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TECHNICAL SPECIFICATION

Smart Body Area Network (SmartBAN);
Enhanced Ultra-Low Power Physical Layer

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Smart Body Area Network (SmartBAN).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document specifies the ultra-low power physical layer (PHY) Smart BAN.

The present document applies to short range, wireless communication between wearable sensors devices and the hub coordinator. The present document specifies the PHY for transmitting on the medium.

The present document describes:

- packet formats;
- modulation;
- forward error correction.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 325 (V1.1.1) (2015-04): "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

D Delay
$\oplus$ eXclusive OR (XOR)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

Ack	Acknowledgement
BAN	Body Area Network
BCH	Broadcast Channel
BT	Bandwidth Time product
CCA	Clear Channel Assessment
CRC	Cyclic Redundancy Check
ED	Energy Detection
FEC	Forward Error Correction
GSFK	Gaussian Frequency Shift Keying
IFS	Inter-Frame Spacing
ISM	Industrial, Scientific and Medical
MAC	Medium Access Control
MPDU	MAC Protocol Data Unit
PHY	Physical Layer
PLCP	Physical Layer Convergence Protocol
PPDU	PHY Protocol Data Unit
PSDU	Physical Layer Service Data Unit

4 Introduction and Background

Modern medical and health monitoring equipment are moving towards the trend of wireless connectivity between the data collection or control centre and the medical devices or sensors. Therefore, the need for a standardized communication interface and protocol between the actors are required. This network of actors performing some medical monitoring or functions is called a Smart Body Area Network (Smart BAN).

The present document specifies the physical layer procedure for Smart BAN.

5 General PHY Framework

5.0 Introduction

This clause provides the basic PHY framework for the nodes and hubs.

5.1 Frequency Spectrum

The frequency of operation shall fall within 2 401 MHz - 2 481 MHz. The channels shall be arranged in blocks of 2 MHz with centre frequencies:

$$f_c = 2\,402 + 2 \times n \text{ MHz, for } n = 0 \text{ to } 39,$$

where n is the channel number.

Table 1 shows the mapping of the channel number to data channel number and control channel number.

Table 1: Mapping of Channel Number to Data and Control Channel Numbers

Channel Number	Centre Frequency (MHz)	Channel Type	Data Channel Number	Control Channel Number
0	2 402	Control		0
1	2 404	Data	0	
…		Data		
11	2 424	Data	10	
12	2 426	Control		1
13	2 428	Data	11	
…		Data		
38	2 478	Data	36	
39	2 480	Control		2

6 Packet Formats

6.1 Physical-Layer Protocol Data Unit (PPDU)

6.1.0 PPDU Structure

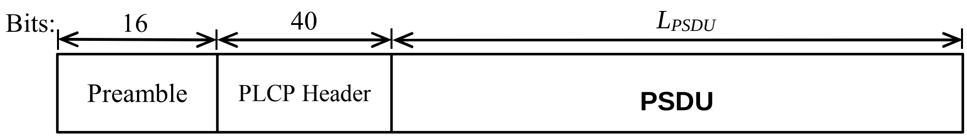

Figure 1: PPDU Structure

6.1.1 Preamble

PPDUs have a sixteen bit preamble used for frequency synchronization, timing synchronization, and automatic gain control.

The preamble for all PPDUs shall be 1010101010101010.

6.1.2 PLCP Header

6.1.2.0 PLCP Header Structure

The PLCP Header is structured as illustrated in Figure 2. The PLCP header consist of the Packet Length, PHY Scheme, Reserved, BCH Parity Bits, and the Header Parity fields.

The PLCP header shall be scrambled by the procedure described in clause 7.4.

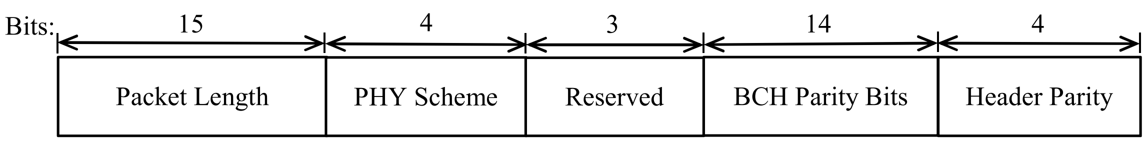

Figure 2: PLCP Header Structure

6.1.2.1 Packet Length

The packet length field indicates the length of the PSDU.

6.1.2.2 PHY Scheme

The PHY Scheme field describes the forward error control (FEC) type and the repetition type the PPDU employs. The mapping of the field bits is as described in Table 2.

