This specification provides a way to secure the SASL and SASL2 handshakes against method and channel-binding downgrades.
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1 Introduction

RFC 6120 ¹ and Extensible SASL Profile (XEP-0388) ² define a way to negotiate SASL mechanisms. When used together with SCRAM mechanisms (RFC 5802 ³) and channel-binding (SASL Channel-Binding Type Capability (XEP-0440) ⁴) the mechanism selection is protected against downgrade attacks by an active MITM tampering with the TLS channel and advertised SASL mechanisms, while the negotiation of the channel-binding types is still not protected against such downgrade attacks.

SASL Channel-Binding Type Capability (XEP-0440) ⁵ tries to mitigate this by making the "tls-server-end-point" (RFC 5929 ⁶) channel-binding mandatory to implement for servers. But that leaves clients not able to implement this type, or any channel-binding at all, vulnerable to downgrades of channel-binding types and SASL mechanisms. Furthermore "tls-server-end-point" provides weaker security guarantees than other channel-bindings like for example "tls-exporter" (defined in RFC 5705 ⁷ and RFC 9266 ⁸).

This specification aims to solve this issue by specifying a downgrade protection for both SASL mechanisms and channel-binding types using an optional SCRAM attribute (see RFC 5802 ⁹). This specification can be used for SASL1 (RFC 6120 ¹⁰) and SASL2 (Extensible SASL Profile (XEP-0388) ¹¹) profiles as well as any other SASL profile.

Note: In the long term the author strives to publish this as an RFC rather than a XEP to also make this protection available to other protocols, after gaining implementation experience.

2 Glossary

This specification uses some abbreviations:

- MITM: man-in-the-middle
- CA: Certificate Authority
- SASL1: the XMPP SASL profile specified in RFC 6120 ¹²

3 Requirements

This protocol was designed with the following requirements in mind:

- Allow detection of SASL mechanism downgrades even if no channel-binding is in use.
- Allow detection of downgrades of channel-binding types.
- Support all currently defined and future SCRAM mechanisms (RFC 5802 and RFC 7677).

Note that this specification intentionally leaves out support for SASL PLAIN. If server and client support PLAIN, no protection against SASL method or channel-binding downgrades is possible and the security relies solely on the underlying TLS channel. As explained in § 13.8.3 of RFC 6120, servers and clients SHOULD NOT support SASL PLAIN unless it is required by the authentication backend.

A compromise might be to use pinning not for concrete SASL mechanisms, but instead pin something better than SASL PLAIN was previously supported. Thus pinning will ensure that authentication won’t fall back to SASL-PLAIN in the future, but also won’t hinder protocol agility for the SCRAM family of SASL mechanisms etc..

3.1 Attack model 1 (list of channel-binding types)

Scenario: Bob connects to Alice’s XMPP server using a client of his choice supporting SCRAM and channel-binding, Eve wants to MITM this connection. Neither Alice’s server nor Bob’s client support SASL PLAIN, but only the SCRAM family of SASL mechanisms.

Prerequisites: Eve, the MITM attacker, managed to either steal the cert+key of Alice’s XMPP server or to convince some CA to give out a cert+key for Alice’s XMPP domain. Maybe Bob even installed a CA of his employer/school and now gets MITMed by his employer/school. Given this scenario and prerequisites, Eve now can passively MITM the XMPP connection, but Bob and Alice are using channel-binding and this allows them to detect Eve and abort authentication. This forces Eve to be an active attacker, manipulating the data in the XMPP stream to get rid of the channel-binding. Eve does so by changing the list of server-advertised channel-bindings to only include some (fictional) channel-binding types she is sure the client does not support. Bob’s client now has the following choices (see also the Security Considerations of SASL Channel-Binding Type Capability (XEP-0440):
1. Authenticate without using channel-binding and signal to the server that the client does not support channel-binding ("n" GS2-flag)

2. Authenticate without using channel-binding and signal to the server that the client does support channel-binding ("y" GS2-flag)

3. Try to authenticate using some channel-binding type

4. Try to authenticate using the pinned channel-binding type

5. Fall back to use the lowest denominator: "tls-server-end-point"

**Case 1** is a successful downgrade from channel-binding to non-channel-binding authentication, Eve "wins".

**Case 2** will always fail the authentication if the server supports channel-binding, Eve does not "win". But authentication will fail even if there is no MITM present but server and client simply happen to have no mutually supported channel-binding type.

