How Attackers Are Compromising Your Networks and What You Can Do About It

ROOTCON18

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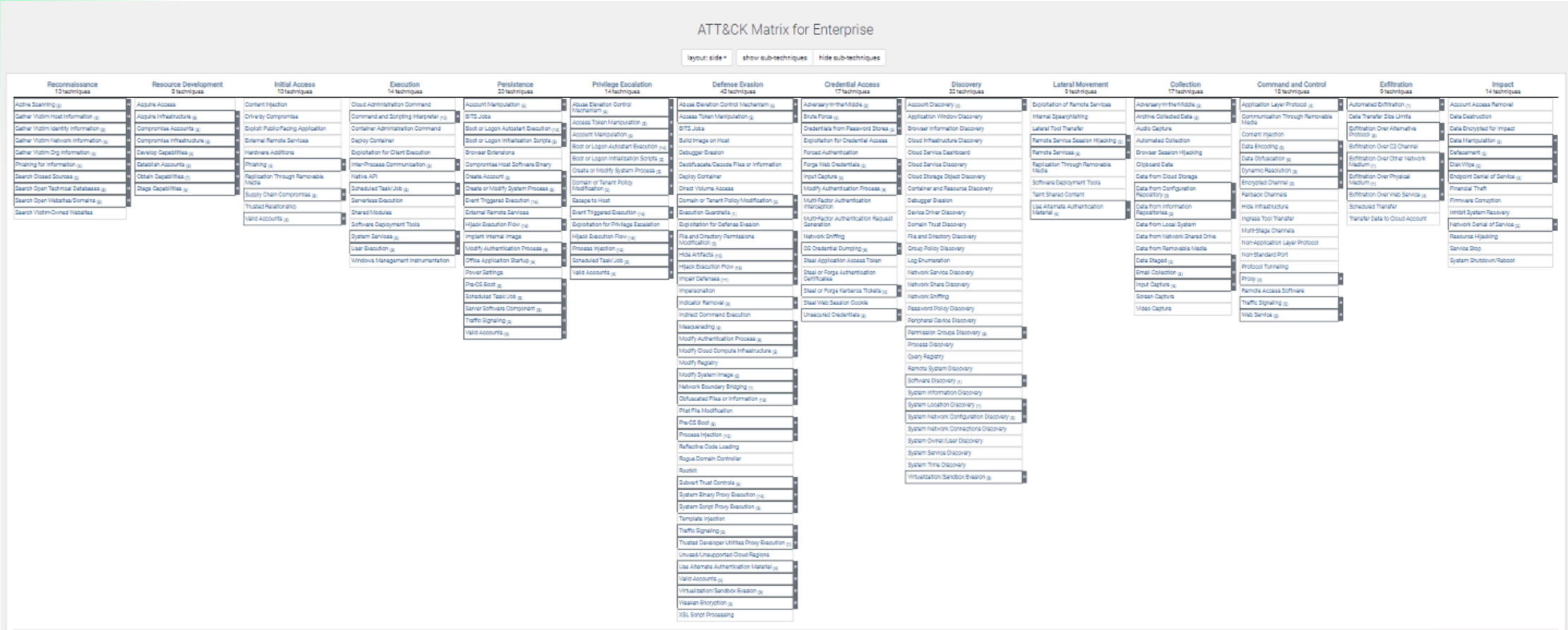
OUTLINE

- What are attackers doing today?
- Windows and Active Directory Primer
- Active Directory Attacks
- Active Directory Defenses


1
RECONNAISSANCE
Harvesting email addresses, conference information, etc.
2
WEAPONIZATION
Coupling exploit with backdoor into deliverable payload
3
DELIVERY
Delivering weaponized bundle to the victim via email, web, USB, etc.
4
EXPLOITATION
Exploiting a vulnerability to execute code on victim's system
5
INSTALL
INSTALLATION
Installing malware on the asset
6
COMMAND & CONTROL (C2)
Command channel for remote manipulation of victim
7
ACTIONS ON OBJECTIVES
With 'Hands on Keyboard' access, intruders accomplish their original goals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Attacker Phases

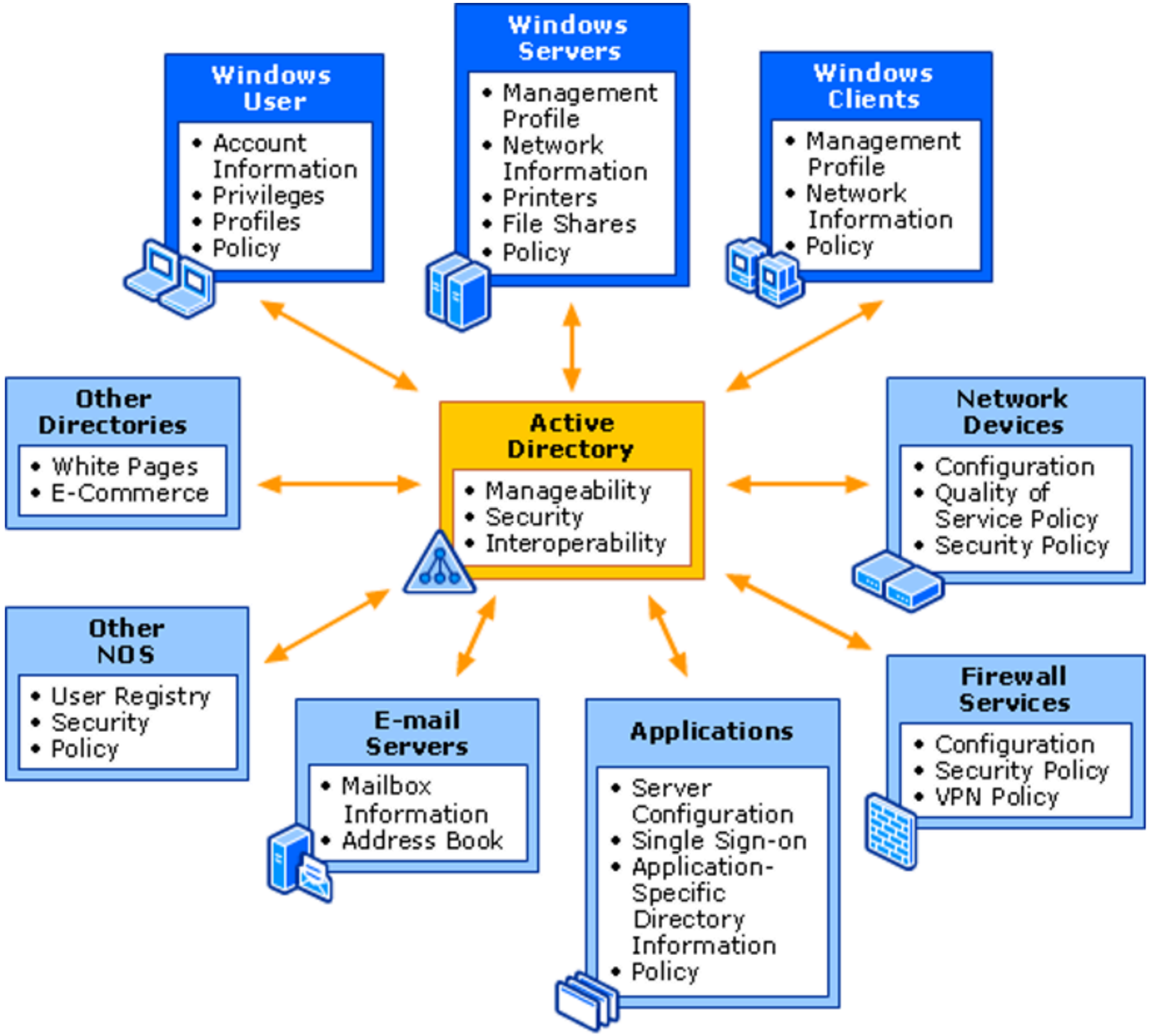
1. **Initial Access**
2. **Escalate Privileges**
3. **Actions on Objectives**

How Do Attackers Gain Access?

