SYNACKTIV

# A study on Windows authentication & Prox-Ez

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# Who are we?



- **Geoffrey Bertoli (*@YofBalibump*) & Pierre Milioni (*@b1two_*)**
  - Pentesters at Synacktiv
- **Working for Synacktiv**
  - Offensive security
  - ~140 ninjas: pentest, reverse engineering, development, CSIRT
  - 4 locations: Paris, Rennes, Lyon, Toulouse, (soon at Lille) & remote
  - We are hiring! → *apply@synacktiv.com*

# Introduction



- **A little bit of history**
  - NTLM introduced in 1993 with Windows NT 3.1
  - NTLMv2 since Windows NT 4.0 SP4 – 1998
  - But here comes the mighty Kerberos
    - Became a standard in 1993 (v5)
    - Introduced in Windows 2000
  - NTLM still widely used nowadays

# Introduction



- **Multiple mitigations against relay**
  - NTLMv1 → v2 (not our focus today)
  - NTLM – MIC (not our focus today)
  - NTLM EPA (Extended Protection for Authentication)
    - Channel Binding
    - Service Binding
  - Kerberos
    - Whole new authentication mechanism
    - More complex than NTLM
    - Mutual authentication
    - Fix relay attack

# Introduction



- **Still of interest today**
  - Lack of (proper) documentation of some topics
  - Not supported by all tools
  - Lack of tooling for these authentications over HTTP
- **Prox-Ez**
  - MitM proxy for Windows authentication over HTTP(s)
  - Single file, born to be patched

# Agenda



- **Quick overview of NTLM**
- **NTLM and relaying**
- **NTLM-EPA (Extended Protection for Authentication)**
  - Channel Binding
  - Service Binding
- **What about Kerberos?**
  - Over HTTP
  - Security overview

# NTLM



- **New Technology Lan Manager**
  - Windows authentication protocol
  - Single Sign-On
  - Based on challenge/response exchange
  - Authenticates a session (TCP connection in case of HTTP)
    - May cause issues/slowdowns with programs that creates new TCP connections for each request

      *BurpSuite now supports TCP connection reuse*

- **… over HTTP**

Client's browser

Web server

Client initial HTTP request
GET / HTTP

Server requires authentication
401 + *WWW-Authenticate: NTLM*

Client NTLM Negotiate message
*Authorization: NTLM <negotiate>*

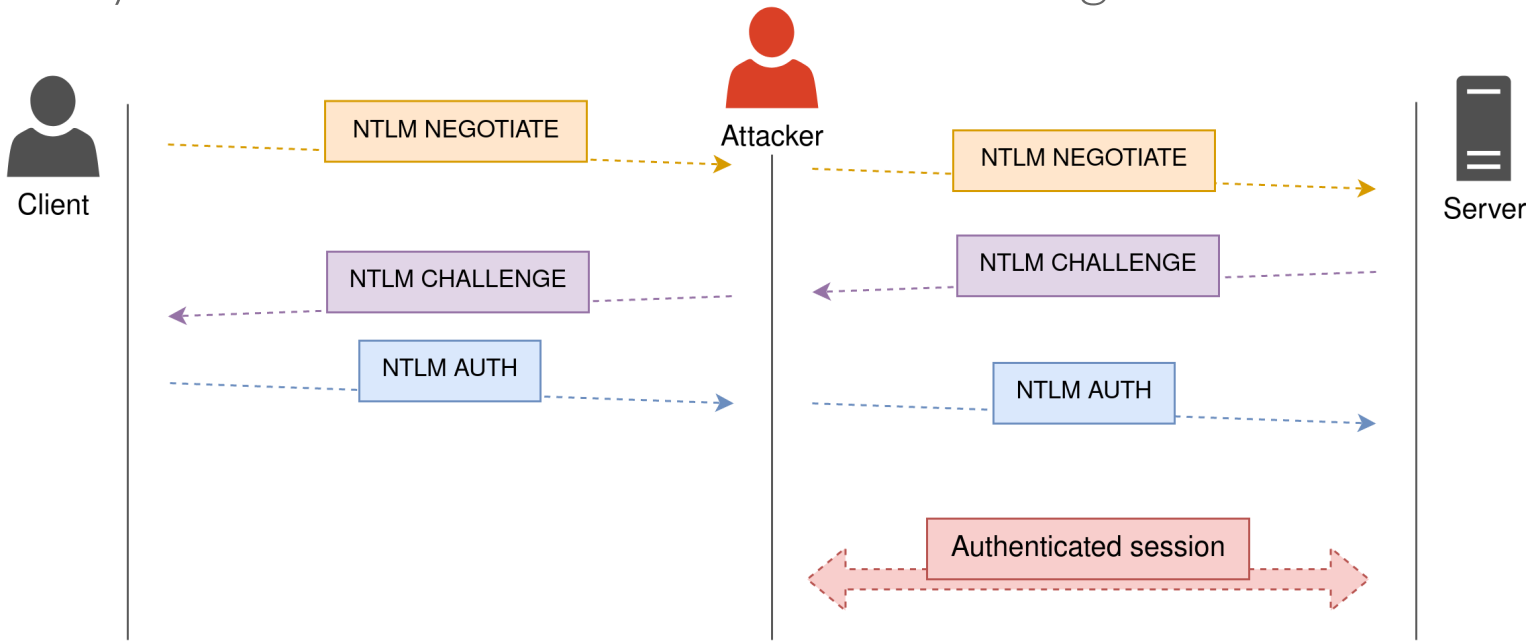
Server NTLM Challenge message
*WWW-Authenticate: NTLM <challenge>*

Client NTLM Auth message
*Authorization: NTLM <auth>*

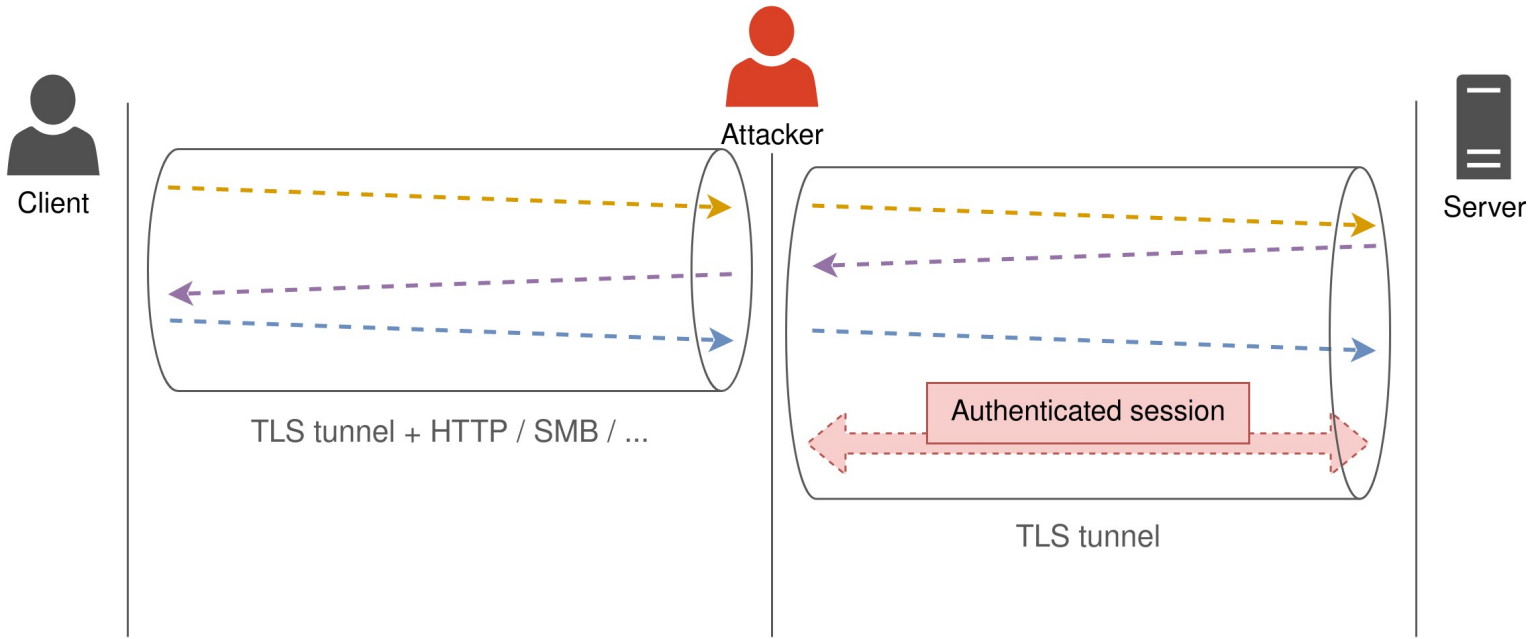
Server returns initially requested page
HTTP/1.1 200

