

6Lo Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 6, 2017

C. Gomez
S. Darroudi
UPC/i2cat
T. Savolainen
Nokia
July 5, 2016

IPv6 over BLUETOOTH(R) Low Energy Mesh Networks
draft-gomez-6lo-blemesh-01

Abstract

[RFC 7668](#) describes the adaptation of 6LoWPAN techniques to enable IPv6 over Bluetooth low energy networks that follow the star topology. However, recent Bluetooth specifications allow the formation of extended topologies as well. This document defines how IPv6 is transported over Bluetooth low energy mesh networks.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on January 6, 2017.

Copyright Notice

Copyright (c) 2016 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](#) and the IETF Trust's Legal Provisions Relating to IETF Documents (<http://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in [Section 4.e](#) of

the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1.	Introduction	2
1.1.	Terminology and Requirements Language	3
2.	Bluetooth LE Mesh Networks	3
3.	Specification of IPv6 over Bluetooth LE mesh networks	3
3.1.	Protocol stack	3
3.2.	Subnet model	4
3.3.	Link model	5
3.3.1.	Stateless address autoconfiguration	5
3.3.2.	Neighbor Discovery	5
3.3.3.	Header compression	6
3.3.4.	Unicast and multicast mapping	7
4.	IANA Considerations	8
5.	Security Considerations	8
6.	Acknowledgements	8
7.	References	8
7.1.	Normative References	8
7.2.	Informative References	9
	Authors' Addresses	9

[1.](#) Introduction

Bluetooth low energy (hereinafter, Bluetooth LE) was first introduced in the Bluetooth 4.0 specification. Bluetooth LE (which has been marketed as Bluetooth Smart) is a low-power wireless technology designed for short-range control and monitoring applications. Bluetooth LE is currently implemented in a wide range of consumer electronics devices, such as smartphones and wearable devices. Given the high potential of this technology for the Internet of Things, the Bluetooth Special Interest Group (Bluetooth SIG) and the IETF have produced specifications in order to enable IPv6 over Bluetooth LE, such as the Internet Protocol Support Profile (IPSP) [[IPSP](#)], and [RFC 7668](#), respectively. Bluetooth 4.0 only supports Bluetooth LE networks that follow the star topology. In consequence, [RFC 7668](#) was specifically developed and optimized for that type of network topology. However, subsequent Bluetooth specifications allow the formation of extended topologies [[BTCrev4.1](#)], such as the mesh topology. The functionality described in [RFC 7668](#) is not sufficient and would fail to enable IPv6 over Bluetooth LE mesh networks. This

document specifies the mechanisms needed to enable IPv6 over Bluetooth LE mesh networks. This specification also allows to run IPv6 over Bluetooth LE star topology networks, albeit without all the topology-specific optimizations contained in [RFC 7668](#).

[1.1](#). Terminology and 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](#)].

The terms 6LoWPAN Node (6LN), 6LoWPAN Router (6LR) and 6LoWPAN Border Router (6LBR) are defined as in [[RFC6775](#)], with an addition that Bluetooth LE central and Bluetooth LE peripheral (see [Section 2](#)) can both be adopted by a 6LN, a 6LR or a 6LBR.

[2](#). Bluetooth LE Mesh Networks

Bluetooth LE defines two Generic Access Profile (GAP) roles of relevance herein: the Bluetooth LE central role and the Bluetooth LE peripheral role. A device in the central role, which is called central from now on, has traditionally been able to manage multiple simultaneous connections with a number of devices in the peripheral role, called peripherals hereinafter. Bluetooth 4.1 introduced the possibility for a peripheral to be connected to more than one central simultaneously, therefore allowing extended topologies beyond the star topology for a Bluetooth LE network. In addition, a device may simultaneously be a central in a set of link layer connections, as well as a peripheral in others. On the other hand, the IPSP enables discovery of IP-enabled devices and the establishment of a link layer connection for transporting IPv6 packets. The IPSP defines the Node and Router roles for devices that consume/originate IPv6 packets and for devices that can route IPv6 packets, respectively. Consistently with Bluetooth 4.1, a device may implement both roles simultaneously.

