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Contents

Intellectual Property Rights 4
Foreword 4
Modal verbs terminology 4
Executive summary 4
Introduction 5
1 Scope 6
2 References 6
2.1 Normative references 6
2.2 Informative references 6
3 Definition of terms, symbols and abbreviations 7
3.1 Terms 7
3.2 Symbols 8
3.3 Abbreviations 8
4 General MAC Framework 9
4.0 Different device types 9
4.1 Frequency Spectrum 9
4.2 Channel Format 9
4.3 User Priorities 9
4.4 Node IDs 10
4.5 Information Units 10
5 Frame Formats 10
5.1 MAC General Frame Format 10
5.2 Management Frames 11
5.2.0 Management Frames for Hub to Hub Communication 11
5.2.1 Hub to Hub Connection Request (H-Creq) 11
5.2.1.1 Hub to Hub Connection Request Frame Format 11
5.2.1.2 Information Module Field for Hub to Hub Connection Request Information Unit 11
5.2.1.3 Information Module Field for Hub to Hub Proposed Uplink Allocation Information Unit 12
5.2.1.4 Information Module Field for Hub to Hub Proposed Downlink Allocation Information Unit 12
5.2.2 Hub to Hub Connection Confirmation (H-Conf) 12
5.3 Control Frames (C-Frame) 13
5.4 Data Frames (D-Frame) 13
6 Hub to Hub Communication 13
6.0 Hub Communication Procedure 13
6.1 Hub to Hub Communication Initialization 13
6.2 Neighbour SmartBAN Discovery 13
6.3 Inter-Beacon Interval Realignment 14
6.4 Resource Pre-Allocation 15
6.5 Hub to Hub Connection Initialization 15
6.6 Hub to Hub Channel Access 16
6.7 Modifying Hub to Hub Connection 16
6.8 Ending Hub to Hub Connection 17
Annex A (normative): Hub to hub communications 18
History 20

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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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Executive summary

The present document defines technical specifications for hub to hub communication capability for ETSI SmartBAN. The specifications extend the general Medium Access Control (MAC) framework defined for SmartBAN by enabling the communication between hubs of two neighbouring SmartBANs.

Hub to hub communication procedure can be divided into eight steps as follows:

1) Hub to hub communication initialization.
2) Neighbour SmartBAN discovery.
3) Inter-beacon interval realignment.
4) Resource pre-allocation.
5) Hub to hub connection initialization.

6) Hub to hub channel access.

7) Modifying hub to hub connection.

8) Ending hub to hub communication.

The present document is structured as follows: firstly, the additional management frames and information units required for the hub to hub communication are defined. Secondly, the present document details the operational procedures for the hub to hub communications. Finally, Annex A includes two normative flowcharts defining the hub to communications.

Introduction

Modern medical and health monitoring equipment is 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, and 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 basic access specifications for Medium Access Control (MAC) are defined in [1] and for physical layer (PHY) in [2]. The present document extends [1] by defining technical specifications for hub to hub communications enabling communication between the hubs of neighbouring SmartBANs.

Additional information can be found in the following documents:

- ETSI EN 300 328-1 [i.1] defines requirements for equipment operating in the 2,4 GHz ISM band;
- IEEE 802.15.6-2012 [i.2] defines an alternative standard for Wireless Body Area Networks; and
- IEEE 802.15.4-2011 [i.3] defines a standard for Wireless Personal Area Networks;
- ETSI TS 103 805 [i.4] defines relay functionality for SmartBAN MAC defined in ETSI TS 103 325 [1].

1 Scope

The present document extends the low complexity Medium Access Control (MAC) for SmartBAN defined in ETSI TS 103 325 [1] with hub to hub communication capability. The main scope of the present document is to define specifications for enabling hub to hub communication between the hubs of neighbouring SmartBANs.

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 referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://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 103 325 (V1.2.1) (2022-07): "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN".

[2] ETSI TS 103 326 (V1.2.1) (2021-07): "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 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 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™ 802.15.6-2012: "IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks".

[i.3] IEEE™ 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)".

