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Salted Challenge Response (SCRAM) SASL Mechanism
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Abstract

   The secure authentication mechanism most widely deployed and used by
   Internet application protocols is the transmission of clear-text
   passwords over a channel protected by Transport Layer Security (TLS).
   There are some significant security concerns with that mechanism,
   which could be addressed by the use of a challenge response
   authentication mechanism protected by TLS. Unfortunately, the
   challenge response mechanisms presently on the standards track all
   fail to meet requirements necessary for widespread deployment, and
   have had success only in limited use.

   This specification describes a family of Simple Authentication and
   Security Layer (SASL, RFC 4422) authentication mechanisms called the
   Salted Challenge Response Authentication Mechanism (SCRAM), which
   addresses the security concerns and meets the deployability
   requirements. When used in combination with TLS or an equivalent
   security layer, a mechanism from this family could improve the
   status-quo for application protocol authentication and provide a
   suitable choice for a mandatory-to-implement mechanism for future
   application protocol standards.

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1. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC2119].

Formal syntax is defined by [RFC5234] including the core rules
defined in Appendix B of [RFC5234].

Example lines prefaced by "C:" are sent by the client and ones
prefaced by "S:" by the server. If a single "C:" or "S:" label
applies to multiple lines, then the line breaks between those lines
are for editorial clarity only, and are not part of the actual
protocol exchange.

1.1. Terminology

This document uses several terms defined in [RFC4949] ("Internet
Security Glossary") including the following: authentication,
authentication exchange, authentication information, brute force,
challenge-response, cryptographic hash function, dictionary attack,
eavesdropping, hash result, keyed hash, man-in-the-middle, nonce,
one-way encryption function, password, replay attack and salt.
Readers not familiar with these terms should use that glossary as a
reference.

Some clarifications and additional definitions follow:

o Authentication information: Information used to verify an identity
   claimed by a SCRAM client. The authentication information for a
   SCRAM identity consists of salt, iteration count, the "StoredKey"
   and "ServerKey" (as defined in the algorithm overview) for each
   supported cryptographic hash function.

o Authentication database: The database used to look up the
   authentication information associated with a particular identity.
   For application protocols, LDAPv3 (see [RFC4510]) is frequently
   used as the authentication database. For network-level protocols
   such as PPP or 802.11x, the use of RADIUS is more common.

o Base64: An encoding mechanism defined in [RFC4648] which converts
   an octet string input to a textual output string which can be
   easily displayed to a human. The use of base64 in SCRAM is
   restricted to the canonical form with no whitespace.

o Octet: An 8-bit byte.

o Octet string: A sequence of 8-bit bytes.

   o Salt: A random octet string that is combined with a password
      before applying a one-way encryption function. This value is used
      to protect passwords that are stored in an authentication
      database.

1.2. Notation

   The pseudocode description of the algorithm uses the following
   notations:

   o ":=": The variable on the left hand side represents the octet
      string resulting from the expression on the right hand side.

   o "+": Octet string concatenation.

   o "[ ]": A portion of an expression enclosed in "[" and "]" may not
      be included in the result under some circumstances. See the
      associated text for a description of those circumstances.

   o HMAC(key, str): Apply the HMAC keyed hash algorithm (defined in
      [RFC2104]) using the octet string represented by "key" as the key
      and the octet string "str" as the input string. The size of the
      result is the hash result size for the hash function in use. For
      example, it is 20 octets for SHA-1 (see [RFC3174]).

   o H(str): Apply the cryptographic hash function to the octet string
      "str", producing an octet string as a result. The size of the
      result depends on the hash result size for the hash function in
      use.

   o XOR: Apply the exclusive-or operation to combine the octet string
      on the left of this operator with the octet string on the right of
      this operator. The length of the output and each of the two
      inputs will be the same for this use.

   o Hi(str, salt):

      U0   := HMAC(str, salt + INT(1))
      U1   := HMAC(str, U0)
      U2   := HMAC(str, U1)
      ...
      Ui-1 := HMAC(str, Ui-2)
      Ui   := HMAC(str, Ui-1)

      Hi := U0 XOR U1 XOR U2 XOR ... XOR Ui

where "i" is the iteration count, "+" is the string concatenation
operator and INT(g) is a four-octet encoding of the integer g,
most significant octet first.

o This is, essentially, PBKDF2 [RFC2898] with HMAC() as the PRF and
   with dkLen == output length of HMAC() == output length of H().

