Transmission of IPv6 Packets over Bluetooth Low Energy
draft-ietf-6lowpan-btle-00

Abstract

   Bluetooth Low Energy is a low power air interface technology that is
   defined by the Bluetooth SIG. The standard Bluetooth radio has been
   widely implemented and available in mobile phones, notebook
   computers, audio headsets and many other devices. The low power
   version of Bluetooth is a new specification and enables the use of
   this air interface with devices such as sensors, smart meters,
   appliances, etc. There is an added value in the ability to
   communicate with sensors over IPv6. This document describes how IPv6
   is transported over Bluetooth Low Energy using 6LoWPAN techniques.

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on October 22, 2011.

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1. Introduction

   Bluetooth Low Energy (BT-LE) is a radio technology targeted for
   devices that operate with coin cell batteries, which means that low
   power consumption is essential. BT-LE can also be integrated into
   existing Bluetooth (BT) devices so that devices such as mobile phones
   and PCs can operate with existing BT accessories as well as BT-LE
   accessories. An example of a use case for a BT-LE accessory is a
   heart rate monitor that sends data via the mobile phone to a server
   on the Internet. BT-LE is designed for transferring small amount of
   data (in most cases less than 10 bytes) less frequently (e.g. every
   500 ms) at modest data rates (e.g. 300 kbps). BT-LE enables low cost
   sensors to send their data over the Internet via a gateway such as a
   mobile phone. BT-LE is an especially attractive technology for
   Internet of Things applications, such as health monitors,
   environmental sensing and proximity applications.

   Considering the expected explosion in the number of sensors, IPv6 is
   an ideal protocol due to the large address space it provides. In
   addition, IPv6 provides tools for autoconfiguration and unattended
   operation, which are particularly suitable for sensor network
   applications. This document describes how IPv6 is used on Bluetooth
   Low Energy links in a power efficient manner along with efficient
   application protocols that enable the integration of BT-LE devices
   into services.

   [RFC4944] specifies the transmission of IPv6 over IEEE 802.15.4. The
   Bluetooth Low Energy link in many respects has similar
   characteristics to that of IEEE 802.15.4. Many of the mechanisms
   defined in [RFC4944] can be applied to the transmission of IPv6 on
   Bluetooth Low Energy links. This document specifies the details of
   IPv6 transmission over Bluetooth Low Energy links.

2. 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].

2.1. Terminology

   Bluetooth Low Energy

      Bluetooth low energy is a low power air interface technology
      specified by the Bluetooth Special Interest Group (SIG).

Gateway

> Network element connecting the BT-LE sensors to the Internet. Can
> be e.g a home gateway or a mobile device.

