

SAMBA EXPERIENCE

Modern Kerberos Features within Samba

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<https://samba.org/~metze/presentations/2020/SambaXP/>

- ▶ The basics of Kerberos (krb5)
- ▶ What is S4U2Self
- ▶ What is FAST/CompoundIdentity
- ▶ What does existing Kerberos libraries support
- ▶ Using S4U2Self/FAST in winbindd
- ▶ Challenges of adding new Features
- ▶ Protocol Testing with Python
- ▶ Questions?

The basics of Kerberos (krb5) (Part1)

- ▶ Kerberos is an authentication protocol
 - ▶ Defined in RFC 4120 and others
 - ▶ Its design consists of 3 components (Clients, KDCs, Servers)
 - ▶ A Realm is typically based on DNS-Names, e.g. EXAMPLE.COM
 - ▶ Strong mutual authentication is offered, which provides replay protection
 - ▶ GSSAPI/SPENEGO is used for client to server authentication
- ▶ Kerberos uses strong symmetric key crypto:
 - ▶ aes256-cts-hmac-sha1-96 (by default)
 - ▶ aes128-cts-hmac-sha1-96 is also possible, but never really used
 - ▶ arcfour-hmac-md5 is still available and uses the unsalted NTHASH
 - ▶ des based crypto is deprecated/disabled in modern networks
- ▶ public-key crypto is also available (PKINIT):
 - ▶ Typically authentication with smartcards
 - ▶ Or other certificate based methods

The basics of Kerberos (krb5) (Part2)

- ▶ The central "Key Distribution Center" (KDC)
 - ▶ Stores encryption keys (typically based on passwords)
 - ▶ Client Principals, e.g. administrator@EXAMPLE.COM
 - ▶ Ticket Granting Ticket (TGT) principal, e.g. krbtgt/EXAMPLE.COM@EXAMPLE.COM
 - ▶ Server Principals, e.g. cifs/files.example.com@EXAMPLE.COM
 - ▶ It provides an "Authentication Service" (AS)
 - ▶ It provides a "Ticket Granting Service" (TGS)
 - ▶ Both services of the KDC provide (grant) Tickets
- ▶ A Ticket consists of a unencrypted part containing:
 - ▶ The realm of the granting KDC
 - ▶ The service principal within the KDC's realm
- ▶ The encrypted part of the Ticket:
 - ▶ Is encrypted with the shared secret between KDC and service
 - ▶ The encryption type and the key version (kvno) identify the key
 - ▶ It contains details about the client/user
 - ▶ A random ticket session key with a midterm lifetime, e.g. 10 hours

The Details of a Ticket (Part1)

```
▼ ticket
  tkt-vno: 5
  realm: W2012R2-L6.BASE
  ▼ sname
    name-type: kRB5-NT-SRV-INST (2)
    ▼ sname-string: 2 items
      SNameString: krbtgt
      SNameString: W2012R2-L6.BASE
  ▼ enc-part
    etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
    kvno: 2
    ▼ cipher: 9636cf01a57fc49aaaa4fd113a8ef8dc03cac02ff4bac5013126a717fa00322b63e32
      Decrypted keytype 18 usage 2 using keytab principal krbtgt@W2012R2-L6.BASE
      ▼ encTicketPart
        Padding: 0
        ▶ flags: 40e10000
        ▼ key
          ▶ Learnt encTicketPart_key keytype 18 (id=733.3) (35ca5dfa...)
            keytype: 18
            keyvalue: 35ca5dfa00e902006bc3dc8bcad17e6ac1fba9190c3fd9cb366b27c3618
            crealm: W2012R2-L6.BASE
        ▼ cname
          name-type: kRB5-NT-PRINCIPAL (1)
          ▼ cname-string: 1 item
            CNameString: Administrator
        ▶ transited
          authtime: 2020-04-28 09:25:32 (UTC)
          starttime: 2020-04-28 09:25:32 (UTC)
          endtime: 2020-04-28 19:25:32 (UTC)
          renew-till: 2020-05-05 09:25:32 (UTC)
        ▼ authorization-data: 1 item
          ▼ AuthorizationData item
            ad-type: aD-IF-RELEVANT (1)
            ▼ ad-data: 3082035a30820356a00402020080a182034c04820348060000000000000000
              ▼ AuthorizationData item
                ad-type: aD-WIN2K-PAC (128)
                ▶ ad-data: 06000000000000000100000020020000680000000000000000a000
```

A Ticket Granting Ticket (TGT)

The Details of a Ticket (Part2)

```

authorization-data: 1 item
  AuthorizationData item
    ad-type: ad-IF-RELEVANT (1)
    ad-data: 3082035a30820356a00402020080a182034c048203480600000000000000010000002002...
      AuthorizationData item
        ad-type: ad-WIN2K-PAC (128) Privilege Attribute Certificate (PAC)
        ad-data: 0600000000000000100000020020000680000000000000000a0000002400000088020000...
          ▶ Verified Server checksum 16 keytype 18 using keytab principal krbtgt@W2012R2-L6.BASE
          ▶ Verified KDC checksum -138 keytype 23 using keytab principal krbtgt@W2012R2-L6.BASE
          Num Entries: 6
          Version: 0
          ▶ Type: Logon Info (1) Windows Authorization Information
          ▶ Type: Client Info Type (10)
          ▶ Type: UPN DNS Info (12)
          ▶ Type: Client Claims Info (13)
          ▶ Type: Server Checksum (6)
          ▶ Type: Privsvr Checksum (7)

```

- ▶ Server and KDC/Privsvr Checksums:
 - ▶ Protect the Authorization Information from changing
- ▶ "Logon Info" contains
 - ▶ The full Windows Authorization Token with group memberships

The Details of a Ticket (Part3)