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, or in the context of the hub to hub communication, from target hub to initiating hub

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 other than the hub 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: node entity that is temporarily assigned by the hub the functionality to relay frames received from the node to the hub or vice versa

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, or in the context of hub to hub communication, from initiating hub to target 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)
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_{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
C-Ass	Connection Assignment
C-Beacon	Control channel Beacon
CCH	Control Channel
C-Frame	Control Frame
D-Beacon	Data channel Beacon
DCH	Data Channel
D-Frame	Data Frame
EUI-48™	Extended Unique Identifier-48 bits
H-Conf	Hub to Hub Connection Confirmation
H-Creq	Hub to Hub Connection Request
IM	Information Module
ISM	Industrial, Scientific and Medical
IU	Information Units
MAC	Medium Access Control
PHY	Physical layer

S-Ras	Slot Reassignment
WBAN	Wireless Body Area Network

4 General MAC Framework

4.0 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. A relay is a node entity temporarily assigned by the hub the functionality to relay frames received from the node to the hub or vice versa. 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.

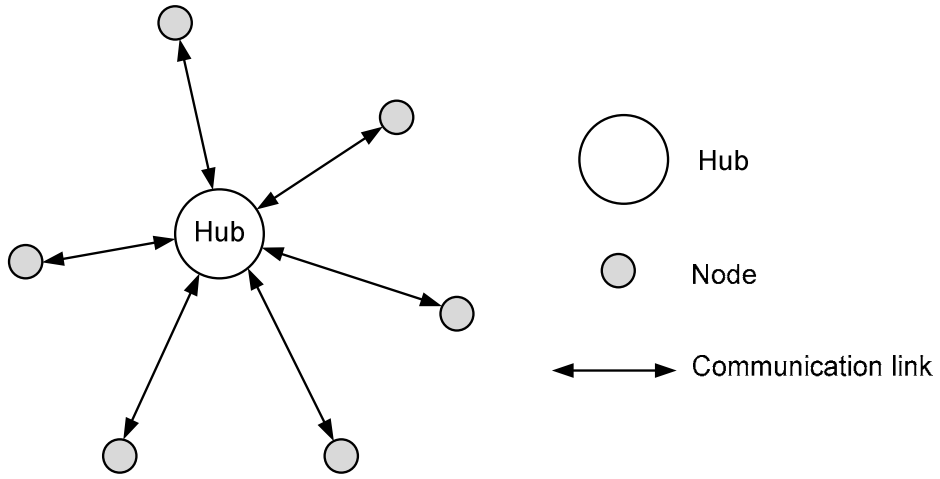

Figure 1: SmartBAN Topology

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.

4.1 Frequency Spectrum

Defined in ETSI TS 103 325 [1].

4.2 Channel Format

Defined in ETSI TS 103 325 [1].

4.3 User Priorities

Defined in ETSI TS 103 325 [1].

4.4 Node IDs

Defined in ETSI TS 103 325 [1].

4.5 Information Units

Information Units (IUs) encapsulate the required information for specific operations. IUs shall be defined as follows:

- IUs for Management, Control, and Data frame types:
  - Defined in ETSI TS 103 325 [1].
- IUs for General purpose frame type:
  - Operations requiring IUs shall use the appropriate Element ID listed in Table 1. An IU shall be formatted as in Figure 2.

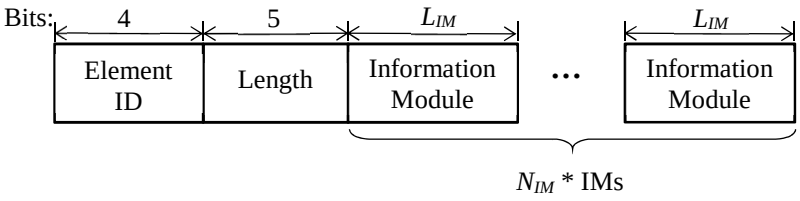

Figure 2: Structure of an Information Unit for General Purpose Frame Type

Table 1: Element ID for relay connectivity and hub to hub communication operations