[2](#). Introduction

This specification describes a family of authentication mechanisms
called the Salted Challenge Response Authentication Mechanism (SCRAM)
which addresses the requirements necessary to deploy a challenge-
response mechanism more widely than past attempts. When used in
combination with Transport Layer Security (TLS, see [[RFC5246](#)]) or an
equivalent security layer, a mechanism from this family could improve
the status-quo for application protocol authentication and provide a
suitable choice for a mandatory-to-implement mechanism for future
application protocol standards.

For simplicity, this family of mechanism does not presently include
negotiation of a security layer. It is intended to be used with an
external security layer such as that provided by TLS or SSH, with
optional channel binding [[RFC5056](#)] to the external security layer.

SCRAM is specified herein as a pure Simple Authentication and
Security Layer (SASL) [[RFC4422](#)] mechanism, but it conforms to the new
bridge between SASL and the Generic Security Services Application
Programming Interface (GSS-API) called "GS2" [[I-D.ietf-sasl-gs2](#)].
This means that this document defines both, a SASL mechanism and a
GSS-API mechanism.

SCRAM provides the following protocol features:

o The authentication information stored in the authentication
   database is not sufficient by itself to impersonate the client.
   The information is salted to prevent a pre-stored dictionary
   attack if the database is stolen.

o The server does not gain the ability to impersonate the client to
   other servers (with an exception for server-authorized proxies).

o The mechanism permits the use of a server-authorized proxy without
   requiring that proxy to have super-user rights with the back-end
   server.

o A standard attribute is defined to enable storage of the
   authentication information in LDAPv3 (see [[RFC4510](#)]).

o Mutual authentication is supported, but only the client is named
   (i.e., the server has no name).

For an in-depth discussion of why other challenge response mechanisms
are not considered sufficient, see [appendix A](#). For more information
about the motivations behind the design of this mechanism, see
[appendix B](#).

Comments regarding this draft may be sent either to the
ietf-sasl@imc.org mailing list or to the authors.

3. SCRAM Algorithm Overview

   Note that this section omits some details, such as client and server
   nonces. See Section 5 for more details.

   To begin with, the client is in possession of a username and
   password. It sends the username to the server, which retrieves the
   corresponding authentication information, i.e. a salt, StoredKey,
   ServerKey and the iteration count i. (Note that a server
   implementation may chose to use the same iteration count for all
   account.) The server sends the salt and the iteration count to the
   client, which then computes the following values and sends a
   ClientProof to the server:

      SaltedPassword := Hi(password, salt)
      ClientKey   := HMAC(SaltedPassword, "Client Key")
      StoredKey   := H(ClientKey)
      AuthMessage   := client-first-message + "," +
                         server-first-message + "," +
                         client-final-message-without-proof
      ClientSignature := HMAC(StoredKey, AuthMessage)
      ClientProof   := ClientKey XOR ClientSignature
      ServerKey   := HMAC(SaltedPassword, "Server Key")
      ServerSignature := HMAC(ServerKey, AuthMessage)

   The server authenticates the client by computing the ClientSignature,
   exclusive-ORing that with the ClientProof to recover the ClientKey
   and verifying the correctness of the ClientKey by applying the hash
   function and comparing the result to the StoredKey. If the ClientKey
   is correct, this proves that the client has access to the user's
   password.

   Similarly, the client authenticates the server by computing the
   ServerSignature and comparing it to the value sent by the server. If
   the two are equal, it proves that the server had access to the user's
   ServerKey.

   The AuthMessage is computed by concatenating messages from the
   authentication exchange. The format of these messages is defined in
   Section 7.

4. **SCRAM Mechanism Names**

   A SCRAM mechanism name is a string "SCRAM-" followed by the
   uppercased name of the underlying hashed function taken from the IANA
   "Hash Function Textual Names" registry (see http://www.iana.org),
   optionally followed by the suffix "-PLUS" (see below). Note that
   SASL mechanism names are limited to 20 characters, which means that
   only hash function names with lengths shorter or equal to 9
   characters (20-length("SCRAM-")-length("-PLUS") can be used. For
   cases when the underlying hash function name is longer than 9
   characters, an alternative 9 character (or shorter) name can be used
   to construct the corresponding SCRAM mechanism name, as long as this
   alternative name doesn't conflict with any other hash function name
   from the IANA "Hash Function Textual Names" registry.

