SDC

STORAGE DEVELOPER CONFERENCE

SNIA SANTA CLARA, 2017

Windows Authentication With Multiple Domains and Forests

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

Update from SambaXP 2017

- 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/

- Check for an updated version of this slides here:
- https://samba.org/~metze/presentations/2017/SDC/

Topics

- Windows Domains, Forests and Trusts
- Netlogon Secure Channel
- Authentication Protocols
- Authorization Token/S4U2Self
- Selective Authentication/Restrict NTLM
- New Kerberos Features
- Trust Routing Table
- Improvements in Samba
- Further Authentication Topics
- Questions?
- Useful links

Trust Types and Directions (low level)

- Trust Types (only relevant ones):
  - LSA_TRUST_TYPE_DOWNLEVEL (NT4)
  - LSA_TRUST_TYPE_UPLEVEL (AD)
- Trust Directions:
  - LSA_TRUST_DIRECTION_INBOUND
  - LSA_TRUST_DIRECTION_OUTBOUND (like on a domain member)
- For further details see my SambaXP talk.

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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, /* only kerberos */
  LSA_TRUST_ATTRIBUTE_QUARANTINED_DOMAIN  = 0x00000004,
  LSA_TRUST_ATTRIBUTE_FOREST_TRANSITIVE   = 0x00000008, /* cross forest trust */
  LSA_TRUST_ATTRIBUTE_CROSS_ORGANIZATION  = 0x00000010, /* selective auth */
  LSA_TRUST_ATTRIBUTE_WITHIN_FOREST       = 0x00000020, /* transitive by default */
  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;
```

Trust Types (high level, Part 1)

- Workstation (Domain Member) Trust
- External Domain Trust
- Forest Trust
- Parent Child Trusts (Within Forest)
- Tree Root Trusts (Within Forest)
- Shortcut Trust (Within Forest)
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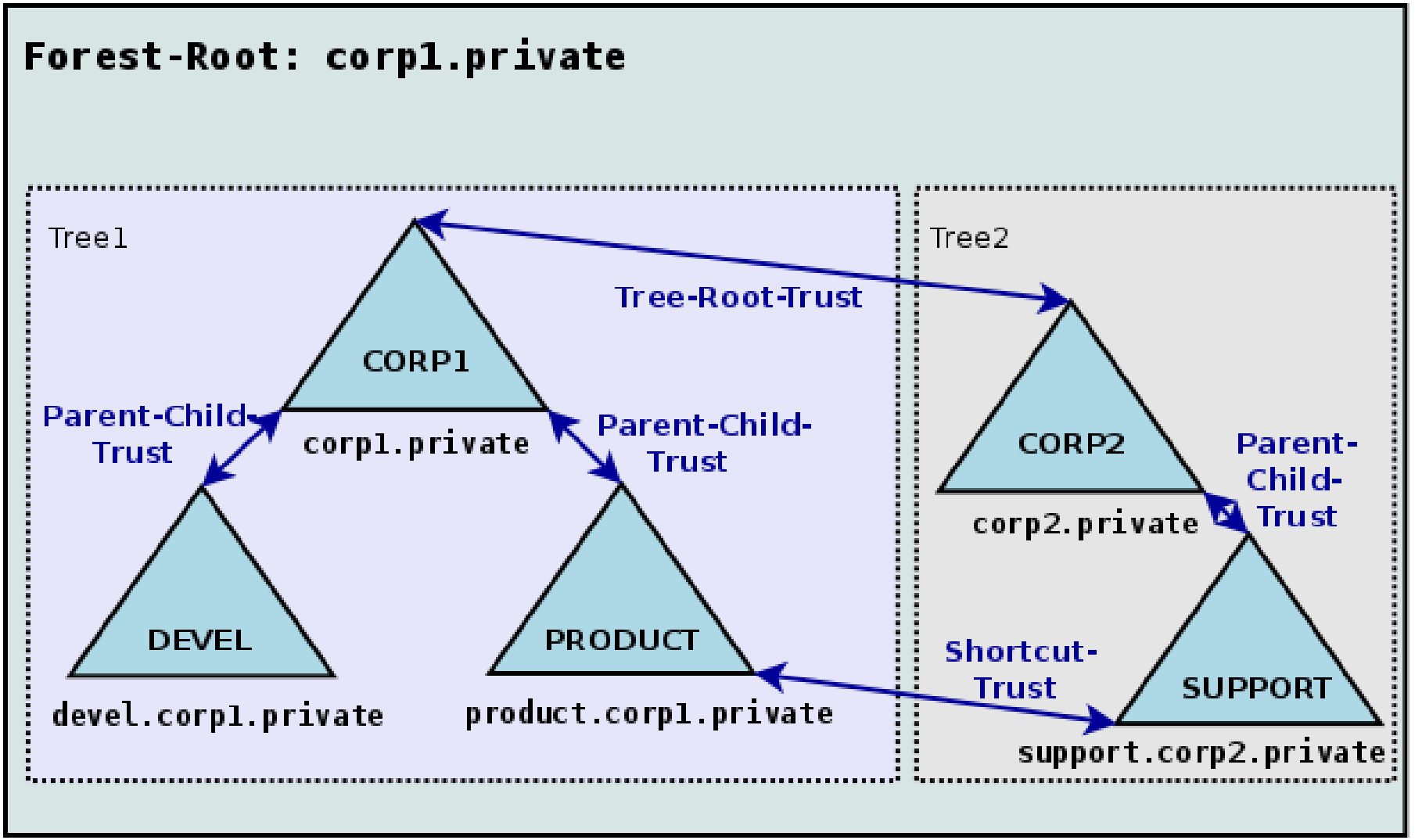
Layout of an Active Directory Forest (with multiple Trees)



Forest Information (with multiple Trees)

- 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

Netlogon Secure Schannel

- 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 bases on DCERPC, see [MS-NRPC].
- 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.
- Forest Trust Information is available via NETLOGON:
  - netr_GetForestTrustInformation() is used to get the details
- For further details see my SambaXP talk.

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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.

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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.

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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 tyipical 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!

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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.
- Details of S4U2Self:
  - The service needs a TGT for the user realm first.
  - Referrals are followed from the service realm to the user realm.
  - Then it requests a S4U2Self Ticket specifying the impersonated user principal and the service principal.
  - In order to get a usable ticket referrals are followed back to the service realm.
  - This requires a two-way trust.

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Forest/Domain-wide Authentication

- Forest/Domain-wide Authentication (the default) allows:
  - Authentication of each principal of the trusted forest/domain