ND-Proxy

> A gateway that operates as a proxy for IPv6 neighbor discovery

3. Bluetooth Low Energy protocol stack

Bluetooth Low Energy is a low power wireless technology developed by
the BT-SIG. The lower layer of the BT-LE stack consists of the RF
and the Link layer which are implemented in the BT-LE controller.
The upper layer consists of the Logical Link Control and Adaptation
Protocol (L2CAP), Generic Attribute protocol (GATT) and Generic
Attribute profile (GAP) as shown in Figure 1. GATT and BT-LE
profiles together enable the creation of applications in a
standardized way without using IP. L2CAP provides multiplexing
capability by multiplexing the data channels from the above layers.
L2CAP also provides fragmentation and reassembly for larger data
packets. Link Layer (LL) is responsible for managing the channels
and Physical Layer (PHY) transmits and receives the actual packets.

```
             +-----------------------------------------+
             |               Applications              |
             +-----------------------------------------+
             |          Generic Access Profile         |
             +-----------------------------------------+
             |         Generic Attribute Profile       |
             +-----------------------------------------+
             | Attribute Protocol |Security Manager    |
             +--------------------+--------------------+
             |   Logical Link Control and Adaptation   |
             +--------------------+--------------------+
             |         Host Controller Interface       |
             +--------------------+--------------------+
             |    Link Layer      | Direct Test Mode   |
             +--------------------+--------------------+
             |               Physical Layer            |
             +--------------------+--------------------+
```
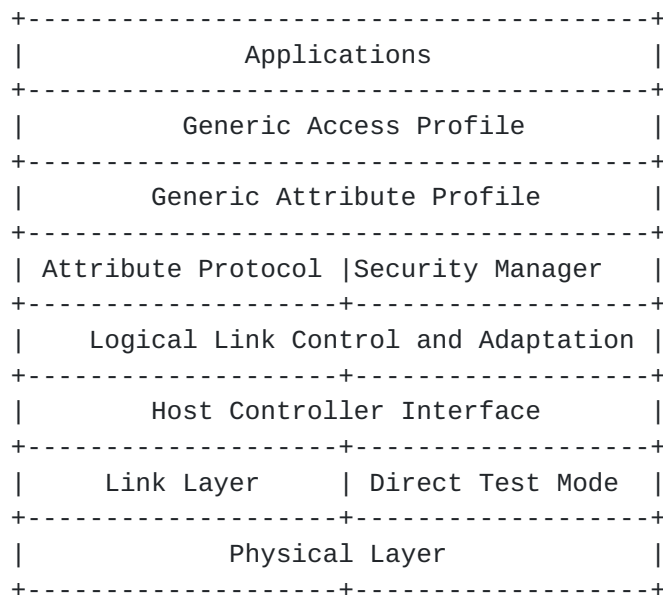
Figure 1: BT-LE Protocol Stack

3.1. Support for IPv6 over BT-LE

   Either a connection oriented channel SHOULD be added to the current
   BT-LE specification, over which parts of 6LoWPAN, IPv6 and
   application protocols can be run or a new fixed channel ID SHOULD be
   reserved for IPv6 traffic. Figure 2 illustrates IPv6 over BT-LE
   stack.

   CoAP is a lightweight protocol specifically designed for resource
   constrained RESTful environments. CoAP is similar to HTTP but more
   compact and runs on UDP. CoAP supports simple Create, Read, Write
   and Delete operations on resources (URIs). CoAP also provides
   mapping to normal HTTP. CoAP overhead in requests is 5 bytes, in
   responses 4 bytes. When considering the total IPv6 + UDP +CoAP
   overhead in requests and responses it would be 10-11 Bytes with link
   local addresses and 34-35 Bytes with global addresses. The rest is
   URL + real payload. If HTTP/TCP was used instead of CoAP/UDP, IPv6 +
   TCP headers alone would take 22 Bytes with link local addresses and
   55 Bytes with global addresses assuming that optional timestamps in
   TCP headers are not used. HTTP overhead, which can vary, will be
   added on top of these. Taking into account the small size of
   physical layer BT-LE PDUs (maximum 255 Bytes in some implementations
   excluding headers), URL can not be too long considering that enough
   space has to be left for the actual payload. URLs could be e.g. '/t'
   instead of '/temperature', and payload can be binary instead of
   ASCII.

```
                    +------------------+
                    |   Applications   |
                    +------------------+
                    |   (CoAP/HTTP)    |
                    +------------------+
                    |   (UDP/TCP)      |
                    +------------------+
                    |  Compressed IPv6 |
                    +------------------+
                    |  BT-LE L2CAP     |
                    +------------------+
                    |  BT-LE Link Layer |
                    +------------------+
                    |  BT-LE Physical  |
                    +------------------+
```

Figure 2: IPv6 over BT-LE Stack

4. Requirements

   BT-LE technology sets strict requirements for low power consumption
   and thus limits the allowed protocol overhead. 6LoWPAN standard
   [RFC4944] provides useful generic functionality like header
   compression, link-local IPv6 addresses, Neighbor Discovery and
   stateless IP-address autoconfiguration for reducing the overhead in
   802.15.4 networks. This functionality can be partly applied to
   BT-LE.

