LoRaWAN® IPv6 Adaptation Layer for End-Devices Specification TS010-1.0.0

NOTICE OF USE AND DISCLOSURE

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LoRaWAN® IPv6 Adaptation Layer for End-Devices Specification TS010-1.0.0

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1 Conventions

The keywords "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 IETF Best Current Practice 14 (BCP14 [RFC2119] [RFC8174]) when, and only when, they appear in all capitals, as shown here.

The tables in this document are informative. The figures in this document are informative. The notes in this document are informative.

Document titles are written as *LoRaWAN Link Layer Specification* and sections within a document are written as “FPort Assignments (*update to match document*)”.

Commands are written ***PackageVersionReq***, bits and bit fields are written `PackageIdentifier`, constants are written RECEIVE_DELAY1, variables are written *N*.

In this document:

- The octet order for all multi-octet fields SHALL be little endian.
- EUI are 8-octet fields and SHALL be transmitted as little endian.
- By default, `RFU` bits are Reserved for Future Use and SHALL be set to 0 by the transmitter of the packet and SHALL be silently ignored by the receiver.

2 Introduction

This document describes how to use Static Context and Header Compression (SCHC), defined in [RFC8724, RFC9011], as an adaptation layer to enable LoRaWAN end-devices to use IPv6-based stacks over LoRaWAN.

Worst-case LoRaWAN application payload sizes are too small to transport IPv6 headers, let alone additional upper layer headers or application payload. Furthermore, LoRaWAN does not natively provide fragmentation and reassembly. An adaptation layer is therefore required to enable IPv6-based applications over a LoRaWAN Layer 2 medium.

SCHC provides header compression and decompression as well as optional fragmentation and reassembly between the application layer of an end-device and its corresponding application northbound of the Application Server. SCHC was designed to be efficient over mediums with Maximum Transmission Units (MTU) on the order of 10s-100s of bytes and is able to cope with widely asymmetric or even unidirectional connectivity.

Using a SCHC adaptation layer, a LoRaWAN link can deliver the 1280 byte MTU required by IPv6 and thus can transport IPv6 and upper layer headers and payloads.

3 SCHC as an adaptation layer for IPv6 over LoRaWAN

LoRaWAN end-devices compliant with this specification SHALL implement the SCHC specifications per [RFC9011, RFC8724], and SHALL conform to the LoRaWAN Layer 2 specification in [TS001] to implement IPv6-based applications.

> **Note:** The generic mechanisms of SCHC are specified in [RFC8724]. Parameters for LoRaWAN communications are specified in [RFC9011].

SCHC operates on a point-to-point logical link between two SCHC entities. Within the context of LoRaWAN, these two entities are considered application-layer (see Figure 1) and consist of:

- the SCHC protocol implemented in the application layer of the end device
- the SCHC protocol implemented as a SCHC gateway northbound of the LoRaWAN Application Server

For downlink multicast, SCHC operates on the unidirectional link between the SCHC layer of the SCHC gateway and the SCHC layer of the end devices belonging to the multicast group.

Each transmitted message starts with the identifier of the SCHC rule (called RuleID) that yielded that message.

A set of rules, referred to as a “context”, is specific to the end device/SCHC gateway pair. This context needs to be provisioned into the end device and into the SCHC gateway before the SCHC communication can start. The manner in which this context is provisioned is out of scope for this document.