**Case 3** can result in a successful or failed authentication, depending on wether the server supports the type randomly selected by the client. Unfortunately a failed authentication due to selecting the wrong channel-binding type can not be distinguished from a failed authentication because of invalid credentials etc. Thus authentication using some channel-binding type will slow down authentication speed, because the client has to cycle through all channel-binding types it supports until it finds one the server supports (and eventually fall back to no channel-binding, if all channel-binding types have been tried). So, if server and client have mutually supported channel-binding types, Eve won’t "win", but authentication will potentially need many roundtrips. If they don’t have mutually supported channel-binding types, Eve wouldn’t have had to manipulate the channel-binding list in the first place.

**Case 4** does not help on first authentication. This could be neglected, but since channel-binding types aren’t that easily ordered by perceived strength and could legitimately change, this could effectively lead to a Denial of Service. For example Alice might want to offload TLS termination because of higher server load and now her server does not support "tls-exporter" anymore but only "tls-server-end-point". A client pinning "tls-exporter" would not be able to connect to Alice’s server anymore after the TLS offloading is in place.

**Case 5** won’t help if Eve managed to steal the cert+key (or the server either somehow does not support the "tls-server-end-point" type).

*This specification solves the problems outlined above by adding an optional SCRAM attribute containing the hash of the client-perceived list of channel-binding types that can be checked by the server and will be cryptographically signed by the authentication password used for SCRAM.*

**3.2 Attack model 2 (SASL mechanism list)**

**Scenario:** Bob connects to Alice’s XMPP server using a client of his choice supporting SCRAM but no channel-binding, Eve wants to MITM this connection. Neither Alice’s server nor Bob’s
client support SASL PLAIN, but only the SCRAM family of SASL mechanisms. Eve wants to
downgrade the used SCRAM mechanism to something weak that she is able to break in X
hours/days (For example some time in the future SCRAM-SHA-1 might be broken that way
and the underlying password could be recovered investing X hours/days of computing time.
But SCRAM-SHA-1 might still be supported by servers for backwards compatibility with older
clients only supporting SCRAM-SHA-1 but not SCRAM-SHA-256 etc.).

**Prerequisites:** Eve, the MITM attacker, managed to either steal the cert+key of Alice’s XMPP
server or to convince some CA to give out a cert+key for Alice’s XMPP domain. Maybe Bob
even installed a CA of his employer/school and now gets MITMed by his employer/school.
Given this scenario and prerequisites, Eve now can passively MITM the XMPP connection,
but if Eve wants to actively downgrade the SASL mechanism used by Bob, he has to actively
change the server-advertised SASL mechanism list. In this scenario Eve actively removes all
SCRAM mechanisms but SCRAM-SHA-1 from the server-advertised list to force Bob’s client to
use SCRAM-SHA-1. Neither Alice nor Bob would detect that.

Pinning of SASL mechanisms could be used for that, but in doing this, Alice would lose some
flexibility. She might have briefly activated SCRAM-SHA-512 and deactivated it again. Now
Bob’s client can not authenticate using SCRAM-SHA-512 anymore and authentication will
always fail, if pinning is used. Pinning won’t help on first connection either. See above for a
pinning + SSDP compromise when still supporting SASL PLAIN.

*This specification solves this problem by adding an optional SCRAM attribute containing the hash of the
client-perceived SASL mechanism list that can be checked by the server and will be cryptographically
signed by the authentication password used for SCRAM.*

4 Protocol

Sections 5.1 and 7 of [RFC 5802](http://tools.ietf.org/html/rfc5802) allow for arbitrary optional attributes inside SCRAM messages.
This specification uses those optional attribute to implement a downgrade protection.

