

# Improving DCERPC Security

[https://wiki.samba.org/index.php/DCERPC\\_Hardening](https://wiki.samba.org/index.php/DCERPC_Hardening)

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(This is rev0)

# Agenda

- ▶ The badlock related bugs
- ▶ Scope of the urgent changes
- ▶ What is DCERPC?
- ▶ Existing Hardening
- ▶ Remaining Problems
- ▶ Proposed Solutions
- ▶ Summary/Status
- ▶ Questions?

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- ▶ I found new problems day after day
- ▶ About 20 problem classes (mostly denial of service and man in the middle)
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# CVE-2016-2110: NTLMSSP problems

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- ▶ After a while I found that NTLMSSP flags, e.g. NTLMSSP\_SIGN/SEAL can be removed by a man in the middle without noticing
- ▶ This has implications on encrypted LDAP traffic
- ▶ A bit of research revealed that Microsoft already implemented downgrade detection into NTLMSSP when using NTLMv2
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- ▶ The problem with this was that any domain member was able to ask the domain controller for NTLM session keys of authentication sessions of all other domain members.
- ▶ The protection mechanism relies on NTLMv2 being used only via NTLMSSP
- ▶ During the research it turned out that the problems in Samba were even worse
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- ▶ This is required in order to prevent Kerberos replay attacks
- ▶ It was required to fix these things in the LDAP server as well as in our two LDAP client libraries
- ▶ At the same time we improved the consistency of behaviors especially regarding the usage of configuration options
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- ▶ For ldaps:// it only applies to tools like samba-tool, ldbsearch, ldbedit and other ldb tools
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## Scope of the urgent changes

- ▶ In order to prevent the man in the middle attacks it was required to change the (default) behavior for some protocols.
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# What is DCE-RPC?

- ▶ Distributed Computing Environment / Remote Procedure Calls
  - ▶ It is an infrastructure to call a function on a remote server
  - ▶ "remote" is connected via some kind of socket (tcp/ip, named pipes, ...)
- ▶ As development environment
  - ▶ Function stubs are typically autogenerated from an Interface Definition Language (IDL)
- ▶ As network protocol defines how:
  - ▶ marshalling of payloads work - transfer syntax (NDR/NDR64)
  - ▶ marshalling of PDUs
  - ▶ PDUs are ordered
  - ▶ authentication and encryption works
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# Wireshark DCERPC (BIND)

## ▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Bind, Fragment:

- Version: 5
- Version (minor): 0
- Packet type: Bind (11)
- ▶ Packet Flags: 0x07
- ▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)
- Frag Length: 198
- Auth Length: 74
- Call ID: 1
- Max Xmit Frag: 5840
- Max Recv Frag: 5840
- Assoc Group: 0x00000000
- Num Ctx Items: 2
- ▶ Ctx Item[1]: Context ID:0, LSARPC, 32bit NDR
- ▶ Ctx Item[2]: Context ID:1, LSARPC, Bind Time Feature Negotiation
- Auth type: SPNEGO (9)
- Auth level: Packet integrity (5)
- Auth pad len: 0
- Auth Rsvd: 0
- Auth Context ID: 1
- ▶ GSS-API Generic Security Service Application Program Interface

# Existing DCERPC Hardening (PFC\_SUPPORT\_HEADER\_SIGN)

- ▶ GSS-API based authentication is used
  - ▶ NTLMSSP, KRB5, SPNEGO
  - ▶ A custom security provider for the NETLOGON service
  - ▶ `gss_wrap_iov()` is required to support header signing
- ▶ MS-RPCE 2.2.2.3 PFC\_SUPPORT\_HEADER\_SIGN Flag.
  - ▶ Same value as PFC\_PENDING\_CANCEL
  - ▶ This flag can be negotiated in the Bind/BindAck exchange
  - ▶ On Windows and modern Samba installations all security providers support it.
  - ▶ It protects the header fields of DCERPC Request/Response PDUs incl. the `sec_trailer`.

