

Device Driver Vulnerabilities

Exploiting VMware Tools HGFS.sys

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Is Windows Update sufficient?

Agenda



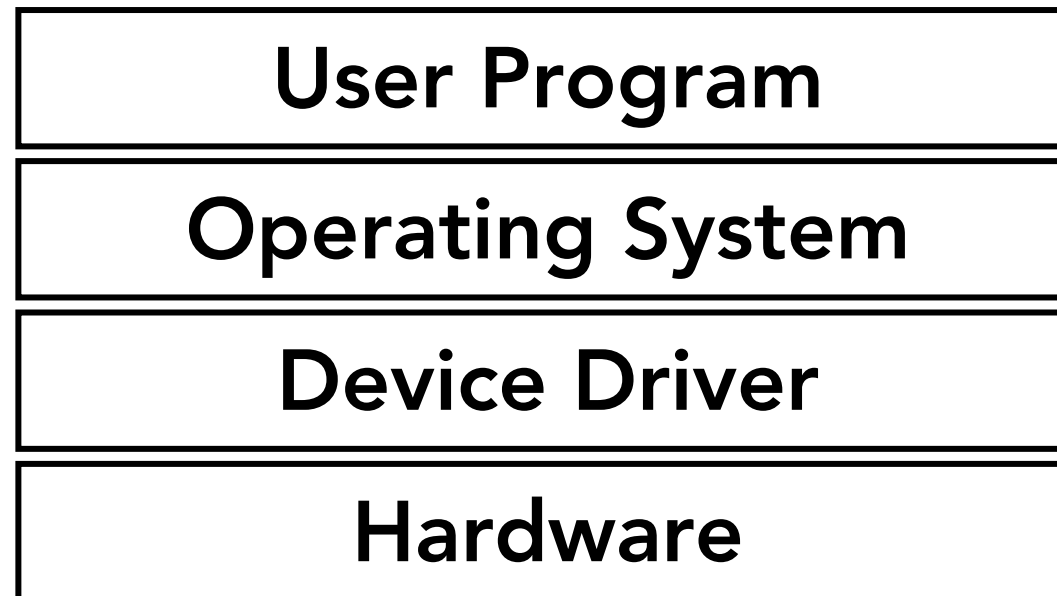
- Introduction
- Driver Vulnerabilities Explained
- Exploiting VMware Tools HGFS.sys
- Demo 1: Local Workstation
- Quick Intro to Hash Injection
- Demo 2: Terminal Server
- Mitigation
- Discussion

Introduction

Why Attacking Device Drivers?

Device drivers:

- Are part of the OS, running with kernel privileges
- Usually talk to hardware



Introduction: Device Drivers



Vulnerabilities lead to:

■ Remote code execution

- ✦ Remote attacker over Ethernet, WiFi, Bluetooth, IrDA

■ Local privilege escalation

- ✦ Local workstation users
- ✦ Malware
- ✦ Terminal Server users

→ **Focus of this presentation: local driver vulnerabilities**

Introduction: Device Drivers



Drivers are frequently:

- **Shipped by 3rd-party vendors**
 - **Written by hardware folks, not kernel developers**
 - **Of bad quality**
 - **Neglected in software patch management**
- Many driver vulnerabilities discovered recently!**

■ Device driver vulnerabilities in security products:

- ✦ Kaspersky Internet Security (2008, 2006)
- ✦ Panda Internet Security / Firewall / Anti-Virus (2008)
- ✦ Trend Micro Anti-Virus (2007)
- ✦ Norton/Symantec Anti-Virus / Internet Security (2007, 2006)
- ✦ ZoneAlarm Firewall (2007, 2003)
- ✦ Computer Associates HIPS, Anti-Virus (2006)
- ✦ avast! Anti-Virus (2005)

■ Windows default driver vulnerabilities:

- ✦ Windows XP/2003 i2omgmt.sys (2008)
- ✦ Windows XP/2003 ndistapi.sys (2007)
- ✦ Windows XP/2003 mrxsmb.sys (2006)

■ Other operating systems affected as well:

- ✦ Linux driver for Omnikey SmartCard reader (2007)