6.1.2.3 BCH Parity Bits

The BCH Parity Bits field shall be generated using a BCH (36,22,t=2) code defined in clause 7.3.3 to protect the Packet Length, PHY Scheme, and Reserved fields.

6.1.2.4 Header Parity

The Header Parity field shall be generated by the CRC polynomial $1 + x + x^4$ on the Packet Length, PHY Scheme, Reserved, and BCH Parity Bits fields.

Table 2: PHY Scheme field bit mapping

Field Value b0 b1	FEC Type
00	None
01	BCH(127,113,2)
10	Reserved
11	Reserved

Field Value b2 b3	Repetition Type
00	None
01	2
10	4
11	Reserved

6.1.3 PSDU

The Physical-Layer Service Data Unit (PSDU) is either an encoded or uncoded MAC Protocol Data Unit (MPDU) as defined clause 6.1 of [1]. The MPDU may be encoded using a BCH (127,113,t=2) code. The encoding procedure shall be described in clause 7.3. The PSDU shall be scrambled using the procedure described in clause 7.4.

7 Modulation and Error Control

7.1 PPDU Formation

The PPDU is formed from the following process described in Figure 3. The dashed boxes represent operations that are optional.

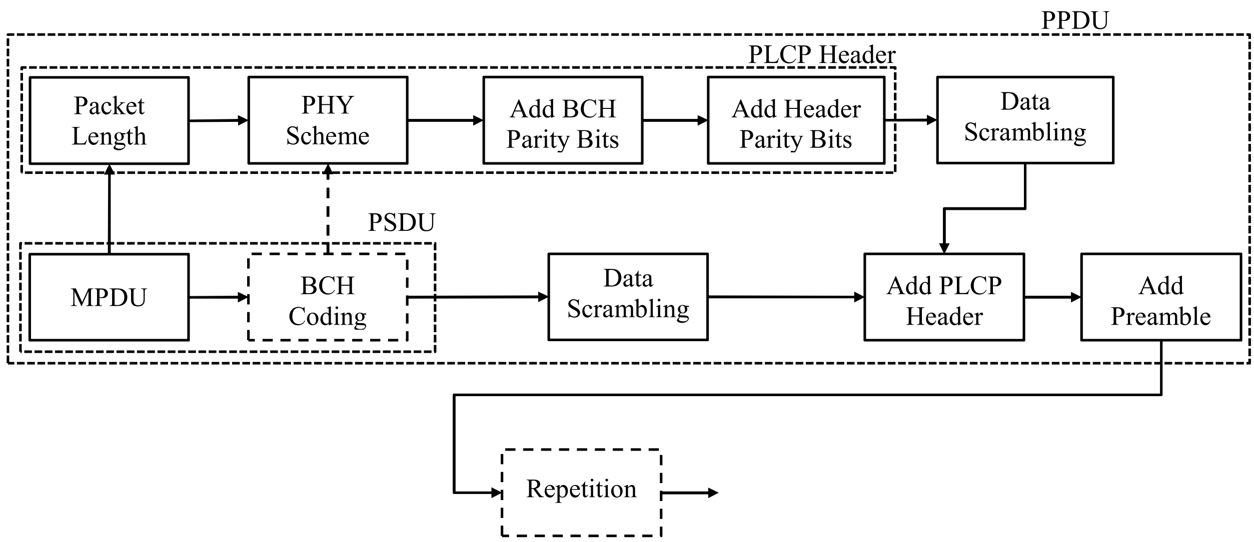

Figure 3: Transmitter Physical Layer Chain

7.2 Modulation

The modulation is Gaussian Frequency Shift Keying (GSFK) with a bandwidth-bit period product BT = 0,5, and modulation index h = 0,5.

A symbol rate, T_{sym}, of 1 MSymbols/s shall be supported in both Control and Data Channels.

Table 3: Physical Layer Throughput

Channel (Data/Control)	Information Flow	Symbol Rate (MSymbols/s)	Code Rate	Repetition	Information Rate (Mbps)
Data/Control	Downlink/Uplink	1,0	1	1	1,0
Data/Control	Downlink/Uplink	1,0	1	2	0,5
Data/Control	Downlink/Uplink	1,0	1	4	0,25
Data/Control	Downlink/Uplink	1,0	113/127	1	0,89
Data/Control	Downlink/Uplink	1,0	113/127	2	0,44
Data/Control	Downlink/Uplink	1,0	113/127	4	0,22

7.3 Repetition and Forward Error Control (FEC)

7.3.1 Repetition

The hubs and nodes may implement repetition coding to reduce errors if required. Should repetition coding be implemented, this shall be indicated in the PHY Scheme field in clause 6.1.2.3. Two repetition schemes shall be supported, 2-repetition, repeating the entire PPDU 2 times, and 4-repetition, repeating the entire PPDU 4 times.

