An **ACE** Up the Sleeve
Designing Active Directory DACL Backdoors

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tl;dr

- DACL/ACE Background
- Enumeration of AD DACLs
- DACL Misconfiguration and Abuse
- Analysis with BloodHound
- Designing ACL Based Backdoors
- Case Studies and Demos
- Defenses
Disclaimer

- There is no exploit/CVE/whatnot here, just ways to purposely implement Active Directory DACL misconfigurations

- These backdoors are post-elevation techniques that require some type of elevated access to the objects you’re manipulating
Why Care?

- It’s often difficult to determine whether a specific AD DACL misconfiguration was set *maliciously* or *configured by accident*.

- These changes also have a minimal forensic footprint and often survive OS and domain functional level upgrades.
  - This makes them a great chance for subtle, long-term domain persistence!

- These may have been in your environment for YEARS!
“As an offensive researcher, if you can dream it, someone has likely already done it...and that someone isn’t the kind of person who speaks at security cons”

Matt Graeber

“Abusing Windows Management Instrumentation (WMI) to Build a Persistent, Asynchronous, and Fileless Backdoor” - BlackHat 2015
1. Background

From ACLs to ACEs
Previous Work

Chemins de contrôle en environnement Active Directory

Chacun son root, chacun son chemin

Lucas Bouillot, Emmanuel Gras

Agence Nationale de la Sécurité des Systèmes d’Information
SSTIC 2014 - 4 juin 2014

https://www.sstic.org/2014/presentation/chemins_de_controle_active_directory/
Previous Work

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Previous Work

Бэкдор в active directory своими руками

Итак, мы все знаем про подлых пользователей с UID=0 в unix, которых может быть больше одного.

Посмотрим, как такое же (а на самом деле, даже более страшное) организовывается в инфраструктуре Windows. Разумеется, мы говорить будем не про локальные виндовые учётные записи, а про Active Directory, т.е. говорить будем об administratore домена. Или, даже, хуже, об enterprise administrator.

Итак, истина номер один: у объектов в active directory есть атрибуты и права доступа. Истина номер два: эти атрибуты можно менять.

https://habrahabr.ru/post/90990/
Securable Objects

- Any securable object in a Windows environment contains a `SECURITY_DESCRIPTOR` structure that contains:
  - A set of control/inheritance bits in the header
  - The security identifier (SID) of the object’s owner
  - The SID of the object’s primary group (not used)
  - A discretionary access control list (DACL)
  - A system access control list (SACL)
- This is a binary structure, but can be described with a Security Descriptor Definition Language (SDDL) string
typedef struct _SECURITY_DESCRIPTOR {
   UCHAR    Revision;
   UCHAR    Sbz1;
   SECURITY_DESCRIPTOR_CONTROL    Control;
   PSID     Owner;
   PSID     Group;
   PACL     Sacl;
   PACL     Dacl;
} SECURITY_DESCRIPTOR, *PISecurity_DESCRIPTOR;

ACLs, DACLs, and SACLs

- Access Control List (ACL) is basically shorthand for the DACL/SACL superset

- An object’s **Discretionary Access Control List** (DACL) and **Security Access Control List** (SACL) are ordered collections of Access Control Entries (ACEs)
  - The DACL specifies what principals/trustees have what rights over the object
  - The SACL allows for auditing of access attempts to the object
ACEs

- All ACEs include:
  - A 32-bit set of flags that control auditing
  - A 32-bit **access mask** that specifies access rights allowed
  - A security identifier (SID) that identifies the principal/trustee that has the given rights

![ACEs Table]

DS_CONTROL_ACCESS

- AD access mask bit that grant privileges that aren’t easily expressed in the access mask
- Interpreted a few different ways
- If the **ObjectAceType** of an ACE with CONTROL_ACCESS set is the GUID of a confidential **property** or property set, this bit controls read access to that property
  - E.g. in the case of the Local Administrator Password Solution (LAPS)
DS_CONTROL_ACCESS and Extended Rights

- If the **ObjectAceType** GUID matches a registered extended-right GUID in the schema, then control_access grants that particular “control access right”

- Examples:
  - **User-Force-Change-Password** on user objects
  - **DS-Replication-Get-Changes** and **DS-Replication-Get-Changes-All** on the domain object itself
In Windows and AD, the Kernel-Mode Security Reference Monitor (SRM) is in charge of deciding the outcome of access requests, based on the canonical order of ACEs on the target object, and the access being requested.