Element ID	Operation	Notation	Description
0000	Isolated Node Notification	I-Notif	The way an isolated node notifies to the WBAN about its new status
0001	Node Status Request	N-Sreq	Explains the node status requirement when a certain node does not transmit in its scheduled slots
0010	Isolated Node Notification Listen	I-Listen	Explains the command details given to the nodes to start listening to Isolated Node Notifications
0011	Relay Nomination	R-Nom	Explains the details about the R-Beacon transmission period
0100	Proposed Relay Link Status	R-Status	Explains if the proposed relay link is successful/unsuccessful
0101	Stop Isolated Node Listening	S-Listen	Explains the command details given to the nodes to stop listening to Isolated Node Notifications
0110	Relay Connection	R-Conn	Describes the details of the relay connection
0111	Isolated Node Slot Reassignment ACK	I-SAck	Acknowledgement by the Isolated node for the new slot allocations
1000	Relay Disconnection Request	R-Dreq	Explains the requirement for a relay disconnection
1001	Relay Beacon	R-Beacon	Explains the beacon frame transmitted from a Relay to an isolated node
1010	Hub to Hub Connection Request	H-Creq	Specifies connection request command from a hub to request connection with a neighbouring hub
1011-1111	Reserved		Reserved

5 Frame Formats

5.1 MAC General Frame Format

Defined in ETSI TS 103 325 [1].

5.2 Management Frames

5.2.0 Management Frames for Hub to Hub Communication

In addition to the management frames defined in ETSI TS 103 325 [1], the following management frames are applied in the context of the present document.

5.2.1 Hub to Hub Connection Request (H-Creq)

5.2.1.1 Hub to Hub Connection Request Frame Format

The Hub to Hub Connection Request frame shall be formatted as an Information Unit as described in clause 4.5. The Information Unit shall consist of at least 3 Information Modules with elements listed in Table 2, Table 3 and Table 4.

5.2.1.2 Information Module Field for Hub to Hub Connection Request Information Unit

Table 2: Information Module Field for Hub to Hub Connection Request Information Unit

Type	Number of bits	Subfields	Number of bits
Hub to Hub Connection Request	≥ 152	Recipient Address	48
		Sender Address	48
		Inter-Beacon Interval	10
		C/M Start Slot	10
		Inactive Start Slot	8
		Multi-use Access	1
		PHY Capability	4
		D-Beacon Sequence Number	8
		Offset to Next D-Beacon	8
		Reserved	7

The Recipient Address Subfield is set to the EUI-48 of the recipient of the current frame.

The Sender Address Subfield is set to the EUI-48 of the sender of the current frame.

The Inter-Beacon Interval Subfield indicates the number of slots in each Inter-Beacon Interval. The length of each slot is indicated in clause 6.1.2 of ETSI TS 103 325 [1].

The Control and Management Period Start Slot Subfield contains the slot number at which the C/M period is set to begin.

The Inactive Period Start Slot Subfield contains the slot number at which the Inactive period is set to begin.

A Multi-use Access Capability Subfield shall indicate if the node sending the Connection Request has Multi-use Access enabled.

The PHY capability Subfield indicates the physical layer capability of the node. The mapping of the field is defined in Table 12 of ETSI TS 103 325 [1].

The D-Beacon Sequence Number Subfield indicates the sequence number of the D-Beacon transmitted by the initiating hub at the beginning of its current Inter-Beacon Interval.

The Offset to Next D-Beacon Subfield indicates the number of remaining slots in the current Inter-Beacon Interval.

5.2.1.3 Information Module Field for Hub to Hub Proposed Uplink Allocation Information Unit

Table 3: Information Module Field for Hub to Hub Proposed Uplink Allocation Information Unit

Type	Number of bits	Subfields	Number of bits
Proposed Uplink Allocation Assignment	32	User Priority	2
		Reserved	2
		Allocation Start	10
		Allocation End	10
		Allocation Period	8

The User Priority subfield shall denote the user priority level assigned to the proposed assignment.

The Allocation Start subfield shall denote the time slot number from which the proposed allocation shall start.

The Allocation End subfield shall denote the time slot number at which the proposed allocation shall end.

The Allocation Period subfield shall denote the sequence number of the initiating hub's Data Channel Beacon from which the proposed allocation shall start.