1. **Phishing**
2. **Login from a publicly exposed service**
3. **Exploitable publicly facing services**
4. **Internal rouge devices**
5. **Supply Chain Attacks**

Active Directory Directory Services

- **Microsoft's proprietary directory service to manage Windows networks**
- **A database that stores information of users, groups, computers, group policies, etc. stored in a domain controller**
  - A server that helps manage the whole AD database.
    - Usernames and passwords are stored here.
- **Changes to the AD database are replicated to other domain controllers inside the domain**



https://learn.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2003/cc780036(v=ws.10)

Active Directory Attacks: The Past 10 Years

1997: Pass-the-hash originally published by Paul Ashton

2001: Sir Dystic of Cult of the Dead Cow (cDc) releases SMBRelay and SMBRelay2

2007: NBNSpoof tool created by Robert Wesley McGrew (LLMNR/NBT-NS)

2008: Hernan Ochoa publishes the Pass-the-Hash toolkit (later became WCE)

2010: Windows Credentials Editor (WCE) by Hernan Ochoa

* Credits to Sean Metcalf's talk "A Decade of Active Directory Attacks: What We've Learned & What's Next" at TROOPERS24

Active Directory Attacks: The Past 10 Years

2011: First version of Mimikatz tool released by Benjamin Delpy

2012: Exploiting Windows Group Policy Preferences (GPP), Responder v1 tool

2013: Invoke-Mimikatz module released by Joe Bialek

2014:

- Abusing Microsoft Kerberos: Sorry You Guys Don't Get It" by Benjamin Delpy (Golden Tickets, Overpass-the-hash, Pass-the-ticket)
- PAC Validation, The 20 Minute Rule and Exceptions blog post about Silver Tickets by Skip Duckwell
- September: Kerberoast released by Tim Medin
- December: PowerView tool released by Will Schroeder

Windows Authentication Protocols

- **There are two authentication protocols present in the Windows world:**
  - NTLM
  - Kerberos
- **Kerberos only works in a domain environment**
  - It won’t work in workgroups
- **NTLM is support beginning Windows NT and later**
  - Uses challenge and response
  - This is different from the NT hash which is also called “NTLM”
- **Two versions of NTLM:**
  - NTLMv1 - insecure
  - NTLMv2 - less vulnerable, default since Windows 2000

Windows Password Representations and Storage

- **Windows can store passwords in two forms**
  - LANMAN
  - NT Hash
- **Local account passwords are stored in the SAM database by default**
- **LANMAN hashes are inherently insecure and should not be used**
- **In Active Directory, LANMAN and NT hashes are stored in the NTDS.dit file found on domain controllers**

LANMAN Hash Algorithm

1. **The password is padded with NULL bytes to exactly 14 characters.**
    a. If the password is longer than 14 characters, it is replaced with 14 NULL bytes for the remaining operations.
2. **The password is converted to all uppercase**
3. **The password is split into two 7-byte (56-bit) keys.**
4. **Each key is used to encrypt a fixed string.**
5. **The two results from step 4 are concatenated and stored as the LM hash.**

LANMAN Challenge/Response

1. **The client initiates a connection**
2. **The server sends a challenge**
3. **The client formulates a response from the challenge:**
    a. Padding LANMAN hash to 21 bytes
    b. Splitting LANMAN hash into three 7-byte pieces
    c. Using each piece as a DES key to encrypt challenge

NOTE:

NTLMv1 does the same thing, but it uses the NT hash as a starting point (not the LANMAN hash)

NT Hash Algorithm

- **The full password is hashed using MD4**
  - Case is preserved
  - Passwords up to 127 characters can be accepted
- **Hash is 128 bits (16 bytes)**
- **Password1234! -> 18C548F970E77575B0717EE09CA50BDC**
- **Not salted**
- **Salting is a process that combines the password with a random numeric value (the salt) before computing the one-way function.**

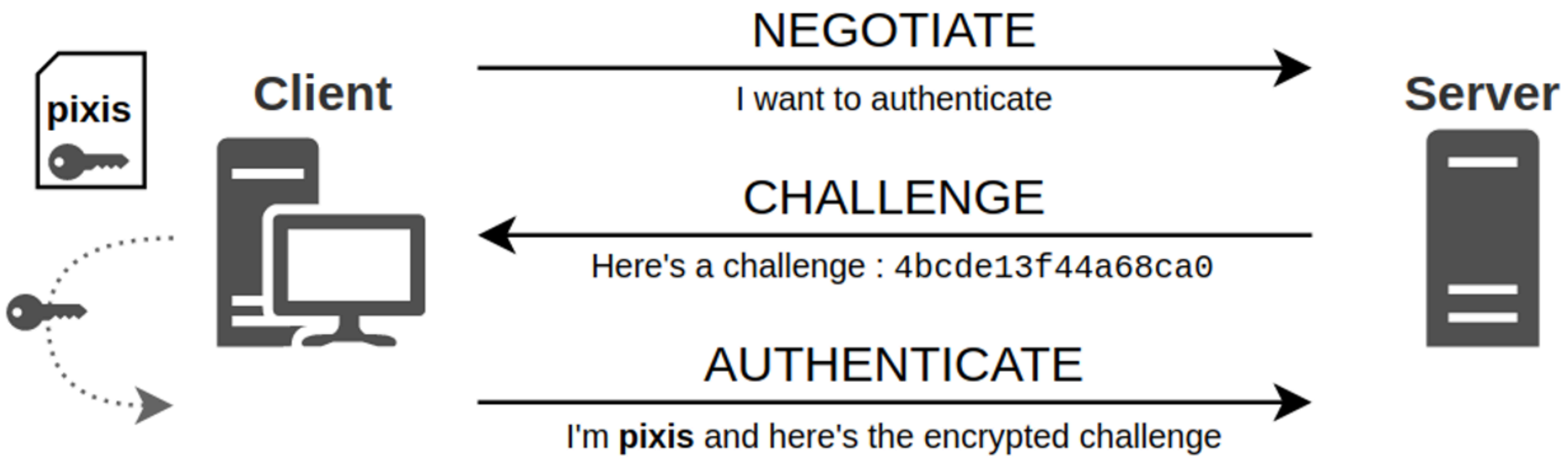
NTLM Authentication

- **NTLM authentication is a family of authentication protocols that are encompassed in the Windows Msv1_0.dll**
- **The NTLM authentication protocols include**
  - LAN Manager version 1 and 2, and NTLM version 1 and 2.
- **The NTLM authentication protocols authenticate users and computers based on a challenge/response mechanism**
- **NTLM =! NT Hash**
- **NT Hash is the password “at rest”**

NTLMv2 Challenge/Response

- **An improved version of authenticating over the network**
- **Client initiates the authentication**
- **The server sends server challenge**
- **Client formulates the response from challenge by:**
  - Creating the HMAC-MD5 of username and domain name with NT hash as the key
  - The result is called the NTLMv2 One-Way Function (OWF)
  - Then the response is created from the HMAC-MD5 of the server challenge, timestamp, client challenge, and other items, using the NTLMv2 OWF as the key