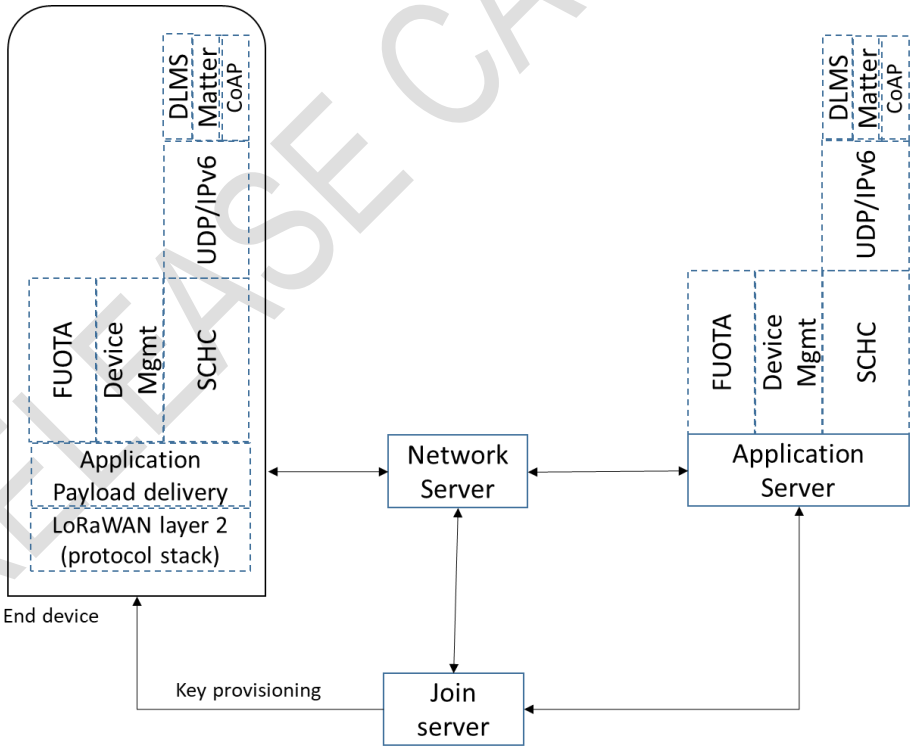

Figure 1: SCHC is the next layer above LoRaWAN layers

Note: Error! Reference source not found. depicts a typical SCHC use, many variations are possible.

Note: SCHC compressors/decompressors may sit at multiple places in the stack, notably when the latter involves encryption.

Note: The SCHC sublayer to the right may be collocated with the LoRaWAN Application Server, or it may reside elsewhere and communicate with the latter using any appropriate protocol.

Note: the SCHC sublayer to the right may or may not be collocated with the application, they may exchange IP packets locally or across any type of IP network.

3.1 IPv6 Interface Identifier computation

The IPv6 interface identifier (`IID`) SHALL be computed as explained in [RFC9011]. This requires that the SCHC implementation has access to the `AppsKey` or a way to compute it.

Note: The IPv6 `IID` generated per [RFC9011] meets the privacy concerns and recommendations listed in [RFC8065]. Notably, it does not disclose the DevEUI and it changes with each change of the device (or multicast group) security session.

3.2 Compression/Decompression

The process of header compression/decompression is defined in [RFC8724]. [RFC8724] allows multiple compression rules to match an incoming packet and does not specify which of the matching rules should eventually be used for compression as long as the rules are installed in both ends. In the case of a multiple match, a SCHC implementation for LoRAWAN SHOULD use a rule which results in the smallest `Compression Residue`, before padding.

Note: The `Compression Residue` is the bits that remain to be sent (beyond the RuleID) after applying the SCHC compression [RFC8724].

Note: The rule with the smallest `Compression Residue` should be selected to reduce the load on the network.

Note: If fragmentation/reassembly is not applied, then the RuleID, of a SCHC compressed packet appears in the port field (FPort) of the LoRaWAN frame. If fragmentation is applied, the RuleID that appears in the FPort field is that of the applied fragmentation, while the compression RuleID is carried in the first fragment's payload, cf [RFC9011], Appendix A.2.

3.3 Fragmentation/ Reassembly

Three possible modes of fragmentation/reassembly are defined in [RFC8724], each of which provides a different reliability and overhead trade-off. [RFC9011] specifies that the SCHC fragmentation mode to be used for LoRaWAN is ACK-on-Error for uplink, ACK-Always for unicast downlink and No-ACK for multicast downlink. The mode in use, as well as other parameter values, are identified by a RuleID.

3.3.1 Uplink Fragmentation

The parameters of uplink fragmentation/reassembly over LoRaWAN are defined in [RFC9011]. The parameters specified in Section 5.6.2 of [RFC9011] SHALL be used. However:

- This document RECOMMENDS that the value of `Retransmission Timer` be reduced further to limit the maximum amount of time the sender may be required to wait for an expected SCHC ACK.
- This document RECOMMENDS that the value of `Inactivity Timer` be reduced further to limit the maximum amount of time the receiver may be required to wait for an expected message.

> **Note:** Section 5.6.2 of [RFC9011] specifies that during uplink fragmentation/ reassembly: the tile size is 10 bytes; the fragment compressed number (FCN) field is 6 bits wide; and up to 4 windows are used. This leads to an MTU of 2520 bytes (4 windows*63 tiles*10 bytes).

3.3.2 Downlink Fragmentation

[RFC9011] provides the default duration of the timers (inactivity and retransmission) for different classes of end-devices. It is RECOMMENDED that these timers be configured to non-default values based on the actual application and the rate of transmission.

