The Risks of RDP and How to Mitigate Them

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GoSecure

About Us

Olivier Bilodeau

Cybersecurity Research Lead at GoSecure

- Jack of all trades, master of none
- Speaker BlackHat, RSAC, SecTor, etc.
- Co-founder MontréHack (hands-on security workshops)
- NorthSec VP Training / Hacker Jeopardy

Lisandro Ubiedo

Security Researcher at GoSecure

- Cloud-based trickery
- Malware analysis and Threat research
- Stratosphere Labs collaborator

Introduction to RDP

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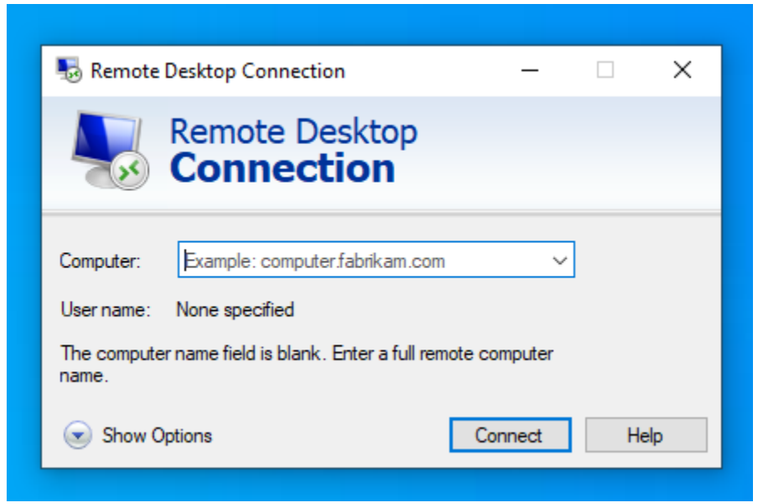
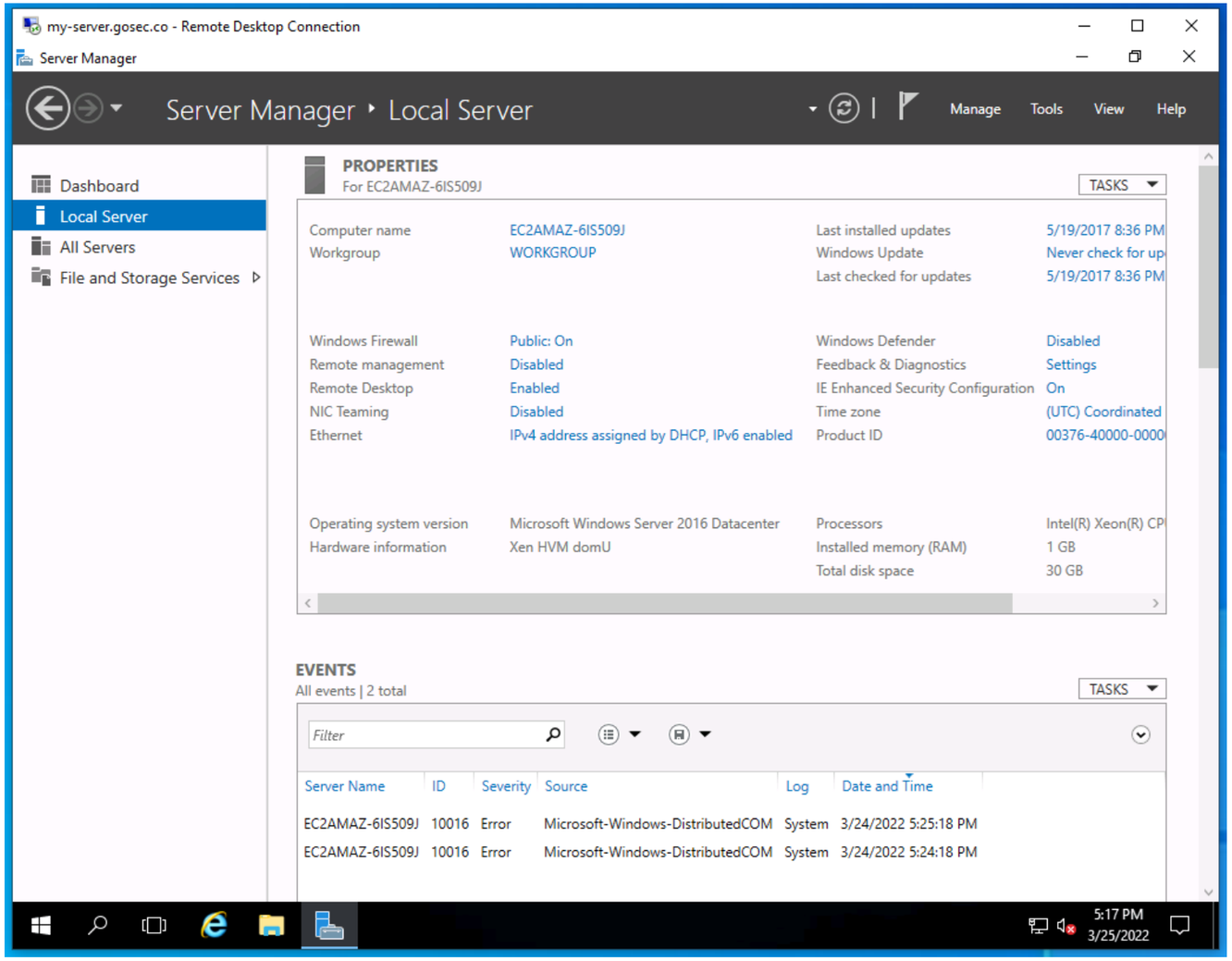
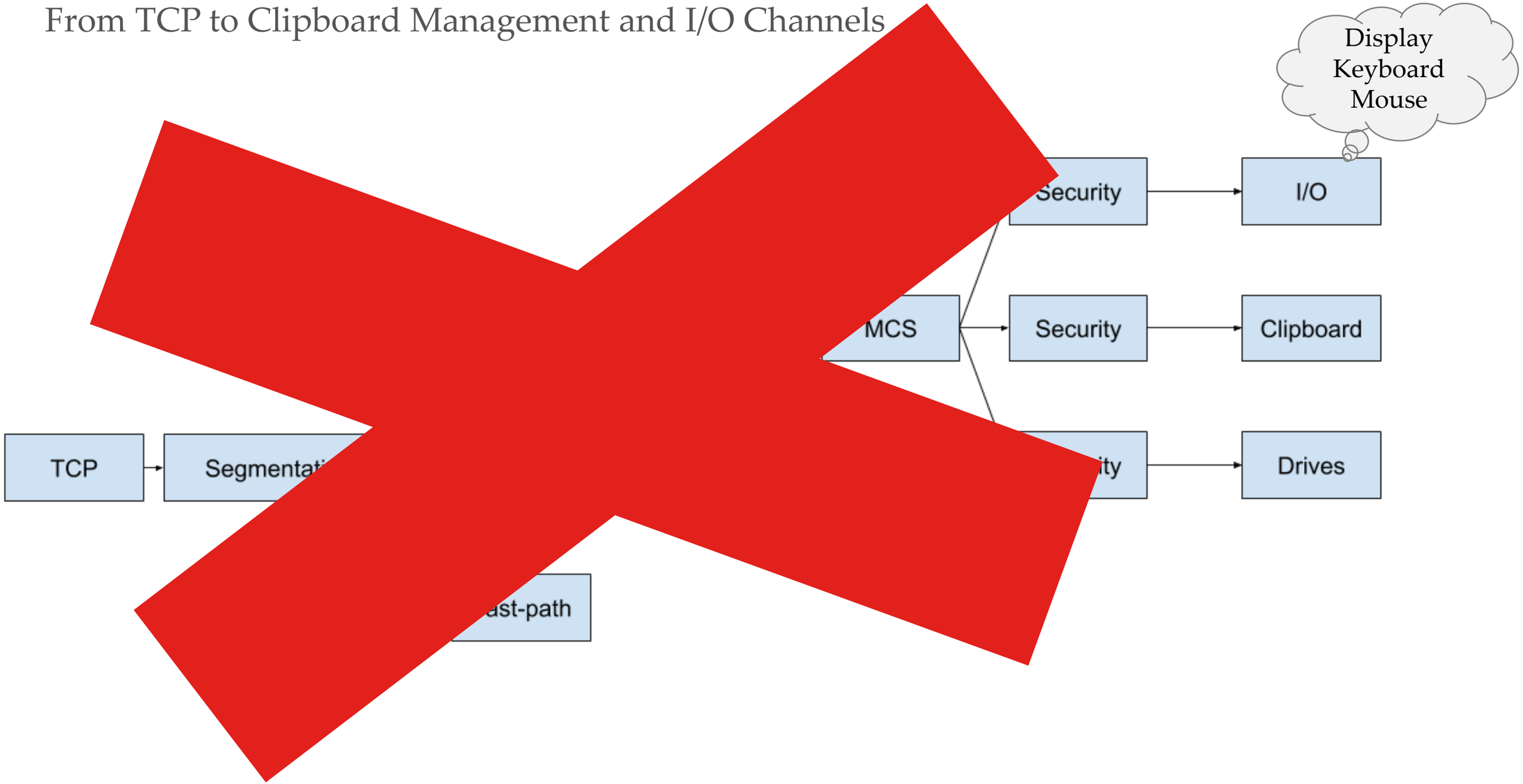
Remote Desktop Protocol





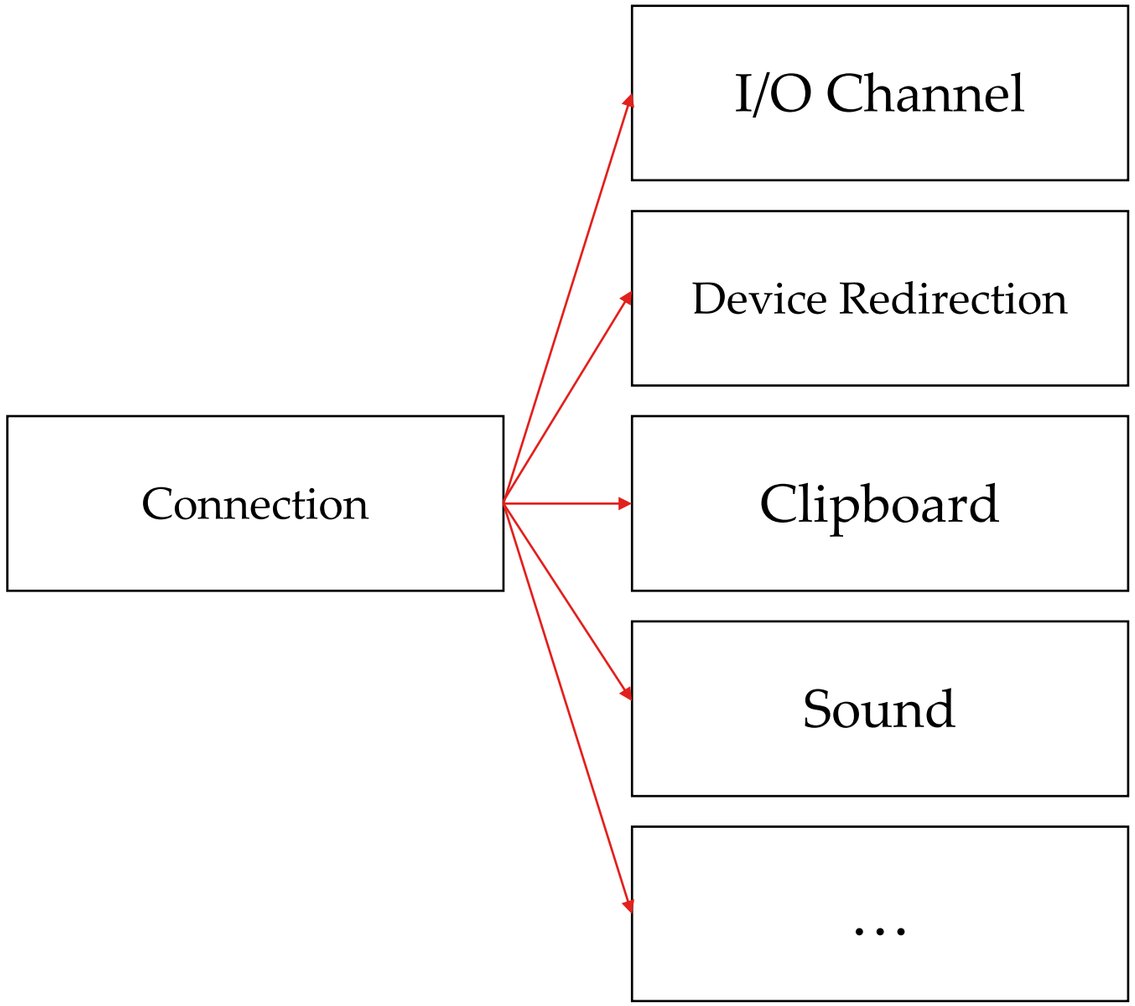
RDP Layers

From TCP to Clipboard Management and I/O Channels

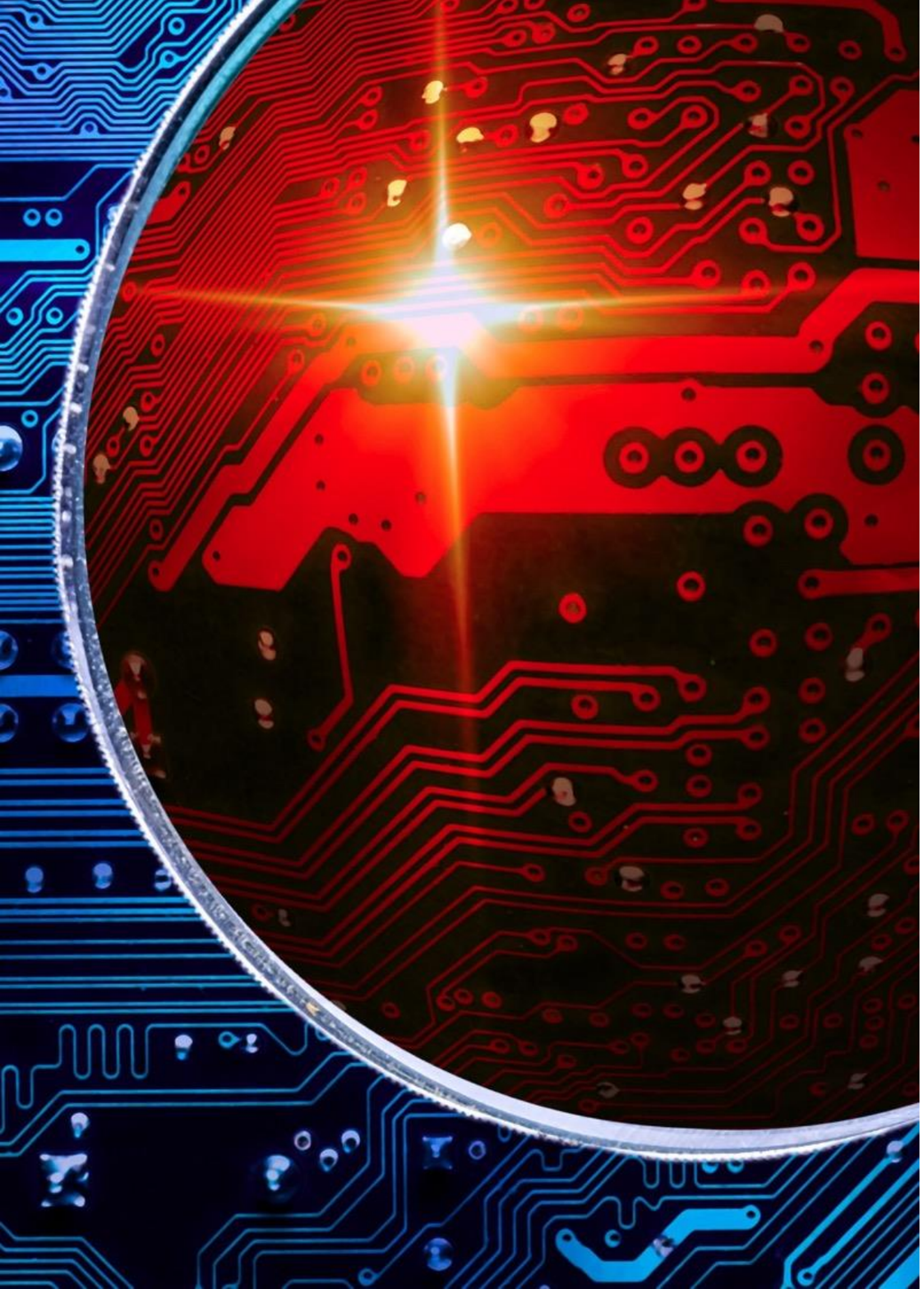


RDP Virtual Channels

Multiplexing data and extensions within a single connection



- Extra RDP features and extensions are implemented in virtual channels
- Server sends a list of available channels during connection phase
- Client chooses which channels to join



