Check Point
SOFTWARE TECHNOLOGIES LTD

Microsoft

Poisoned RDP

He Said, She Said – Poisoned RDP Offense and Defense

@EyalItkin

@dana_baril

Who Are We?

Eyal Itkin

Security Researcher

Check Point Research cp<r>

@EyalItkin

Dana Baril

Security Researcher

Microsoft Defender ATP

@dana_baril

BlueKeep ?

- A **different** vulnerability in the Remote Desktop Protocol
  - Unauthenticated RCE in Microsoft's RDP Servers
  - Disclosed by the UK national CERT in May 2019

CVE-2019-0708 | Remote Desktop Services Remote Code Execution Vulnerability

Security Vulnerability

Published: 05/14/2019

- We are going to focus on a **different** attack vector

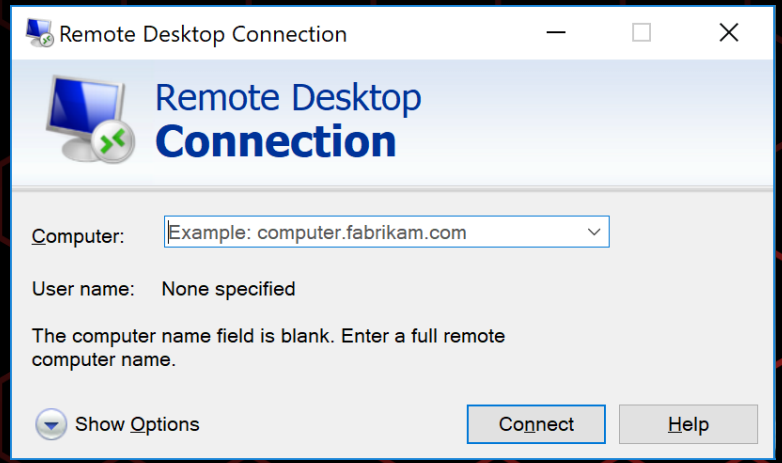
Motivation

- Lazy Lateral Movement
- “Ambush” privileged users
- IT Staff
  - Gain credentials
- Malware Researchers
  - Escape isolated virtual machines

Remote Desktop Protocol (RDP)

“Client” **“Server”**

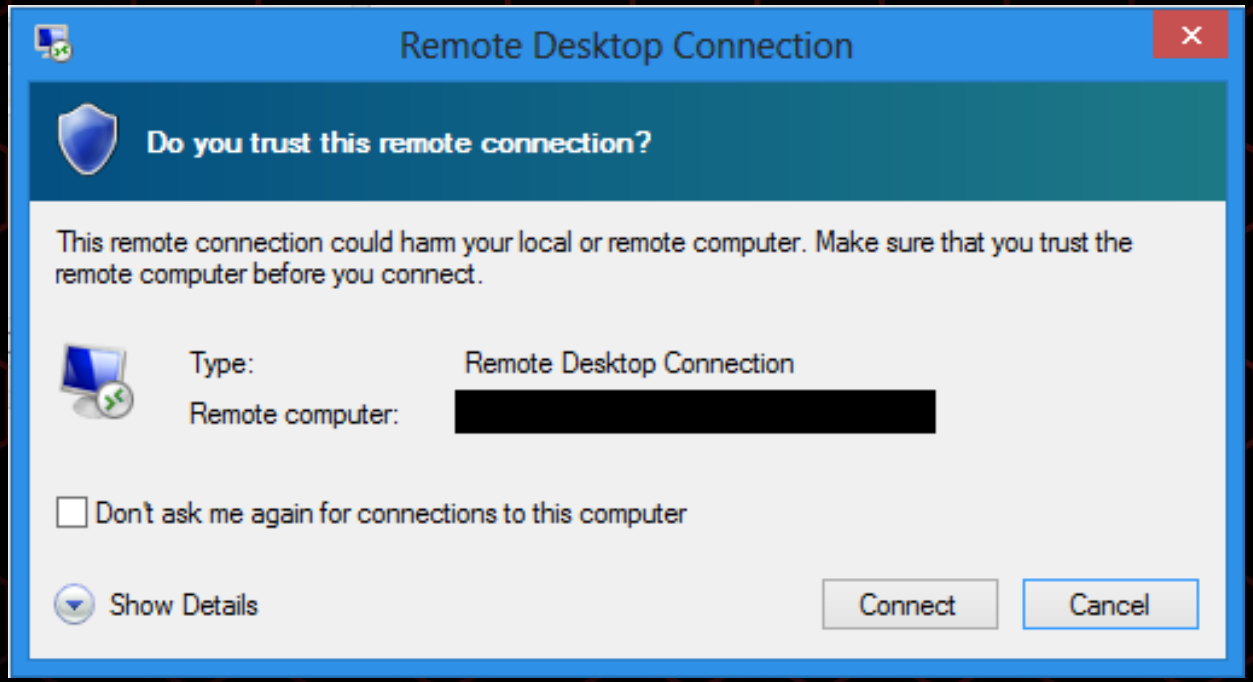
- Connects to a remote Windows Machine
  - Remote corporate PC / Server
  - Local / Remote Virtual Machine
- A.K.A. `mstsc`
- Attack doesn’t require “Admin”