4.1 Server Indicates Support

The server uses the optional attribute "d" with the value "ssdp" in its server-first-message to
indicate support for this specification.

A client supporting this specification but not seeing this attribute advertised by the server
MAY abort the authentication. It is RECOMMENDED to wait until the whole SCRAM flow hash
been completed to distinguish the case of a server not supporting this specification from a
MITM stripping out this optional SCRAM attribute.

4.2 Client Sends Downgrade Protection Hash

If the server indicated support for this spec in the server-first-message and the client supports it, the client calculates a hash for the server-advertised list of SASL mechanisms and channel-binding types as follows.

Note: All sorting operations MUST be performed using "i;octet" collation as specified in Section 9.3 of RFC 4790.

1. Initialize an empty ASCII string \( S \)
2. Sort all server-advertised SASL mechanisms and append them to string \( S \) joined by delimiter "," (\%x2C)
3. If the server used SASL Channel-Binding Type Capability (XEP-0440) to advertise channel-bindings, append "|" (\%x7C) to \( S \)
4. If the server used SASL Channel-Binding Type Capability (XEP-0440) to advertise channel-bindings, sort all server-advertised channel-binding types and append them to string \( S \) joined by delimiter "," (\%x2C)
5. Hash \( S \) using the same hash mechanism as used for the SCRAM mechanism currently in use and encode the result using base64.

The client then adds the optional attribute "d" with the base64 encoded hash obtained in step 5 to its client-final-message. The client MAY send this attribute even if the server did not advertise support.

Note: If the server simultaneously advertises SASL1 and SASL2, only the mechanism list of the SASL protocol the client uses for authentication MUST be considered for hashing.

4.3 Server Verifys The Downgrade Protection Hash

Upon receiving the client-final-message the server calculates its own base64 encoded hash using the list of SASL mechanisms and channel-binding types it advertised using SASL1 or SASL2 and SASL Channel-Binding Type Capability (XEP-0440) by applying the same algorithm as defined in Client Sends Downgrade Protection Hash.

The server then extracts the base64 encoded hash presented by the client in the optional attribute "d" and compares it to its own hash. If the hashes match, the list of SASL mechanisms and channel-binding types has not been changed by an active MITM.

If the hashes do not match, the server MUST fail the authentication as specified in RFC 6120 section 6.5 or Extensible SASL Profile (XEP-0388) section 2.6.2 using the "aborted"
error-condition. If Extensible SASL Profile (XEP-0388) is used, the application-specific error-condition "downgrade-detected" in the namespace "urn:xmpp:ssdp:0" MUST be added, too. It MAY further include an optional descriptive text to further clarify this error as specified in Extensible SASL Profile (XEP-0388) section 6.2.6 or RFC 6120 section 6.5. If additional SCRAM data is provided, the used SCRAM "server-error-value" MUST be "downgrade-detected".
Non-XMPP implementations MAY use a SCRAM "server-error-value" of "downgrade-detected" alongside any protocol specific error-condition.

4.4 Full Example

This sections contains an example based on the ones provided in Extensible SASL Profile (XEP-0388).

Listing 1: Full SCRAM-SHA-1-PLUS authentication flow using the optional attribute defined in this spec

```xml
<!-({}-)
Client sending stream header
-{>-)
<stream:stream
  from='user@example.org'
  to='example.org'
  version='1.0'
  xml:lang='en'
  xmlns='jabber:client'
  xmlns:stream='http://etherx.jabber.org/streams'>
<!-({}-)
Server responding with stream header and features
-{>-)
<stream:stream
  from='example.org'
  id='++TR84Sm6A3hnt3Q065SnAbbK3Y='
  to='user@example.org'
  version='1.0'
  xml:lang='en'
  xmlns='jabber:client'
  xmlns:stream='http://etherx.jabber.org/streams'>
<stream:features>
  <authentication xmlns='urn:xmpp:sasl:2'>
    <mechanism>SCRAM-SHA-1</mechanism>
  </authentication>
</stream:stream>
```

