Compression Format for IPv6 Datagrams in 6LoWPAN Networks
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Status of this Memo

Abstract

This document specifies an IPv6 header compression format for IPv6
packet delivery in 6LoWPAN networks. The compression format relies
on shared context to allow compression of arbitrary prefixes. This
document specifies compression of well-known multicast addresses and
a framework for compressing next headers. UDP compression is
specified within this framework.

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1. Introduction

The IEEE 802.15.4 standard specifies an MTU of 128 bytes, (including
the length byte) on a wireless link with a link throughput of 250
kbps or less[ieee802.15.4]. The 6LoWPAN adaptation format [RFC4944]
was specified to carry IPv6 datagrams over IEEE 802.15.4 links,
taking into account limited bandwidth, memory, or energy resources
that are expected in IEEE 802.15.4 applications. The 6LoWPAN
adaptation format defines a Mesh Addressing header to support sub-IP
forwarding, a Fragmentation header to support the IPv6 minimum MTU
requirement [RFC2460], and stateless header compression for IPv6
datagrams (LOWPAN_HC1 and LOWPAN_HC2) to reduce the relatively large
IPv6 and UDP headers down to (in the best case) several bytes.

LOWPAN_HC1 is most effective for link-local unicast communication,
where IPv6 addresses carry the link-local prefix and an Interface
Identifier (IID) directly derived from IEEE 802.15.4 addresses. In
this case, both addresses may be completely elided. This scenario is
most effective when communication remains local to a mesh-under
network where any forwarding occurs below IP and all 6LoWPAN nodes
are connected by a single IP hop. Even so, LOWPAN_HC1 cannot elide
the IPv6 Hop Limit. In cases where communication only occurs over a
single IP hop, there may be cases where a common IPv6 Hop Limit is
used.

Routable addresses must be used when communicating in a route-over
network where forwarding occurs at IP or when communicating with
devices external to the 6LoWPAN network. In this scenario,
LOWPAN_HC1 requires both IPv6 source and destination addresses to
carry the prefix in-line. Furthermore, in route-over networks, the
Mesh Addressing header may not be used and the IID must be carried
in-line. However LOWPAN_HC1 requires 64-bits for the IID when
carried in-line and cannot be shortened even when it is derived
directly from the IEEE 802.15.4 16-bit short address. When sending
to an IPv6 multicast address, LOWPAN_HC1 requires the full 128-bit
multicast address to be carried in-line. Multicast addresses are
commonly used for neighbor discovery, such as in IPv6 ND.

LOWPAN_HC1 can be extended to include a LOWPAN_HC2 octet to support
compression of UDP, TCP, or ICMPv6. RFC 4944 [RFC4944] only defines
compression for UDP, where UDP ports may be compressed and the UDP
Length may be elided. However, LOWPAN_HC1 also does not provide any
flexibility in supporting future compression mechanisms for next
headers other than UDP, TCP or ICMPv6.

This document specifies a header compression format for IPv6
datagrams. This format improves on the header compression format
defined in RFC 4944 [RFC4944] by generalizing it to support a broader

   range of communication paradigms, including both mesh-under and
   route-over configurations; communication to nodes internal and
   external to the 6LoWPAN network; and multicast communication. This
   document also defines a flexible framework for compressing arbitrary
   next headers and defines UDP header compression within this
   framework. This compression format carries forward the design
   concepts in RFC 4944 [RFC4944], minimizing any state and relying on
   shared context among all nodes in a 6LoWPAN network.

1.1. Requirements Language

   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 RFC 2119 [RFC2119].

