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TRILL: Group Keying
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Abstract

This document specifies a general group keying protocol. It also provides use profiles for the application of this group keying protocol to multi-destination TRILL Extended RBridge Channel message security and TRILL over IP packet security.

Status of This Memo

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1. Introduction

This document specifies a general group keying protocol in Section 2. In addition, it provides, in Section 3, the use profile for the application of this group keying protocol to TRILL [RFC6325] [RFC7780] Extended RBridge Channel message security [RFC7178] [RFC7978]. It is anticipated that there will be other uses for this group keying protocol, for example in connection with link security in [TRILLoverIP].

1.1 Terminology and Acronyms

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].

This document uses terminology and acronyms defined in [RFC6325] and [RFC7178]. Some of these are repeated below for convenience along with additional new terms and acronyms.

AES - Advanced Encryption Standard.

Data Label - VLAN or FGL.

DTLS - Datagram Transport Level Security [RFC6347].

FGL - Fine Grained Label [RFC7172].

GKd - A distinguished station in a group that is in charge of

which group keying (Section 2) is in use.

GKs - Stations in a group other than GKd (Section 2).

HKDF - Hash based Key Derivation Function [RFC5869].

IS-IS - Intermediate System to Intermediate System [RFC7176].

keying material - The set of a Key ID, a secret key, and a cypher suite.

PDU - Protocol Data Unit.

RBridge - An alternative term for a TRILL switch.

SHA - Secure Hash Algorithm [RFC6234].

TRILL - Transparent Interconnection of Lots of Links or Tunneled Routing in the Link Layer.

TRILL switch - A device that implements the TRILL protocol [RFC6325] [RFC7780], sometimes referred to as an RBridge.

2. Group Keying Protocol

This section defines a general Group Keying Protocol that provides shared secret group keys. Any particular use of this protocol will require a profiling giving further details and specifics for that use. The protocol is not suitable for discovery messages but is intended for use between members of a group that have already established pair-wise security.

2.1 Assumptions

The following are assumed:

- All pairs of stations in the group can engage in pairwise

communication with unicast messages and each can groupcast a message to the other group members.
- At any particular time, there is a distinguished station GKd in the group that is in charge of keying for the groupcast data messages to be sent to the group. The group wide shared secret keys established by GKd are referred to herein as "dynamic" keys.
- Pairwise keying has been negotiated between GKd and each other station GKs1, GKs2, ... GKsN in the group. These keys are referred to in this protocol as "pairwise" keys.
- One or more keys, other than the dynamic or pairwise keys, are already in place at all group member stations. These are referred to as "stable" keys.

When keying material is stored by a station, it is accompanied by a "use flag" indicating whether or not that keying material is usable for groupcast transmissions.

2.2 Group Keying Procedure Overview

GKd sends unicast keying messages to the other stations in the group and they respond as specified below and in further detail in the particular use profile for this Group Keying Protocol. All such keying messages MUST be encrypted and authenticated using the pairwise keys as further specified in the use profile.

Typically, GKd sends a keying message to each GKs with keying material. After successful acknowledgement of receipt from each GKs, GKd sends a keying message to each GKs instructing it to use the dynamic key GKd has set. It would be common for GKd to set a new dynamic key at each GKs while an older dynamic key is in use so that GKd can more promptly roll over to the new key when appropriate.

To avoid an indefinite build up of keying material at a GKs, keys have a lifetime specified by GKd and GKd can send a message deleting a key. (GKd can also send a message indicating that a key is no longer to be used but leaving it set.) Should the space available at a GKs for keying material be exhausted, on receipt of a Set Key keying message for a new key ID GKs discards a dynamic key it has and originates a Delete Key message to the source of that dynamic key.

2.3 Transmission and Receipt of Group Data Messages

If a group has only two members, then pairwise security is used between them.

When a group has more than two members and a station in the group transmits a data message to the group, if the transmitter has one or more keys set by GKd that it has been instructed to use, it uses one of those keys and its associated cypher suite to groupcast the data message. If it has no such key, then it uses serial unicast to send the data message to each other member of the group, negotiating pairwise keys with them if it does not already have such pairwise keys. Thus it is a responsibility of GKd not to authorize the use of a groupcast key until it knows that all the GKs have that key.