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# Wireshark DCERPC PFC\_SUPPORT\_HEADER\_SIGN

```
Version: 5
Version (minor): 0
Packet type: Bind (11)
▼ Packet Flags: 0x07
  0... .... = Object: Not set
  .0.. .... = Maybe: Not set
  ..0. .... = Did Not Execute: Not set
  ...0 .... = Multiplex: Not set
  .... 0... = Reserved: Not set
  .... .1.. = Cancel Pending: Set PFC_SUPPORT_HEADER_SIGN
  .... ..1. = Last Frag: Set
  .... ...1 = First Frag: Set
▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)
  Frag Length: 198
  Auth Length: 74
  Call ID: 1
  Max Xmit Frag: 5840
  Max Recv Frag: 5840
  Assoc Group: 0x00000c58
  Num Ctx Items: 2
▶ Ctx Item[1]: Context ID:0, LSARPC, 32bit NDR
▶ Ctx Item[2]: Context ID:1, LSARPC, Bind Time Feature Negotiation
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# Existing DCERPC hardening (Verification Trailer)

- ▶ MS-RPCE 2.2.2.13 Verification Trailer
  - ▶ A hidden structure injected at the end of the DCERPC Request stub data
  - ▶ Identified by a 8 byte magic value (0x8a, 0xe3, 0x13, 0x71, 0x02, 0xf4, 0x36, 0x71)
  - ▶ It contains an array of optional command structures
- ▶ `rpc_sec_vt_bitmask` protects the PFC\_SUPPORT\_HEADER\_SIGN negotiation
- ▶ `rpc_sec_vt_header2` protects the header fields if PFC\_SUPPORT\_HEADER\_SIGN is not available
- ▶ `rpc_sec_vt_pcontext` protects the negotiation of the presentation context (Interfaceld/TransferSyntax)

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# Wireshark DCERPC Request PDU

- ▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Request, Fragment: Single
  - Version: 5
  - Version (minor): 0
  - Packet type: Request (0)
  - ▶ Packet Flags: 0x03
  - ▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)
    - Frag Length: 240
    - Auth Length: 16
    - Call ID: 2
    - Alloc hint: 188
    - Context ID: 0
    - Opnum: 6
    - Auth type: SPNEGO (9)
    - Auth level: Packet integrity (5)
    - Auth pad len: 4
    - Auth Rsvrd: 0
    - Auth Context ID: 1
    - [\[Response in frame: 66\]](#)
  - ▼ Complete stub data (188 bytes)
    - Payload stub data (44 bytes)
    - ▶ Verification Trailer
  - ▶ GSS-API Generic Security Service Application Program Interface
  - ▶ Local Security Authority, lsa\_OpenPolicy

# Wireshark DCERPC Verification Trailer

## ▼ Complete stub data (104 bytes)

Payload stub data (44 bytes)

### ▼ Verification Trailer

SEC\_VT\_SIGNATURE: 8ae3137102f43671

#### ▼ Command: BITMASK\_1

▶ Command: 0x0001, Cmd: BITMASK\_1

Length: 4

▶ rpc\_sec\_vt\_bitmask: 0x00000001, CLIENT\_SUPPORT\_HEADER\_SIGNING

#### ▼ Command: PCONTEXT, END

▶ Command: 0x4002, Cmd: PCONTEXT, SEC\_VT\_COMMAND\_END

Length: 40

#### ▼ pcontext

Abstract Syntax: LSARPC

Version: 0x00000000

Transfer Syntax: 32bit NDR

Version: 0x00000002

# Existing DCERPC hardening (Bind Time Features)

- ▶ MS-RPCE 2.2.2.14 BindTimeFeatureNegotiationBitmask
  - ▶ A way to negotiate new features
- ▶ Current defined features:
  - ▶ SecurityContextMultiplexingSupported
  - ▶ KeepConnectionOnOrphanSupported

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- ▶ Current defined features:
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# Wireshark DCERPC Bind Time Features (BIND)

- ▶ Ctx Item[1]: Context ID:0, LSARPC, 32bit NDR
- ▼ Ctx Item[2]: Context ID:1, LSARPC, Bind Time Feature Negotiation
