



**SDC** 

STORAGE DEVELOPER CONFERENCE

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# Windows Authentication With Multiple Domains and Forests

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Check for updates: <https://samba.org/~metze/presentations/2017/SDC/>



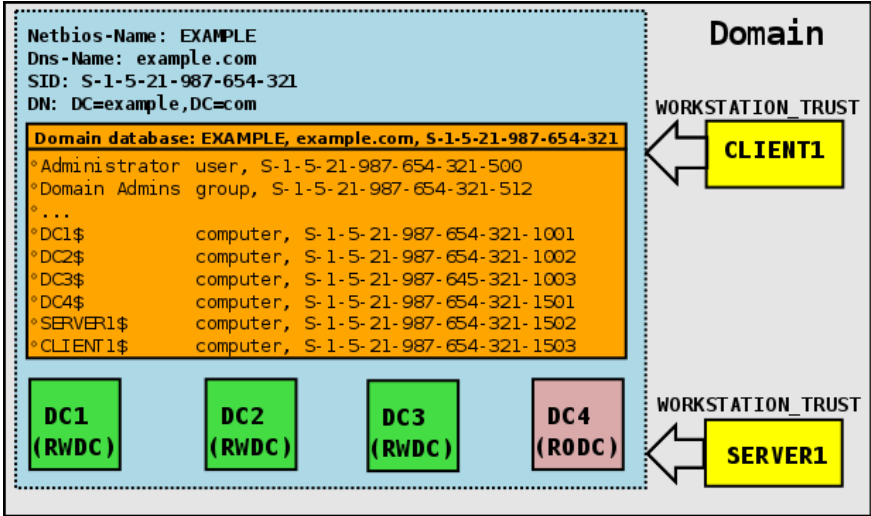
- ▶ This is an update to my talk at SambaXP.
- ▶ "The Important Details Of Windows Authentication"
- ▶ Please have a look at the slides:
- ▶ <https://samba.org/~metze/presentations/2017/SambaXP/>
- ▶ An audio recording is also available here:
- ▶ [https://sambaxp.org/archive\\_data/SambaXP2017-AUDIO/Day3/Track2/](https://sambaxp.org/archive_data/SambaXP2017-AUDIO/Day3/Track2/)
- ▶ Check for an updated version of this slides here:
- ▶ <https://samba.org/~metze/presentations/2017/SDC/>

(draft)

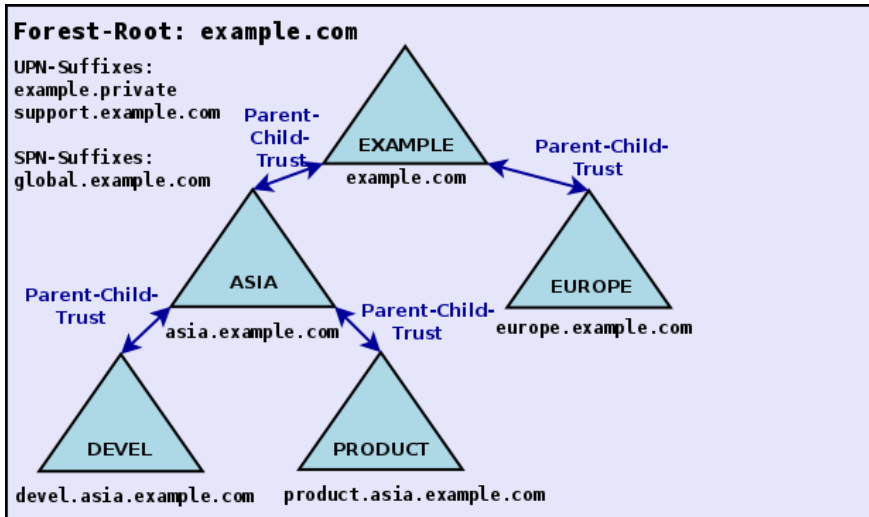


- ▶ Windows Domains, Forests and Trusts
- ▶ Netlogon Secure Channel
- ▶ Authentication Protocols
- ▶ Authorization Token
- ▶ Trust Routing Table
- ▶ New Kerberos Features
- ▶ Thanks!
- ▶ Questions?

