS
                        Comma-separated functions
  -o OUT_FILE, --out-file OUT_FILE
                        Output basename (w/o extension)
  --int2eh              Use the old `int 2eh` instruction in place of `syscall`
  --wow64               Add support for WoW64, to run x86 on x64
  -v, --verbose         Enable debug output
  -d, --debug           Enable syscall debug (insert software breakpoint)
PS C:\Users\User\Desktop\SysWhispers3-master> python.exe .\syswhispers.py -a x64 -c msvc -m jumper_randomized -f NtMapViewOfSection -o Syscalls -v

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     /|                     |  @Jackson_T
    `-'                     '  @modexpblog, 2021

                      Edits by @klezVirus,  2022
SysWhispers3: Why call the kernel when you can whisper?


Complete! Files written to:
        Syscalls.h
        Syscalls.c
        Syscalls-asm.x64.asm
Press a key to continue...
PS C:\Users\User\Desktop\SysWhispers3-master> 
```

Syscalls-asm.x64.asm

```
.code

EXTERN SW3_GetSyscallNumber: PROC

EXTERN SW3_GetRandomSyscallAddress: PROC

NtMapViewOfSection PROC
        mov [rsp +8], rcx                      ; Save registers.
        mov [rsp+16], rdx
        mov [rsp+24], r8
        mov [rsp+32], r9
        sub rsp, 28h
        mov ecx, 01A80161Bh                     ; Load function hash into
ECX.
        call SW3_GetRandomSyscallAddress        ; Get a syscall offset from
a different api.
        mov r15, rax                            ; Save the address of the
syscall {since SW3_GetRandomSyscallAddress will return the address of the
'syscall' instruction in rax register}
        mov ecx, 01A80161Bh                     ; Re-Load function hash
into ECX (optional).
        call SW3_GetSyscallNumber               ; Resolve function hash
into syscall number. {Now, eax has the SSN}
```

```
        add rsp, 28h
        mov rcx, [rsp+8]                        ; Restore registers.
        mov rdx, [rsp+16]
        mov r8, [rsp+24]
        mov r9, [rsp+32]
        mov r10, rcx
        jmp r15                                 ; Jump to -> Invoke system
call. {r15 is the address of a random 'syscall' instruction in ntdll.dll}
NtMapViewOfSection ENDP

end
```

SW3_GetSyscallNumber and **SW3_GetRandomSyscallAddress**

The `SW3_GetSyscallNumber` function finds the syscall and `SW3_GetRandomSyscallAddress` fetches the address of the `syscall` instruction of a random syscall inside of `ntdll.dll` because the `jumper_randomized` option was used.

```
EXTERN_C DWORD SW3_GetSyscallNumber(DWORD FunctionHash)
{
    // Ensure SW3_SyscallList is populated.
    if (!SW3_PopulateSyscallList()) return -1;

    for (DWORD i = 0; i < SW3_SyscallList.Count; i++)
    {
        if (FunctionHash == SW3_SyscallList.Entries[i].Hash)
        {
            return i;
        }
    }

    return -1;
}


EXTERN_C PVOID SW3_GetRandomSyscallAddress(DWORD FunctionHash)
{
    // Ensure SW3_SyscallList is populated.
    if (!SW3_PopulateSyscallList()) return NULL;

    DWORD index = ((DWORD) rand()) % SW3_SyscallList.Count;

    while (FunctionHash == SW3_SyscallList.Entries[index].Hash){
        // Spoofing the syscall return address
        index = ((DWORD) rand()) % SW3_SyscallList.Count;
    }
    return SW3_SyscallList.Entries[index].SyscallAddress;
}
```