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Transmission of IPv6 Packets over Wireless Body Area Networks (WBANs)
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Abstract

Wireless Body Area Networks (WBANs) intend to facilitate use cases related to medical field. IEEE 802.15.6 defines PHY and MAC layer and is designed to deal with better penetration through the human tissue without creating any damage to human tissues with the approved MICS (Medical Implant Communication Service) band by USA Federal Communications Commission (FCC). Devices of WBANs conform to this IEEE standard.

This specification defines details to enable transmission of IPv6 packets, method of forming link-local and statelessly autoconfigured IPv6 addresses on WBANs.

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1. Introduction

Wireless Body Area Networks (WBANs) are comprised of devices that conform to the [IEEE802.15.6], standard by the IEEE. IEEE 802.15.6 provides specification for the MAC layer to access the channel. The coordinator divides the channel into superframe time structures to

allocate resources [SURVEY-WBAN] [MAC-WBAN]. Superframes are bounded by equal length beacons through the coordinator. Usually beacons are sent at beacon periods except inactive superframes or limited by regulation.

Task group for 802.15.6 was established by IEEE in November 2007 for standardisation of WBANs and it was approved in 2012. This standard works in and around human body and focus on operating at lower frequencies and short range. The focus of this document is to design a communication standard for MAC and physical layer to support different applications, namely, medical and no-medical applications. Medical applications refer to collection of vital information in real time (monitoring) for diagnoses and treatment of various diseases with help of different sensors (accelerometer, temperature, BP and EMG etc.). It defines a MAC layer that can operate with three different PHY layers i.e. human body communication (HBC), ultra-wideband (UWB) and Narrowband (NB). IEEE 802.15.6 provides specification for MAC layer to access the channel. The coordinator divides the channel into superframe time structures to allocate resources. Superframes are bounded by equal length beacons through coordinator. The purpose of the draft is to highlight the need of IEEE 802.15.6 for WBASNs and its integration issues while connecting it with IPv6 network. The use cases are provided to elaborate the scenarios with implantable and wearable biomedical sensors. 6lowpan provides IPv6 connectivity for IEEE 802.15.4; however, it does not work with IEEE 802.15.6 due to the difference in frame format in terms of size and composition.

1.1. Frame Format and Addressing Modes

Figure 1 shows the general MAC frame format consisting of a 56-bit header, variable length frame body, and 18-bit FrameCheck Sequence (FCS). The maximum length of the frame body is 255 octets. The MAC header further consists of 32-bit frame control, 8-bit recipient Identification (ID), 8-bit sender ID, and 8-bit WBAN ID fields. The frame control field carries control information including the type of frame, that is, beacon, acknowledgement, or other control frames. The recipient and sender ID fields contain the address information of the recipient and the sender of the data frame, respectively. The WBAN ID contains information on the WBAN in which the transmission is active. The first 8-bit field in the MAC frame body carries message freshness information required for nonce construction and replay detection. The frame payload field carries data frames, and the last 32-bit Message Integrity Code (MIC) carries information about the authenticity and integrity of the frame. The IEEE 802.15.6 standard supports two kinds of addresses:

1. 8-bit short address, which is the sender ID. This address is located in the MAC header used for communication.

2. 48-bit EUI-48 address, which is used for the association process. For some certain frame types, e.g. Security Association frames, this MAC address exists inside the MAC payload, for the node joining process.

```
                     Octets      7          0-255          2
                            +--------+-----------------+--------+
                            |  MAC   |  MAC frame body |        |
                            | header |Variable length: |   FCS  |
                            |        |  0-255 bytes    |        |
                            +--------+-----------------+--------+
                            <--MHR--><--------X--------><---FTR-->
                              /       \
                             /         \
                            /           \
         +---------+------------+-------------+-------------+
         |  Frame  | Recipient  |   Sender    |     Ban     |
         | control |     ID     |     ID      |     ID      |
         +---------+------------+-------------+-------------+
  Octets <---4----><-----1-----><------1-----><-------1------>
```

Figure 1: The general MAC frame format of IEEE 802.15.6

1.2. Why 6lo is required for IEEE 802.15.6

Based on the characteristics defined in the overview section, the following sections elaborate on the main problems with IP for WBANs.