More HTTP requests can be sent
in this authenticated TCP connection

- **NTLM relaying**
  - Attacker in a relaying position (able to forward messages from a client)
  - Relays the client's authentication to the targeted server



- **NTLM relaying – Over TLS**
  - Attacker in a relaying position
  - Relays the client's authentication to the targeted server



# NTLM EPA – Channel Binding

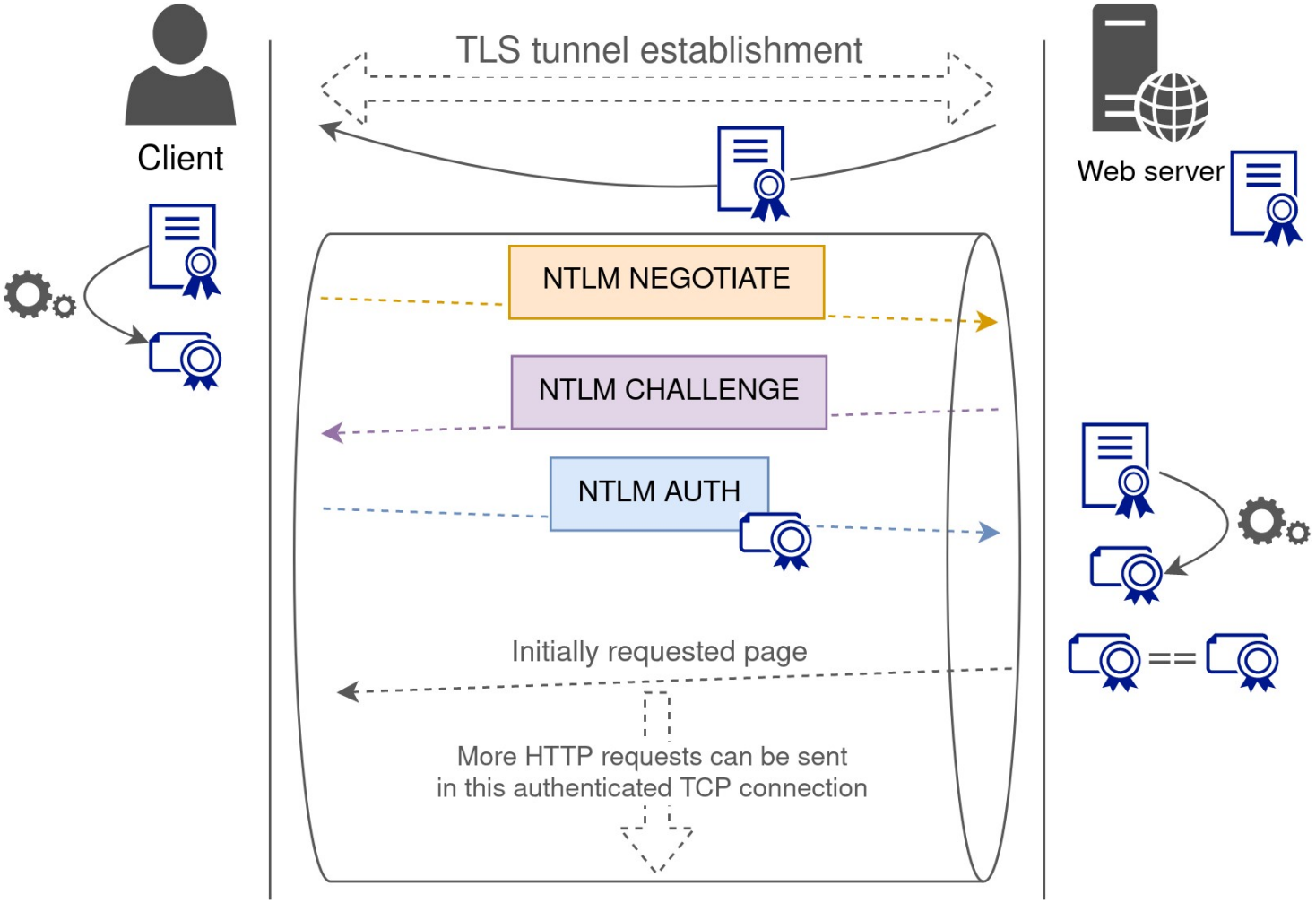


- **Channel Binding**
  - Microsoft's solution to protect against MitM attacks
  - Used on TLS based communications
  - "Binds" the authentication to the outer TLS channel

    → Adds a token that depends on the TLS tunnel into the NTLM authentication
  - Can be *required* by the server
    - Any client without the proper token are denied access