Poisoned RDP ?

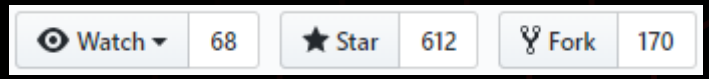
- Collect credentials from the victim
- Attack & Take over the victim’s computer

RDP Clients

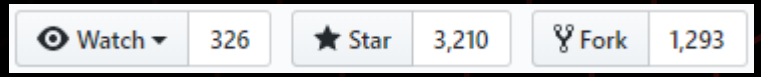

Remote Desktop Connection
Do you trust this remote connection?
This remote connection could harm your local or remote computer. Make sure that you trust the remote computer before you connect.
Type:
Remote Desktop Connection
Remote computer:
[redacted]
Don't ask me again for connections to this computer
Show Details
Connect
Cancel

Our Targets

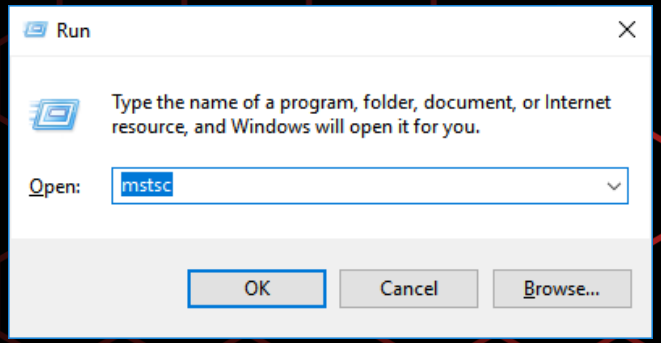
- Open Source RDP Clients
  - rdesktop



  - FreeRDP



- Microsoft's default client
  - mstsc.exe



1. Start with the easiest target

- Pick the simplest open source - `rdesktop`
- Audit the code and learn how RDP works
- Find potentially vulnerable features / modules
- Gradually gain confidence
- Move on when scanned all of the code

Lessons on RDP

- Protocol consists of logical channels
  - BlueKeep exploits the internal (non-public) `MS_T120` channel
- Contains multiple authentication methods
- Screen updates are sent using Bitmaps
- Basic Clipboard types are shared

2. Break rdesktop

- Naïve C code with less than minimal checks
  - Almost no checks that minimal input was received
- Found 11 critical vulnerabilities (19 Overall)
- CVEs:
  - CVE 2018-8791 – CVE 2018-8800
  - CVE 2018-20174 – CVE 2018-20182

