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Smart Body Area Network (SmartBAN);
Applying SmartBAN MAC (ETSI TS 103 325)
for various use-cases

Reference
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Foreword

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

Modal verbs terminology

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1 Scope

The present document is focussed on the exploitation of the reference SmartBAN MAC for various use-cases, which includes:

i) the provision of detailed requirements of the use-cases; and

ii) corresponding execution with various SmartBAN PHY-MAC parameters.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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 referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

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.

[i.1] ETSI TR 103 394 (V1.1.1) (01-2018): "Smart Body Area Networks (SmartBAN); System Description".

[i.2] ETSI TS 103 325 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN".

[i.3] ETSI TS 103 326 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBAN); Enhanced Ultra-Low Power Physical Layer".

[i.4] IEEE Std. 802.15.6™-2012: "IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks".

[i.5] M. M. Alam, E. B. Hamida, D. B. Arbia, M. Maman, F. Mani, B. Denis, R. D"Errico (2016): "Realistic Simulation for Body Area and Body-To-Body Networks", Sensors.

[i.6] R. Khan, M. M. Alam, T. Paso, J. Haapola (2019): "Throughput and Channel Aware MAC Scheduling for SmartBAN Standard", IEEE Access.

[i.7] ETSI TR 103 395: "Smart Body Area Networks (SmartBAN); Measurements and modelling of SmartBAN Radio Frequency (RF) environment".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

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

$\times$	Multiplication
ϵ	GFSK modulation constant
BW	Channel bandwidth
d	On-body link distance (cm), depending upon the on-body node positions
$\frac{E_b}{N_0}$	Energy of bit-to-noise ratio
h	GFSK modulation index
$L_{MACheader}$	MAC header length in bits
L_{parity}	Frame parity
$L_{PLCPheader}$	PLCP header length in bits
$L_{preamble}$	Physical layer preamble length in bits
m_0	The average decay rate in dB/cm for the surface wave traveling around the perimeter of the body
N	Payload size in bits
n_P	Gaussian random variable with zero mean and unity variance
P_0	The average loss close to the antenna
P_1	The average attenuation of components in an indoor environment radiated away from the body and reflected back towards the receiving antenna
P_b	Bit error probability
PL^{dB}	Pathloss in dB
P_N^{dB}	Receiver Sensitivity
P_{Tx}^{dB}	Transmission power level in dB
Q()	Mathematical Q function
REP	Number of PPDU transmissions/repetitions
R_{sym}	Symbol/Information rate
SNR^{dB}	Signal-to-Noise Ratio in dB
T_{ACK}	PPDU acknowledgement duration
$\mathrm{T_{IFS}}$	IFS duration
$\mathrm{T_{min}}$	Minimum slot duration in SmartBAN
$\mathrm{T_{slot}}$	Scheduled access or C/M slot duration in SmartBAN
$T_{TX,max}$	Maximum PPDU transmission duration

3.3 Abbreviations

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

Ack.	Acknowledgement
AWGN	Additive White Gaussian Noise
BAN	Body Area Network
BCH	Bose-Chaudhuri-Hocquenghem Code
BER	Bit Error Rate
C/M	Control and Management
CMB3	Channel Model 3B
D-Beacon	Data Beacon
Dch	Data channel
D-CM3B	Deterministic CM3B
ECG	ElectroCardioGram
EEG	ElectroEncephaloGram
EMG	ElectroMyoGraph
FCS	Frame Check Sequence
FEC	Forward Error Correction
GFSK	Gaussian Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GPS	Global Positioning System
IBI	Inter Beacon Interval
IFS	Inter Frame Spacing
KPI	Key Performance Indicator

LOS	Line Of Sight
MAC	Medium Access Control
MPDU	MAC Protocol Data Unit
MRC	Maximal Ratio Combining
MSD	MusculoSkeletal Disorder
NLOS	Non-Line Of Sight
PER	Packet Error Rate
PHY	PHYsical layer
PLCP	Physical Layer Convergence Protocol
PPDU	Physical Layer Protocol Data Unit
PRR	Packet Reception Rate
PSD	Power Spectral Density
PSDU	Physical Layer Service Data Unit
QoS	Quality of Service
RF	Radio Frequency
S-CM3B	Static CM3B
SNR	Signal-to-Noise Ratio

4 Introduction and background

Telemedicine and telehealth monitoring systems require the collection of vital information via sensors, and in some cases transmission of appropriate feedback, from/to remote patients or subjects through a central hub. Therefore, the need for a standardized communication interface and protocol between the communicating entities is required. This network of agents performing some medical monitoring or functions is called a Smart Body Area Network (SmartBAN).