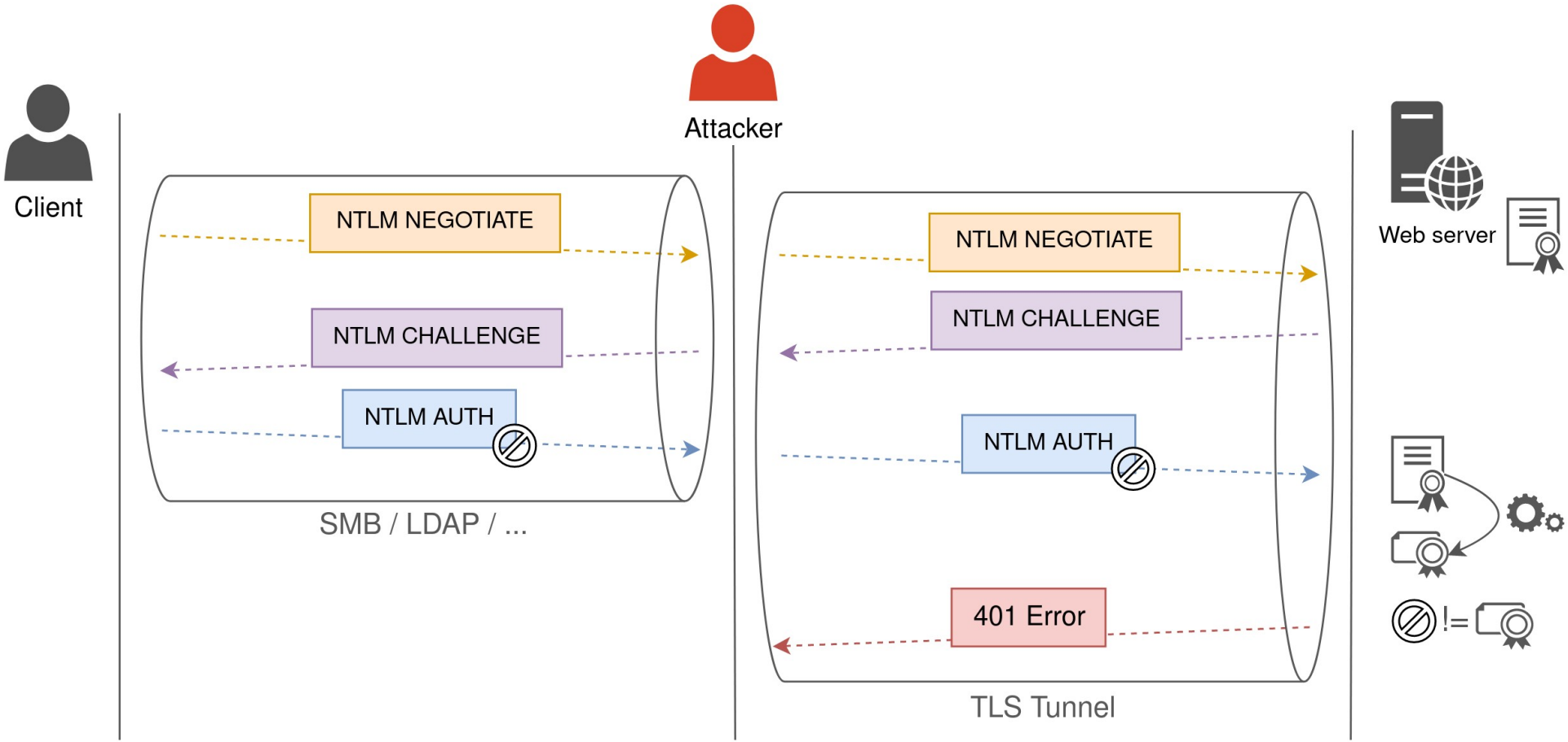
# NTLM EPA – Channel Binding





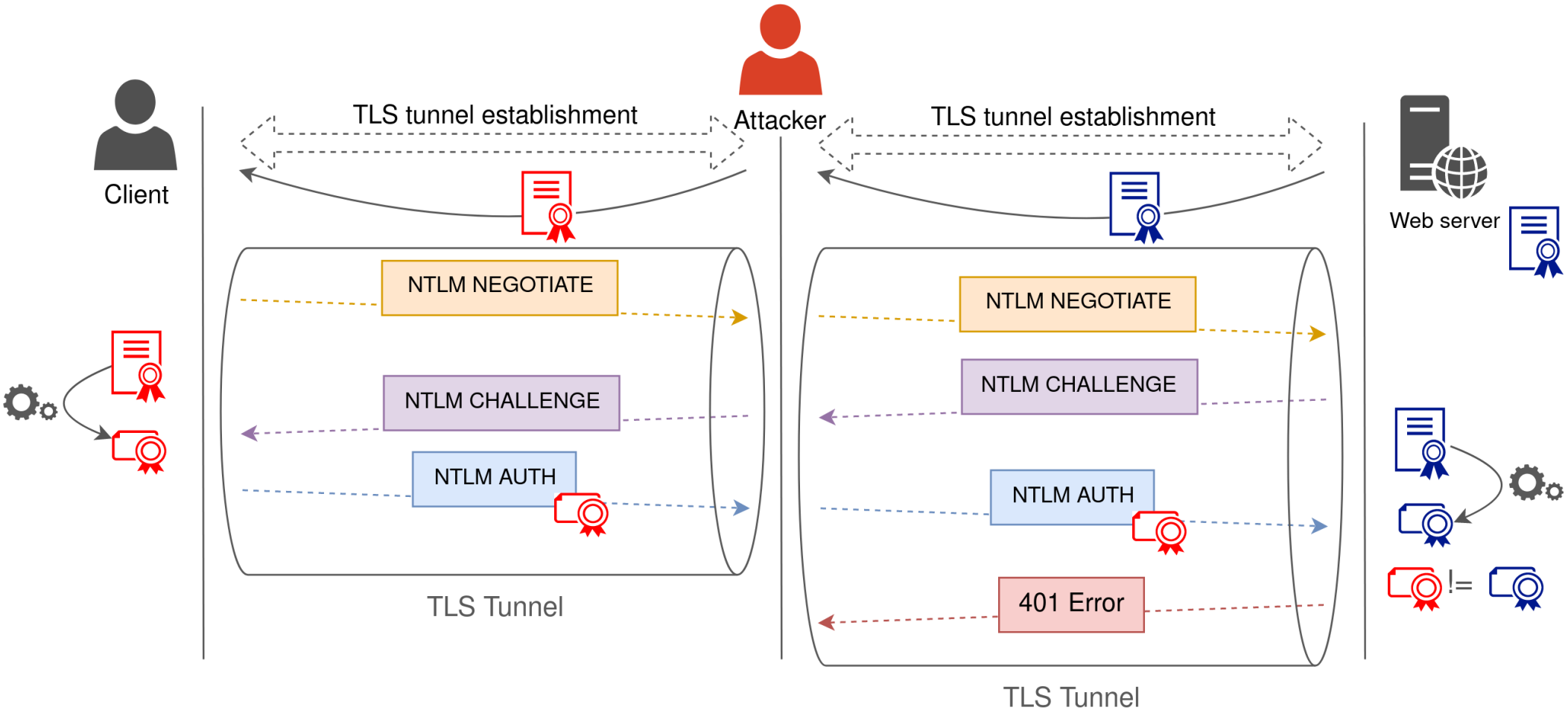
# NTLM EPA – Channel Binding





# NTLM EPA – Channel Binding





# NTLM EPA – Channel Binding



- **CBT: *Channel Binding Token***
  - Hash of the server's certificate
  - With the hash function used to compute the certificate's signature

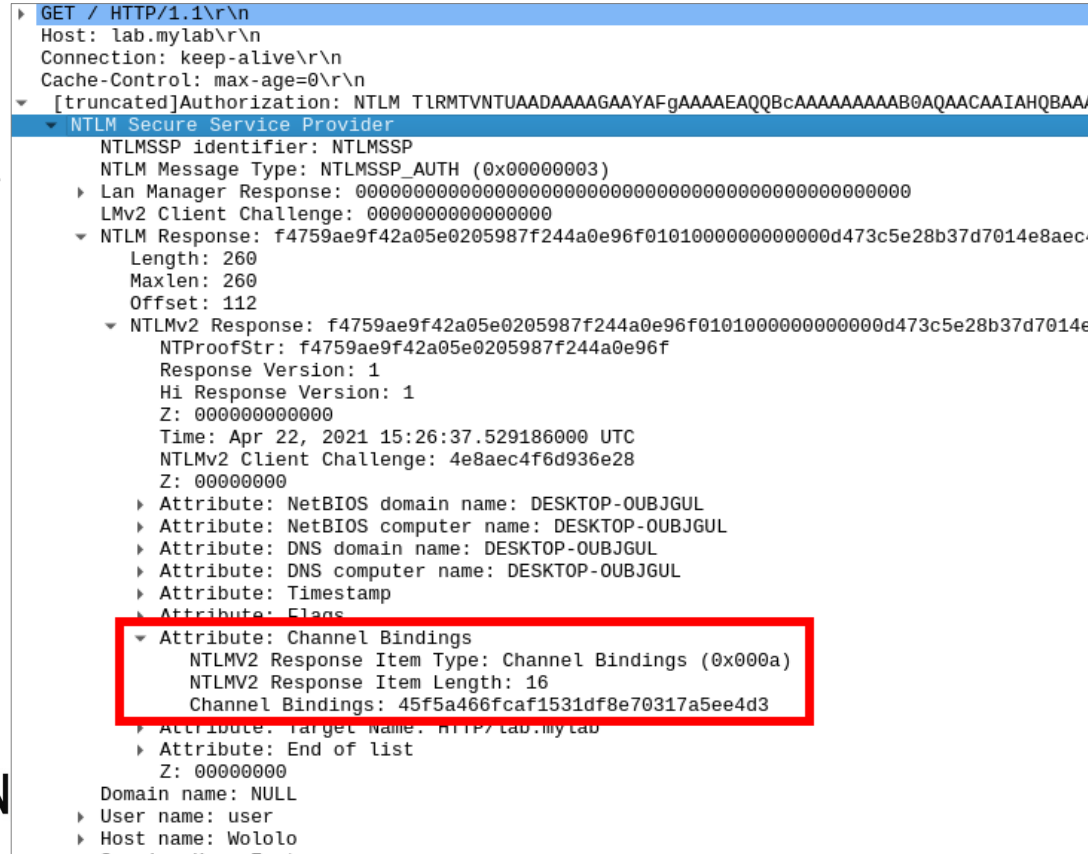
| Certificate signature's hash function | MD5 / SHA-1 | Other hash function | No hash function / multiple hash functions |
|---|---|---|---|
| CBT's hash function | SHA-256 | Signature's hash function | Undefined |

# NTLM EPA – Channel Binding



- ***Channel Bindings* attribute**

- Derived from the CBT
- Inserted in the NTLM *AUTH* message
- Cannot be modified
  - Protected by the MIC value (HMAC)
    → protected by the *Flags* attribute
    → protected by *NTProofStr*
    → protected by the client's secret



# NTLM EPA – Channel Binding



- **Channel Binding**
  - Still not supported by many clients
    → no authentication possible if EPA is required
  - How to use our tools against EPA protected websites?