# Layout of a single Windows Domain



# Layout of an Active Directory Forest (with one Tree)

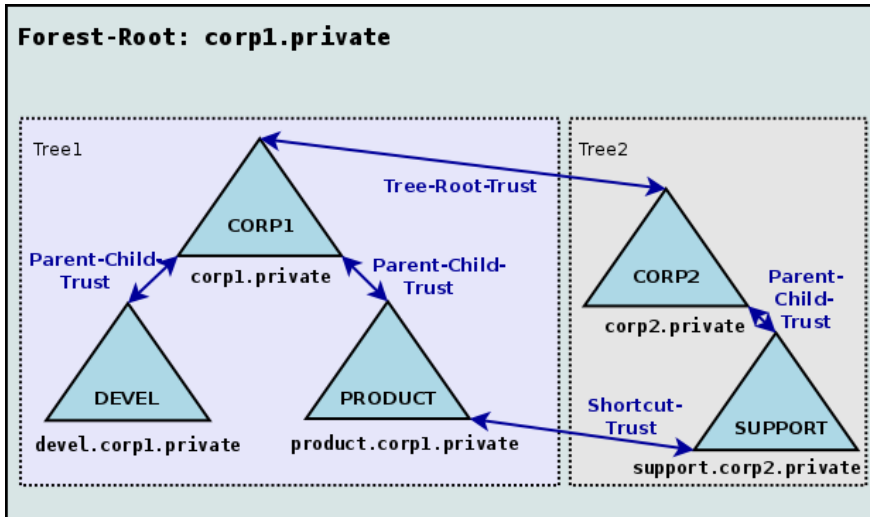


# Forest Information (with one Tree)



- ▶ TOP\_LEVEL\_NAME: example.com
- ▶ TOP\_LEVEL\_NAME: example.private
- ▶ DOMAIN\_INFO: EXAMPLE; example.com; S-1-5-21-99-88-11
- ▶ DOMAIN\_INFO: ASIA; asia.example.com; S-1-5-21-99-88-22
- ▶ DOMAIN\_INFO: DEVEL; devel.asia.example.com; S-1-5-21-99-88-33
- ▶ DOMAIN\_INFO: PRODUCT; product.asia.example.com; S-1-5-21-99-88-44
- ▶ DOMAIN\_INFO: EUROPE; europe.example.com; S-1-5-21-99-88-44

# Layout of an Active Directory Forest (with multiple Trees)



# Forest Information (with multiple Tree)



- ▶ TOP\_LEVEL\_NAME: corp1.private
- ▶ TOP\_LEVEL\_NAME: corp2.private
- ▶ DOMAIN\_INFO: CORP1; corp1.private; S-1-5-21-77-88-11
- ▶ DOMAIN\_INFO: DEVEL; devel.corp1.private; S-1-5-21-77-88-22
- ▶ DOMAIN\_INFO: PRODUCT; product.corp1.private; S-1-5-21-99-88-33
- ▶ DOMAIN\_INFO: CORP2; corp2.private; S-1-5-21-99-88-44
- ▶ DOMAIN\_INFO: SUPPORT; support.corp2.private; S-1-5-21-99-88-55



# Trust Types (low level)



- ▶ `LSA_TRUST_TYPE_DOWNLEVEL`
  - ▶ This is used for NT4 Domains.
  - ▶ It can only handle NTLMSSP.
- ▶ `LSA_TRUST_TYPE_UPLEVEL`
  - ▶ This is used for AD Domains.
  - ▶ It supports NTLMSSP by default.
  - ▶ It supports Kerberos, the Realm is the Dns-Domain-Name.
- ▶ `LSA_TRUST_TYPE_MIT`
  - ▶ This is used for trusts to RFC4120-compliant Kerberos.
  - ▶ Unlikely to be implemented in Samba.
- ▶ `LSA_TRUST_TYPE_DCE`
  - ▶ Not used in Windows.