5. Bluetooth Low Energy roles and network topology

   BT-LE defines two Link Layer roles: the Master Role and the Slave
   Role. A device in the Master Role, which is called master, can
   manage multiple simultaneous connections with a number of devices in
   the Slave Role, called slaves. A slave can only be connected to a
   single master. Hence, a BT-LE network (i.e. a BT-LE piconet) follows
   a star topology.

   A master is assumed to be less constrained than a slave. Hence,
   master and slave can correlate with 6LBR and host, respectively.

   A significant difference between IEEE 802.15.4 and BT-LE is that the
   former supports the mesh topology (and requires a routing protocol),
   whereas BT-LE does not currently support the formation of multihop
   networks. In consequence, the mesh header defined in [RFC4944] for
   mesh under routing MUST NOT be used in BT-LE networks. On the other
   hand, a BT-LE device MUST NOT play the role of a 6LR.

   In BT-LE, communication only takes place between a master and a
   slave. Hence, in a BT-LE network using IP, a radio hop is equivalent
   to an IP link and vice versa.

6. BT-LE network connectivity scenarios

   In many applications, the BT-LE network will be connected to the
   Internet. In this case, the master/6LBR has at least one non-BT-LE
   interface connected to the Internet.

```
           h             _____
            \          /              \
        h ---- 6LBR --- |   Internet   |
            /          _____/
           h
                                 h:      host
          <-- BT-LE -->          6LBR:   6LoWPAN Border Router
```
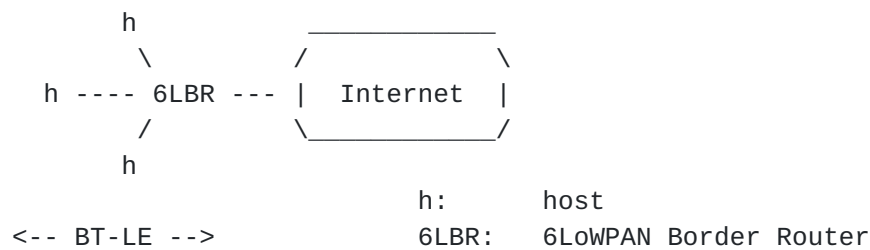
Figure 3: BT-LE network connected to the Internet

6to4 and 6RD are possibilities when the 6LBR has only IPv4 uplink
connectivity. The 6LBR would act as 6to4/6RD router and advertise
6to4/6RD prefix into the BT-LE network. The 6to4 prefix is
constructed by combining well-known IPv6 prefix with public IPv4
address. The 6RD prefix is constructed by combining network specific
IPv6 prefix with public or private IPv4 addresses. These
technologies require the 6LBR device to perform IPv6 into IPv4
encapsulation, and in particular in 6RD case also require tunnel
endpoint in the access network.

If the 6LBR has no IPv6 uplink Internet connectivity available via
any of the abovementioned means, the 6LBR may employ IPv6 to IPv4
protocol translation technology. This allows BT-LE nodes to connect
to Internet destinations as long as the destination has globally
reachable IPv4 address. The BT-LE network would be numbered with ULA
addresses, which IPv6 stacks on BT-LE nodes would consider as global
addresses.

In some scenarios, the BT-LE network may transiently or permanently
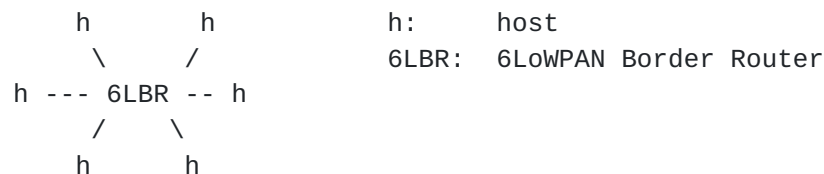be an isolated network.

```
           h       h         h:      host
            \     /          6LBR:   6LoWPAN Border Router
         h --- 6LBR -- h
            /     \
           h       h
```

Figure 4: Isolated BT-LE network

7. Addressing Model

The link model of BT-LE needs to be considered and what kind of
addressing is possible.

