Windows Authentication With Multiple Domains and Forests

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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:

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.
The content of the trustAttributes attribute in Samba:

```c
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_ATTRIBUTEUSES_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)

For further details see my SambaXP talk.
Layout of an Active Directory Forest (with multiple Trees)

Forest-Root: corp1.private

Tree1
- CORP1
  - Parent-Child Trust
    - corp1.private
      - DEVELO
        - devel.corp1.private
      - PRODUCT
        - product.corp1.private
  - Tree-Root-Trust

Tree2
- CORP2
  - Parent-Child Trust
    - corp2.private
  - Shortcut Trust
    - SUPPORT
      - support.corp2.private

Windows Trusts (7/34)
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.
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 (KR5 - Kerberos 5)
      - MechType: 1.3.6.1.4.1.311.2.2.10 (NTLMSPP - Microsoft NTLM Security Support Provider)
        - mechToken: 60820c5106092a86488e6f71201020201006e820c4030820c...
        - krb5_blob: 60820c5106092a86488e6f71201020201006e820c4030820c...
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

<table>
<thead>
<tr>
<th>AS-REQ</th>
<th><a href="mailto:Administrator@W2012R2-L4.BASE">Administrator@W2012R2-L4.BASE</a></th>
<th>00:00:00:09:00:01</th>
<th>00:00:00:09:01:83</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS-REP</td>
<td>krbtgt/W2012R2-L4.BASE@W2012R2-L4.BASE</td>
<td>00:00:00:09:01:83</td>
<td>00:00:00:09:00:01</td>
</tr>
<tr>
<td>TGS-REQ</td>
<td>cifs/w2008r2-133.w4edom-l4.base@W2012R2-L4.BASE</td>
<td>00:00:00:09:00:01</td>
<td>00:00:00:09:01:83</td>
</tr>
<tr>
<td>TGS-REP</td>
<td>krbtgt/W4EDOM-L4.BASE@W2012R2-L4.BASE</td>
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<td>00:00:00:09:00:01</td>
</tr>
<tr>
<td>Session Setup Request</td>
<td></td>
<td>00:00:00:09:00:01</td>
<td>00:00:00:09:01:32</td>
</tr>
<tr>
<td>Session Setup Response</td>
<td></td>
<td>00:00:00:09:01:32</td>
<td>00:00:00:09:00:01</td>
</tr>
</tbody>
</table>

- 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

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.
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!
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.
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.
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.
Restrict NTLM... (Part1)

- Windows has several 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
    - Restrict NTLM: Add server exceptions in this domain
    - Restrict NTLM: Audit NTLM authentication in this domain
    - NT_STATUS_NTLM_BLOCKED is generated if NTLM is not allowed
Restrict NTLM... (Part 2)

- 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.
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 truly random passwords.
  - The solution is to use a ticket created with the computer account to protect the users AS-REQ.
New Kerberos Features (Part 2)

- 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 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.
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.
  - TGTs are only valid for a short time.
  - There’s also a special forest trust mode for PIM.
  - More research is required to fully understand how PIM works.
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
  - Reduce DNS and CLDAP requests, especially from the Kerberos libraries
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 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 winbinddd to a trusted domain.
- The routing table needs to be used within winbinddd.
- 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.
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 winbinddd:
  - 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.
Full async authentication stack (Part1)

old semi-async gensec_update api in Samba:

```c
NTSTATUS gensec_update_ev (struct gensec_security *gensec_security,
                         TALLOC_CTX *out_mem_ctx,
                         struct tevent_context *ev,
                         const DATA_BLOB in, DATA_BLOB *out);
```

- Using gensec_update_ev() as a server:
  - Was possible for local non-blocking authentication on an AD DC
  - Is not usable with remote authentication at all
  - Nested event loops are like threads without mutexes

Async gensec_update api attribute in Samba:

```c
struct tevent_req *gensec_update_send(TALLOC_CTX *mem_ctx,
                                       struct tevent_context *ev,
                                       struct gensec_security *gensec_security,
                                       const DATA_BLOB in);

NTSTATUS gensec_update_recv(struct tevent_req *req,
                            TALLOC_CTX *out_mem_ctx,
                            DATA_BLOB *out);

NTSTATUS gensec_update(struct gensec_security *gensec_security,
                        TALLOC_CTX *out_mem_ctx,
                        const DATA_BLOB in, DATA_BLOB *out);
```
Full async authentication stack (Part2)

- Changing the callers to:
  - Use the sync wrapper gensec_update() if they only act as server only accepting Kerberos
  - 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.

- auth_check_password_send/recv() was rewritten:
  - To allow backends to optionally provide check_password_send()/recv()
  - Only source4/auth/ntlm/auth_winbind.c (used as AD DC) makes use of it (yet).

- Auth methods in use:
  - NTLM auth: "anonymous sam winbind sam_ignoredomain"
  - NETLOGON: "sam winbind"
  - winbinddd: "sam"
Next Steps

- Disable SAMR and LDAP access as AD DC to trusted domains
- Make use of S4U2Self in winbindd
- Kerberos FAST in winbindd
- LSA LookupSids/LookupsNames
- Let winbindd use the trust routing table
- Automatic creation of foreignSecurityPrincipal objects
- Implement SID expanding/filtering
- Selective Authentication
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
Questions?

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

Useful links follow on the next page...
Useful links (Part 1)

- [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)