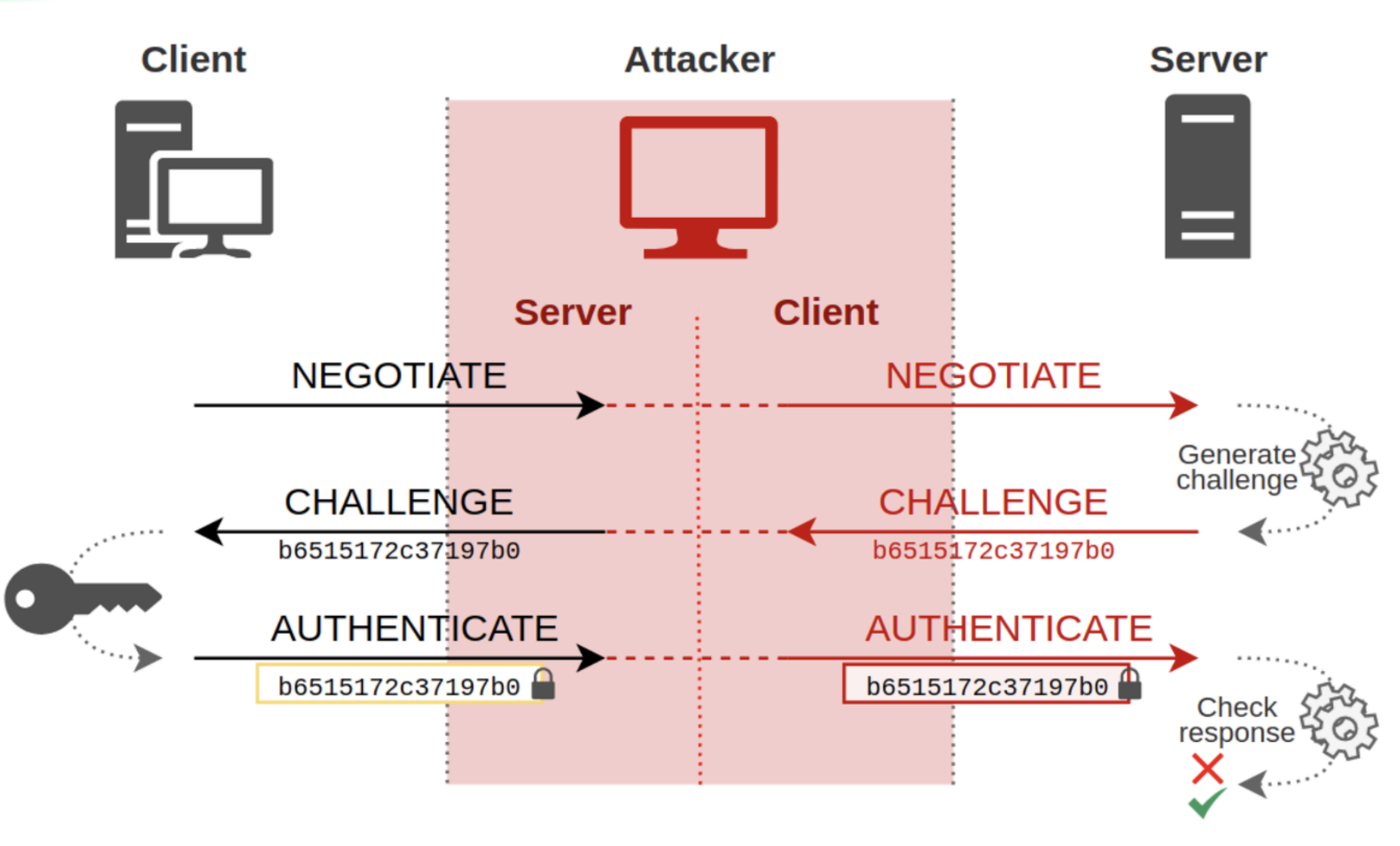
NTLMv2 in Action



https://en.hackndo.com/ntlm-relay/

Attacks on NTLMv2

- **Several attacks in AD utilize the capability in Windows to relay authentication material**
  - Sniffing of an NTLMv2 Challenge-Response
  - Relaying an SMB connection using NTLMv2
  - Instigating a connection from the victim to the attacker
    - Can be sniffed or relayed
- **Passively listen or coerce connections -> Relay to target -> Profit (dump credentials, command execution, elevate permissions)**
- **Cannot be used for “pass-the-hash”**
- **Responder, mitm6, PCredz, Hashcat**



https://en.hackndo.com/ntlm-relay/

Password Attacks

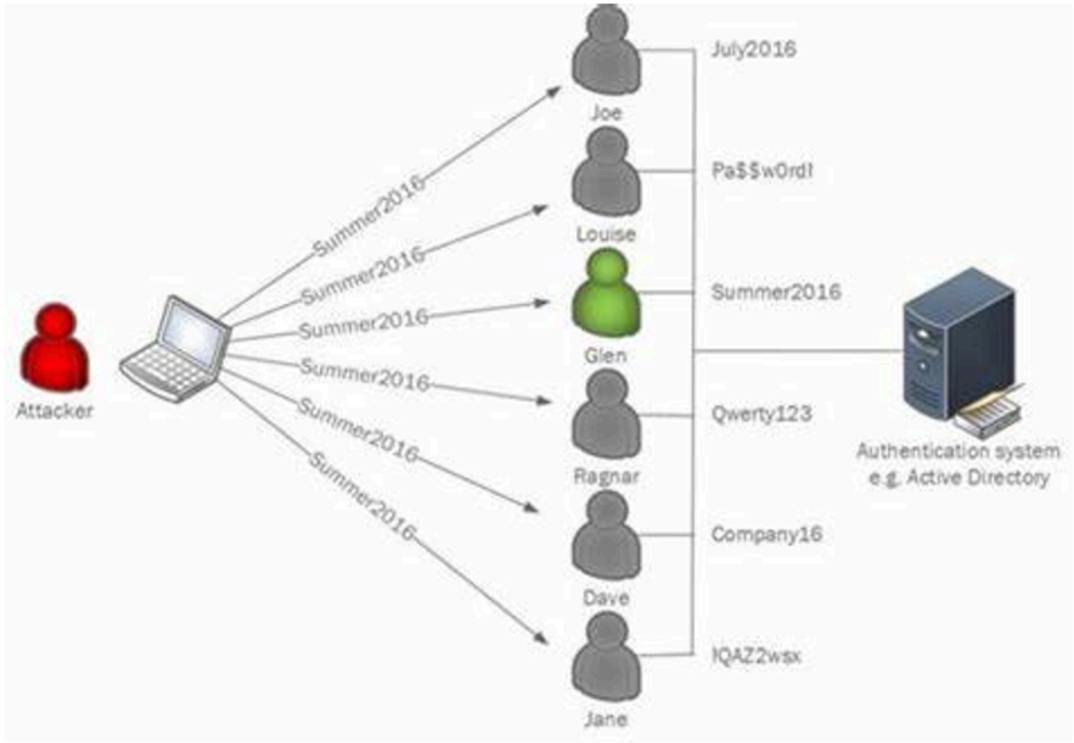
- **Password attacks can be categorized into two:**
  - Online
  - Offline
- **An online password attack is usually performed over the network with the attempt of logging in to the system**
- **A offline password attack attempts to recover the plaintext password from a gathered hash**

Password Reuse

- **Passwords are usually reused by end users and system administrators**
  - This means that a compromise of a user can be used as well to access other systems
- **Remember that a users in general would attempt to barely meet the requirements of a password policy**
  - This can lead to common passwords already found in dictionary lists
  - Passwords such as Summer2022! or Fall2022! satisfies Windows' default password policy

Password Spraying

- Password spraying is an online password attack where one password is used for many usernames
- Lesser likelihood for locking users out
- Attackers just need to get this correct once to gain a foothold



https://www.microsoft.com/en-us/security/blog/2020/04/23/protecting-organization-password-spray-attacks/

What About Unique Passwords?

- **Windows Local Administrator Password Solution (Windows LAPS) is a Windows feature that automatically manages and backs up the password of a local administrator account**
- **The implementation of LAPS adds two new attributes:**
  - ms-mcs-AdmPwd
  - ms-mcs-AdmPwdExpirationTime
- **Native LAPS PowerShell cmdlets, LAPSToolkit, PowerView, several tools exist to help you view the password**

Credential Dumping

“Adversaries may attempt to dump credentials to obtain account login and credential material, normally in the form of a hash or a clear text password. Credentials can be obtained from OS caches, memory, or structures.

Credentials can then be used to perform Lateral Movement and access restricted information.”

OS Credential Dumping

Sub-techniques (8)

ID	Name
T1003.001	LSASS Memory
T1003.002	Security Account Manager
T1003.003	NTDS
T1003.004	LSA Secrets
T1003.005	Cached Domain Credentials
T1003.006	DCSync
T1003.007	Proc Filesystem
T1003.008	/etc/passwd and /etc/shadow

https://attack.mitre.org/techniques/T1003/

Mimikatz

Mimikatz is a famous tool used to extract credentials in Windows environments

Plaintext passwords, hashes, PIN code, Kerberos tickets

Can be used to perform pass-the-hash and pass-the-ticket, or forge Golden Tickets

```
  .#####.   mimikatz 2.0 alpha (x86) release "Kiwi en C" (Apr  6 2014 22:02:03)
 .## ^ ##.
 ## / \ ##  /* * *
 ## \ / ##   Benjamin DELPY `gentilkiwi` ( benjamin@gentilkiwi.com )
 '## v ##'   http://blog.gentilkiwi.com/mimikatz             (oe.eo)
  '#####'                                     with  13 modules * * */


mimikatz # privilege::debug
Privilege '20' OK

mimikatz # sekurlsa::logonpasswords

Authentication Id : 0 ; 515764 (00000000:0007deb4)
Session           : Interactive from 2
User Name         : Gentil Kiwi
Domain            : vm-w7-ult-x
SID               : S-1-5-21-1982681256-1210654043-1600862990-1000
        msv :
         [00000003] Primary
         * Username : Gentil Kiwi
         * Domain   : vm-w7-ult-x
         * LM       : d0e9aee149655a6075e4540af1f22d3b
         * NTLM     : cc36cf7a8514893efccd332446158b1a
         * SHA1     : a299912f3dc7cf0023aef8e4361abfc03e9a8c30
        tspkg :
         * Username : Gentil Kiwi
         * Domain   : vm-w7-ult-x
         * Password : waza1234/
```