RDP Security

- RC4 + Graphical login (dead)
- TLS + Graphical login (legacy)
- TLS + Network Level Authentication (NLA) which relies on CredSSP
- Remote Credential Guard and RestrictedAdmin

The Risks of RDP: MITM

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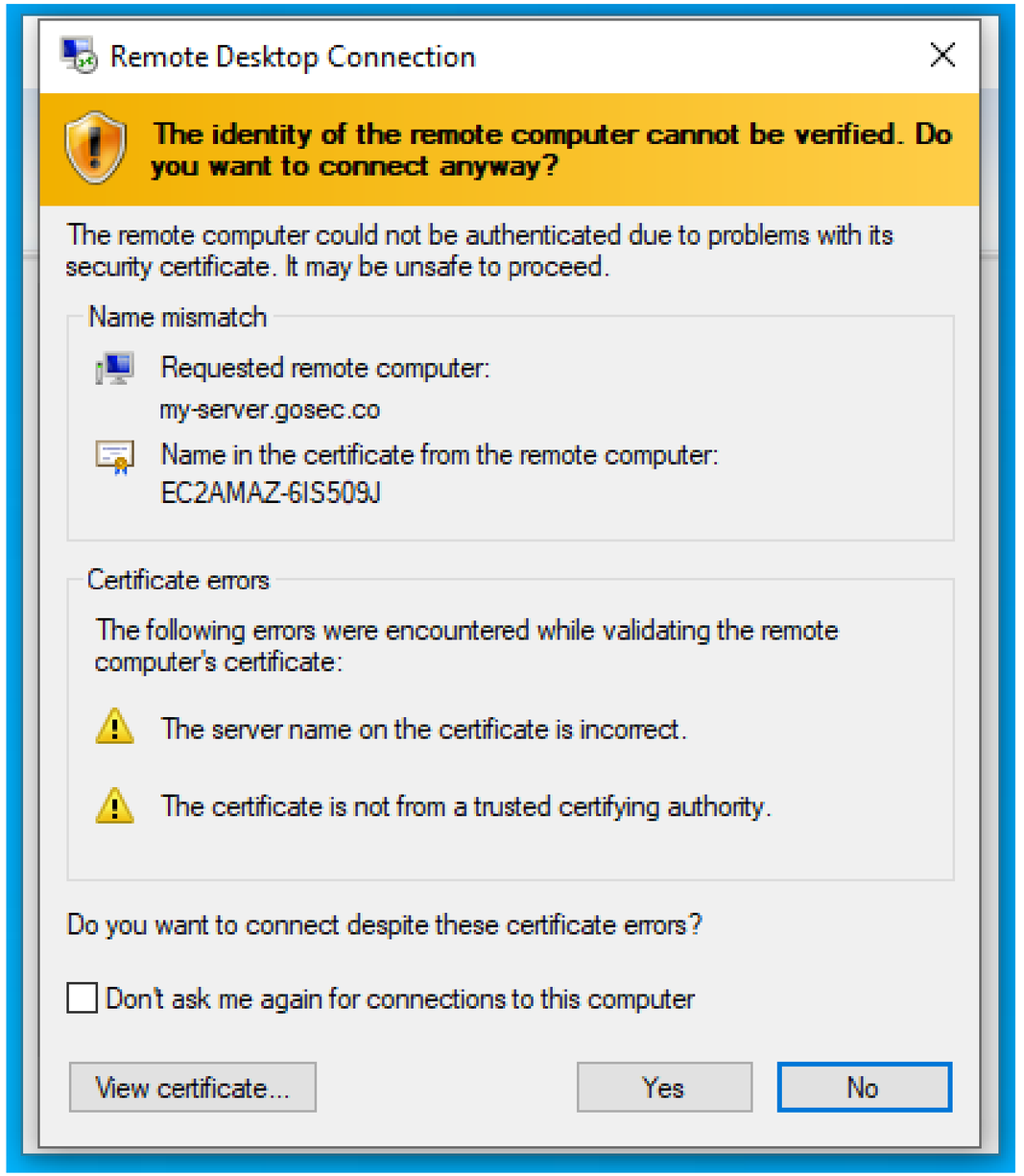
MITM Risks

- **Security Downgrade Attacks**
  - NLA -> TLS
- **Clicking Through Warnings**
- **Impact**
  - Display
  - Keyboard
  - Clipboard
  - Server-side takeover
  - Client-side file stealing
  - Client-side takeover*



*: implementation pending

Attack Video Demo

But first...

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Our Attack Tool: PyRDP

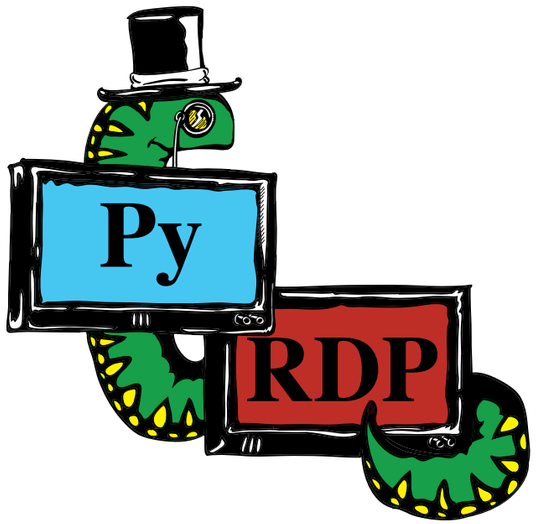
Learn More About It!

Source Code / Documentation

- https://github.com/GoSecure/pyrdp
- PyRDP ReadMe
- PyRDP Transparent Proxying Guide
- Windows RDP Certificate Extraction
- RDP Connection Sequence
- RDP Basic Protocol Specification

Past Presentations & Blogs

- Introduction Blog Post
- NorthSec 2019 Talk
- BlackHat Arsenal 2019
- Blog: PyRDP on Autopilot
- DerbyCon 2019 (Video)
- DEFCON 28 Demo Labs
- Blog: Announcing PyRDP 1.0
- 1.0 released at SecTor 2020
- BlackHat Arsenal 2021



Attack Video Demo

(link to video)

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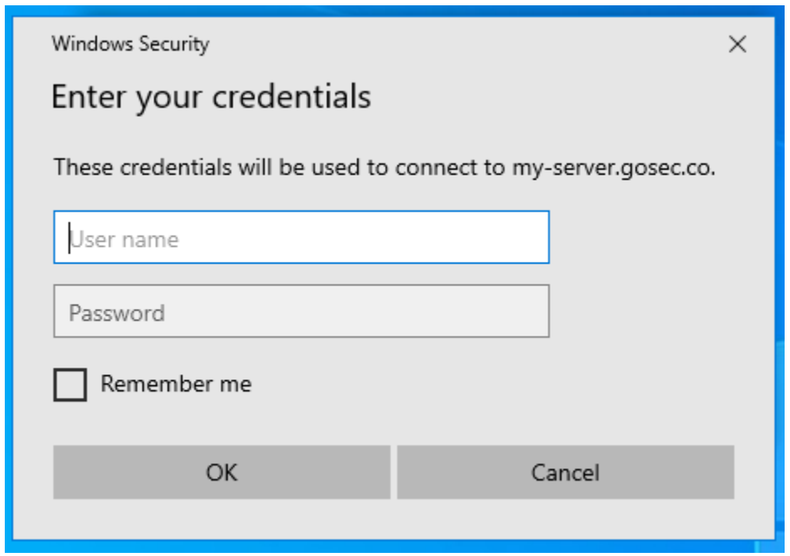
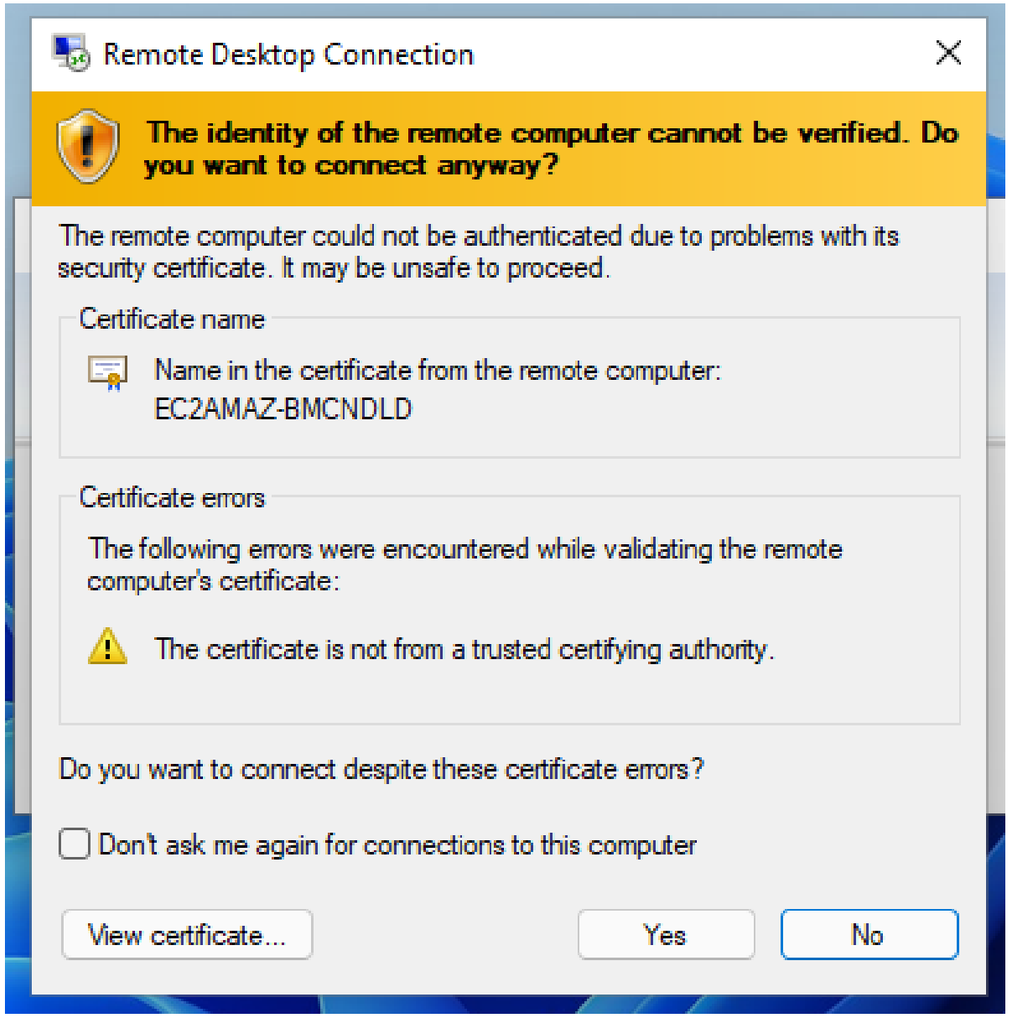
Detect Security Protocol Downgrade