2. IPv6 Header Compression

   In this section, we define the LOWPAN_IPHC encoding format for
   compressing the IPv6 header. To enable effective compression
   LOWPAN_IPHC relies on information pertaining to the entire 6LoWPAN
   network. LOWPAN_IPHC assumes the following will be the common case
   for 6LoWPAN communication: Version is 6; Traffic Class and Flow Label
   are both zero; Payload Length can be inferred from lower layers from
   either the 6LoWPAN Fragmentation header or the IEEE 802.15.4 header;
   Hop Limit will be set to a well-known value by the source; addresses
   assigned to 6LoWPAN interfaces will be formed using the link-local
   prefix or a single routable prefix assigned to the entire 6LoWPAN
   network; addresses assigned to 6LoWPAN interfaces are formed with an
   IID derived directly from either the 64-bit extended or 16-bit short
   IEEE 802.15.4 addresses.

```
                          1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   LOWPAN_IPHC   |  Uncompressed fields follow...
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
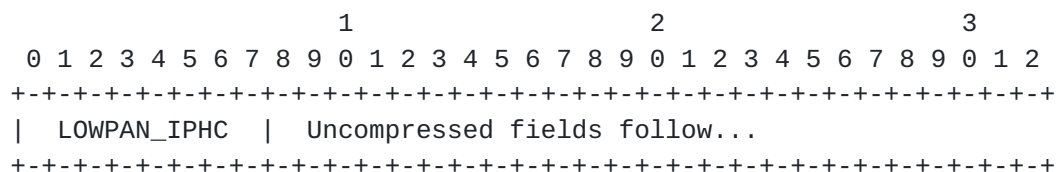
                       Figure 1: LOWPAN_IPHC Header

   The LOWPAN_IPHC encoding utilizes a two octets, with uncompressed
   fields following, as shown in Figure 1. With the above scenario, the
   LOWPAN_IPHC can compress the IPv6 header down to two octets (the
   LOWPAN_IPHC encoding) with link-local communication. When
   communicating over multiple IP hops, LOWPAN_IPHC can compress the
   IPv6 header down to 7 octets (2-octet LOWPAN_IPHC, 1-octet Hop Limit,
   2-octet Source Address, and 2-octet Destination Address).

2.1. **LOWPAN_IPHC Encoding Format**

```
      0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5
    +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
    | T |VF |NH | HLIM  |      rsv      |  SAM  |  SAC  |  DAM  |  DAC  |
    +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

                    Figure 2: LOWPAN_IPHC Encoding

   T: Traffic Class (bit 0):
      0: Full 8 bits for Traffic Class are carried in-line.
      1: Traffic Class is elided and implicitly 0.
   VF: Version and Flow Label (bit 1):
      0: Full 4 bits for Version and 20 bits for Flow Label are carried
         in-line.
      1: Version and Flow Label are elided. Version is implicitly 6.
         Traffic Class and Flow Label are implicitly 0.

   NH: Next Hop (bit 2):
      0: Full 8 bits for Next Hop are carried in-line.
      1: Next Hop is elided and the next header is compressed using
         LOWPAN_NHC, which is discussed in Section 3.
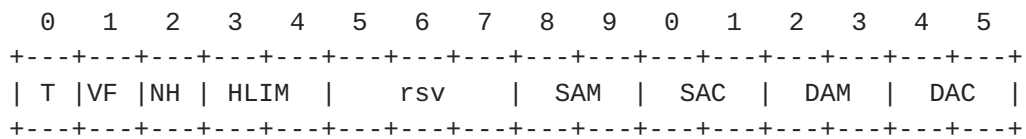
   HLIM: Hop Limit (bits 3-4):
      00: All 8 bits of Hop Limit are carried in-line.
      01: All 8 bits of Hop Limit are elided and the Hop Limit is
         assumed to be 1.
      10: All 8 bits of Hop Limit are elided and the Hop Limit is
         assumed to be 64.
      11: All 8 bits of Hop Limit are elided and the Hop Limit is
         assumed to be 255.

   rsv: Reserved (bit 5-7)

   SAC: Source Address Mode (bits 8-9):
      00: All 128 bits of Source Address are carried in-line.
      01: 64-bit Compressed IPv6 address.
      10: 16-bit Compressed IPv6 address.
      11: All 128 bits of Source Address are elided.

   SAC: Source Address Context (bits 10-11): Identifies the compression
      context when the source address is compressed. The value '00' is
      reserved and indicates a link-local address.

DAM: Destination Address Mode (bits 12-13):
    00: All 128 bits of Destination Address are carried in-line.
    01: 64-bit Compressed IPv6 address.
    10: 16-bit Compressed IPv6 address.
    11: All 128 bits of Destination Address are elided.

DAC: Destination Address Context (bits 14-15): Identifies the
    compression context when the destination address is compressed.
    The value '00' is reserved and indicates a link-local address.