This document assumes a Bluetooth LE mesh network whereby link layer connections have been established between neighboring IPv6-enabled devices. In an IPv6-enabled Bluetooth LE mesh network, a node is a neighbor of another node, and vice versa, if a link layer connection has been established between both by using the IPSP functionality for discovery and link layer connection establishment for IPv6 packet

transport.

[3.](#) Specification of IPv6 over Bluetooth LE mesh networks

[3.1.](#) Protocol stack

Figure 1 illustrates the protocol stack for IPv6-enabled Bluetooth LE mesh networks. There are two main differences with the IPv6 over Bluetooth LE stack in [RFC 7668](#): a) the adaptation layer below IPv6 (labelled as "6Lo for Bluetooth LE mesh") is now adapted for Bluetooth LE mesh networks, and b) the protocol stack for IPv6 over Bluetooth LE mesh networks includes IPv6 routing functionality.

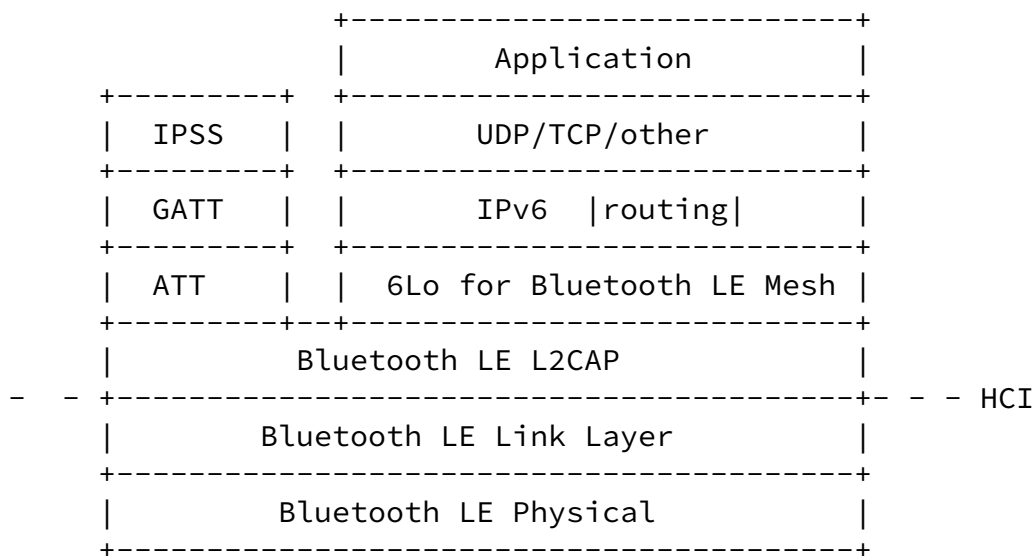


Figure 1: Protocol stack for IPv6-enabled Bluetooth LE mesh networks

[3.2.](#) Subnet model

For IPv6-based Bluetooth LE mesh networks, a multilink model has been chosen, as further illustrated in Figure 2. As IPv6 over Bluetooth LE is intended for constrained nodes, and for Internet of Things use cases and environments, the complexity of implementing a separate subnet on each peripheral-central link and routing between the subnets appears to be excessive. In this specification, the benefits of treating the collection of point-to-point links between a central and its connected peripherals as a single multilink subnet rather than a multiplicity of separate subnets are considered to outweigh

the multilink model's drawbacks as described in [[RFC4903](#)].