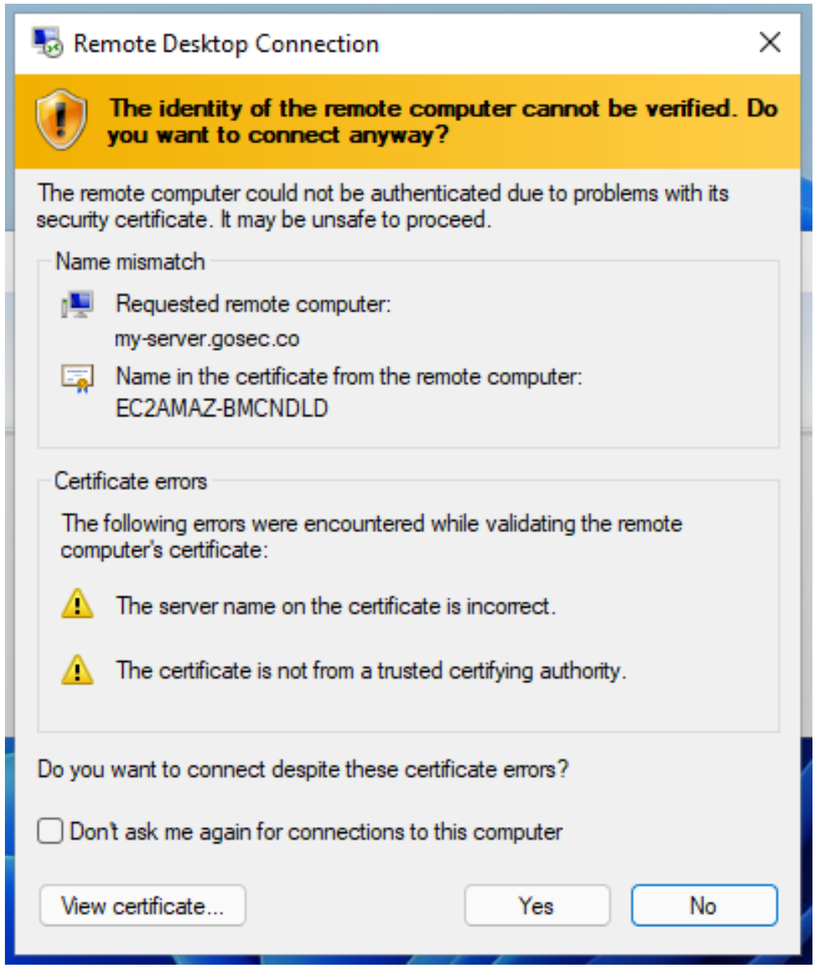
Normal Flow

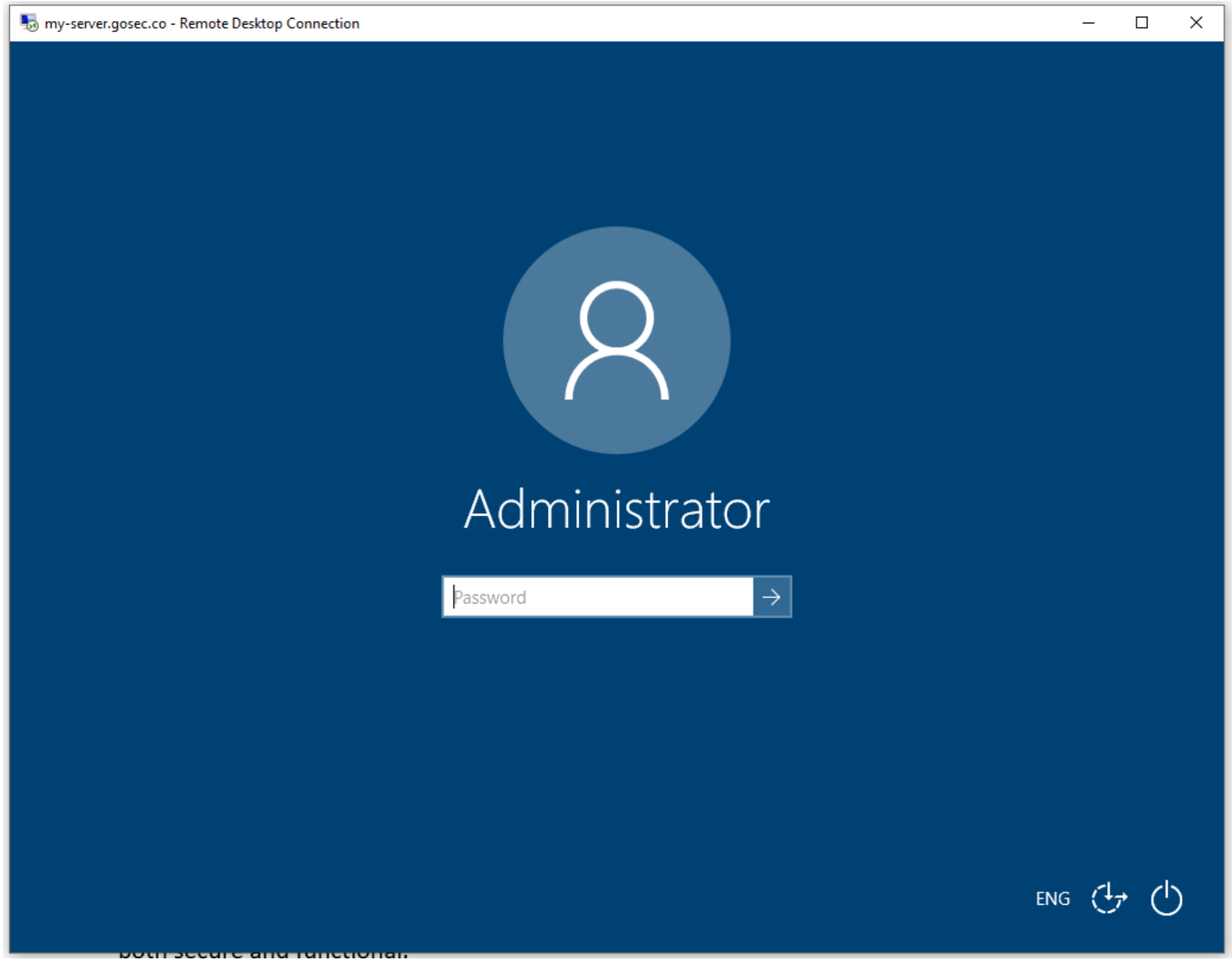




Detect Security Protocol Downgrade

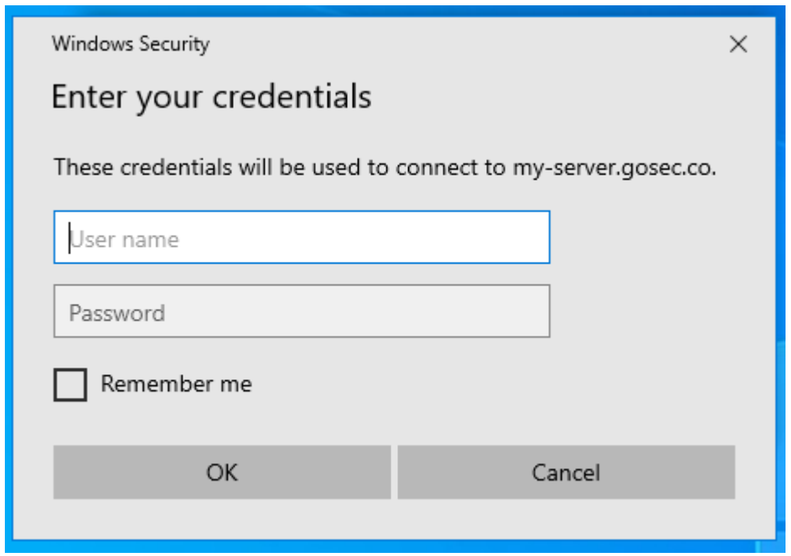
Degraded Flow

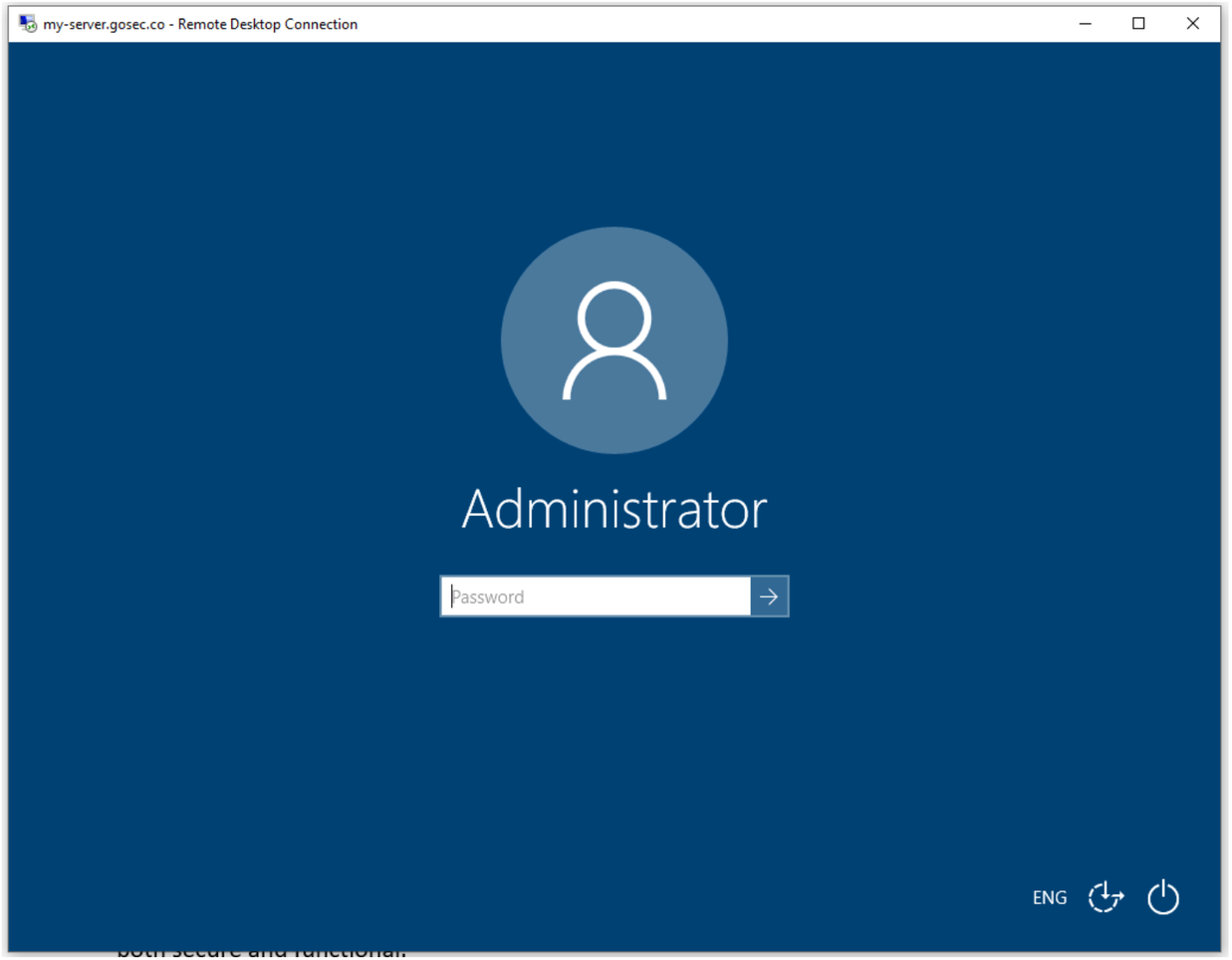




Detect Security Protocol Downgrade

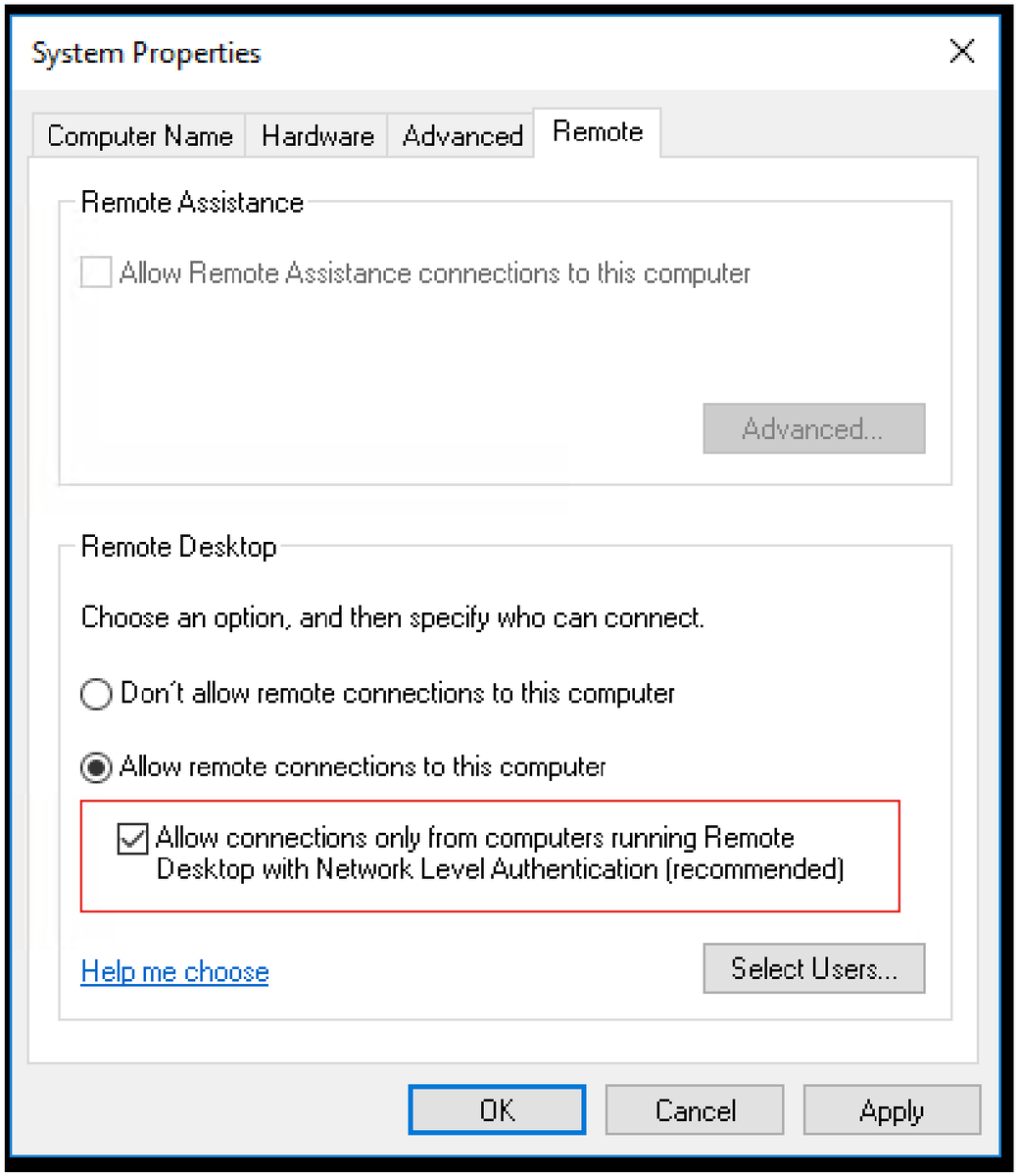
Graphical Login instead of NLA Prompt



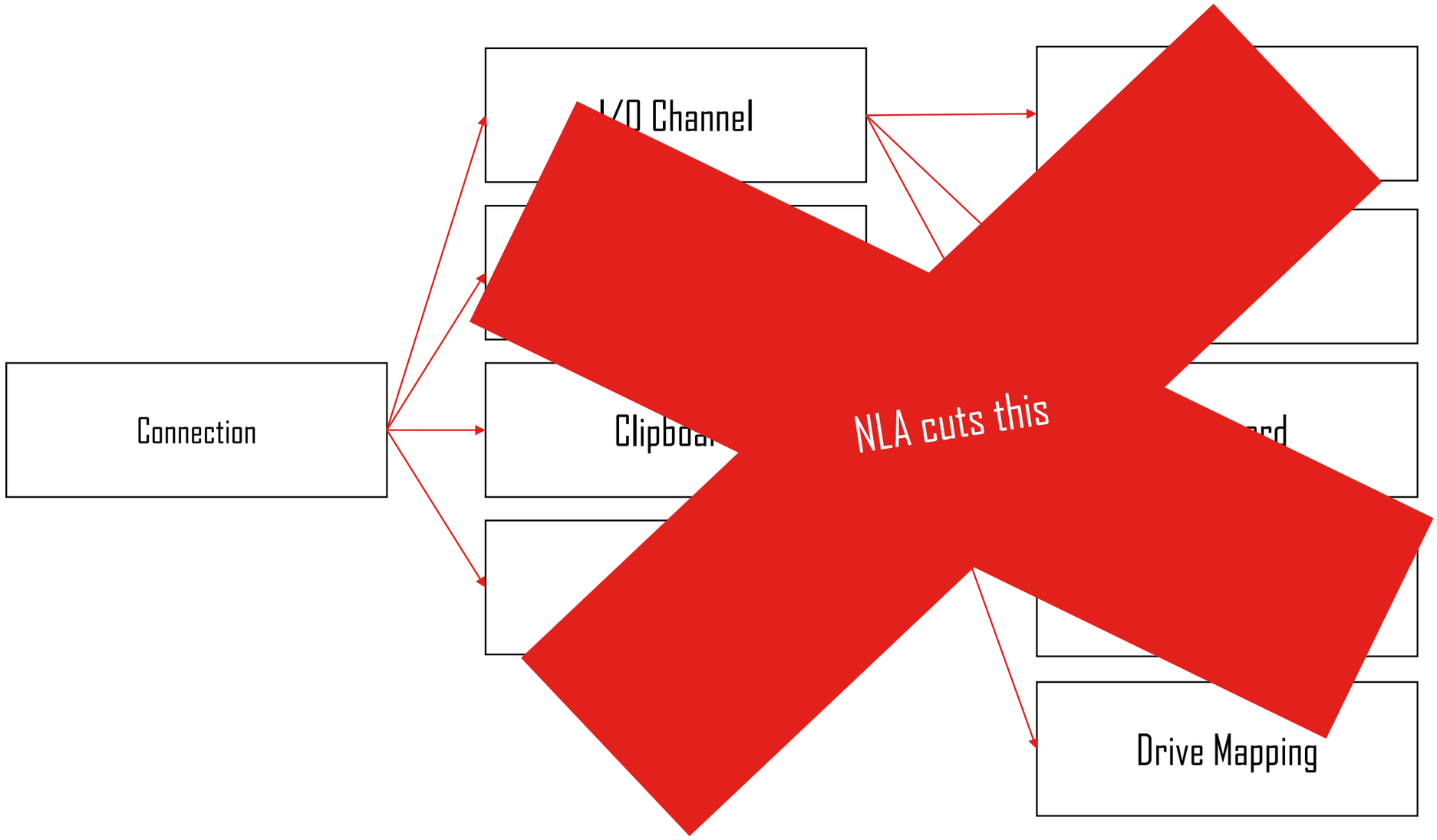


What is Network Level Authentication (NLA)?

- Authentication **before** session establishment
- Security Advantages
  - Attack Surface Reduction
  - DoS Resistance
  - Single Sign-On
- Introduced in RDP 6.0
- By default since Server 2012 and Windows 8