- ▼ PAC_LOGON_INFO:
 - Referent ID: 0x00020000
 - Logon Time: Apr 28, 2020 11:21:14.090883000 CEST
 - Logoff Time: Infinity (absolute time)
 - Kickoff Time: Infinity (absolute time)
 - PWD Last Set: Mar 20, 2015 10:57:31.494778400 CET
 - PWD Can Change: Mar 21, 2015 10:57:31.494778400 CET
 - PWD Must Change: Infinity (absolute time)
 - ▶ Acct Name: Administrator
 - ▶ Full Name
 - ▶ Logon Script
 - ▶ Profile Path
 - ▶ Home Dir
 - ▶ Dir Drive
 - Logon Count: 3220
 - Bad PW Count: 1
 - User RID: 500
 - Group RID: 513
 - Num RIDs: 5
 - ▶ GroupIDs
 - ▶ User Flags: 0x00000020
 - User Session Key: 00000000000000000000000000000000
 - ▶ Server: W2012R2-188
 - ▶ Domain: W2012R2-L6
 - ▶ SID pointer:
 - Dummy1 Long: 0x00000000
 - Dummy2 Long: 0x00000000
 - ▶ User Account Control: 0x00000210
 - Dummy4 Long: 0x00000000
 - Dummy5 Long: 0x00000000
 - Dummy6 Long: 0x00000000
 - Dummy7 Long: 0x00000000
 - Dummy8 Long: 0x00000000
 - Dummy9 Long: 0x00000000
 - Dummy10 Long: 0x00000000
 - Num Extra SID: 2
 - ▶ SID_AND_ATTRIBUTES_ARRAY:
 - ▶ ResourceGroupIDs

The Authentication Service (AS) Exchange (Part1)

- ▶ The AS-Exchange authenticates a client/user
 - ▶ The client proves its identity to the KDC
 - ▶ The KDC returns a Ticket Granting Ticket (TGT)
 - ▶ Typically two round trips
- ▶ First AS-REQ without Pre-Authentication
 - ▶ Gives an Error-Message with PRE-AUTH-REQUIRED
 - ▶ Returns the Password-Salt
 - ▶ May also provide the capabilities of the KDC
- ▶ AS-REQ with Password Pre-Authentication
 - ▶ A timestamp is encrypted with the client/user key
 - ▶ A ticket for the krbtgt service is returned in the AS-REP
 - ▶ The content of the encTicketPart is only known to the KDC
 - ▶ The content of the encASRepPart is encrypted with the client/user key
 - ▶ encTicketPart and encASRepPart contain the same ticket session key
 - ▶ The TGT's ticket session key is a shared secret between client and KDC

The Authentication Service (AS) Exchange (Part2)

- ▶ Internet Protocol Version 4, Src: 172.31.99.189, Dst: 172.31.9.188
- ▶ Transmission Control Protocol, Src Port: 49163, Dst Port: 88, Seq: 3829371254, Ack: 3818202977, Len: 315
- ▼ Kerberos
 - ▶ Record Mark: 315 bytes
 - ▼ as-req
 - pvno: 5
 - msg-type: krb-as-req (10) **AS-REQ with Password Pre-Authentication**
 - ▼ padata: 2 items
 - ▼ PA-DATA pA-ENC-TIMESTAMP
 - ▼ padata-type: pA-ENC-TIMESTAMP (2)
 - ▼ padata-value: 303da003020117a236043433f05e451883c424c3a59fad7fe347581a91eaec42b945fb26...
 - etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
 - ▼ cipher: 33f05e451883c424c3a59fad7fe347581a91eaec42b945fb265e6bb3838def8e178f861b...
 - ▶ Decrypted keytype 23 usage 1 using keytab principal Administrator@W2012R2-L6.BASE
 - patimestamp: 2020-04-22 14:19:23 (UTC)
 - pausec: 351183
 - ▼ PA-DATA pA-PAC-REQUEST
 - ▼ padata-type: pA-PAC-REQUEST (128)
 - ▼ padata-value: 3005a0030101ff
 - include-pac: True
 - ▼ req-body
 - Padding: 0
 - ▶ kdc-options: 40810010
 - ▼ cname
 - name-type: kRB5-NT-PRINCIPAL (1)
 - ▼ cname-string: 1 item
 - CNameString: administrator
 - realm: w2012r2-l6.base
 - ▼ sname
 - name-type: kRB5-NT-SRV-INST (2)
 - ▼ sname-string: 2 items
 - SNameString: krbtgt
 - SNameString: w2012r2-l6.base
 - till: 2037-09-13 02:48:05 (UTC)
 - rtime: 2037-09-13 02:48:05 (UTC)
 - nonce: 71702650
 - ▶ etype: 6 items
 - ▶ addresses: 1 item W2012R2-189<20>

The Authentication Service (AS) Exchange (Part3)

- ▼ **as-rep**
 - pvno: 5
 - msg-type: krb-as-rep (11) **AS-REP returns a TGT**
 - crealm: W2012R2-L6.BASE
 - ▼ cname
 - name-type: kRB5-NT-PRINCIPAL (1)
 - ▼ cname-string: 1 item
 - CNameString: Administrator
 - ▼ **ticket**
 - tko-vno: 5
 - realm: W2012R2-L6.BASE
 - ▼ sname
 - name-type: kRB5-NT-SRV-INST (2)
 - ▼ sname-string: 2 items
 - SNameString: krbtgt
 - SNameString: W2012R2-L6.BASE
 - ▶ **enc-part**
 - ▼ **enc-part**
 - etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
 - kvno: 1
 - ▼ **cipher: 656c0716f51d2c1de417b8c981b461178d1e90fa470ec81b17cecc9d1c2365635db726ff...**
 - ▶ Decrypted keytype 23 usage 3 using keytab principal Administrator@W2012R2-L6.BASE
 - ▼ **encASRepPart**
 - ▶ **key**
 - ▶ last-req: 1 item
 - nonce: 71702650
 - key-expiration: 2037-09-14 02:48:05 (UTC)
 - Padding: 0
 - ▶ flags: 40e10000
 - ▶ authtime: 2020-04-22 14:19:23 (UTC)
 - ▶ starttime: 2020-04-22 14:19:23 (UTC)
 - ▶ endtime: 2020-04-23 00:19:23 (UTC)
 - ▶ renew-till: 2020-04-29 14:19:23 (UTC)
 - srealm: W2012R2-L6.BASE
 - ▼ sname
 - name-type: kRB5-NT-SRV-INST (2)
 - ▼ sname-string: 2 items
 - SNameString: krbtgt
 - SNameString: W2012R2-L6.BASE
 - ▶ caddr: 1 item W2012R2-189<20>
 - ▶ encrypted-pa-data: 1 item