# MitM Proxy – Prox-Ez ("prox easy")



- **Why?**
  - Be able to use any tool against HTTP(s) servers using
    - NTLM
    - NTLM-EPA
    - *Kerberos*
  - Be able to control the authentication

# MitM Proxy – Prox-Ez ("prox easy")

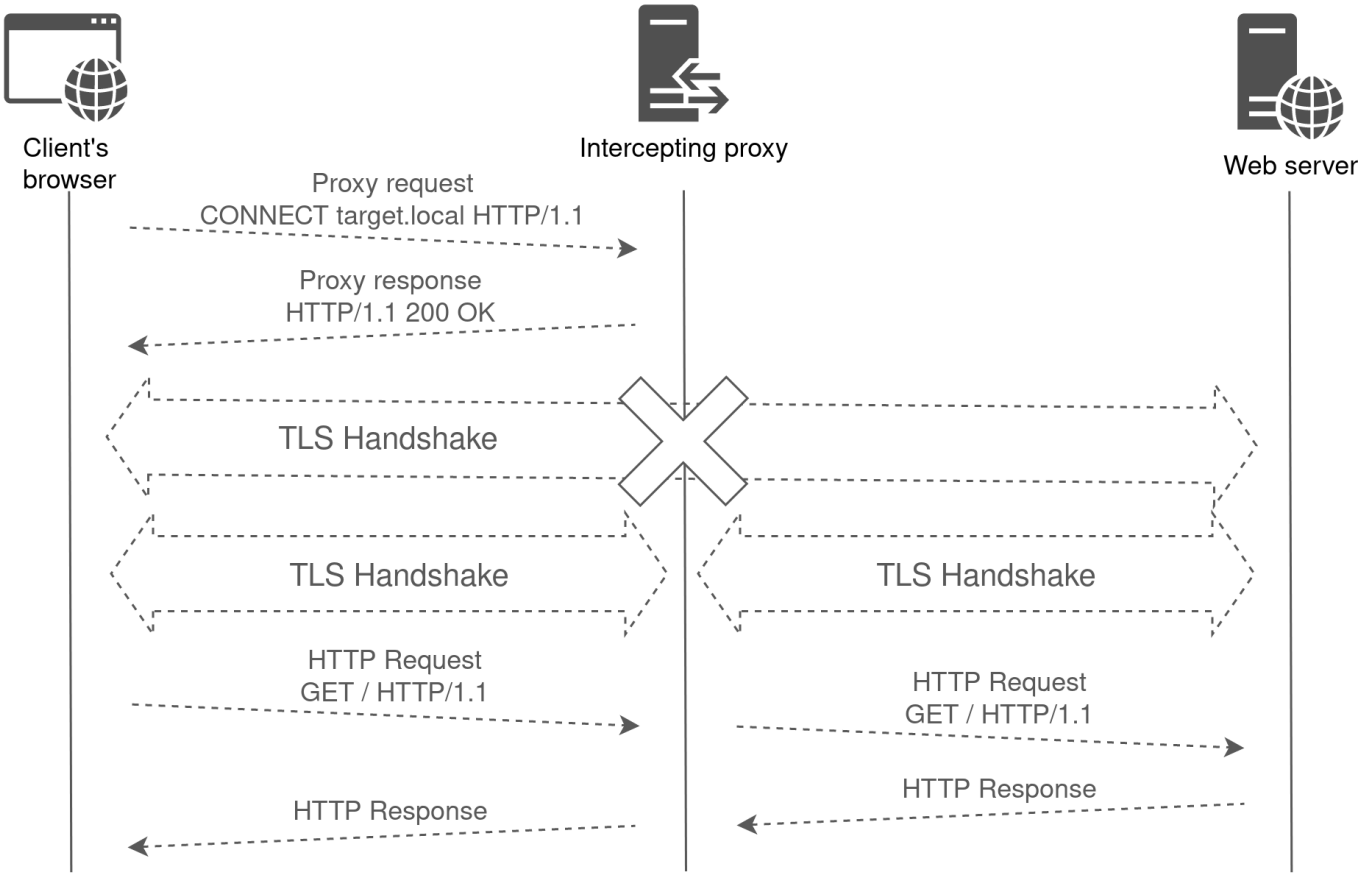


- **How?**
  - Has to work with TLS
    → TLS interception
    → Register a custom certificate authority on the client
    → Generate on-the-fly certificates
  - Good documentation on *mitmproxy* website