4 SCHC for header compression of upper layers

[RFC8724] specifies the generic SCHC header compression/decompression and fragmentation/reassembly mechanisms. It also describes the application of SCHC to compress the UDP/IPv6 headers. The generic compression/decompression mechanisms of [RFC8724] MAY be used in compressing headers of upper layers, in conjunction with IPv6 compression or independently.

When using Constrained Application Protocol (COAP), it is RECOMMENDED to apply SCHC header compression as described in [RFC8824]. When using Device Language Message Specification (DLMS), it is RECOMMENDED to apply SCHC header compression as described in [DLMSBLUEBOOK].

5 Glossary

LoRaWAN	Long Range Network Protocol
SCHC	Static Context and Header Compression
IID	Interface Identifier
Ack	Acknowledgement
RuleID	Rule identifier
FPort	Port Field
FCN	Fragment Compressed Number
MTU	Maximum Transmission Unit
DevEUI	Device Extended Unique Identifier
Appskey	Application session key

6 Bibliography

6.1 References

[RFC8065] Thaler, D., "Privacy Considerations for IPv6 Adaptation-Layer Mechanisms", RFC 8065, DOI 10.17487/RFC8065, February 2017, <https://www.rfc-editor.org/info/rfc8065>.

[RFC8724] Minaburo, A., Toutain, L., Gomez, C., Barthel, D., and JC. Zuniga, "SCHC: Generic Framework for Static Context Header Compression and Fragmentation", RFC 8724, DOI 10.17487/RFC8724, April 2020, <https://www.rfc-editor.org/info/rfc8724>.

[RFC8824] Minaburo, A., Toutain, L., and R. Andreasen, "Static Context Header Compression (SCHC) for the Constrained Application Protocol (CoAP)", RFC 8824, DOI 10.17487/RFC8824, June 2021, <https://www.rfc-editor.org/info/rfc8824>.

[RFC9011] Gimenez, O., Ed., and I. Petrov, Ed., "Static Context Header Compression and Fragmentation (SCHC) over LoRaWAN", RFC 9011, DOI 10.17487/RFC9011, April 2021, <https://www.rfc-editor.org/info/rfc9011>.

[TS001] LoRaWAN® L2 1.0.4 Specification, LoRa Alliance, October 2021.

[DLMSBLUEBOOK] COSEM Interface Classes and OBIS Object Identification System, the Blue Book, Ed. 14, DLMS User Association, August 2020.

Appendix A: SCHC refresher

This section is not normative, but rather summarizes information from [RFC8724] and [RFC9011] deemed relevant for implementation over LoRaWAN, and is provided for the reader's convenience. In case of ambiguity or inconsistency, the RFCs prevail.

Table 1 presents the LoRaWAN parameters that are used for the SCHC operation.

Parameter	Description	Usage in SCHC
DevEUI	Device Extended Unique Identifier; used to identify the end-device	- used in computing the IPv6 IID - used by the SCHC gateway to retrieve the rule set in use for that device
AppSKey	Encrypts the LoRaWAN frame payload	- used in computing the IPv6 IID
FPort	Port field; used to specify the application	- used to carry the RuleID

Table 1: LoRaWAN parameters and fields used in SCHC

Table 2 provides a description of general SCHC parameters.

Parameter	Usage in SCHC	Notes on operation with LoRaWAN
RuleID	Rule identifier; identifies the compression or fragmentation rule that yielded the SCHC message.	- a RuleID that identifies a fragmentation/ reassembly rule always appears in the FPort field of the LoRaWAN frame - a RuleID that identifies a compression rule appears in the FPort field if no fragmentation/ reassembly is applied. Otherwise, the compression RuleID is carried in the first fragment's payload - because they appear in the FPort field, RuleIDs used with LoRaWAN are 8 bits wide and are in the range of [1…223], as allowed by [TS001]
IID	IPv6 Interface Identifier	- the SCHC implementation needs to have access to the AppSKey in order to generate the IID as mandated by [RFC9011]. This ensures that there is no observable correlation with the hardware identifier (DevEUI).

Table 2: General SCHC parameters

Table 3 presents SCHC parameters used in uplink fragmentation.