When a station in the group receives data that has been groupcast to the group, if the receiver has the key referenced by the data message the receiver decrypts and verifies it. If verification fails or if the receiver does not have the required key, the receiver discards the data message. Thus whether GKs has been directed to "use" a key by GKd is relevant only to transmission, not reception.

2.4 Changes in Group Membership or GKd

When a new station joins the group, GKd should send that station the currently in-use group key and instruct it to use that key and send it other keys known to the group members and intended for future use.

If GKd detects that one or more stations that were members of the group are no longer members of the group, it SHOULD generate and distribute a new group key to the remaining group members, instruct them to use this new key, and delete from them any old keys known to the departed group member station(s) or at least instructing them to disuse such old keys that are marked for use; however, in the case of groups with large and/or highly dynamic membership, where a station might frequently leave and then rejoin, it may, as a practical matter, be necessary to rekey less frequently.

A new group member can become GKd due to the previous GKd leaving the group or a configuration change or the like. A GKs MUST NOT use keying material set by a station that it determines is not GKd. To avoid a gap in service, a station that is not GKd MAY set keying material at other stations in the group; however, such a non-GKd station cannot set the use flag for any such keying material. It is RECOMENDED that the second highest priority station to be GKd set such keying material at all other stations in the group. Should a station run out of room for keying material, it SHOULD discard keying material set by a station with lower priority to be GKd before discarding keying material set by a higher priority station and among keys set by GKd is SHOULD discard the lest recently used first.

2.5 Group Keying Messages

Keying messages start with a Version number. This document specifies Version zero.

Keying messages are structured as

- a Version number,
- a Response flag,
- a Key ID length,
- the Key ID of a stable key,
- a group keying use profile identifier,
- possible padding, and finally
- an AES key wrapped [RFC5649] [RFC3394] vector of additional fields wrapped using the stable key identified and using AES-256, as shown in Figure 2.1 below.

Keying messages are always sent unicast and encrypted and authenticated with the appropriate pairwise key, all as further specified for the particular use profile. It will typically be possible for GKd to calculate the keying message once, including the AES wrapping under a stable key, then send that message to various GKs using the different pairwise keys for each GKs.

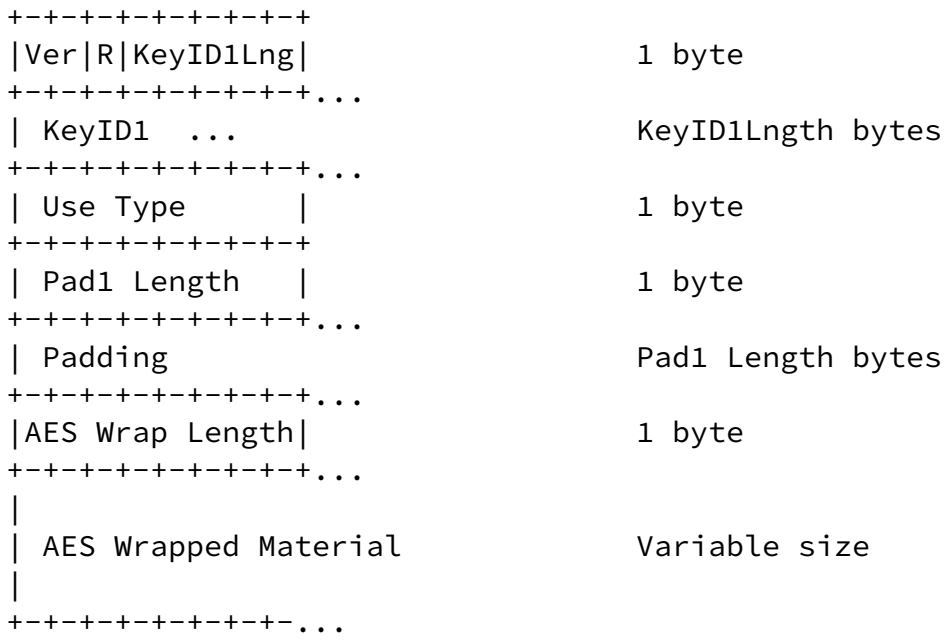


Figure 2.1. Keying Message Structure

The fields in Figure 2.1 are as follows:

Ver - Group Keying protocol version. This document specifies version zero.