# MitM Proxy – Prox-Ez ("prox easy")



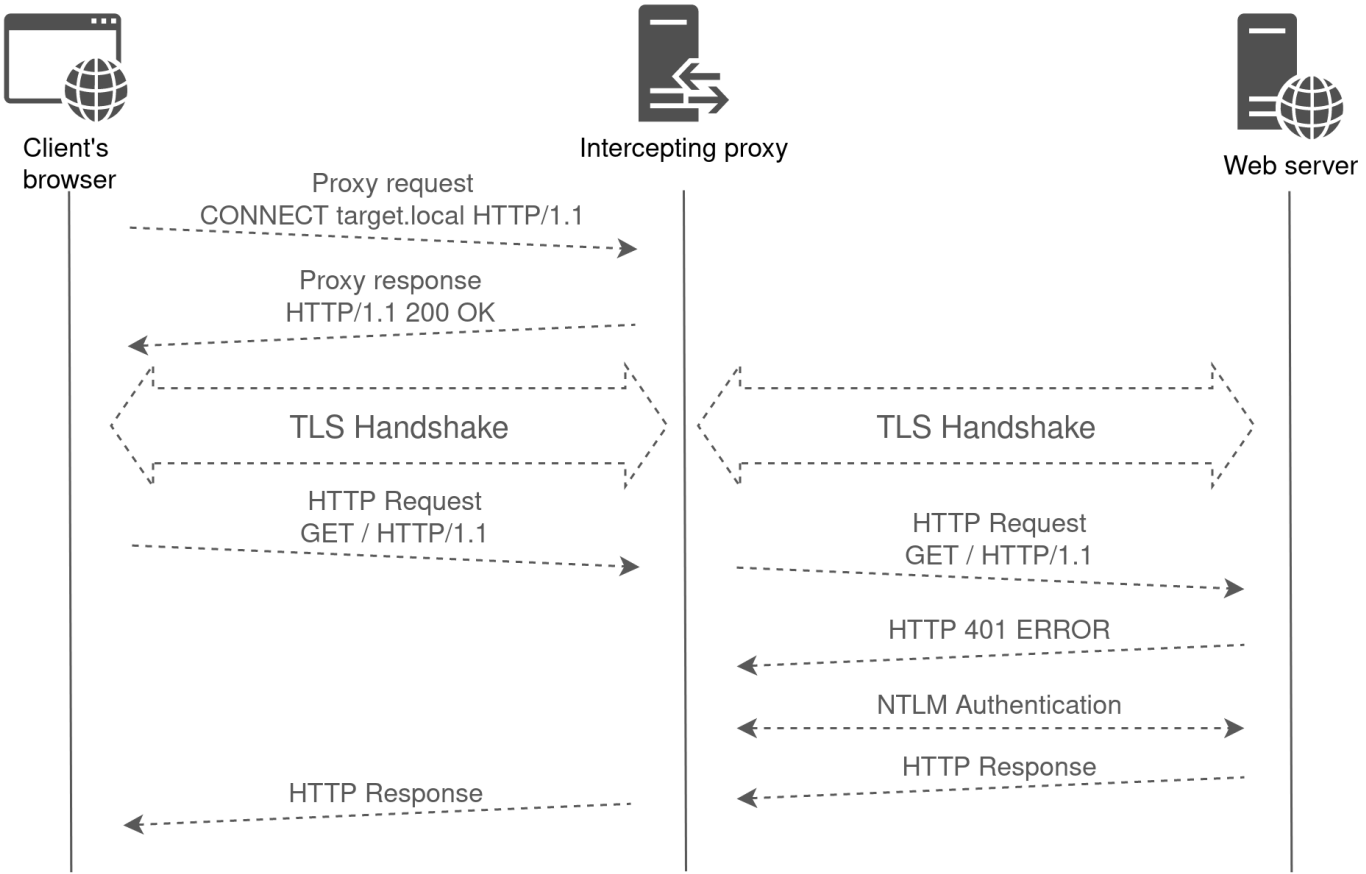
- **How?**
  - TLS interception



# MitM Proxy – Prox-Ez ("prox easy")



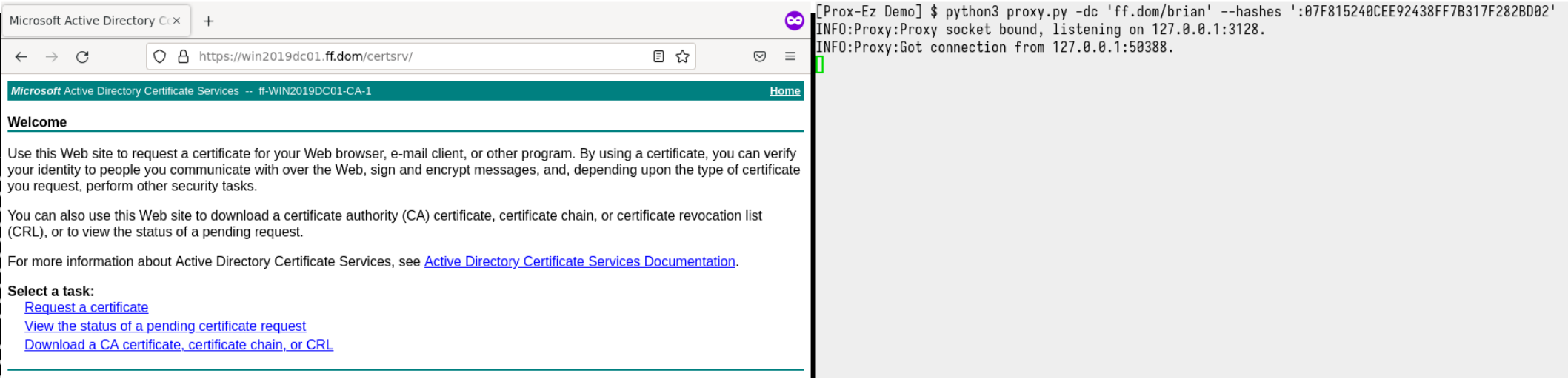
- **How?**
  - TLS interception



# MitM Proxy – Prox-Ez ("prox easy")



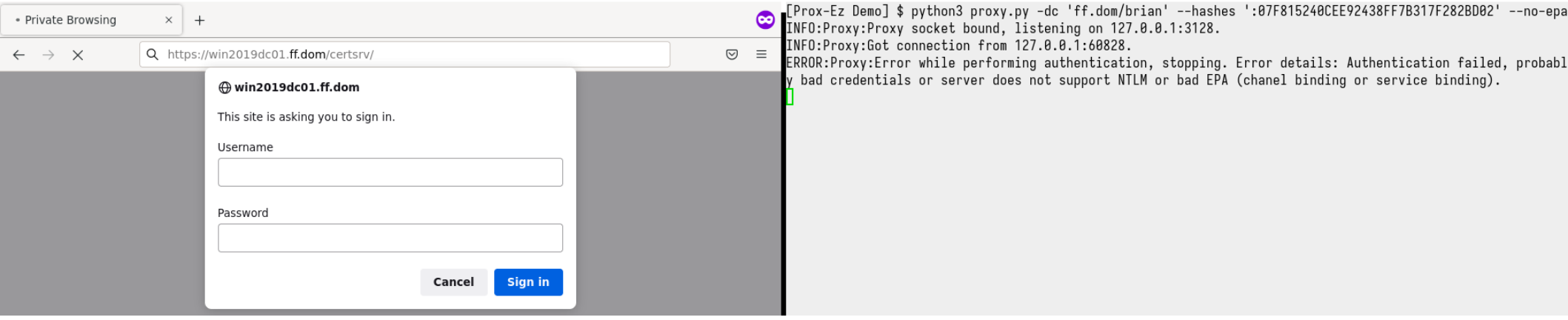
- **Demo**



# MitM Proxy – Prox-Ez ("prox easy")



- Demo



# NTLM EPA – Service Binding

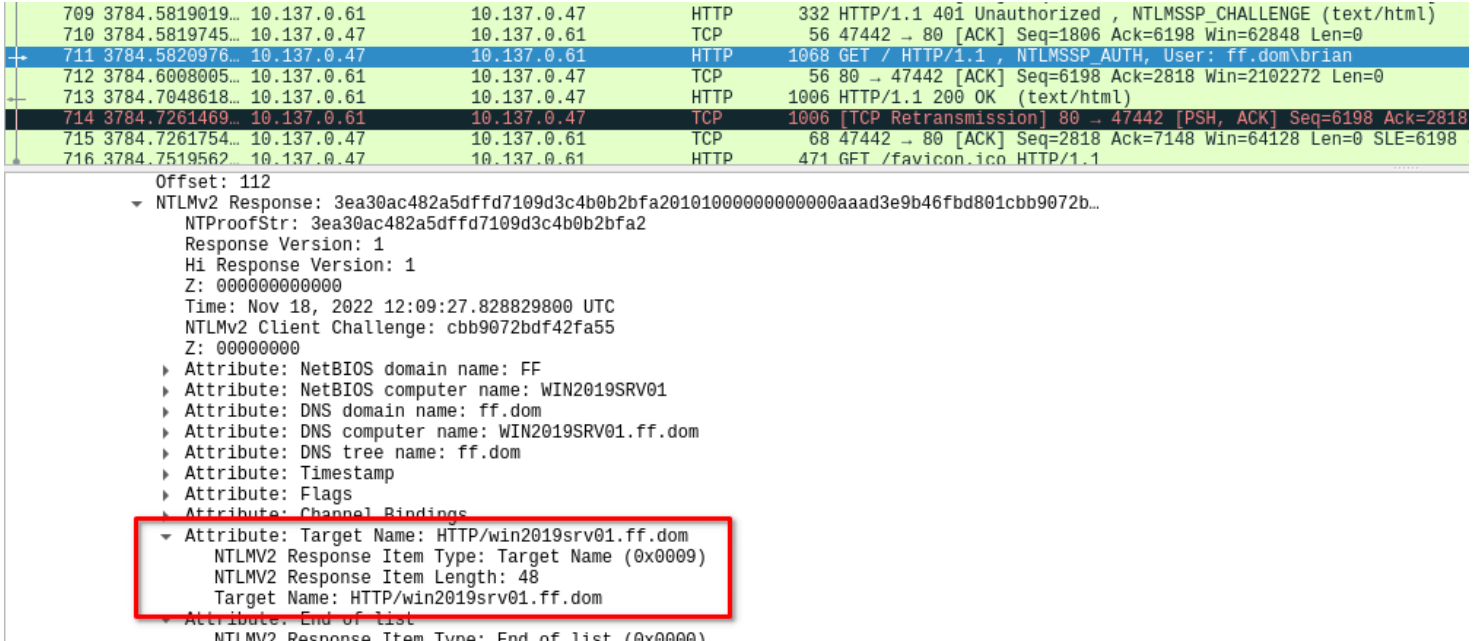


- **Service Binding**
  - Channel Binding requires TLS, now what about plain HTTP?
    - (Don't do plain HTTP)
  - Microsoft implemented a new protection
    - Service Binding
  - Same objective as Channel Binding → Prevent MitM attacks

# NTLM EPA – Service Binding



- **Service Binding**
  - New attribute in the NTLM *AUTH* message
    - Identifies the targeted resource