   For interoperability, all SCRAM clients and servers MUST implement
   the SCRAM-SHA-1 authentication mechanism, i.e. an authentication
   mechanism from the SCRAM family that uses the SHA-1 hash function as
   defined in [RFC3174].

   The "-PLUS" suffix is used only when the server supports channel
   binding to the external channel. In this case the server will
   advertise both, SCRAM-SHA-1 and SCRAM-SHA-1-PLUS, otherwise the
   server will advertise only SCRAM-SHA-1. The "-PLUS" exists to allow
   negotiation of the use of channel binding. See Section 6.

5. **SCRAM Authentication Exchange**

   SCRAM is a SASL mechanism whose client response and server challenge
   messages are text-based messages containing one or more attribute-
   value pairs separated by commas. Each attribute has a one-letter
   name. The messages and their attributes are described in
   Section 5.1, and defined in Section 7.

   This is a simple example of a SCRAM-SHA-1 authentication exchange
   when the client doesn't support channel bindings:

      C: n,,n=Chris Newman,r=ClientNonce
      S: r=ClientNonceServerNonce,s=PxR/wv+epq,i=128
      C: c=biwsCg==,r=ClientNonceServerNonce,p=WxPv/siO5l+qxN4
      S: v=WxPv/siO5l+qxN4

   [[anchor5: Note that the all hashes above are fake and will be fixed
   during AUTH48.]]

   With channel-binding data sent by the client this might look like
   this:

      C: p=tls-server-end-point,,n=Chris Newman,r=ClientNonce
      S: r=ClientNonceServerNonce,s=PxR/wv+epq,i=128
      C: c=cD10bHMtc2VydmVyLWVuZC1wb2ludCwsy1hFtXOnZ+ySrQM6srFp
         l/77uqvtxrg7nBY1BetEr/g=,r=ClientNonceServerNonce,p=Wx
         Pv/siO5l+qxN4
      S: v=WxPv/siO5l+qxN4

   [[anchor6: Note that all hashes above are fake and will be fixed
   during AUTH48.]]

   First, the client sends a message containing:

   o a GS2 header consisting of a flag indicating whether channel
      binding is supported-but-not-used, not supported, or used, and an
      optional SASL authorization identity;

   o SCRAM username and a random, unique nonce attributes.

   Note that the client's first message will always start with "n", "y"
   or "p", otherwise the message is invalid and authentication MUST
   fail. This is important, as it allows for GS2 extensibility (e.g.,
   to add support for security layers).

In response, the server sends the user's iteration count i, the
user's salt, and appends its own nonce to the client-specified one.
The client then responds with the same nonce and a ClientProof
computed using the selected hash function as explained earlier. The
server verifies the nonce and the proof, verifies that the
authorization identity (if supplied by the client in the first
message) is authorized to act as the authentication identity, and,
finally, it responds with a ServerSignature, concluding the
authentication exchange. The client then authenticates the server by
computing the ServerSignature and comparing it to the value sent by
the server. If the two are different, the client MUST consider the
authentication exchange to be unsuccessful and it might have to drop
the connection.

5.1. SCRAM Attributes

This section describes the permissible attributes, their use, and the
format of their values. All attribute names are single US-ASCII
letters and are case-sensitive.

Note that the order of attributes in client or server messages is
fixed, with the exception of extension attributes (described by the
"extensions" ABNF production), which can appear in any order in the
designated positions. See the ABNF section for authoritative
reference.

o a: This is an optional attribute, and is part of the GS2
   [I-D.ietf-sasl-gs2] bridge between the GSS-API and SASL. This
   attribute specifies an authorization identity. A client may
   include it in its first message to the server if it wants to
   authenticate as one user, but subsequently act as a different
   user. This is typically used by an administrator to perform some
   management task on behalf of another user, or by a proxy in some
   situations.

      Upon the receipt of this value the server verifies its
      correctness according to the used SASL protocol profile.
      Failed verification results in failed authentication exchange.

      If this attribute is omitted (as it normally would be), or
      specified with an empty value, the authorization identity is
      assumed to be derived from the username specified with the
      (required) "n" attribute.

      The server always authenticates the user specified by the "n"
      attribute. If the "a" attribute specifies a different user,
      the server associates that identity with the connection after
      successful authentication and authorization checks.