  - Authentication to each service in the trusting forest/domain
- Authorization is handled by:
  - Using ACLs on individual resources (objects, files, ...)
  - Access might be granted just by "Authenticated Users" ACEs.
- One-way trusts:
  - Often used to limit the authentication between organizations.
  - Make the use of S4U2Self impossible.

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Selective Authentication (Cross Organization Trusts)

- Trusts can be marked for selective authentication:
  - Using LSA_TRUST_ATTRIBUTE_CROSS_ORGANIZATION
  - The trusting end adds the OTHER_ORGANIZATION SID (S-1-5-1000) to any token
  - By default authentication of trusted principals to trusting services is rejected with STATUS_AUTHENTICATION_FIREWALL_FAILED.
- Selective authentication checking:
  - Only done if the token contains S-1-5-1000
  - The "AllowedToAuthenticateTo" extended access right is required on the AD object of the service.
- Advantages of selective authentication:
  - It is much more flexible than the all or nothing of one-way trusts.
  - It allows S4U2Self to work.
- Status of selective authentication within Samba:
  - Not implemented yet, similar to all SID expanding/filtering.

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Restrict NTLM... (Part1)

- Windows has serveral ways to restrict the use of NTLM based authentication:
- Client:
  - Restrict NTLM: Outgoing NTLM traffic to remote servers
  - Restrict NTLM: Add remote server exceptions for NTLM authentication
  - NT_STATUS_NOT_SUPPORTED is generated if NTLM is not allowed
- Server:
  - Restrict NTLM: Incoming NTLM Traffic
  - Restrict NTLM: Audit Incoming NTLM Traffic
  - NT_STATUS_NOT_SUPPORTED is generated if NTLM is not allowed
- Domain Controller:
  - Restrict NTLM: NTLM authentication in this domain
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  - NT_STATUS_NTLM_BLOCKED is generated if NTLM is not allowed

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  - Restrict NTLM: Audit NTLM authentication in this domain
  - NT_STATUS_NTLM_BLOCKED is generated if NTLM is not allowed

Restrict NTLM... (Part1)

- Windows has serveral ways to restrict the use of NTLM based authentication:
- Client:
  - Restrict NTLM: Outgoing NTLM traffic to remote servers
  - Restrict NTLM: Add remote server exceptions for NTLM authentication
  - NT_STATUS_NOT_SUPPORTED is generated if NTLM is not allowed
- Server:
  - Restrict NTLM: Incoming NTLM Traffic
  - Restrict NTLM: Audit Incoming NTLM Traffic
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- Domain Controller:
  - Restrict NTLM: NTLM authentication in this domain
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Restrict NTLM... (Part2)

- With Samba 4.7 we'll have the following options "ntlm auth":
  - "ntlmv1-permitted" (alias "yes") - Allow NTLMv1 and above for all clients.
  - "ntlmv2-only" (alias "no") - Do not allow NTLMv1 to be used, but permit NTLMv2.
  - "mschapv2-and-ntlmv2-only" - Only allow NTLMv1 when the client promises that it is providing MSCHAPv2 authentication (such as the ntlm_auth tool).
  - "disabled" - Do not accept NTLM (or LanMan) authentication of any level, nor permit NTLM password changes.
  - The default is "ntlmv2-only".
- Before Samba 4.7:
  - We just had "yes" and "no", just controlling NTLMv1 usage.
  - The default was "no"