- ▶ Trusting vs. Trusted Domain
  - ▶ Users of the "trusted" domain can access resources of the "trusting" domain.
- ▶ LSA\_TRUST\_DIRECTION\_INBOUND
  - ▶ The local domain is the "trusted" domain.
  - ▶ The specified/remote domain is the "trusting" domain.
  - ▶ Also known as INCOMING.
- ▶ LSA\_TRUST\_DIRECTION\_OUTBOUND
  - ▶ The local domain is the "trusting" domain.
  - ▶ The specified/remote domain is the "trusted" domain.
  - ▶ Also known as OUTGOING.



- ▶ Non-Transitive Trust
  - ▶ This is just a trust between two single domains.
- ▶ Transitive Trust
  - ▶ The trust between two single domains is expanded to indirect trusts.
  - ▶ DOM1 trusts DOM2, while DOM2 trusts DOM3, so DOM1 implicitly trusts DOM3.
  - ▶ In some situations a transitive trust is some kind of default route.



- ▶ Workstation (Domain Member) Trust
  - ▶ LSA\_TRUST\_DIRECTION\_OUTBOUND to the primary domain.
  - ▶ LSA\_TRUST\_TYPE\_DOWNLEVEL (NT4) or LSA\_TRUST\_TYPE\_UPLEVEL (AD).
  - ▶ Transitive Trust as default route.
  - ▶ computer account can only reliable access its primary domain.
- ▶ External Domain Trust
  - ▶ LSA\_TRUST\_TYPE\_DOWNLEVEL (NT4) or LSA\_TRUST\_TYPE\_UPLEVEL (AD).
  - ▶ Non-Transitive
- ▶ Forest Trust
  - ▶ LSA\_TRUST\_TYPE\_UPLEVEL (AD) between two forest root domains.
  - ▶ Transitive Trust (by default) between the two forests only.

# Trust Types (high level, Part 2 within Forests)



## ▶ Parent Child Trusts

- ▶ LSA\_TRUST\_DIRECTION\_INBOUND and LSA\_TRUST\_DIRECTION\_OUTBOUND
- ▶ LSA\_TRUST\_TYPE\_UPLEVEL (AD).
- ▶ LSA\_TRUST\_ATTRIBUTE\_WITHIN\_FOREST.
- ▶ The child is a DNS-subdomain of the parent
- ▶ Transitive Trust, on the parent with a route to the child and the related grandchildren.
- ▶ Transitive Trust, on the child as default route.
- ▶ Automatically created together with the child domain.

## ▶ Tree Root Trusts

- ▶ Similar to Parent Child Trust.
- ▶ The new tree root is not DNS-domain below the forest root.
- ▶ Transitive Trust, on the forest root with a route to the new tree root and the related grandchildren.
- ▶ Transitive Trust, on the child as default route.
- ▶ Automatically created together with the new tree root domain.



## ▶ Shortcut Trust

- ▶ LSA\_TRUST\_DIRECTION\_INBOUND and/or LSA\_TRUST\_DIRECTION\_OUTBOUND
- ▶ LSA\_TRUST\_TYPE\_UPLEVEL (AD).
- ▶ LSA\_TRUST\_ATTRIBUTE\_WITHIN\_FOREST.
- ▶ Non-Transitive, acts as direct route to the specified domain.
- ▶ Created by an administrator for performance reasons.