https://github.com/gentilkiwi/mimikatz

DCSync

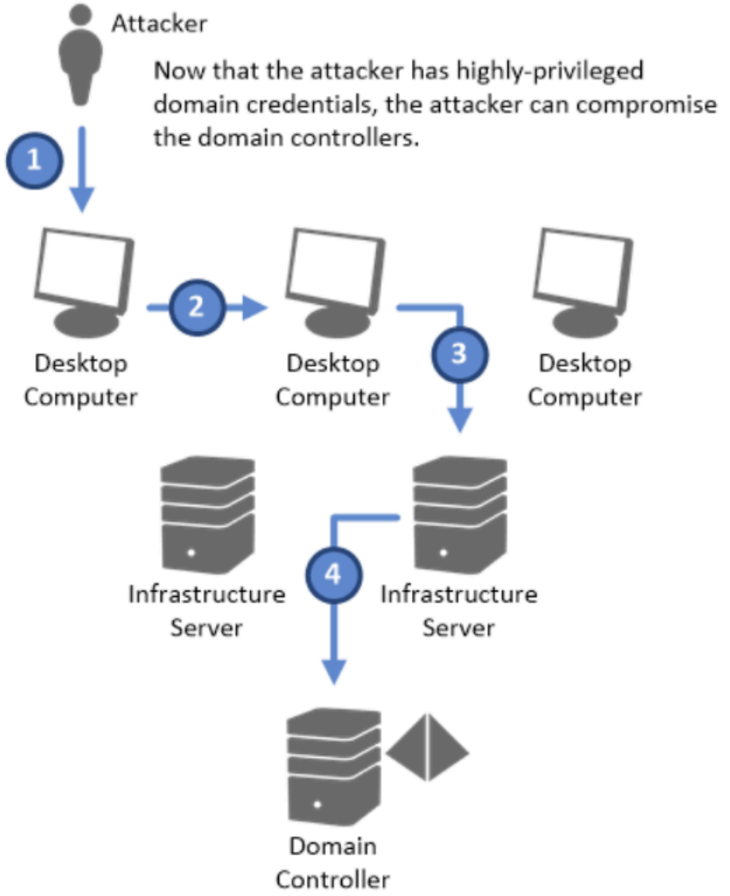
- **Uses the domain replication protocol to pretend as a DC and extract hashes**
- **Technique discovered by Benjamin Delpy, presented at Black Hat 2018**
- **Replicate information using the Directory Replication Service Remote Protocol (MS-DRSR)**
  - You cannot turn off this feature, it is necessary for the domain

```
PS C:\Users\chris.admin\Desktop> Invoke-Mimikatz -Command '"lsadump::dcsync /use
r:dev\krbtgt"'
Hostname: WINDOWS4.dev.testlab.local / S-1-5-21-4275052721-3205085442-277024194
2

  .#####.   mimikatz 2.0 alpha (x64) release "Kiwi en C" (Aug 23 2015 23:05:23)
 .## ^ ##.
 ## / \ ##  /* * *
 ## \ / ##   Benjamin DELPY 'gentilkiwi' ( benjamin@gentilkiwi.com )
 '## v ##'   http://blog.gentilkiwi.com/mimikatz             (oe.eo)
  '#####'                                     with 16 modules * * */


mimikatz(powershell) # lsadump::dcsync /user:dev\krbtgt
[DC] 'dev.testlab.local' will be the domain
[DC] 'SECONDARY.dev.testlab.local' will be the DC server

[DC] 'dev\krbtgt' will be the user account

Object RDN           : krbtgt

** SAM ACCOUNT **

SAM Username         : krbtgt
Account Type         : 30000000 ( USER_OBJECT )
User Account Control : 00000202 ( ACCOUNTDISABLE NORMAL_ACCOUNT )
Account expiration   :
Password last change : 4/18/2015 3:24:57 PM
Object Security ID   : S-1-5-21-4275052721-3205085442-2770241942-502
Object Relative ID   : 502

Credentials:
  Hash NTLM: 8b7c904343e530c4f81c53e8f614caf7
    ntlm- 0: 8b7c904343e530c4f81c53e8f614caf7
    lm  - 0: e05671e8363b1a1300afd2b86ddc3af6
```


https://blog.harmj0y.net/redteaming/mimikatz-and-dcsync-and-extrasids-oh-my/

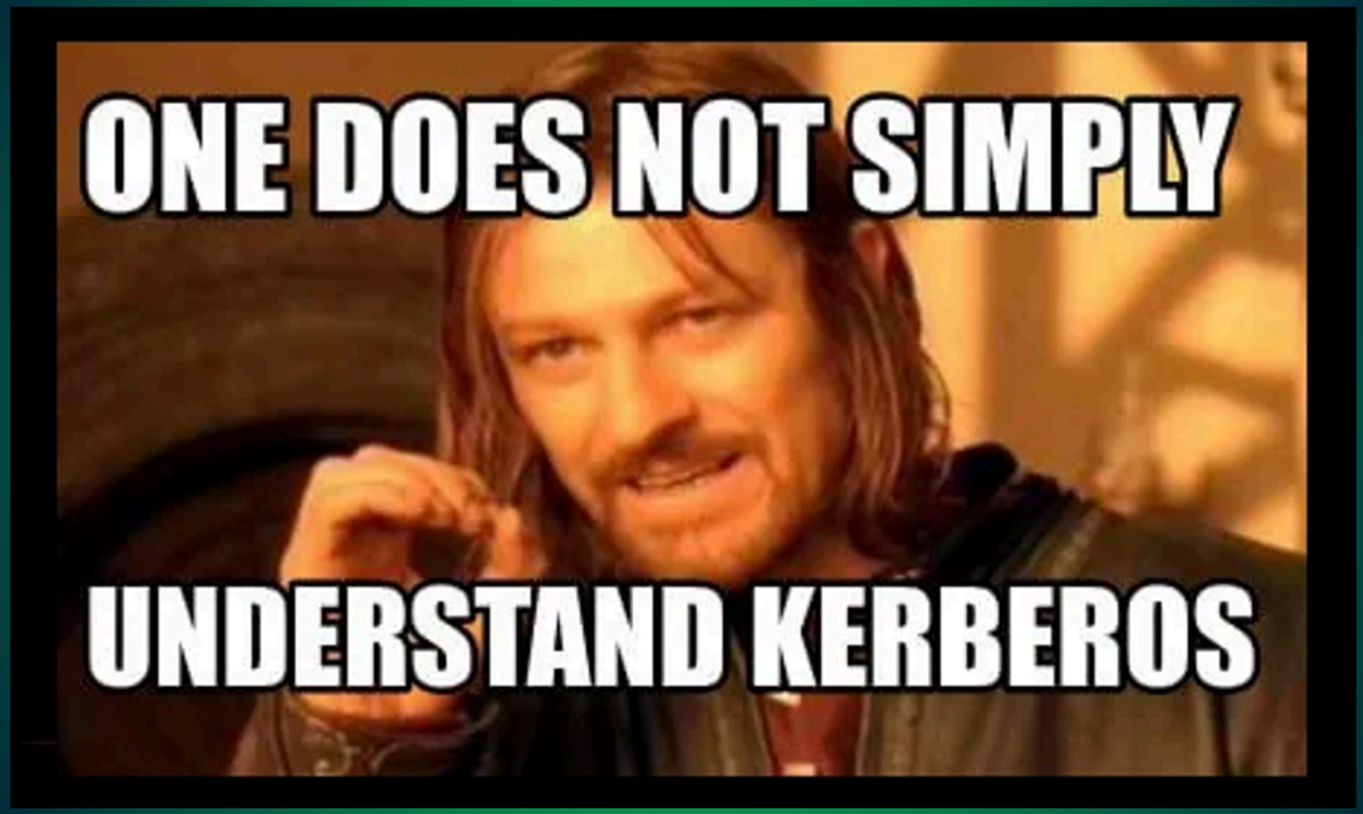
Pass-the-Hash

- **Hashes are extracted from memory, SAM, NTDS.dit**
- **Use the hash directly to authenticate to other systems**
  - Tools places the hash in the memory of LSASS
  - Windows automatically presents this material to target resources
- **No need to know the “plaintext”**
- **Basically, this is how Windows works**
- **Several benefits**
  - No account lockout
  - Cracking is not required
  - Gives access as the user whose hash is employed