In the present document, several SmartBAN use-cases have been thoroughly described in terms of their data rate and latency requirements. In addition to the SmartBAN use-cases provided in ETSI TR 103 394 [i.1], few more use-cases have also been introduced which are specially challenging because of their high data rate requirements and real time latency constraints. Among the given SmartBAN use-cases, three example use-cases are considered as low, medium and high data rate applications. SmartBAN physical (PHY) and Medium Access Control (MAC) layer performance is evaluated in terms of Packet Reception Rate (PRR), attainable throughput and latency as primary Key Performance Indicators (KPIs). The technical report not only evaluates the potential of SmartBAN PHY-MAC layer for satisfying the application-specific Quality of Service (QoS) requirements but also investigates the necessary physical (PHY), MAC and Radio Frequency (RF) parameters for attaining the targeted QoS.

5 Overview of SmartBAN PHY-MAC

5.0 Introduction

This clause elaborates the ultra-low power PHY layer and low complexity scheduled access MAC layer details in SmartBAN.

5.1 PHY-MAC structure

Figure 1 shows the Inter Beacon Interval (IBI) structure on Data channel (Dch) for single Physical Layer Protocol Data Unit (PPDU) transmission, in which the IBI duration starts with Data beacon (D-Beacon), followed by scheduled access, Control and Management (C/M) and Inactive durations. Each scheduled access or C/M slot is respectively composed of data or C/M PPDU, and PPDU acknowledgement (Ack.), separated by Inter Frame Spacing (IFS). Within PPDU, a MAC frame body is appended with MAC header and frame parity to create a MAC Protocol Data Unit (MPDU) ETSI as defined in TS 103 325 [i.2]. An MPDU in Bose-Chaudhuri-Hocquenghem (BCH) coded or uncoded form creates a Physical-layer Service Data Unit (PSDU) which is combined with Physical Layer Convergence Protocol (PLCP) header and preamble to constitute a PPDU. The optional BCH encoding and/or PPDU repetitions serve as Forward Error Correction (FEC) techniques to improve system performance. Similarly, the IBI format and its individual slots with two PPDU repetitions as defined in ETSI TS 103 326 [i.3] are illustrated in figure 2. Figure 3 and figure 4 depict MAC [i.2] and PLCP [i.3] header formats respectively.