The requirement for IPv6 connectivity within WBANs is driven by the following:

- o The number of devices in WBANs makes network auto configuration and statelessness highly desirable. And for this, IPv6 has (default auto-configuration as a) ready solutions.

- o The large number of devices poses the need for a large address space, moreover a WBAN may consist of 256 nodes maximum and IPv6 is helpful to solve this address space limitation.

- o Given the limited packet size of WBANs, the IPv6 address format allows subsuming of IEEE 802.15.6 addresses if so desired. Applications within WBANs are expected to originate small packets. Adding all layers for IP connectivity should still allow transmission in one frame, without incurring excessive fragmentation and reassembly. Furthermore, protocols must be

designed or chosen so that the individual "control/protocol packets" fit within a single 802.15.6 frame. Along these lines, IPv6's requirement of sub-IP reassembly may pose challenges for low-end WBANs healthcare devices that do not have enough RAM or storage for a 1280-octet packet [RFC2460].

- o Simple interconnectivity to other IP networks including the Internet.

- o However, given the limited packet size, headers for IPv6 and layers above must be compressed whenever possible.

2. Conventions and Terminology

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].

3. Topology and Scope of Communication

This is a standard for short-range, wireless communication in the vicinity of, or inside, a human body (but not limited to humans). It uses existing industrial scientific medical (ISM) bands as well as frequency bands approved by national medical and/or regulatory authorities. Support for quality of service (QoS), extremely low power, and data rates from 10Kbps to 10 Mbps is required while simultaneously complying with strict non-interference guidelines where needed. The Table 1 shows a comparison of WBAN and other available technologies in terms of data rate and power consumption.

Standard	Provided data rate	Power requirement	Battery lifetime
802.11 ac (WiFi)	700 Mbps	100 mW - 1000 mW	Hours - days
Bluetooth	1Mbps - 10 Mbps	4 mW - 100 mW	Days - weeks
Wibree	600 Kbps maximum	2 mW - 10 mW	Weeks - months
ZigBee	250 Kbps	3 mW - 10 mW	Weeks - months

802.15.4	250 Kbps maximum	3 mW - 10 mW	Weeks - months
802.15.6	1Kbps - 10 Mbps	0.1 mW - 2 mW	Months - years

Table 1: Comparison of WBAN

Data rates, typically up to 10Mbps, can be offered to satisfy an evolutionary set of entertainment and healthcare services. Current personal area networks (PANs) do not meet the medical (proximity to human tissue) and relevant communication regulations for some application environments. They also do not support the combination of reliability, QoS, low power, data rate, and non-interference required to broadly address the breadth of body area network (BAN) applications.

The IEEE 802.15.6 working group has considered WBANs to operate in either a one-hop or two-hop star topology with the node in the centre of the star being placed on a location like the waist. Two feasible types of data transmission exist in the one-hop star topology: transmission from the device to the coordinator and transmission from the coordinator to the device. The communication methods that exist in the star topology are beacon mode and non-beacon mode. In a two-hop start WBAN, a relay-capable node may be used to exchange data frames between a node and the hub.

4. Protocol Stack

The IPv6 over IEEE 802.15.6 protocol stack is presented in Figure 2. It contains six elements from bottom to top including IEEE 802.15.6 PHY layer, IEEE 802.15.6 MAC layer, Adaptation layer for IPv6 over

IEEE 802.15.6, IPv6 layer, TCP/UDP layer and Application layer.The adaptation layer supports the mechanisms like stateless address auto-configuration, header compression and fragmentation and reassembly.

```
+-----------------------------------------+
|            Application Layer            |
+-----------------------------------------+
|                 TCP/UDP                 |
```

```
+----------------------------------------+
|                                        |
|                 IPv6                   |
|                                        |
+----------------------------------------+
| Adaptation layer for IPv6 over 802.15.6|
+----------------------------------------+
|               MAC Layer                |
|           (IEEE 802.15.6)              |
+----------------------------------------+
|               PHY Layer                |
|           (IEEE 802.15.6)              |
+----------------------------------------+
```

Figure 2: Protocol stack for IPv6 over IEEE 802.15.4

5. Maximum Transmission Unit (MTU)

The IPv6 packets have the MTU of 1280 octects and its expects from every link layer to send data by following this MTU or greater. Thus maximum Transmission Unit (MTU) of MAC layer describes the implementation of fragmentation and reassembly mechanism for the adaption IPv6 layer over IEEE 802.15.6.