  - Context ID: 1
  - Num Trans Items: 1
  - ▶ Abstract Syntax: LSARPC V0.0
  - ▼ Transfer Syntax[1]: Bind Time Feature Negotiation V1
    - Transfer Syntax: Bind Time Feature Negotiation UUID:6cb71c2c-9812-4540-0300-000000000000
    - ▶ Bind Time Features: 0x0003, Security Context Multiplexing Supported, Keep Connection On Orphan Supported
    - ver: 1

# Wireshark DCERPC Bind Time Features (BIND ACK)

- ▼ Ctx Item[1]: Acceptance, 32bit NDR
  - Ack result: Acceptance (0)
  - Transfer Syntax: 32bit NDR
  - Syntax ver: 2
- ▼ Ctx Item[2]: Negotiate ACK, NULL
  - Ack result: Negotiate ACK (3)
  - ▶ Bind Time Features: 0x0003, Security Context Multiplexing Supported, Keep Connection On Orphan Supported
  - Transfer Syntax: NULL
  - Syntax ver: 0



# Design problems of current DCERPC implementations

- ▶ DCERPC Fault, Cancel and Orphan PDUs don't include any integrity nor privacy protection.
- ▶ DCERPC\_NCA\_S\_OP\_RNG\_ERROR is typically used to indicate that a specific opnum is not implemented by the server
- ▶ DCERPC\_NCA\_S\_FAULT\_INVALID\_TAG is typically used to indicate that a specific information level is not supported
- ▶ There are higher level protection against downgrades required.
- ▶ The most important protocols don't have known downgrade problems.
- ▶ But it would be good to have real protection at the DCERPC layer.

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- ▶ SMB 3.x has support for generic encryption
  - ▶ It wraps SMB 2/3 PDUs inside an SMB2 TRANSFORM\_HEADER PDU.
- ▶ SMB 3.1.1 has finally a working downgrade protection
  - ▶ A SHA512 preauth hash is calculated over the Negotiate and SessionSetup PDUs.
- ▶ BindTimeFeatureNegotiation and Verification Trailer should be able to build a backward compatible solution for DCERPC.
  - ▶ DCERPC\_BIND\_TIME\_SUPPORT\_PREAUTH
  - ▶ DCERPC\_BIND\_TIME\_PROTECT\_ALL\_PDUS
  - ▶ DCERPC\_BIND\_TIME\_SUPPORT\_WRAP

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# DCERPC\_BIND\_TIME\_SUPPORT\_PREAUTH

- ▶ DCERPC\_BIND\_TIME\_SUPPORT\_PREAUTH is negotiated in the Bind/BindAck exchange.
  - ▶ The DCERPC\_BIND\_ACK\_RESULT\_NEGOTIATE\_ACK element is filled with a random transfer\_syntax value as salt (16 bytes).
- ▶ All DCERPC Bind, BindAck, AlterContext, AlterContextResp and Auth3 PDUs update a rolling preauth hash.
  - ▶ These are triggered by the client and are strictly ordered.
  - ▶ Client and Server start with a zero preauth hash.
  - ▶ The preauth hash is updated when sending or receiving an unprotected PDU.
  - ▶  $\text{PREAUTH\_SHA512} = \text{SHA512}(\text{PREAUTH\_SHA512}, \text{PDU})$ .
- ▶ DCERPC\_SEC\_VT\_COMMAND\_PREAUTH is added to verification trailer of the first request.
  - ▶ DCERPC\_SEC\_VT\_COMMAND\_PREAUTH contains a 16 byte SALT.
  - ▶ It also contains the result of  $\text{SHA512}(\text{PREAUTH\_SHA512} + \text{SALT})$ .

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  - ▶  $\text{PREAUTH\_SHA512} = \text{SHA512}(\text{PREAUTH\_SHA512}, \text{PDU})$ .
- ▶ DCERPC\_SEC\_VT\_COMMAND\_PREAUTH is added to verification trailer of the first request.
  - ▶ DCERPC\_SEC\_VT\_COMMAND\_PREAUTH contains a 16 byte SALT.
  - ▶ It also contains the result of  $\text{SHA512}(\text{PREAUTH\_SHA512} + \text{SALT})$ .

# Wireshark DCERPC Bind Time Features (PREAUTH Bind)