- encASRepPart mirrors:**
- * the ticket session key
- * other details of the ticket

The Client/Server Authentication (AP) Exchange (Part1)

- ▶ The AP-Exchange authenticates a client to a service
 - ▶ The client proves knowledge about the provides Ticket
 - ▶ It can be used directly for GSSAPI client to server authentication
 - ▶ But it can also be used to authenticate requests to the KDC
- ▶ AP-REQ provides a Ticket and an Authenticator
 - ▶ The Authenticator is encrypted with the ticket session key
 - ▶ The Authenticator contains the client principal of the ticket
 - ▶ It also contains the current time of the client
 - ▶ It may contain a Checksum in order to protect other fields
 - ▶ The GSSAPI-Checksum (0x8003) contains a negotiation structure
 - ▶ It may contain a random initiator subkey and sequence number
 - ▶ It may contain optional AuthorizationData
- ▶ AP-REP provides mutual authentication to the AP-Exchange
 - ▶ It is also encrypted with the ticket session key
 - ▶ That proves that the service as able to decrypt the ticket
 - ▶ It echoes the client time from the Authenticator
 - ▶ It may contain a random acceptor subkey and sequence number

The Client/Server Authentication (AP) Exchange (Part3)

- Security Blob: a181b53081b2a0030a0100a10b06092a864882f712010202a2819d04819a60819706092a...
- GSS-API Generic Security Service Application Program Interface
 - Simple Protected Negotiation
 - negTokenTarg
 - negResult: accept-completed (0)
 - supportedMech: 1.2.840.48018.1.2.2 (MS KRB5 - Microsoft Kerberos 5)
 - responseToken: 60819706092a864886f71201020202006f8187308184a003020105a10302010fa2783076...
 - krb5_blob: 60819706092a864886f71201020202006f8187308184a003020105a10302010fa2783076...
 - KRB5 OID: 1.2.840.113554.1.2.2 (KRB5 - Kerberos 5)
 - krb5_tok_id: KRB5_AP_REP (0x0002)
 - Kerberos
 - ap-rep
 - pvno: 5
 - msg-type: krb-ap-rep (15) **AP-REP for GSSAPI/Kerberos-Authentication**
 - enc-part
 - etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
 - cipher: 1337174a7c899aa478e228696fa4573b4ea387d87901b8e641c7849344fd284398bf366a...
 - Decrypted keytype 18 usage 12 using learnt encTicketPart_key in frame 288 (id=288.1)
 - encAPRepPart
 - ctime: 2020-04-22 14:19:23 (UTC)
 - cusec: 3
 - subkey
 - Learnt encAPRepPart_subkey keytype 18 (id=309.1) (13e1ab2f...)
 - keytype: 18
 - keyvalue: 13e1ab2f087262325c46f7c4b2ce7a0634fb6afd98a1bff52be59ad10f3bb146
 - seq-number: 122357393
 - Provides learnt encAPRepPart_subkey in frame 309 keytype 18 (id=309.1 same=0) (13e1ab2f...)
 - Used learnt encTicketPart_key in frame 288 keytype 18 (id=288.1 same=2) (aac249b...)

The Ticket-Granting Service (TGS) Exchange (Part1)

- ▶ The TGS-Exchange allows the client/user to tickets for server
 - ▶ If a client wants to access a service it needs a service ticket
 - ▶ The client can use its TGT to get a service ticket
- ▶ TGS-REQ provides an AP-REQ and information about the service
 - ▶ The PA-TGS-REQ contains an AP-REQ to authenticate the request
 - ▶ The service principal is given in the body.
- ▶ TGS-REP typically returns a service ticket
 - ▶ The content of the entTicketPart is only known to the service
 - ▶ encTGSRepPart is encrypted with the TGT session key
 - ▶ encTicketPart and encTGSRepPart contain the same ticket session key
 - ▶ The ticket session key is a shared secret between client and server
- ▶ TGS-REQ can also return a referral TGT
 - ▶ The service principal may be located in different realm
 - ▶ A referral TGT looks like krbtgt/SERVER.REALM@CLIENT.REALM
 - ▶ The client retries at SERVER.REALM

The Ticket-Granting Service (TGS) Exchange (Part2)

```
▼ tgs-req
  pvno: 5
  msg-type: krb-tgs-req (12)
  ▼ padata: 2 items
    ▼ PA-DATA pA-TGS-REQ
      ▼ padata-type: pA-TGS-REQ (1)
        ▼ padata-value: 6e82053e3082053aa003020105a10302010ea20703050000000000a38204816182041
          ▼ ap-req
            pvno: 5
            msg-type: krb-ap-req (14) AP-REQ within a TGS-REQ
            Padding: 0
            ap-options: 00000000 using the TGT from the AS-REP
            ticket
            ▼ authenticator
              etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
              ▼ cipher: 7962f94008b22c4f82132ce6f45b5080138c2c660935c529aa35842a6b8921b48ea
                ▼ Decrypted keytype 18 usage 7 using learnt encTicketPart_key in frame 276
                  authenticator
                    authenticator-vno: 5
                    crealm: W2012R2-L6.BASE
                    ▼ cname
                      name-type: kRB5-NT-PRINCIPAL (1)
                      ▼ cname-string: 1 item
                        CNameString: Administrator
                    ▼ cksum
                      cksumtype: cKSUMTYPE-RSA-MD5 (7)
                      checksum: 2e907aefb7c2e901ce1db2e1a26c2557
                      cusec: 1
                      ctime: 2020-04-22 14:19:23 (UTC)
                      seq-number: 71702603
            ► PA-DATA pA-PAC-OPTIONS
          ▼ req-body
            Padding: 0
            kdc-options: 40810000
            realm: W2012R2-L6.BASE
            ▼ sname
              name-type: kRB5-NT-SRV-INST (2)
              ▼ sname-string: 2 items
                SNameString: cifs
                SNameString: w2012r2-188.w2012r2-l6.base
            till: 2037-09-13 02:48:05 (UTC)
            nonce: 71702603
            ► etype: 5 items
            ► enc-authorization-data
```