By understanding the order of evaluation the SRM uses for these access decisions, an attacker may more effectively hide malicious ACEs, or even entire security principals from defenders.
SRM and Canonical ACE Order

- The “canonical” order of ACE evaluation:
  - Explicit **DENY**
  - Explicit **ALLOW**
  - Inherited **DENY**
  - Inherited **ALLOW**

- Inherited privileges are further complicated by generational distance from which the object inherits that ACE: generationally closer inherited ACEs are given priority
DACL Enumeration

You Don’t Know
What You Can’t Find
The **SecurityMasks** property of a .NET **DirectorySearcher** object can be set to retrieve the DACL, SACL, and/or Owner information for an object through LDAP.

```csharp
using System.DirectoryServices;
...
DirectorySearcher src = new DirectorySearcher("...");
src.PropertiesToLoad = new string[] {ntSecurityDescriptor, ...};
SearchResultCollection res = src.FindAll();
```

PowerView

- PowerView’s **Get-DomainObjectACL** function wraps the .NET/LDAP method to enumerate the DACLs for any given domain object
  - The security descriptor is parsed and individual ACEs are output on the pipeline
  - The **-ResolveGUIDs** flag will build an environment-specific mapping of right GUIDS to display names
- By default, **any domain authenticated user can enumerate DACLs for most objects in the domain!**
PowerView

Get-DomainObjectAcl -Identity harmj0y -ResolveGUIDs | ? {$_._.SecurityIdentifier -match $(ConvertTo-SID eviluser)}

AceQualifier : AccessAllowed
ObjectDN : CN=harmj0y,CN=Users,DC=testlab,DC=local
ActiveDirectoryRights : WriteProperty
ObjectAceType : Script-Path
ObjectSID : S-1-5-21-883232822-274137685-4173207997-1111
InheritanceFlags : None
BinaryLength : 56
AceType : AccessAllowedObject
ObjectAceFlags : ObjectAceTypePresent
IsCallback : False
PropagationFlags : None
SecurityIdentifier : S-1-5-21-883232822-274137685-4173207997-1115
AccessMask : 52
AuditFlags : None
IsInherited : False
AceFlags : None
InheritedObjectAceType : All
OpaqueLength : 0
3.

DAACL
(Mis)configurations
And Abuse!
Elevation vs. Persistence

- Our work in this area was first motivated by a desire to find AD misconfigurations for the purposes of domain privilege escalation
  - I.e. searching for specific ACE relationships that result in a lesser-privileged object modifying a higher-privileged one

- This presentation is about *modifying/adding* ACEs (or chains of ACEs) in order to provide persistence in a domain environment
AD Generic Rights

- **GenericAll**
  - Allows ALL generic rights to the specified object
  - Also grants “control rights” (see next slide)

- **GenericWrite**
  - Allows for the modification of (almost) all properties on a specified object

- Both are abusable with PowerView’s **Set-DomainObject**, and these two rights generally apply to most objects for takeover
AD Control Rights

- Rights that allow a trustee/principal to gain control of the object in some way

- **WriteDacl** grants the ability to modify the DACL in the object security descriptor
  - Abusable with PowerView: `Add-DomainObjectAcl`

- **WriteOwner** grants the ability to take ownership of the object
  - Object owners implicitly have full rights!
  - Abusable with PowerView: `Set-DomainObjectOwner`
The two takeover primitives are forcing a password reset, and targeted Kerberoasting through SPN modification (to recover creds).

So the additional rights we care about are:
- `WriteProperty` to all properties
- `WriteProperty` to servicePrincipalName
- All extended rights
- `User-Force-Change-Password` (extended)

Abusable through `Set-DomainObjectOwner` and `Set-DomainUserPassword`
Target: Group Objects

- The main takeover primitive involves adding a user to the target group

- So the additional rights we care about are:
  - WriteProperty to all properties
  - WriteProperty to the member property

- Abusable through Add-DomainGroupMember
Target: Computer Objects

- If LAPS is enabled:
  - We care about `DS_CONTROL_ACCESS` or `GenericAll` to the `ms-MCS-AdmPwd` (plaintext password) property

- Otherwise, we don’t know of a practical way to abuse a control relationship to computer objects :(  
  - If you have any ideas, please let us know!
Target: Domain Objects

- The main takeover primitive involves granting a user domain replications rights (for DCSync)

- So the main effective right we care about is **WriteDacl**, so we can grant a principal DCSync rights with **Add-DomainObjectAcl**
Target:
Group Policy Objects

- The main takeover primitive involves the right to edit the group policy (that’s then linked to an OU/site/domain)
  - This gives the ability to compromise users/computers in these containers

- So the additional rights we care about are:
  - WriteProperty to all properties
  - WriteProperty to GPC-File-Sys-Path

- GPOs can be edited on SYSVOL
BloodHound Analysis

Arroooooooooo
BloodHound Analysis

- BloodHound enables simple, graphical analysis of control relationships in AD
- **Defenders** can use this for least privilege enforcement, identifying misconfigured ACLs, and detecting non-stealthy ACL-enabled backdoors
- **Attackers** can use this to identify ACL-enabled escalation paths, select targets for highly stealthy backdoors, and understand privilege relationships in the target domain
BloodHound Analysis

- Left: Principals with direct control over the “Domain Admins” group
- Several Exchange security groups have “GenericAll” rights over the “Domain Admins” group
5. Designing Active Directory DACL Backdoors

Primitives for Pwnage
Objective

- We want to implement an Active Directory DACL-based backdoor that:
  - Facilitates the regaining of elevated control in the AD environment
  - Blends in with normal ACL configurations (“hiding in plain sight”), or is otherwise hidden from easy enumeration by defenders

- Let’s see what we can come up with!
Stealth Primitive: Hiding the DACL

- Effectively hiding DACLs from defenders requires two steps

- Change the **object owner** from “Domain Admins” to the attacker account.