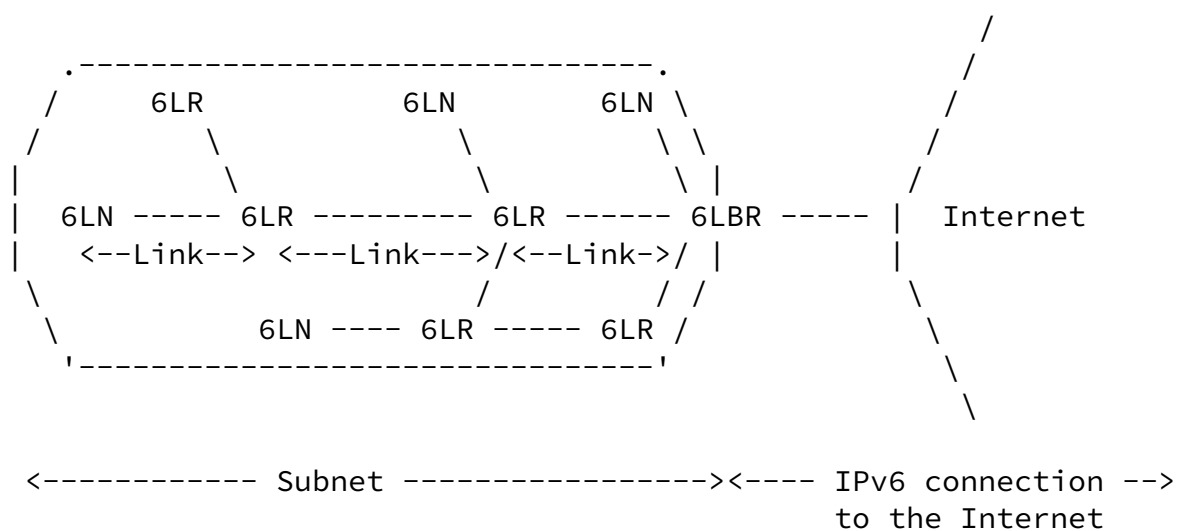


Figure 2: Example of an IPv6-based Bluetooth LE mesh network connected to the Internet

One or more 6LBRs are connected to the Internet. 6LNs are connected to the network through a 6LR or a 6LBR. A prefix is used on the whole subnet.

IPv6-enabled Bluetooth LE mesh networks MUST follow a route-over approach. This document does not specify the routing protocol to be used in an IPv6-enabled Bluetooth LE mesh network.

[3.3.](#) Link model

[3.3.1.](#) Stateless address autoconfiguration

6LN, 6LR and 6LBR IPv6 addresses of a Bluetooth LE mesh network are configured as per [section 3.2.2 of RFC 7668](#).

Multihop DAD functionality as defined in [section 8.2 of RFC 6775](#), or some substitute mechanism (see [section 3.3.2](#)), MUST be supported.

[3.3.2.](#) Neighbor Discovery

'Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)' [[RFC6775](#)] describes the neighbor discovery approach as adapted for use in several 6LoWPAN topologies, including the mesh topology. The route-over functionality of [RFC 6775](#) MUST be supported.

The following aspects of the Neighbor Discovery optimizations [[RFC6775](#)] are applicable to Bluetooth LE 6LNs:

1. A Bluetooth LE 6LN MUST NOT register its link-local address. A Bluetooth LE 6LN MUST register its non-link-local addresses with its routers by sending a Neighbor Solicitation (NS) message with the Address Registration Option (ARO) and process the Neighbor Advertisement (NA) accordingly. The NS with the ARO option MUST be sent irrespective of the method used to generate the IID. The ARO option requires use of an EUI-64 identifier [[RFC6775](#)]. In the case of Bluetooth LE, the field SHALL be filled with the 48-bit device address used by the Bluetooth LE node converted into 64-bit Modified EUI-64 format [[RFC4291](#)].

If the 6LN registers for a same compression context multiple addresses that are not based on Bluetooth device address, the header compression efficiency will decrease (see the next subsection).

2. For sending Router Solicitations and processing Router Advertisements the Bluetooth LE 6LNs MUST, respectively, follow Sections [5.3](#) and [5.4](#) of the [\[RFC6775\]](#).