Fields carried in-line (in part or in whole) appear in the same order
as they do in the IPv6 header format [RFC2460]. IPv6 addresses may
be compressed to 64 or 16 bits or completely elided. The IPv6
Payload Length field MUST always be elided and inferred from lower
layers using the 6LoWPAN Fragmentation header or the IEEE 802.15.4
header.

2.2. IPv6 Unicast Address Compression

IPv6 unicast addresses may be compressed to 64, 16, or 0 bits. When
an IPv6 unicast address is compressed, the compression context
identifies the value of the elided bits. A compression value of '00'
indicates the link-local prefix. The mapping between a specific
context and prefix may be obtained through simple modifications to
IPv6 Neighbor Discovery. However, the specification of those
mechanisms are out of scope of this document. Care should be taken
when renumbering a network. Nodes SHOULD only use a context after
all of its neighbors have been configured with the same context
information with high probability. New information within a context
SHOULD only be assigned after all nodes in the network have received
notification of its deprecation with high probability.

There may be cases where the compressor and decompressor are out of
sync within a context. In this cases, the decompressor may
reconstruct the IPv6 address using the incorrect prefix. To prevent
such errors, upper-layer integrity checks (e.g. psuedo-header
checksum) that cover both source and destination addresses SHOULD be
used.

When an IPv6 unicast address is compressed to 64 bits, the last 64
bits are carried in-line. When an IPv6 unicast address is compressed
to 16 bits, the last 16 bits are carried in line. Because the 16-bit
compressed form is also used for IPv6 multicast address compression,
the 16-bit address space is divided into multiple ranges. For
unicast addresses, the first bit carried in-line must be zero.

```
                               1
                 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |0|  Last 15 bits of IPv6 Addr  |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
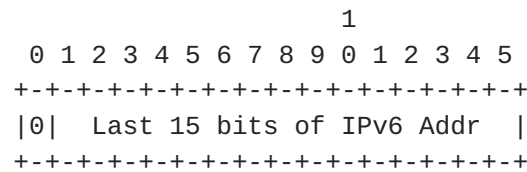
       Figure 3: 16-bit Compressed IPv6 Unicast Address Encoding

   When an address is completely elided, the IID is inferred from lower
   layers (either from the 6LoWPAN Mesh Addressing header or from the
   IEEE 802.15.4 header). The prefix is inferred from the identified
   context. Any remaining bits in between are implicitly zero.

   To elide the IID, it MUST be derivable from IEEE 802.15.4 addresses.
   An IID may be derived from the IEEE EUI-64 address by creating a
   Modified EUI-64 IID from the IEEE EUI-64 address, as defined in RFC
   4291 [RFC4291]. The universal/local bit in the Modified IEEE EUI-64
   IID must be set to '1', indicating universal scope. An IID may also
   be derived from the 16-bit short address and PAN ID, as defined in
   RFC 4944 [RFC4944]. Note, however, that the most significant bit in
   the short address must be zero.

2.3. IPv6 Multicast Address Compression

   IPv6 multicast addresses may be compressed to 16 bits by utilizing a
   different 6LoWPAN short address range. This document allocates
   another range of 8192 values to be used for well-known IPv6 multicast
   addresses.

```
                               1
                 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |Range| Scope | Mapped Group ID |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
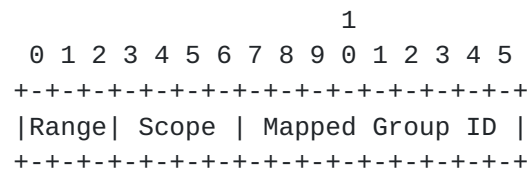
         Figure 4: Compressed IPv6 Multicast Address Encoding

   Range (bits 0-2): Must be set to '101' (TBD), which identifies the
      6LoWPAN short address range for compressed IPv6 multicast
      addresses.
   Scope (bits 3-6): 4-bit multicast scope as specified in RFC 4007
      [RFC4007].
   Mapped Group ID (bits 7-15): 9-bit mapped multicast group
      identifier.

   The full 128-bit multicast address can be reconstructed from the 16-
   bit mapped multicast address. By definition, the 3-bit range
   identifier indicates the well-known multicast prefix (0xFF) in

addition to a flags field set to all zeros (indicating a permanently assigned multicast address, that the multicast address is not assigned based on the network prefix, and that it doesn't embed the address of a Rendezvous Point). The 4-bit scope is carried in-line and the 112-bit group ID is derived from the 9-bit mapped group ID using a well-known mapping maintained by the Internet Assigned Numbers Authority (IANA).