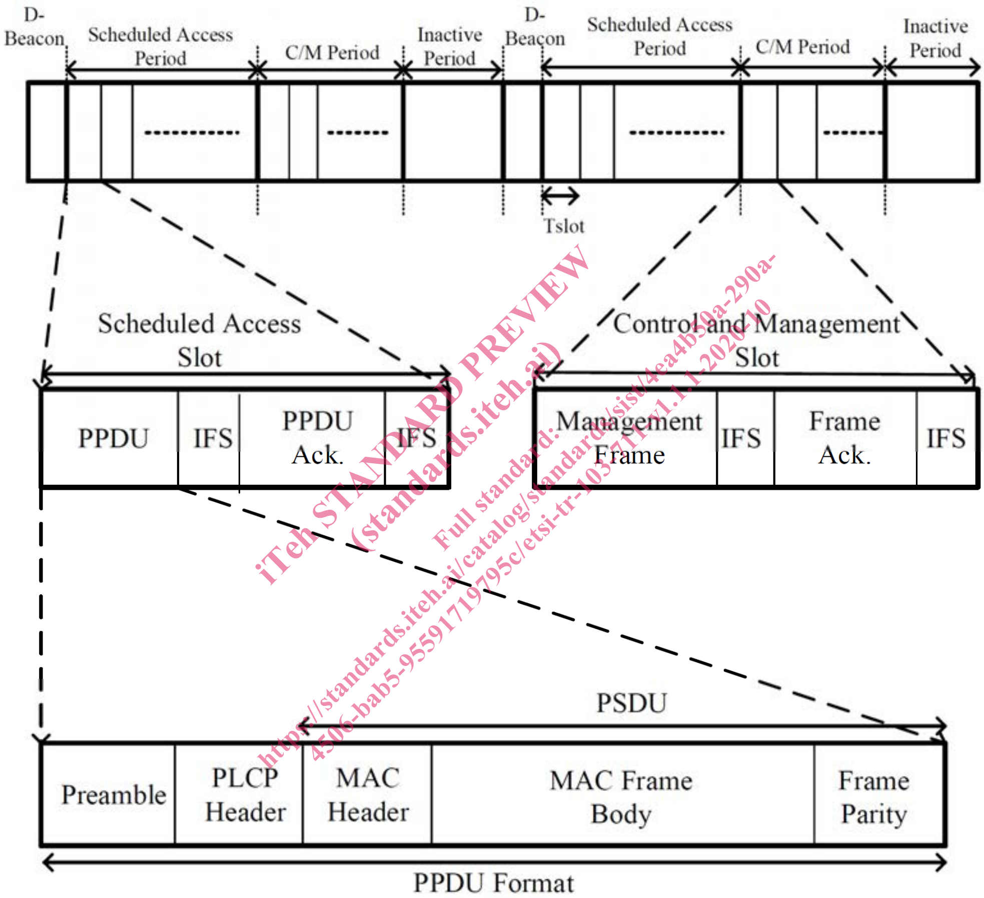

Figure 1: IBI format with no PPDU repetitions in scheduled access and C/M durations

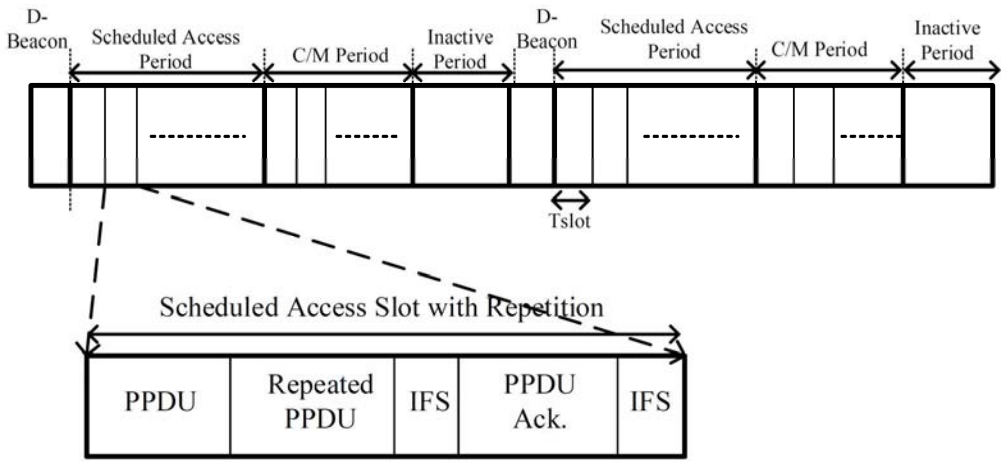

Figure 2: IBI format with two PPDU repetitions in scheduled access duration

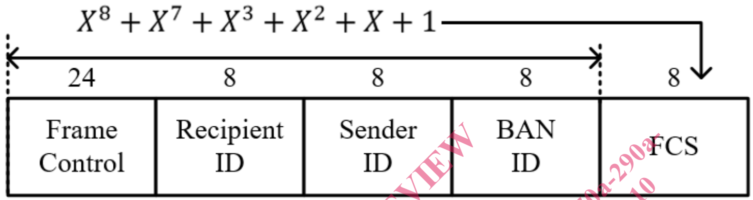

Figure 3: MAC Header

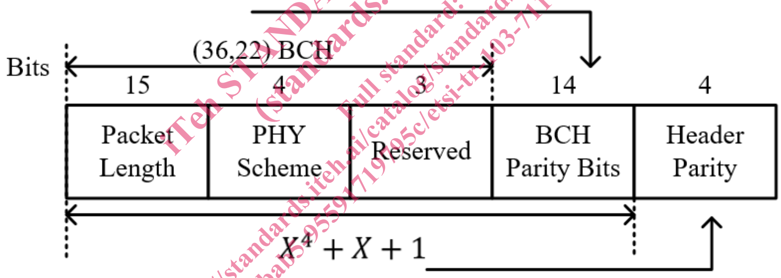

Figure 4: PLCP Header

5.2 System parameters

The technical requirements and key parameter values for SmartBAN PHY ETSI TS 103 326 [i.3] and MAC ETSI TS 103 325 [i.2] layer structure, as discussed in the clause 5.1, are summarized in table 1.