The Ticket-Granting Service (TGS) Exchange (Part3)

- ▼ tgs-rep
 - pvno: 5
 - msg-type: krb-tgs-rep (13) **TGS-REP returns a Service Ticket**
 - crealm: W2012R2-L6.BASE
 - ▼ cname
 - name-type: kRB5-NT-PRINCIPAL (1)
 - ▼ cname-string: 1 item
 - CNameString: Administrator
 - ▶ ticket
 - ▼ enc-part
 - etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
 - ▼ cipher: f9514721510e74ab6aa03b9a630f088c3ddf30e1fc8f8ca5321588d0022df6f03870
 - ▶ Decrypted keytype 18 usage 8 using learnt encTicketPart_key in frame 276
 - ▼ encTGSRepPart
 - ▶ key
 - ▶ last-req: 1 item
 - nonce: 71702603
 - Padding: 0
 - ▶ flags: 40a50000
 - authtime: 2020-04-22 14:19:23 (UTC)
 - starttime: 2020-04-22 14:19:23 (UTC) **encTGSRepPart mirrors:**
 - endtime: 2020-04-23 00:19:23 (UTC) *** the ticket session key**
 - renew-till: 2020-04-29 14:19:23 (UTC) *** other details of the ticket**
 - srealm: W2012R2-L6.BASE
 - ▼ sname
 - name-type: kRB5-NT-SRV-INST (2)
 - ▼ sname-string: 2 items
 - SNameString: cifs
 - SNameString: w2012r2-188.w2012r2-l6.base
 - ▶ encrypted-pa-data: 2 items

Full GSSAPI-SPNEGO Kerberos Authentication

266	16:19:23,633714	172.31.99.189	172.31.9.188	KRB5	AS-REQ	
267	16:19:23,635954	172.31.9.188	172.31.99.189	KRB5	KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED	
274	16:19:23,639049	172.31.99.189	172.31.9.188	KRB5	AS-REQ	Get TGT
276	16:19:23,640708	172.31.9.188	172.31.99.189	KRB5	AS-REP	
285	16:19:23,643592	172.31.99.189	172.31.9.188	KRB5	TGS-REQ	Get Service Ticket
288	16:19:23,651244	172.31.9.188	172.31.99.189	KRB5	TGS-REP	
297	16:19:23,654939	172.31.99.189	172.31.9.188	KRB5	TGS-REQ	Get Delegation TGT
300	16:19:23,656231	172.31.9.188	172.31.99.189	KRB5	TGS-REP	
307	16:19:23,657824	172.31.99.189	172.31.9.188	SMB2	Session Setup Request	GSSAPI/SPNEGO
309	16:19:23,659965	172.31.9.188	172.31.99.189	SMB2	Session Setup Response	

- ▶ Client to KDC
 - ▶ The client gets a Ticket Granting Ticket (TGT) via the AS-Exchange
 - ▶ The client uses the TGT for the TGS-Exchange to get a Service Ticket
 - ▶ The Service Ticket may contain OK-AS-DELEGATE
 - ▶ If so the client uses the initial TGT to get a fresh delegation TGT
- ▶ Client to Service (e.g. SMB server)
 - ▶ The client uses the Service ticket for the GSSAPI AP-REQ
 - ▶ The GSSAPI-Checksum contains the delegation TGT
 - ▶ The delegation is exclusive for the specific server
 - ▶ The delegation ticket session key needs to be isolated
 - ▶ The server returns an AP-REP with an acceptor subkey
 - ▶ The acceptor subkey is the base for signing/encryption

S4U, FAST, Compound Identity

- ▶ S4U2Self/S4U2Proxy ([MS-SFU]):
 - ▶ Allow the usage of Kerberos of an impersonated user
 - ▶ Typically when the frontend authentication didn't use Kerberos
- ▶ Flexible Authentication Secure Tunneling (FAST) (RFC6113):
 - ▶ Protects the AS-REQ with a relative weak user password
 - ▶ The protection is based on the strong machine account password
 - ▶ It prevents offline dictionary attacks
 - ▶ It allows Compound Identities to be used
 - ▶ The PAC within service tickets contains a DEVICE_INFO element
 - ▶ The DEVICE_INFO contains a subset of the machine accounts LOGON_INFO
 - ▶ The service sees from on which device the client was authenticated

