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       Transmission of IPv6 Packets over Wireless Body Area Networks (WBANs)
                       draft-sajjad-6lo-wban-01

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.

   This Internet-Draft will expire on May 3, 2018.

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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------>
```
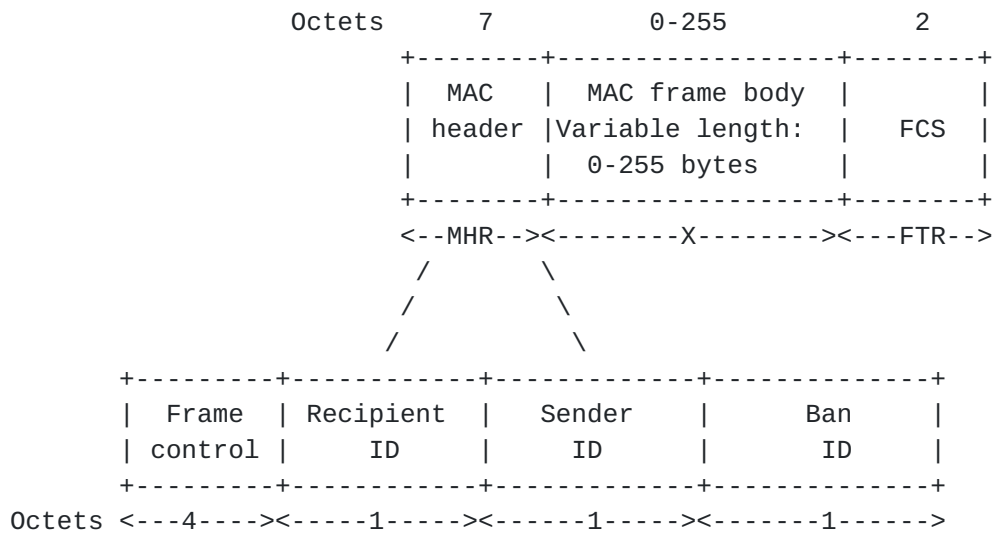
        Figure 1: The general MAC frame format of IEEE 802.15.6

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)          |
            +----------------------------------------+
```
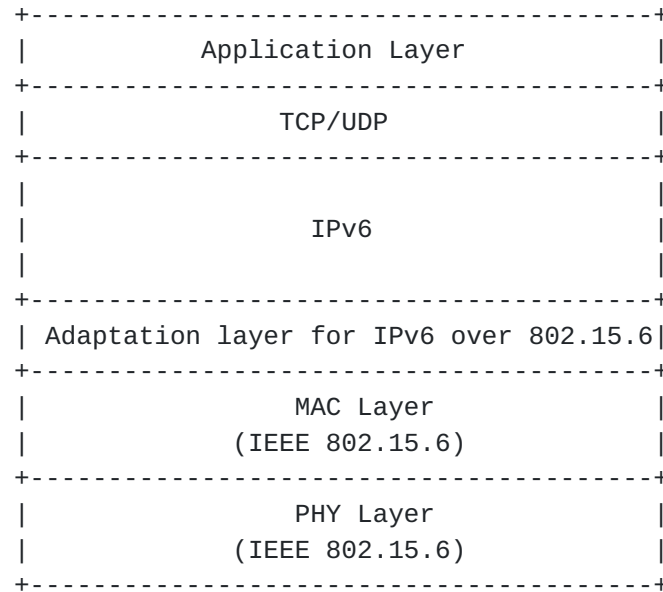
            Figure 2: Protocol stack for IPv6 over IEEE 802.15.4