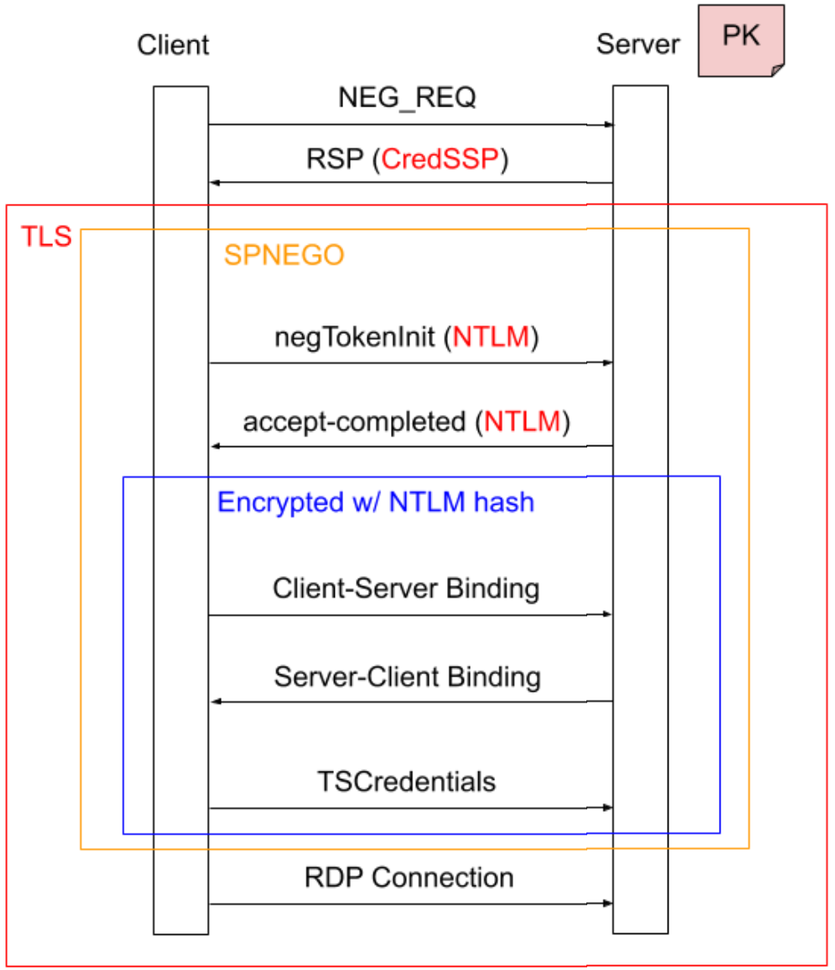
Attack Surface Reduction



Authentication: CredSSP

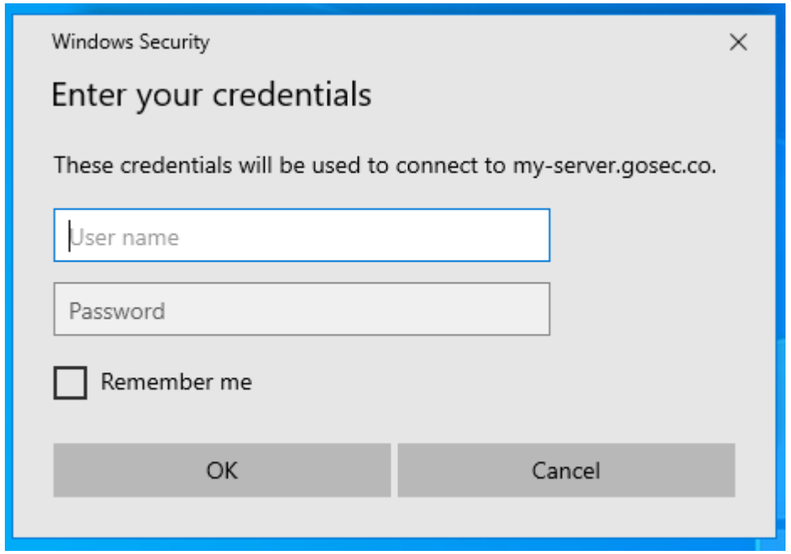
NLA's Authentication Mechanism

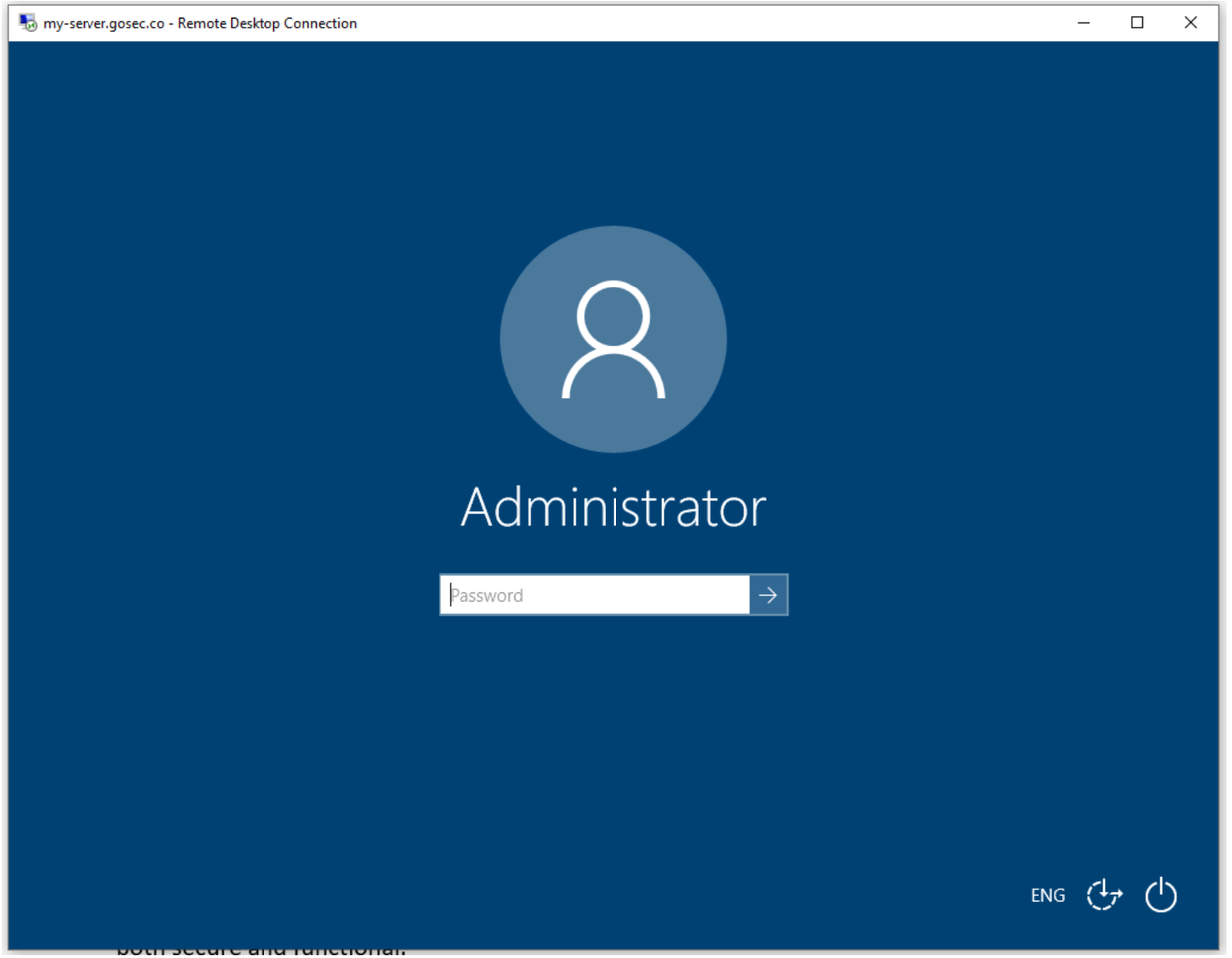
- Initial plaintext negotiation method
- TLS Channel
- SPNEGO
  - NTLM
  - Kerberos
- Crypto prevents MITM
  - E(H(PK | Challenge), NTLM-Hash)



NLA Attack #1: Downgrade Attack

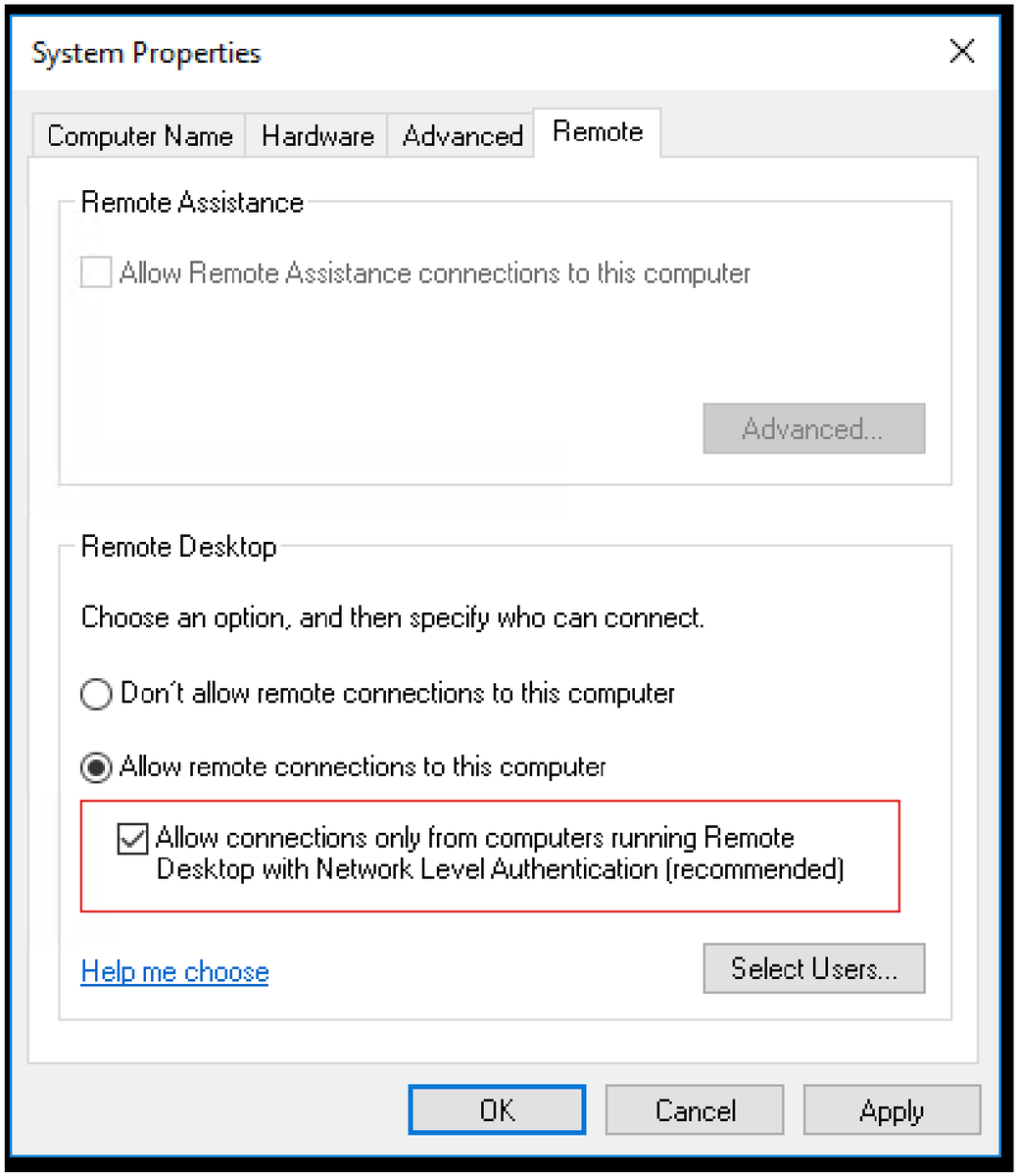
Downgrade the NEG_REQ to remove CredSSP from supported protocols





Prevent NLA Downgrade Attacks

- Enforce NLA at the Server Side
  - This is the **default**



Prevent NLA Downgrade Attacks

For Reference

PowerShell/Registry

```
reg add "HKLM\SYSTEM\CurrentControlSet\Control\Terminal Server\WinStations\RDP-Tcp" /v
UserAuthentication /t REG_DWORD /d 0 /f;
```

Group policy

Under

```
Computer Configuration/Administrative Templates/Windows Components/Remote Desktop Settings/Remote
Desktop Session Host/Security
```

Set

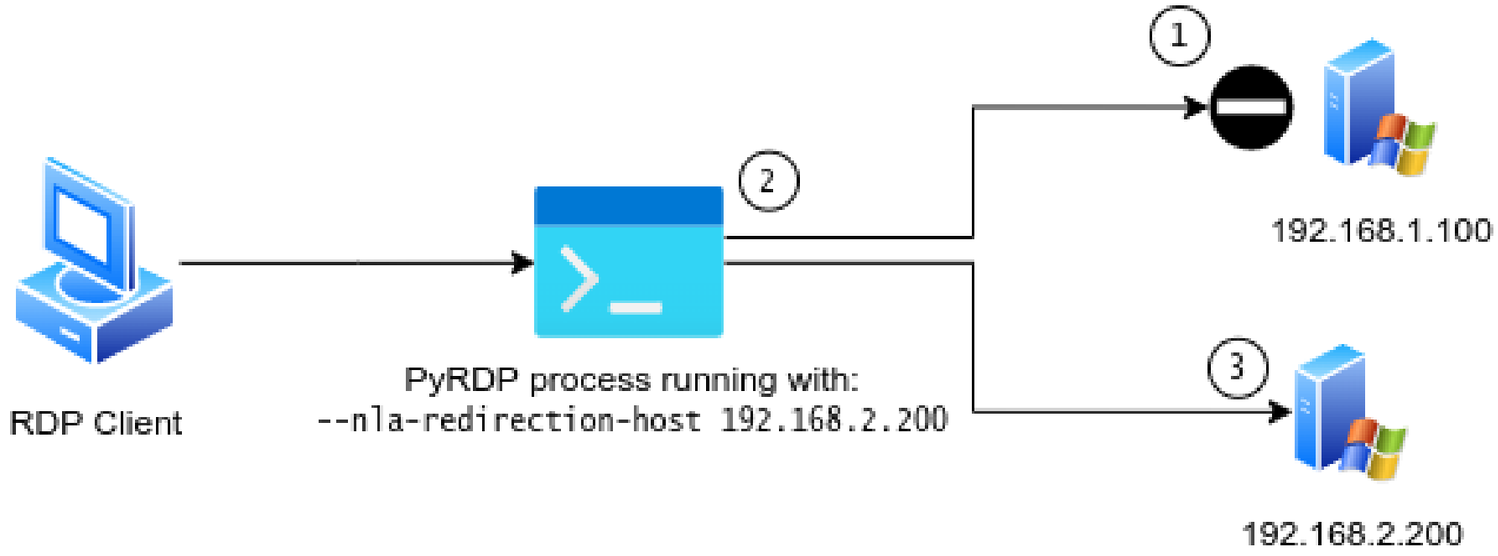
```
Require user authentication for remote connections by using Network Level Authentication
```