Parameter	Value and size for use with LoRaWAN [RFC9011]	Notes regarding the use with LoRaWAN

RuleID	recommended value of 20 (on 8 bits), named FPortUp	- the RuleID for uplink fragmentation can be different from the recommended value but it must be different from the downlink fragmentation RuleID.
Fragmentation mode	ACK-on-Error	- A SCHC ACK is sent (downlink) only for windows with missing tiles. No SCHC ACK is sent for windows fully received.
Windows Index	its size is 2 bits	- Windows handle successive tiles. Up to 4 windows can be used. The windows index is incremented by 1 from 0 upward. A windows is the set of tiles that is acknowledged by a single SCHC ACK message.
Tile size	The tile size is 10 bytes	- A tile is a quantum of payload transported by a fragment. The tile is of fixed size in Ack-on-Error mode. The tile is small enough that a fragment containing a single tile can be transported by LoRaWAN under the smallest defined maximum payload size. This allows deferred retransmission of lost tiles, even if the LoRaWAN maximum payload size has been reduced by a change in data rate parameters.
Fragment Compressed Number (FCN)	The size is 6 bits	- FCN conveys the progress in the sequence of tiles. - The maximum number of tiles in a window is 63. - Within a window, the FCN is decremented from 62 downward. The FCN value of 0 designates the last tile of a non-final window. The FCN value of 63 (All-1 bits) has a special meaning: it means that the very last tile (not necessarily of index 0) of a SCHC Packet has been transmitted (last tile of last window). This special encoding saves one bit in the header, which would be needed to signal “End of packet”
Retransmission _timer	The recommended value per [RFC9011] is 12 hours	- A SCHC Fragment sender uses retransmission timer to abort waiting for an expected SCHC ACK. - Recommended to be further reduced to limit the sender’s waiting time depending on the application

Inactivity_timer	The recommended value per [RFC9011] is 12 hours	- A SCHC Fragment receiver uses inactivity timer to abort waiting for a SCHC F/R message. - Recommended to be further reduced to limit receiver's waiting time depending on the application
MAX_ACK_REQUESTS	Value specified is 8	- Maximum number of retries for a specific SCHC ACK
Bitmap (in SCHC ACK)	Each bit in the ACK bitmap acknowledges one tile. The bitmap is compressed (see [RFC8724]), which results in discrete bitmap sizes. Applied to LoRaWAN [RFC9011], these values are 5, 13, 21, 29, 37, 45, 53, 61, 62 or 63	

262 **Table 3: SCHC parameters used in Uplink fragmentation**

263 Table 4 presents the SCHC parameters used in unicast downlink fragmentation.

Parameter	Value and size for use with LoRaWAN [RFC9011]	Notes regarding the use with LoRaWAN
RuleID	-recommended value of RuleID is 21 (on 8 bits), named FPortDown	- The RuleID for downlink fragmentation can be different from the recommended value but must be different from the uplink fragmentation RuleID.
Fragmentation mode	ACK-Always	- A SCHC ACK is sent (uplink) for each window.
FCN	The size of the FCN field is 1 bit	- A window contains only 1 tile
MAX_ACK_REQUESTS	The value is 8	- maximum number of retries for a specific SCHC ACK
Windows Index	The size is be 1 bit Value alternates between 0 and 1	
Tile size	Size is variable	- Because the retransmission is immediate (as opposed to deferred), there is no issue with MTU change. The retransmission can cut a tile with the new MTU.

Inactivity_Timer for class A end-devices	Recommended value per [RFC9011] is 36 hours	- The timer should be adapted to the rate of transmission
Retransmission_timer for class A end-devices	Recommended value per [RFC9011] is INACTIVITY_TIMER/(MAX_ACK_REQUESTS + 1)	- The timer should be adapted to application
Inactivity_Timer for class B end-devices	Recommended value per [RFC9011] is 12 hours	- The timer should be adapted to application
Retransmission_timer for class B end-devices	Recommended value per [RFC9011] is 3 times the ping slot periodicity	- The timer should be adapted to application
Inactivity_Timer for class C end-devices	Recommended value per [RFC9011] is 12 hours	- The timer should be adapted to application
Retransmission_timer for class C end-devices	Recommended value per [RFC9011] is 30 sec	- The timer should be adapted to application

264 **Table 4: SCHC parameters used in unicast Downlink fragmentation**

265 Table 5 presents the SCHC parameters used in multicast downlink fragmentation.

Parameter	Value and size for use with LoRaWAN [RFC9011]	Notes regarding the use with LoRaWAN
RuleID	-recommended value of RuleID is 21 (on 8 bits), named FPortDown	- The RuleID for downlink fragmentation can be different from the recommended value but must be different from the uplink fragmentation RuleID.
Fragmentation mode (multicast)	No-ACK	- No SCHC ACK is ever sent. The reassembled packet is silently dropped if the CRC check fails.
Windows	Windows are not used in No-ACK mode	
FCN	The size of the FCN field is 1 bit	- FCN value 1 signals the last fragment.

266 **Table 5: SCHC parameters used in multicast Downlink fragmentation**