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A. Brandt
J. Buron
Sigma Designs
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Transmission of IPv6 packets over ITU-T G.9959 Networks
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Abstract

This document describes the frame format for transmission of IPv6 packets and a method of forming IPv6 link-local addresses and statelessly autoconfigured IPv6 addresses on ITU-T G.9959 networks.

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 [[RFC2119](#)].

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Internet-Draft

IPv6 over G.9959

February 2013

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Table of Contents

1.	Author's notes	3
1.1.	Reader's guidance	3
2.	Introduction	3
2.1.	Terms used	3
3.	ITU-T G.9959 parameters to use for IPv6 transport	4
3.1.	Addressing mode	4
3.2.	IPv6 Multicast support	4
3.3.	G.9959 MAC PDU size and IPv6 MTU	5
3.4.	Transmission status indications	5
3.4.1.	IPv6 Socket interface considerations	6
3.4.2.	IPv6 Routing protocol interface considerations	6
3.5.	Transmission security	6
4.	LoWPAN Adaptation Layer and Frame Format	6
4.1.	Dispatch Type and Header	7
5.	LoWPAN addressing	8
5.1.	Stateless Address Autoconfiguration of routable IPv6 addresses	9
5.2.	IPv6 Link Local Address	9
5.3.	Unicast Address Mapping	9
6.	Header Compression	10
7.	IANA Considerations	10
8.	Z-Wave Alllliance Considerations	11
9.	Security Considerations	11
10.	Acknowledgements	11
11.	References	12
11.1.	Normative References	12
11.2.	Informative References	12
	Authors' Addresses	13

[1.](#) Author's notes

This chapter MUST be deleted before going for last call.

[1.1.](#) Reader's guidance

This document borrows heavily from [RFC4944](#), "Transmission of IPv6 Packets over IEEE 802.15.4 Networks". The process of creating this document was mainly a simplification; removing the following topics:

- o EUI-64 link-layer addresses
- o Fragmentation layer
- o Mesh routing

The 16-bit short addresses of 802.15.4 have been changed to 8-bit G.9959 NodeIDs.

[2.](#) Introduction

The ITU-T G.9959 recommendation [[G.9959](#)] targets low-power Personal Area Networks (PANs). This document defines the frame format for transmission of IPv6 [[RFC2460](#)] packets as well as the formation of IPv6 link-local addresses and statelessly autoconfigured IPv6 addresses on G.9959 networks.

The general approach is to adapt elements of the 6LoWPAN [[RFC4944](#)] specification to G.9959 networks. G.9959 provides a Segmentation and Reassembly (SAR) layer for transmission of datagrams larger than the G.9959 MAC PDU.

In addition to IPv6 application communication, the frame format defined in this specification may be used by IPv6 routing protocols such as RPL [[RFC6550](#)] or P2P-RPL [[P2P-RPL](#)] to implement IPv6 routing

over G.9959 networks.

G.9959 networks may implement mesh routing between nodes below the IP layer. Mesh routing is out of scope of this document.

[2.1.](#) Terms used

AES: Advanced Encryption Scheme

EUI-64: Extended Unique Identifier

HomeID: Link-Layer Network Identifier

Brandt & Buron

Expires August 12, 2013

[Page 3]

Internet-Draft

IPv6 over G.9959

February 2013

IID: Interface Identifier

MAC: Media Access Control

MTU: Maximum Transmission Unit

NodeID: Link-Layer Node Identifier (Short Address)

PAN: Personal Area Network

PDU: Protocol Data Unit

SAR: Segmentation And Reassembly

ULA: Unique Local Address

[3.](#) ITU-T G.9959 parameters to use for IPv6 transport

This chapter outlines properties applying to the PHY and MAC of G.9959 and how to use these for IPv6 transport.

[3.1.](#) Addressing mode

G.9959 defines how a unique 32-bit HomeID network identifier is assigned by a network controller and how an 8-bit NodeID host identifier is allocated. NodeIDs are unique within the logical network identified by the HomeID. The logical network identified by the HomeID maps directly to an IPv6 subnet identified by one or more

IPv6 prefixes.

An IPv6 host SHOULD construct its link-local IPv6 address and routable IPv6 addresses from the G.9959 NodeID in order to facilitate IP header compression as described in [[RFC6282](#)].

A word of caution: since HomeIDs and NodeIDs are handed out by a network controller function during inclusion, identifier validity and uniqueness is limited by the lifetime of the logical network membership. This can be cut short by a mishap occurring to the network controller. Having a single point of failure at the network controller suggests that deployers of high-reliability applications should carefully consider adding redundancy to the network controller function.

[3.2.](#) IPv6 Multicast support

[RFC3819] recommends that IP subnetworks support (subnet-wide) multicast. G.9959 supports direct-range IPv6 multicast while subnet-

wide multicast is not supported natively by G.9959. Subnet-wide multicast may be provided by an IP routing protocol or a mesh routing protocol operating below the LoWPAN layer. Mesh routing is out of scope of this document.

