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Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN

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 low complexity Medium Access Control (MAC) for SmartBAN.

The present document applies to short range, wireless communication between wearable sensors devices and the hub coordinator. The present document specifies MAC protocol designed to facilitate spectrum sharing with other devices.

The present document describes:

- Channel Structure.
- MAC Frame Formats.
- MAC functions.

The devices are capable of operating in all or any part of the frequency band shown in Table 1.

Table 1: Industrial, Scientific and Medical (ISM) frequency band

Direction of Transmission	Industrial, Scientific and Medical (ISM) frequency band
Transmit / Receive	2,4 GHz to 2,4835 GHz

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.

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 necessary for the application of the present document.

[1] ETSI TS 103 326 (V1.2.1): "Smart Body Area Network (SmartBan); Enhanced Ultra-Low Power Physical Layer".

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.

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 EN 300 328-1 (V1.3.1): "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".

[i.2] IEEE™ Std. 802.15.6-2012: "IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks".

[i.3] IEEE™ Std. 802.15.4-2011: "IEEE Standard for Local and metropolitan area networks - Part 15:4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specification for Low-Rate Wireless Personal Area Networks".

[i.4] ETSI TS 103 805: "Smart Body Area Network (SmartBAN); Relay Functionality for SmartBAN Medium Access Control (MAC)".

[i.5] ETSI TS 103 806: "Smart Body Area Network (SmartBAN); Hub to Hub Communication for SmartBAN Medium Access Control (MAC)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

active period: period within the superframe period that is ready for frame reception and transmission

active state: internal power management state that is ready for the frame reception and transmission

allocation: one or more time intervals that a node or a hub obtains using an access method for initiating one or more frame transactions

beacon: frame transmitted by a hub to facilitate network management, such as the coordination of medium access and power management of the nodes in the SmartBAN, and to facilitate clock synchronization therein

beacon period: duration when a beacon is transmitted

connection: relation between a node and a hub in a Body Area Network (BAN), substantiated by an identification assigned to the node by the hub and by access arrangement between them

device: entity conforming to the SmartBAN medium access control and physical interface to the wireless medium

downlink: communication link for transfer of management and data traffic from a hub to a node

frame: uninterrupted sequence of octets delivered by the Medium Access Control (MAC) sublayer to the Physical (PHY) layer, or vice versa, within a node or a hub

hub: entity that possesses a node's functionality and coordinates the medium access and power management of the nodes in the SmartBAN

hub to hub mode: optional enhanced operation mode where hubs of neighbouring SmartBANs may form a connection, obtain allocation(s), and transmit and receive management and data traffic between them

inactive period: period in time following an active transmission sequence during which the equipment does not transmit or receive

medical device: any instrument, apparatus, appliance, software, material or other article, whether used alone or in combination, together with any accessories, including the software intended by its manufacturer to be used specifically for diagnostic and/or therapeutic purposes and necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of:

- diagnosis, prevention, monitoring, treatment or alleviation of disease;
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap;
- investigation, replacement or modification of the anatomy or of a physiological process;

- control of conception,

and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means

multi-use channel access mode: mode of operation where the slot structure during the scheduled and control and management periods is accessible by multiple different priorities based on a temporal order

node: entity conforming to the SmartBAN medium access control and physical interface to the wireless medium

operating frequency: frequency at which the equipment can be operated

priority channel access: highest priority access during multi-use channel access

relay mode: optional enhanced operation mode where a node entity is temporarily assigned by the hub the functionality to relay frames received from another node to the hub and vice versa

re-use channel access: lowest priority access during multi-use channel access enables re-use of scheduled but not utilized slots

scheduled access: one or more scheduled reoccurring time intervals that a node and a hub obtains using scheduled access for initiating frame transactions

NOTE: A scheduled allocation is an uplink or downlink allocation suitable for servicing high or low duty cycle periodic or quasi-periodic traffic on a committed schedule.

star network: logical network partition comprising a hub and zero or more nodes whose medium access and power management are coordinated by the hub

uplink: communication link for transfer of management and data traffic from a node to a hub