      The syntax of this field is the same as that of the "n" field
      with respect to quoting of '=' and ','.

   o n: This attribute specifies the name of the user whose password is
      used for authentication (a.k.a. "authentication identity"). A
      client must include it in its first message to the server. If the
      "a" attribute is not specified (which would normally be the case),
      this username is also the identity which will be associated with
      the connection subsequent to authentication and authorization.

      Before sending the username to the server, the client MUST
      prepare the username using the "SASLPrep" profile [RFC4013] of
      the "stringprep" algorithm [RFC3454]. If the preparation of
      the username fails or results in an empty string, the client
      SHOULD abort the authentication exchange (*).

      (*) An interactive client can request a repeated entry of the
      username value.

      Upon receipt of the username by the server, the server SHOULD
      prepare it using the "SASLPrep" profile [RFC4013] of the
      "stringprep" algorithm [RFC3454]. If the preparation of the
      username fails or results in an empty string, the server SHOULD
      abort the authentication exchange.

      The characters ',' or '=' in usernames are sent as '=2C' and
      '=3D' respectively. If the server receives a username which
      contains '=' not followed by either '2C' or '3D', then the
      server MUST fail the authentication.

   o m: This attribute is reserved for future extensibility. In this
      version of SCRAM, its presence in a client or a server message
      MUST cause authentication failure when the attribute is parsed by
      the other end.

   o r: This attribute specifies a sequence of random printable
      characters excluding ',' which forms the nonce used as input to
      the hash function. No quoting is applied to this string. As
      described earlier, the client supplies an initial value in its
      first message, and the server augments that value with its own
      nonce in its first response. It is important that this be value
      different for each authentication. The client MUST verify that
      the initial part of the nonce used in subsequent messages is the
      same as the nonce it initially specified. The server MUST verify
      that the nonce sent by the client in the second message is the
      same as the one sent by the server in its first message.

   o c: This REQUIRED attribute specifies base64-encoded of a header

       and the channel-binding data. It is sent by the client in its
       second authentication message. The header consist of:

       * the GS2 header from the client's first message (recall: a
          channel binding flag and an optional authzid). This header is
          going to include channel binding type prefix (see [RFC5056], if
          and only if the client is using channel binding;

       * followed by the external channel's channel binding data, if and
          only if the client is using channel binding.

   o s: This attribute specifies the base64-encoded salt used by the
      server for this user. It is sent by the server in its first
      message to the client.

   o i: This attribute specifies an iteration count for the selected
      hash function and user, and must be sent by the server along with
      the user's salt.

      For SCRAM-SHA-1/SCRAM-SHA-1-PLUS SASL mechanism servers SHOULD
      announce a hash iteration-count of at least 4096. Note that a
      client implementation MAY cache SaltedPassword/ClientKey for
      later reauthentication to the same service, as it is likely
      that the server is going to advertise the same salt value upon
      reauthentication. This might be useful for mobile clients
      where CPU usage is a concern.

   o p: This attribute specifies a base64-encoded ClientProof. The
      client computes this value as described in the overview and sends
      it to the server.

   o v: This attribute specifies a base64-encoded ServerSignature. It
      is sent by the server in its final message, and is used by the
      client to verify that the server has access to the user's
      authentication information. This value is computed as explained
      in the overview.

6. Channel Binding

   SCRAM supports channel binding to external secure channels, such as
   TLS. Clients and servers may or may not support channel binding,
   therefore the use of channel binding is negotiable. SCRAM does not
   provide security layers, however, therefore it is imperative that
   SCRAM provide integrity protection for the negotiation of channel
   binding.

   Use of channel binding is negotiated as follows:

   o Servers SHOULD advertise both non-PLUS (SCRAM-<hash-function>) and
      the PLUS-variant (SCRAM-<hash-function>-PLUS) SASL mechanism
      names. If the server cannot support channel binding, it MAY
      advertise only the non-PLUS variant. If the server would never
      succeed authentication of the non-PLUS variant due to policy
      reasons, it MAY advertise only the PLUS-variant.

   o If the client negotiates mechanisms then the client MUST select
      SCRAM-<hash-function>-PLUS if offered by the server and the client
      wants to select SCRAM with the given hash function. [[anchor7: Is
      the following correct?]] Otherwise, if the client does not
      negotiate mechanisms then it MUST select only SCRAM-<hash-
      function> (not suffixed with "-PLUS").

