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GSS-API Key Exchange with SHA2  
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## Abstract

This document specifies additions and amendments to [RFC4462](#). It defines a new key exchange method that uses SHA-2 for integrity and deprecates weak DH groups. The purpose of this specification is to modernize the cryptographic primitives used by GSS Key Exchanges.

## Status of This Memo

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[1.](#) Introduction

SSH GSS-API Methods [[RFC4462](#)] allows the use of GSSAPI [[RFC2743](#)] for authentication and key exchange in SSH. It defines three exchange methods all based on DH groups and SHA-1. This document updates [RFC4462](#) with new methods intended to support environments that desire to use the SHA-2 cryptographic hash functions.

[2.](#) Rationale

Due to security concerns with SHA-1 [[RFC6194](#)] and with MODP groups with less than 2048 bits [[NIST-SP-800-131Ar1](#)] we propose the use of hashes based on SHA-2 [[RFC6234](#)] with DH group14, group15, group16, group17 and group18 [[RFC3526](#)]. Additionally we add support for key exchange based on Elliptic Curve Diffie Hellman with the NIST P-256, P-384 and P-521 [[SEC2v2](#)] as well as the X25519 and X448 [[RFC7748](#)] curves. Following the practice of [[RFC8268](#)] only SHA-256 and SHA-512 hashes are used for DH groups. For NIST curves the same curve-to-hashing algorithm pairing used in [[RFC5656](#)] is adopted for consistency.

[3.](#) Document Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14 RFC2119](#) [RFC2119] [RFC8174](#) [RFC8174] when, and only when, they appear in all capitals, as shown here.

#### 4. New Diffie-Hellman Key Exchange methods

This document adopts the same naming convention defined in [\[RFC4462\]](#) to define families of methods that cover any GSS-API mechanism used with a specific Diffie-Hellman group and SHA-2 Hash combination.

Key Exchange Method Name	Implementation Recommendations
gss-group14-sha256-*	SHOULD/RECOMMENDED
gss-group15-sha512-*	MAY/OPTIONAL
gss-group16-sha512-*	SHOULD/RECOMMENDED
gss-group17-sha512-*	MAY/OPTIONAL
gss-group18-sha512-*	MAY/OPTIONAL

Table 1: New key exchange algorithms

Each key exchange method prefix is registered by this document. The IESG is the change controller of all these key exchange methods; this does NOT imply that the IESG is considered to be in control of the corresponding GSS-API mechanism.

Each method in any family of methods (Table 2) specifies GSS-API-authenticated Diffie-Hellman key exchanges as described in [Section 2.1 of \[RFC4462\]](#). The method name for each method (Table 1) is the concatenation of the family name prefix with the Base64 encoding of the MD5 hash [\[RFC1321\]](#) of the ASN.1 DER encoding [\[ISO-IEC-8825-1\]](#) of the corresponding GSS-API mechanism's OID. Base64 encoding is described in [Section 4 of \[RFC4648\]](#).

Family Name prefix	Hash Function	Group	Reference
gss-group14-sha256-	SHA-256	2048-bit	<a href="#">Section 3</a> of

gss-group15-sha512-	SHA-512	MODP	[RFC3526]
		3072-bit	Section 4 of
gss-group16-sha512-	SHA-512	MODP	[RFC3526]
		4096-bit	Section 5 of
gss-group17-sha512-	SHA-512	MODP	[RFC3526]
		6144-bit	Section 6 of
gss-group18-sha512-	SHA-512	MODP	[RFC3526]
		8192-bit	Section 7 of
		MODP	[RFC3526]

Table 2: Family method references

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## 5. New Elliptic Curve Diffie-Hellman Key Exchange methods

In [RFC5656] new SSH key exchange algorithms based on Elliptic Curve Cryptography are introduced. We reuse much of [section 4 of \[RFC5656\]](#) to define GSS-API-authenticated ECDH Key Exchanges.

Additionally, we also utilize the curves defined in [\[I-D.ietf-curdle-ssh-curves\]](#) to complement the three classic NIST-defined curves required by [\[RFC5656\]](#).