- Add a new explicit ACE, denying the **Everyone** principal the “Read Permissions” privilege.
Stealth Primitive: Hiding the DACL
Stealth Primitive: Hiding the Principal

- Hiding a principal from defenders requires three steps:
  a. Change the principal owner to itself, or another controlled principal.
  b. Grant explicit control of the principal to either itself, or another controlled principal.
  c. On the OU containing your hidden principal, deny the “List Contents” privilege to “Everyone”
Stealth Primitive: Hiding the Principal

There are no items to show in this view.
Primitives: Summary

- We know which ACEs result in object takeover
- We can control who can enumerate the DACL
- We can hide principals/trustees that are present in a specific ACE
Backdoor Case Studies

“If you can dream it...”
A Hidden DCSync Backdoor

- Backdoor:
  - Add **DS-Replication-Get-Changes** and **DS-Replication-Get-Changes-All** on the domain object itself where the principal is a user/computer account the attacker controls
  - The user/computer doesn’t have to be in any special groups or have any other special privileges!

- Execution:
  - DCSync whoever you want!
Exploitation
AdminSDHolder

- **Backdoor:**
  - Attacker grants themselves the **User-Force-Change-Password** right on **CN=AdminSDHolder,CN=System**
  - Every 60 minutes, this permission is cloned to every sensitive/protected AD object through SDProp
  - Attacker “hides” their account using methods described

- **Execution:**
  - Attacker force resets the password for any **adminCount=1** account
Exploitation
LAPS

- Microsoft’s “Local Administrator Password Solution”
- Randomizes a machine’s local admin password every 30 days. Password stored in the confidential `ms-Mcs-AdmPwd` attribute on computer objects
- Administered with the AdmPwd.PS cmdlets
  - `Find-AdmPwdExtendedRights` - “Audit” who can read `ms-Mcs-AdmPwd`

Who can read AdmPwd?

- **DS_CONTROL_ACCESS** where the ACE
  - applies to AdmPwd and all descendant computers
  - applies to AdmPwd and all descendant objects
  - applies to any object and all descendant objects
  - applies to any object and all descendant computers

- Above checks are necessary for **GENERIC_ALL**

- Object control == Ability to grant the above rights
  - You are the owner
  - You can become the owner:
    - WriteDACL, WriteOwner, DS-Set-Owner
Shortcomings of Find-AdmPwdExtendedRights

- **DS_CONTROL_ACCESS** where the ACE
  - applies to AdmPwd and all descendant computers
  - applies to AdmPwd and all descendant objects*
  - applies to any object and all descendant objects
  - applies to any object and all descendant computers

- Above checks are necessary for GENERIC_ALL

- Object control == Ability to grant the above rights
  - You are the owner
  - You can become the owner
    - WriteDACL, WriteOwner
    - DS-Set-Owner Extended Right
Exploitation

Backdoor:

- Add an ACE to OU or Computer that applies to the AdmPwd property and any descendant object

```powershell
$RawObject = Get-DomainOU -Raw Servers
$TargetObject = $RawObject.GetDirectoryEntry()
$AdmPwdGuid = (Get-DomainGUIDMap).GetEnumerator() | ` ?{$_._.value -eq 'ms-Mcs-AdmPwd'} | select -ExpandProperty name
$ACE = New-ADObjectAccessControlEntry -InheritanceType Descendents ` -AccessControlType Allow -PrincipalIdentity "Domain Users" ` -Right ExtendedRight -ObjectType $AdmPwdGuid
$TargetObject.PsBase.CommitChanges()
```
Normal user can’t access ms-mcs-AdmPwd

PS C:\> whoami
corpwest\johnsmith
PS C:\> Find-AdmPwdExtendedRights -OrgUnit Servers -IncludeComputers | fl

ObjectDN : OU=Servers,DC=corpwest,DC=local
ExtendedRightHolders : {NT AUTHORITY\SYSTEM, CORPWEST\Domain Admins, CORPWEST\ServerAdmins}

ObjectDN : CN=Exchange,OU=Servers,DC=corpwest,DC=local
ExtendedRightHolders : {NT AUTHORITY\SYSTEM, CORPWEST\Domain Admins}