   o If the client supports channel binding and the server appears to
      support it (i.e., the client sees SCRAM-<hash-function>-PLUS), or
      if the client wishes to use channel binding but the client does
      not negotiate mechanisms, then the client MUST set the GS2 channel
      binding flag to "p" in order to indicate the channel binding type
      it is using and it MUST include the channel binding data for the
      external channel in the computation of the "c=" attribute (see
      Section 5.1).

   o If the client supports channel binding but the server does not
      appear to (i.e., the client did not see SCRAM-<hash-function>-
      PLUS) then the client MUST either fail authentication or it MUST
      chose the non-PLUS mechanism and set the GS2 channel binding flag
      to "y" and MUST NOT include channel binding data for the external
      channel in the computation of the "c=" attribute (see
      Section 5.1).

   o If the client does not support channel binding then the client
      MUST set the GS2 channel binding flag to "n" and MUST NOT include
      channel binding data for the external channel in the computation
      of the "c=" attribute (see Section 5.1).

   o Upon receipt of the client first message the server checks the GS2

channel binding flag (gs2-cb-flag).

* If the flag is set to "y" and the server supports channel
  binding the server MUST fail authentication. This is because
  if the client sets the GS2 channel binding flag set to "y" then
  the client must have believed that the server did not support
  channel binding -- if the server did in fact support channel
  binding then this is an indication that there has been a
  downgrade attack (e.g., an attacker changed the server's
  mechanism list to exclude the -PLUS suffixed SCRAM mechanism
  name(s)).

* If the channel binding flag was "p" and the server does not
  support the indicated channel binding type then the server MUST
  fail authentication.

The server MUST always validate the client's "c=" field. The server
does this by constructing the value of the "c=" attribute and then
checking that it matches the client's c= attribute value.

For more discussions of channel bindings, and the syntax of the
channel binding data for various security protocols, see [RFC5056].

6.1. Default Channel Binding

A default channel binding type agreement process for all SASL
application protocols that do not provide their own channel binding
type agreement is provided as follows.

Clients and servers MUST implement the "tls-unique" [tls-unique]
channel binding type. Clients and servers SHOULD choose the highest-
layer/innermost end-to-end TLS channel as the channel to bind to.

Clients SHOULD choose the tls-unique channel binding type.
Conversely, clients MAY choose a different channel binding type based
on user input, configuration, or a future, as-yet undefined channel
binding type negotiation protocol. Servers MUST choose the channel
binding type indicated by the client, if they support it.