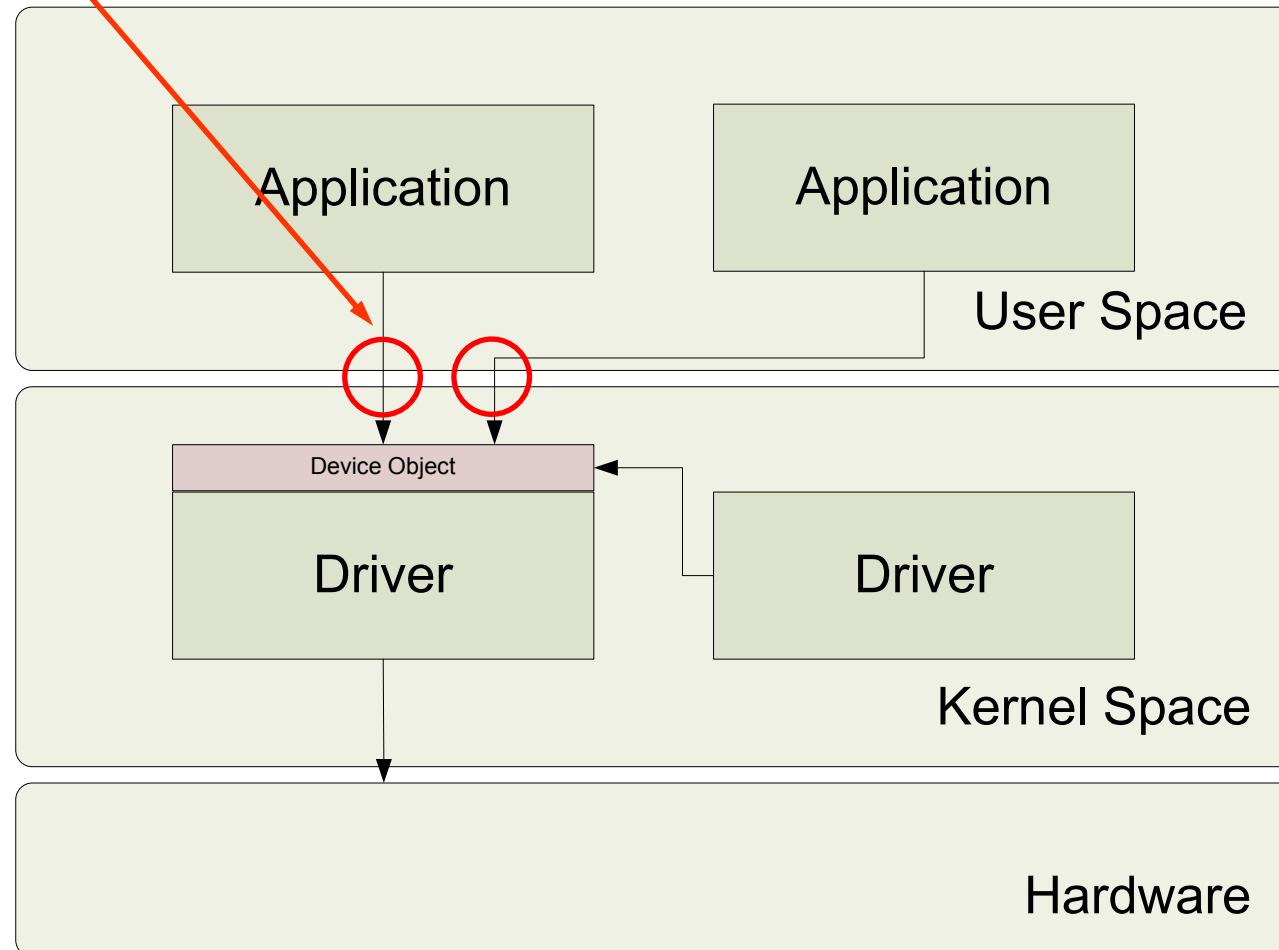
Driver Vulnerabilities Explained

How to Attack Device Drivers

Driver Vulnerabilities Explained



DeviceIoControl



Driver Vulnerabilities Explained



- Device object = virtual file

```
\Device\MyDriver  
\\.\MyDriver
```

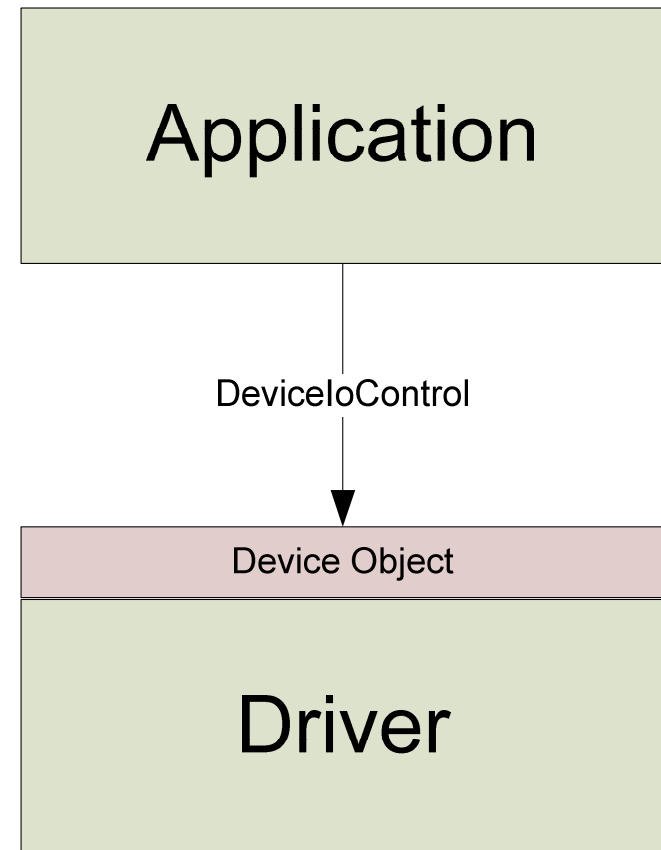
- Communication with driver

- Created by driver:

```
IoCreateDevice ("\\Device\MyDriver");  
IoCreateSymbolicLink ("\\.\MyDriver");
```