3.2 Symbols

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

×	Mathematical multiplication of the term immediately preceding the symbol and the term immediately following the symbol
CP_{max}	Maximum Contention Probability
CP_{min}	Minimum Contention Probability
GHz	Gigahertz
L_D	Number of time slots in Inter-Beacon Interval
L_F	Length of MAC Frame Body (bits)
L_{SLOT}	Slot length variable utilized in calculating the duration of a time slot
MHz	Megahertz
N_{CM}	Number of time slots in Control and Management Period
N_S	Number of time slots in Schedule Period
T_C	Interval between control channel beacons
T_D	Inter-Beacon Interval
T_{IFS}	Duration of Inter-Frame Spacing
T_{MUA}	Total duration of sensing period in Multi-use Channel Access
T_S	Duration of a time slot

3.3 Abbreviations

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

ACK	ACKnowledgement
BAN	Body Area Network
BC	Backoff Counter
BCH	Bose-Chaudhuri-Hocquenghem (code)
BE	Backoff Exponent
C-Ass	Connection Assignment

C-Beacon	Control Channel Beacon
CCH	Control Channel
C-Frame	Control Frame
CP	Contention Probability
CRC	Cyclic Redundancy Check
C-Req	Connection Request
D/SR	Downlink/Slot Reassignment
D-Beacon	Data Channel Beacon
DCH	Data Channel
D-Frame	Data Frame
D-Req	Disconnection Request
D-Res	Disconnection Response
EUI-48™	Extended Unique Identifier-48 bits
FCS	Frame Check Sequence
FEC	Forward Error Correction
IFS	Inter-Frame Spacing
IM	Information Module
ISM	Industrial, Scientific and Medical
IU	Information Units
MAC	Medium Access Control
MCA	Multi-use Channel Access
MPDU	MAC Protocol Data Unit
NACK	Negative Acknowledgement
NID	Node ID
PBC	Priority Backoff BE Counter
PCA	Priority Channel Access
PHY	Physical Layer
PRT	Priority Re-Transmission
RBC	Re-use Backoff Counter
RCA	Re-use Channel Access
REP	Repetition Coding
RT	Re-Transmission
Rx	Receive
SACA	Slotted Aloha Channel Access
S-Ras	Slot Reassignment
Tx	Transmit
UP	User Priority

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, 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 (SmartBAN).

A SmartBAN is a simple, low complexity, low energy communication network that allows wireless connectivity between the devices and a hub. The distinct features of the SmartBAN are ease of access, minimal listening, reliable data transfer, provision of additional control messages (in the form of C-Beacons) for the low duty cycling nodes while maintaining a simple and flexible protocol. SmartBAN also provides a multi-use channel access mechanism for emergency and other high priority access and improved channel utilization.

The distinct characteristics of the SmartBAN are:

i) asymmetrical relation between the hub and the device, where the hub performs most scheduling and computations;

ii) minimized listening period for the node;

iii) additional provisioning of beaconing messages and thus reliable and enhanced connectivity.

Additional information can be found from the following documents:

- ETSI EN 300 328-1 [i.1] defines requirements for equipment operating in the 2,4 GHz ISM band;
- IEEE™ Std. 802.15.6-2012 [i.2] defines an alternative standard for Wireless Body Area Networks; and
- IEEE™ Std. 802.15.4-2011 [i.3] defines a standard for Wireless Personal Area Networks.

5 General MAC Framework

5.0 Different device types

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

Two different device types can participate in SmartBAN: medical sensor device (node) and coordinator device (hub). A hub is a device that acts as a SmartBAN coordinator. A node is any device that acts as an information source or an information sink. One hub and at least one node constitute a SmartBAN.

A SmartBAN shall be organized into a star topology consisting of at least one node communicating directly with the hub.