To **Enable**

Can't be disabled by users afterwards 👍

NLA Attack #2: Redirection to Non-NLA

1. Detects NLA enforcement
2. Transparently redirects
3. To an attacker controlled non-NLA system



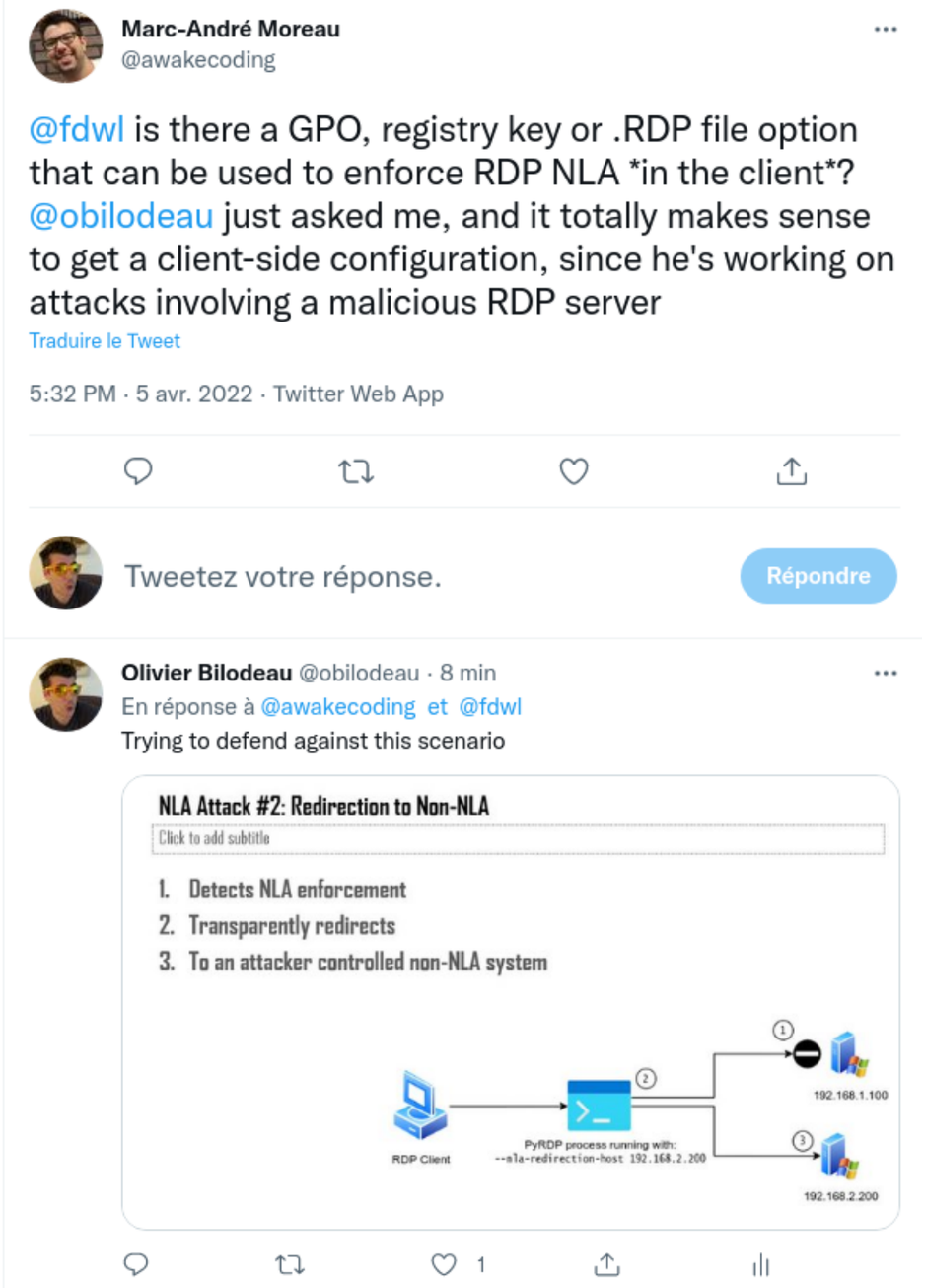
Prevent Redirection to Non-NLA

Bad News

No specific way to enforce NLA on the client side

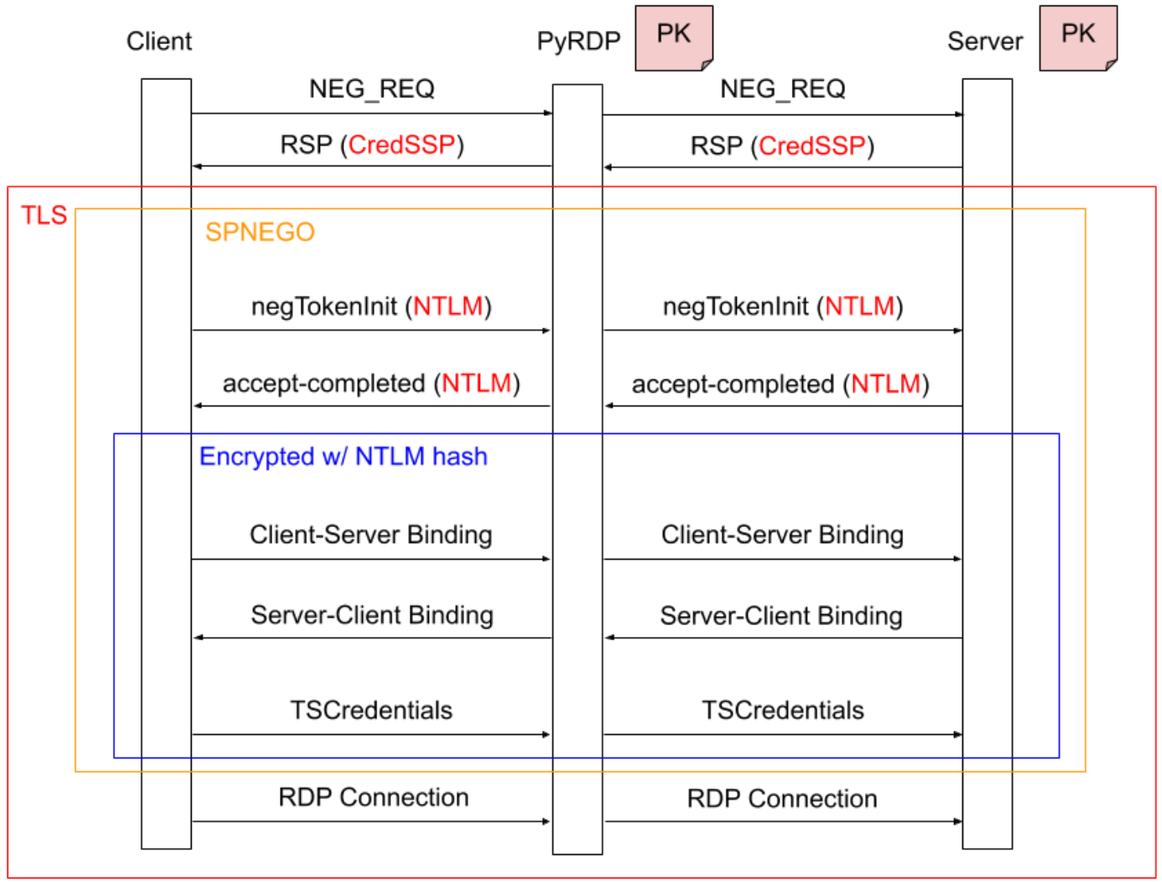
Good News

More general mitigation advice coming up



NLA Attack #3: NLA MITM

- No tampering at the SPNEGO layer
- But the crypto said?
  - E(H(PK | Challenge), NTLM-Hash)
- Requires substantial setup
  - Server certificate and private key*



*: https://github.com/GoSecure/pyrdp/blob/master/docs/cert-extraction.md

NLA Bypass Mitigation

More Bad News

No specific way to enforce NLA on the client side

Good News

More general mitigation advice coming up

NetNTLMv2 Hash Capture

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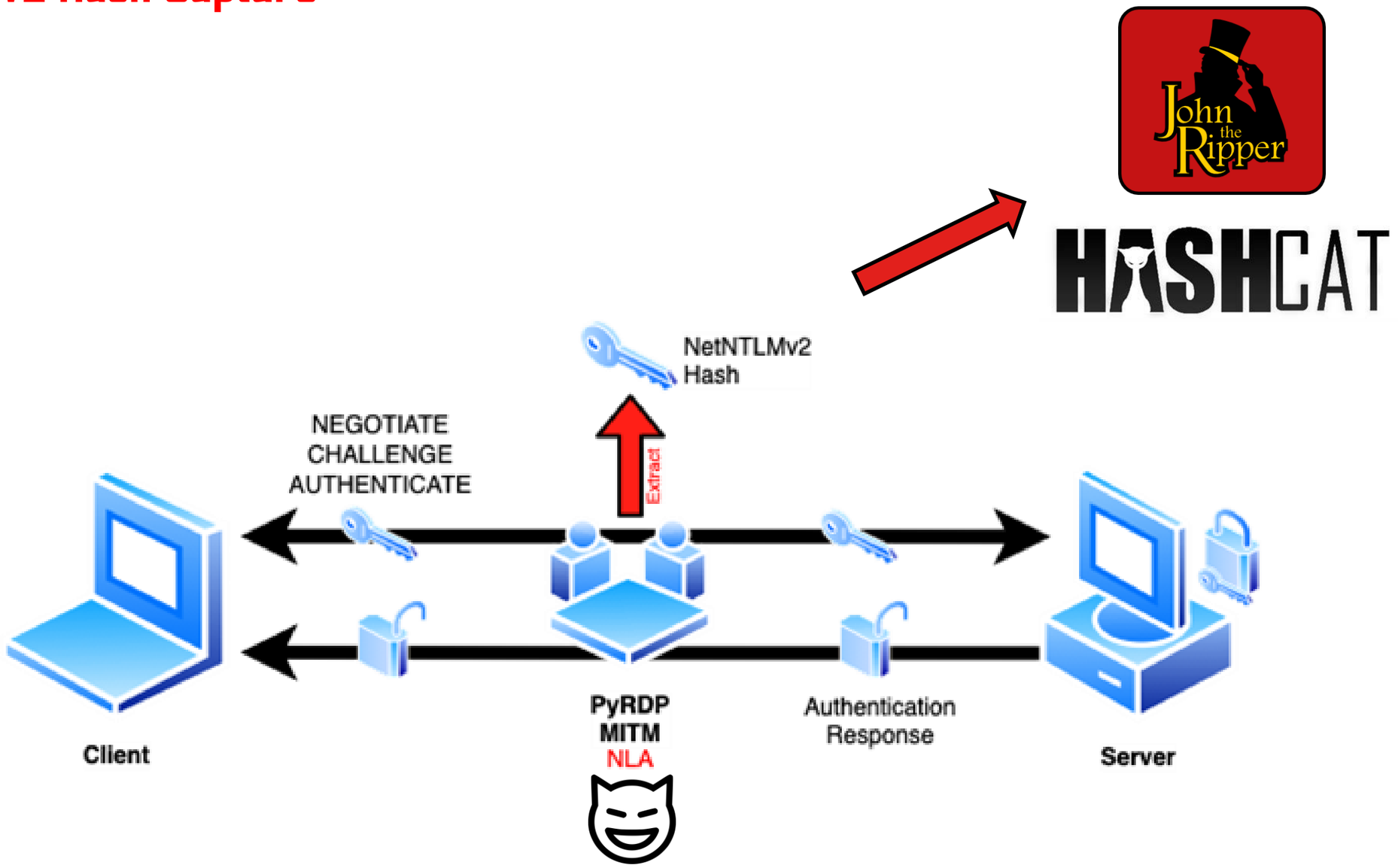
NetNTLMv2 Hash Capture

- On an NLA authentication

- Victim is tricked into connecting to rogue RDP
- The NTLM hash capture is done on-the-fly
- Hashes can be cracked using password cracking tools

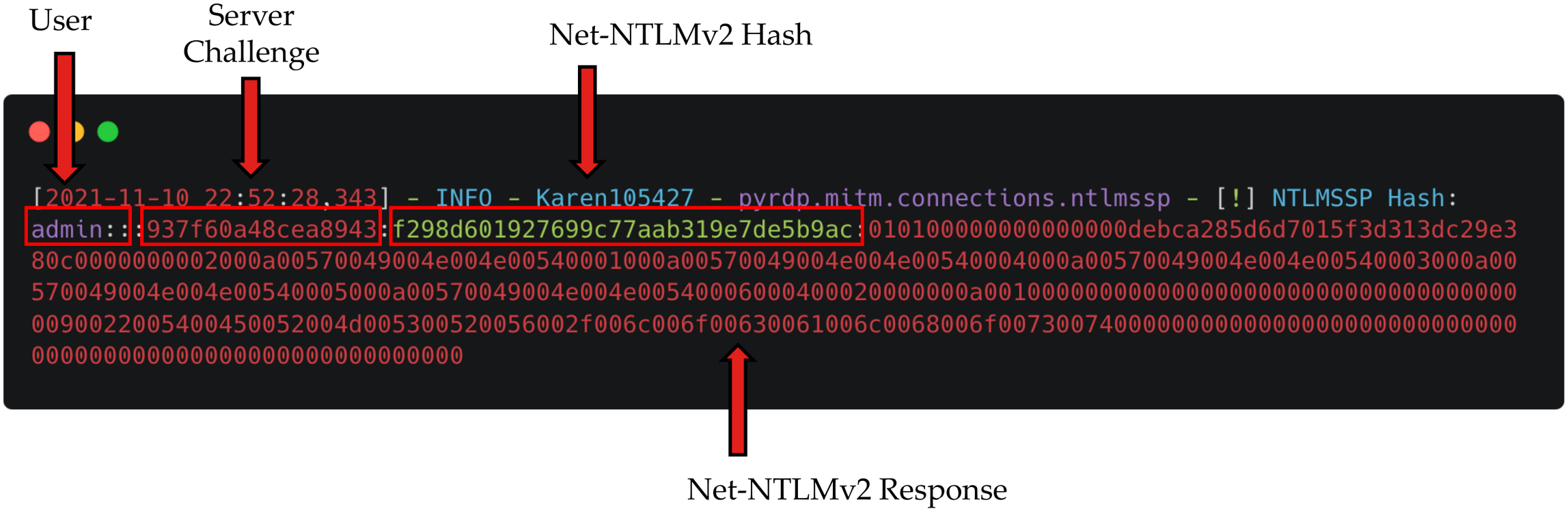
NetNTLMv2 Hash Capture

(cont.)



NetNTLMv2 Hash Capture

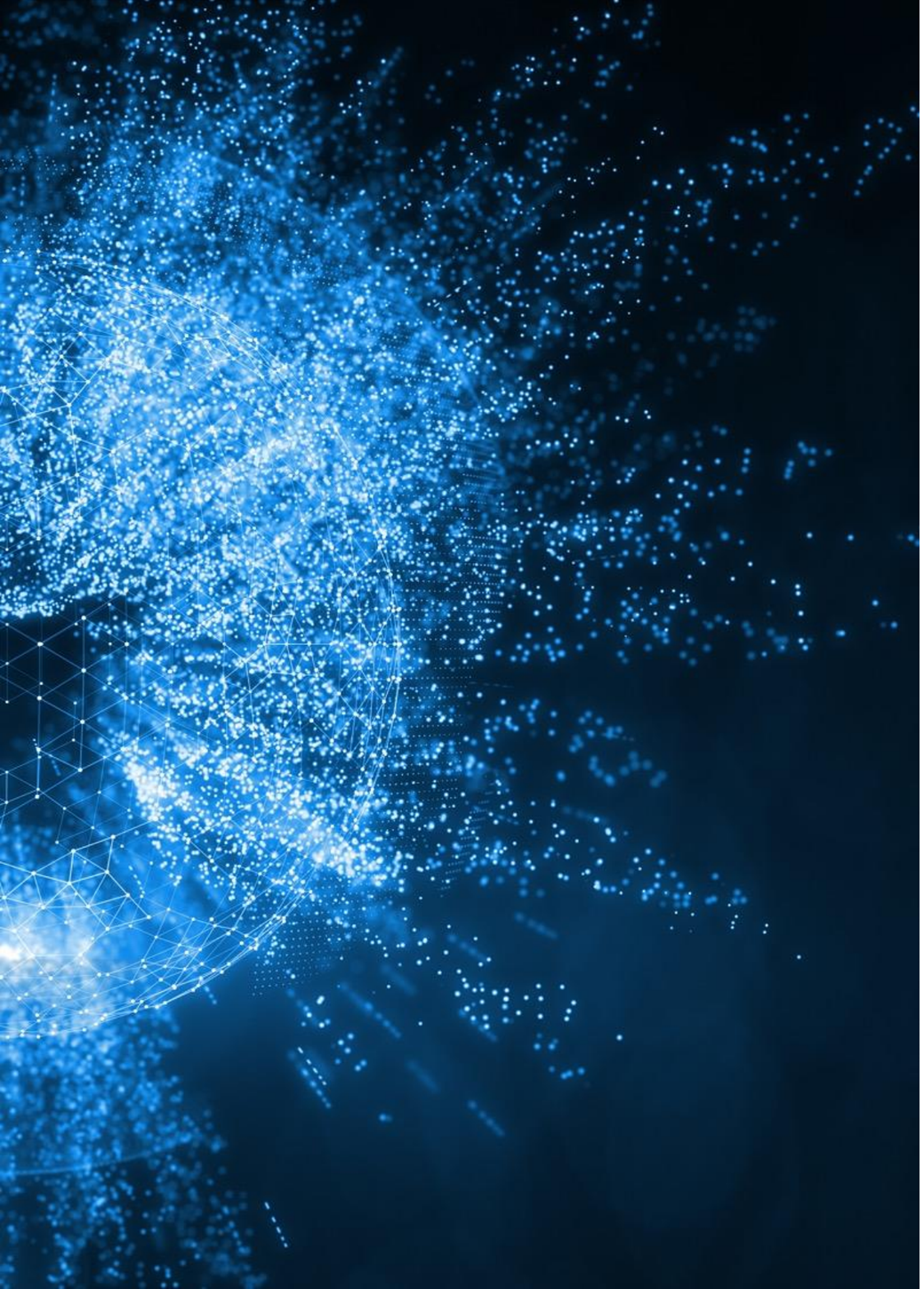
Example of captured hash



NetNTLMv2 Hash Cracking

With john (hashcat works too)

```
$ john --format=netntlmv2 --wordlist=~/wordlist/rockyou.txt hashes.txt
Using default input encoding: UTF-8
Loaded 1 password hash (netntlmv2, NTLMv2 C/R [MD4 HMAC-MD5 32/64])
Will run 8 OpenMP threads
Press 'q' or Ctrl-C to abort, almost any other key for status
purple           (admin)
1g 0:00:00:00 DONE (2022-04-07 14:44) 14.28g/s 58514p/s 58514c/s 58514C/s
123456..oooooo
Session completed
```



Preventing Hash Capture

- Verify connection to RDP server
  - Server address
  - Domain name
- Always look for valid certificates
  - Attack tools will often use hardcoded certificate values
- Never use RDP on untrusted networks!
- Avoid NTLM / Use Kerberos
- Audit NTLM usage*

How Bad is it Really?

Demo!

(link to video)

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Certificates with RDP?