8. MTU Issues

Generally the sensors generate data that fits into one Link Layer
packet (23 bytes) that is transferred to the collector periodically.
IP data packets may be much larger and hence MTU size should be the
size of the IP data packet. Larger L2CAP packets can be transferred
with the Segmentation And Reassembly (SAR) feature of the Link Layer.
If an implementation cannot support the larger MTU size (due to cost)
then SAR MUST be supported at upper layers.

Existing SAR functionality defined in [RFC4944] MAY also be used,
taking into account BT-LE specific features such as different MTU in
the L2CAP layer.

9. LoWPAN Adaptation for BT-LE and frame format

Transmission of IPv6 Packets over IEEE 802.15.4 Networks [RFC4944]
defines an adaptation layer between IP and 802.15.4 radio networks.
In these networks link layer does not support SAR functionality and
thus IP packets must fit into the payload that is available in the
127 octect long physical frame after variable size frame overhead has
been added. In BT-LE networks this kind of adaptation is not
required if SAR is supported in the Link Layer.

10. IPv6 Address configuration

The Interface Identifier for a BT-LE interface MAY be formed from the
48-bit public device Bluetooth address as per the "IPv6 over
Ethernet" specification [RFC2464].

An IPv6 prefix used for stateless autoconfiguration [RFC4862] of a
BT-LE interface MUST have a length of 64 bits.

SLAAC and other means to configure an address on a BT-LE device.
Neighbor Discovery Optimization for Low-power and Lossy Networks
[I-D.ietf-6lowpan-nd]. Well-known gateway or server addresses can be
hard-coded in the sensors.

11. IPv6 LLA in BLE

The IPv6 link-local address [RFC4291] for a BT-LE interface is formed
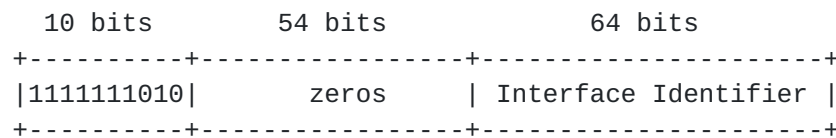by appending the Interface Identifier, as defined above, to the
prefix FE80::/64.

```
         10 bits        54 bits               64 bits
       +----------+----------------+---------------------+
       |1111111010|     zeros      | Interface Identifier |
       +----------+----------------+---------------------+
```

Figure 5: IPv6 link-local address in BT-LE

12. Unicast and Multicast address mapping

Reuse the same format specified for 802.15.4?

13. Header compression

Compression Format for IPv6 Datagrams in Low Power and Lossy Networks
(6LoWPAN) [I-D.ietf-6lowpan-hc] is the basis of the IPv6 header
compression mechanism defined in this specification. Whereas
[I-D.ietf-6lowpan-hc] exploits intra-packet redundancies due to the
formation of Interface Identifiers from MAC addresses, BT-LE data
channel PDUs include neither source nor destination MAC addresses.
Instead, BT-LE Link Layer packets include the Access Address, a 32-
bit value that identifies a Link Layer connection between a master
and a slave. In consequence, the Interface Identifier compression
mechanisms used in this specification are different from those used
in [I-D.ietf-6lowpan-hc].

In [RFC4944] different types of frame formats and related headers
have been defined to support fragmentation and mesh addressing. In
BT-LE context latest version of LoWPAN compressed IPv6 header SHOULD
be used by default. Support for fragmentation and mesh headers MAY
be added. However, since BT-LE operates on a star topology, mesh
headers SHOULD not be required. In BT-LE link with header
compression IPv6 header (originally 40 Bytes) can be compressed to
only 2 Bytes with link-local addresses and 26 Bytes with Global
addresses. UDP header (originally 8 Bytes) can be compressed to 4
Bytes.

This specification assumes that the following will be the common case
when using IPv6 on top of BT-LE networks: 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
BT-LE Link Layer header; Hop Limit will be set to a well-known value
by the source; IPv6 addresses assigned to BT-LE interfaces will be
formed using the link-local prefix or a small set of routable
prefixes assigned to the entire BT-LE network.