3. Find complicated features

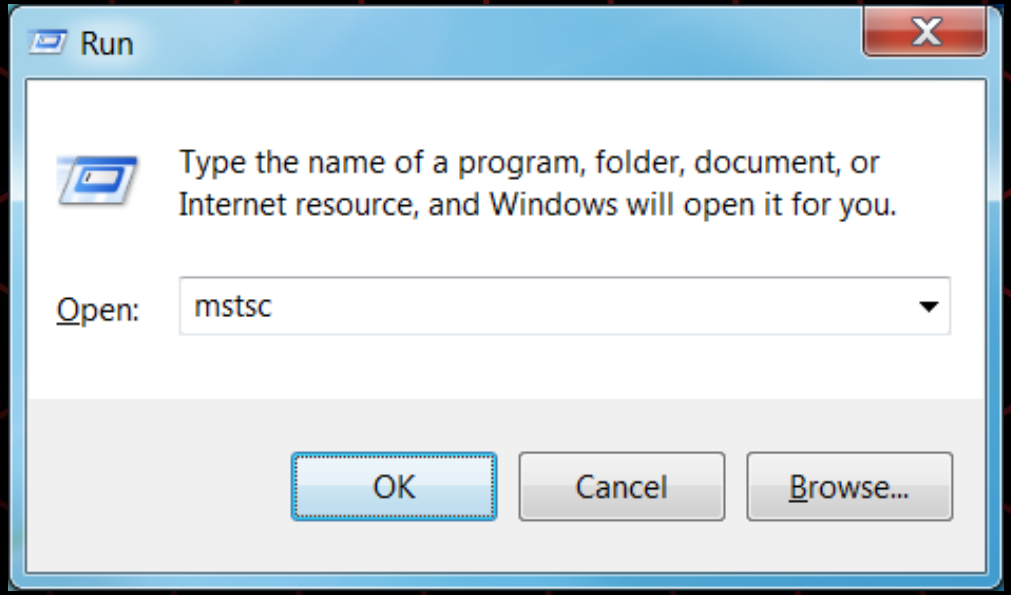
- CVE 2018-8795: Integer-Overflow in Bitmap Parsing

```
in_uint16_le(s, width)    16 bits:    0x8000
in_uint16_le(s, height)   16 bits:    0x8001
in_uint16_le(s, bpp)      16 bits:         4
// Allocate space       > 32 bits:   0x20000
bmpdata = xmalloc(width * height * bpp)
bitmap_decompress(bmpdata, width, height, bpp);
```

4. Break FreeRDP

- The C code looks better
  - Still has a few cracks if we look deep enough
  - Again, vulnerable to Bitmap parsing
- Found 5 critical vulnerabilities (6 Overall)
- CVEs:
  - CVE 2018-8784 – CVE 2018-8789

mstsc.exe


Run
Type the name of a program, folder, document, or Internet resource, and Windows will open it for you.
Open:
mstsc
OK
Cancel
Browse...

5. Break `mstsc.exe` ?

- PoCs from previous targets failed ☹
- The code is robust
  - Smart buffers check for parsing errors
- Includes many more features
- Where should we go now?

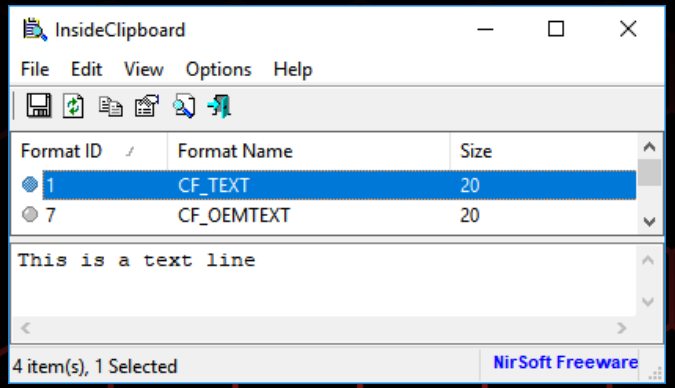
Back to the Drawing board

Clip

- Until now, the clipboard shared text:
  - CF_TEXT
  - CF_UNICODETEXT
- It seems like Microsoft supports many more formats now
- Let’s dig into the clipboard

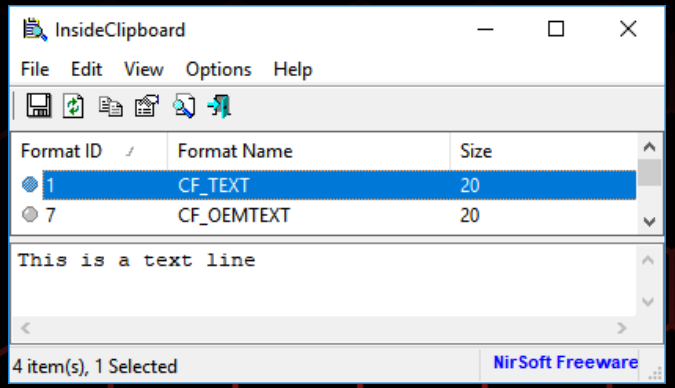
Clipboard 101

- A kernel data structure that stores data
  - One clipboard per session (“connection”)
  - Shared between processes
- Stores data (blobs) by ID / Name
- **Caution:** Clipboard data is not trusted. Parse the data carefully before using it in your application.