### 5.1. Generic GSS-API Key Exchange with ECDH

This section reuses much of the scheme defined in [Section 2.1 of \[RFC4462\]](#) and combines it with the scheme defined in [Section 4 of \[RFC5656\]](#); in particular, all checks and verification steps prescribed in [Section 4 of \[RFC5656\]](#) apply here as well.

Key-agreement schemes ECDHE-Curve25519 and ECDHE-Curve448 perform the Diffie-Helman protocol using the functions X25519 and X448, respectively. Implementations MUST compute these functions using the algorithms described in [\[RFC7748\]](#). When they do so, implementations MUST check whether the computed Diffie-Hellman shared secret is the all-zero value and abort if so, as described in [Section 6 of \[RFC7748\]](#). Alternative implementations of these functions SHOULD abort when either input forces the shared secret to one of a small set of values, as discussed in [Section 7 of \[RFC7748\]](#).

This section defers to [\[RFC7546\]](#) as the source of information on GSS-API context establishment operations, [Section 3](#) being the most

relevant. All Security Considerations described in [[RFC7546](#)] apply here too.

The parties each generate an ephemeral key pair, according to Section 3.2.1 of [[SEC1v2](#)]. Keys are verified upon receipt by the parties according to Section 3.2.3.1 of [[SEC1v2](#)].

For NIST Curves the keys use the uncompressed point representation and MUST be converted using the algorithm in Section 2.3.4 of [[SEC1v2](#)]. If the conversion fails or the point is transmitted using the compressed representation, the key exchange MUST fail.

A GSS Context is established according to [Section 4 of \[RFC5656\]](#); The client initiates the establishment using `GSS_Init_sec_context()` and the server responds to it using `GSS_Accept_sec_context()`. For the negotiation, the client MUST set `mutual_req_flag` and `integ_req_flag` to "true". In addition, `deleg_req_flag` MAY be set to "true" to request access delegation, if requested by the user. Since the key exchange process authenticates only the host, the setting of

`anon_req_flag` is immaterial to this process. If the client does not support the "gssapi-keyex" user authentication method described in [Section 4 of \[RFC4462\]](#), or does not intend to use that method in conjunction with the GSS-API context established during key exchange, then `anon_req_flag` SHOULD be set to "true". Otherwise, this flag MAY be set to true if the client wishes to hide its identity. This key exchange process will exchange only a single message token once the context has been established, therefore the `replay_det_req_flag` and `sequence_req_flag` SHOULD be set to "false".

The client MUST include its public key with the first message it sends to the server during this process; if the server receives more than one key or none at all, the key exchange MUST fail.

During GSS Context establishment multiple tokens may be exchanged by the client and the server. When the GSS Context is established (`major_status` is `GSS_S_COMPLETE`) the parties check that `mutual_state` and `integ_avail` are both "true". If not the key exchange MUST fail.

Once a party receives the peer's public key it proceeds to compute a shared secret `K`. For NIST Curves the computation is done according to Section 3.3.1 of [[SEC1v2](#)] and the resulting value `z` is converted

to the octet string K using the conversion defined in Section 2.3.5 of [SEC1v2]. For curve25519 and curve448 the algorithms in Section 6 of [RFC7748] are used instead.

To verify the integrity of the handshake, peers use the Hash Function defined by the selected Key Exchange method to calculate H:

$H = \text{hash}(V\_C \parallel V\_S \parallel I\_C \parallel I\_S \parallel K\_S \parallel Q\_C \parallel Q\_S \parallel K).$

The GSS\_GetMIC() call is used by the server with H as the payload and generates a MIC. The GSS\_VerifyMIC() call is used by the client to verify the MIC.

If any GSS\_Init\_sec\_context() or GSS\_Accept\_sec\_context() returns a major\_status other than GSS\_S\_COMPLETE or GSS\_S\_CONTINUE\_NEEDED, or any other GSS-API call returns a major\_status other than GSS\_S\_COMPLETE, the key exchange MUST fail. The same recommendations expressed in Section 2.1 of [RFC4462] are followed with regards to error reporting.

