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# LPWAN Static Context Header Compression (SCHC) for IPv6 and UDP draft-toutain-lpwan-ipv6-static-context-hc-00

#### Abstract

This document describes a header compression scheme for IPv6, IPv6/ UDP based on static contexts. This technique is especially tailored for LPWA networks and could be extended to other protocol stacks.

During the IETF history several compression mechanisms have been proposed. First mechanisms, such as RoHC, are using a context to store header field values and send smaller incremental differences on the link. Values in the context evolve dynamically with information contained in the compressed header. The challenge is to maintain sender's and receiver's contexts synchronized even with packet losses. Based on the fact that IPv6 contains only static fields, 6LoWPAN developed an efficient context-free compression mechanisms, allowing better flexibility and performance.

The Static Context Header Compression (SCHC) combines the advantages of RoHC context which offers a great level of flexibility in the processing of fields, and 6LoWPAN behavior to elide fields that are known from the other side. Static context means that values in the context field do not change during the transmission, avoiding complex resynchronization mechanisms, incompatible with LPWA characteristics. In most of the cases, IPv6/UDP headers are reduced to a small identifier.

This document focuses on IPv6/UDP headers compression, but the mechanism can be applied to other protocols such as CoAP. It will be described in a separate document.

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## **<u>1</u>**. Introduction

Headers compression is mandatory to bring the internet protocols to the node within a LPWA network [I-D.minaburo-lp-wan-gap-analysis].

Nevertheless, LPWA networks offer good properties for an efficient header compression:

- o Topology is star oriented, therefore all the packets follows the same path. For the needs of this draft, the architecture can be summarized to End-Systems (ES) exchanging information with LPWAN Application Server (LA). The exchange goes trhough a single LPWA Compressor (LC). In most of the cases, End Systems and LC form a star topology. ESs and LC maintain a static context for compression. Static context means that context information is not learned during the exchange.
- o Traffic flows are mostly deterministic, since End-Systems embed built-in applications. Contrary to computers or smartphones, new applications cannot be easily installed.

First mechanisms such as RoHC use a context to store header field values and send smaller incremental differences on the link. The first version of RoHC targeted IP/UDP/RTP stack. RoHCv2 extends the principle to any protocol and introduces a formal notation [RFC4997] describing the header and associating compression functions to each

[Page 2]

field. To be efficient the sender and the receiver must check that the context remains synchronized (i.e. contains the same values). Context synchronization imposes to periodically send a full header or at least dynamic fields. If fully compressed, the header can be compatible with LPWA constraints. However, the first exchanges or context resynchronisations impose to send uncompressed headers, which may be bigger than the original one. This will force the use of inefficient fragmentation mechanisms. For some LPWA technologies, duty cycle limits can also delay the resynchronization. Figure 1 illustrates this behavior.

sync Λ +-+ sync sync Λ +-+ +-+ | IPv6 | | | IPv6 
 v
 i
 i
 i
 i

 -----+
 i
 i
 i
 i

 +--+
 i
 i
 i
 i
 V +----+ | +-+-+ | | +----+ L | C | | | | +-+-+ + +-+-+ | | C | |t|| |||||||||||||||||||||||| | X | | +-+-+-+-+-+-+-+-+-+-+ | | X | | t| | <-----> | | t| +--+ | header size of sent packets | +--+ +----+ +----+

Figure 1: RoHC Compressed Header size evolution.

On the other hand, 6LoWPAN [<u>RFC4944</u>] is context-free based on the fact that IPv6, its extensions or UDP headers do not contain incremental fields. The compression mechanism described in [<u>RFC6282</u>] is based on sending a 2-byte bitmap, which describes how the header should be decompressed, either using some standard values or sending information after this bitmap. [<u>RFC6282</u>] also allows for UDP compression.

In the best case, when Hop limit is a standard value, flow label, DiffServ fields are set to 0 and Link Local addresses are used over a single hop network, the 6LoWPAN compressed header is reduced to 4 bytes. This compression ratio is possible because the IID are derived from the MAC addresses and the link local prefix is known from both sides. In that case, the IPv6 compression is 4 bytes and UDP compression is 2 bytes, which fills half of the payload of a SIGFOX frame, or more than 10% of a LoRaWAN payload (with spreading factor 12).

The Static Context Header Compression (SCHC) combines the advantages of RoHC context, which offers a great level of flexibility in the

[Page 3]

LPWAN SCHC

processing of fields, and 6LoWPAN behavior to elide fields that are known from the other side. Static context means that values in the context field do not change during the transmission, avoiding complex resynchronization mechanisms, incompatible with LPWA characteristics. In most of the cases, IPv6/UDP headers are reduced to a small context identifier.