```
Num Ctx Items: 2
▶ Ctx Item[1]: Context ID:0, LSARPC, 32bit NDR
▼ Ctx Item[2]: Context ID:1, LSARPC, Bind Time Feature Negotiation
  Context ID: 1
  Num Trans Items: 1
  ▶ Abstract Syntax: LSARPC V0.0
  ▼ Transfer Syntax[1]: Bind Time Feature Negotiation V1
    Transfer Syntax: Bind Time Feature Negotiation UUID:6cb71c2c-9812-4540-0700-000000000000
    ▼ Bind Time Features: 0x0007,
      .... ..1 = Security Context Multiplexing Supported: True
      .... ..1. = Keep Connection On Orphan Supported: True
      .... ..1.. = Support SHA512 PREAUTH Verification: True
      .... ..0... = Support protection of all PDUs: False
    ver: 1
    Auth type: SPNEGO (9)
    Auth level: Packet integrity (5)
    Auth pad len: 0
    Auth Rsvd: 0
    Auth Context ID: 1
  ▶ GSS-API Generic Security Service Application Program Interface
```

# Wireshark DCERPC Bind Time Features (PREAUTH Ack)

- Num results: 2
  - ▶ Ctx Item[1]: Acceptance, 32bit NDR
  - ▼ Ctx Item[2]: Negotiate ACK, ad6a9956-cce7-45d2-801a-ca2d0d3c4216
    - Ack result: Negotiate ACK (3)
    - ▼ Bind Time Features: 0x0004, Support SHA512 PREAUTH Verification
      - .... .. 0 = Security Context Multiplexing Supported: False
      - .... .. 0. = Keep Connection On Orphan Supported: False
      - .... .. .1.. = Support SHA512 PREAUTH Verification: True
      - .... .. 0... = Support protection of all PDUs: False
    - Transfer Syntax: ad6a9956-cce7-45d2-801a-ca2d0d3c4216
    - Syntax ver: 0
    - Auth type: SPNEGO (9)
    - Auth level: Packet integrity (5)
    - Auth pad len: 0
    - Auth Rsvrd: 0
    - Auth Context ID: 1
- ▶ GSS-API Generic Security Service Application Program Interface

# Wireshark DCERPC Verification Trailer (PREAUTH)

- ▼ Complete stub data (188 bytes)
  - Payload stub data (44 bytes)
  - ▼ Verification Trailer
    - SEC\_VT\_SIGNATURE: 8ae3137102f43671
    - ▶ Command: BITMASK\_1
    - ▶ Command: PCONTEXT
    - ▼ Command: PREAUTH, END
      - ▶ Command: 0x4004, Cmd: PREAUTH, SEC\_VT\_COMMAND\_END
      - Length: 80
      - ▼ preauth
        - Salt: 5cf16b4a22602a6c10fd7678de2c235f
        - SHA512 Hash: 96a9bd8be3572ade794b5cad6e4371dc23d87296f1f5c2c9...

# Wireshark DCERPC Bind Time Features (PROTECT\_ALL\_PDUs Bind)