R - Response flag. If set to one, indicates a response message. If set to zero, indicated a request or no-op message.

KeyID1Lngth, KeyID1 - KeyID1 identifies the stable AES-256 key wrapping key (also known as the Key Encrypting Key (KEK)) as further specified in the use profile. KeyID1Lngth is a byte that gives the length of KeyID1 in bytes as an unsigned integer.

Use Type - Specifies the particular group security use profile such as RBridge Extension (Section 3) or IP link [TRILLoverIP].

Pad1 Length, Pad1 - Padding to obscure the non-padded message size. Pad1 Length may be from 0 to 255 and gives the length of the padding as an unsigned integer. Each byte of padding MUST be equal to Pad1 Length. For example, 3 bytes of

padding with length is 0x03030303.

AES Wrap Length - An unsigned byte that gives the length of the AES Wrapped Material in units of 8 bytes. The length of AES key wrapped material is, as specified in [RFC5649], always a multiple of 8 bytes (64 bits) and not less than 16 bytes. Thus an AES Wrap Length of 0 or 1 is invalid.

AES Wrapped Material - The output of the AES Key Wrapping operation on the message vector of fields using the specified stable key.

The vector of fields contained within the AES-256 key wrapping is specified for the various keying messages in subsections below. The contents of this wrapped vector are protected by the AES wrapping as well as being authenticated and super-encrypted by the pairwise keyed security used for sending the overall keying message. The stable key used for AES wrapping MUST be different from the outer message pairwise key.

Each group keying message contains, in the AES wrapped vector of fields, a message type and a message ID set by the sender of a request. These fields are returned in the corresponding response to assist in the matching of response to requests, except that there is no response to the No-Op message.

If no response is received to a request (other than a No-Op message) for an amount of time configurable in milliseconds from 1 to (2**15 - 1), the request is re-transmitted with the same message ID. These retries can occur up to a configurable number of times from 1 to 8. Unless otherwise provided in the particular use profile, the default response delay threshold is 200 milliseconds and the default maximum number of retries is 3.

Keying messages are sent with a priority configurable on a per device per use type basis. The default priority is specified in the use profile.

Since the minimum length of the AES Wrapped Material is 16 bytes [RFC5649], the minimum valid size of a keying message is 20 bytes, even if KeyID1 Length and Pad1 Length are zero. All multi-byte fields are in network order, that is, with the most significant byte first.

2.6 Set Key Message

The structure of the wrapped vector of fields for the Set Key keying message is as show in Figure 2.2. A recipient automatically determines the overall length provided for this vector of fields inside the AES wrapping as a byproduct of the process of AES unwrapping [RFC5649].