- Accessed by application:

```
handle = CreateFile ("\\.\MyDriver");  
DeviceIoControl (handle, COMMAND, ...);  
CloseHandle (handle);
```



Driver Vulnerabilities Explained

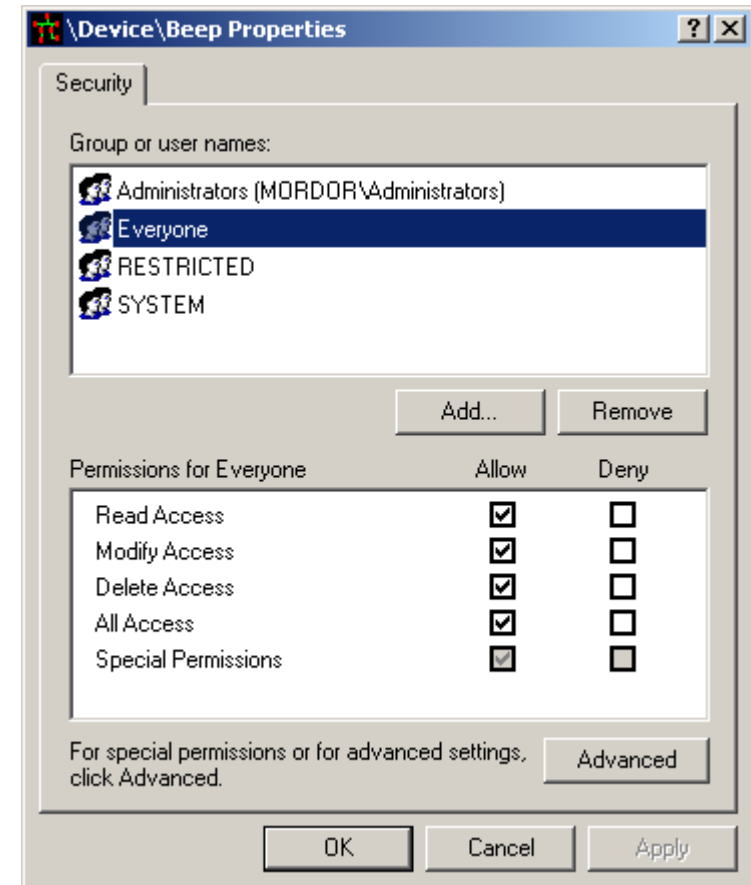


Driver access control:

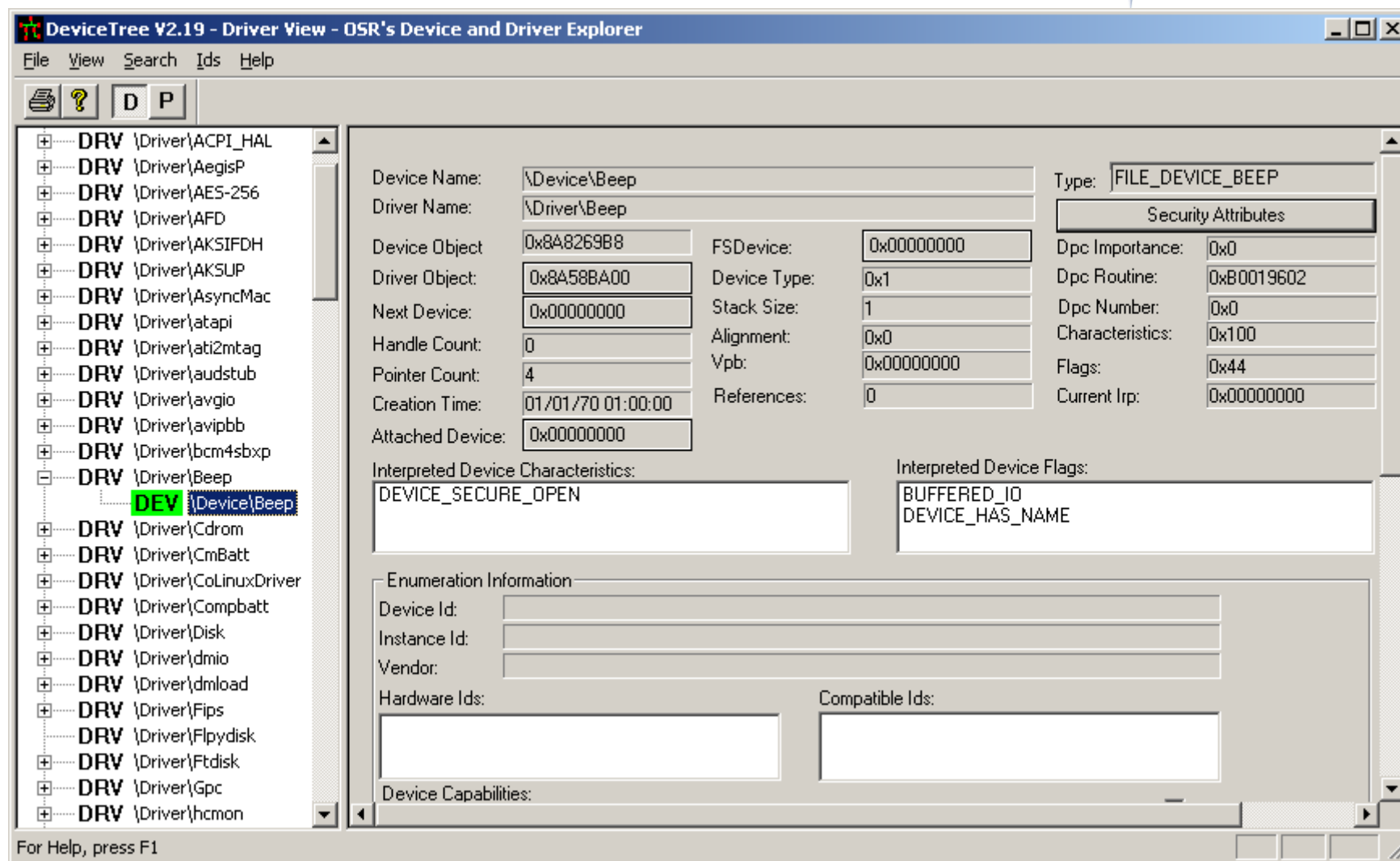
- Device objects have Access Control Lists (ACLs)
- Only harmless device objects should be accessible to users

To inspect driver access control:

- DeviceTree utility
 - ✦ Drivers
 - ✦ Device objects
 - ✦ Device ACLs



Driver Vulnerabilities Explained



Driver Vulnerabilities Explained



- **Each driver is responsible for security checks**
 - ✦ Sanity checks on data from user space apps
 - ✦ ACL setup / enforcement

- **We have a vulnerability, if:**
 - ✦ Device ACL allows access to "Everyone"
 - ✦ Privileged operations can be executed
 - ✦ by design
 - ✦ by accident: buffer overflows, writing to user supplied memory addresses, ...

- **Exploit (local privilege escalation):**
 - ✦ Open vulnerable device object as normal user
 - ✦ Send malicious data to device object
 - ✦ Malicious code executed with kernel privileges
 - ➔ Gain SYSTEM privileges

Exploiting VMware Tools HGFS.sys

Gaining SYSTEM Privileges

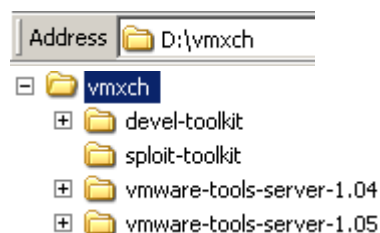
■ VMware Tools

- ✦ Drivers and utilities installed within guest
- ✦ Host to guest time sync, performance, GUI usability
- ✦ Deployed on all VMs
- ✦ Not patched using standard update mechanisms

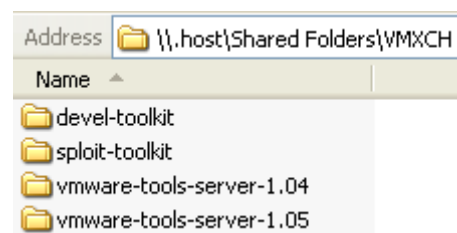
■ HGFS: Host-Guest File System

- ✦ Access files on host from guest
- ✦ Supported only on VMware Workstation
- ✦ Driver present on VMware Server and ESX as well