3. The router behavior for 6LRs and 6LBRs is described in [Section 6 of RFC 6775](#). However, as per this specification, routers SHALL NOT use multicast NSs to discover other routers' link layer addresses.

4. Border router behavior is described in [Section 7 of RFC 6775](#).

[RFC 6775](#) defines substitutable mechanisms for distributing prefixes and context information ([section 8.1 of RFC 6775](#)), as well as for Duplicate Address Detection across a route-over 6LoWPAN ([section 8.2 of RFC 6775](#)). Implementations of this specification MUST support the features described in sections [8.1](#) and [8.2](#) of [RFC 6775](#) unless some alternative ("substitute") from some other specification is supported.

[3.3.3](#). Header compression

Header compression as defined in [RFC 6282](#) [\[RFC6282\]](#), which specifies the compression format for IPv6 datagrams on top of IEEE 802.15.4, is REQUIRED as the basis for IPv6 header compression on top of Bluetooth LE. All headers MUST be compressed according to [RFC 6282](#) [\[RFC6282\]](#) encoding formats.

To enable efficient header compression, when the 6LBR sends a Router Advertisement it MUST include a 6LoWPAN Context Option (6CO) [\[RFC6775\]](#) matching each address prefix advertised via a Prefix Information Option (PIO) [\[RFC4861\]](#) for use in stateless address autoconfiguration.

The specific optimizations of [RFC 7668](#) for header compression, which exploit the star topology and ARO, cannot be generalized in a Bluetooth LE mesh network. Still, a subset of those optimizations can be applied in some cases in a Bluetooth LE mesh network. In particular, the latter comprise link-local interactions, non-link-local packet transmissions originated and performed by a 6LN, and non-link-local packet transmissions originated by a 6LN neighbor and sent to a 6LN. For the rest of packet transmissions, context-based

compression MAY be used.

When a device transmits a packet to a neighbor, the sender MUST fully elide the source IID if the source IPv6 address is the link-local address based on the sender's Bluetooth device address (SAC=0, SAM=11). The sender also MUST fully elide the destination IPv6 address if it is the link-local-address based on the neighbor's Bluetooth device address (DAC=0, DAM=11).

When a 6LN transmits a packet, with a non-link-local source address that the 6LN has registered with ARO in the next-hop router for the indicated prefix, the source address MUST be fully elided if it is the latest address that the 6LN has registered for the indicated prefix (SAC=1, SAM=11). If the source non-link-local address is not the latest registered by the 6LN, then the 64-bits of the IID SHALL be fully carried in-line (SAC=1, SAM=01) or if the first 48-bits of the IID match with the latest address registered by the 6LN, then the last 16-bits of the IID SHALL be carried in-line (SAC=1, SAM=10).

When a router transmits a packet to a neighboring 6LN, with a non-link-local destination address, the router MUST fully elide the destination IPv6 address if the destination address is the latest registered by the 6LN with ARO for the indicated context (DAC=1, DAM=11). If the destination address is a non-link-local address and not the latest registered, then the 6LN MUST either include the IID part fully in-line (DAM=01) or, if the first 48-bits of the IID match to the latest registered address, then elide those 48-bits (DAM=10).

[3.3.4.](#) Unicast and multicast mapping

The Bluetooth LE Link Layer does not support multicast. Hence, traffic is always unicast between two Bluetooth LE neighboring nodes. If a node needs to send a multicast packet to several neighbors, it has to replicate the packet and unicast it on each link. However, this may not be energy efficient, and particular care must be taken if the node is battery powered. A router (i.e. a 6LR or a 6LBR) MUST keep track of neighboring multicast listeners, and it MUST NOT forward multicast packets to neighbors that have not registered as listeners for multicast groups the packets belong to.

[4.](#) IANA Considerations

There are no IANA considerations related to this document.

5. Security Considerations

The security considerations in [RFC 7668](#) apply.

IPv6-enabled Bluetooth LE mesh networks require a routing protocol to find end-to-end paths. Unfortunately, the routing protocol may generate additional opportunities for threats and attacks to the network.