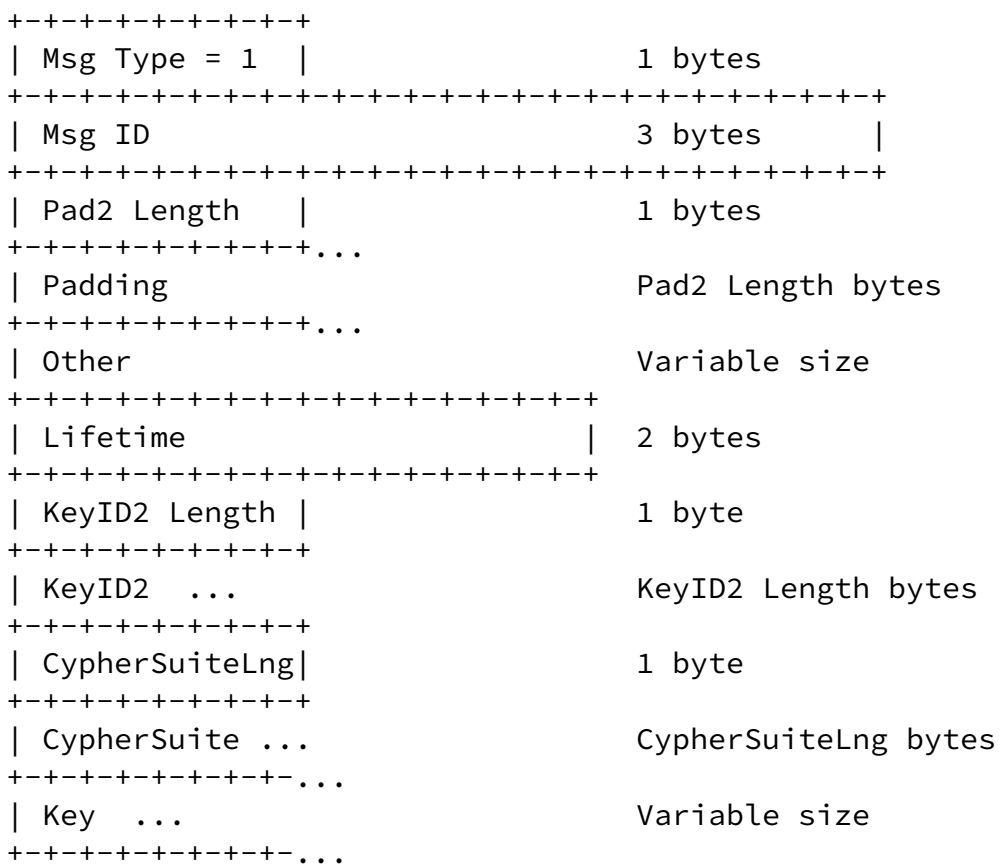


Figure 2.2. Set Key Message Inner Structure

The fields are as follows:

Msg Type = 1 for Set Key message

Msg ID - A 3 byte quantity to be included in the corresponding response message to assist in matching requests and responses. Msg ID zero has a special meaning in responses and MUST NOT be used in a Set Key message or any other group keying request message.

Pad2 Length, Pad2 - Padding to obscure the size of the unapdded AES wrapped data. Pad2 Length may be from 0 to 255 and gives the length of the padding as an unsigned integer. Each byte of padding MUST be equal to Pad1 Length. For example, 2 bytes of padding with length byte is 0x020202.

Other - Additional information if specified in the use profile. If Other information in this message is not mentioned in the use profile, there is none and this portion of the wrapped information is null. If a use profile specifies Other information it must be possible to determine its length so that following fields can be properly parsed and so that the size of the Key field can be deduced.

Lifetime - A 2-byte unsigned integer. After that number of seconds plus one second, the key and associated information being set MUST be discarded. Unless otherwise specified for a particular use profile of this group keying protocol, the default Lifetime is 15,000 seconds or a little over four hours.

KeyID2 Length, KeyID2 - KeyID2 identifies the group key and associated information being set as further specified in the use profile. KeyID2 Length is an unsigned byte that gives the length of KeyID2 in bytes.

CypherSuiteLng, CypherSuite - CypherSuite identifies the cypher suite associated with the key being set as further specified in the use profile. CypherSuite Length is an unsigned byte the gives the length of CypherSuite in bytes.

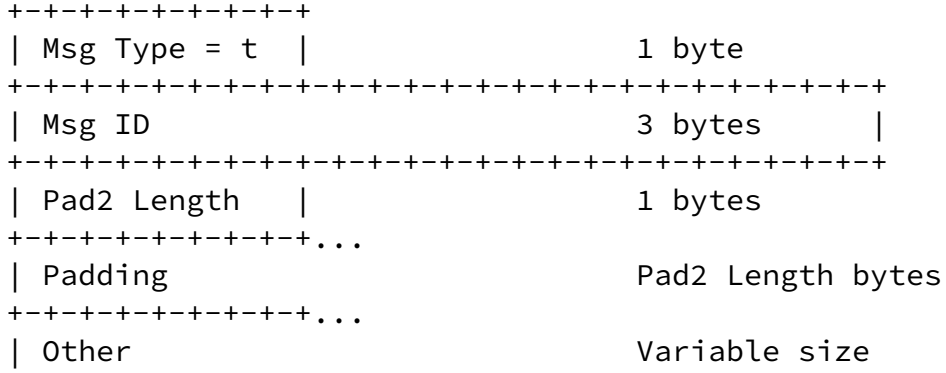
Key - This is the actually group shared secret keying material

being set. Its length is deduced from the overall length of the vector of fields (found by the AES unwrap operation) and the length of the preceding fields.