Table 1: SmartBAN PHY-MAC Layer Parameters

Parameters	SmartBAN PHY Layer
Data rates	Nominally 1 kbps to 100 kbps (vital sign monitoring), up to 1 Mbps
Transmission rate (PHY)	Up to 1 Mbps
Preamble ($L_{preamble}$)	2 octets
PLCP Header ($L_{PLCPheader}$)	5 octets
PPDU Transmissions	Single PPDU Transmission, 2-PPDU Repetitions, 4-PPDU Repetitions
FEC Provision	BCH (127,113,t=2) Encoding over MPDU (Optional), Repetitions (2,4) over PPDU (Optional)
Modulation	Gaussian Frequency Shift Keying (GFSK) BT=0,5, h=0,5
Bandwidth per channel	2 MHz
Communication Distance	1,5 m
Parameters	**SmartBAN MAC Layer**
Data Frame Transmission	Scheduled Access, Multi-Use Channel Access (Optional)
Control and Management Frame Transmission	Slotted ALOHA Access, Multi-Use Channel Access (Optional)
Max. node capacity	Up to 16 nodes (typically 8)
Network topology	Star network+ optionally relay and mesh are envisioned
Latency	10 ms (real-time, high priority transmissions), approx. 100 ms regular traffic.
MAC Header ($L_{MACheader}$)	7 octets
Frame Parity (L_{parity})	2 octets
Minimum Slot Duration (T_{min})	625 µs
Scheduled access or C/M slot duration (T_{slot})	i×T_{min}, where i∈{1,2,4,8,16,32}
IFS Duration (T_{IFS})	150 µs

6 SmartBAN use-cases

6.0 Introduction

A number of use-cases have been identified as potential scenarios for SmartBAN in this clause and their required data rates and implementation modes (real time/non real time) are specified. In addition to the use-cases described in ETSI TR 103 394 [i.1], few more use-cases have also been identified in this technical report that potentially have high data rate requirements and involve real time monitoring. The use-cases taken from ETSI TR 103 394 [i.1] include:

i) safety and fall monitoring;

ii) stress monitoring;

iii) sleep monitoring;

iv) blood pressure fluctuation monitoring;

v) abnormal cardiac rhythm monitoring;

vi) apnea monitoring; and

vii) precise athlete monitoring applications.

Following are among the newly described use-cases:

i) musculoskeletal disorder monitoring;

ii) neuromuscular disorder monitoring;

iii) rescue and emergency management;

iv) entertainment; and

v) emotion detection.

All the given use-cases are primarily classified into health monitoring and non-medical use-case categories. These use-cases serve as the examples of scenarios from which the QoS requirements are derived.

6.1 Health monitoring use-cases

6.1.0 Introduction

These use-cases include the sensor-based monitoring of vital signs in medical and healthcare sector for the diagnoses and treatment of sickness.

6.1.1 Safety and fall monitoring

Table 2: Safety and fall monitoring as defined in ETSI TR 103 394 [i.1]

Situations	Home	Outdoors	Hospital	Office
Example of use-case				
Attaching patch-type sensors on an elderly adult body, an alert signal and his/her pulse data are transmitted to the data server when he/she feels physically sick and/or when his/her fall is detected. These data and signal are also reported to care workers immediately.				
Necessity of accurate time stamping on the sensor data		Yes		
Sensors	**Sampling rate/Quantization**	**Bit rate**	**Number of sensors**	**Real time/ Non real time**
Pulse wave or ECG	10 bit to 16 bit, 64 Hz to 1 kHz	640 bps to 16 kbps	1	Real time
Accelerometer/Gyroscopic all-in-one sensor (multiple number of sensors are attached on a body)	10 bit to 16 bit, 500 Hz to 1 kHz	5 kbps to 16 kbps	1 to 3	Real time, Near real time
Required Data Rate Range: 5,64 kbps to 64 kbps (determined by sampling rate, quantization and no: of nodes)				

6.1.2 Stress monitoring

Table 3: Stress monitoring as defined in ETSI TR 103 394 [i.1]

Situations	Home	Office	Outdoors	Hospital
Example of use-case				
Logging daily physical and emotional stress and use the data for health management.				
Necessity of accurate time stamping on the sensor data		Yes		
Sensors	**Sampling rate/Quantization**	**Bit rate**	**Number of sensors**	**Real time/ Non real time**
Pulse wave or ECG	10 bit to 16 bit, 64 Hz to 1 kHz	640 bps to 16 kbps	1	Non real time
Required Data Rate Range: 640 bps to 16 kbps (determined by sampling rate, quantization and no: of nodes)				