[RFC 7416](#) [[RFC 7416](#)] provides a systematic overview of threats and attacks on the IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL), as well as countermeasures. While this specification does not state the routing protocol to be used in IPv6-enabled Bluetooth LE mesh networks, the guidance of [RFC 7416](#) is useful when RPL is used in such scenarios. Furthermore, such guidance may partly apply for other routing protocols as well.

6. Acknowledgements

The Bluetooth, Bluetooth Smart and Bluetooth Smart Ready marks are registered trademarks owned by Bluetooth SIG, Inc.

The authors of this document are grateful to all [RFC 7668](#) authors, since this document borrows many concepts (albeit, with necessary extensions) from [RFC 7668](#).

Carles Gomez has been supported in part by the Spanish Government Ministerio de Economia y Competitividad through project TEC2012-32531, and FEDER.

7. References

7.1. Normative References

- [BTCorev4.1] Bluetooth Special Interest Group, "Bluetooth Core Specification Version 4.1", December 2013, <<https://www.bluetooth.org/en-us/specification/adopted-specifications>>.
- [IPSP] Bluetooth Special Interest Group, "Bluetooth Internet Protocol Support Profile Specification Version 1.0.0", December 2014, <<https://www.bluetooth.org/en-us/specification/adopted-specifications>>.

- [RFC2119] Bradner, 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>>.
- [RFC4291] Hinden, R. and S. Deering, "IP Version 6 Addressing Architecture", [RFC 4291](#), DOI 10.17487/RFC4291, February 2006, <<http://www.rfc-editor.org/info/rfc4291>>.
- [RFC4861] Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)", [RFC 4861](#), DOI 10.17487/RFC4861, September 2007, <<http://www.rfc-editor.org/info/rfc4861>>.
- [RFC6282] Hui, J., Ed. and P. Thubert, "Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks", [RFC 6282](#), DOI 10.17487/RFC6282, September 2011, <<http://www.rfc-editor.org/info/rfc6282>>.
- [RFC6775] Shelby, Z., Ed., Chakrabarti, S., Nordmark, E., and C. Bormann, "Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)", [RFC 6775](#), DOI 10.17487/RFC6775, November 2012, <<http://www.rfc-editor.org/info/rfc6775>>.
- [RFC7668] Nieminen, J., Savolainen, T., Isomaki, M., Patil, B., Shelby, Z., and C. Gomez, "IPv6 over BLUETOOTH(R) Low Energy", [RFC 7668](#), DOI 10.17487/RFC7668, October 2015, <<http://www.rfc-editor.org/info/rfc7668>>.

[7.2](#). Informative References

- [RFC4903] Thaler, D., "Multi-Link Subnet Issues", [RFC 4903](#), DOI 10.17487/RFC4903, June 2007, <<http://www.rfc-editor.org/info/rfc4903>>.
- [RFC7416] Tsao, T., Alexander, R., Dohler, M., Daza, V., Lozano, A., and M. Richardson, Ed., "A Security Threat Analysis for the Routing Protocol for Low-Power and Lossy Networks (RPLs)", [RFC 7416](#), DOI 10.17487/RFC7416, January 2015, <<http://www.rfc-editor.org/info/rfc7416>>.

Authors' Addresses

Internet-Draft IPv6 over Bluetooth LE mesh networks

July 2016

Carles Gomez
Universitat Politecnica de Catalunya/Fundacio i2cat
C/Esteve Terradas, 7
Castelldefels 08860
Spain

Email: carlesgo@entel.upc.edu

Seyed Mahdi Darroudi
Universitat Politecnica de Catalunya/Fundacio i2cat
C/Esteve Terradas, 7
Castelldefels 08860
Spain

Email: s.darroudi2014@yahoo.com

Teemu Savolainen
Nokia
Visiokatu 3
Tampere 33720
Finland

Email: teemu.savolainen@nokia.com