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    |
      +----------+----------------------+----------------------------+
```
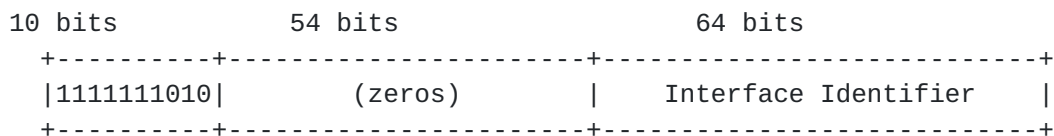
           Figure 3: IPv6 Link Local Address in IEEE 802.15.6

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.

9. References

9.1. Normative References

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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
                    ##   #              ## ##
                      ##                   #
```
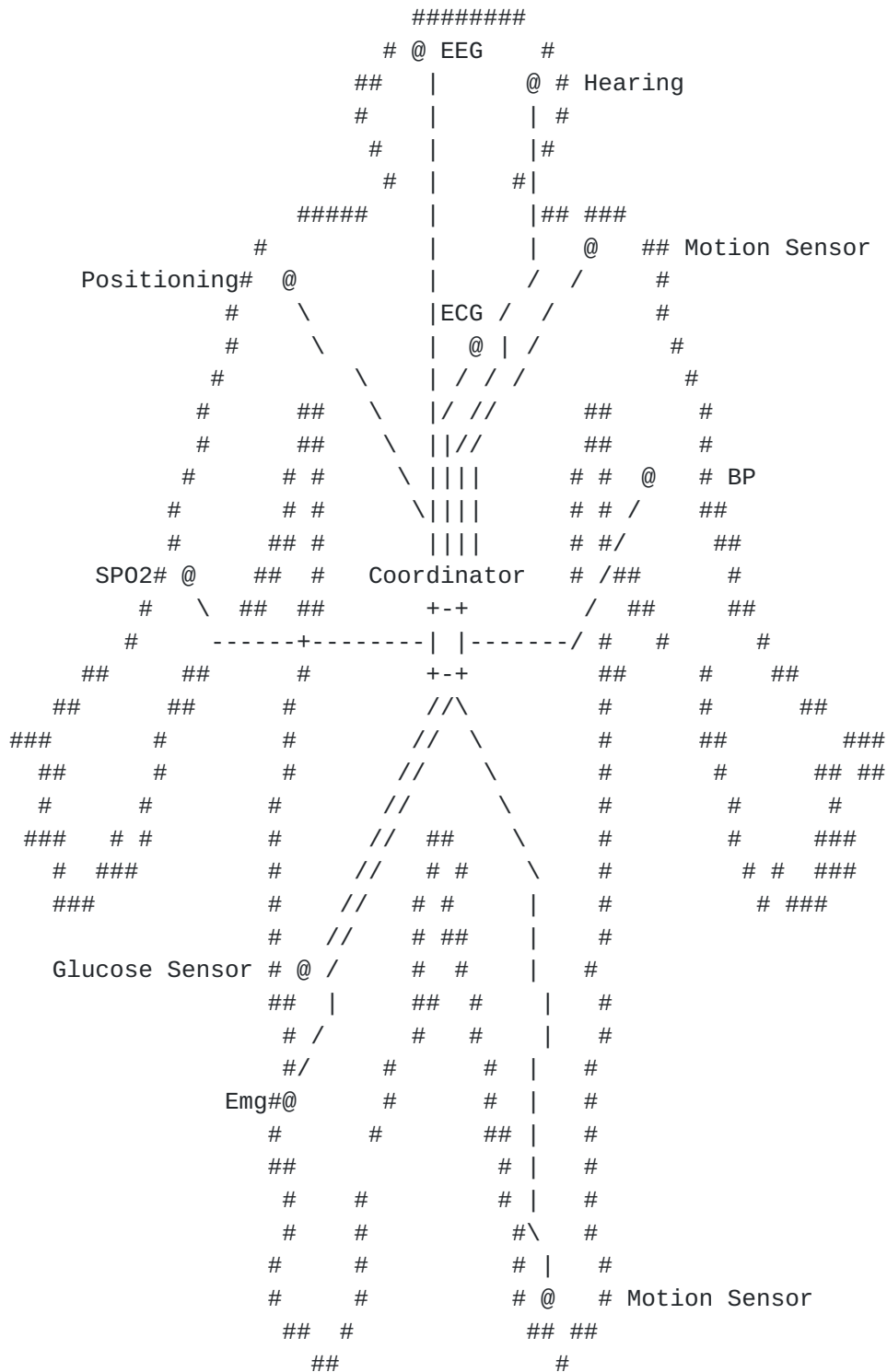
                 Figure 4: Patient monitoring use case - Spoke Hub