The IEEE 802.15.6 has the MTU of 256 octects, if we consider link layer security overhead (16 octects for AES-128) leaves 240 octects which is not sufficient to complete a IPv6 packet.Therefore, an adaption layer below IP layer is required to manage fragmentation and reassembly issues.

6. Specification of IPv6 over WBAN

Due to stringent QoS requirements in WBAN, a 6lo adaption layer is needed to support the transmission of IPv6 packets.6 LoWPAN standards [RFC4944], [RFC6775] and [RFC6282] provides useful information including link-local IPv6 address,stateless address auto-configuration, unicast and multicast address mapping,header compression and fragmentation and reassembly. These standards are reffered in the specifications of 6lo adaptation layer which is illustrated in the following following subsections:

6.1. Stateless Address Autoconfiguration

An IEEE 802.15.6 device performs stateless address autoconfiguration to obtain an IPv6 Iterface Identifier(IID). The IPv6 EUI-64 format address is obtained through the EUI-48 bit MAC address of IEEE 802.15.6 node.The 64-bit IID SHALL be derived by utilizing 8-bit node address and 8-bit BAN ID (part of MAC header) as follows:

ID: 0xYY00:00FF:FE00:00XX

Where YY is the BAN ID, XX is the node address. As this generated IID is not golbally unique, the "Universal/Local" (U/L) bit (7th bit) SHALL be set to zero.

6.2. IPv6 Link-Local Address

The IPv6 link-local address [RFC4291] for an IEEE 802.15.6 interface is generated by appending the interface identifier to the prefix FE80::/64.

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

Figure 3: IPv6 Link Local Address in IEEE 802.15.6

6.3. Unicast and Multicast Address Mapping

The address resolution procedure for mapping IPv6 unicast addresses into IEEE 802.15.6 link-layer addresses follows the general description in section 7.2 of [RFC4861], unless otherwise specified. Multicast address mapping is not supported in IEEE 802.15.6.

6.4. Header Compression

The IEEE 802.15.6 PHY layer supports a maximum PSDU (PHY Service Data Unit) of 256 octets. Because of the limited PHY payload, header compression at 6lo adaptation layer is of great importance and MUST be applied. The compression of IPv6 datagrams within IEEE 802.15.6 frames refers to [RFC6282], which updates [RFC4944].Multiple header compression stacks are defined in RFC6282 which specifies the fragmentation methods for IPv6 datagrams on top of IEEE 802.15.4;however, for IEEE 802.15.6, a LoWPAN encapsulated LoWPAN_HC1 compressed IPv6 datagram can be used as IEEE 802.15.6 does not require mesh header due to IEEE 802.15.6 communication scope.Moreover, static header compression techniques of [RFC7400] can also be used as header compression.

6.5. Fragmentation and Reassembly

IEEE 802.15.6 provides Fragmentation and reassembly (FAR) for payload of 256 bytes. FAR as defined in [RFC4944], which specifies the fragmentation methods for IPv6 datagrams on top of IEEE 802.15.4 MUST be adapted to work with IEEE 802.15.6. All headers MUST be compressed according to [RFC4944] encoding formats, but the default MTU of IEEE 802.15.6 is 256 bytes which MUST be considered.

7. IANA Considerations

[TBD]

8. Security and Privacy Considerations

IPv6 over WBAN's applications often require confidentiality and integrity protection. This can be provided at the application, transport, network, and/or at the link.IEEE 802.15.6 considers the security as a key requirement for healthcare applications and defines a complete framework. This framework defines three levels of security which can be used according to requirements.Overall, it covers privacy, confidentiality, encryption and authentication.AES-64 is preffered for encryption due to its efficiency.