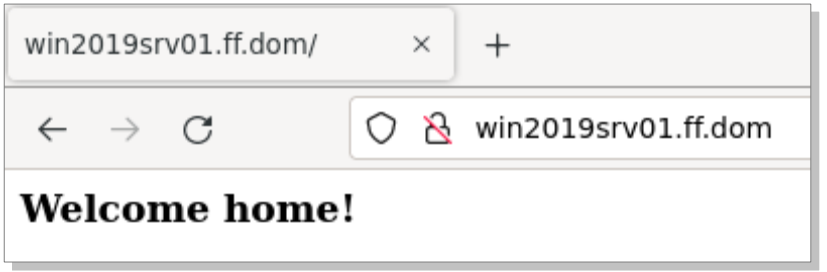
# NTLM EPA – Service Binding



- **Service Binding**
  - New attribute in the NTLM *AUTH* message
    - Identifies the targeted resource
    - Taken from the browser URL

```
711 3784.5820976… 10.137.0.47   10.137.0.61   HTTP   1068 GET / HTTP/1.1 , NTLMSSP_AUTH, User: ff.dom\brian
712 3784.6008005… 10.137.0.61   10.137.0.47   TCP      56 80 → 47442 [ACK] Seq=6198 Ack=2818 Win=2102272 Len=0
713 3784.7048618… 10.137.0.61   10.137.0.47   HTTP   1006 HTTP/1.1 200 OK  (text/html)
714 3784.7261469… 10.137.0.61   10.137.0.47   TCP    1006 [TCP Retransmission] 80 → 47442 [PSH, ACK] Seq=6198 Ack=2818
715 3784.7261754… 10.137.0.47   10.137.0.61   TCP      68 47442 → 80 [ACK] Seq=2818 Ack=7148 Win=64128 Len=0 SLE=6198
716 3784.7519562… 10.137.0.47   10.137.0.61   HTTP    471 GET /favicon.ico HTTP/1.1
```

```
Offset: 112
NTLMv2 Response: 3ea30ac482a5dffd7109d3c4b0b2bfa20101000000000000aaad3e9b46fbd801cbb9072b…
   NTProofStr: 3ea30ac482a5dffd7109d3c4b0b2bfa2
   Response Version: 1
   Hi Response Version: 1
   Z: 000000000000
   Time: Nov 18, 2022 12:09:27.828829800 UTC
   NTLMv2 Client Challenge: cbb9072bdf42fa55
   Z: 00000000
   Attribute: NetBIOS domain name: FF
   Attribute: NetBIOS computer name: WIN2019SRV01
   Attribute: DNS domain name: ff.dom
   Attribute: DNS computer name: WIN2019SRV01.ff.dom
   Attribute: DNS tree name: ff.dom
   Attribute: Timestamp
   Attribute: Flags
   Attribute: Channel Bindings
   Attribute: Target Name: HTTP/win2019srv01.ff.dom
      NTLMV2 Response Item Type: Target Name (0x0009)
      NTLMV2 Response Item Length: 48
      Target Name: HTTP/win2019srv01.ff.dom
   Attribute: End of list
   NTLMV2 Response Item Type: End of list (0x0000)
```



# NTLM EPA – Service Binding



- **Service Binding**
  - New attribute in the NTLM *AUTH* message
    - Identifies the targeted resource
    - Taken from the browser URL
  - If the authentication targets another server than the one receiving the authentication → denied access

# NTLM EPA – Service Binding



- **Service Binding**
  - The web server needs to be configured with the proper SPNs
    - No implicit SPN
    - All the alternative DNS records
  - Bad integration in IIS
    - No graphical option
    - Manual modification of *C:\Windows\System32\inetsrv\Config*

# NTLM EPA – Service Binding



## Service Binding

```
# C:\Windows\System32\inetsrv\Config
<location path="Default Web Site">
  <system.webServer>
    <security>
      <authentication>
        <windowsAuthentication enabled="true" useKernelMode="false">
          <providers>
            <clear />
            <add value="NTLM" />
          </providers>
          <extendedProtection tokenChecking="Require" flags="Proxy,ProxyCohosting">
            <spn name="HTTP/win2019srv01.ff.dom" />
          </extendedProtection>
        </windowsAuthentication>
        <anonymousAuthentication enabled="false" />
      </authentication>
    </security>
  </system.webServer>
</location>
```

# NTLM EPA – Service Binding



## Service Binding

| *flags* options | Behavior | Remark |
|---|---|---|
| Empty / None | Only verify CBT | HTTP is not protected ; HTTPs is protected |
| *Proxy* | Only verify SPN | HTTP is not working (no authentication possible) ; HTTPs is protected |
| *Proxy,ProxyCohosting* | Only verify SPN | Both HTTP and HTTPs are protected and work |
| *Proxy,NoServiceNameCheck* | Does not verify anything | HTTP is not working (no authentication possible) ; HTTPs is not protected but a SPN has to be provided (any value) |
| *Proxy,ProxyCohosting,NoServiceNameCheck* | Does not verify anything | Both HTTP and HTTPs are not protected (no SPN required) |

# NTLM EPA – Service Binding

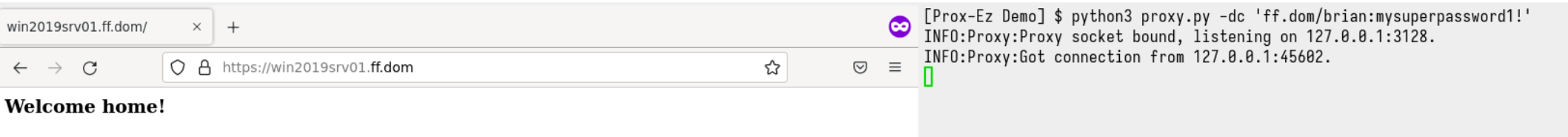


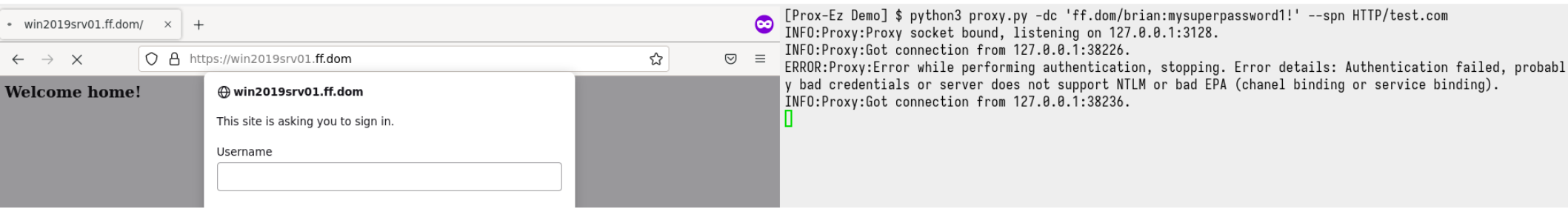
- **Service Binding**
  - Service Binding configuration is cumbersome
  - Default EPA configuration → Service Binding not enforced
  - Enforced EPA but plain HTTP available → vulnerable to MitM attacks