- In future:
  - We may implement more flexible schema similar to Windows
  - This would allow us to keep NTLM alive for specific servers.

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New Kerberos Features (Part 1)

- 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 KDC resource group compression:
  - This reduced the size of the PAC with a large number of resource group memberships.
  - Samba should implement this once we implement the SID expanding/filtering.
- Windows 2012 introduced support for Kerberos FAST (armoring):
  - 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.
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- Windows 2012 introduced support for Branch Aware clients:
  - The client can tell on RODC not to forward a TGS-REQ
  - The client can force a forward to an RWDC
- 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 autorization token of the user will also have information of the device, which can be used to use more advanced access restrictions.
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  - An administrator can define and assign "claims".
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New Kerberos Features (Part 3)

- Windows 2012R2 introduced the Protected Users Security Group
  - SID: S-1-5-21-<domain>-525
  - Members can use Kerberos with AES keys
  - Members can not use Kerberos delegation
  - The TGT is only valid for 4 hours by default
  - Credentials are never cached
- Windows 2012R2 introduced Authentication Policies and Authentication Policy Silos:
  - Like "Selective Authentication" within a Forest.
  - More research is required to fully understand all details
- 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.
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Goals for Samba

- We need:
  - A scalable and robust authentication subsystem on domain members.
  - Full support for trusted domains/forests as active directory domain controller.
- Most of the logic is handled by winbindd:
  - The requirements of DCs and domain members are similar
  - We just need to correct abstraction that can handle all possible trust flavours.
- Limit avoidable network communication:
  - Use idmap backends with IDMAP_TYPE_BOTH support => no LookupSid anymore
  - No domain controller communication when accepting Kerberos authentication
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Using a strict trust routing table (Part1)

- 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.
  - Only NETLOGON and LSA LookupSids/Names using Netlogon secure channel.
  - No SAMR and no LDAP anymore (at least by default)

Using a strict trust routing table (Part2)

- 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 talks to a KDC in the primary domain and follows 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.
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Removing "map untrusted to domain" option

- When a client authenticates as UNKNOWN\user
  it get silently mapped to LOCALSAMNAME\user

- Up to now we fetched a list of trusted domains from winbindd:
  - This list was used to evaluate if the domain is "untrusted"
  - "map untrusted to domain = yes/no" controls to what the "untrusted" domain name is mapped to.
  - But this is completely unreliable, e.g. with one-way trusts and other situations.