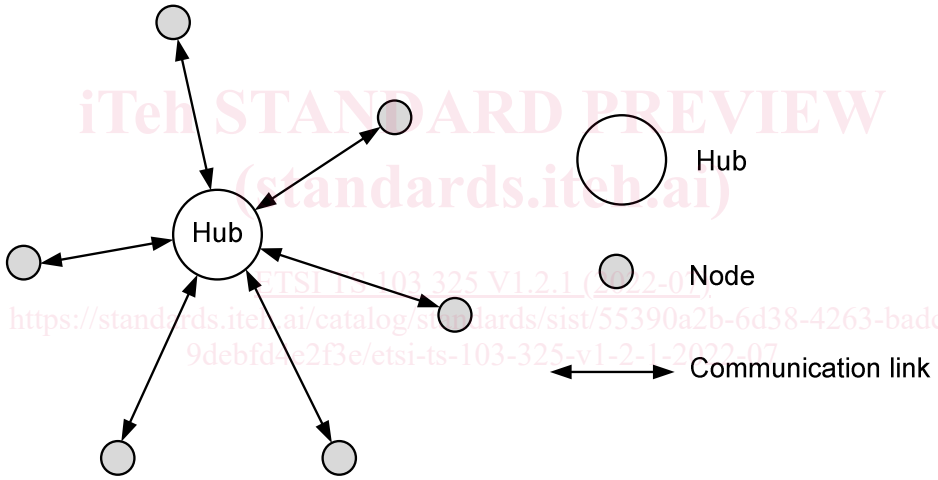

Figure 1: SmartBAN Topology

The hub and nodes shall communicate using communication media known as channels. A SmartBAN shall use two different channel entities to enable communication between the hub and nodes. The channel entities are assigned the following names:

- Data Channel (DCH)
- Control Channel (CCH)

Each SmartBAN shall utilize one Control Channel (CCH) and one Data Channel (DCH) at any one time.

The general MAC framework defined in the present document is extended with optional enhanced operation modes defined in the following ETSI deliverables:

- ETSI TS 103 805 [i.4] defines relay functionality; and
- ETSI TS 103 806 [i.5] defines hub to hub communication for SmartBAN.

5.1 Frequency Spectrum

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

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

The channels are categorized into data and control channels with:

- 3 Control channels, where control frames (in the form of Control Channel Beacon) from the hub is transmitted;
- 37 Data channels, where data, control, and management frames are transmitted.

The channels list can be found in ETSI TS 103 326 [1].

5.2 Channel Format

5.2.1 Control Channel (CCH) Format

Only hub devices shall transmit on control channels. A hub shall select one control channel from the list of control channels in ETSI TS 103 326 [1], Table 1 and transmit one Control Channel Beacon frame (C-Beacon) on the chosen Control Channel (CCH) every T_C seconds. The format of the C-Beacon is set out in clause 6.1.

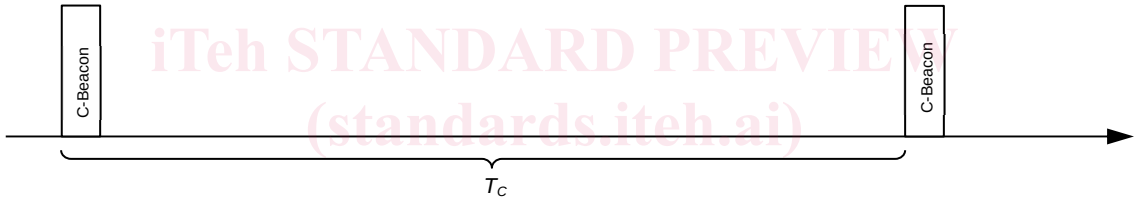

Figure 2: Control Channel

5.2.2 Data Channel (DCH) Format

5.2.2.0 Data channel description

Both hub and node devices may transmit on the data channels. A hub shall select one data channel from the list of data channels in ETSI TS 103 326 [1], Table 1 on which both hub and node devices in the associated SmartBAN may transmit. For any SmartBAN, the data channel is partitioned into time intervals of T_D seconds, known as the Inter-Beacon Interval. The boundaries of each Inter-Beacon Interval shall be marked by the transmission of a Data Channel Beacon (D-Beacon). A hub shall transmit a D-Beacon at the beginning of each Inter-Beacon Interval.

Each Inter-Beacon Interval shall be partitioned into L_D distinct time epochs known as slots. The duration of each time slot is T_S. The duration of each Inter-Beacon Interval shall be $L_D \times T_S$ seconds. Any device transmitting in a time slot shall ensure that the transmission takes place within the duration of that time slot.