# MitM Proxy – Prox-Ez ("prox easy")



- **Even if not widely used**
  - Prox-Ez implements EPA-Service binding



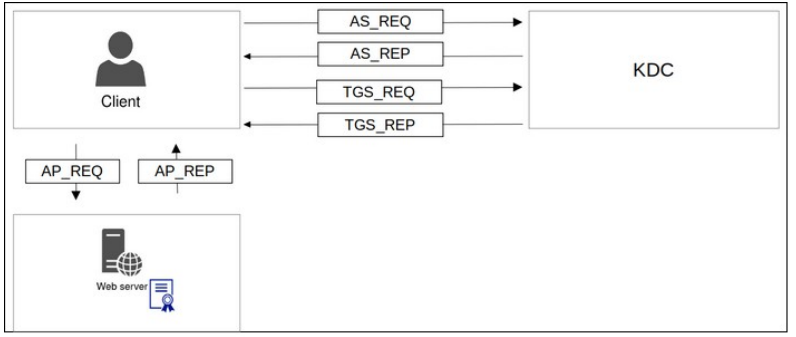



# Kerberos



## Why Kerberos ?

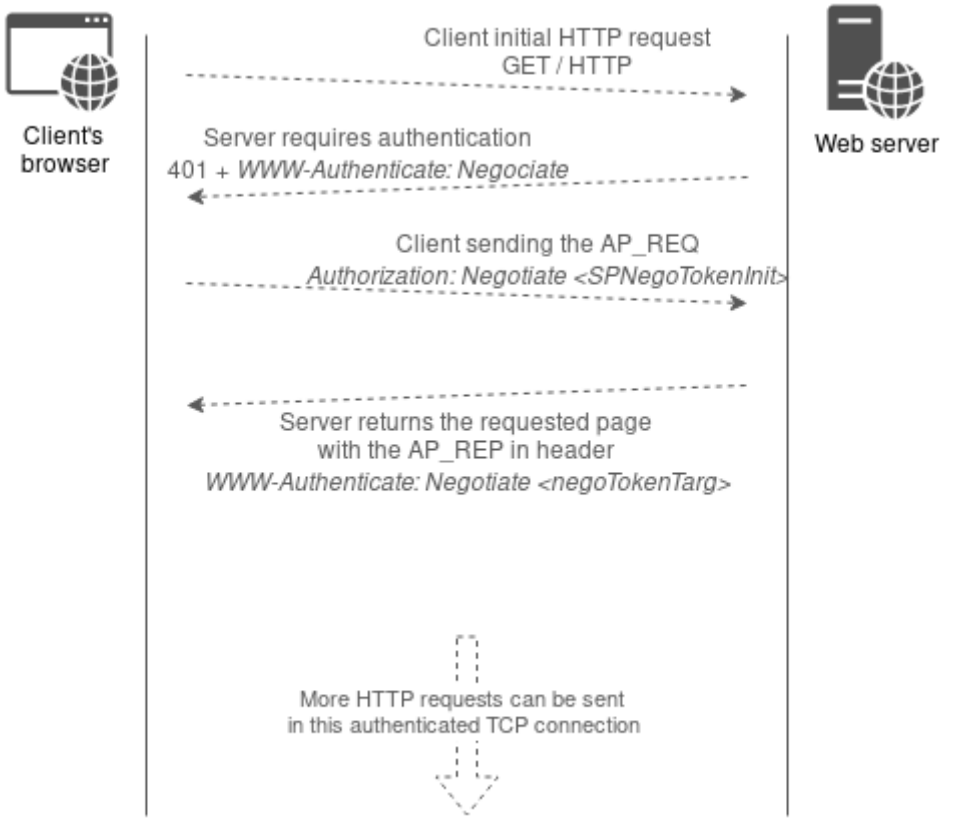
- Microsoft recommend enabling EPA as primary mitigation against relay attack (such as PetitPotam)
- In addition, disable NTLM and replace it by Kerberos
- Kerberos feature “Mutual Authentication”



# Kerberos



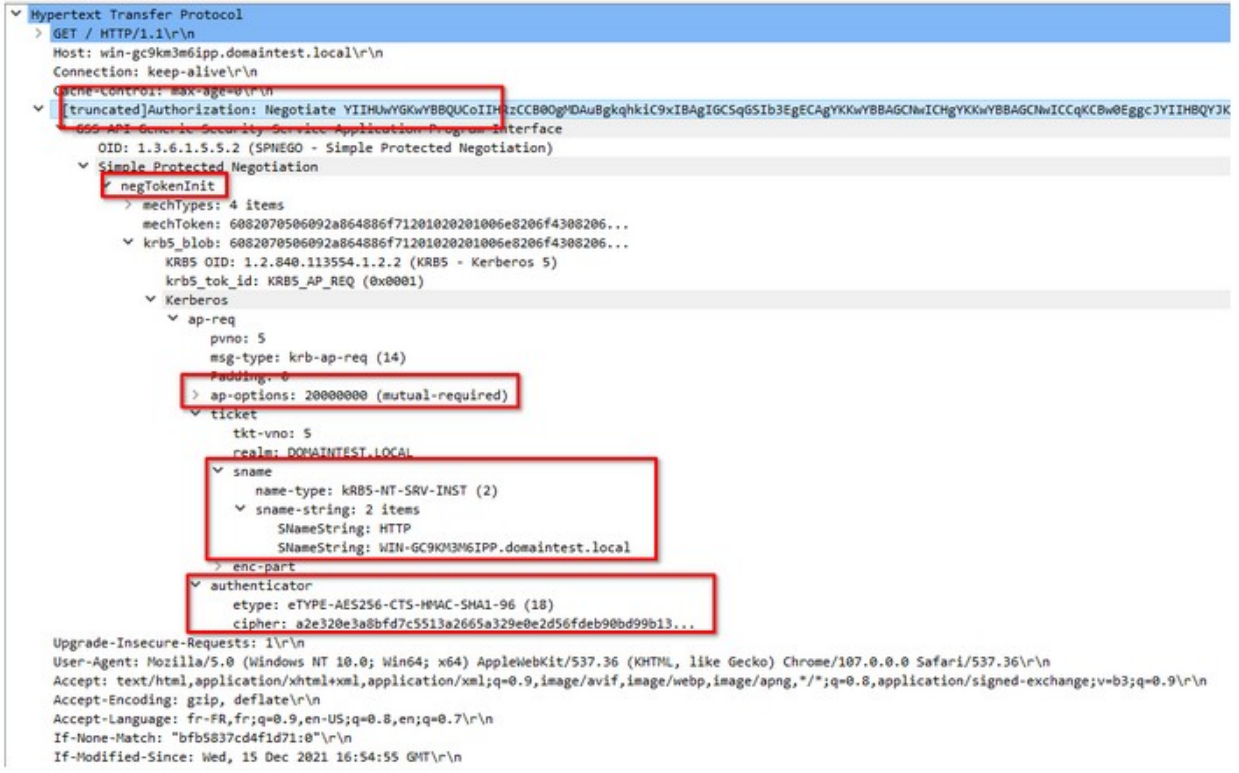
- **...over HTTP?**
  - Similar to NTLM
  - The client sent the AP_REQ in a specific header