- It's the job of our DC to decide about trusts:
  - We need to pass non local authentication always (unchanged) to a DC.
  - NO_SUCH_USER together with authoritative=0 indicates a possible fallback.
  - We have this fixed by "map untrusted to domain = auto" in Samba 4.7
  - Samba 4.8 will remove that option completely while keeping the auto behavior.

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Full async authentication stack (Part1)

old semi-async gensec_update api in Samba:

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NTSTATUS gensec_update_ev(struct gensec_security *gensec_security,
                          TALLOC_CTX *out_mem_ctx,
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- Using gensec_update_ev() as a server:
  - Was possible for local non-blocking authentication on an AD DC
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  - Nested event loops are like threads without mutexes

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  - Make use of the fully async gensec_update_send/recv() pair.
- The hardest part was rewriting of spnego.c
  - That module needed 82 patches in order to untangle the logic and make it completely async.
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Further Authentication Topics

- Let lower privileged services use kerberos authentication:
  - Needs explicit PAC verification with a domain controller
  - Needs a gss-proxy like gensec module
  - Let winbindd proxy an gss-proxy like interface
- Kerberos (constrained) delegation (S4U2Proxy)
- Further hardening
  - Extended Protection TLS Channel Binding Token CBT
  - Server SPN target name validation level (SmbServerNameHardeningLevel, UnverifiedTargetName)
- Public Key Cryptography Based User-to-User Authentication
  - PKU2U (like Kerberos with PKINIT)
  - But the target server acts as a KDC over the gss_[init,accept]_sec_context() channel
  - Will replace NTLM in workgroup kind of setups
- [Group] Managed Service Accounts

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Questions?

- Stefan Metzmacher, `metze@samba.org`
- https://www.sernet.com

Useful links follow on the next page...

Useful links (Part1)

- [MS-APDS] Authentication Protocol Domain Support
- [MS-AUTHSOD] Authentication Services Protocols Overview
- [MS-DTYP] Windows Data Types
- [MS-LSAD] Local Security Authority (Domain Policy) Remote Protocol
- [MS-LSAT] Local Security Authority (Translation Methods) Remote Protocol
- [MS-NLMP] NT LAN Manager (NTLM) Authentication Protocol
- [MS-PAC] Privilege Attribute Certificate Data Structure
- [MS-WMOD] Windows Management Protocols Overview

- draft-zhu-pku2u-09
- draft-zhu-negoex-04

Useful links (Part2)

- TECHNET: Authentication Policies and Authentication Policy Silos
- TECHNET: Changes in Kerberos Authentication (Windows 2008R2)
- TECHNET: Introducing Forest Search Order (Windows 2008R2)
- TECHNET: How Domain and Forest Trusts Work
- TECHNET: Kerberos Constrained Delegation Overview
- TECHNET: Extended Protection for Authentication
- TECHNET: Public Key Cryptography based User to User Authentication Overview (PKU2U)
- TECHNET: Protected Users Security Group
- TECHNET: Security Considerations for Trusts
- TECHNET: Server SPN target name validation level
- TECHNET: Windows Authentication Technical Overview
- TECHNET: What's New in Kerberos Authentication (Windows 2012)