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9.2. Informative References

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Appendix A. Patient monitoring use case - Spoke Hub

Refer following diagram:


```
                                 ########
                               # @ EEG    #
                             ##   |      @ # Hearing
                             #    |      | #
                              #   |      |#
                               #  |     #|
                         #####    |      |## ###
                      #           |      |   @   ## Motion Sensor
          Positioning#  @         |      /  /     #
                    #    \        |ECG /  /       #
                    #     \       |  @ | /         #
                   #         \    | / / /           #
                  #      ##   \   |/ //      ##      #
                  #      ##    \  ||//       ##      #
                 #      # #     \ ||||      # #  @   # BP
                #       # #      \||||      # # /    ##
                #      ## #       ||||      # #/      ##
           SPO2# @    ##  #   Coordinator   # /##      #
              #   \  ##  ##       +-+        /  ##     ##
             #     ------+--------| |-------/ #   #      #
          ##     ##      #        +-+         ##     #    ##
        ##      ##      #         //\         #      #      ##
     ###       #        #        //  \        #      ##        ###
       ##      #        #       //    \       #       #      ## ##
       #      #        #       //      \      #        #      #
      ###   # #        #      //  ##    \     #        #     ###
        #  ###         #     //   # #    \    #         # #  ###
        ###            #    //   # #     |    #          # ###
                       #   //    # ##    |    #
        Glucose Sensor # @ /     #  #    |   #
                       ##  |     ##  #    |   #
                        # /      #   #    |   #
```

```
                        #/     #      #  |   #
                    Emg#@      #      #  |   #
                       #      #       ## |   #
                       ##              # |   #
                        #    #         # |   #
                        #    #          #\   #
                       #     #          # |   #
                       #     #          # @   # Motion Sensor
                        ##  #            ## ##
                          ##               #
```

Figure 4: Patient monitoring use case - Spoke Hub

Appendix B. Patient monitoring use case - Connected

Refer following diagram:

```
                                 ########
                              #   @ EEG    #
                             ##   |\-----@ # Hearing
                             #     |      \#
                              #    |     # |
                               #    |   ##  |Motion Sensor
                       #######      |     ##|####
                      #              |       |   ##
          Positioning#   @            |      @    #
                    #    /\        ECG|       \   #
                    #   /  \----------@        \   #
                   #   /                        |  #
                  #  /   ##                 ##   |  #
                 # /    # #                 # #  @   # BP
                #/     ## #                 # ##  |   ##
           SPO2# @    ##  #                 #  ## |    #
             #    \ #    #                   #   #|     #
          ##     ## \    #                   ##   | #    ##
       ##      #      \ #                     #  |    #      ## ##
      ###   # #        # \        ##          #  |     #     ###
        #  ###         #   \      # #          # |       # #  ###
```

```
        ###            #   |     # #          # |        # ###
                       #   |     # ##         # |
        Glucose Sensor #   @     #  #        #  |
                        # /     #    #       # /
                        #|    ##      #      #/
                        #/     #      #      #|
                    Emg#@      #      #      #|
                       #  \    #      #      #|
                       #    \  #      #      #|
                       #     \#       ##     #|
                       ##     \        #     #|
                        #     #\       #     #|
                        #    #  \      #     #|
                        #    #    \    #     #|
                        #    #     \   ##    #/
                        #    #       \ ##    /
                        #    #        \ ##  /#
                       ##    #          \  |  #
                       #     #          # \/  #
                        #    #           # @ # Motion Sensor
                          ##               #
```

Figure 5: Patient monitoring use case - Connected

Appendix C. Changes

Compared with version-00, this updated draft is no longer all informative. Two main changes have been made as below:

1. Introduction part of 802.15.6 is simplified and more focused on the features that relates to the 6lo-WBAN adaptation layer, e.g. MAC frame format including MAC address and MTU, topology and scope of communication, and why the 6lo-WBAN adaptation layer is needed.

2. The 6lo-WBAN adaptation layer is specified in this draft titled as "Specification of IPv6 over WBAN" that lists the main features needs to be added in the 6lo adaptation layer including the formation of IID, IPv6 link-local address, unicast address mapping, header compression, and fragmentation and reassembly. These parts have never been mentioned in other documents related to WBAN, and in this version, we provide a guidance for such IPv6

enabled WBAN implementations.

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