<mechanism>SCRAM-SHA-1-PLUS</mechanism>

<inline xmlns='urn:xmpp:sasl:2'>
    Server indicates that XEP-0198 can be negotiated "inline"
</inline>

<enable xmlns='urn:xmpp:sm:3'/>

<bind xmlns='urn:xmpp:bind2:1'/>

<inline xmlns='urn:xmpp:sasl:cb:0'>
    Server indicates that XEP-0198 can be negotiated
</inline>

<bind xmlns='urn:xmpp:bind2:1'/>

<authenticate xmlns='urn:xmpp:sasl:2' mechanism='SCRAM-SHA-1-PLUS'>
    Base64 of: 'p=tlsexporter,,n=user,r=12C4CD5C-E38E-4A98-8F6D
    -15C38F51CCC6' -{}
</authenticate>

<initial-response>
    cD10bHMtZXhwb3J0ZXM1ciixyPTEyQzRDRDVLUzOEUtNEN5OC04RjZELTE1QzM4RjUxQ0ND
    ==</initial-response>

<software>AwesomeXMPP</software>
<device>Kiva's Phone</device>
</authenticate>

<authenticate xmlns='urn:xmpp:sasl:2' mechanism='SCRAM-SHA-1-PLUS'>
    Base64 of: 'r=12C4CD5C-E38E-4A98-8F6D-15C38F51CCC6a09117a6-ac50-4f2f
    -93f1-93799c2bd6f,s=QSXCR+Q6seK8bf92,i=4096,d=ssdp'
</authenticate>

<challenge xmlns='urn:xmpp:sasl:2'>
    cj0xMkM0Q0Q1Qy1FMzhFLTRBOtOEY2RC0xNUMzOEY1UMDQzZhMDkxMTdhNi1hYzUwLTrmMmYtOTNnMMS=
</challenge>

<authenticate>
    The client responds with the base64 encoded SCRAM-SHA-1-PLUS client-final-message (password: 'pencil')
including the base64-encoded SHA-1 hash of the mechanism and channel binding lists.

Attribute "d" contains base64-encoded SHA-1 hash of 'SCRAM-SHA-1, SCRAM-SHA-1-PLUS|tls-exporter,tls-server-end-point'

Base64 of: c= cD10bHMtZXhwb3J0ISLmcoQvdBDepD40sw1mAWV3dg1a1Wh1tYPTBwVidTOVu, r=12C4CD5C-e3BE-4A98-8FD6-15C38F51CCC6a09117a6-ac50-4f2f-93f1-93799 c2bd6f6, p=UApo7xo6Pa9J+VaejFz/dG7BomU=, d= dRc3RenuSY9ypgPpERowoaySQZY=

The c-attribute contains the GS2-header and channel-binding data blob (32 bytes) as defined in RFC 5802.

5 Security Considerations

Using SCRAM attributes makes them part of the HMAC signatures used in the SCRAM protocol flow efficiently protecting them against any MITM attacker not knowing the password used.

6 IETF Interaction

This protocol shall be superseded by any IETF RFC providing some or all of the functionality provided by this specification. If such a specification exists implementations SHOULD NOT implement this XEP and SHOULD implement the superseding RFC.
7  IANA Considerations

This document requires no interaction with the Internet Assigned Numbers Authority (IANA) 29.

8  XMPP Registrar Considerations

This specification does not need any interaction with the XMPP Registrar 30.

9  XML Schema

This specification does not specify any new XML elements.

29The Internet Assigned Numbers Authority (IANA) is the central coordinator for the assignment of unique parameter values for Internet protocols, such as port numbers and URI schemes. For further information, see <http://www.iana.org/>.

30The XMPP Registrar maintains a list of reserved protocol namespaces as well as registries of parameters used in the context of XMPP extension protocols approved by the XMPP Standards Foundation. For further information, see <https://xmpp.org/registrar/>.