IPv6 multicast packets MUST be carried via G.9959 broadcast.

As per [[G.9959](#)], this is accomplished as follows:

1. The destination HomeID of the G.9959 MAC PDU MUST be the HomeID of the logical network
2. The destination NodeID of the G.9959 MAC PDU MUST be the broadcast NodeID (0xff)

G.9959 broadcast MAC PDUs are only intercepted by nodes within the logical network identified by the G.9959 HomeID.

[3.3.](#) G.9959 MAC PDU size and IPv6 MTU

IPv6 packets MUST use G.9959 transmission profiles which support MAC PDU payload sizes of 150 bytes or higher, e.g. the R3 profile.

[RFC2460] specifies that IPv6 packets may be up to 1280 octets. However, a full IPv6 packet does not fit in an G.9959 MAC PDU. The maximum G.9959 R3 MAC PDU payload size is 158 octets. G.9959 link-layer security imposes an overhead, which in the extreme case leaves 130 octets available.

G.9959 provides Segmentation And Reassembly for payloads up to 1350 octets. Segmentation however adds further overhead. It is therefore desirable that datagrams can fit into a single G.9959 MAC PDU. IPv6 Header Compression [[RFC6282](#)] improves the chances that a short IPv6 packet can fit into a single G.9959 frame.

[3.4.](#) Transmission status indications

The G.9959 MAC layer provides native acknowledgement and retransmission of MAC PDUs. The G.9959 SAR layer does the same for larger datagrams. A mesh routing layer may provide a similar feature for routed communication. Acknowledgment and retransmission improves the transmission success rate and frees higher layers from the burden of implementing individual retransmission schemes. The feature may however introduce challenges to existing TCP rate control algorithms and it may mask problematic links from IP routing protocols.

[3.4.1.](#) IPv6 Socket interface considerations

An IPv6 socket implementation communicating over G.9959 MUST have access to status indications such as link-layer delivery confirmation and Ack timeout from the MAC layer. If there is a mesh routing layer below the LoWPAN layer, the IPv6 socket implementation MUST have access to status indications such as delivery confirmation and Ack timeout from the mesh routing layer. This will allow the IPv6 socket implementation to adjust its transmissions to the available bandwidth of the G.9959 network; transmitting a new IPv6 packet only when it positively knows that the previous transmission ended (with fail or success).

[3.4.2.](#) IPv6 Routing protocol interface considerations

An IPv6 routing stack communicating over G.9959 MUST have access to delivery status indications such as link-layer delivery confirmation and Ack timeout from the MAC layer. This will allow the IP routing stack to adjust its routing decisions or alternatively initiate route rediscovery based on status indications from the link layer.

[3.5.](#) Transmission security

G.9959 provides link-layer security based on a common network key. Mission critical applications such as door locks and meters SHOULD deploy additional application layer security measures for end-to-end authentication and encryption.

Implementations claiming conformance with this specification MUST enable G.9959 common network key security.

[4.](#) LoWPAN Adaptation Layer and Frame Format

The LoWPAN encapsulation formats defined in this chapter are the payload in the G.9959 MAC PDU or the G.9959 SAR PDU. IPv6 header compression [[RFC6282](#)] MUST be supported by implementations of this specification.

All LoWPAN datagrams transported over G.9959 are prefixed by a LoWPAN encapsulation header stack. The LoWPAN payload (e.g. an IPv6 packet) follows this encapsulation header. Each header in the header stack contains a header type followed by zero or more header fields. An IPv6 header stack may contain, in the following order, addressing, hop-by-hop options, routing, fragmentation, destination options, and finally payload [[RFC2460](#)]. The LoWPAN header format is structured the same way. Currently only payload options are defined for the LoWPAN header format.

The definition of LoWPAN headers consists of the dispatch value, the definition of the header fields that follow, and their ordering constraints relative to all other headers. Although the header stack structure provides a mechanism to address future demands on the LoWPAN adaptation layer, it is not intended to provide general purpose extensibility. This document specifies a small set of 6LoWPAN header types using the 6LoWPAN header stack for clarity, compactness, and orthogonality.