# Trust Attributes (low level)



The content of the trustAttributes attribute in Samba:

```
typedef [public,bitmap32bit] bitmap {
    LSA_TRUST_ATTRIBUTE_NON_TRANSITIVE           = 0x00000001,
    LSA_TRUST_ATTRIBUTE_UPLEVEL_ONLY            = 0x00000002,
    LSA_TRUST_ATTRIBUTE_QUARANTINED_DOMAIN      = 0x00000004,
    LSA_TRUST_ATTRIBUTE_FOREST_TRANSITIVE       = 0x00000008,
    LSA_TRUST_ATTRIBUTE_CROSS_ORGANIZATION      = 0x00000010,
    LSA_TRUST_ATTRIBUTE_WITHIN_FOREST          = 0x00000020,
    LSA_TRUST_ATTRIBUTE_TREAT_AS_EXTERNAL       = 0x00000040,
    LSA_TRUST_ATTRIBUTE_USES_RC4_ENCRYPTION     = 0x00000080
    // TODO LSA_TRUST_ATTRIBUTE_CROSS_ORGANIZATION_NO_TGT_DELEGATION = 0x00000200
    // TODO LSA_TRUST_ATTRIBUTE_PIM_TRUST        = 0x00000400
} lsa_TrustAttributes;
```

# Forest (routing) Information



- ▶ The information about a forest:
  - ▶ can be queried from the forest root of the "trusted" forest by `netr_GetForestTrustInformation()` constructed by the information under `CN=Partitions,CN=Configuration,...`
  - ▶ is stored in the "msDS-TrustForestTrustInfo" attribute in the root domain of the "trusting" forest.
- ▶ It is an array of records of the following types:
  - ▶ `FOREST_TRUST_DOMAIN_INFO` includes Netbios-Name, DNS-Name and Domain-Sid.
  - ▶ `FOREST_TRUST_TOP_LEVEL_NAME` includes a top level DNS-Name that part of the forest (including all DNS-subdomains).
  - ▶ `FOREST_TRUST_TOP_LEVEL_NAME_EX` includes a top level DNS-Name that is explicitly excluded from the forest (including all DNS-subdomains).
  - ▶ Individual records will be disabled if conflicts with other trusts are detected.
  - ▶ Individual records can also be disabled by the admin.





- ▶ Having an LSA\_TRUST\_DIRECTION\_OUTBOUND Trust:
  - ▶ Means the "trusting" workstation/domain can establish a Netlogon Secure Channel to DCs of the "trusted" domain using the computer/trust account.
  - ▶ The NETLOGON protocol is based on DCERPC, see [MS-NRPC].
- ▶ Establishing a global session state with a "trusted" DC:
  - ▶ `netr_ServerReqChallenge()` and `netr_ServerAuthenticate[2,3]()` are used to do a challenge/response authentication
  - ▶ The global session state is indexed by the computer name of the "client".
  - ▶ The global session state contains the initial session key, a sequence number.
  - ▶ Samba uses 'struct netlogon\_creds\_CredentialState' for this state.
  - ▶ This state is stored in `netlogon_creds_cli.tdb` (on the client) and `schannel_store.tdb` (on the server).



- ▶ A lot of functions operate on the global session state:
  - ▶ netr\_LogonSamLogon[WithFlags](), netr\_ServerPasswordSet[2](), netr\_LogonGetDomainInfo(), netr\_GetForestTrustInformation() and others.
  - ▶ All functions using 'netr\_Authenticator' arguments.
  - ▶ These functions do some rolling crypto on the global session state.
  - ▶ These functions need to be strictly ordered (globally!)
  - ▶ Some of them also encrypt some application level fields with the current global session key.



- ▶ The NETLOGON protocol implements a custom DCERPC authentication type (auth\_type=68):
  - ▶ The DCERPC Bind/AlterContext just passes the domain and computer names to the server.
  - ▶ The server takes a copy of the current global session based on the provided computer name.
  - ▶ This copy will be the session key for the lifetime of the DCERPC auth context.
  - ▶ Client and server provide DCERPC\_AUTH\_LEVEL\_INTEGRITY or DCERPC\_AUTH\_LEVEL\_PRIVACY protection for the auth context.
  - ▶ The connection doesn't support concurrent multiplexing and only one request at a time.