S4U2Self Request (Part1)

```
▼ Tgs-req
  pvno: 5
  msg-type: krb-tgs-req (12)
  ▼ padata: 4 items
    ▼ PA-DATA pA-TGS-REQ
      ▼ padata-type: pA-TGS-REQ (1)
        ▼ padata-value: 6e8205b1308205ada003020105a10302010ea2070305000000000a38204ca618204c630...
          ▼ ap-req
            pvno: 5
            msg-type: krb-ap-req (14)
            Padding: 0
            ap-options: 00000000
            ticket
            ▼ authenticator
              etype: eTYPE-ARCFOUR-HMAC-MD5 (23)
              ▼ cipher: 15060a7e25ee362cf53e7f2104c9e4b485acf56e172754542a32795119e149b9578660cbe...
                Decrypted keytype 23 usage 7 using learnt encTicketPart_key in frame 548 (id=548.1 same=2)
                ▼ authenticator
                  authenticator-vno: 5
                  crealm: S2-W2012-L4.S1-W2012-L4.W2012R2-L4.BASE
                  ▼ cname
                    name-type: kRB5-NT-PRINCIPAL (1)
                    ▼ cname-string: 1 item
                      CNameString: UB1604-165$ S4U2Self Request uses the server's TGT
                  ▼ cksum
                    cksumtype: cKSUMTYPE-RSA-MD5 (7)
                    checksum: 519fc74e4afe7cbbad71ef27b1bdf52
                    cusec: 1954
                    ctime: 2020-01-27 12:58:49 (UTC)
                    ▼ subkey
                  ► PA-DATA pA-FX-FAST
                ► PA-DATA pA-FOR-X509-USER
                  ▼ padata-type: pA-FOR-X509-USER (130)
                    ▼ padata-value:
                      ▼ user-id
                        nonce: 617889277
                        ▼ cname
                          name-type: kRB5-NT-ENTERPRISE-PRINCIPAL (10)
                          ▼ name-string: 1 item
                            KerberosString: somebla2@BLA2
                          crealm: BLA2.BASE
                          Padding: 0
                          options: 20000000
                        ► checksum
                      ► PA-DATA pA-FOR-USER
                        ▼ padata-type: pA-FOR-USER (129)
                          ▼ padata-value:
                            ▼ name
                              name-type: kRB5-NT-ENTERPRISE-PRINCIPAL (10)
                              ▼ name-string: 1 item
                                KerberosString: somebla2@BLA2
                              realm: BLA2.BASE
                            ► cksum
                              auth: Kerberos
                      ▼ req-body
```

PA-FOR-X509-USER:
* Modern way for S4U2Self
* Missing in Samba KDCs
* A client principal or X509-Certificate can be used to identify the user
* Enterprise Principal are supported by Windows KDCs

PA-FOR-USER:
* Legacy way for S4U2Self
* Also supported in Samba KDCs
* Can only specify the client principal
* Enterprise Principals doesn't seem to work against Windows KDCs

S4U2Self Request (Part2)

	411	KRB5	AS-REQ		
	412	KRB5	KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED		
S2-W2012-L4...	422	KRB5	AS-REQ	TGT for UB1604-165\$@S2-W2012-L4.S1-W2012-L4.W2012R2-L4.BASE	
	425	KRB5	AS-REP		
	433	KRB5	AS-REQ		AS-REQ for somebla2@BLA2@S2-W2012-L4...
	434	KRB5	KRB Error: KDC_ERR_WRONG_REALM		Referred to bla.base
BLA.BASE	449	KRB5	AS-REQ		AS-REQ for somebla2@BLA2@BLA.BASE
	450	KRB5	KRB Error: KDC_ERR_WRONG_REALM		Referred to bla2.base
BLA2.BASE	466	KRB5	AS-REQ		AS-REQ for somebla2@BLA2@BLA2.BASE
	467	KRB5	KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED		=> BLA2.BASE knows it
	475	KRB5	TGS-REQ	Request: krbtgt/BLA2.BASE@S2-W2012-L4...	
S2-W2012-L4...	479	KRB5	TGS-REP		=> Referral TGT: krbtgt/S1-W2012-L4...@S2-W2012-L4...
	501	KRB5	TGS-REQ	Request: krbtgt/BLA2.BASE@S1-W2012-L4...	
S1-W2012-L4...	505	KRB5	TGS-REP		=> Referral TGT: krbtgt/W2012R2-L4...@S1-W2012-L4...
	522	KRB5	TGS-REQ	Request: krbtgt/BLA2.BASE@W2012R2-L4.BASE	
	527	KRB5	TGS-REQ		=> Proxied from RODC to RWDC
W2012R2-L4...	529	KRB5	TGS-REP		=> Back from RWDC to RODC
	535	KRB5	TGS-REP		=> Referral TGT: krbtgt/BLA.BASE@W2012R2-L4.BASE
	544	KRB5	TGS-REQ	Request: krbtgt/BLA2.BASE@BLA.BASE	
BLA.BASE	548	KRB5	TGS-REP		=> Final-Referral TGT: krbtgt/BLA2.BASE@BLA.BASE
	556	KRB5	TGS-REQ	S4U2Self for host/UB1604-165.S2-W2012-L4...@BLA2.BASE	
BLA2.BASE	560	KRB5	TGS-REP		=> Referral TGT: krbtgt/BLA.BASE@BLA2.BASE S4U2Self-PAC
	568	KRB5	TGS-REQ	S4U2Self for host/UB1604-165.S2-W2012-L4...@BLA.BASE	
BLA.BASE	574	KRB5	TGS-REP		=> Referral TGT: krbtgt/W2012R2-L4...@BLA.BASE S4U2Self-PAC
	582	KRB5	TGS-REQ	S4U2Self for host/UB1604-165.S2-W2012-L4...@W2012R2-L4.BASE	
	587	KRB5	TGS-REQ		=> Proxied from RODC to RWDC
W2012R2-L4...	589	KRB5	TGS-REP		=> Back from RWDC to RODC
	595	KRB5	TGS-REP		=> Referral TGT: krbtgt/S1-W2012-L4...@W2012R2-L4.BASE S4U2Self-PAC
	604	KRB5	TGS-REQ	S4U2Self for host/UB1604-165.S2-W2012-L4...@S1-W2012-L4...	
S1-W2012-L4...	608	KRB5	TGS-REP		=> Referral TGT: krbtgt/S2-W2012-L4...@S1-W2012-L4... S4U2Self-PAC
	616	KRB5	TGS-REQ	S4U2Self for host/UB1604-165.S2-W2012-L4...@S2-W2012-L4...	
S2-W2012-L4...	620	KRB5	TGS-REP		S4U2Self Ticket for somebla2@BLA2@BLA2.BASE