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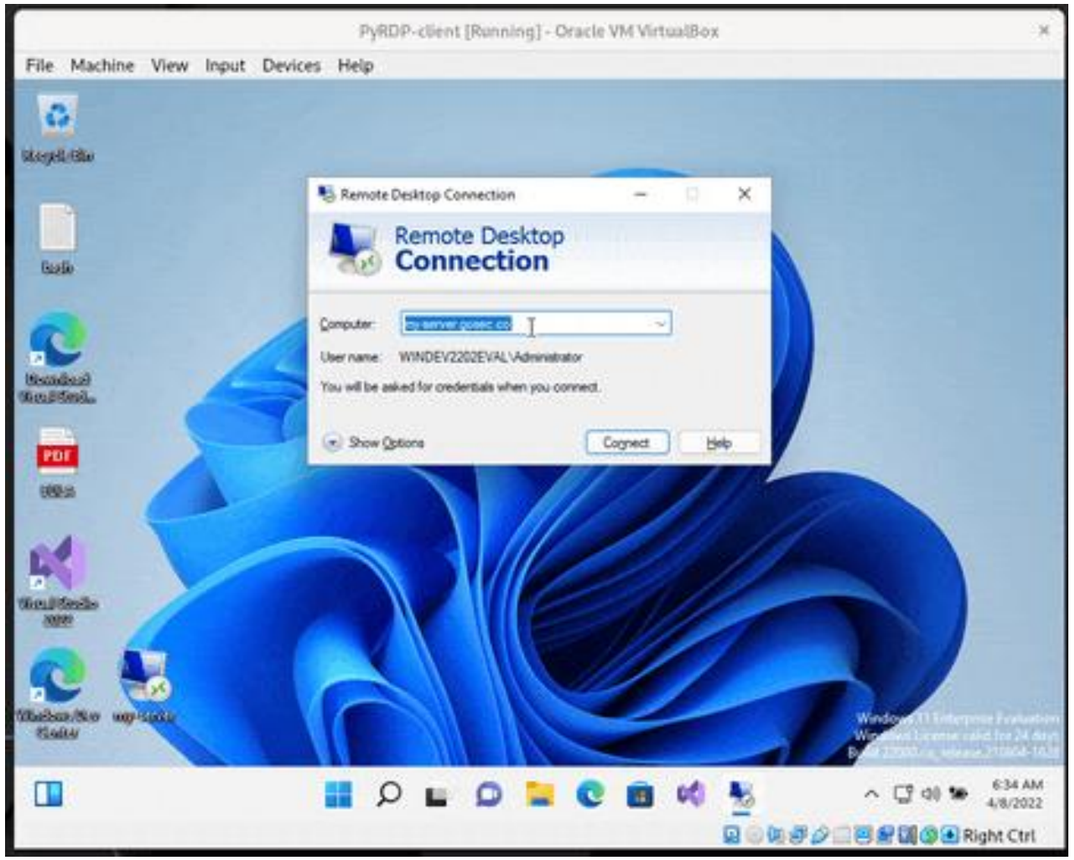
Use Let's Encrypt to Protect RDP

- It works!
- Impractical
  - No auto-renewal or expose ports 80/443
  - Must use a domain name



Attacker Controlled Let's Encrypt Signed Certificate

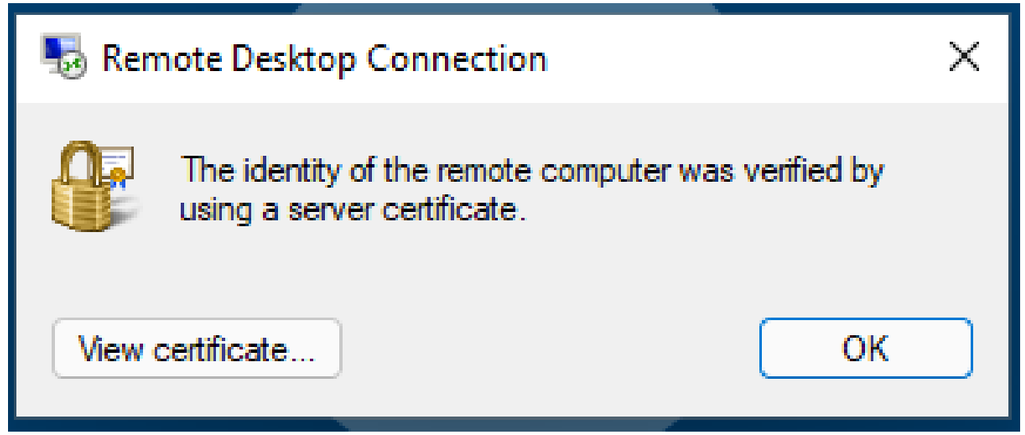
Easy way to increase trust in a server

Non-NLA only PyRDP requires it

Step by step:

```
# with DNS already pointing to the PyRDP server
snap install core; snap refresh core
snap install --classic certbot
certbot certonly –standalone
```

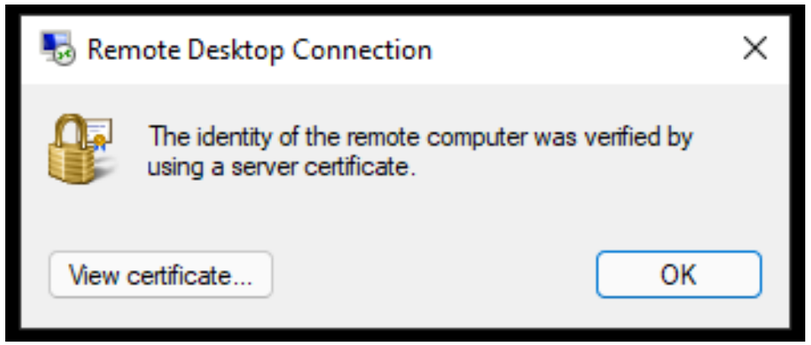
```
Please enter the domain name(s) you would like on your certificate (comma and/or
space separated) (Enter 'c' to cancel): my-server.gosec.co
Requesting a certificate for my-server.gosec.co

Successfully received certificate.
Certificate is saved at: /etc/letsencrypt/live/my-server.gosec.co/fullchain.pem
Key is saved at:         /etc/letsencrypt/live/my-server.gosec.co/privkey.pem
This certificate expires on 2022-07-05.
```




```
pyrdp-mitm.py -i 172.19.0.1 -c /etc/letsencrypt/live/my-server.gosec.co/fullchain.pem –k \
    /etc/letsencrypt/live/my-server.gosec.co/privkey.pem 52.23.235.42
```

Copy on Attacker Controlled Server

If you want to support/attack NLA



Step by step:

```
openssl pkcs12 -export -passin "pass:admin" -passout "pass:admin" \
    -out my-server.pfx -inkey cert.key -in fullchain.pem
# Copy pfx to RDP Server
# In Admin PowerShell console:
$password = ("admin" | ConvertTo-SecureString -AsPlainText -Force);
$thumbprint = (Import-PfxCertificate -FilePath C:\Windows\Temp\cert.pfx -
CertStoreLocation cert:\LocalMachine\My -Password $password).Thumbprint;
$path = (Get-WmiObject -class "Win32_TSGeneralSetting" -Namespace
root\cimv2\terminalservices -Filter "TerminalName='RDP-tcp'").__path;
wmic /namespace:\\root\cimv2\TerminalServices PATH Win32_TSGeneralSetting Set
SSLCertificateSHA1Hash="$thumbprint";
```

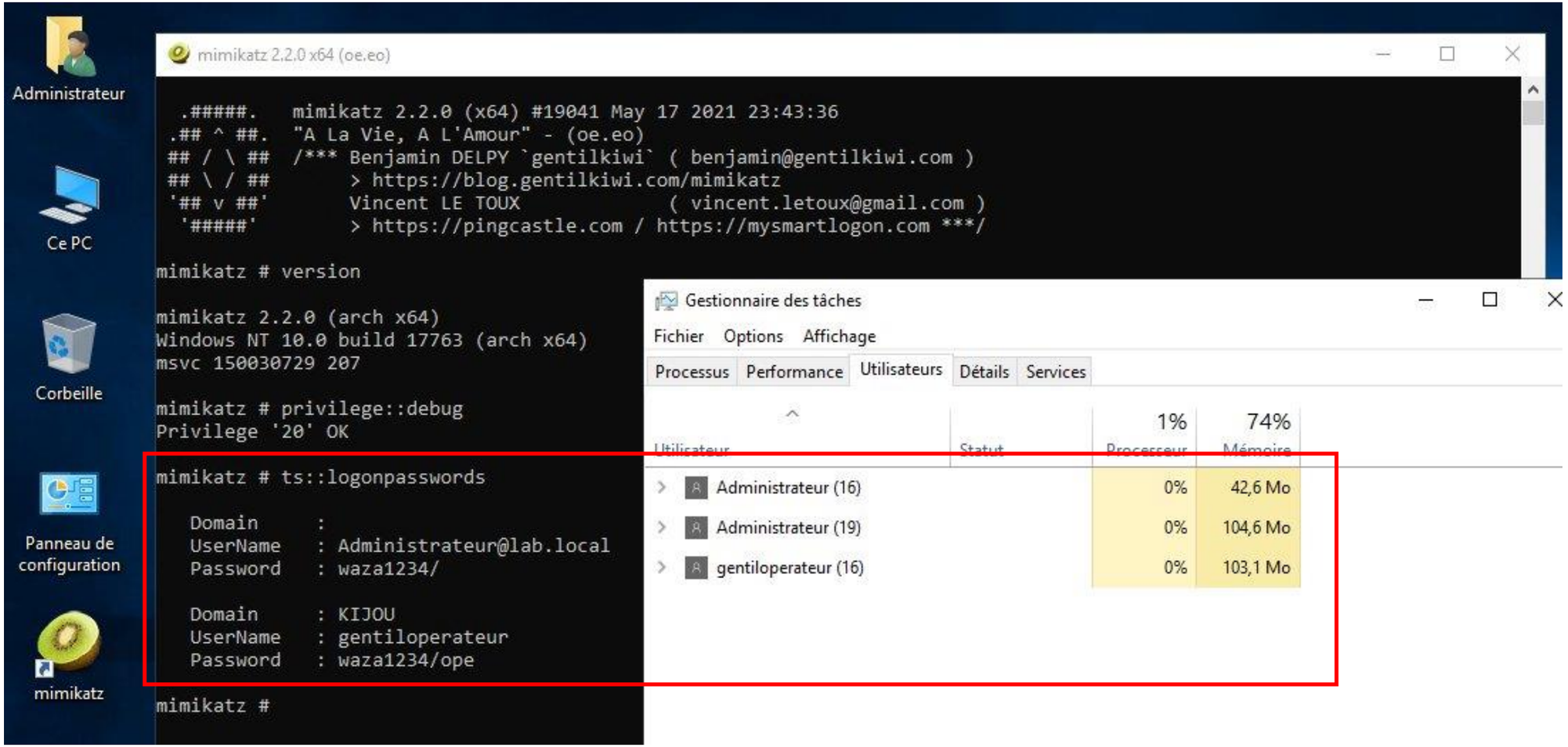
Stealing Credentials

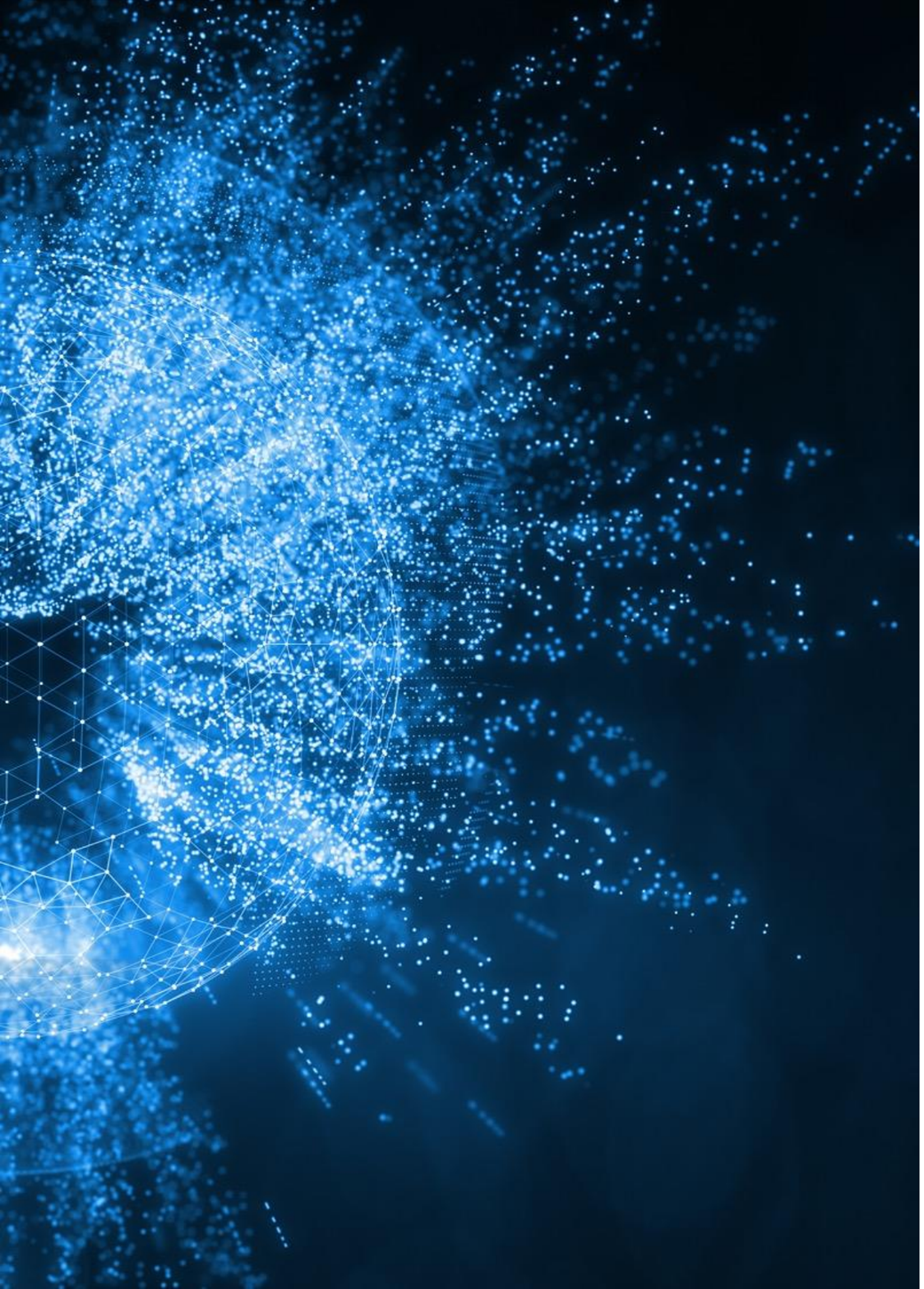
Stealing Credentials

- Credentials are sent as part of NLA connection
- Terminal Service saves passwords in memory
- Passwords are in cleartext
- Mimikatz to the rescue :)

Stealing Credentials

(cont.)





Prevent credentials theft

Three ways of protecting from this attack:

1. Restricted Admin Mode
    - Avoid sending reusable credentials
2. Remote Credential Guard
    - Same as Restricted Admin Mode
3. Smartcard Authentication
    - Physical smart cards used for authentication

Prevent credentials theft

Windows Defender Remote Credential Guard

- Kerberos
- NTLM
- Access to services from server
- Prevent Pass-the-Hash
- Prevent use of credentials after disconnection

- Credentials protected by Windows Defender Remote Credential Guard
- Connect to other systems using SSO
- Host must support Windows Defender Remote Credential Guard

Restricted Admin Mode

- Kerberos
- NTLM
- Access to services from server
- Prevent Pass-the-Hash
- Prevent use of credentials after disconnection