7. **Formal Syntax**

   The following syntax specification uses the Augmented Backus-Naur
   Form (ABNF) notation as specified in [RFC5234]. "UTF8-2", "UTF8-3"
   and "UTF8-4" non-terminal are defined in [RFC3629].


```
     ALPHA = <as defined in RFC 5234 appendix B.1>
     DIGIT = <as defined in RFC 5234 appendix B.1>
     UTF8-2 = <as defined in RFC 3629 (STD 63)>
     UTF8-3 = <as defined in RFC 3629 (STD 63)>
     UTF8-4 = <as defined in RFC 3629 (STD 63)>

     generic-message = attr-val *("," attr-val)
                       ;; Generic syntax of any server challenge
                       ;; or client response

     attr-val        = ALPHA "=" value

     value           = 1*value-char

     value-safe-char = %x01-2B / %x2D-3C / %x3E-7F /
                       UTF8-2 / UTF8-3 / UTF8-4
                       ;; UTF8-char except NUL, "=", and ",".

     value-char      = value-safe-char / "="

     base64-char     = ALPHA / DIGIT / "/" / "+"

     base64-4        = 4base64-char

     base64-3        = 3base64-char "="

     base64-2        = 2base64-char "=="

     base64          = *base64-4 [base64-3 / base64-2]

     posit-number = %x31-39 *DIGIT
                       ;; A positive number

     saslname        = 1*(value-safe-char / "=2C" / "=3D")
                       ;; Conforms to <value>

     authzid         = "a=" saslname
                       ;; Protocol specific.

     cb-name         = 1*(ALPHA / DIGIT / "." / "-")
                        ;; See RFC 5056 section 7.
```

```
                        ;; E.g. "tls-server-end-point" or
                        ;; "tls-unique"

     gs2-cbind-flag  = "p=" cb-name / "n" / "y"
                        ;; "n" -> client doesn't support channel binding
                        ;; "y" -> client does support channel binding
                        ;;        but thinks the server does not.
                        ;; "p" -> client requires channel binding.
                        ;; The selected channel binding follows "p=".

     gs2-header      = gs2-cbind-flag "," [ authzid ] ","
                        ;; GS2 header for SCRAM
                        ;; (the actual GS2 header includes an optional
                        ;; flag to indicate that the GSS mechanism is not
                        ;; "standard" but since SCRAM is "standard" we
                        ;; don't include that flag).

     username        = "n=" saslname
                        ;; Usernames are prepared using SASLPrep.

     reserved-mext  = "m=" 1*(value-char)
                        ;; Reserved for signalling mandatory extensions.
                        ;; The exact syntax will be defined in
                        ;; the future.

     channel-binding = "c=" base64
                        ;; base64 encoding of cbind-input

     proof           = "p=" base64

     nonce           = "r=" c-nonce [s-nonce]
                        ;; Second part provided by server.

     c-nonce         = value

     s-nonce         = value

     salt            = "s=" base64

     verifier        = "v=" base64
                        ;; base-64 encoded ServerSignature.

     iteration-count = "i=" posit-number
                        ;; A positive number

     client-first-message =
                        gs2-header [reserved-mext ","]
                        username "," nonce ["," extensions]
```

```
server-first-message =
                [reserved-mext ","] nonce "," salt ","
                iteration-count ["," extensions]

client-final-message-without-proof =
                channel-binding "," nonce [","
                extensions]

client-final-message =
                client-final-message-without-proof "," proof

gss-server-error = "e=" value
server-final-message = gss-server-error /
                verifier ["," extensions]
                ;; The error message is only for the GSS-API
                ;; form of SCRAM, and it is OPTIONAL to
                ;; implement it.

extensions = attr-val *("," attr-val)
                ;; All extensions are optional,
                ;; i.e. unrecognized attributes
                ;; not defined in this document
                ;; MUST be ignored.

cbind-data    = 1*OCTET

cbind-input   = gs2-header [ cbind-data ]
                ;; cbind-data MUST be present for
                ;; gs2-cbind-flag of "p" and MUST be absent
                ;; for "y" or "n".
```

8. SCRAM as a GSS-API Mechanism

   This section and its sub-sections and all normative references of it
   not referenced elsewhere in this document are INFORMATIONAL for SASL
   implementors, but they are NORMATIVE for GSS-API implementors.

   SCRAM is actually also GSS-API mechanism. The messages are the same,
   but a) the GS2 header on the client's first message and channel
   binding data is excluded when SCRAM is used as a GSS-API mechanism,
   and b) the RFC2743 section 3.1 initial context token header is
   prefixed to the client's first authentication message (context
   token).

   The GSS-API mechanism OID for SCRAM is <TBD> (see Section 10).

8.1. GSS-API Principal Name Types for SCRAM

   SCRAM does not name acceptors. Therefore only GSS_C_NO_NAME and
   names of type GSS_C_NT_ANONYMOUS shall be allowed as the target name
   input of GSS_Init_sec_context() when using a SCRAM mechanism.

   SCRAM supports only a single name type for initiators:
   GSS_C_NT_USER_NAME. GSS_C_NT_USER_NAME is the default name type for
   SCRAM.

   There is no name canonicalization procedure for SCRAM beyond applying
   SASLprep as described in Section 5.1.

   The query, display and exported name syntax for SCRAM principal names
   is the same: there is no syntax -- SCRAM principal names are free-
   form. (The exported name token does, of course, conform to [RFC2743]
   section 3.2, but the "NAME" part of the token is just a SCRAM user
   name.)

8.2. GSS-API Per-Message Tokens for SCRAM

   The per-message tokens for SCRAM as a GSS-API mechanism SHALL BE the
   same as those for the Kerberos V GSS-API mechanism [RFC4121], using
   the Kerberos V "aes128-cts-hmac-sha1-96" enctype [RFC3962].

   The 128-bit session key SHALL be derived by using the least
   significant (right-most) 128 bits of HMAC(StoredKey, "GSS-API session
   key" || ClientKey || AuthMessage).

   SCRAM does support PROT_READY, and is PROT_READY on the initiator
   side first upon receipt of the server's reply to the initial security
   context token.