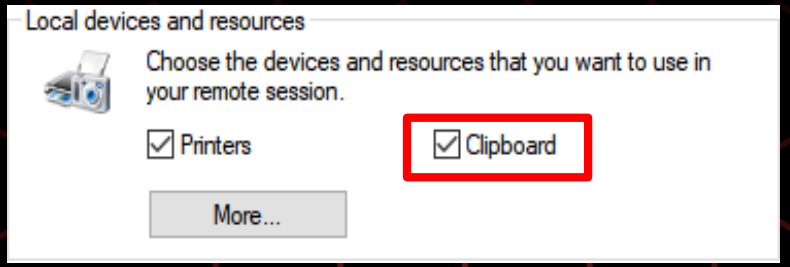
Clipboard 101

- A kernel data structure that stores data
  - One clipboard per session (“connection”)
  - Shared between processes
- Stores data (blobs) by ID / Name
- “**Caution:** Clipboard data is not trusted. Parse the data carefully before using it in your application.” (MSDN)



Clipboard Over RDP

- Everything in the clipboard is synchronized automatically
- Black Lists instead of White Lists
  - Some formats are discarded by ID
  - Some formats are discarded by Name
- To avoid syncing “heavy” content, all content is subject to “delayed rendering”

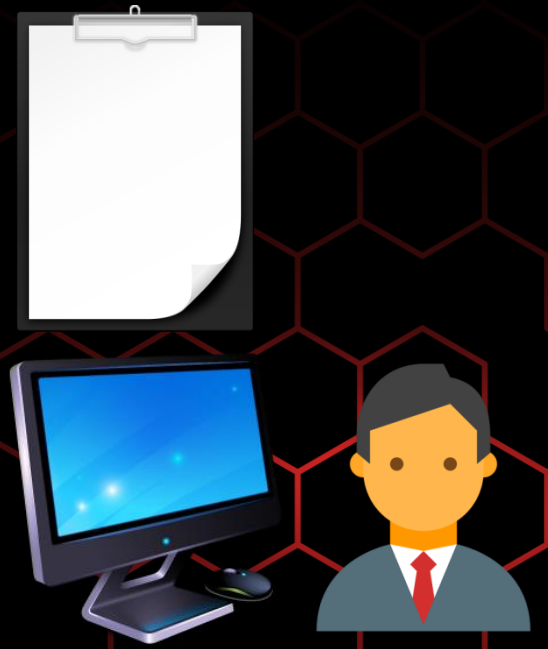


Drag & Drop

- Internally, copying files is called “Drag & Drop”
- Copying files uses multiple formats
  - `CF_HDROP` – lists the file names
  - `FileGroupDescriptorW` – full metadata
  - Many more…
- Let’s see how it works in practice

Drag & Drop In Action – Ctrl+C

RDP Server



RDP client

Drag & Drop In Action – Ctrl+C

RDP Server

RDP client

Drag & Drop In Action – Ctrl+V

Drag & Drop In Action – Ctrl+V

Drag & Drop In Action – Ctrl+V

RDP Server

RDP client

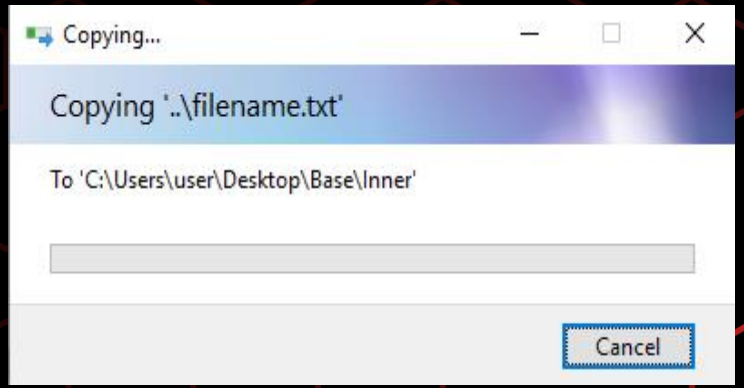
Drag & Drop In Action – Ctrl+V

FileGroupDescriptorW

- Proprietary blob structure
- Contains a list of file records
  - Meta data (timestamps)
  - File path – filename
- Client passes it directly to the clipboard

Path Canonicalization

@GullOmer: “try to find where they sanitize the path”



Path Traversal Over RDP

- We received a CVE from Microsoft: CVE 2019-0887
- When using “Copy & Paste” a malicious server can:
  - Drop arbitrary files to arbitrary locations
- Drop your script in the Startup folder and that’s it

Taking it one step further

- The clipboards are **fully** synchronized
  - Ctrl+C updates the clipboard
  - Each update sends a `CLIPRDR_FORMAT_LIST`
  - The receiver updates his clipboard accordingly
- What does it mean?