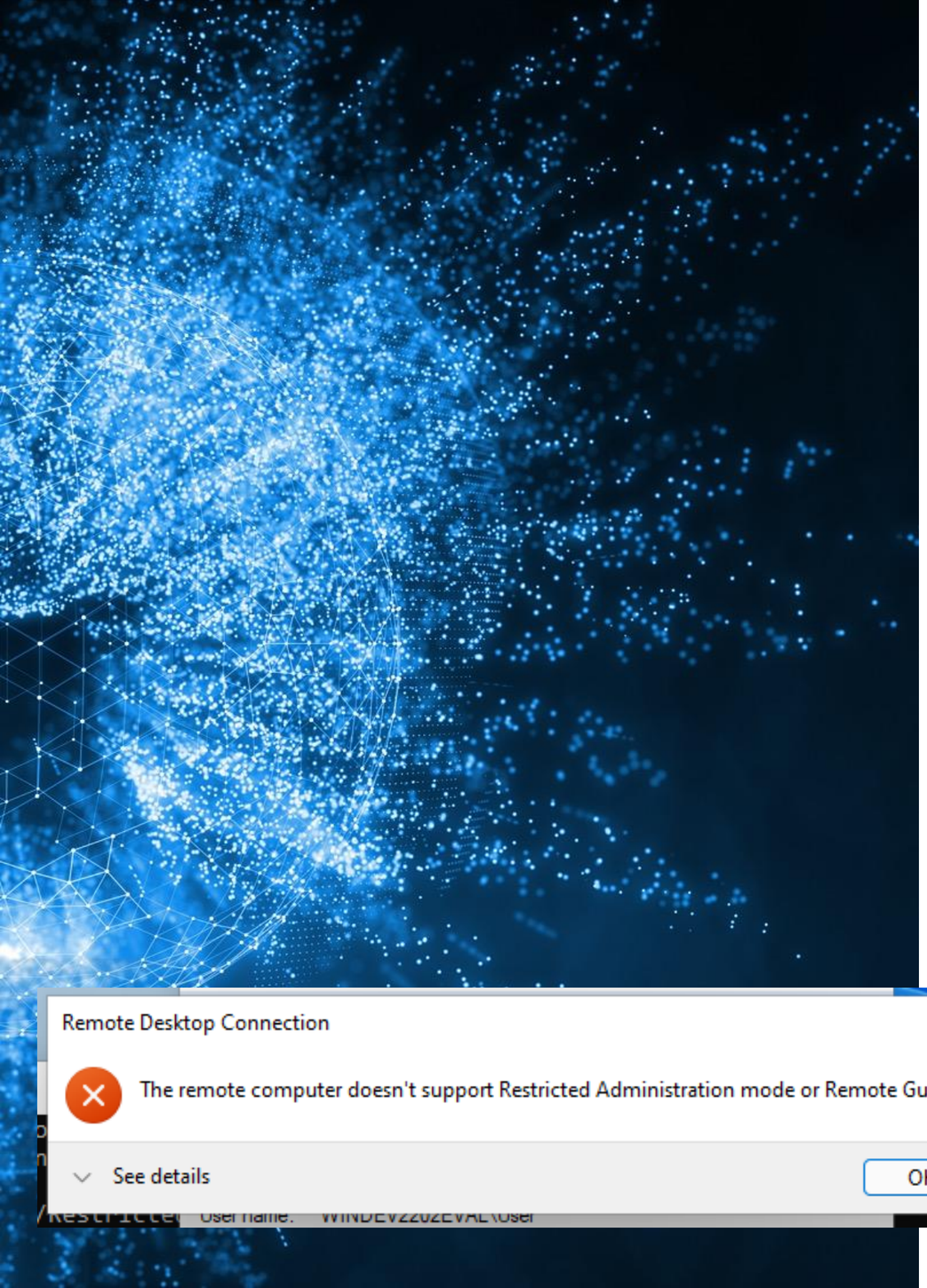
- Credentials used are remote server local admin credentials
- Connect to other systems using the host's identity
- Host must support Restricted Admin mode
- Highest protection level
- Requires user account administrator rights

= Credential protection

= Credentials

Feature	Remote Desktop	Windows Defender Remote Credential Guard	Restricted Admin mode
Protection benefits	Credentials on the server are not protected from Pass-the-Hash attacks.	User credentials remain on the client. An attacker can act on behalf of the user *only* when the session is ongoing	User logs on to the server as local administrator, so an attacker cannot act on behalf of the "domain user". Any attack is local to the server
Version support	The remote computer can run any Windows operating system	Both the client and the remote computer must be running **at least Windows 10, version 1607, or Windows Server 2016**.	The remote computer must be running **at least patched Windows 7 or patched Windows Server 2008 R2**. For more information about patches (software updates) related to Restricted Admin mode, see Microsoft Security Advisory 2871997.
Helps prevent	N/A	• Pass-the-Hash • Use of a credential after disconnection	• Pass-the-Hash • Use of domain identity during connection
Credentials supported from the remote desktop client device	• **Signed on** credentials • **Supplied** credentials • **Saved** credentials	• **Signed on** credentials only	• **Signed on** credentials • **Supplied** credentials • **Saved** credentials
Access	**Users allowed**, that is, members of Remote Desktop Users group of remote host.	**Users allowed**, that is, members of Remote Desktop Users of remote host.	**Administrators only**, that is, only members of Administrators group of remote host.
Network identity	Remote Desktop session **connects to other resources as signed-in user**.	Remote Desktop session **connects to other resources as signed-in user**.	Remote Desktop session **connects to other resources as remote host's identity**.
Multi-hop	From the remote desktop, **you can connect through Remote Desktop to another computer**	From the remote desktop, you **can connect through Remote Desktop to another computer**.	Not allowed for user as the session is running as a local host account
Supported authentication	Any negotiable protocol.	Kerberos only.	Any negotiable protocol

Enabling Restricted Admin Mode



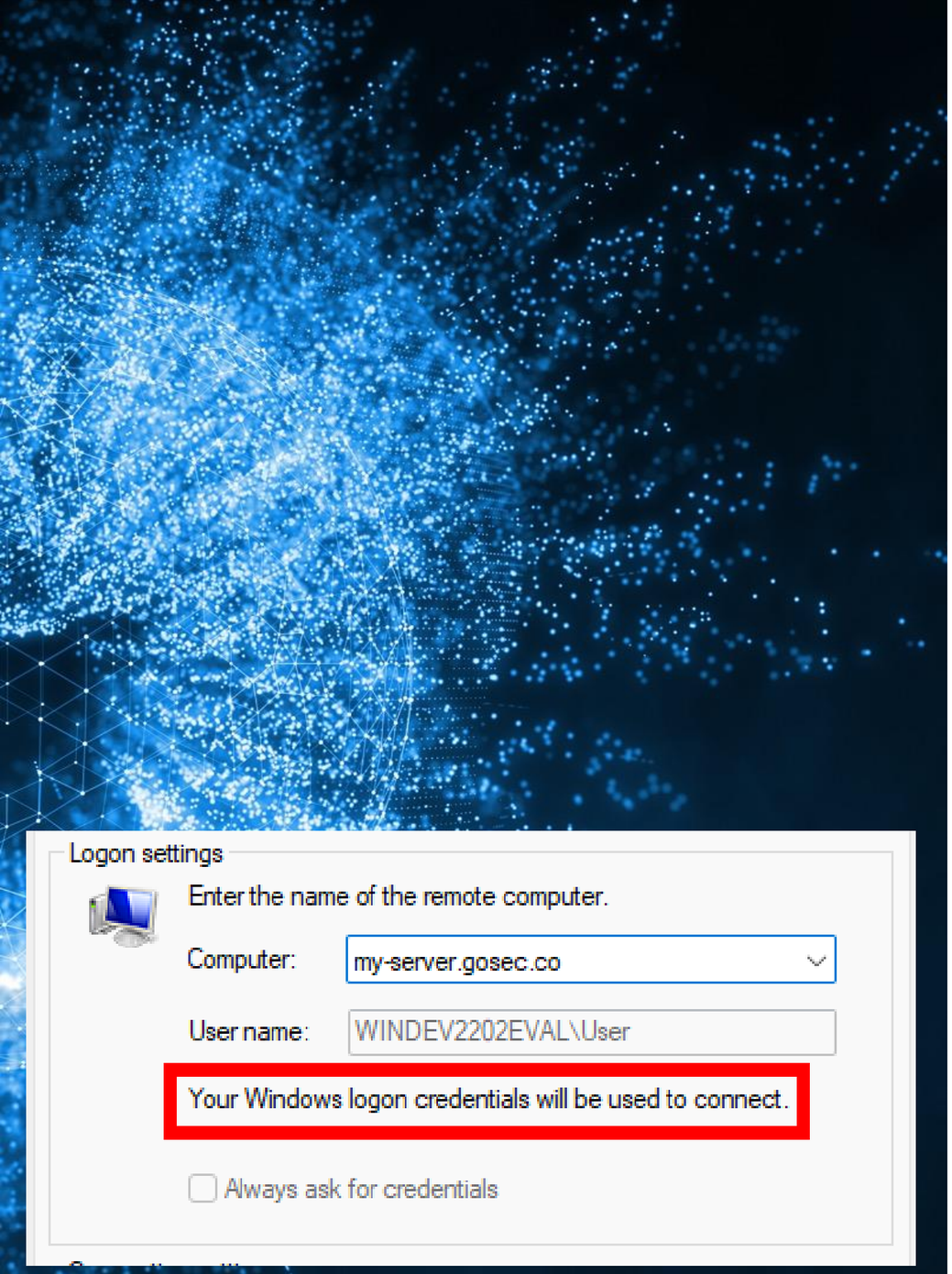
- Edit the RDP server's registry and enable this mode:

```
reg add
HKLM\SYSTEM\CurrentControlSet\Control\Lsa /v
DisableRestrictedAdmin /d 0 /t REG_DWORD
```

- No reboot required.
- To connect to the RDP server with this mode enabled you must run on the client:

```
mstsc.exe /RestrictedAdmin
```

Enabling Remote Credential Guard



- Edit the RDP server's registry and enable this mode:

```
reg add HKLM\SYSTEM\CurrentControlSet\Control\Lsa
/v DisableRestrictedAdmin /d 0 /t REG_DWORD
```

- No reboot required.
- To connect to the RDP server with this mode enable you can run on the client:

```
mstsc.exe /remoteGuard
```

- Or via GPO

https://docs.microsoft.com/en-us/windows/security/identity-protection/remote-credential-guard#using-windows-defender-remote-credential-guard

Backdooring RDP

GoSecure

Backdooring RDP

Accessibility tools can be backdoored

Applications like **sethc.exe** can be used:

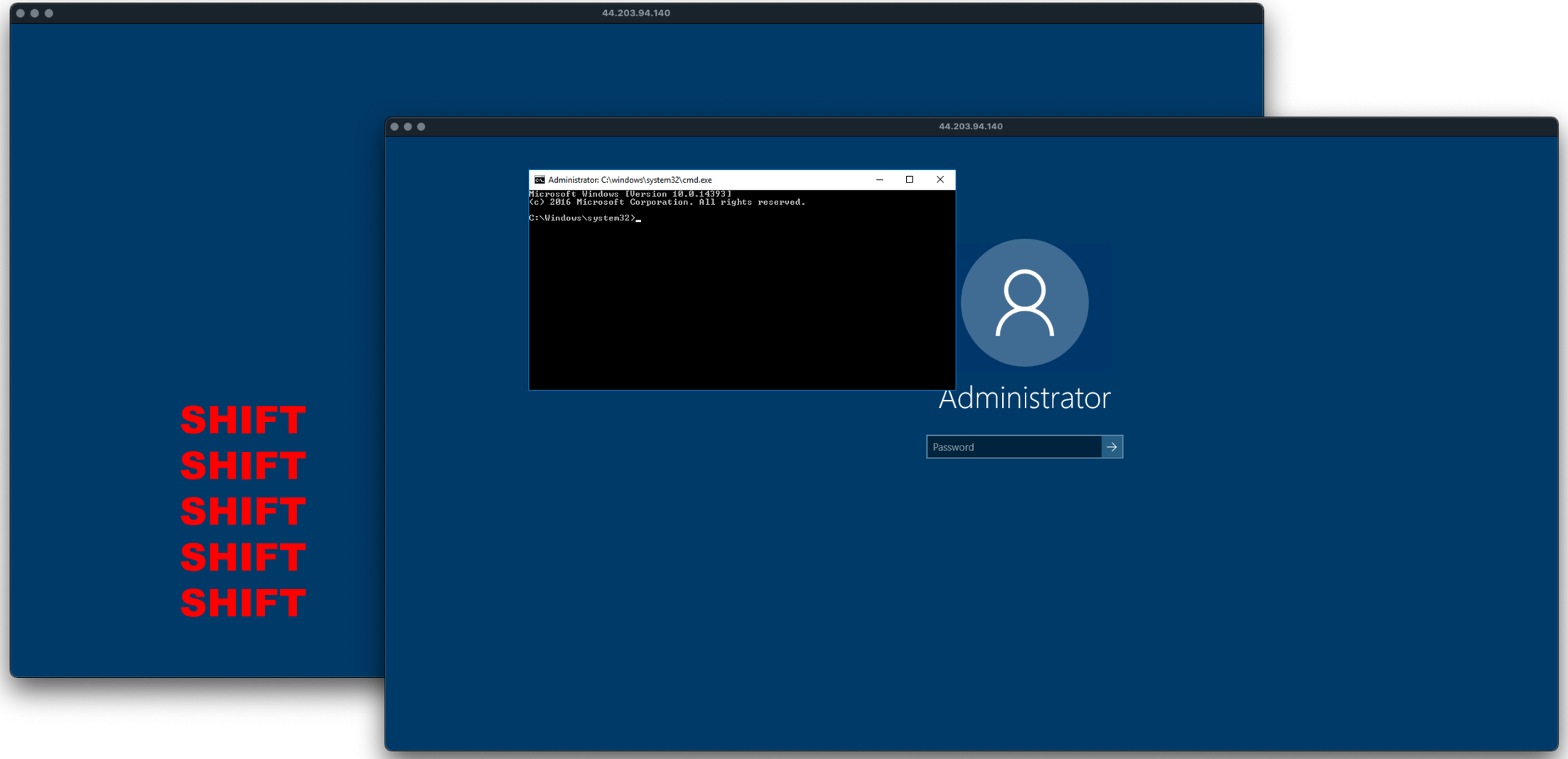
- Log into the system
- Add a debugger for this application via Registry

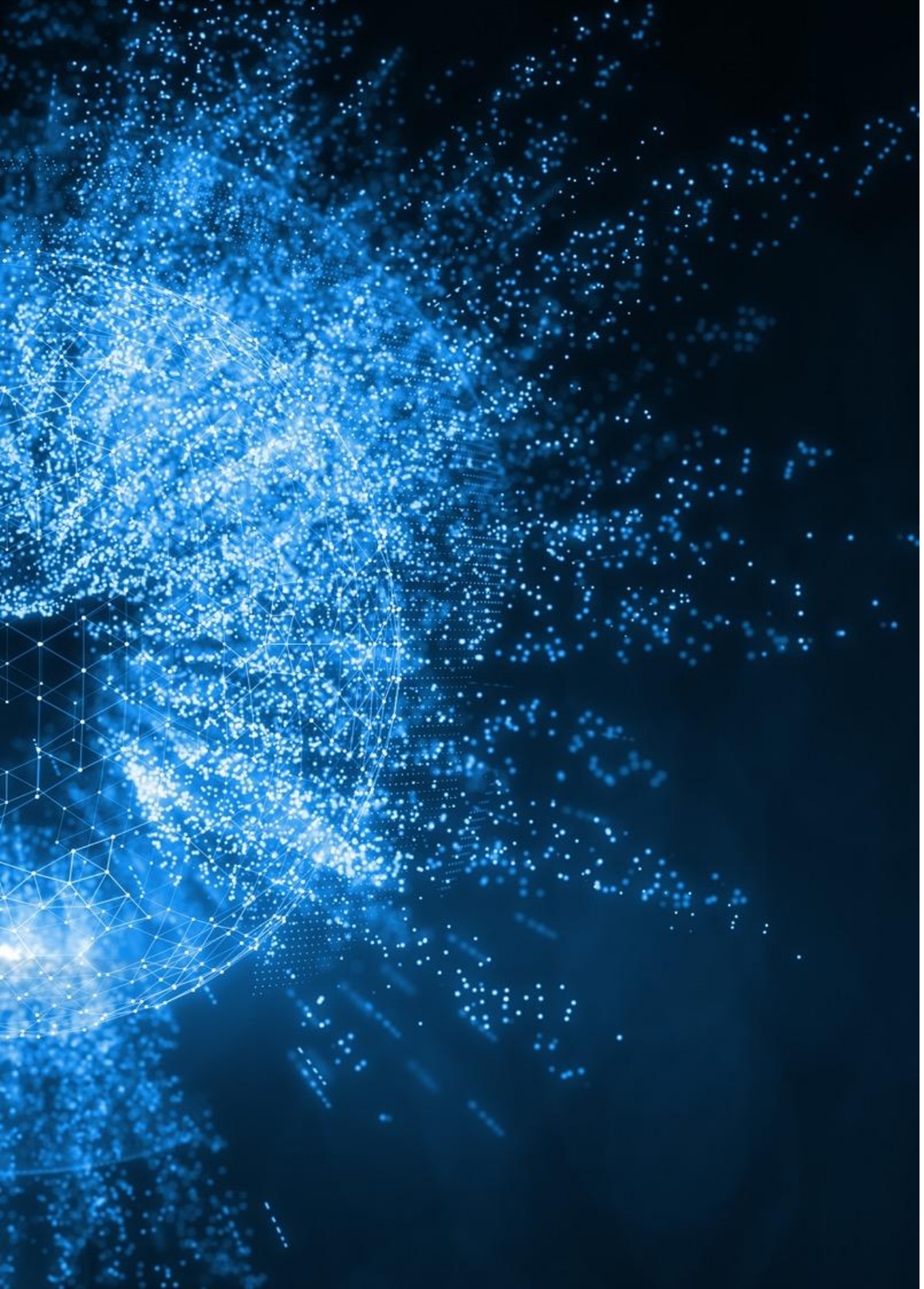
```
HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\Image File Execution Options\sethc.exe
```

```
"Debugger"="C:\Windows\System32\cmd.exe"
```

Backdooring RDP

(cont.)