[4.1.](#) Dispatch Type and Header

The dispatch type is defined by a zero bit as the first bit and a one bit as the second bit. The dispatch type and header are shown here:

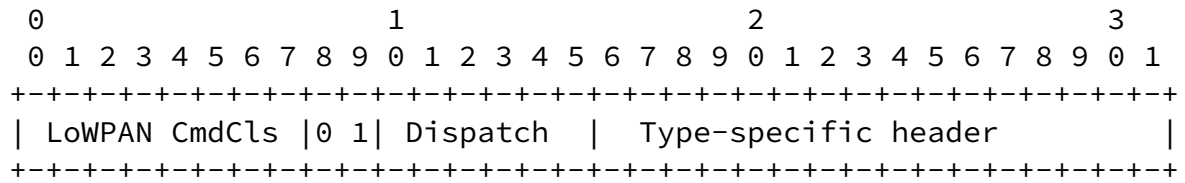


Figure 1: Dispatch Type and Header

LoWPAN CmdCls: LoWPAN Command Class identifier, [[G.9959](#)]. Specifies that the following bits are a LoWPAN encapsulated datagram. Non-LoWPAN protocols MUST ignore the contents following the LoWPAN Command Class identifier. TBD: Explicit value to be assigned by Z-Wave Alliance before last call of this Internet Draft. Refer to [Section 8](#).

Dispatch: 6-bit selector. Identifies the header type immediately following the Dispatch Header.

Type-specific header: A header determined by the Dispatch Header.

The dispatch value may be treated as an unstructured namespace. Only a few symbols are required to represent current LoWPAN functionality. Although some additional savings could be achieved by encoding additional functionality into the dispatch byte, these measures would tend to constrain the ability to address future alternatives.

Dispatch values used in this specification are compatible with the dispatch values defined by [[RFC4944](#)] and [[RFC6282](#)].

Pattern	Header Type	Reference
01 000000	ESC - Dispatch octet #2 follows	[RFC6282]
01 000001	IPv6 - Uncompressed IPv6 Addresses	[RFC4944]
...	reserved - Defined or reserved	[RFC4944]
01 1xxxxx	LoWPAN_IPHC - LoWPAN_IPHC compressed IPv6	[RFC6282]
1x xxxxxx	reserved - Defined or reserved	[RFC4944]

Figure 2: Dispatch Value Bit Pattern

IPv6: Specifies that the following header is an uncompressed IPv6 header.

ESC: Specifies that the following header is a single 8-bit field for an additional Dispatch value. It allows support for Dispatch values larger than 63. Note: [RFC4944] assigns the value 01 111111 for ESC. That assignment was deprecated by [RFC6282].

LoWPAN_IPHC: IPv6 Header Compression. Refer to [RFC6282].

5. LoWPAN addressing

IPv6 addresses are derived from link-layer address information to save memory in devices and to facilitate efficient IP header compression.

A G.9959 NodeID is 8 bits in length. NodeIDs are mapped into the restricted space of IEEE EUI-64 addresses by setting the middle 16 bits to 0xfffe, the bottom 8 bits to the NodeID, and all other bits to zero. As a result, an Interface Identifier (IID) generated from a NodeID has the form:

IID = 0000:00ff:fe00:00XX

where XX carries the G.9959 NodeID. The universal/local bit is zero to indicate local scope.

This mapping differs from that presented in [Appendix A of \[RFC4291\]](#). Using the restricted space ensures that there is no overlap with IIDs generated from unrestricted IEEE EUI-64 addresses. Also, including 0xfffe in the middle of the IID helps avoid overlap with other locally managed IIDs. Further, the mapping enables efficient IP Header Compression as per [RFC6282].

5.1. Stateless Address Autoconfiguration of routable IPv6 addresses

The IID defined above MUST be used whether autoconfiguring a ULA IPv6 address [[RFC4193](#)] or a globally routable IPv6 address [[RFC3587](#)] in G.9959 subnets.

5.2. IPv6 Link Local Address

The IPv6 link-local address [[RFC4291](#)] for a G.9959 interface is formed by appending the IID to the IPv6 link local prefix FE80::/64.

The "Universal/Local" (U/L) bit MUST be set to zero in keeping with the fact that this is not a globally unique value [[EUI64](#)].

The resulting link local address is formed as follows:

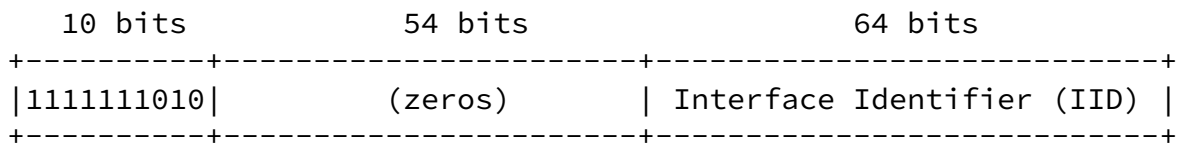


Figure 3: IPv6 Link Local Address

5.3. Unicast Address Mapping

The address resolution procedure for mapping IPv6 unicast addresses into G.9959 link-layer addresses follows the general description in [Section 7.2 of \[RFC4861\]](#). The Source/Target Link-layer Address option MUST have the following form when the link layer is G.9959.