```
Num Ctx Items: 2
▶ Ctx Item[1]: Context ID:0, LSARPC, 32bit NDR
▼ Ctx Item[2]: Context ID:1, LSARPC, Bind Time Feature Negotiation
  Context ID: 1
  Num Trans Items: 1
  ▶ Abstract Syntax: LSARPC V0.0
  ▼ Transfer Syntax[1]: Bind Time Feature Negotiation V1
    Transfer Syntax: Bind Time Feature Negotiation UUID:6cb71c2c-9812-4540-0f00-000000000000
    ▼ Bind Time Features: 0x000f,
      .... ..1 = Security Context Multiplexing Supported: True
      .... ..1. = Keep Connection On Orphan Supported: True
      .... ..1.. = Support SHA512 PREAUTH Verification: True
      .... ..1... = Support protection of all PDUs: True
  ver: 1
Auth type: SPNEGO (9)
Auth level: Packet integrity (5)
Auth pad len: 0
Auth Rsvrd: 0
Auth Context ID: 1
```

---



# Wireshark DCERPC Bind Time Features (PROTECT\_ALL\_PDUs Ack)

```
Num results: 2
▶ Ctx Item[1]: Acceptance, 32bit NDR
▼ Ctx Item[2]: Negotiate ACK, d38da7fa-a8a8-4ee8-9069-f840f6752401
  Ack result: Negotiate ACK (3)
  ▼ Bind Time Features: 0x000c, Support SHA512 PREAUTH Verification, Support protection of all PDUs
    .... ..0 = Security Context Multiplexing Supported: False
    .... ..0. = Keep Connection On Orphan Supported: False
    .... ..1. = Support SHA512 PREAUTH Verification: True
    .... ..1... = Support protection of all PDUs: True
  Transfer Syntax: d38da7fa-a8a8-4ee8-9069-f840f6752401
  Syntax ver: 0
```

# Wireshark DCERPC Fault PDU

## ▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Fault, Fragment:

Version: 5

Version (minor): 0

Packet type: Fault (3)

▶ Packet Flags: 0x03

▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)

Frag Length: 32

Auth Length: 0

Call ID: 2

Alloc hint: 24

Context ID: 0

Cancel count: 0

▶ Status: `nca_s_fault_access_denied` (0x00000005)

[Opnum: 45]

[\[Request in frame: 55\]](#)

[Time from request: 0.000305000 seconds]

# Wireshark DCERPC Fault PDU (Protected)

## ▼ Distributed Computing Environment / Remote Procedure Call (DCE/RPC) Fault, Fragment:

Version: 5

Version (minor): 0

Packet type: Fault (3)

▶ Packet Flags: 0x03

▶ Data Representation: 10000000 (Order: Little-endian, Char: ASCII, Float: IEEE)

Frag Length: 68

Auth Length: 28

Call ID: 2

Alloc hint: 24

Context ID: 0

Cancel count: 0

▶ Status: nca\_s\_fault\_access\_denied (0x00000005)

Auth type: SPNEGO (9)

Auth level: Packet integrity (5)

Auth pad len: 0

Auth Rsvrd: 0

Auth Context ID: 1

[Opnum: 45]

[\[Request in frame: 55\]](#)

[Time from request: 0.002011000 seconds]

Fault stub data (0 bytes)

▶ GSS-API Generic Security Service Application Program Interface

# IDL definition the DCERPC (ncacn) PDU

The ncacn pdu IDL description in Samba:

```
typedef [public] struct {
    uint8 rpc_vers;           /* RPC version */
    uint8 rpc_vers_minor;    /* Minor version */
    dcerpc_pkt_type ptype;   /* Packet type */
    dcerpc_pfc_flags pfc_flags; /* Fragmentation flags */
    uint8 drep[4];          /* NDR data representation */
    uint16 frag_length;     /* Total length of fragment */
    uint16 auth_length;     /* authenticator length */
    uint32 call_id;        /* Call identifier */
    [switch_is(ptype)] dcerpc_payload u;
} ncacn_packet;
```

# IDL definition of the Payload union

The ncaen payload destruction union:

```
typedef [nodiscard] union {
  [case(DCERPC_PKT_REQUEST)]    dcerpc_request    request;
  [case(DCERPC_PKT_RESPONSE)]  dcerpc_response  response;
  [case(DCERPC_PKT_FAULT)]     dcerpc_fault      fault;
  [case(DCERPC_PKT_BIND)]      dcerpc_bind        bind;
  [case(DCERPC_PKT_BIND_ACK)]  dcerpc_bind_ack    bind_ack;
  [case(DCERPC_PKT_BIND_NAK)]  dcerpc_bind_nak    bind_nak;
  [case(DCERPC_PKT_ALTER)]     dcerpc_bind        alter;
  [case(DCERPC_PKT_ALTER_RESP)] dcerpc_bind_ack  alter_resp;
  [case(DCERPC_PKT_SHUTDOWN)]  dcerpc_shutdown   shutdown;
  [case(DCERPC_PKT_CO_CANCEL)] dcerpc_co_cancel  co_cancel;
  [case(DCERPC_PKT_ORPHANED)]  dcerpc_orphaned   orphaned;
  [case(DCERPC_PKT_AUTH3)]     dcerpc_auth3      auth3;
  [case(DCERPC_PKT_RTS)]       dcerpc_rts        rts;
  /* WRAP packets used to improve privacy */
  [case(DCERPC_PKT_WRAP)]      dcerpc_wrap       wrap;
} dcerpc_payload;
```

# dcerpc\_wrap (work in progress) definition

The IDL function definition (in Samba):

```
typedef [public] struct {
    //TODO/DISCUSS:
    // - add random confounder at the beginning
    // - add explicit verification traller
    // - allow extra preauth hash check PDU
    // - callid random?
    // - flags?
    // - How to detect downgrades on the client
    //   without breaking against old servers

    /* this contains the real ncacn_packet blob and the auth verifier */
    [flag(NDR_REMAINING)] DATA_BLOB pdu_and_verifier;
} dcerpc_wrap;
```

# Defining the Numbers...

- ▶ The specific numbers for flags and types need to be agreed on
  - ▶ It would be good if Microsoft could assign them in MS-RPCE
  - ▶ Are other vendors also interested to implement (at least parts of) this?
- ▶ Bind Time Features:
  - ▶ DCERPC\_BIND\_TIME\_SUPPORT\_PREAUTH = 0x0004
  - ▶ DCERPC\_BIND\_TIME\_PROTECT\_ALL\_PDUS = 0x0008
  - ▶ DCERPC\_BIND\_TIME\_SUPPORT\_WRAP = 0x0010
- ▶ Verification Trailer Command:
  - ▶ DCERPC\_SEC\_VT\_COMMAND\_PREAUTH = 0x0004
- ▶ PDU Type:
  - ▶ DCERPC\_PKT\_WRAP = 21

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# New DCERPC testing infrastructure

- ▶ Low-level protocol testing
  - ▶ python/samba/tests/dcerpc/raw\_protocol.py
  - ▶ This uses our python bindings to marshall PDUs and use raw sockets
  - ▶ This becomes a full DCERPC testsuite exploring almost each bit in the protocol
  - ▶ Windows 2012R2 is the current reference implementation
  - ▶ Currently 75 tests in master and 50 more waiting for review

Calling the raw protocol testsuite (in a Samba source tree):

```
$ export SMB_CONF_PATH=/dev/null
$ export SERVER=w2012r2-188.w2012r2-16.base
$ export USERNAME=administrator
$ export PASSWORD=A1b2C3d4
$ python/samba/tests/dcerpc/raw_protocol.py -v -f TestDCERPC_BIND
```

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# Application level problems (LSA and SAMR)

- ▶ Some LSA and SAMR functions use an SMB application session key
  - ▶ This implies that they only work on ncacn\_np
  - ▶ They can't use DCERPC level authentication (integrity/privacy)
  - ▶ They rely on SMB signing/encryption
- ▶ There're used to be a wellknown transport session key for authenticated DCERPC
  - ▶ It was the constant "SystemLibraryDTC"
  - ▶ All recent versions of Samba and Windows return NT\_STATUS\_NO\_USER\_SESSION\_KEY instead
  - ▶ DCERPC\_AUTH\_LEVEL\_CONNECT is not supported anymore
- ▶ samr\_Connect5() and lsa\_OpenPolicy2() can be used to negotiate a new behaviour
  - ▶ It's possible to avoid application level encryption
  - ▶ It could rely on DCERPC\_AUTH\_LEVEL\_PRIVACY
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# Questions?

[https://wiki.samba.org/index.php/DCERPC\\_Hardening](https://wiki.samba.org/index.php/DCERPC_Hardening)

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- ▶ <http://www.sernet.com>

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