Nodes MUST accept both the compressed and uncompressed form of well-known multicast addresses that they subscribe to. Doing so removes any ambiguity of which form to use as both will work. Conversely, nodes MUST NOT subscribe to well-known multicast addresses that are not defined by the well-known mapping.

This document defines an initial mapping. Additional mappings between 9-bit mapped group IDs and 112-bit group IDs may be specified in the future.

```
        +-------+---------+----------------------+
        | 9-bit | 112-bit | Description          |
        +-------+---------+----------------------+
        |   1   |    1    | All Nodes Addresses  |
        |   2   |    2    | All Routers Addresses |
        +-------+---------+----------------------+
```

                9-bit to 112-bit Group ID Mapping

2.4. 16-bit Compressed Address Ranges

To use the 16-bit compressed address format for different kinds of addresses (e.g. unicast or multicast), LOWPAN_IPHC utilizes the 16-bit short address ranges as specified in RFC 4944. This document specifies another range, for compressed multicast addresses.

Range 0, 0xxxxxxxxxxxxxxx: As specified in RFC 4944.

Range 2, 100xxxxxxxxxxxxx: As specified in RFC 4944.

Range 1, 101xxxxxxxxxxxxx: The remaining 13 bits represent a
   compressed IPv6 multicast address, as described in Section 2.3.

Range 3, 110xxxxxxxxxxxxx: Reserved.

Range 4, 111xxxxxxxxxxxxx: Reserved.

3. IPv6 Next Header Compression

   LOWPAN_IPHC elides the IPv6 Next Header field when the NH bit is set
   to 1. It also indicates the use of 6LoWPAN next header compression,
   LOWPAN_NHC. The value of IPv6 Next Header is recovered from the
   first bits in the LOWPAN_NHC encoding. The following bits are
   specific to the IPv6 Next Header value. Figure 5 shows the structure
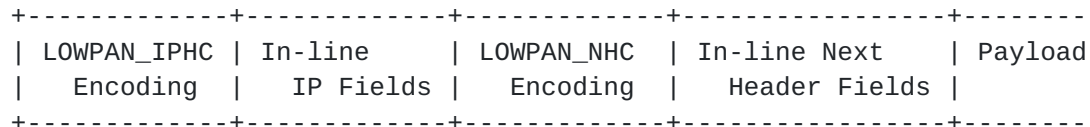   of an IPv6 datagram compressed using LOWPAN_IPHC and LOWPAN_NHC.

```
+-------------+-------------+-------------+-----------------+--------
| LOWPAN_IPHC | In-line     | LOWPAN_NHC  | In-line Next    | Payload
|   Encoding  |   IP Fields |   Encoding  |   Header Fields |
+-------------+-------------+-------------+-----------------+--------
```

        Figure 5: Typical LOWPAN_IPHC/LOWPAN_NHC Header Configuration

3.1. LOWPAN_NHC Format

   Compression formats for different next headers are identified by a
   variable length bit-pattern immediately following the LOWPAN_IPHC
   compressed header. When defining a next header compression format,
   the number of bits used SHOULD be determined by the perceived
   frequency of using that format. However, the number of bits and any
   remaining encoding bits SHOULD respect octet alignment. The
   following bits are specific to the next header compression format.
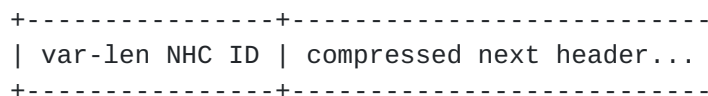   In this document, we define a compression format for UDP headers.

```
        +----------------+---------------------------
        | var-len NHC ID | compressed next header...
        +----------------+---------------------------
```

                   Figure 6: LOWPAN_NHC Encoding

3.2. LOWPAN_UDP Header Compression

   This document defines a compression format for UDP headers using
   LOWPAN_NHC. The LOWPAN_UDP compression format is shown in Figure 7.
   Bits 0 through 5 represent the NHC ID and '111110' indicates the
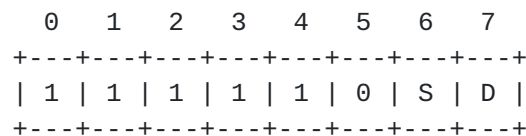   specific UDP header compression encoding defined in this section.

```
               0   1   2   3   4   5   6   7
             +---+---+---+---+---+---+---+---+
             | 1 | 1 | 1 | 1 | 1 | 0 | S | D |
             +---+---+---+---+---+---+---+---+
```