If GKs already has a dynamic key set under KeyID2, the key's value and associated cypher suite are compared with those in the Set Key messages. If they are the same, the only receiver action is to update the Lifetime information associated with KeyID2 and send a Response message. If they are different, the lifetime, cypher suite, and key (and possibly Other material) are replaced, the use flag is cleared, and a Response message sent.

2.7 Use, Delete, Disuse, or Deleted Key Messages

The structure of the wrapped material for the Use Key, Delete Key, and Disuse Key keying messages are the same as each other except for the message type. This structure is shown in Figure 2.3



```
+-+-+-+-+-+-+-+-+...
| KeyID2 Length |                    1 byte
+-+-+-+-+-+-+-+-+
| KeyID2  ...                        KeyID2 bytes
+-+-+-+-+-+-+-+-+
```

Figure 2.3. Use, Delete, Disuse, or Deleted Key Message

The Msg Type field specifies the particular message as follows:

Msg Type	Message
2	Use Key
3	Delete Key
4	Disuse Key
5	Deleted Key

The remaining fields are as specified in Section 2.4. KeyID2 indicates the key to be used, deleted, for which use should cease, or which has been deleted, depending on the message type.

It is RECOMMENDED that these messages be padded so as to be the same length as a typical Set Key message.

The Deleted Key is sent by a station believing itself to be GKd instructing some GKs to delete a key. When a GKs spontaneously deletes a key, it sends a Deleted Key message to the station from which it received the key. The message types for Delete Key and Deleted Key are different to minimize confusion in corner cases such as the GKd changing while messages are in flight. The Msg ID used in a Deleted Key message is created by the sending GKs from a space of Msg IDs associated with that GKs which is independent of the Msg IDs used in requests originated by GKd.

2.8 Response Message

The structure of the wrapped material for the Response group keying message is as show below in Figure 2.4. A response message is

indicated by the R bit in the first byte of the message outside the key wrapping.

A response MUST NOT be sent due to the receipt of a response. The R bit is outside of the key wrapping so that this rule can be enforced even in cases of difficulty in unwrapping.

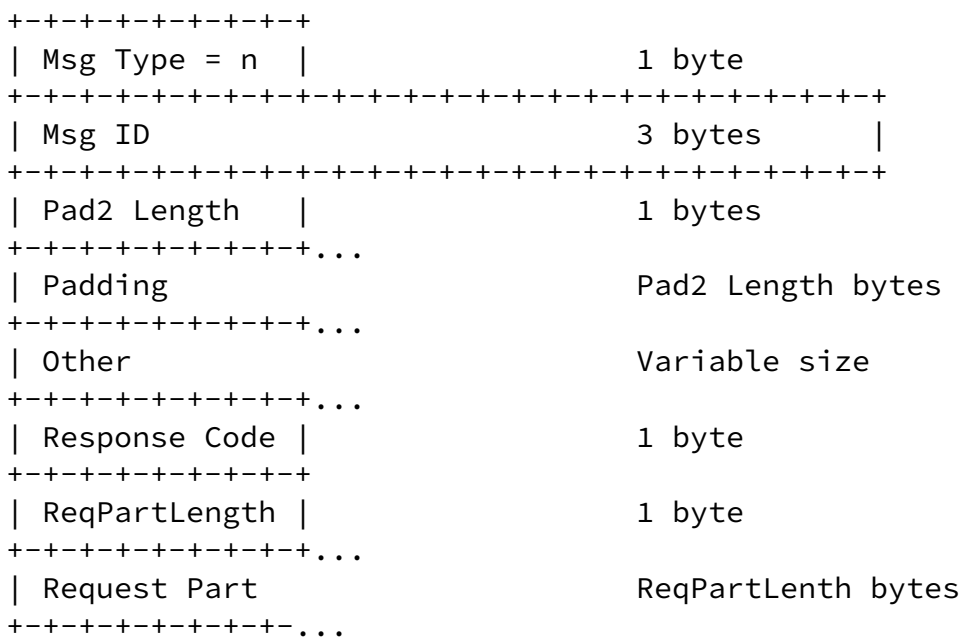


Figure 2.4. Response Message Inner Structure

Except as specified below, the fields are as specified for the Key Set message.