https://www.microsoft.com/en-us/download/details.aspx?id=36036

Kerberos

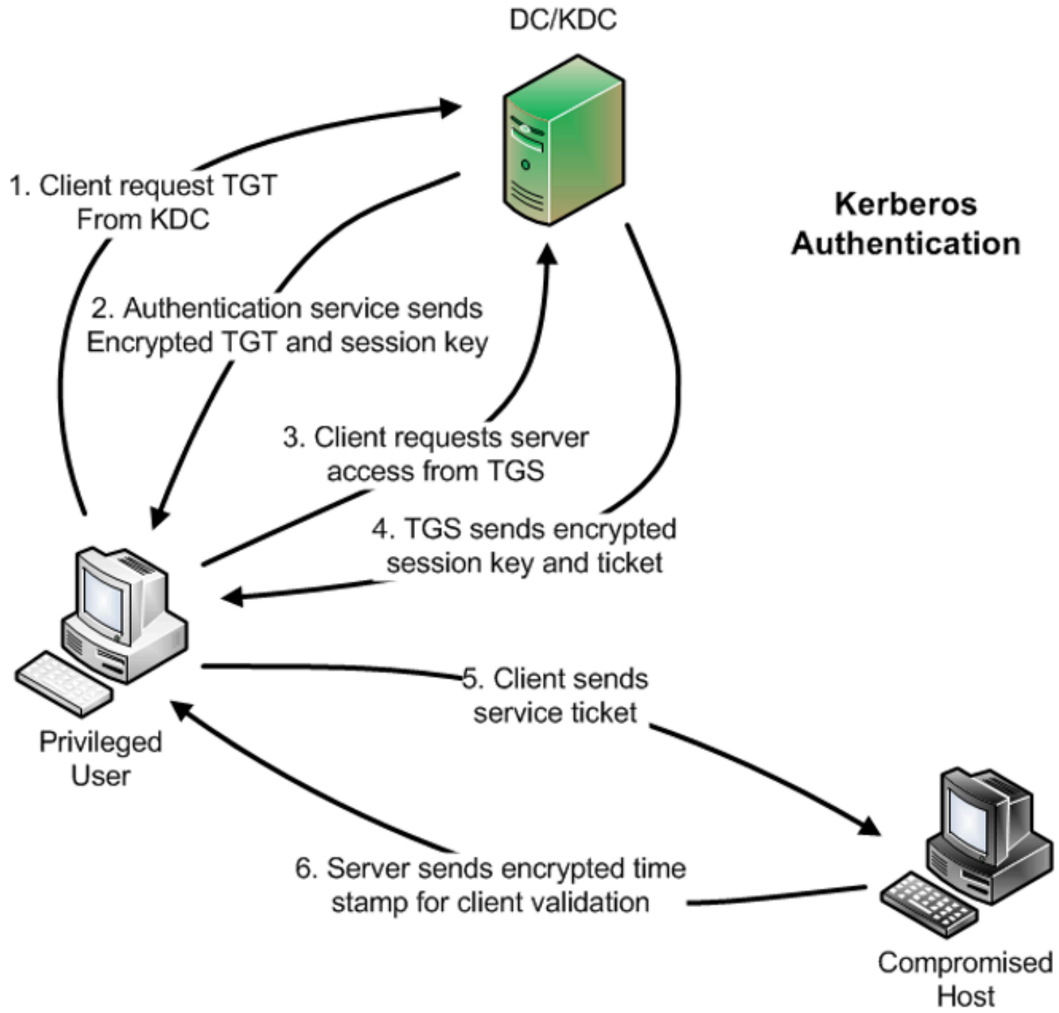


What is Kerberos?

- Kerberos is the main and preferred authentication protocol in Windows domains
- Kerberos relies on Service Principal Names (SPNs) and computer names for authentication
- Whenever we use an IP address, Kerberos can’t work – it will fall back to NTLM authentication
- NTLMv2 is rarely disabled in any environment

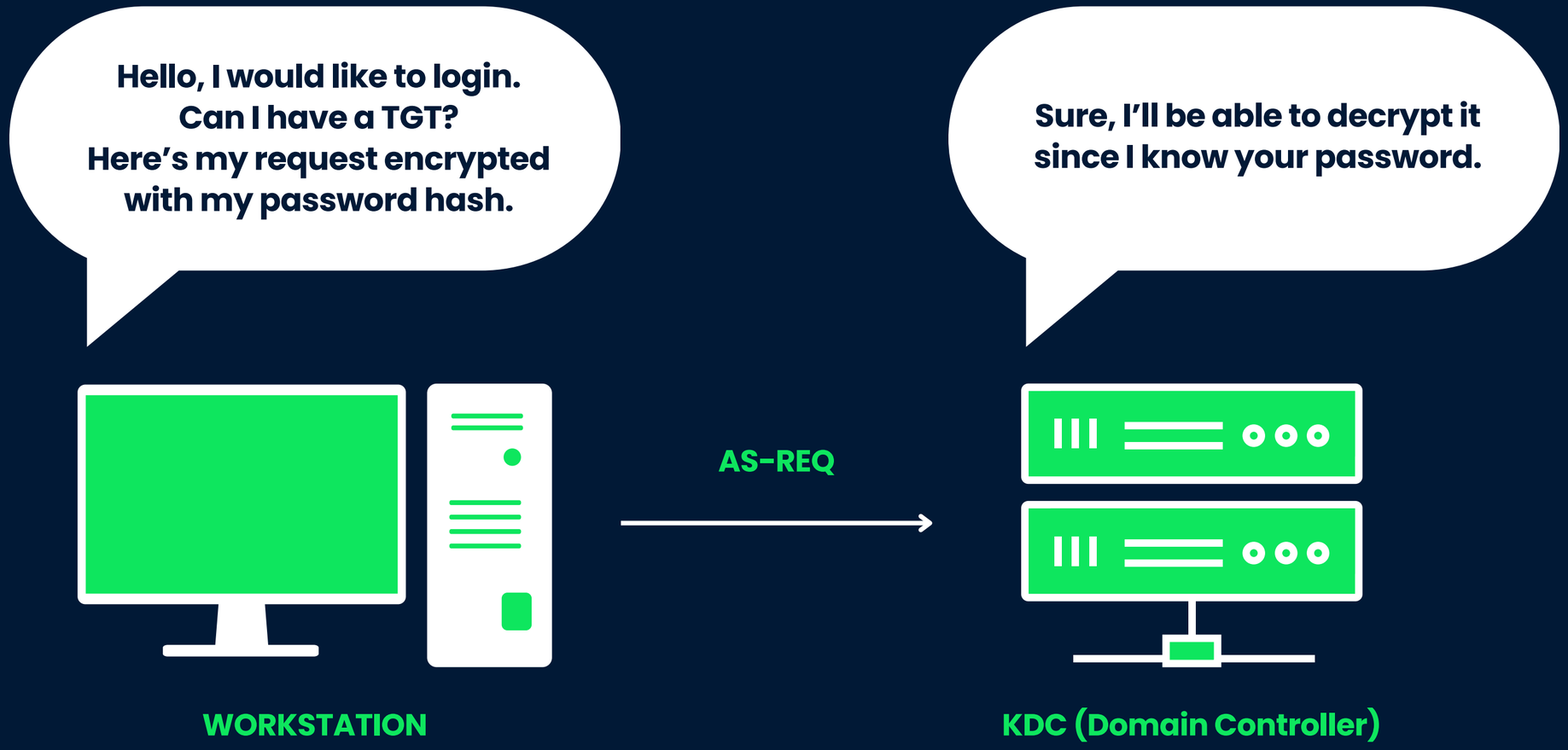
Kerberos Authentication

- **Kerberos is a network authentication protocol based on tickets**
- **Three main pieces:**
  - KDC (Key Distribution Center)
  - Client requesting access
  - Service the client is attempting to obtain access to
- **Pre-authentication leading to a Ticket Granting Ticket**
- **Request a Service Ticket**
- **Use Service Ticket**
- **The Privilege Attribute Certificate (PAC) is inside Kerberos tickets, defining if the user has access to the resource**



https://www.sans.org/blog/kerberos-in-the-crosshairs-golden-tickets-silver-tickets-mitm-and-more/