Detect backdoors via Accessibility tools

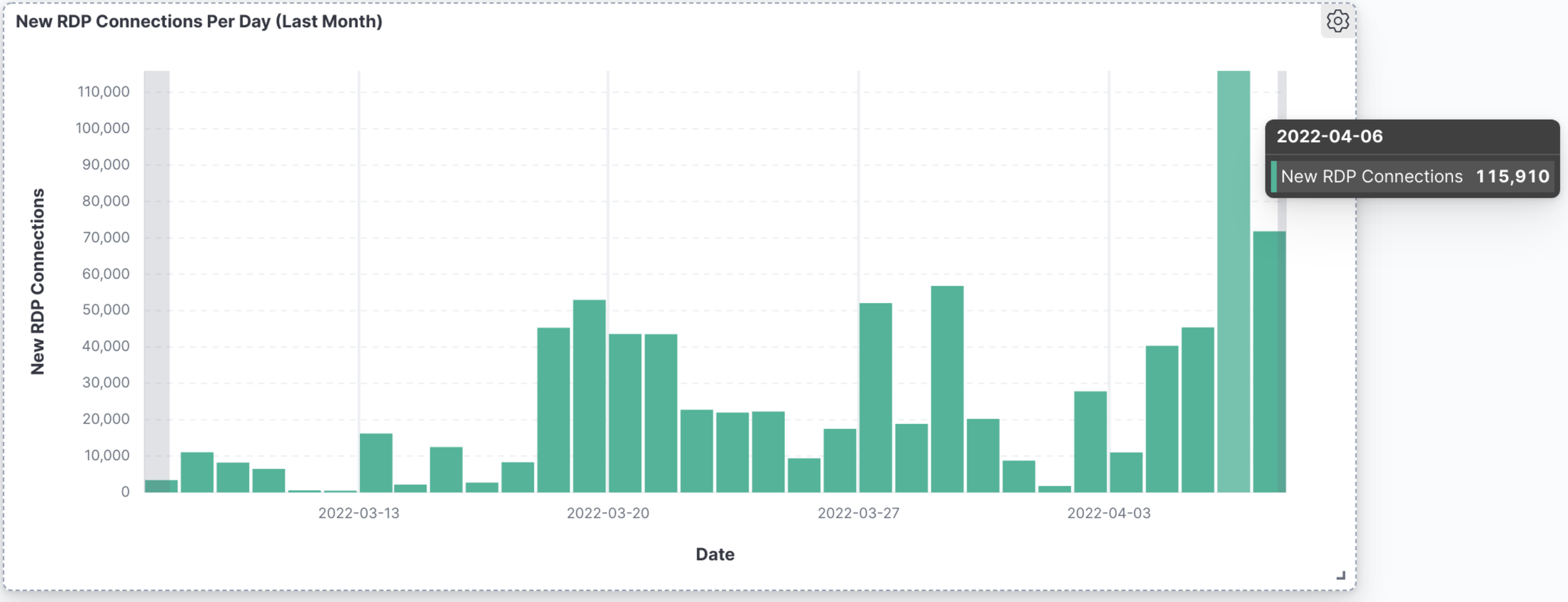
- Make sure that previous Registry entry or similar were not added
- Automatic check for backdooring
  - Use Sticky-Keys-Slayer* to check for Utilman.exe or sethc.exe backdoor
- Windows Defender
  - Threat: Behavior:Win32/AccessibilityEscalation.A
  - Blacklist some system tools as debuggers
    - cmd.exe
    - taskmgr.exe

(*) https://github.com/linuz/Sticky-Keys-Slayer

Exposed RDP

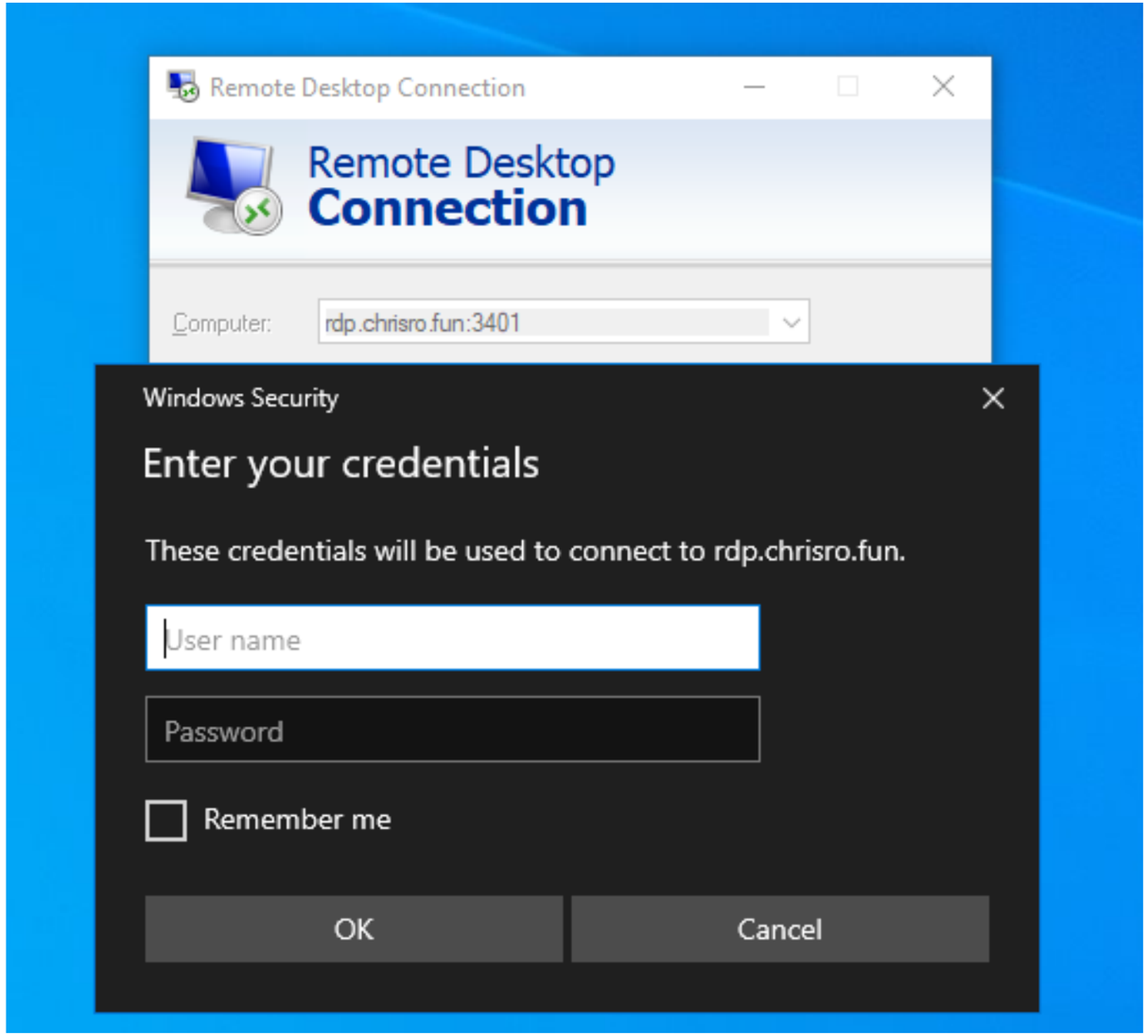
GoSecure

Attacks on Exposed RDP Systems



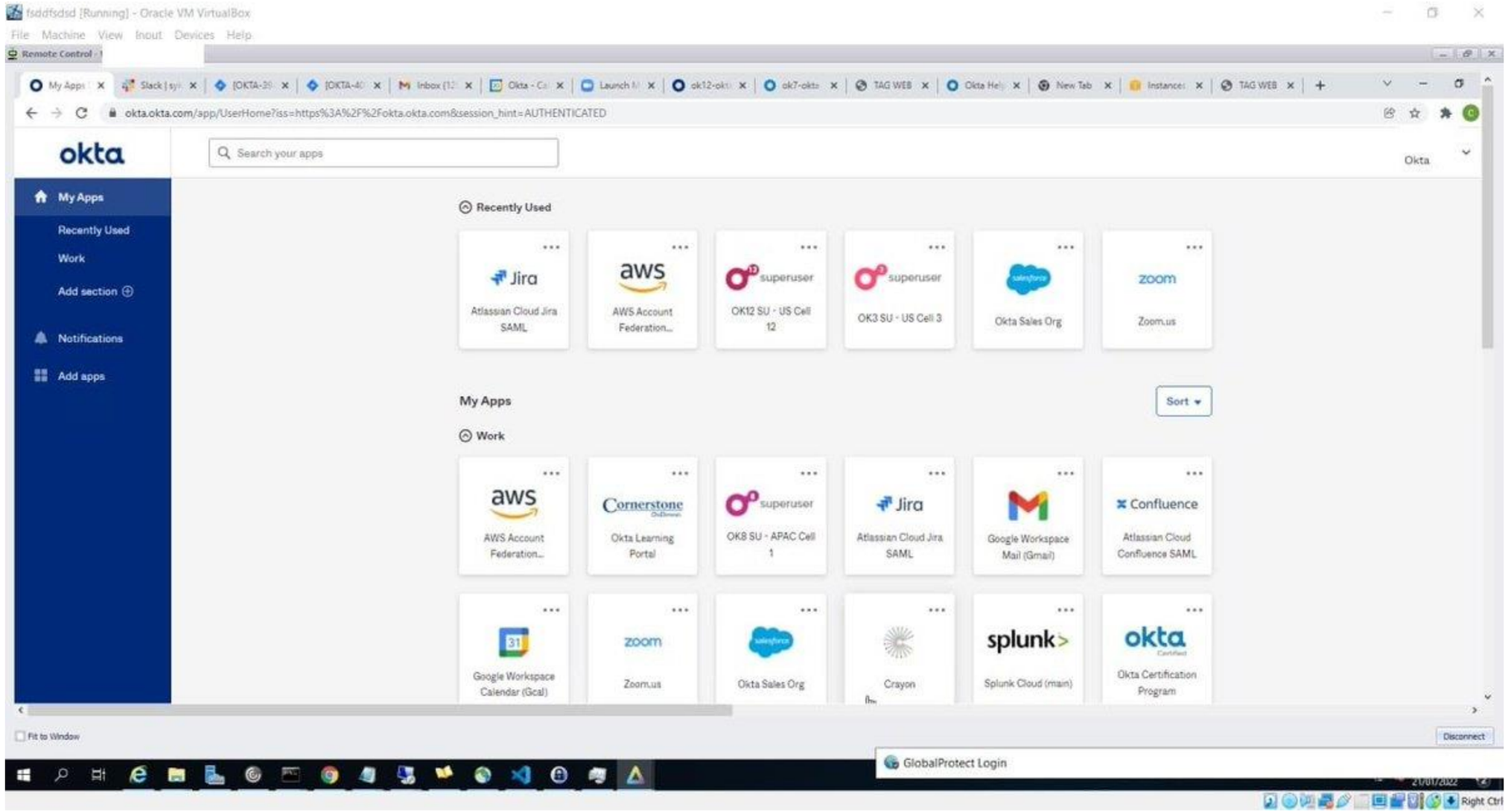
Risks of RDP

Case in point: Okta



Risks of RDP

Case in point: Okta



Wrapping Up

Recap of the Risks

Attacks on the Client

- Stealing files, clipboard, keystrokes
- Recording screen
- Stealing hashed or plaintext credentials
- Code exec via DLL Sideloading*
- RDP Phishing aka Rogue RDP

Attacks on the Server

- Credential Bruteforcing
- Session takeover
- Command injection

Future Work

Defensive Side

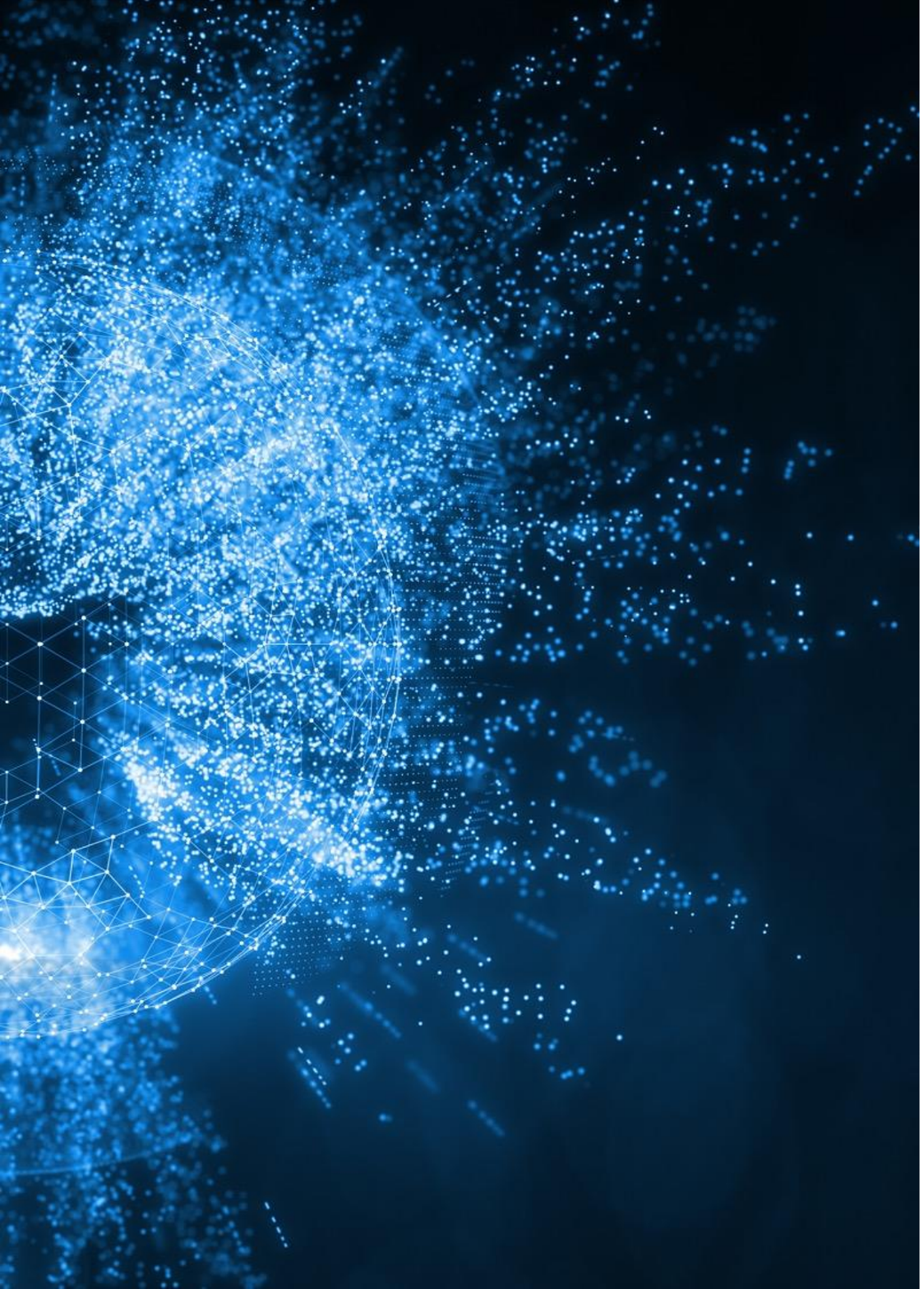
- RD Gateway
- Require valid TLS with specific CA
- NTLM Restrictions
- Shadow Attack Framework (AutoRDPwn)
- Enterprise-scale mitigation
- Blog, blog, blog!

Offensive Side

- RestrictedAdmin with PyRDP
- Kerberos Downgrade
- Shadow Attack Framework (AutoRDPwn)
- RD Gateway

Red Team Take Aways

- RDP is often misconfigured and under the radar
- You can do more than credential bruteforcing with it
  - Attack clients
  - Attack servers
  - Attack both!
  - Not a lot of EDR/XDR coverage



Blue Team Take Aways

- Today: Never use RDP on unprotected networks!
- Today: Train users to not click through certificate errors!
- Soon: Make sure NLA is enforced on all RDP servers (default, often deactivated)
- Long-term: Carefully roll-out Remote Credential Guard or Restricted Admin client-side enforcement

Resources

- https://docs.microsoft.com/en-us/windows-hardware/customize/desktop/unattend/microsoft-windows-terminalservices-rdp-winstationextensions
- https://www.gosecure.net/blog/2020/10/20/announcing-pyrdp-1-0/
- https://www.gosecure.net/blog/2022/01/17/capturing-rdp-netntlmv2-hashes-attack-details-and-a-technical-how-to-guide/
- https://www.darkoperator.com/blog/2012/3/17/configuring-network-level-authentication-for-rdp.html
- https://docs.microsoft.com/en-us/windows-server/remote/remote-desktop-services/clients/rdp-files