- ▶ Usage of DCERPC authentication type (auth\_type=68)
  - ▶ It is typically used for a protected NETLOGON connection.
  - ▶ It is also used for LSA connections and the `lsa_LookupNames4()` and `lsa_LookupSids3()` calls.
  - ▶ Typically the "trusting" side of the trust should only use these NETLOGON and LSA connections to communicate with the "trusted" domain.



- ▶ Authentication verification uses NETLOGON:
  - ▶ `netr_LogonSamLogon[WithFlags,Ex]()` is typically used to verify NTLMSSP authentication.
  - ▶ But it's not limited to NTLMSSP, e.g. Kerberos PAC-Validation.
- ▶ Authentication should scale:
  - ▶ `netr_LogonSamLogonEx()` is an optimization of `netr_LogonSamLogon[WithFlags]()`.
  - ▶ It isn't bound to the `netr_Authenticator` global ordering.
  - ▶ It avoids application level encryption with the current global session key in most cases if `DCERPC_AUTH_LEVEL_PRIVACY` is in use.
  - ▶ It can use multiple DCERPC connections to scale.

# SPNEGO Authentication example



- ▶ All application protocols used in active directory domains use SPNEGO (RFC 4178, [MS-SPNG]) in order to negotiate between NTLMSSP ([MS-NLMP]) or Kerberos (RFC 4120, [MS-KILE])

## ▼ SMB2 (Server Message Block Protocol version 2)

### ▶ SMB2 Header

### ▼ Session Setup Request (0x01)

▶ StructureSize: 0x0019

▶ Flags: 0

▶ Security mode: 0x02, Signing required

▶ Capabilities: 0x00000001, DFS

Channel: None (0x00000000)

Previous Session Id: 0x0000000000000000

### ▼ Security Blob: 60820c9306062b0601050502a0820c8730820c83a0243022...

Offset: 0x00000058

Length: 3223

### ▼ 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: 3 items

MechType: 1.2.840.48018.1.2.2 (MS KRB5 - Microsoft Kerberos 5)

MechType: 1.2.840.113554.1.2.2 (KRB5 - Kerberos 5)

MechType: 1.3.6.1.4.1.311.2.2.10 (NTLMSSP - Microsoft NTLM Security Support Provider)

mechToken: 60820c5106092a864886f71201020201006e820c4030820c...

▶ krb5\_blob: 60820c5106092a864886f71201020201006e820c4030820c...

# Kerberos Network Traffic With Trusts



- ▶ Client (administrator@W2012R2-L4.BASE) (HW 00:00:00:09:00:01)
- ▶ DC in Client-Domain (W2012R2-L4.BASE) (HW 00:00:00:09:01:83)
- ▶ Forest-Trust between W2012R2-L4.BASE and W4EDOM-L4.BASE
- ▶ DC in Server-Domain (W4EDOM-L4.BASE) (HW 00:00:00:09:01:33)
- ▶ Server (w2008r8-132) in W4EDOM-L4.BASE (HW 00:00:00:09:01:32)
- ▶ Access to \\w2008r2-132.w4edom-l4.base using Kerberos

AS-REQ	administrator@W2012R2-L4.BASE	00:00:00:09:00:01	00:00:00:09:01:83
AS-REP	krbtgt/W2012R2-L4.BASE@W2012R2-L4.BASE	00:00:00:09:01:83	00:00:00:09:00:01
TGS-REQ	cifs/w2008r2-133.w4edom-l4.base@W2012R2-L4.BASE	00:00:00:09:00:01	00:00:00:09:01:83
TGS-REP	krbtgt/W4EDOM-L4.BASE@W2012R2-L4.BASE	00:00:00:09:01:83	00:00:00:09:00:01
TGS-REQ	cifs/w2008r2-133.w4edom-l4.base@W4EDOM-L4.BASE	00:00:00:09:00:01	00:00:00:09:01:33
TGS-REP	cifs/w2008r2-133.w4edom-l4.base@W4EDOM-L4.BASE	00:00:00:09:01:33	00:00:00:09:00:01
Session Setup Request		00:00:00:09:00:01	00:00:00:09:01:32
Session Setup Response		00:00:00:09:01:32	00:00:00:09:00:01