Kerberos in a nutshell



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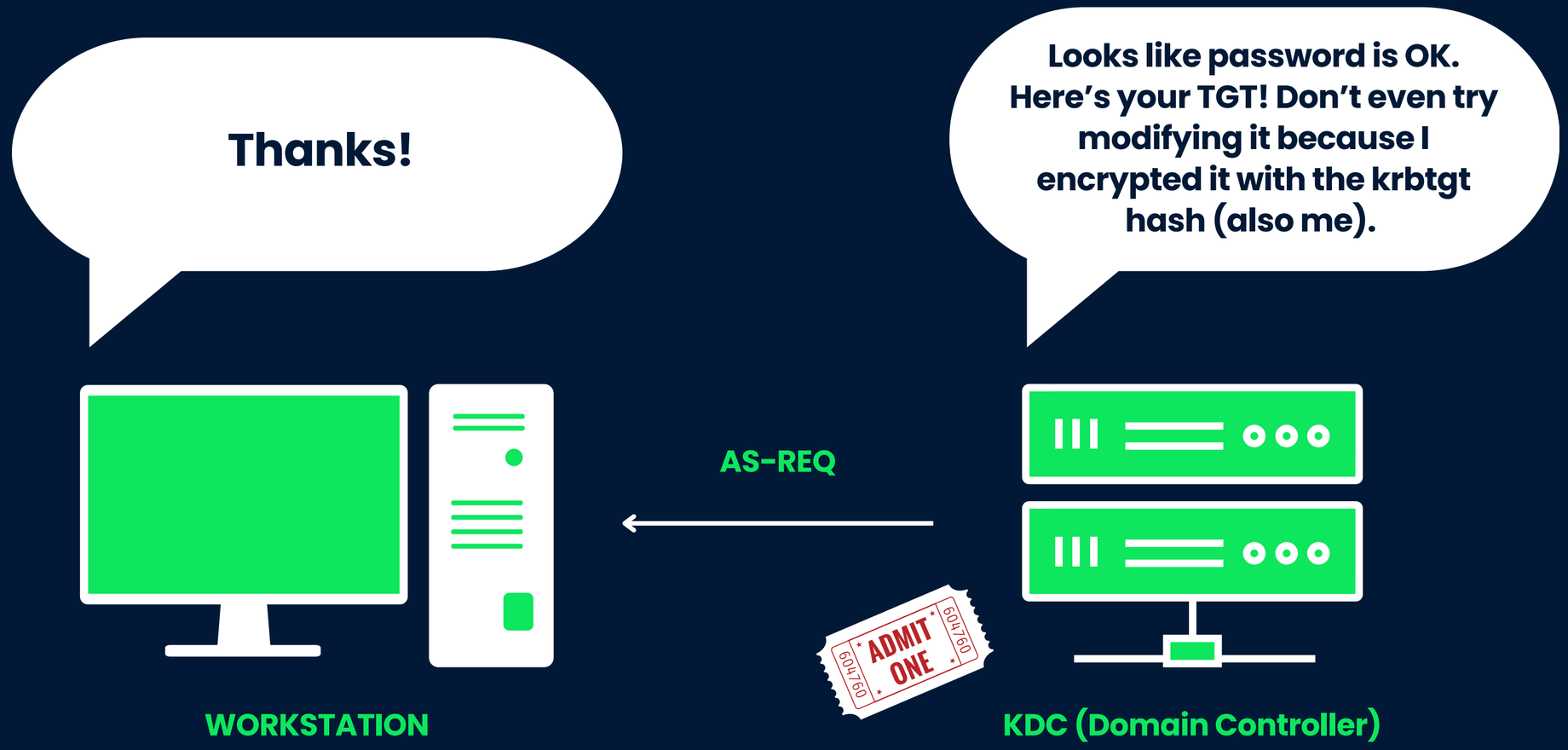

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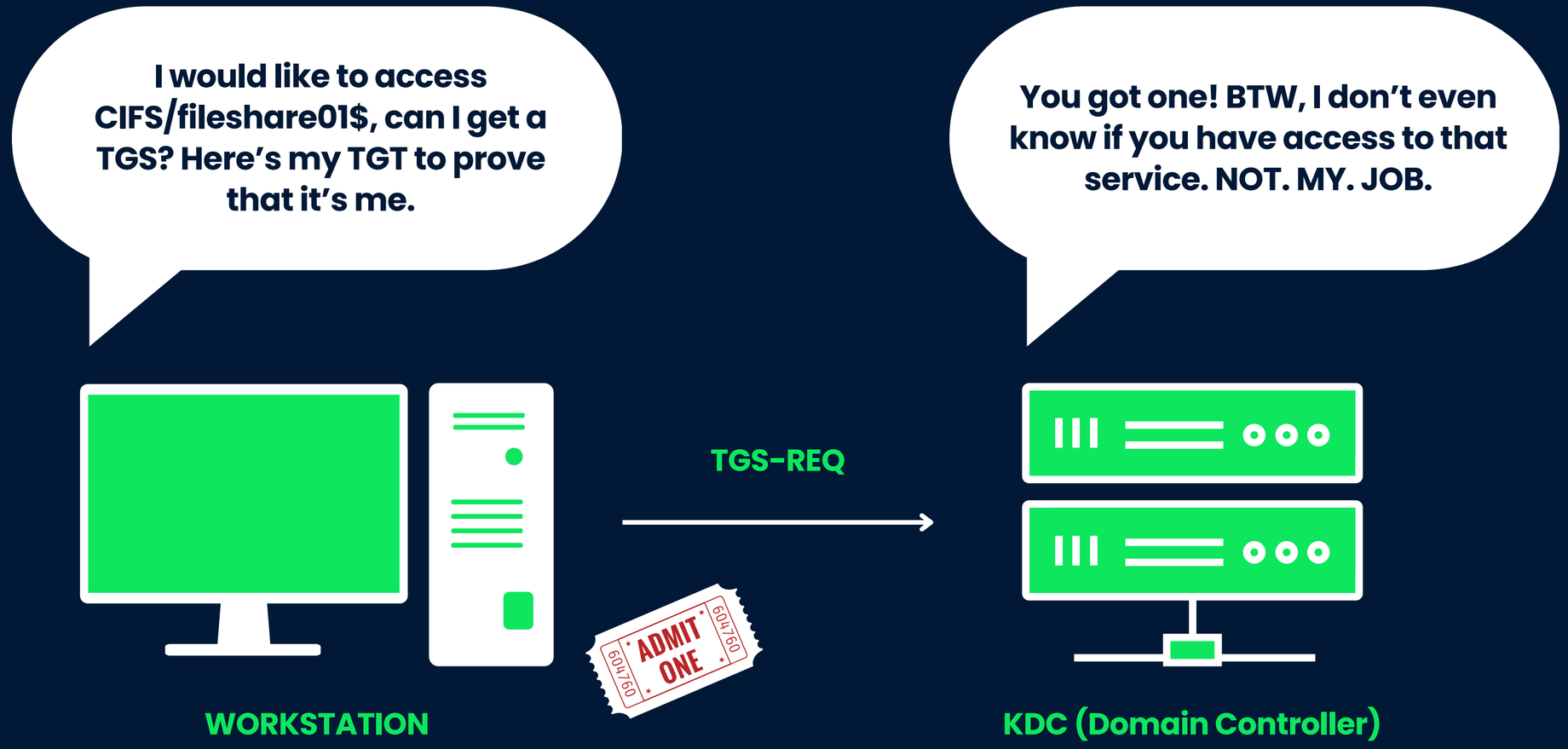