When repetition is employed, the original PPDU along with its repeated versions shall be treated as one single PPDU.

An example of 2-repetition and 4-repetition is shown in Figure 4.

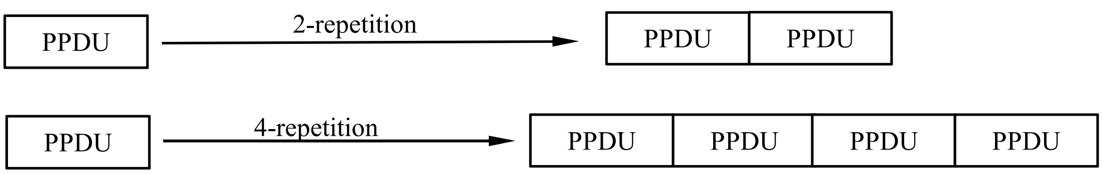

Figure 4: An example of 2-repetition and 4-repetition

7.3.2 BCH (127,113,*t*=2) Encoding

For error correction control of MPDU, a systematic BCH(127,113,*t*=2) code may be employed. *t* indicates the maximum number of bits that can be corrected. The generator polynomial of the BCH(127,113,*t*=2) code is:

$$g(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1. \quad (1)$$

The encoding process is as follows:

1) Calculate the number of padding bits, $N_{padding}$. The number of padding bits depends on the length of the MPDU, L_{MPDU}, and can be calculated as:

$$N_{padding} = \left\lceil \frac{L_{MPDU}}{k} \right\rceil \times k - L_{MPDU},$$

where k = 113,

2) Append $N_{padding}$ zero bits to the end of the MPDU

3) Partition the padded MPDU into subpackets with length of *k*

4) Compute the parity bits for each subpackets using the generator polynomial g(*x*)

5) Remove $N_{padding}$ bits from the last subpacket

6) Append the parity bits generated for each subpacket to each subpacket

7) Reassemble the expanded subpackets in the same order they were dissembled to produce the PSDU

7.3.3 BCH (36, 22, *t*=2) Encoding

For error correction control of the Packet Length, PHY Scheme, and Reserved fields of the PLCP header, a systematic BCH(36,22,*t*=2) code shall be employed. The BCH code is a shortened code derived from the primitive BCH (127, 113, *t*=2) described in clause 7.3.2. The encoding process is as follows:

1) Set $N_{padding} = 91$.

2) Append $N_{padding}$ zero bits to the end of the Packet Length, PHY Scheme, and Reserved fields, the resulting 113 bits are treated as a subpacket in clause 7.3.2.

3) Compute the parity bits for the subpacket using the generator polynomial g(x) in (1).

4) Remove $N_{padding}$ bits from the subpacket.

5) Append the generated parity bits to the subpacket.

7.4 Scrambling

A data scrambler can be used when necessary. The scrambling sequence is generated by the scrambling polynomial is $1 + x^{14} + x^{15}$, with an initial state of 000100100001010. The output of the data scrambler is:

$$x[n] = x[n\text{-}14] \oplus x[n\text{-}15].$$

Figure 5 shows an implementation of the data scrambler. D denotes the delay operation.

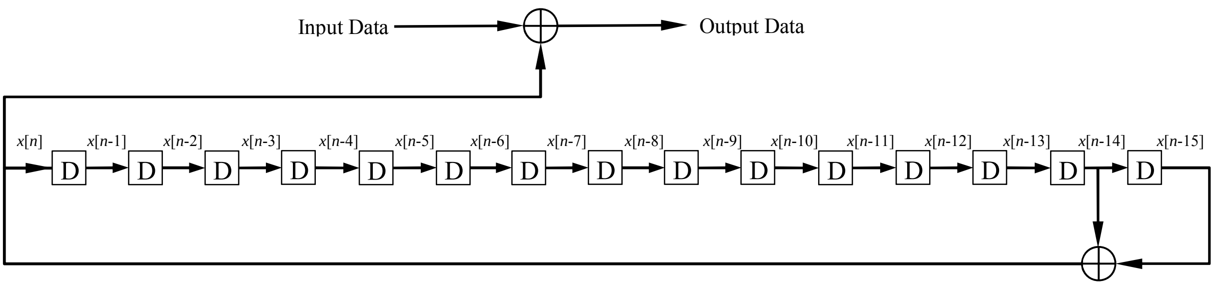

Figure 5: Data scrambler

8 Other Requirements

8.1 Packet Length

In this clause, we calculate the maximum permitted length of PPDUs and MPDUs.