# Kerberos



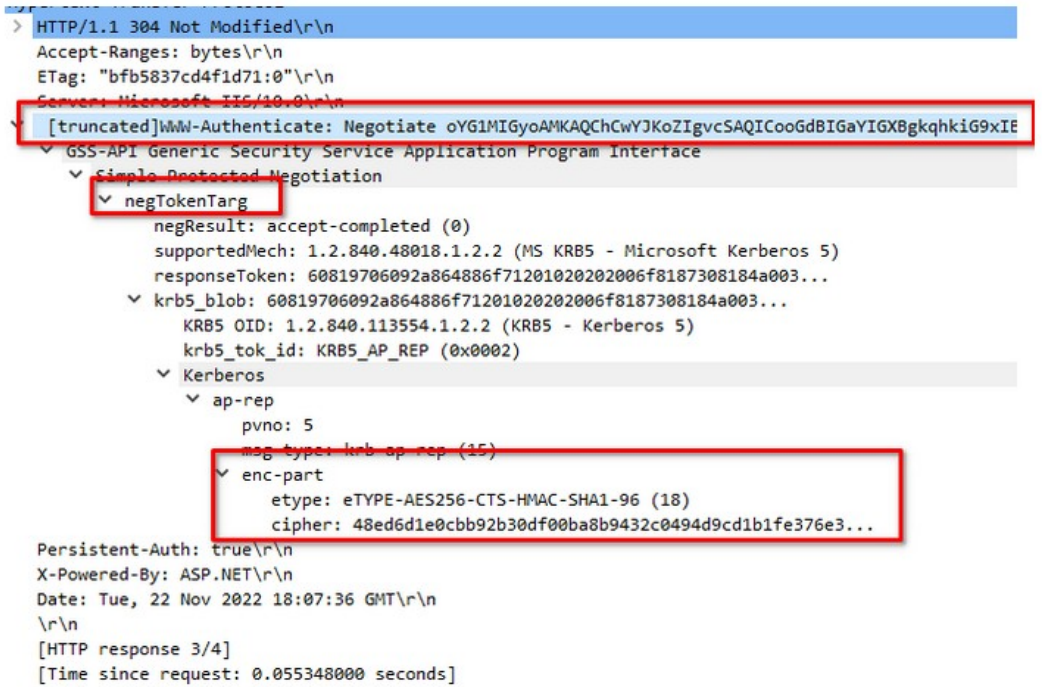
- Let's have a closer look



# Kerberos



- Let’s have a closer look



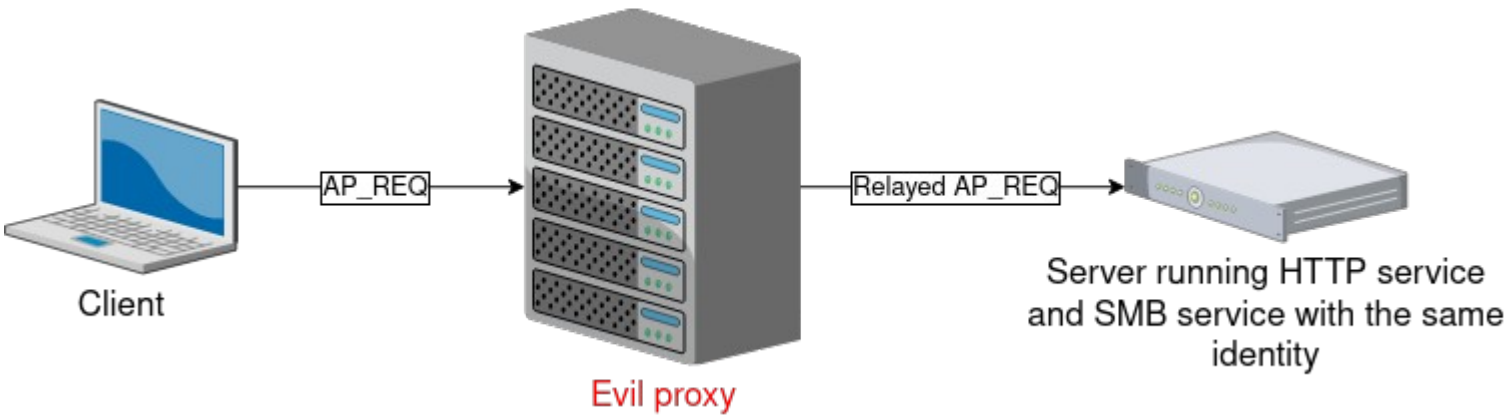
# Kerberos

## Security overview

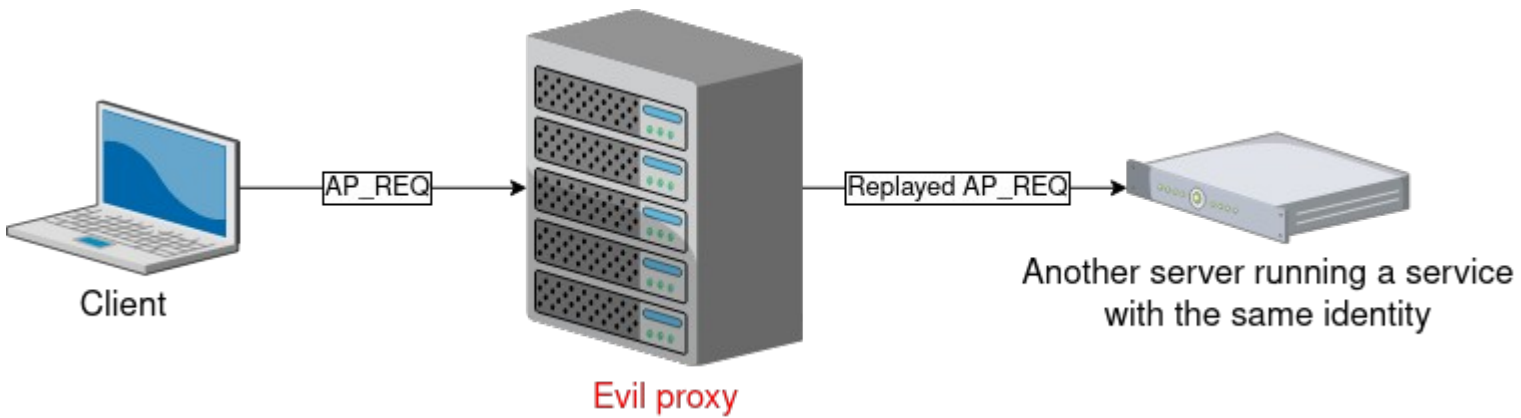
- Two security measures to prevent replay attack
  - AP_REQ contain a timestamp : <5min
  - Host stores a MD5 hash of each AP_REQ : KRB_AP_ERR_REPEAT

  - AP_REQ contains SPN of the service : Not verified

- **Security overview**
  - Relay on a server using the same identity



- **Security overview**
  - Replay on another server using the same identity



# Kerberos



- **Why do we need a proxy**
  - Still not supported by many clients (Firefox, …)
    → No authentication possible if Kerberos is enforced
  - How to use our tools against Kerberos protected websites?
    - BurpSuite
    - Certipy
    - …

# MitM Proxy – Prox-Ez ("prox easy")

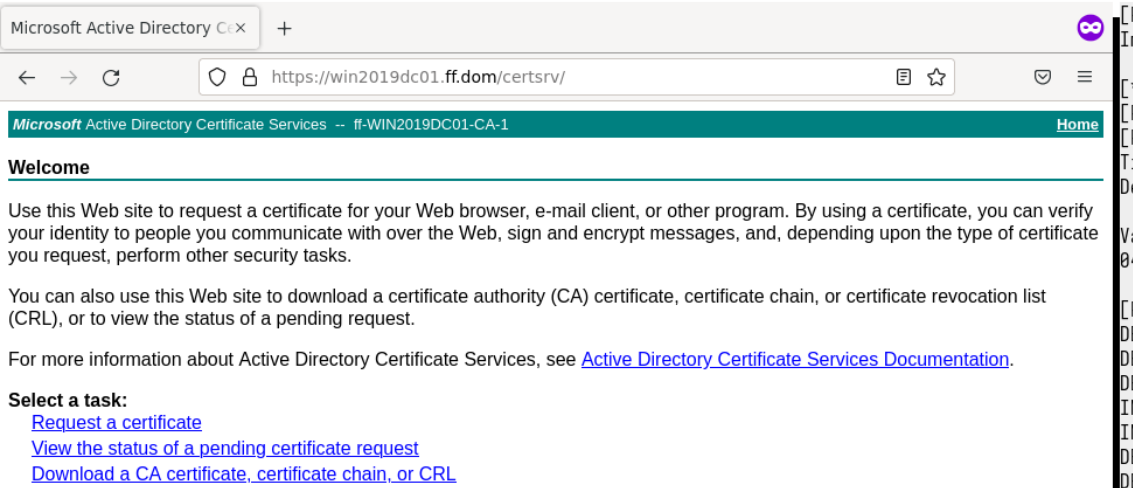


- **Prox-EZ implement Kerberos authentication**
  - Standard user/password capabilities
  - Pass-the-ticket capabilities (from TGT or ST)
  - Overpass-the-hash capabilities (from the NT hash)

# MitM Proxy – Prox-Ez ("prox easy")



- Demo




```
[Prox-Ez Demo] $ getTGT.py 'ff.dom/brian:mysuperpassword1!'
Impacket v0.9.24 - Copyright 2021 SecureAuth Corporation

[*] Saving ticket in brian.ccache
[Prox-Ez Demo] $ export KRB5CCNAME=brian.ccache
[Prox-Ez Demo] $ klist
Ticket cache: FILE:brian.ccache
Default principal: brian@FF.DOM

Valid starting       Expires              Service principal
04/19/2023 16:27:42  04/20/2023 02:27:42  krbtgt/FF.DOM@FF.DOM
        renew until 04/20/2023 16:27:42
[Prox-Ez Demo] $ python3 proxy.py -dc 'ff.dom/brian' -k -d
DEBUG:Proxy:Entered proxy, creating sockets.
DEBUG:Proxy:Proxy socket created.
DEBUG:Proxy:Binding proxy socket.
INFO:Proxy:Proxy socket bound, listening on 127.0.0.1:3128.
INFO:Proxy:Got connection from 127.0.0.1:43272.
DEBUG:Proxy:Creating new process.
DEBUG:Proxy:Handling connection.
DEBUG:Proxy.Client<->ProxyHelper:Creating new ClientToProxyHelper
DEBUG:Proxy.Client<->ProxyHelper:Our state: IDLE; their state: IDLE
DEBUG:Proxy.Client<->ProxyHelper:Received

        CONNECT win2019dc01.ff.dom:443 HTTP/1.1
        user-agent: Mozilla/5.0 (X11; Linux x86_64; rv:102.0) Gecko/20100101 Firefox/102.0
        proxy-connection: keep-alive
        connection: keep-alive
        host: win2019dc01.ff.dom:443
```

# MitM Proxy – Prox-Ez ("prox easy")



- **Available on GitHub:**
  - *https://github.com/synacktiv/Prox-Ez*
  - PR & issues are welcome

README.md

## Prox-Ez: The Swiss Army Knife of HTTP auth

This HTTP proxy handles all HTTP authentications on your behalf.

It supports NTLM EPA (channel binding and service binding), kerberos, pass-the-hash, overpass-the-hash (pass-the-key) and pass-the-ticket (TGT and TGS).

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# Any question?

Linked articles:
https://www.synacktiv.com/publications/dissecting-ntlm-epa-with-love-building-a-mitm-proxy.html
https://www.synacktiv.com/publications/a-study-on-windows-http-authentication-part-ii.html

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