Msg Type, Msg ID - The content of these field is copied from the message in reply to which this Response message is sent unless there is an error that stops the replying station from determining them, in which case the special value zero is used for the Msg Type and Msg ID. Errors where the Msg Type and ID could not be determined are indicated by a Response Code with their high order bit set to one, that is, the 0b10000000 bit set.

Response Code - An unsigned byte giving the response as enumerated in Table 2.2 in Section 2.8.1. Any Response Code other than a success indicates that the receiver took no action on the request other than sending an error Response message.

ReqPartLength, Request Part: It is usually usefully to include some or all of the request in error responses.

- If the Response Code high order two bits are zero, the request succeeded and ReqPartLength MUST be set to zero so Request Part will be null.

- If the Response Code high order two bits are zero one (0b01), then there was an error in the part of the request inside the AES key wrapping but the unwrap process was successful. ReqPartLength is the length of the request message material include in the Request Part field. The included request material is from the unwrapped vector of fields started with the Msg Type byte.
- If the Response Code high order bit is one (the 0b10000000 is set), then there was an error parsing the material outside the AES key wrap or an error in the AES unwrapping process. ReqPartLength is the length of the request message part included in the Request Part field. The included part of the request starts with the first byte of the message (the byte containing the version, response flag, and KeyID1 Length).

2.8.1 Response Codes

The high order two bits of the Response Code have meaning as shown in Table 2.1.

Top 2 Bits	Category
0b00	Success
0b01	AES wrap contents
0b10/11	Outside of AES wrap contents

Response Decimal	Response Hex	Meaning
0	0x00	Success
1	0x01	Success and the key at an existing key ID was changed
2-47	0x02-0x2F	Unassigned
48-63	0x30-0x3F	Reserved for special success codes defined in use profiles
64	0x40	Malformed inner fields (see Note 2 below)
65	0x41	Unknown or zero Msg Type in a request
66	0x42	Zero Msg ID in a request
68	0x43	Invalid length KeyID2
69	0x44	Unknown KeyID2
70	0x45	Invalid length CypherSuite
71	0x46	Unknown CyperSuite

72	0x47	Bad Key (see Note 3 below)
73-111	0x49-0x6F	Unassigned
112-127	0x70-0x7F	Reserved for error codes defined in use profiles and related to the AES wrapped contents
128	0x80	Malformed message (see Note 1 below)
129	0x81	Invalid length KeyID1
130	0x82	Unknown KeyID1
131	0x83	Unknown Use Type
131	0x84	AES unwrap fails test 1, see Section 3 [RFC5649]
132	0x85	AES unwrap fails test 2, see Section 3 [RFC5649]
133	0x86	AES unwrap fails test 3, see Section 3 [RFC5649]
134-175	0x86-0x7F	Unassigned
176-191	0xB0-0xBF	Reserved for error codes defined in use profiles and related to parts of message outside the AES wrap contents
192	0xC0	No keys set
193	0xC1	Referenced key unknown
194	0xC2	Referenced key known but use flag not set
195-255	0xC3-0xFF	Reserved

Response Code Notes:

Note 1 Message is too short or too long, AES wrapped material is too short, Padding bytes are not the required value, or similar fundamental message format problems.

Note 2 The AES wrapped inner vector of fields is too short or too long, Padding bytes are not the required value, or similar fundamental vector of fields format problems.

Note 3 Key is not a valid length for CypherSuite or other internal checks on key (for example, parity bits in a 64 bit DES key (not that you should be using DES)) fail.

2.8 No-Op Message

The No-Op message is a dummy message intended for use in disguising metadata deducable from keying message transmissions. It requires no response although a recipient can always decided to send a No-Op message to a station from which it has received such a message.