AS-REQ with FAST

```
msg-type: krb-as-req (10)
└─ padata: 1 item
  └─ PA-DATA pA-FX-FAST
    └─ padata-type: pA-FX-FAST (136)
      └─ padata-value: a082070830820704a082056e3082056aa003020101a18205610482055d6e820559308205...
        └─ armored-data
          └─ armor
            └─ armor-type: fx-FAST-ARMOR-AP-REQUEST (1)
              └─ armor-value: 6e82055930820555a803020105a10302010ea2070305000000000a38204906182048c30...
                └─ ap-req
                  pvno: 5
                  msg-type: krb-ap-req (14)
                  Padding: 0
                  ap-options: 00000000
                  ticket
                  authenticator
                    etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                    cipher: 45242c71a01d99d8a67027cb116b462e85e6240f1cea87d93ea60a463b8fc7eded981ca...
                    Decrypted keytype 18 usage 11 using learnt encTicketPart_key in frame 143 (id=143.1 same=20) (e834a91)
                    authenticator
                      authenticator-vno: 5
                      crealm: W2012R2-L6.BASE
                      cname
                        name-type: kRBS-NT-PRINCIPAL (1)
                        cname-string: 1 item
                          CNameString: W2012R2-189$
                        cusec: 36
                        ctime: 2020-04-28 09:25:32 (UTC)
                    subkey
                    seq-number: 0
                req-checksum
                enc-fast-req
                  etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                  cipher: 121f6837a8d82aa3cf743030b6f361b381f4d158154924fa8f797b10f636e99cdd1dde...
                  Derived KrbFastReq_FAST_armorKey keytype 18 (id=730.3) (25ff154b...)
                  Decrypted keytype 18 usage 51 using derived KrbFastReq_FAST_armorKey in frame 730 (id=730.3 same=0) (25ff154b)
                  [Expert Info (Chat/Security): Decrypted keytype 18 usage 51 using derived KrbFastReq_FAST_armorKey in frame 730 (id=730.3 same=0) (25ff154b)]
                  [Expert Info (Chat/Security): Used keymap=all_keys num_keys=181 num_tries=0]
                  [Expert Info (Chat/Security): SRC1 learnt authenticator_subkey in frame 730 keytype 18 (id=730.2 same=0) (e834a91)]
                  [Expert Info (Chat/Security): SRC2 learnt encTicketPart_key in frame 143 keytype 18 (id=143.1 same=20) (e834a91)]
                  Padding: 0
                  fast-options: 00000000
                  padata: 3 items
                    └─ PA-DATA pA-ENCRYPTED-CHALLENGE
                      └─ padata-type: pA-ENCRYPTED-CHALLENGE (138)
                        └─ padata-value: 3041a093020112a23a0438839f326a92a4ab6604a2c817f25a13a8f8774db09b52e2d77f...
                          etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                          cipher: 839f326a92a4ab6604a2c817f25a13a8f8774db09b52e2d77f48f73a20cdbc65c3307587...
                          Derived clientchallengearmor keytype 18 (id=730.4) (e8c09569...)
                          Decrypted keytype 18 usage 54 using derived clientchallengearmor in frame 730 (id=730.4 same=0) (e8c09569)
                          [Expert Info (Chat/Security): Decrypted keytype 18 usage 54 using derived clientchallengearmor in frame 730 (id=730.4 same=0) (e8c09569)]
                          [Expert Info (Chat/Security): Used keymap=all_keys num_keys=181 num_tries=134]
                          [Expert Info (Chat/Security): SRC1 derived KrbFastReq_FAST_armorKey in frame 730 keytype 18 (id=730.3 same=0) (25ff154b)]
                          [Expert Info (Chat/Security): SRC2 keytab principal Administrator@W2012R2-L6.BASE keytype 23 (id=23.1 same=0) (e834a91)]
                          patimestamp: 2020-04-28 09:25:32 (UTC)
                          pausec: 264163
                        └─ PA-DATA pA-PAC-REQUEST
                          └─ PA-DATA pA-PAC-OPTIONS
                            req-body
                            Padding: 0
```

AS-REQ with a FAST armor:
*** using the machine account GTG**

FastReq is encrypted with the derived FAST_armor_key

The Challenge is encrypted with a derived key of:
*** FAST_armorKey**
*** administrator password key**