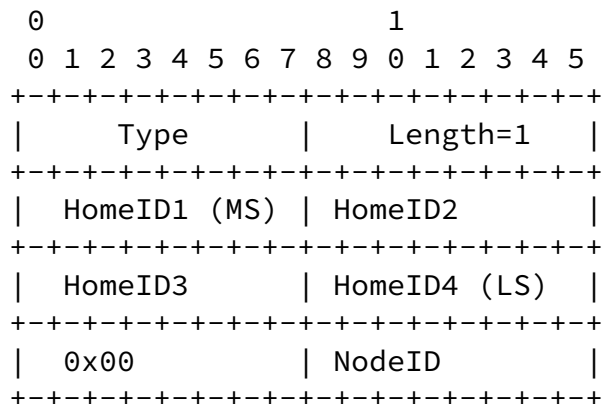


Figure 4: IPv6 Unicast Address Mapping

Option fields:

Type: The value 1 signifies the Source Link-layer address. The value 2 signifies the Destination Link-layer address.

Length: This is the length of this option (including the type and length fields) in units of 8 octets. The value of this field is always 1 for G.9959 NodeIDs.

HomeID: This is the G.9959 HomeID the actual interface currently responds to. The link-layer address may change if the interface joins another network at a later time.

NodeID: This is the G.9959 NodeID the actual interface currently responds to. The link-layer address may change if the interface joins another network at a later time.

6. Header Compression

IPv6 header fields SHOULD be compressed. If IPv6 header compression is used, it MUST be according to [\[RFC6282\]](#). This section will simply identify substitutions that should be made when interpreting the text of [\[RFC6282\]](#).

In general the following substitutions should be made:

- o Replace "802.15.4" with "G.9959"
- o Replace "802.15.4 short address" with "G.9959 NodeID"
- o Replace "802.15.4 PAN ID" with "G.9959 HomeID"

When a 16-bit address is called for (i.e., an IEEE 802.15.4 "short address") it MUST be formed by padding the G.9959 NodeID to the left with zeros:

```

0                                     1
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-----+-----+-----+-----+
|           0x00           |   NodeID   |
+-+-+-----+-----+-----+-----+

```

64 bit 802.15.4 address details should be ignored. This document only specifies the use of short addresses.

[7.](#) IANA Considerations

This document makes no request of IANA.

Brandt & Buron

Expires August 12, 2013

[Page 10]

Internet-Draft

IPv6 over G.9959

February 2013

Note to RFC Editor: this section may be removed on publication as an RFC.

[8.](#) Z-Wave Allliance Considerations

This document requests that the Z-Wave Alliance assigns a Command Class identifier for the LoWPAN Command Class; refer to [Section 4.1](#).

Note to RFC Editor: this section may be removed on publication as an RFC.

[9.](#) Security Considerations

The method of derivation of Interface Identifiers from 8-bit NodeIDs preserves uniqueness within the logical network. However, there is no protection from duplication through forgery. Neighbor Discovery in G.9959 links may be susceptible to threats as detailed in [\[RFC3756\]](#). G.9959 networks may feature mesh routing. This implies additional threats due to ad hoc routing as per [\[KW03\]](#). G.9959 provides capability for link-layer security. G.9959 nodes MUST use link-layer security with a common key. Doing so will alleviate the majority of threats stated above. A sizeable portion of G.9959 devices is expected to always communicate within their PAN (i.e., within their subnet, in IPv6 terms). In response to cost and power consumption considerations, these devices will typically implement the minimum set of features necessary. Accordingly, security for such devices may rely on the mechanisms defined at the link layer by G.9959. G.9959 relies on the Advanced Encryption Standard (AES) for authentication and encryption of G.9959 frames and further employs challenge-response handshaking to prevent replay attacks.

It is also expected that some G.9959 devices (e.g. billing and/or safety critical products) will implement coordination or integration functions. These may communicate regularly with IPv6 peers outside the subnet. Such IPv6 devices are expected to secure their end-to-end communications with standard security mechanisms (e.g., IPsec, TLS, etc).

10. Acknowledgements

Thanks to the authors of [RFC 4944](#) and [RFC6282](#) and members of the IETF 6LoWPAN working group; this document borrows extensively from their work. Thanks to Kerry Lynn, Tommas Jess Christensen and Erez Ben-Tovim for useful discussions which helped shape this document.

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Brandt & Buron

Expires August 12, 2013

[Page 12]

Internet-Draft

IPv6 over G.9959

February 2013

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Authors' Addresses

Anders Brandt
Sigma Designs

Emdrupvej 26A, 1.
Copenhagen O, 2100
Denmark

Phone:

Fax:

Email: anders_brandt@sigmadesigns.com

Jakob Buron
Sigma Designs
Emdrupvej 26A, 1.
Copenhagen O, 2100
Denmark

Phone:

Fax:

Email: jakob_buron@sigmadesigns.com