8.3. GSS_Pseudo_random() for SCRAM

The GSS_Pseudo_random() [RFC4401] for SCRAM SHALL be the same as for
the Kerberos V GSS-API mechanism [RFC4402]. There is no acceptor-
asserted sub-session key for SCRAM, thus GSS_C_PRF_KEY_FULL and
GSS_C_PRF_KEY_PARTIAL are equivalent for SCRAM's GSS_Pseudo_random().

9. **Security Considerations**

   If the authentication exchange is performed without a strong security
   layer, then a passive eavesdropper can gain sufficient information to
   mount an offline dictionary or brute-force attack which can be used
   to recover the user's password. The amount of time necessary for
   this attack depends on the cryptographic hash function selected, the
   strength of the password and the iteration count supplied by the
   server. An external security layer with strong encryption will
   prevent this attack.

   If the external security layer used to protect the SCRAM exchange
   uses an anonymous key exchange, then the SCRAM channel binding
   mechanism can be used to detect a man-in-the-middle attack on the
   security layer and cause the authentication to fail as a result.
   However, the man-in-the-middle attacker will have gained sufficient
   information to mount an offline dictionary or brute-force attack.
   For this reason, SCRAM includes the ability to increase the iteration
   count over time.

   If the authentication information is stolen from the authentication
   database, then an offline dictionary or brute-force attack can be
   used to recover the user's password. The use of salt mitigates this
   attack somewhat by requiring a separate attack on each password.
   Authentication mechanisms which protect against this attack are
   available (e.g., the EKE class of mechanisms).

   If an attacker obtains the authentication information from the
   authentication repository and either eavesdrops on one authentication
   exchange or impersonates a server, the attacker gains the ability to
   impersonate that user to all servers providing SCRAM access using the
   same hash function, password, iteration count and salt. For this
   reason, it is important to use randomly-generated salt values.

   SCRAM does not negotiate a hash function to use. Hash function
   negotiation is left to the SASL mechanism negotiation. It is
   important that clients be able to sort a locally available list of
   mechanisms by preference so that the client may pick the most
   preferred of a server's advertised mechanism list. This preference
   order is not specified here as it is a local matter. The preference
   order should include objective and subjective notions of mechanism
   cryptographic strength (e.g., SCRAM with a successor to SHA-1 may be
   preferred over SCRAM with SHA-1).

   Note that to protect the SASL mechanism negotiation applications
   normally must list the server mechs twice: once before and once after
   authentication, the latter using security layers. Since SCRAM does
   not provide security layers the only ways to protect the mechanism

negotiation are: a) use channel binding to an external channel, or b)
use an external channel that authenticates a user-provided server
name.

A hostile server can perform a computational denial-of-service attack
on clients by sending a big iteration count value.

10. IANA Considerations

   IANA is requested to add the following entries to the SASL Mechanism
   registry established by [RFC4422]:

   To: iana@iana.org
   Subject: Registration of a new SASL mechanism SCRAM-SHA-1

   SASL mechanism name (or prefix for the family): SCRAM-SHA-1
   Security considerations: Section 7 of [RFCXXXX]
   Published specification (optional, recommended): [RFCXXXX]
   Person & email address to contact for further information:
    IETF SASL WG <ietf-sasl@imc.org>
   Intended usage: COMMON
   Owner/Change controller: IESG <iesg@ietf.org>
   Note:

   To: iana@iana.org
   Subject: Registration of a new SASL mechanism SCRAM-SHA-1-PLUS

   SASL mechanism name (or prefix for the family): SCRAM-SHA-1-PLUS
   Security considerations: Section 7 of [RFCXXXX]
   Published specification (optional, recommended): [RFCXXXX]
   Person & email address to contact for further information:
    IETF SASL WG <ietf-sasl@imc.org>
   Intended usage: COMMON
   Owner/Change controller: IESG <iesg@ietf.org>
   Note:

   Note that even though this document defines a family of SCRAM-
   mechanisms, it doesn't register a family of SCRAM- mechanisms in the
   SASL Mechanisms registry. IANA is requested to prevent future
   registrations of SASL mechanisms starting with SCRAM- without
   consulting the SASL mailing list <ietf-sasl@imc.org> first.

   Note to future SCRAM- mechanism designers: each new SCRAM- SASL
   mechanism MUST be explicitly registered with IANA and MUST comply
   with SCRAM- mechanism naming convention defined in Section 4 of this
   document.