In a link-local communication, the IPv6 destination address can be
elided. In fact, the node that receives a data channel PDU through a
Link Layer connection can infer that the IPv6 destination address of
the packet is its own IPv6 address. If a node knows the IPv6 address
of the other endpoint of the Link Layer connection, the IPv6 source
address can also be elided. The mechanism by which a node learns the
IPv6 link-local address (or the Interface Identifier) of the other
endpoint of the connection is TBD.

When a BT-LE slave transmits an IPv6 packet to a remote destination
using global IPv6 addresses, the slave can elide the IPv6 source
address. This is possible if the following two conditions are met:
1) the master/6LBR can derive the prefix of the source IPv6 address
from a context shared with the slaves; and 2) the master/6LBR
maintains a table that relates the Access Address of each Link Layer
connection and the Interface Identifier of the corresponding slave.
The mechanism by which the master/6LBR maintains the above mentioned
table is TBD. The slave can also elide the prefix of the destination
IPv6 address if a context is defined for the IPv6 destination
address.

When a master/6LBR receives an IPv6 packet sent by a remote node
outside the BT-LE network, and the destination of the packet is a
slave, the master/6LBR can elide the Interface Identifier of the IPv6
destination address by exploiting the information contained in the
table mentioned above. The prefixes of the IPv6 destination and
source addresses can also be elided if a context is defined for them.

Some parts of the base HC encoding may need to be modified/redefined
in order to enable the new functionality described herein. TBD in
future versions.

In a link-local communication, the IPv6 header can be compressed down
to 2 bytes in the best case.

14. IANA Considerations

This document does not have any IANA requests at this time. This may
change with further development of the specification.

15. Security Considerations

The transmission of IPv6 over bluetooth low energy links has similar
requirements and concerns for security as ZigBee. Security at the IP
layer needs to be reviewed as part of the development of the IPv6
over Bluetooth Low Energy specification.

BT-LE Link Layer supports encryption and authentication by using the
CCM mechanism and a 128-bit AES block cipher. Upper layer security
mechanisms may exploit this functionality when it is available.
(Note: CCM does not consume bytes from the maximum per-packet L2CAP
data size, since the link layer data unit has a specific field for
them when they are used.)

Key management in BT-LE is provided by the Security Manager Protocol
(SMP).

16. Additional contributors

Kanji Kerai and Jari Mutikainen from Nokia have contributed
significantly to this document.

17. Normative References

[I-D.ietf-6lowpan-hc]
            Hui, J. and P. Thubert, "Compression Format for IPv6
            Datagrams in Low Power and Lossy Networks (6LoWPAN)",
            draft-ietf-6lowpan-hc-15 (work in progress),
            February 2011.

[I-D.ietf-6lowpan-nd]
            Shelby, Z., Chakrabarti, S., and E. Nordmark, "Neighbor
            Discovery Optimization for Low-power and Lossy Networks",
            draft-ietf-6lowpan-nd-15 (work in progress),
            December 2010.

[RFC2119]   Bradner, S., "Key words for use in RFCs to Indicate
            Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC2464]   Crawford, M., "Transmission of IPv6 Packets over Ethernet
            Networks", RFC 2464, December 1998.

[RFC4291]   Hinden, R. and S. Deering, "IP Version 6 Addressing
            Architecture", RFC 4291, February 2006.

[RFC4862]   Thomson, S., Narten, T., and T. Jinmei, "IPv6 Stateless
            Address Autoconfiguration", RFC 4862, September 2007.

[RFC4944]   Montenegro, G., Kushalnagar, N., Hui, J., and D. Culler,
            "Transmission of IPv6 Packets over IEEE 802.15.4
            Networks", RFC 4944, September 2007.

[RFC4994]   Zeng, S., Volz, B., Kinnear, K., and J. Brzozowski,

                    "DHCPv6 Relay Agent Echo Request Option", RFC 4994,
                    September 2007.

Appendix A.   **Bluetooth Low Energy basics**

   This section will provide background material on the basics of
   bluetooth low energy.

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