Scenario #1 - Eavesdropping

- When the client copies a password we get it too
- This is a **feature** of the synced clipboard
- We know in advance when the client is going to copy a file on **his** computer

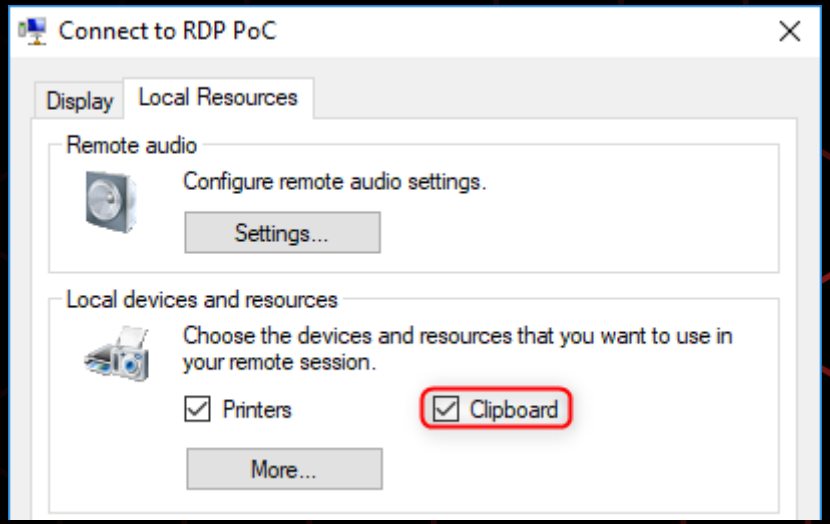
Scenario #2 – Ctrl+V Only Attack

- Once again, ambush the client
- When he copies a file, start the attack
- Send an update message and switch his clipboard to a malicious `FGDw`
- His Ctrl+V will trigger the path traversal

Did we break them all ?

Hyper-V

- Never used it till now
- Installed a Hyper-V machine, and



Hyper-V? RDP!

- Microsoft uses RDP for accessing virtualized machines
- The GUI connection to the VM is transferred over RDP!
- Our PoC worked on the first attempt
- We just found a Guest-to-Host VM Escape ☺