TGS-REQ with FAST, Compound Identity

```
▼ tgs-req
  pvno: 5
  msg-type: krb-tgs-req (12)
  ▼ padata: 2 items
    ▼ PA-DATA pA-TGS-REQ
      ▼ padata-type: pA-TGS-REQ (1)
        ▼ padata-value: 6e8205a5308205a1a003020105a10302010ea2070305000000000a38204b9618204b530...
          ▼ ap-req
            pvno: 5
            msg-type: krb-ap-req (14) TGS-REQ with a user TGT
            Padding: 0
            ▶ ap-options: 00000000
            ▶ ticket
            ▶ authenticator
          ▼ PA-DATA pA-FX-FAST
            ▼ padata-type: pA-FX-FAST (136)
              ▼ padata-value: a082066730820663a08205733082056fa003020101a1820566048205626e82055e308205...
                ▼ armored-data
                  ▼ armor
                    armor-type: fx-FAST-ARMOR-AP-REQUEST (1)
                    ▼ armor-value: 6e82055e3082055aa003020105a10302010ea2070305000000000a38204906182048c30...
                      ▼ ap-req
                        pvno: 5
                        msg-type: krb-ap-req (14) Armored with a machine account TGT:
                        Padding: 0
                        ▶ ap-options: 00000000
                        ▶ ticket
                        ▶ authenticator
                      ▶ req-checksum
                    ▼ enc-fast-req
                      etype: eTYPE-AES256-CTS-HMAC-SHA1-96 (18)
                      ▼ cipher: bc18410514074ca4e15a236f7c43f5e4e8e4cb809865d6dbf1212e61c04ac1116c901a24...
                        ▼ Derived KrbFastReq_FAST_armorKey keytype 18 (id=743.5) (02f51922...)
                          ▶ [Expert Info (Chat/Security): Derived KrbFastReq_FAST_armorKey keytype 18 (id=743.5) (02f51922...)]
                          ▶ [Expert Info (Chat/Security): SRC1 learnt authenticator_subkey in frame 743 keytype 18]
                          ▶ [Expert Info (Chat/Security): SRC2 learnt encTicketPart_key in frame 143 keytype 18 (id=743.5)]
                        ▼ Derived KrbFastReq_explicitArmorKey keytype 18 (id=743.6) (449a429e...)
                          ▶ [Expert Info (Chat/Security): Derived KrbFastReq_explicitArmorKey keytype 18 (id=743.6) (449a429e...)]
                          ▶ [Expert Info (Chat/Security): SRC1 derived KrbFastReq_FAST_armorKey in frame 743 keytype 18]
                          ▶ [Expert Info (Chat/Security): SRC2 learnt authenticator_subkey in frame 743 keytype 18]
                        ▶ Decrypted keytype 18 usage 51 using derived KrbFastReq_explicitArmorKey in frame 743 (id=743.6)
                        Padding: 0
                        ▶ fast-options: 00000000
                        ▶ padata: 1 item
                        ▼ req-body
                          Padding: 0
                          ▶ kdc-options: 40810000
                          ▶ realm: W2012R2-L6.BASE
                          ▶ sname
                          ▶ till: 2037-09-13 02:48:05 (UTC)
                          ▶ nonce: 2000422842
                          ▶ etype: 5 items
                    ▶ req-body
```

*** used for the FAST_armorKey**

The explicitArmorKey combines:
*** FAST_armorKey**
*** PA_TGS_REQ authenticator_subkey**

This forms the Compound Identity

Using S4U2Self in winbindd (Part1)

- ▶ winbindd provides group membership information for users
 - ▶ For tools like 'id', 'wbinfo -i', 'wbinfo -user-sids' and others
- ▶ Typically winbindd gets the Authorization Token via authentication
 - ▶ Either via netr_LogonSamLogon vor NTLM
 - ▶ Or via the "PAC Logon Info" element of the Kerberos service ticket
- ▶ 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 use cases.

Using S4U2Self in winbindd (Part2)

- ▶ winbindd tries to get the 'tokenGroups' of the user object via LDAP
 - ▶ 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 ([MS-SFU]):
 - ▶ It allows a service to ask a KDC for a service ticket for a given user.
 - ▶ From a given SID we can only lookup the NT4-Names of the account
 - ▶ We need to use Enterprise-Principals like, user@DOMAIN1@DOMAIN2.EXAMPLE.COM
 - ▶ Sadly there're quite some bugs in current versions of MIT Kerberos and Heimdal (both client and server)

krb5_{init,tkt}_creds_step() APIs (Part1)

- ▶ The usage of S4U2Self with trusted domains/realms is complex:
 - ▶ The example showed that a lot of transiting KDCs must be reached
 - ▶ We should use site-aware KDCs (domain controllers) for all steps
- ▶ Currently winbindd prepares a custom krb5.conf
 - ▶ It fills in the KDC ip addresses for the default realm
 - ▶ But it's not possible to know all hops before calling krb5 functions
- ▶ It would be good if the Kerberos libraries would only do Kerberos
 - ▶ We can do (site-aware) DC lookups much more efficient.
 - ▶ It would be good to do the networking interaction on our own.
 - ▶ We should do parallel async requests in order to avoid long timeouts.

krb5_{init,tkt}_creds_step() APIs (Part2)

- ▶ There are step APIs, which allow doing things on our own:
 - ▶ They just generate Request PDUs and return the designated realm
 - ▶ The result from a KDC should be passed in the next round
 - ▶ This continues as long as the CONTINUE flag is returned.

```
krb5_error_code
krb5_init_creds_step(krb5_context context,
                    krb5_init_creds_context ctx,
                    krb5_data *in,
                    krb5_data *out,
                    krb5_realm *realm,
                    unsigned int *flags); /* ..._CONTINUE flag */

krb5_error_code
krb5_tkt_creds_step(krb5_context context,
                   krb5_tkt_creds_context ctx,
                   krb5_data *in,
                   krb5_data *out,
                   krb5_realm *realm,
                   unsigned int *flags); /* ..._CONTINUE flag */
```

- ▶ It's ideal for us, but they are sadly not feature complete:
 - ▶ MIT doesn't allow S4USelf and S4U2Proxy via these APIs
 - ▶ Heimdal has only an unexported krb5_init_creds_step() function
 - ▶ There are work in progress patches for MIT and Heimdal

krb5_{init,tkt}_creds_step() APIs (Part3)

- ▶ For Samba we need to have async non-blocking functions:
 - ▶ Async programming in Samba use the tevent_req infrastructure
- ▶ We abstract the network details in 'struct smb_krb5_network':
 - ▶ This allows us to use different strategies
 - ▶ winbindd may use a different strategie than cmdline tools
 - ▶ It also avoids linking dependencies.

```
struct tevent_req *smb_krb5_network_transaction_send(
    TALLOCTX *mem_ctx,
    struct tevent_context *ev,
    struct smb_krb5_network *net_ctx,
    const char *realm,
    uint32_t ds_flags, /* netr_DsRGetDCName_flags */
    const DATA_BLOB req_blob);
NTSTATUS smb_krb5_network_transaction_recv(struct tevent_req *req,
    TALLOCTX *mem_ctx,
    DATA_BLOB *rep_blob);
```

krb5_{init,tkt}_creds_step() APIs (Part4)