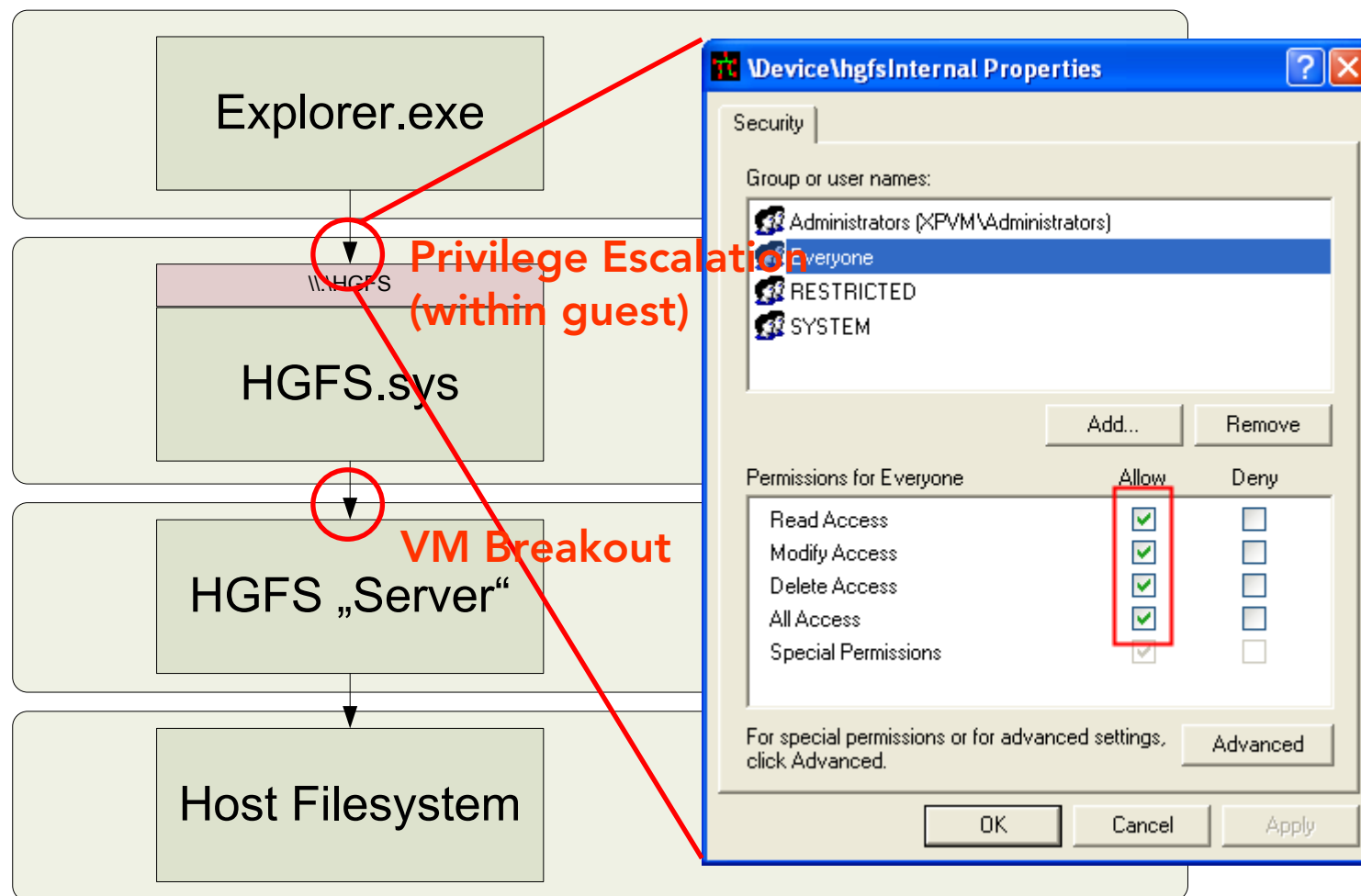
✦ on host:



within guest:



VMware Tools HGFS.sys



■ Vulnerability published without all technical details / no exploit

II. DESCRIPTION

Local exploitation of an input validation vulnerability within VMware's Hgfs.sys driver could allow an unprivileged attacker to execute arbitrary code within the kernel of a Windows guest operating system.

When a VMware guest operating system has the VMware Tools package installed, the hgfs.sys driver is loaded on the machine. This driver allows any user to open the device "\\.\hgfs" and issue IOCTLs with a buffering mode of METHOD_NEITHER. This allows untrusted user mode code to pass kernel addresses as arguments to the driver.

With specially constructed input, a malicious user can use functionality within the driver to patch kernel addresses and execute arbitrary code in kernel mode.