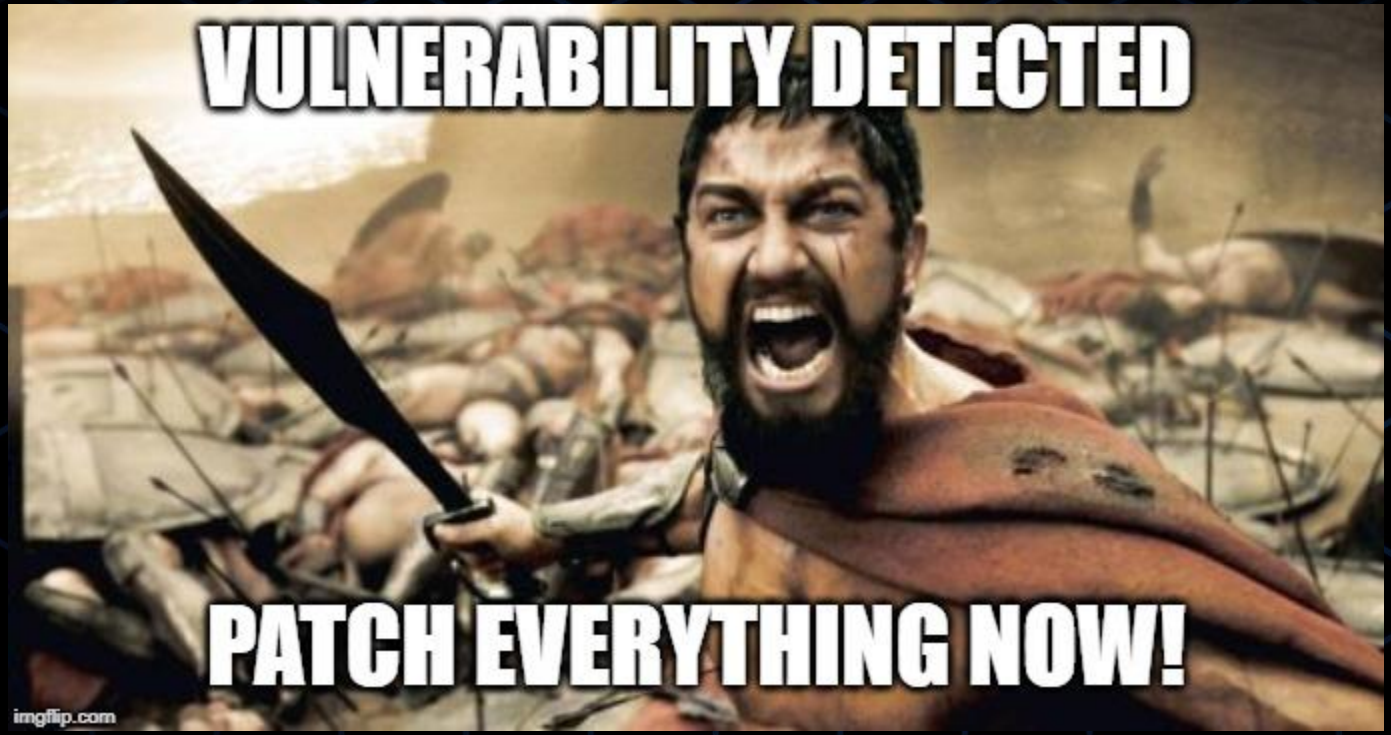
Hyper-V Demo

https://youtu.be/nSGlMJqQEh0

Note on WDAG and friends

- Windows Defender Application Guard
  - Browsing “risky” sites with a virtualized Edge browser
- Uses `hvsirdpclient.exe` instead of `mstsc.exe`
- This time, MS uses White-lists instead of Black-Lists
  - Clipboard is off by default
  - The clipboard permits only 2 format types: Text & Images
- The White list blocks our vulnerability, good job ☺

Defense

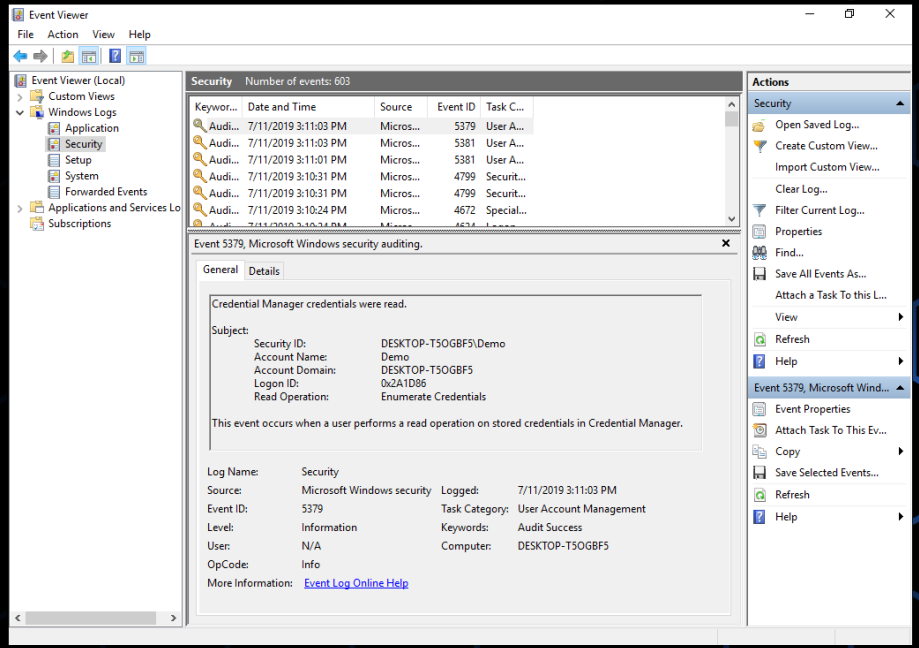

VULNERABILITY DETECTED
PATCH EVERYTHING NOW!
imgflip.com

A patch is not enough

- Users remain vulnerable until they install patch
- Detect using existing telemetry
- Detection must be implemented on “victim” machine
- RDP anomaly detection won’t cut it

Event Tracing for Windows (ETW)