              Figure 7: Compressed UDP Header Encoding

   S: Source Port (bit 6):
      0: All 16 bits of Source Port are carried in-line.
      1: First 12 bits of Source Port are elided and the remaining 4
         bits are carried in-line. The Source Port is recovered by: P +
         short_port, where P is 61616 (0xF0B0).

   D: Destination Port (bit 7):
      0: All 16 bits of Destination Port are carried in-line.
      1: First 12 bits of Destination Port are elided and the remaining
         4 bits are carried in-line. The Destination Port is recovered
         by: P + short_port, where P is 61616 (0xF0B0).

   Fields carried in-line (in part or in whole) appear in the same order
   as they do in the IPv6 header format [RFC0768]. IPv6 addresses may
   be compressed to 64 or 16 bits or completely elided. The UDP Length
   field MUST always be elided and is inferred from lower layers using
   the 6LoWPAN Fragmentation header or the IEEE 802.15.4 header.

3.3. ISA100_UDP Header Compression

   This document defines a compression format for UDP headers using
   LOWPAN_NHC. The LOWPAN_UDP compression format is shown in Figure 8.
   Bits 0 through 4 represent the NHC ID and '11110' indicates the
   specific UDP header compression encoding defined in this section.

```
                0   1   2   3   4   5   6   7
              +---+---+---+---+---+---+---+---+
              | 1 | 1 | 1 | 1 | 0 | C | S | D |
              +---+---+---+---+---+---+---+---+
```

           Figure 8: Compressed ISA100.11a UDP Header Encoding

   C: Checksum (bit 5):
      0: All 16 bits of Checksum are carried in-line. The Checksum MUST
         be included if there are no other end-to-end integrity checks
         that are stronger than what is provided by the UDP checksum.
         Such an integrity check MUST be end-to-end and cover the IPv6
         pseudo-header, UDP header, and UDP payload.
      1: All 16 bits of Checksum are elided. The Checksum is recovered
         by recomputing it.

   S: Source Port (bit 6):
      0: All 16 bits of Source Port are carried in-line.
      1: First 12 bits of Source Port are elided and the remaining 4
         bits are carried in-line. The Source Port is recovered by: P +
         short_port, where P is 61616 (0xF0B0).

   D: Destination Port (bit 7):
      0: All 16 bits of Destination Port are carried in-line.
      1: First 12 bits of Destination Port are elided and the remaining
         4 bits are carried in-line. The Destination Port is recovered
         by: P + short_port, where P is 61616 (0xF0B0).

   Fields carried in-line (in part or in whole) appear in the same order
   as they do in the IPv6 header format [RFC0768]. IPv6 addresses may
   be compressed to 64 or 16 bits or completely elided. The UDP Length
   field MUST always be elided and is inferred from lower layers using
   the 6LoWPAN Fragmentation header or the IEEE 802.15.4 header.

4. IANA Considerations

   This document defines a new IPv6 header compression format for
   6LoWPAN networks. The document allocates a new Dispatch type value
   of 0x03 (TBD) for LOWPAN_IPHC.

   This document reserves another 16-bit short address range from RFC
   4944 for use with 16-bit compressed well-known IPv6 multicast
   addresses.

   This document creates a new IANA registry for mapped well-known
   multicast addresses, mapping 112-bit group identifiers to compressed
   9-bit ones. The registry MUST include the All Nodes Address (1) and
   the All Routers Address (2).

5. Security Considerations

   The definition of LOWPAN_IPHC permits the compression of header
   information on communication that could take place in its absence,
   albeit in a less efficient form. It recognizes that a IEEE 802.15.4
   PAN may have associated with it a global prefix. How that global
   prefix is assigned and managed is beyond the scope of this document.

6. Acknowledgements

   Thanks to Pascal Thubert for useful discussions in helping shape the
   header compression mechanisms. Thanks to Carsten Bormann for useful
   feedback and discussion.

7. References

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