■ Steps to exploit the vulnerability:

- ✦ Setup lab environment
- ✦ Locate the vulnerability
- ✦ Analyze the vulnerability
- ✦ Write an exploit

VMware Tools HGFS.sys



- ACL: "Everybody" may open device object and send requests to driver
 - Driver fails to validate input from user space for certain IoControl commands
 - Driver writes zero to a memory address
 - Memory address under full control of caller
- Write NULL to arbitrary kernel memory address

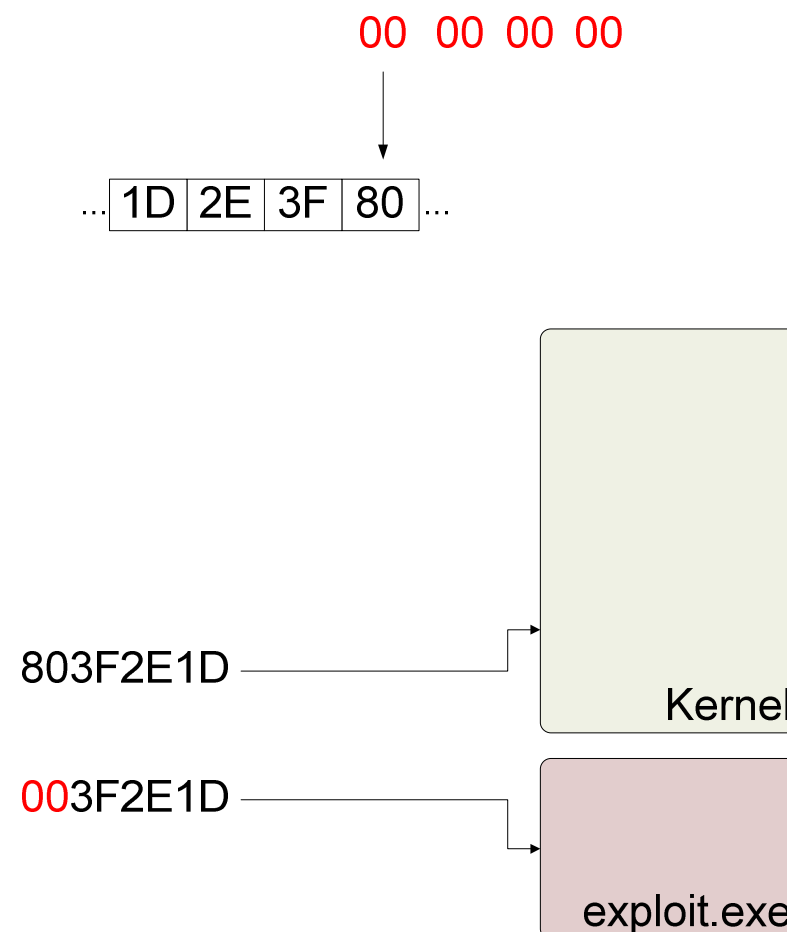
```
00015B66 . 66:8B06 MOV AX,WORD PTR DS:[ESI]
00015B69 > 66:8945 9C MOV WORD PTR SS:[EBP-64],AX
00015B6D . 66:8945 9E MOV WORD PTR SS:[EBP-62],AX
00015B71 . 6A 01 PUSH 1
00015B73 . 8D45 90 LEA EAX,DWORD PTR SS:[EBP-70]
00015B76 . 50 PUSH EAX
00015B77 . 8D45 9C LEA EAX,DWORD PTR SS:[EBP-64]
00015B7A . 50 PUSH EAX
00015B7B . FF15 F4700100 CALL DWORD PTR DS:[<&ntoskrnl.RtlCompar
00015B81 . 85C0 TEST EAX,EAX
00015B83 . 74 3A JE SHORT hgfs.00015BBF
00015B85 . FF35 142B0200 PUSH DWORD PTR DS:[22B14]
00015B88 . 8D45 90 LEA EAX,DWORD PTR SS:[EBP-70]
00015B8E . 50 PUSH EAX
00015B8F . FF15 CC700100 CALL DWORD PTR DS:[<&ntoskrnl.RtlInitUn
00015B95 . 897D A0 MOV DWORD PTR SS:[EBP-60],EDI
00015B98 . 0FB745 90 MOVZX EAX,WORD PTR SS:[EBP-70]
00015B9C . 3906 CMP DWORD PTR DS:[ESI],EAX
00015B9E . 73 03 JNB SHORT hgfs.00015BA3
00015BA0 . 66:8B06 MOV AX,WORD PTR DS:[ESI]
00015BA3 > 66:8945 9C MOV WORD PTR SS:[EBP-64],AX
00015BA7 . 66:8945 9E MOV WORD PTR SS:[EBP-62],AX
00015BAB . 6A 01 PUSH 1
00015BAD . 8D45 90 LEA EAX,DWORD PTR SS:[EBP-70]
00015BB0 . 50 PUSH EAX
00015BB1 . 8D45 9C LEA EAX,DWORD PTR SS:[EBP-64]
00015BB4 . 50 PUSH EAX
00015BB5 . FF15 F4700100 CALL DWORD PTR DS:[<&ntoskrnl.RtlCompar
00015BB8 . 85C0 TEST EAX,EAX
00015BBD . 75 12 JNZ SHORT hgfs.00015BD1
00015BBF > 0FB745 90 MOVZX EAX,WORD PTR SS:[EBP-70]
00015BC3 . 8B4D A4 MOV ECX,DWORD PTR SS:[EBP-5C]
00015BC6 . 8901 MOV DWORD PTR DS:[ECX],EAX
00015BC8 . C743 1C 040001 MOV DWORD PTR DS:[EBX+1C],4
00015BCF . EB 00 JMP SHORT hgfs.00015BDE
00015BD1 > 8B45 A4 MOV EAX,DWORD PTR SS:[EBP-5C]
00015BD4 . 8320 00 AND DWORD PTR DS:[EAX],0
00015BD7 > C745 BC 340001 MOV DWORD PTR SS:[EBP-44],C0000034
00015BDE > 807D C8 00 CMP BYTE PTR SS:[EBP-38],0
00015BE2 . 74 10 JE SHORT hgfs.00015BF4
00015BE4 . 8B45 BC MOV EAX,DWORD PTR SS:[EBP-44]
00015BE7 . 8943 18 MOV DWORD PTR DS:[EBX+18],EAX
00015BEA . 32D2 XOR DL,DL
00015BEC . 8BCB MOV ECX,EBX
00015BEE . FF15 44700100 CALL DWORD PTR DS:[<&ntoskrnl.IofComple
00015BF4 > FF15 78700100 CALL DWORD PTR DS:[<&ntoskrnl.KeLeaveCr
00015BFA . 807D B8 00 CMP BYTE PTR SS:[EBP-48],0
00015BFE . B8 03010000 MOV EAX,103
00015C03 . 75 03 JNZ SHORT hgfs.00015C08
00015C05 . 8B45 BC MOV EAX,DWORD PTR SS:[EBP-44]
00015C08 > 8B4D F0 MOV ECX,DWORD PTR SS:[EBP-10]
00015C0B . 64:890D 000001 MOV DWORD PTR FS:[0],ECX
00015C12 . 5F POP EDI
00015C13 . 5E POP ESI
00015C14 . 5B POP EBX
00015C15 . C9 LEAVE
00015C16 . C2 0800 RETN 8
```