### 2. Static Context Header Compression

Static Context Header Compression (SCHC) avoids context synchronization, which is the most bandwidth-consuming operation in RoHC. Based on the fact that the nature of data flows is highly predictable in LPWA networks, a static context may be stored on the End-System (ES). The other end, the LPWA Compressor (LC) can learn the context through a provisioning protocol during the identification phase (for instance, as it learns the encryption key).

The context contains a list of rules (cf. Figure 2). Each rule contains itself a list of field descriptions composed of a target value (TV), a matching operator (MO) and a Compression/Decompression Function (CDF).

	Rule N		
   Rul	е і		+
Rule 1 + Field 1   Target Value	+   Matching Operator	++   Comp/Decomp Fct	
Field 2   Target Value	Matching Operator	++   Comp/Decomp Fct   ++	
· · · · · · · · · · · · · · · · · · ·	 +	 ++	
Field N   Target Value +	Matching Operator +	Comp/Decomp Fct   ++	  -+ 

### Figure 2: Compression Decompression Context

The rule does not describe the compressed/decompressed packet format which must be known from the compressor/decompressor. The rule just describes the compression/decompression behavior for a field.

The main idea of the compression scheme is to send the rule number (or rule id) to the other end instead of known field values.

Minaburo & Toutain Expires March 27, 2017

[Page 4]

Matching a field with a value and header compression are related operations; If a field matches a rule containing the value, it is not necessary to send it on the link. Since contexts are synchronized, reading the rule's value is enough to reconstruct the field's value at the other end.

On some other cases, the value need to be sent on the link to inform the other end. The field value may vary from one packet to another, therefore the field cannot be used to select the rule id.

## 2.1. Simple Example

A simple header is composed of 3 fields (F1, F2, F3). The compressor receives a packet containing respectively [F1:0x00, F2:0x1230, F3:0xABC0] in those fields. The Matching Operators (as defined in <u>Section 3</u>) allow to select Rule 5 as represented in Figure 3; F1 value is ignored and F2 and F3 packet field values are matched with those stored in the rule Target Values.



#### Figure 3: Matching Rule

The Compression/Decompression Function (as defined in <u>Section 4</u> describes how the fields are compressed. In this example, all the fields are elided and only the rule number has to be sent to the other end.

The decompressor receives the rule number and reconstructs the header using the values stored in the Target Value column.

Note that F1 value will be set to 0x00 by the decompressor, even if the original header field was carrying a different value.

To allow a range of values for field F2 and F3, the MSB() Matching Operator and LSB() Compression/Decompression Function can be used (as defined in <u>Section 3</u> and <u>Section 4</u>). In that case the rule will be rewritten as defined in Figure 4.

[Page 5]

	Rule 5 Target Value	Matching Operator	Comp/Decomp Fct	
F1	0×00	Ignore	not-sent	
F2	0x1230	MSB(12)	LSB(4)	
F3	0xABC0	MSB(12)	LSB(4)	

## Figure 4: Matching Rule

In that case, if a packet with the following header fields [F1:0x00, F2:0x1234, F3:0xABCD] arrives to the compressor, the new rule 5 will be selected and sent to the other end. The compressed header will be composed of the single byte [0x4D]. The decompressor receives the compressed header and follows the rule to reconstruct [0x00, 0x1234, 0xABCD] applying a OR operator between the target value stored in the rule and the compressed field value sent.

## **<u>2.2</u>**. Packet processing

The compression/decompression process follows several steps:

- o compression rule selection: the goal is to identify which rule will be used to compress the headers. To each field is associated a matching rule for compression. Each header field's value is compared to the corresponding target value stored in the rule for that field using the matching operator. If all the fields satisfied the matching operator, the packet is processed using this Compression Decompression Function functions. Otherwise the next rule is tested. If no eligible rule is found, then the packet is dropped.
- o sending: The rule number is sent to the other end followed by data resulting from the field compression. The way the rule number is sent depends of the layer two technology and will be specified in a specific document. For exemple, it can either be included in a Layer 2 header or sent in the first byte of the L2 payload.
- o decompression: The receiver identifies the sender through its device-id (e.g. MAC address) and select the appropriate rule through the rule number. It applies the compression decompression function to reconstruct the original header fields.

Minaburo & Toutain Expires March 27, 2017

[Page 6]

Internet-Draft

LPWAN SCHC

# <u>3</u>. Matching operators

It may exist some intermediary cases, where part of the value may be used to select a field and a variable part has to be sent on the link. This is true for Least Significant Bits (LSB) where the most significant bit can be used to select a rule id and the least significant bits have to be sent on the link.