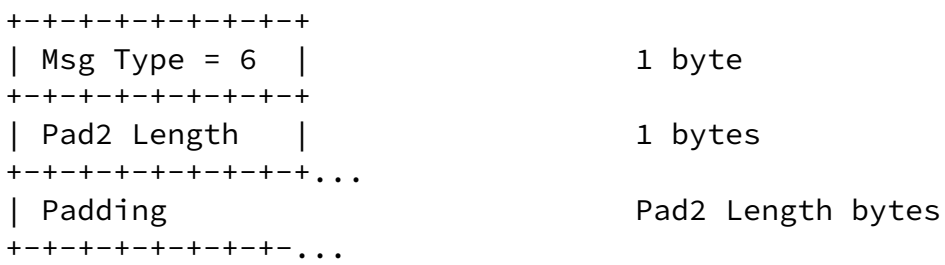


Figure 2.5. No-Op Message Inner Structure

The Msg Type is set to 6 to indicate a No-Op message.

Pad2 Length and Padding are as specified in Section 2.6. It is RECOMMENDED that Pad2 Length in a No-Op message be such as to make its length confusable with the length of a Set Key message.

2.9 General Security Considerations

This section gives some general security considerations of this group keying protocol as distinguished from security considerations of a particular use profile.

The method by which the stations in the group discover each other is specified in the group keying use profile. GKd controls group access and generally learns whatever it needs to know about GKs during the pairwise authentication and pairwise keying process.

The group keying provided by this protocol is shared secret keying. This means that data messages can only be authenticated as coming from some group member but not as coming from a specific group member. If this level of authentication is insufficient, GKd can simply not set keys or not set them as usable. This will force all stations in the group that are configured to use security for multi-destination transmissions to the group to serial unicast data to the other group members using pairwise keying.

The content value of padding fields in the Group Keying protocol is fixed so that it cannot be used as a covert channel. The length of padding could still be so used.

3. Extended RBridge Channel Group Keyed Security

This section specifies a profile of the group keying protocol defined in Section 2. This profile provides shared secret keying to secure multi-destination Extended RBridge Channel messages [RFC7978]. The keys put in place by the group keying protocol are available for use as DTLS pre-shared keys with the DTLS and Composite Security of multi-destination Extended RBridge Channel messages as specified in Section 3.2.

For this group keying use profile, a group is identified by TRILL Data Label (VLAN or FGL [RFC7172]) and consists of the data reachable [RFC7780] RBridges with interest in that Data Label. GKd is the RBridge in the group that, of those group members supporting the Group Keying Protocol, is the highest priority to be a TRILL distribution tree root. If not all members of the group support the Group Keying Protocol, then there are two cases for multi-destination Channel Tunnel RBridge Channel messages:

(1) If the sender and at least two other group members support the Group Keying Protocol, it SHOULD, for efficiency, send a secured multi-destination RBridge Channel message to cover the group and serially unicast to the group members not supporting the Group

Keying Protocol.
(2) In other cases the sender serially transmits the data to the group members using pairwise security.

3.1 Transmission of Group Keying Messages

Keying messages themselves are sent as unicast Extended RBridge Channel messages carrying a Group Keying protocol (see Section 5.2) RBridge Channel message. They MUST use DTLS Pairwise or Composite (STypes 2 or 3) security.

The RBridge Channel fields profile for this Group Keying Use Type is as follows:

Priority of Group Keying messages for this SHOULD be 6 unless the network manager chooses to use a lower priority after determining that such lower priority group keying messages will yield acceptable performance. Priority 7 SHOULD NOT be used as it may cause interference with the establishment and maintenance of adjacency.

Use Type = 1

KeyID1 Length = 2, KeyID1 is an [RFC5310] key ID.

CypherSuiteLng = 2, CypherSuite is the cypher suite used in

groupcast extended RBridge Channel data messages for the corresponding KeyID2. This a DTLS [RFC6347] cypher suite.

KeyID2 Length = 1, KeyID2 is the index under which a group key is set. Group keys are, in effect, indexed by this KeyID2 and the nickname of the GKd as used in the Ingress Nickname field of the TRILL Header of Group Keying messages.