PS C:\> Get-DomainComputer Exchange -Properties name,ms-mcs-AdmPwd

name
----
Exchange
Privileged attacker adds backdoor to Servers OU

```powershell
PS C:\> whoami
corpwest\itadmin
PS C:\> $RawObject = Get-DomainOU -Raw Servers
PS C:\> $TargetObject = $RawObject.GetDirectoryEntry()
PS C:\> $AdmPwdGuid = (Get-DomainGUIDMap).GetEnumerator() | `{
    ?{$_ .value -eq 'ms-Mcs-AdmPwd'} | select -ExpandProperty name
PS C:\> $ACE = New-ADObjectAccessControlEntry -InheritanceType Descendents `-AccessControlType Allow -PrincipalIdentity "Domain Users" `-Right ExtendedRight -ObjectType $AdmPwdGuid
PS C:\> $TargetObject.PsBase.CommitChanges()
PS C:\>
```
Domain user can access AdmPwd! LAPS cmdlet doesn’t detect it!

PS C:\> whoami
corpwest\johnsmith
PS C:\> Find-AdmPwdExtendedRights -OrgUnit Servers -IncludeComputers | fl

ObjectDN : OU= Servers, DC= corpwest, DC= local
ExtendedRightHolders : { NT AUTHORITY\ SYSTEM, CORPWEST\ Domain Admins, CORPWEST\ ServerAdmins}

ObjectDN : CN= Exchange, OU= Servers, DC= corpwest, DC= local
ExtendedRightHolders : { NT AUTHORITY\ SYSTEM, CORPWEST\ Domain Admins}

PS C:\> Get-DomainComputer Exchange -Properties name, ms-mcs-AdmPwd

name          ms-mcs-admpwd
Exchange n.H54m-]Bq;46#3dtV2&
Exchange Strikes Back

- Exchange Server introduces several schema changes, new *nested* security groups, and **MANY** control relationships to Active Directory, making it a perfect spot to blend in amongst the noise.

- Pre Exchange Server 2007 SP1, this included the “**WriteDACL**” privilege against the domain object itself, which was distributed down to ALL securable objects!
Exchange Strikes Back

- Backdoor:
  - Identify a non-protected security group with local admin rights on one or more Exchange servers
  - Grant "Authenticated Users" full control over this security group
  - Change the owner of the group to an Exchange server
  - Deny "Read Permissions" on this group to the "Everyone" principal
Exchange Strikes Back

- Execution:
  - Regain access to the Active Directory domain as any user
  - Add your current user to the back-doored security group
  - Use your new local admin rights on an Exchange server to execute commands as the SYSTEM user on that computer.
  - Exchange Trusted Subsystem often has full control of the domain, so this may include DCSync!
Exploitation

GODS vs HUMANS

DEMO
Abusing GPOs

- **Backdoor:**
  - Attacker grants herself **GenericAll** to **any** user object with the attacker as the trustee
  - Grant that “patsy” user **WriteDacl** to the default domain controllers GPO

- **Execution:**
  - Force resets the “patsy” account password
  - Adds a DACL to the GPO that allows write access for the patsy to **GPC-File-Sys-Path** of the GPO
  - Grants the patsy user **SeEnableDelegationPrivilege** rights in GptTmpl.inf
  - Executes a constrained delegation attack using the patsy account’s credentials
Exploitation
Defenses

All is (Probably) Not Lost ;}
Proper event log tuning and monitoring is pretty much your only hope for performing real “forensics” on these actions.

- But if you weren’t collecting event logs when the backdoor was implemented, you might not ever know who the perpetrator was :(  

For example:

- Event log 4738 (“A user account was changed”), filtered by the property modified
Replication Metadata

- Metadata remnants from domain controller replication can grant a few clues
  - Specifically, *when* a given attribute was modified, and from what domain controller the modification event occurred on

- This points you in the right direction, but needs to be used with event logs to get the full picture
  - More information in a post soon on http://blog.harmj0y.net
SACLs

- SACLs contain ACEs that, “specify the types of access attempts that generate audit records in the security event log of a domain controller”

- You don’t have to SACL every success/failure action on every object type and property:
  - A great start- build SACLs for all of the attack primitives we’ve talked about on the specific target objects we’ve outlined
Sidenote: Future Work

- We were not able to utilize NULL DACLs or otherwise manipulate the header control bits (i.e. `SE_DACL_PRESENT`)
  - Any attempts to set `ntSecurityDescriptor` on an object remotely ignores any header bits, however this warrants another look

- Research additional control relationships
  - Particularly any relationship that allows for computer object takeover
Credits

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- **Lee Christensen (@tifkin_)**
- Jeff Dimmock (@bluscreenofjeff)
- Matt Graeber (@mattifestation)
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Questions?

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