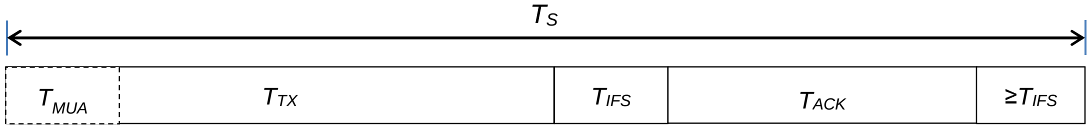

Figure 6: Channel Access Slot Structure

Each time slot is partitioned into 2 transmission phases (T_{TX} and T_{ACK}) and 2 or more transition phases. The time allocated to the initial transmission phase is dependent on several factors:

- Time for transmitting the Acknowledgement frame.

- Inter-Frame Spacing.
- Channel Access Mode.
- PHY Scheme.

The time for transmitting the Acknowledgement frame is:

$$T_{ACK} = (L_{preamble} + L_{PLCPheader} + L_{header} + L_{parity})/R_{sym},$$

where $L_{preamble}$, $L_{PLCPheader}$, L_{header}, L_{parity}, and R_{sym} are the length (in bits) of the PHY preamble, PLCP header, MAC header, MAC parity field, and the symbol rate respectively.

Therefore, the maximum permissible time for the initial transmission phase is:

$$T_{TX,max} = (T_S - T_{MUA} - T_{ACK} - 2 \times T_{IFS})/N_{rep},$$

where N_{rep} is the number of time the PPDU is repeated, as indicated in PHY Scheme field in the PLCP Header. T_{MUA} is the sensing time in the Multi-use Access mode. For Scheduled and Slotted Aloha channel access modes, $T_{MUA} = 0$. Consequently, the maximum length (in bits) of the PSDU is:

$$L_{PSDU,max} = T_{TX,max} \times R_{sym} - (L_{preamble} + L_{PLCPheader}).$$

In the case where no BCH encoding is employed, $L_{PSDU,max} = L_{MPDU,max}$. When BCH($n$, k) encoding in employed, the maximum length of the MPDU is:

$$L_{MPDU,max} = \lfloor L_{PSDU,max}/n \rfloor \times k + \kappa;$$

where:

$$\kappa = \begin{cases} (L_{PSDU,max}\ \%\ n) - (n-k); & if\ \left(L_{PSDU,max}\ \%\ n\right) > (n-k), \\ 0; & if\ (L_{PSDU,max}\ \%\ n) < (n-k). \end{cases}$$

Hence, the maximum length of the MAC Frame Body, $L_{F,max}$ is:

$$L_{F,max} = L_{MPDU} - L_{header} - L_{parity}.$$

8.2 Clear Channel Assessment

The PHY shall provide the capability to perform Clear Channel Assessment (CCA) in devices which support the Multi-use Access Channel Access mode according to at least one of the following three methods:

1) CCA Mode 1: Energy above threshold. CCA shall report a busy medium upon detecting any energy above the Energy Detection (ED) threshold;

2) CCA Mode 2: Carrier sense only. CCA shall report a busy medium only upon the detection of a signal compliant with the present document. This signal may be above or below the ED threshold. The CCA detection time shall be $\leq T_{MUA}$;

3) CCA Mode 3: Carrier sense with energy above threshold. CCA shall report a busy medium using a logical combination of the following:

   a) Detection of a signal with the modulation and characteristics of the PHY that is currently in use by the device, and

   b) Energy above the ED threshold, where the logical operator may be AND or OR.

The CCA parameters are subject to the following criteria:

- The ED threshold shall be -75 dBm.
- The CCA detection time shall be $\leq T_{MUA}$. Any CCA procedures required by local regulatory requirements shall also be supported.

Annex A (informative): Bibliography

ETSI EN 300 328-1 (V1.3.1) (2001-12): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband Transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum modulation techniques; Part 1: Technical characteristics and test conditions".

ETSI TS 103 129 (V1.1.2) (2014-03): "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation of a carrier identification system (DVB-CID) for satellite transmission".

History

Document history		
V1.1.1	April 2015	Publication