VMware Tools HGFS.sys



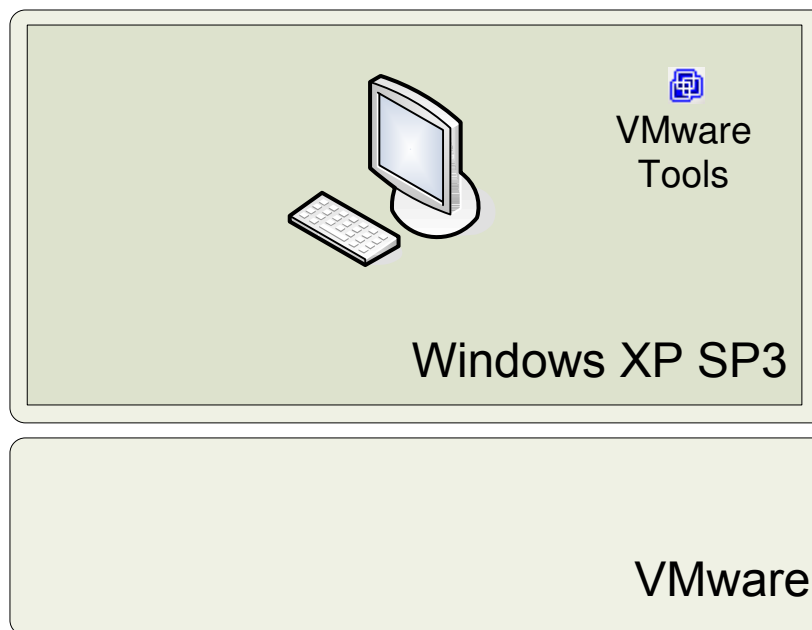
- Find address used as jump target by kernel
 - Partially overwrite with NULL
 - Place shellcode at modified address
 - Wait until kernel jumps to modified address
- Exploit shellcode run by kernel