Each Inter-Beacon Interval shall consist of four distinct periods:

- Beacon Period, consisting of one single time slot, where the hub shall transmit the D-Beacon frame. No nodes shall transmit in this period.
- Scheduled Period, consisting of N_S time slots, where scheduled transmissions and acknowledgements occur.
- Control and Management Period, consisting of N_{CM} time slots, where unscheduled access and management and control signalling occur.
- Inactive Period, where no transmission occurs.

The time slots shall be identified by a 10 bit sequence denoting the position of the time slot in an Inter-Beacon Interval. The Beacon Period, consisting of 1 time slot, shall have the sequence number 0000000000. Subsequent time slots shall have sequence numbers incremented by the number of time slots following the Beacon Period.

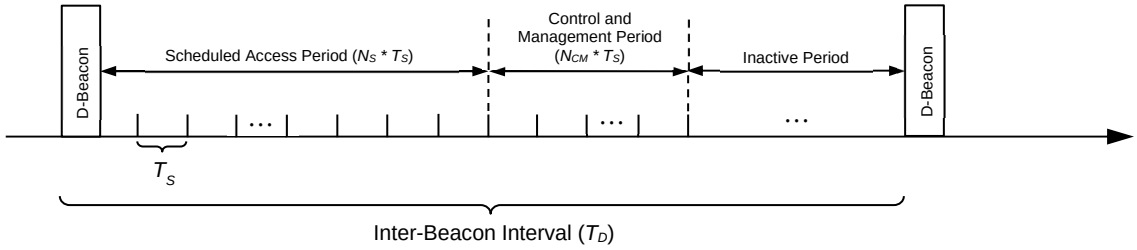

Figure 3: Access Periods in Data Channel

The Scheduled Access Period shall begin on the slot boundary immediately following the Beacon. The Scheduled Access Period may be of zero length, in which case, the Control and Management Period shall begin immediately following the Beacon Period. The Control and Management Period shall begin on the slot boundary immediately following the Scheduled Access Period. The Inactive Period shall begin on the slot boundary immediately following the Control and Management Period.

Three types of channel access mechanisms can be used in the access periods:

- Scheduled Channel Access, in the Scheduled Access Period.
- Slotted Aloha Channel Access, in the Control and Management Period.
- Multi-use Channel Access, in both Scheduled Access and Control and Management Period.

The hub shall support all three types of channel access mechanisms. Nodes shall always support Scheduled Channel Access and Slotted Aloha Channel Access, and may support Multi-use Channel Access. Multi-use Channel Access may only be used when every node in the SmartBAN supports it. Each channel access mechanism shall adhere to its respective slot structure as described in clause 5.2.2.1.

5.2.2.1 Scheduled Access Slot Structure

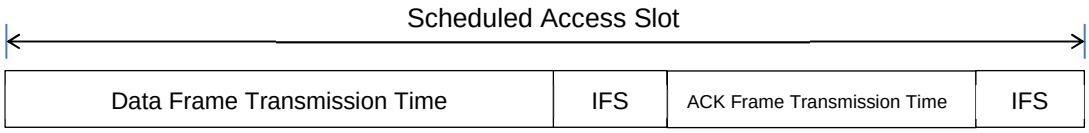

Figure 4: Scheduled Access Slot Structure

The Scheduled Access time slots shall follow the structure as illustrated in Figure 4. Any Scheduled Access time slots allocated by the hub shall be in the Scheduled Access Period.

The Scheduled Access slot shall consist of at most 2 transmission periods:

- Data Frame Transmission: The device allocated the time slot shall transmit.
- ACK Frame Transmission: If the ACK policy of the received frame defined in clause 6.1.1.1.2 is '0' and the transmission is successful, the receiving device shall transmit an Acknowledgement Frame. If ACK policy is '1' and the transmission is not successful, the receiving device shall transmit a Negative Acknowledgement (NACK) Frame. The ACK Frame Transmission period shall commence 1 IFS after the end of the Data Transmission period and end at least 1 IFS before the end of the time slot.