- ▶ In combination we'll have the following low level functions
 - ▶ They build the foundation for more complex things
 - ▶ We'll have only one GENSEC gsskrb5 implementation
 - ▶ S4U2Self, S4U2Proxy can be implemented on top

```
struct tevent_req *smb_krb5_init_creds_get_send(  
    TALLOC_CTX *mem_ctx,  
    struct tevent_context *ev,  
    struct smb_krb5_network *net_ctx,  
    krb5_context krb5_ctx,  
    krb5_init_creds_context init_creds_ctx);  
NTSTATUS smb_krb5_init_creds_get_recv(struct tevent_req *req);  
  
struct tevent_req *smb_krb5_tkt_creds_get_send(  
    TALLOC_CTX *mem_ctx,  
    struct tevent_context *ev,  
    struct smb_krb5_network *net_ctx,  
    krb5_context krb5_ctx,  
    krb5_tkt_creds_context tkt_creds_ctx);  
NTSTATUS smb_krb5_tkt_creds_get_recv(struct tevent_req *req);
```

Highlevel Samba APIs (Part1)

- ▶ At the application level we'll have some simple functions
 - ▶ The most common thing is a login into the local machine
 - ▶ This would be used for pam_winbind with Kerberos
 - ▶ We use the common cli_credentials abstraction for user and machine

APIs for a local Kerberos login, e.g. in winbindd:

```
struct tevent_req *smb_krb5_kinit_login_send(TALLOC_CTX *mem_ctx,
                                             struct tevent_context *ev,
                                             struct loadparm_context *lp_ctx,
                                             struct cli_credentials *user_creds,
                                             const char *machine_spn,
                                             struct cli_credentials *machine_creds,
                                             struct gensec_settings *gensec_settings,
                                             struct auth4_context *auth_context);

NTSTATUS smb_krb5_kinit_login_recv(struct tevent_req *req,
                                 TALLOC_CTX *mem_ctx,
                                 struct auth_session_info **_session_info);

NTSTATUS smb_krb5_kinit_login(struct loadparm_context *lp_ctx,
                             struct cli_credentials *user_creds,
                             const char *machine_principal,
                             struct cli_credentials *machine_creds,
                             struct gensec_settings *gensec_settings,
                             struct auth4_context *auth_context,
                             TALLOC_CTX *mem_ctx,
                             struct auth_session_info **_session_info);
```

Highlevel Samba APIs (Part2)

- ▶ In order to use S4U2Self we'll have a simple function
 - ▶ It takes the machine account credentials
 - ▶ And the user principal for the impersonated user
 - ▶ It creates a special cli_credentials structure
 - ▶ This can be used as any other cli_credentials object
 - ▶ Typically as user_creds for smb_krb5_kinit_login()

APIs for S4U2Self, e.g. in winbindd:

```
NTSTATUS cli_credentials_s4u_upn_creds(TALLOC_CTX *mem_ctx,
                                     struct cli_credentials *machine_creds,
                                     const char *machine_spn,
                                     const char *user_upn,
                                     struct cli_credentials **_s4u_user_creds);
```

Highlevel Samba APIs (Part3)

- ▶ In order to use FAST for Compound Identity we'll have a simple function
 - ▶ It takes the machine account credentials
 - ▶ And the user credentials
 - ▶ It creates a special cli_credentials structure
 - ▶ This can be used as any other cli_credentials object
 - ▶ Typically as user_creds for smb_krb5_kinit_login()

APIs for FAST, CompoundIdentity, e.g. in winbindd:

```
NTSTATUS cli_credentials_compound_creds(TALLOC_CTX *mem_ctx,  
                                     struct cli_credentials *machine_creds,  
                                     struct cli_credentials *user_creds,  
                                     struct cli_credentials **_compound_user_creds);
```


Challenges of adding new Features (Part1)

- ▶ Adding the missing features to upstream MIT and Heimdal
 - ▶ We need to do quite a bit as research to find how the protocols works
 - ▶ New features to be added for Samba should be complete
 - ▶ Libraries with half implemented features are useless
 - ▶ They would make the code in Samba way too complex to work with
 - ▶ We would not be able to test all combinations!
 - ▶ We found more than once: untested code is broken code!
- ▶ It's also very time consuming to discuss the correct APIs
 - ▶ Upstream MIT/Heimdal may reject changes, which use legacy concepts
- ▶ Currently we need to handle 3 different Kerberos libraries:
 - ▶ External MIT
 - ▶ External Heimdal
 - ▶ Internal Heimdal (imported copy of upstream from 2011)

Challenges of adding new Features (Part2)

- ▶ Syncing the internal Heimdal with upstream
 - ▶ This would make things much easier for new features
 - ▶ It would bring support for FAST, which would also help the AD DC
 - ▶ But it comes with a risk of breaking AD DC setups
- ▶ We currently only have very limited Kerberos testing
 - ▶ We only do highlevel tests with gssapi usage
 - ▶ We have some special tests abusing send_to_kdc hooks
 - ▶ The interaction with send_to_kdc depends on implementation details
 - ▶ We don't have real protocol detail testing

Protocol Testing with Python

- ▶ We recently added infrastructure for protocol tests:
 - ▶ This is based on pyasn1 and cryptography.hazmat
 - ▶ It allows testing each bit in the protocol
 - ▶ Very similar to our DCERPC raw_protocol testing and smbtorture
- ▶ We have just some simple tests
 - ▶ But it's relatively easy to add more detailed tests
 - ▶ They will make it much easier to upgrade Heimdal safely
 - ▶ It will also add confidence when making the MIT KDC production ready
- ▶ Researching new features
 - ▶ Protocol tests help finding details about S4U2Self or FAST
 - ▶ Much easier than prototyping than the C libraries
 - ▶ Wireshark Kerberos decryption also helps a lot
 - ▶ wireshark/master (~3.3.0) from yesterday has a much improved kerberos dissector

Questions?

- ▶ Stefan Metzmacher, metze@samba.org
- ▶ <https://www.sernet.com>
- ▶ <https://samba.plus>

Slides: <https://samba.org/~metze/presentations/2020/SambaXP/>