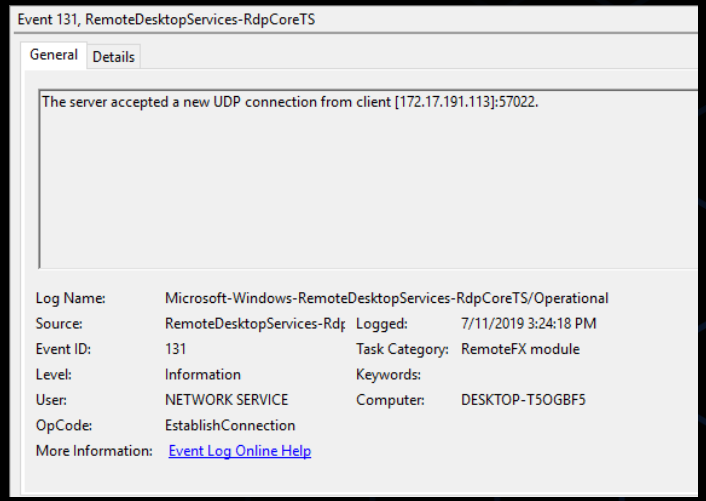
- Kernel-level tracing facility that lets you log kernel or application-defined events



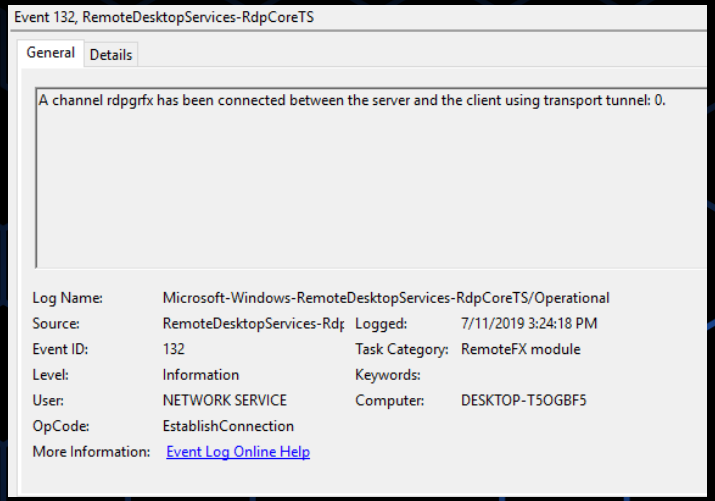
RDP Connections Events

Provider Guid: 1139c61b-b549-4251-8ed3-27250a1edec8

Microsoft-Windows-RemoteDesktopServices-RdpCoreTS



Events 131 – accepting connection



Event 132 – channel connected

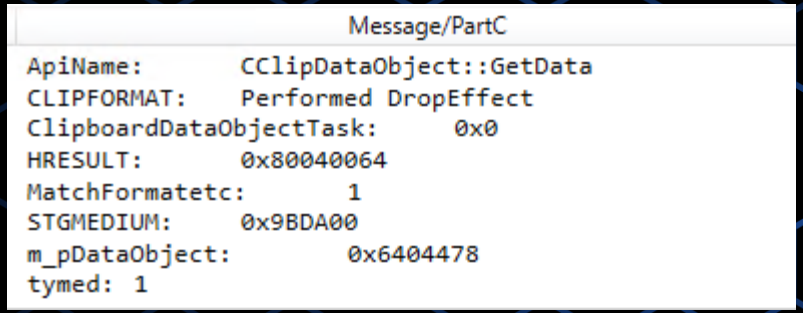
Clipboard Events

Non-manifested provider, tracing clipboard API usages

Provider guid: 3e0e3a92-b00b-4456-9dee-f40aba77f00e

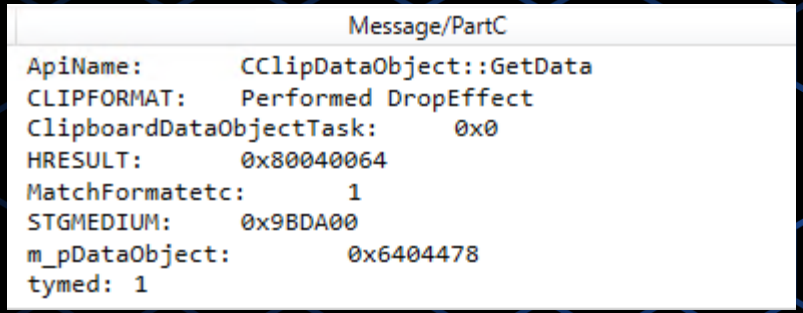
Microsoft.Windows.OLE.Clipboard

Task name: OLE_Clipboard_MethodDiagnostics



Clipboard Events

- Selected properties:
  - ApiName: GetData, SetData
  - CLIPFORMAT: Returned clipboard format (bitmap, text, Unicode text, etc.).
  - HRESULT: Api HResult
  - Tymed: Paste destination medium
- **No clipboard content!**



Telemetry Demo

https://www.youtube.com/watch?v=q9Lox_rfqvw

Detection Logic – Basic

- While in RDP:
  1. When multiple files are copied in a short period of time
  2. Triggers a scan

File Creation Events

- In order to overcome the file information gap, we need more data!
- Security products have file creation indications

Detection Logic

- While in RDP:
  1. When multiple files are copied in a short period of time
  2. Correlate file creation with the same timestamps
  3. If the correlated files are in different directories – alert!