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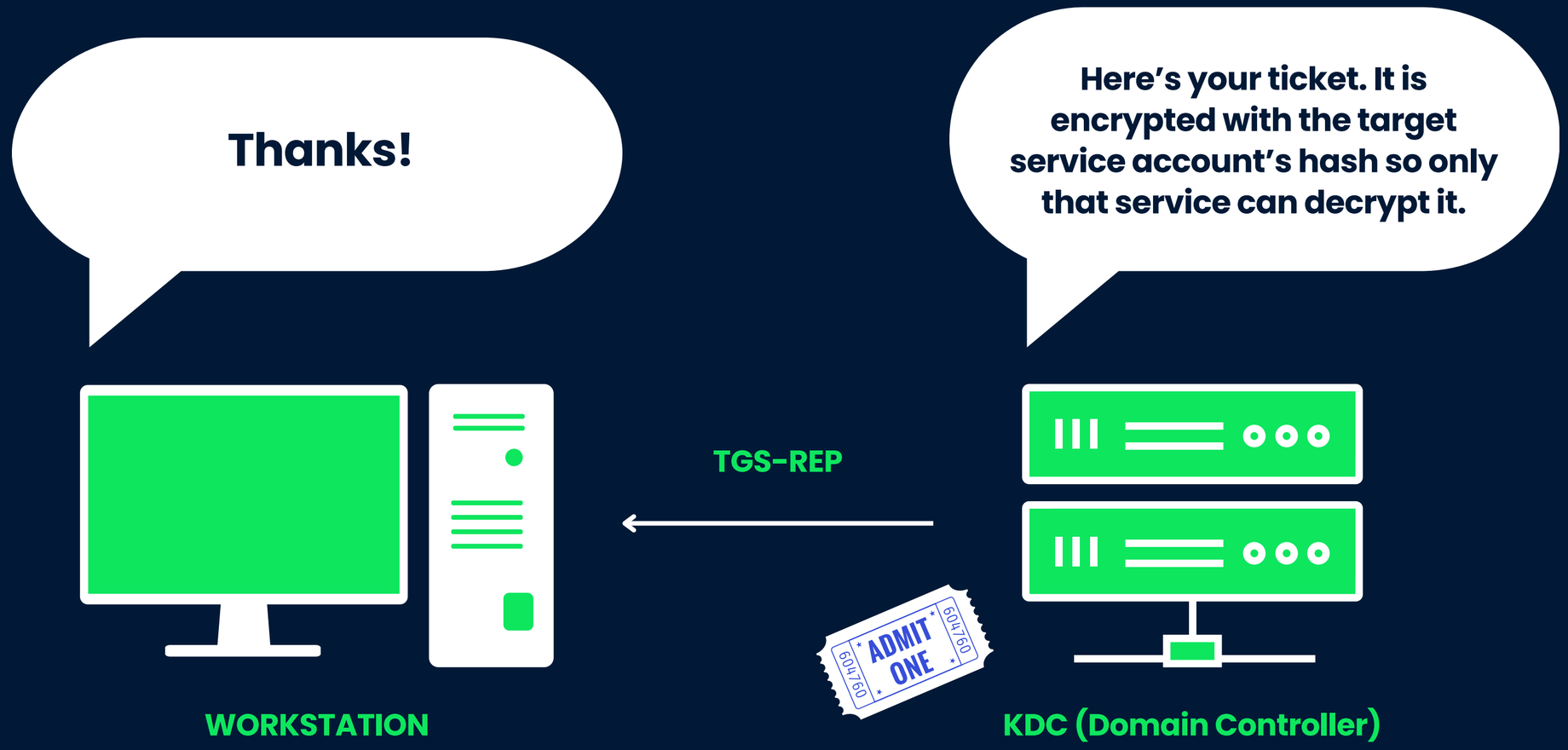
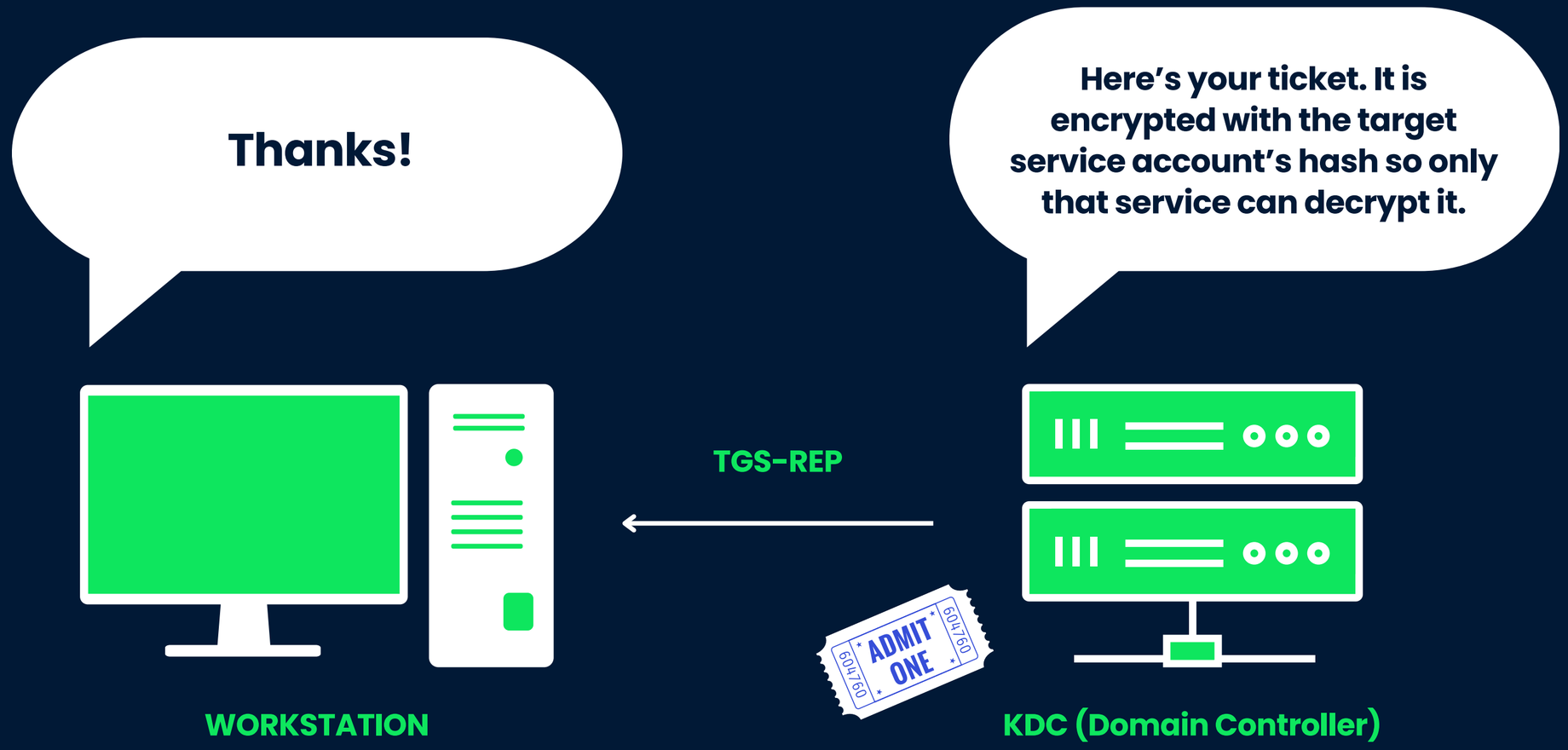


Kerberoasting

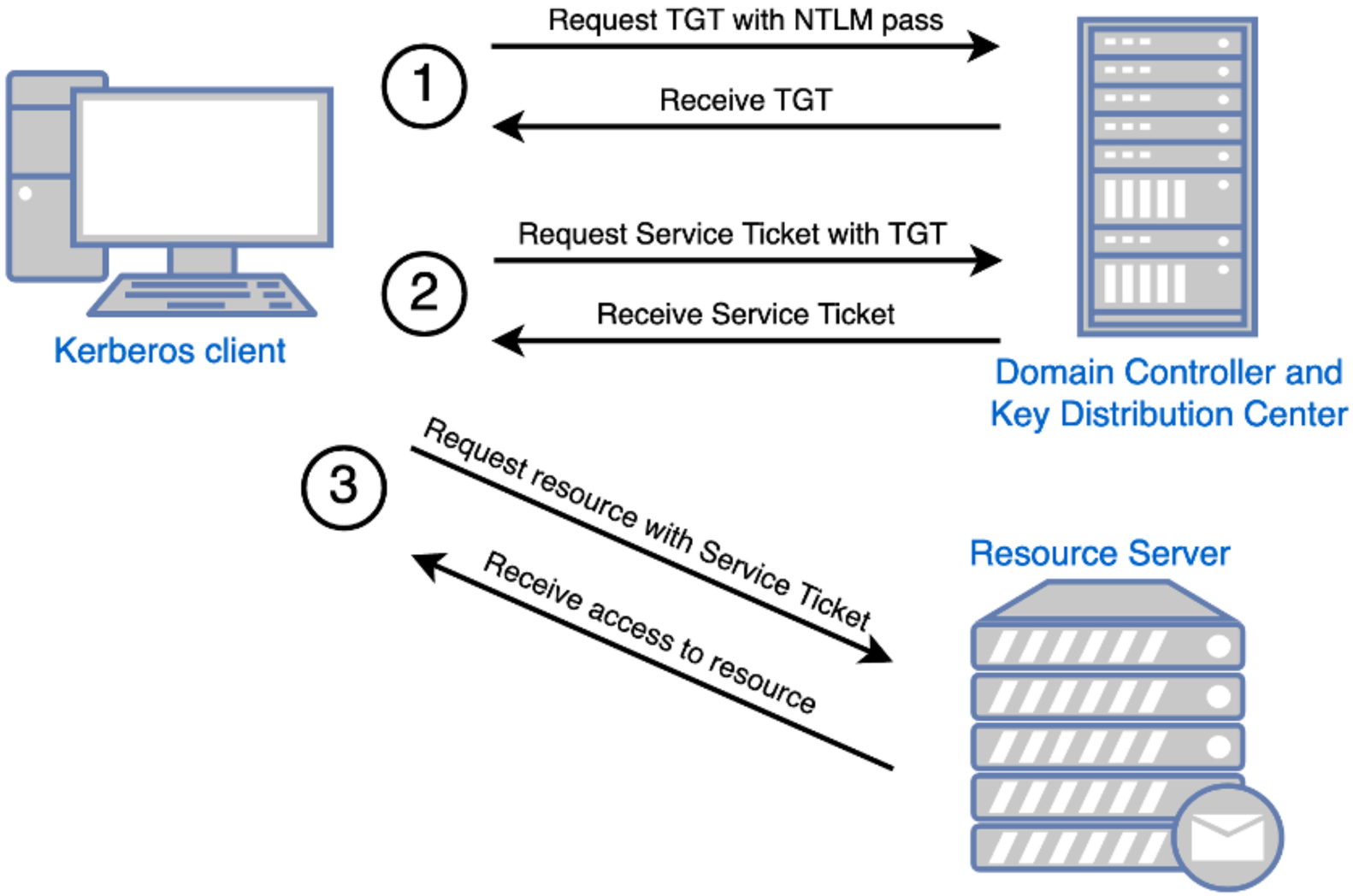
- **An attack discovered by Tim Medin last 2014**
- **A client can request a ticket for any service**
  - The client does not need permissions to the service
  - The service could be inaccessible due to a firewall
  - The service could be offline
  - The server could be recycled, as long as the SPN Exists
- **Kerberoasting is basically requesting tickets and cracking it offline**