Appendix B. Patient monitoring use case - Connected

   Refer following diagram:

```
                        ########
                     #    @ EEG     #
                     ##    |\-----@ # Hearing
                     #     |        \#
                      #    |      # |
                       #    |    ##  |Motion Sensor
               #######        |     ##|####
                  #            |      |   ##
          Positioning#   @            |      @    #
                 #     /\        ECG|        \    #
                 #    /  \----------@           \    #
                #   /                            |   #
                # /    ##                      ##    |  #
               # /     # #                     # #  @   # BP
              #/       ## #                    # ##  |    ##
           SPO2# @     ##  #                    #  ## |     #
             #    \ #     #                     #   #|      #
            ##      ## \    #                      ##   | #     ##
          ##       #      \ #                       #  |    #       ## ##
         ###    # #       # \          ##           #  |       #      ###
          #   ###         #    \        # #           # |       # #   ###
          ###            #    |     # #            # |        # ###
                         #    |      # ##           # |
           Glucose Sensor #    @       #   #          #   |
                          # /       #     #        # /
                          #|      ##        #       #/
                          #/       #         #      #|
                        Emg#@       #         #      #|
                         #  \       #         #      #|
                         #    \  #        #      #|
                         #      \#         ##      #|
                         ##       \          #      #|
                          #       #\          #      #|
                          #      #  \         #      #|
                          #      #    \        #      #|
                          #      #      \     ##     #/
                          #      #        \ ##     /
                          #      #          \ ##  /#
                         ##       #            \  |   #
                          #       #             # \/   #
                           #      #                # @ # Motion Sensor
                             ##                    #
```
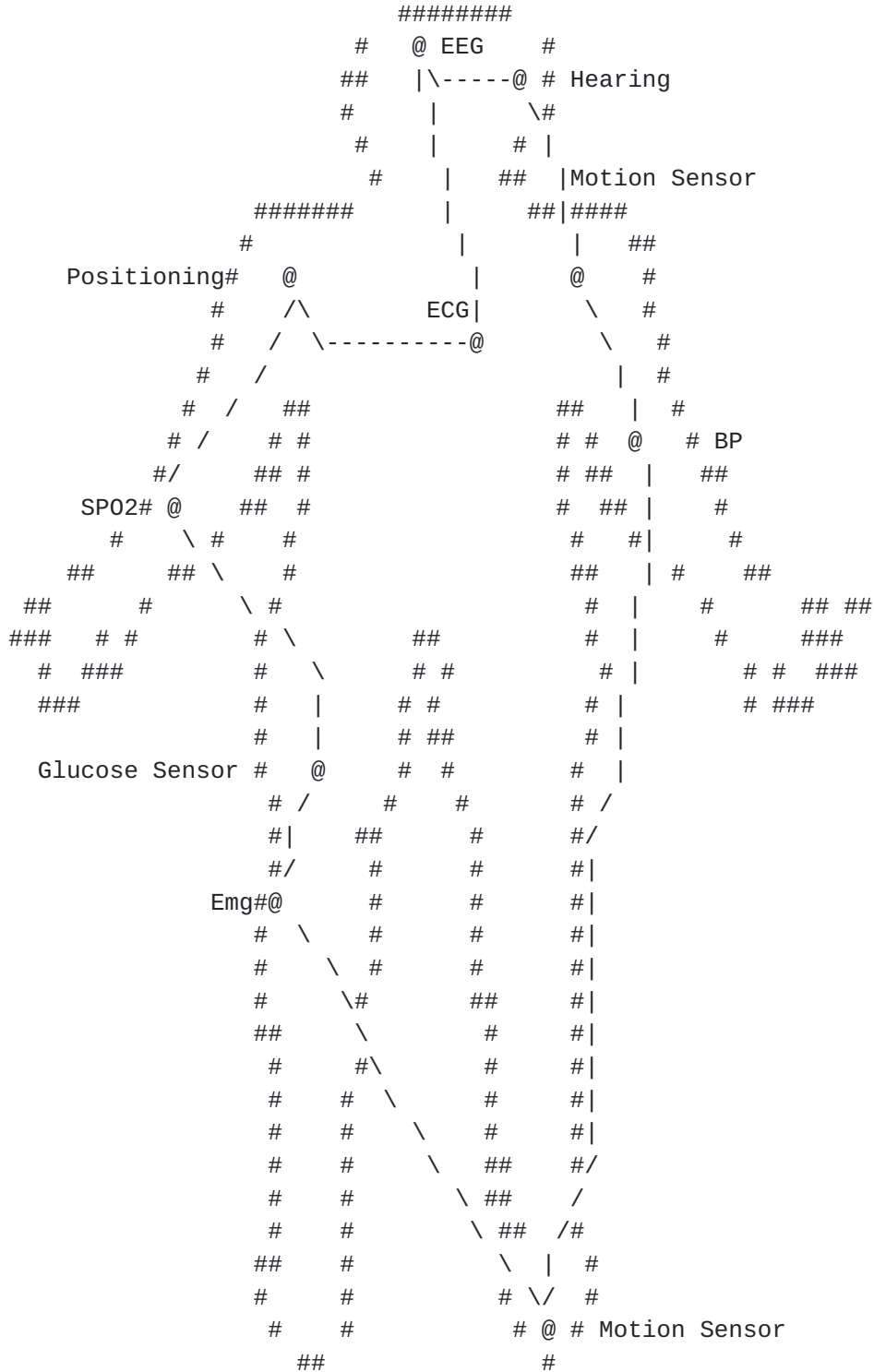
                Figure 5: Patient monitoring use case - Connected

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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