3.2 Transmission of Protected Multi-destination Data

Protected Extended RBridge Channel [RFC7978] messages are multicast (M bit set to one in the TRILL Header) and set the SType field to a

new value for "Group Secured" (See Section 5.3). The data is formatted as one byte of Key ID followed by data formatted as TLS 1.2 [RFC5246] application_data using the cyphersuite and keying material stored under the Key ID.

4. TRILL Over IP Group Keyed Security

This section specifies a profile of the group keying protocol defined in Section 2. This profile provides shared secret keying to secure TRILL over IP messages [TRILLoverIP]. The keys put in place by the group keying protocol are available for use as IPSEC keys.

For this group keying use profile, a group is identified by an IP multicast address and consists of the adjacent [RFC7177] RBridges reachable with that multicast address. GKd is the RBridge in the group that, of those group members supporting the Group Keying Protocol, has the highest priority to be a TRILL distribution tree root. If not all members of the group support the Group Keying Protocol, then there are two cases for multi-destination TRILL over IP messages:

(1) If the sender and at least two other group members support the Group Keying Protocol, it SHOULD, for efficiency, send a secured IPSEC message to cover the group and serially unicast to the group members not supporting the Group Keying Protocol.
(2) In other cases the sender serially transmits the data to the group members using pairwise security.

4.1 Transmission of Group Keying Messages

tbd

Use Type = 2

tbd

4.2 Transmission of Protected Multi-destination Data

tbd

5. IANA Considerations

This section gives IANA Considerations.

5.1 Group Keying Protocol

IANA is requested to perform the following actions:

1. Establish a protocol parameters web page for "Group Keying Protocol Parameters" with the initial registries on that page as specified below in this section.

2. Establish a "Message Type" registry on the Group Keying Protocol Parameters page as follows:

   Registration Procedure: IETF Review

   Reference: [this document]

Type	Description	Reference
0	Reserved	[This document]
1	Set Key	[This document]
2	Use Key	[This document]
3	Delete Key	[This document]
4	Disuse Key	[This document]
5	Deleted Key	[This document]
6	No-Op	[This document]
7-250	Unassigned	
251-254	Reserved for Private Use	[This document]
255	Reserved	[This document]

3. Establish a "Group Keying Use Profile" registry on the Group Keying Protocol Parameters page as follows:

   Registration Procedure: IETF Review

   Reference: [This document]

Profile	Description	Reference
0	Reserved	[This document]
1	Extended RBridge Channel	[This document]
2	TRILL over IP	[This document]
3-250	Unassigned	
251-254	Reserved for Private Use	[This document]
255	Reserved	[This document]

4. Establish a "Response Code" registry on the Group Keying Protocol Parameters page as show below taking entries from the Response Code table in Section 2.8.1 above. In the table of values, the Reference column should be "[This document]" except where the Meaning is "Unassigned" or "Reserved".

   Registration Procedure: IETF Review

   Reference: [This document]

   Note: The top two bits of the Response Code indicate a category as specified in Section 2.8.1 of [this document].

Response Decimal	Response Hex	Meaning	Reference
0	0x00	Success	[this document]
...	...	...	
255	0xFF	Reserved	

5.2 Group Keying RBridge Channel Protocol Numbers

IANA is requested to assign TBD1 as the RBridge Channel protocol numbers, from the range assigned by Standards Action, for use when the "Group Keying" protocol is transmitted over Extended RBridge Channel messages.

The added RBridge Channel protocols registry entry on the TRILL Parameters web page is as follows:

Protocol	Description	Reference
TBD1	Group Keying	Section 2 of [this document]

5.3 Group Secured Extended RBridge Channel SType

IANA is requested to assign TBD2 as the Group Secured SType in the

"Extended RBridge Channel Security Types Subregistry" on the TRILL Parameters web page as follows:

SType	Description	Reference
TBD2	Group Secured	Section 3.2 of [this document]

6. Security Considerations

TBD

See [RFC7457] in connection with TLS and DTLS security.

Normative References

[RFC2119] - BBradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

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