The following is an overview of the key exchange process:

```
Client                                     Server
-----                                     -----
Generate ephemeral key pair.
Calls GSS_Init_sec_context().
SSH_MSG_KEXGSS_INIT ----->

                                     Verify received key is valid.
(Optional) <----- SSH_MSG_KEXGSS_HOSTKEY

(Loop)
|                                     Calls GSS_Accept_sec_context().
|                                     <----- SSH_MSG_KEXGSS_CONTINUE
| Calls GSS_Init_sec_context().
| SSH_MSG_KEXGSS_CONTINUE ----->
```

```
        Calls GSS_Accept_sec_context().
          Generate ephemeral key pair.
            Compute shared secret.
              Computes hash H.
                Calls GSS_GetMIC( H ) = MIC.
<----- SSH_MSG_KEXGSS_COMPLETE
```

```
Verify received key is valid.
Compute shared secret.
Compute hash = H
Calls GSS_VerifyMIC( MIC, H )
```

This is implemented with the following messages:

The client sends:

```
byte      SSH_MSG_KEXGSS_INIT
string    output_token (from GSS_Init_sec_context())
string    Q_C, client's ephemeral public key octet string
```

The server may respond with:

```
byte      SSH_MSG_KEXGSS_HOSTKEY
string    server public host key and certificates (K_S)
```

The server sends:

```
byte      SSH_MSG_KEXGSS_CONTINUE
string    output_token (from GSS_Accept_sec_context())
```

Each time the client receives the message described above, it makes another call to GSS\_Init\_sec\_context().

The client sends:

```
byte      SSH_MSG_KEXGSS_CONTINUE
string    output_token (from GSS_Init_sec_context())
```

As the final message the server sends either:

```
byte      SSH_MSG_KEXGSS_COMPLETE
```

```
string    Q_S, server's ephemeral public key octet string
string    mic_token (MIC of H)
boolean   TRUE
string    output_token (from GSS_Accept_sec_context())
```

Or the following if no output\_token is available:

```
byte      SSH_MSG_KEXGSS_COMPLETE
string    Q_S, server's ephemeral public key octet string
string    mic_token (MIC of H)
boolean   FALSE
```

The hash H is computed as the HASH hash of the concatenation of the following:

```
string    V_C, the client's version string (CR, NL excluded)
string    V_S, server's version string (CR, NL excluded)
string    I_C, payload of the client's SSH_MSG_KEXINIT
string    I_S, payload of the server's SSH_MSG_KEXINIT
string    K_S, server's public host key
string    Q_C, client's ephemeral public key octet string
string    Q_S, server's ephemeral public key octet string
mpint    K, shared secret
```

This value is called the exchange hash, and it is used to authenticate the key exchange. The exchange hash SHOULD be kept secret. If no SSH\_MSG\_KEXGSS\_HOSTKEY message has been sent by the server or received by the client, then the empty string is used in place of K\_S when computing the exchange hash.

Since this key exchange method does not require the host key to be used for any encryption operations, the SSH\_MSG\_KEXGSS\_HOSTKEY message is OPTIONAL. If the "null" host key algorithm described in [Section 5 of \[RFC4462\]](#) is used, this message MUST NOT be sent.

If the client receives a SSH\_MSG\_KEXGSS\_CONTINUE message after a call to GSS\_Init\_sec\_context() has returned a major\_status code of GSS\_S\_COMPLETE, a protocol error has occurred and the key exchange MUST fail.

If the client receives a SSH\_MSG\_KEXGSS\_COMPLETE message and a call

to `GSS_Init_sec_context()` does not result in a `major_status` code of `GSS_S_COMPLETE`, a protocol error has occurred and the key exchange MUST fail.