More Detection Logics

- Startup folder as a destination
  - Anomaly detection
  - Files scanning
- Clipboard as an attack vector
  - File pasting anomaly - number of pasted files or the files directories
- Malicious files dropping
  - File creation anomaly - file path, creation time and file name

OS Patch

- Verify the RDP clipboard: `ValidateFilePaths`

```
000000016AB893FC   CFormatDataPacker::DecodeFormatData(void * *,ulong,uchar *,ulong)
000000016AB89640   call        ?FileDescriptorW@CClipFormatTypes@@QEAAIXZ
000000016AB89645   xor         b4 r9d, b4 r9d
000000016AB89648   mov         b4 r8d, b4 ebp                                  // unsigned int
000000016AB8964B   cmp         b4 ebx, b4 eax
000000016AB8964D   mov         rdx, r14                                        // unsigned __int8 *
000000016AB89650   lea         rax, ss:[rsp+arg_10]
000000016AB89655   setz        b1 r9b                                          // int
000000016AB89659   mov         ss:[rsp+var_28], rax                            // int *
000000016AB8965E   call        ?ValidateFilePaths@CFormatDataPacker@@AEAAJPEAEKHPEAH@Z
000000016AB89663   mov         b4 ebx, b4 eax
000000016AB89665   test        b4 eax, b4 eax

000000016AB89667   jns         0x16AB896AD
```

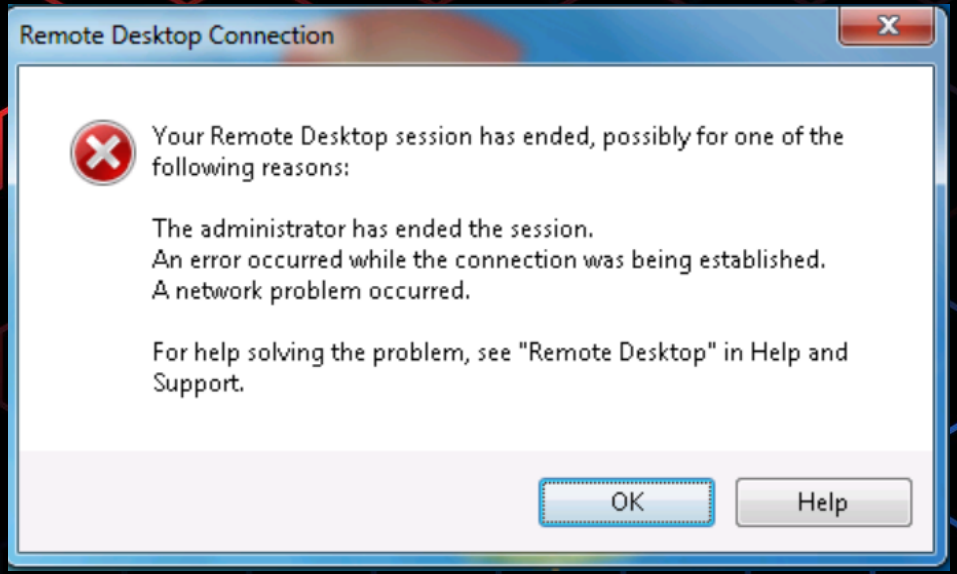
- Verify canonical path before pasting:

```
pszFilename = pCurrentFileRecord->szFilename;
status_code = PathCchCanonicalize(&pszPathOut, 0x104ui64, pszFilename);
if ( (status_code & 0x80000000) != 0 )
{
```

What have we learned ?

- Design lesson: Think twice before connecting different modules
  - Clipboards were designed to be used locally, and therefore trusted
  - When sharing across machines it made sense to enable clipboard sharing
  - However, this exposed machines to clipboards they can no longer trust
- Windows telemetry is an important tool in the defender’s toolbox
- Our industry can benefit from cross-community collaborations

That’s all folks



@EyalItkin

@dana_baril