   We hereby request that IANA assign a GSS-API mechanism OID for SCRAM.

11. Acknowledgements

This document benefited from discussions on the SASL WG mailing list. The authors would like to specially thank Dave Cridland, Simon Josefsson and Jeffrey Hutzelman for their contributions to this document.

Appendix A. Other Authentication Mechanisms

   The DIGEST-MD5 [I-D.ietf-sasl-digest-to-historic] mechanism has
   proved to be too complex to implement and test, and thus has poor
   interoperability. The security layer is often not implemented, and
   almost never used; everyone uses TLS instead. For a more complete
   list of problems with DIGEST-MD5 which lead to the creation of SCRAM
   see [I-D.ietf-sasl-digest-to-historic].

   The CRAM-MD5 SASL mechanism, while widely deployed has also some
   problems, in particular it is missing some modern SASL features such
   as support for internationalized usernames and passwords, support for
   passing of authorization identity, support for channel bindings. It
   also doesn't support server authentication. For a more complete list
   of problems with CRAM-MD5 see [I-D.ietf-sasl-crammd5-to-historic].

   The PLAIN [RFC4616] SASL mechanism allows a malicious server or
   eavesdropper to impersonate the authenticating user to any other
   server for which the user has the same password. It also sends the
   password in the clear over the network, unless TLS is used. Server
   authentication is not supported.

Appendix B. Design Motivations

   The following design goals shaped this document. Note that some of
   the goals have changed since the initial version of the document.

   o The SASL mechanism has all modern SASL features: support for
      internationalized usernames and passwords, support for passing of
      authorization identity, support for channel bindings.

   o The protocol supports mutual authentication.

   o The authentication information stored in the authentication
      database is not sufficient by itself to impersonate the client.

   o The server does not gain the ability to impersonate the client to
      other servers (with an exception for server-authorized proxies),
      unless such other servers allow SCRAM authentication and use the
      same salt and iteration count for the user.

   o The mechanism is extensible, but [hopefully] not overengineered in
      this respect.

   o Easier to implement than DIGEST-MD5 in both clients and servers.

Appendix C. **Internet-Draft Change History**

   (RFC Editor: Please delete everything after this point)

   Changes since -10

   o Converted the source for this I-D to XML.

   o Added text to make SCRAM compliant with the new GS2 design.

   o Added text on channel binding negotiation.

   o Added text on channel binding, including a reference to RFC5056.

   o Added text on SCRAM as a GSS-API mechanism. This noted as not
      relevant to SASL-only implementors -- the normative references for
      SCRAM as a GSS-API mechanism are segregated as well.

   Changes since -07

   o Updated References.

   o Clarified purpose of the m= attribute.

   o Fixed a problem with authentication/authorization identity's ABNF
      not allowing for some characters.

   o Updated ABNF for nonce to show client-generated and server-
      generated parts.

   o Only register SCRAM-SHA-1 with IANA and require explicit
      registrations of all other SCRAM- mechanisms.

   Changes since -06

   o Removed hash negotiation from SCRAM and turned it into a family of
      SASL mechanisms.

   o Start using "Hash Function Textual Names" IANA registry for SCRAM
      mechanism naming.

   o Fixed definition of Hi(str, salt) to be consistent with [RFC2898].

   o Clarified extensibility of SCRAM: added m= attribute (for future
      mandatory extensions) and specified that all unrecognized
      attributes must be ignored.

   Changes since -05

o Changed the mandatory to implement hash algorithm to SHA-1 (as per
   WG consensus).

o Added text about use of SASLPrep for username canonicalization/
   validation.

o Clarified that authorization identity is canonicalized/verified
   according to SASL protocol profile.

o Clarified that iteration count is per-user.

o Clarified how clients select the authentication function.

o Added IANA registration for the new mechanism.

o Added missing normative references (UTF-8, SASLPrep).

o Various editorial changes based on comments from Hallvard B
   Furuseth, Nico William and Simon Josefsson.

Changes since -04

o Update Base64 and Security Glossary references.

o Add Formal Syntax section.

o Don't bother with "v=".

o Make MD5 mandatory to implement. Suggest i=128.

Changes since -03

o Seven years have passed, in which it became clear that DIGEST-MD5
   suffered from unacceptably bad interoperability, so SCRAM-MD5 is
   now back from the dead.

o Be hash agnostic, so MD5 can be replaced more easily.

o General simplification.

12. References

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