## 5.2. ECDH Key Exchange Methods

Key Exchange Method Name	Implementation Recommendations
<code>gss-nistp256-sha256-*</code>	SHOULD/RECOMMENDED
<code>gss-nistp384-sha384-*</code>	MAY/OPTIONAL
<code>gss-nistp521-sha512-*</code>	MAY/OPTIONAL
<code>gss-curve25519-sha256-*</code>	SHOULD/RECOMMENDED
<code>gss-curve448-sha512-*</code>	MAY/OPTIONAL

Table 3: New key exchange methods

Each key exchange method prefix is registered by this document. The IESG is the change controller of all these key exchange methods; this does NOT imply that the IESG is considered to be in control of the corresponding GSS-API mechanism.

Each method in any family of methods (Table 4) specifies GSS-API-authenticated Elliptic Curve Diffie-Hellman key exchanges as described in [Section 5.1](#). The method name for each method (Table 3) is the concatenation of the family method name with the Base64 encoding of the MD5 hash [[RFC1321](#)] of the ASN.1 DER encoding [[ISO-IEC-8825-1](#)] of the corresponding GSS-API mechanism's OID. Base64 encoding is described in [Section 4 of \[RFC4648\]](#).

Family Name prefix	Hash Function	Parameters / Function Name	Definition
gss-nistp256-sha256-	SHA-256	secp256r1	<a href="#">Section 2.4.2</a> of <a href="#">[SEC2v2]</a>
gss-nistp384-sha384-	SHA-384	secp384r1	<a href="#">Section 2.5.1</a> of <a href="#">[SEC2v2]</a>
gss-nistp521-sha512-	SHA-512	secp521r1	<a href="#">Section 2.6.1</a> of <a href="#">[SEC2v2]</a>
gss-curve25519-sha256-	SHA-256	X25519	<a href="#">Section 5</a> of <a href="#">[RFC7748]</a>
gss-curve448-sha512-	SHA-512	X448	<a href="#">Section 5</a> of <a href="#">[RFC7748]</a>

Table 4: Family method references

## 6. Deprecated Algorithms

Because they have small key lengths and are no longer strong in the face of brute-force attacks, the algorithms in the following table are considered deprecated and SHOULD NOT be used.

### Deprecated Algorithms

Key Exchange Method Name	Implementation Recommendations
gss-group1-sha1-*	SHOULD NOT
gss-group14-sha1-*	SHOULD NOT
gss-gex-sha1-*	SHOULD NOT

## 7. IANA Considerations

This document augments the SSH Key Exchange Method Names in [\[RFC4462\]](#).

IANA is requested to update the SSH Protocol Parameters [[IANA-KEX-NAMES](#)] registry with the following entries:

Key Exchange Method Name	Reference
gss-group1-sha1-*	This draft
gss-group14-sha1-*	This draft
gss-gex-sha1-*	This draft
gss-group14-sha256-*	This draft
gss-group15-sha512-*	This draft
gss-group16-sha512-*	This draft
gss-group17-sha512-*	This draft
gss-group18-sha512-*	This draft
gss-nistp256-sha256-*	This draft
gss-nistp384-sha384-*	This draft
gss-nistp521-sha512-*	This draft
gss-curve25519-sha256-*	This draft
gss-curve448-sha512-*	This draft

## [8.](#) Security Considerations

### [8.1.](#) New Finite Field DH mechanisms

Except for the use of a different secure hash function and larger DH groups, no significant changes has been made to the protocol described by [[RFC4462](#)]; therefore all the original Security Considerations apply.

### [8.2.](#) New Elliptic Curve DH mechanisms

Although a new cryptographic primitive is used with these methods the actual key exchange closely follows the key exchange defined in [[RFC5656](#)]; therefore all the original Security Considerations as well as those expressed in [[RFC5656](#)] apply.

### [8.3.](#) GSSAPI Delegation

Some GSSAPI mechanisms can act on a request to delegate credentials to the target host when the `deleg_req_flag` is set. In this case, extra care must be taken to ensure that the acceptor being authenticated matches the target the user intended. Some mechanism implementations (such as commonly used `krb5` libraries) may use insecure DNS resolution to canonicalize the target name; in these cases spoofing a DNS response that points to an attacker-controlled machine may result in the user silently delegating credentials to the attacker, who can then impersonate the user at will.

## [9.](#) References

### [9.1.](#) Normative References

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