Demo I

Local Workstation

Demo I: Local Workstation



Hash Injection

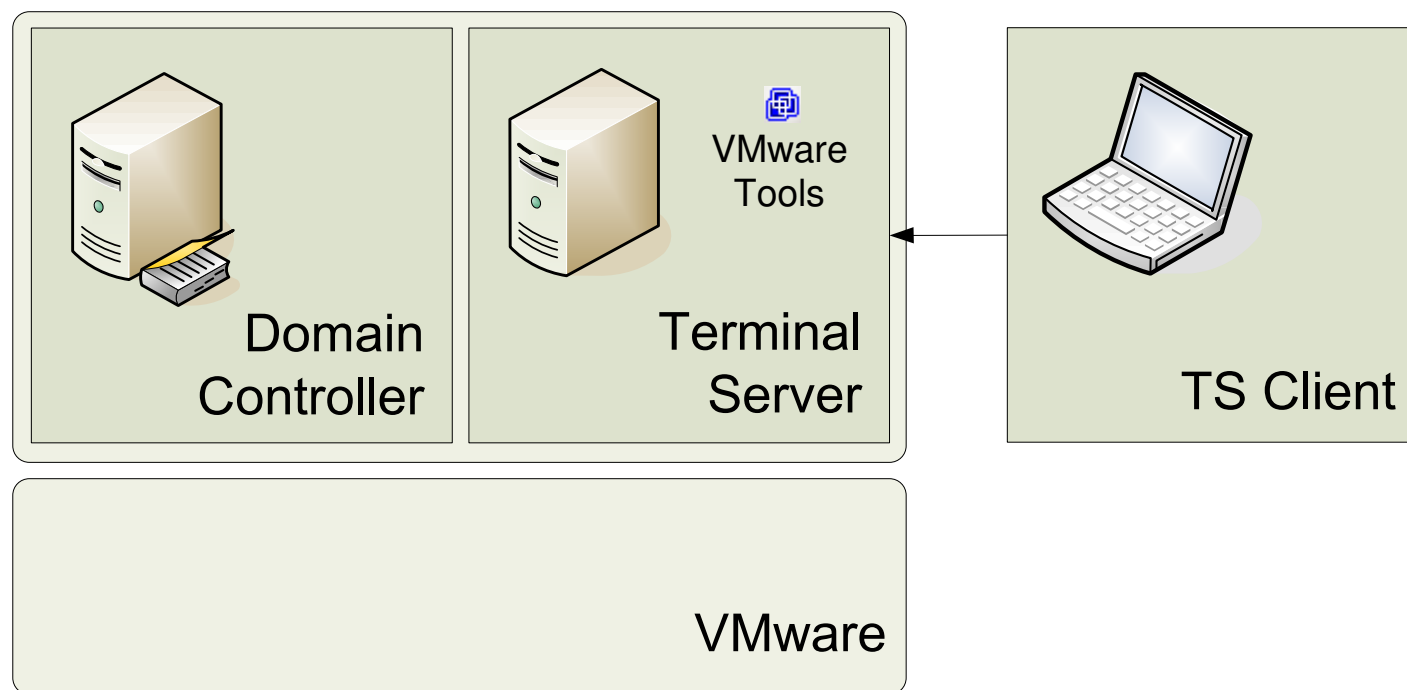
A Quick Introduction

- **Windows uses cryptographical hashes of user passwords: LM/NTLM hashes**
- **Windows stores LM/NTLM hashes locally, even for AD users**
 - ✦ AD user hashes are cached until reboot
- **Stored hashes can be dumped**
 - ✦ Requires local admin or SYSTEM privileges
- **Attack 1: Offline dictionary attack to find password**
- **Attack 2: Inject hashes into running process; use hashes to authenticate in the domain without knowing the password**

Demo II

Terminal Server

Demo II: Terminal Server



Mitigation

Lessons Learned

Is Windows Update sufficient?

Mitigation: Driver Vulnerabilities



Windows Update is not sufficient!

- **3rd-party drivers require patch management too**
- **Prefer hardware natively supported by Windows**
 - ✦ No 3rd-party drivers
 - ✦ Updated as part of OS patch management
- **Audit remaining 3rd-party drivers for vulnerabilities**
- **Driver security as hardware evaluation criterion**
 - ✦ Quality of drivers also means security
 - ✦ Vendor's security history
 - ✦ Vendor's responsiveness to driver bugs

Mitigation: Terminal Servers



- **Patching (of course)**
- **Restrict which software terminal server users may run**
 - ✦ White list, not black list
 - ✦ No development utilities
 - ✦ No scripting languages (e.g. Python)
- **Secure web access / perimeter security**

Mitigation: Hash Injection



- **No local admin rights for regular employees**
 - ✦ Developers can be local admin on separate systems not in the domain
- **Only use domain admin accounts to logon to domain controllers; never logon to member servers or workstations**
 - ✦ Use dedicated admin accounts for member server administration
- **Monitor audit event ID 552**
 - ✦ Triggered by hash injection
 - ✦ Triggered by legitimate services as well

References



- **VMware Tools HGFS Local Privilege Escalation Vulnerability**
<http://labs.idefense.com/intelligence/vulnerabilities/display.php?id=712>
- **OSR DeviceTree by Mark Cariddi:**
<http://www.osronline.com/article.cfm?article=97>
- **Kartoffel – Secure Your Driver**
<http://kartoffel.reversemode.com/>
- **Remote and Local Exploitation of Network Drivers**
<https://www.blackhat.com/presentations/bh-usa-07/Bulygin/Presentation/bh-usa-07-bulygin.pdf>
- **Hash Injection Attack**
[http://www.csnc.ch/static/download/Hash Injection Attack E.pdf](http://www.csnc.ch/static/download/Hash%20Injection%20Attack%20E.pdf)