- ▶ The client talks to DCs directly.
- ▶ The server gets the authorization data from the kerberos ticket

# NTLMSSP Network Traffic With Trusts



- ▶ Client (administrator@W2012R2-L4.BASE) (HW 00:00:00:09:00:01)
- ▶ DC in Client-Domain (W2012R2-L4.BASE) (HW 00:00:00:09:01:83)
- ▶ Forest-Trust between W2012R2-L4.BASE and W4EDOM-L4.BASE
- ▶ DC in Server-Domain (W4EDOM-L4.BASE) (HW 00:00:00:09:01:33)
- ▶ Server (w2008r8-132) in W4EDOM-L4.BASE (HW 00:00:00:09:01:32)
- ▶ Access to \\w2008r2-132.w4edom-l4.base using NTLMSSP

Session Setup Request, NTLMSSP_NEGOTIATE	00:00:00:09:00:01	00:00:00:09:01:32
Session Setup Response, Error: STATUS_MORE_PROCESSING_REQUIRED, NTLMSSP...	00:00:00:09:01:32	00:00:00:09:00:01
Session Setup Request, NTLMSSP_AUTH, User: W2012R2-L4.BASE\administrator	00:00:00:09:00:01	00:00:00:09:01:32
NetrLogonSamLogonEx request	00:00:00:09:01:32	00:00:00:09:01:33
NetrLogonSamLogonWithFlags request	00:00:00:09:01:33	00:00:00:09:01:83
NetrLogonSamLogonWithFlags response	00:00:00:09:01:83	00:00:00:09:01:33
NetrLogonSamLogonEx response	00:00:00:09:01:33	00:00:00:09:01:32
Session Setup Response	00:00:00:09:01:32	00:00:00:09:00:01

- ▶ The server talks to the DC in its own domain only.
- ▶ The DC may forward the request to trusted domains.



# The result of a successful authentication



- ▶ Inputs to authentication:
  - ▶ The client typically provides a full qualified username together with a password.
  - ▶ Smartcards can also be used to do Kerberos (PKINIT) authentication.
- ▶ Output from authentication:
  - ▶ The target server needs to make sure the client is authenticated.
  - ▶ Typically client and server negotiate a session key.
  - ▶ The target server gets an authorization token for the authenticated user.
  - ▶ The authorization token is contained in the Kerberos service ticket.
  - ▶ `netr_LogonSamLogon[WithFlags,Ex]()` provides the authorization token for NTLMSSP.

# The authorization token



- ▶ Elements in the token:
  - ▶ It contains things like username, fullname, logon\_domain, various timestamps.
  - ▶ The most important information is the list of group memberships.
- ▶ The token provided by the "trusted" domain:
  - ▶ Needs to be expanded with local groups on the "trusting" side.
  - ▶ Needs to be do SID-Filtering on "trusting" side to avoid faked group memberships.
  - ▶ The exact SID-Filtering rules depend on the trustAttribute values.
  - ▶ It is important to do the expanding and filtering on all trust boundaries of a transitive chain.
  - ▶ Currently Samba does not do any SID-Filtering at all!
- ▶ In Samba we use 'struct auth\_session\_info' for the expanded token:
  - ▶ It contains a list of SIDS.
  - ▶ The details of the Windows user.
  - ▶ It contains a uid and a list of gid's.
  - ▶ The unix username.

# Authorization Token without Authentication (Part1)

- ▶ There're some situations when a service needs to impersonate a user locally:
  - ▶ This can happen without getting an authentication for that user.
  - ▶ SSH public-key authentication, sudo or nfs3 access are typical usecases.
- ▶ Getting an authorization token without authentication is tricky:
  - ▶ Currently winbindd tries to get the 'tokenGroups' of the user object via LDAP
  - ▶ In situations with trusted domains it means that winbindd will try to connect a DC of the users primary domain without having a direct trust to it.
  - ▶ There're a lot of situations where this doesn't work, e.g. with OUTBOUND only trusts.
  - ▶ It is a very hard task because the expanding and filtering at the trust boundaries of the transitive chain can't be simulated.
  - ▶ So the result is often wrong!