Several matching operators are defined:

- o equal: a field value in a packet matches with a field value in a rule if they are equal.
- o ignore: no check is done between a field value in a packet and a field value in the rule. The result is always true.
- o MSB(length): a field value of length T in a packet matches with a field value in a rule if the most significant "length" bits are equal.

## **<u>4</u>**. Compression Decompression Functions (CDF)

The Compression Decompression Functions (CDF) describe the action taken during the compression and inversely the action taken by the decompressor to restore the original value.

/	+	+	\
Function	Compression	Decompression	Ì
 _	1	1	
not-sent	elided	use value stored in ctxt	T
value-sent	send	build from received value	I
LSB(length)	send LSB	ctxt value OR rcvd value	I
compute-IPv6-length	elided	compute IPv6 length	I
compute-UDP-length	elided	compute UDP length	I
compute-UDP-checksum	elided	compute UDP checksum	I
ESiid-DID	elided	build IID from L2 ES addr	I
LAiid-DID	elided	build IID from L2 LA addr	I
\	+	+	/

## Figure 5: Compression and Decompression Functions

Figure 5 lists all the functions defined to compress and decompress a field. The first column gives the function's name. The second and third columns outlines the compression/decompression process.

Minaburo & Toutain Expires March 27, 2017

[Page 7]

As with 6LoWPAN, the compression process may produce some data, where fields that were not compressed (or were partially compressed) will be sent in the order of the original packet. Information added by the compression phase must be aligned on byte boundaries, but each individual compression function may generate any size.

Internet-Draft

/-----| Field |Comp Decomp Fct | Behavior +----+ The value is not sent, but each |IPv6 version |not-sent |IPv6 DiffServ | |end agrees on a value, which can |be different from 0. |IPv6 FL |Depending on the matching operator,| |IPv6 NH |value-sent |the entire field value is sent or | |an adjustment to the context value | |IPv6 Length |compute-IPv6-length|Dedicated fct to reconstruct value | +-----+ |IPv6 Hop Limit|not-sent+MO=ignore |The receiver takes the value stored| |in the context. It may be different| |from one originally sent, but in a | |star topology, there is no risk of | |loops Inot-sent+matching |Receiver and sender agree on a |specific value. |Explicitly sent |value-sent |IPv6 ESPrefix |not-sent |The 64 bit prefix is stored on |IPv6 LAPrefix | |the context |value-sent |Explicitly send 64 bits on the link| +----+ |IPv6 ESiid |IID is not sent, but stored in the | |not-sent |IPv6 LAiid | |context |ESiid-DID|LAiid-DID|IID is built from the ES/LA Dev. ID| |value-sent |IID is explicitly sent on the link.| |Size depends of the L2 technology | --+------|In the context UDP ESport |not-sent |UDP LAport |value-sent Send the 2 bytes of the port number |LSB(length) or least significant bits if MSB |matching is specified in the |matching operator. ----+ |UDP length |compute-UDP-length |Dedicated fct to reconstruct value | +----+ [UDP Checksum |compute-UDP-checksum]Dedicated fct to reconstruct value] +----+

Figure 6: SCHC functions' example assignment for IPv6 and UDP Figure 6 gives an example of function assignment to IPv6/UDP fields.

Minaburo & Toutain Expires March 27, 2017

[Page 9]

### 4.1. Compression Decompression Functions (CDF)

#### <u>4.1.1</u>. not-sent

The compressor do not sent the field value on the link. The decompressor restore the field value with the one stored in the matched rule.

## 4.1.2. value-sent

The compressor send the field value on the link, if the matching operator is "=". Otherwise the matching operator indicates the information that will be sent on the link. For a LSB operator only the Least Significant Bits are sent.

## 4.1.3. LSB(length)

The compressor sends the "length" Least Significant Bits. The decompressor combines with a OR operator the value received with the Target Value.

#### 4.1.4. ESiid-DID, LAiid-DID

These functions are used to process respectively the End System and the LA Device Identifier (DID). The IID value is computed from device ID present in the Layer 2 header. The computation depends on the technology and the device ID size.

## 4.1.5. Compute-\*

These functions compute the field value based on received information. They are elided during the compression and reconstructed during the decompression.

- o compute-ipv6-length: compute the IPv6 length field as described in
  [RFC2460].
- o compute-udp-length: compute the IPv6 length field as described in
  [RFC0768].
- o compute-udp-checksum: compute the IPv6 length field as described in [RFC0768].