Kerberos in a nutshell



Golden Ticket

- **A Golden Ticket is a forged TGT signed with the krbtgt hash**
  - Can be created without any interaction with the KDC - Kerberos is “stateless”
  - We do need the krbtgt hash (which means we have administrative privileges on the domain)
- **Tickets created using Mimikatz is valid for 10 years**

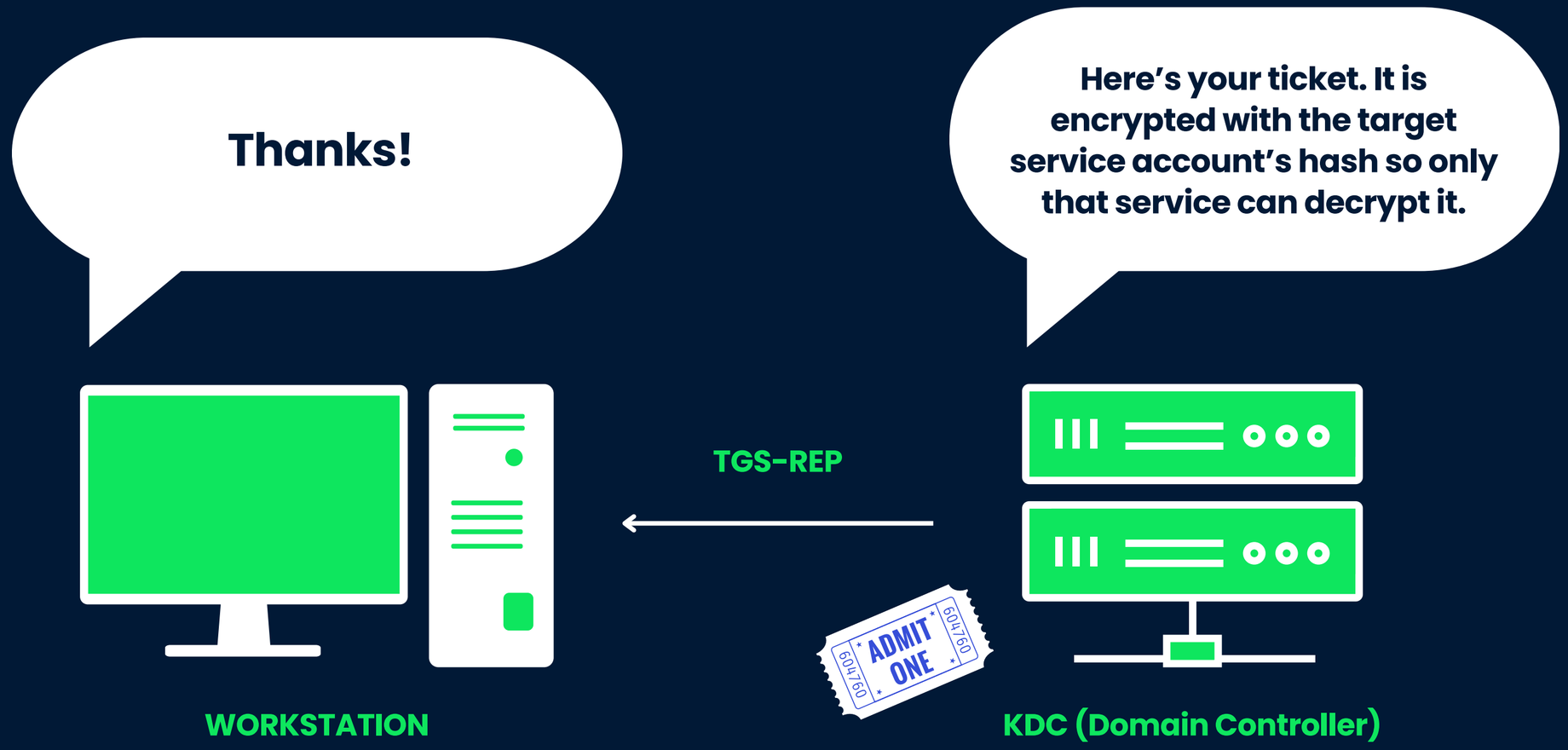


https://www.optiv.com/insights/source-zero/blog/kerberos-domains-achilles-heel

Silver Ticket

- **Remember, service ticket is signed using the service account's hash**
- **If we have the service account's hash, we can modify the PAC to escalate privileges and sign it**
- **This will work as long as the KDC does not validate the second signature**
  - HTTP and IIS will always verify due to the nature of AppPools
  - CIFS (SMB), HOST, MSSQLSvc, TERMSRV won't verify

Kerberos: TGS-REP



Active Directory Certificate Services (AD CS)

- **AD CS is a server role using Microsoft's Public Key Infrastructure (PKI)**
  - PKI is used for trust and encryption
    - Internally generated and trusted TLS certificates for HTTPS sites
    - Authentication via certificates for wireless and VPN
    - Authenticating and encrypting email
- **SpecterOps researchers identified several attacks again the most common AD CS misconfigurations**
  - 5 credential or certificate thefts methods
  - 6 account and domain persistence mechanism
  - 8 escalation techniques, including ways to become Domain Admin
- **Released at BlackHat 2021 by Will Schroeder and Lee Christensen**
  - https://specterops.io/wp-content/uploads/sites/3/2022/06/Certified_Pre-Owned.pdf

AD CS: ESC1

- **A escalation scenario where a regular domain user can become domain admin**
- **The Enterprise CA grants low-privileged users enrollment rights.**
  - The Enterprise CA's configuration must permit low-privileged users the ability to request certificates.
- **Manager approval is disabled.**
  - This setting necessitates that a user with CA "manager" permissions review and approve the requested certificate before the certificate is issued.
- **No authorized signatures are required.**
  - This setting requires any CSR to be signed by an existing authorized certificate.
- **An overly permissive certificate template security descriptor grants certificate enrollment rights to low-privileged users.**
  - Having certificate enrollment rights allows a low-privileged attacker to request and obtain a certificate based on the template.

What To Do Against Relaying Attacks

- **Relaying attacks all happen because of DNS Fallback**
- **Look for usage of LLMNR/NBNS/mDNS using Wireshark**
- **Test disabling the mentioned protocols**
- **Why did DNS fail? Figure that problem out**
- **Disable WPAD (Windows Proxy AutoDiscovery)**
- **Test SMB Signing**
  - Known to slow down SMB transfers. The amount of the performance loss depends greatly on the capabilities of the hardware involved.

What To Do Against Credential Stealing and Reuse

- **Domain Protected Users**
  - Prevents caching of credentials in memory
  - Kerberos will only use AES128 and AES256
  - When the domain functional level is 2012R2, NTLM is not allowed
- **Use “Protected Process”**
- **Windows Credential Guard**
- **Remote Credential Guard**

What To Do Against Kerberoasting

- Look for Kerberoastable accounts
- Disable the use of RC4 as encryption type
- Create a Fine-Grained Password Policy
- Apply Fine-Grained Password Policy to each Kerberoastable account

What To Do Against Password Attacks

MICROSOFT ENTRA PASSWORD PROTECTION

1. **Create a custom list of banned passwords**
2. **Install small agent on each on-prem DC**
3. **Start in Audit Mode, move to Enforced**

CONCLUSION

- **Attackers will always need initial access**
  - Can you detect it?
  - How long can you detect it?
- **Once they gain access, they will move inside your network**
  - Can you detect it?
  - How long can you detect it?
- **Reduce the ways attackers can get in**
- **Reduce the time to detect**
- **Increase their time to escalate**

Thank You

ROOTCON18