## Authorization Token without Authentication (Part2)

- ▶ The only reliable solution is S4U2Self:
  - ▶ S4U2Self ([MS-SFU]), a Kerberos extension, allows a service to ask a KDC for an service ticket for a given user.
  - ▶ Sadly there're quite some bugs in current versions of MIT Kerberos and Heimdal.
  - ▶ But the bugs can be fixed.



- ▶ Making efficient and robust usage of trust relationships:
  - ▶ It is required to construct a routing table that knows about routing via transitive trusts.
  - ▶ The table is constructed by the list of direct trusts and their (optionally) related forest information.
  - ▶ The goal is that communication only appears between direct trusts.



- ▶ Using the routing table for Kerberos:
  - ▶ The routing table is mainly used in the KDC, which means the basics for two-way (INBOUND and OUTBOUD) trusts as an AD DC are already in place.
  - ▶ The client just talk to a KDC in the primary domain and follow referrals, it doesn't really need the routing table.
- ▶ Using the routing table for NTLMSSP:
  - ▶ It also needs to be used the NETLOGON and LSA servers in order to find out if a requests should be routed via winbindd to a trusted domain.
  - ▶ The routing table needs to be used within winbindd.
  - ▶ This will make the code much more robust as a domain member.
  - ▶ And it will also provide the basics for two-way (INBOUND and OUTBOUD) trusts as an AD DC.



- ▶ Samba provided features
  - ▶ We try to emulate the features of the Windows 2008R2 DC functional level
  - ▶ Everything else will need some development effort.
- ▶ Windows 2012 introduced support for Kerberos FAST:
  - ▶ Typically Kerberos authentication requests (AS-Req) use the password of the user to encrypt a timestamp.
  - ▶ This allows attackers to do offline dictionary against the users typically less random password.
  - ▶ Typically the passwords of trust accounts, e.g. computer accounts have trully random passwords.
  - ▶ The solution is to use a ticket created with the computer account to protect the users AS-REQ.



- ▶ Windows 2012 introduced support for Compound Identities:
  - ▶ If the client uses FAST, the KDC is able to know from which device (computer) the user is coming.
  - ▶ This KDC add a new PAC\_DEVICE\_INFO element to the Kerberos ticket.
  - ▶ As result the authorization token of the user will also have information of the device, which can be used to use more advanced access restrictions.
- ▶ Windows 2012 introduced support for CLAIMS:
  - ▶ An administrator can define and assign "claims".
  - ▶ It allows more flexible access control beside using groups.
  - ▶ The Kerberos ticket will contain PAC\_CLIENT\_CLAIMS\_INFO and PAC\_DEVICE\_CLAIMS\_INFO
  - ▶ More research is required to fully understand how CLAIMS work.





- ▶ Windows 2016 introduced support for Privileged Identity Management (PIM):
  - ▶ This feature will add timed group memberships
  - ▶ E.g. an administrative user will only be a member of the domain admins group for an hour.
  - ▶ The lifetime for Kerberos tickets is very limited compared to the default of 10 hours, with a renew up to a week.
  - ▶ There's also a special forest trust mode for PIM.
  - ▶ More research is required to fully understand how PIM work.



- ▶ TECHNET: "How Domain and Forest Trusts Work"
- ▶ [MS-AUTHSOD]
- ▶ [MS-PAC]
- ▶ [MS-LSAD]
- ▶ [MS-LSAT]
- ▶ [MS-DTYP]

Draft !!!

# Questions?



- ▶ Stefan Metzmacher, [metze@samba.org](mailto:metze@samba.org)
- ▶ <https://www.sernet.com>

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