## 5. Examples

This section gives some scenarios of the compression mechanism for IPv6/UDP. The goal is to illustrate the SCHC behavior.

Minaburo & Toutain Expires March 27, 2017 [Page 10]

# **<u>5.1</u>**. IPv6/UDP compression in a star topology

The most common case will be a LPWA end-system embeds some applications running over CoAP. In this example, the first flow is for the device management based on CoAP using Link Local addresses and UDP ports 123 and 124. The second flow will be a CoAP server for measurements done by the end-system (using ports 5683) and Global Addresses alpha::IID/64 to beta::1/64. The last flow is for legacy applications using different ports numbers, the destination is gamma::1/64.

Figure 7 presents the protocol stack for this end-system. IPv6 and UDP are represented with dotted lines since these protocols are compressed on the radio link.

Managment	Data	
++-   CoAP   +  +- . UDP .	CoAP     + UDP	legacy     + UDP
. IPv6 .	IPv6 .	IPv6 .
+6LPWA +	L2 techno	logies   +

End System or LPWA GW

Figure 7: Simplified Protocol Stack for LP-WAN

Note that in some LPWA technologies, only End Systems have a device ID . Therefore it is necessary to define statically an IID for the Link Local address for the LPWA Compressor.

Rule 0

+	++	+		++	+
Field	Value	Match	Function	Sent	
IPv6 version	6	equal	not-sent		Ť
IPv6 DiffServ	0	equal	not-sent		I
IPv6 Flow Label	0	equal	not-sent		I
IPv6 Length		ignore	comp-IPv6-l		I
IPv6 Next Header	17	equal	not-sent		I
IPv6 Hop Limit	255	ignore	not-sent		I
IPv6 ESprefix	FE80::/64	equal	not-sent		I
IPv6 ESiid		ignore	ESiid-DID		I
IPv6 LCprefix	FE80::/64	equal	not-sent	11	Ì

Minaburo & Toutain Expires March 27, 2017 [Page 11]

IPv6 LAiid	::1	equal	not-sent	
UDP ESport UDP LAport UDP Length UDP checksum	+  123  124     +		not-sent not-sent comp-UDP-1 comp-UDP-c	
Rule 1				
+	+   Value	Match	Function	Sent
IPv6 version  IPv6 DiffServ  IPv6 Flow Label  IPv6 Length  IPv6 Next Header  IPv6 Hop Limit  IPv6 ESprefix  IPv6 ESiid  IPv6 LAprefix  IPv6 LAiid	6  0  17  255  alpha/64    beta/64  ::1000	equal     equal     equal     ignore     equal     equal     equal     equal	<pre>not-sent not-sent comp-IPv6-1 not-sent not-sent not-sent ESiid-DID not-sent not-sent</pre>	
UDP ESport UDP LAport UDP Length UDP checksum	5683  5683       	equal     equal     ignore     ignore	not-sent not-sent comp-UDP-1 comp-UDP-c	
Rule 2				
+   Field	+   Value	++   Match	Function	+++    Sent
+  IPv6 version  IPv6 DiffServ  IPv6 Flow Label  IPv6 Length  IPv6 Next Header  IPv6 Hop Limit  IPv6 ESprefix  IPv6 ESiid  IPv6 LAprefix  IPv6 LAiid +====================================	+  6  0  17  255  alpha/64   gamma/64  ::1000 +=========	+   equal     equal     ignore     equal     equal     equal     equal     equal	not-sent not-sent comp-IPv6-1 not-sent not-sent not-sent ESiid-DID not-sent not-sent	+++
UDP ESport  UDP LAport  UDP Length  UDP checksum	8720  8720 	MSB(12)    MSB(12)    ignore     ignore	LSB(4) LSB(4) comp-UDP-1 comp-UDP-c	lsb      lsb   

Minaburo & Toutain Expires March 27, 2017 [Page 12]

## Figure 8: Context rules

All the fields described in the three rules Figure 8 are present in the IPv6 and UDP headers. The ESDevice-ID value is found in the L2 header.

The second and third rules use global addresses. The way the ES learn the prefix is not in the scope of the document. One possible way is to use a management protocol to set up in both end rules the prefix used on the LPWA network.

The third rule compresses port numbers on 4 bits. This value is selected to maintain alignment on byte boundaries for the compressed header.

## <u>6</u>. Acknowledgements

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Minaburo & Toutain Expires March 27, 2017 [Page 13]

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Minaburo & Toutain Expires March 27, 2017 [Page 14]