5.2.1.4 Information Module Field for Hub to Hub Proposed Downlink Allocation Information Unit

Table 4: Information Module Field for Hub to Hub Proposed Downlink Allocation Information Unit

Type	Number of bits	Subfields	Number of bits
Proposed Downlink Allocation Assignment	32	User Priority	2
		Reserved	2
		Allocation Start	10
		Allocation End	10
		Allocation Period	8

The Proposed Downlink Allocation Assignment field shall be structured in the same way as the Proposed Uplink Allocation Assignment field described in clause 5.2.1.3.

5.2.2 Hub to Hub Connection Confirmation (H-Conf)

The Hub to Hub Connection Confirmation frame shall be formatted as an Information Unit as described in clause 4.5. The Information Unit shall consist of at least 1 Information Module with elements listed in Table 5.

Table 5: Hub to Hub Connection Confirmation

Type	Number of bits	Subfields	Number of bits
Hub to Hub Connection Confirmation	8	Connection Confirmation	1
		Reserved	7

The Connection Confirmation subfield indicates whether the target hub confirms the Proposed Uplink Allocation Assignment and the Proposed Downlink Allocation Assignment. The bits layout of the Information Module is indicated in Table 6. If bit b1 is set to 1, the target hub confirms the Proposed Uplink Allocation Assignment and the Proposed Downlink Allocation Assignment.

Table 6: Information Bits Layout in a Hub to Hub Connection Assignment Frame

b8	b7	b6	b5	b4	b3	b2	b1
x	x	x	x	x	x	x	Connection Confirmation

5.3 Control Frames (C-Frame)

Defined in ETSI TS 103 325 [1].

5.4 Data Frames (D-Frame)

Defined in ETSI TS 103 325 [1].

6 Hub to Hub Communication

6.0 Hub Communication Procedure

A hub wishing to make a connection to a hub of a neighbouring SmartBAN may follow the procedures defined in the following clauses.

6.1 Hub to Hub Communication Initialization

When hub to hub mode is 'ON', the hub increases its C-Beacon transmit rate to a minimum of 2 / T_D, where T_D is the inter-beacon interval duration of the hub's DCH. This procedure shall be applied by both hubs initiating hub to hub communication (initiating hub) and hubs accepting hub to hub communication (target hub).

6.2 Neighbour SmartBAN Discovery

The initiating hub shall begin to issue an alternating inactive period duration in every forthcoming inter-beacon interval in its DCH, resulting in two different inter-beacon interval durations, T_D and T_D', as illustrated in Figure 3. The varying length of the T_D shifts the relative occurrence on the inactive period of the initiating hub with respect to the constant cyclical C-Beacon transmissions of the target hub.

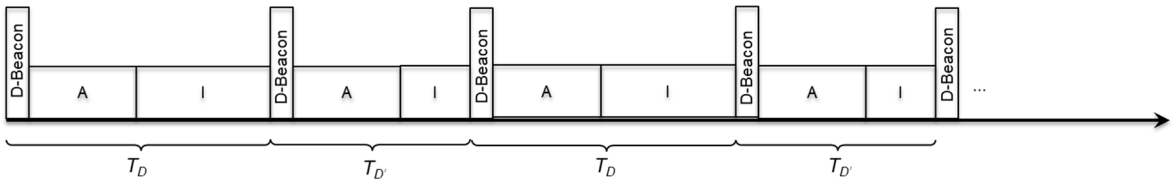

Figure 3: Alternating inactive period duration in the DCH. Symbols 'A' and 'I' denote the active period and inactive period, respectively

Next, the initiating hub sets a timer, and it shall monitor the CCHs during the inactive periods of its DCH to acquire a C-Beacon transmitted by the target hub, as illustrated in Figure 4. Each CCH is monitored until the timer expires, and the list of acquired C-Beacons is reported to the higher layer entity. Alternatively, the initiating hub may terminate the monitoring after a predefined C-Beacon or C-Beacons have been acquired.

The initiating hub may acquire the BAN ID, DCH Number, Slot length and the number of time slots in each Inter-beacon Interval of the target hub from the C-Beacon.

A flowchart describing the neighbour SmartBAN discovery process is presented in Figure A.1 of Annex A.

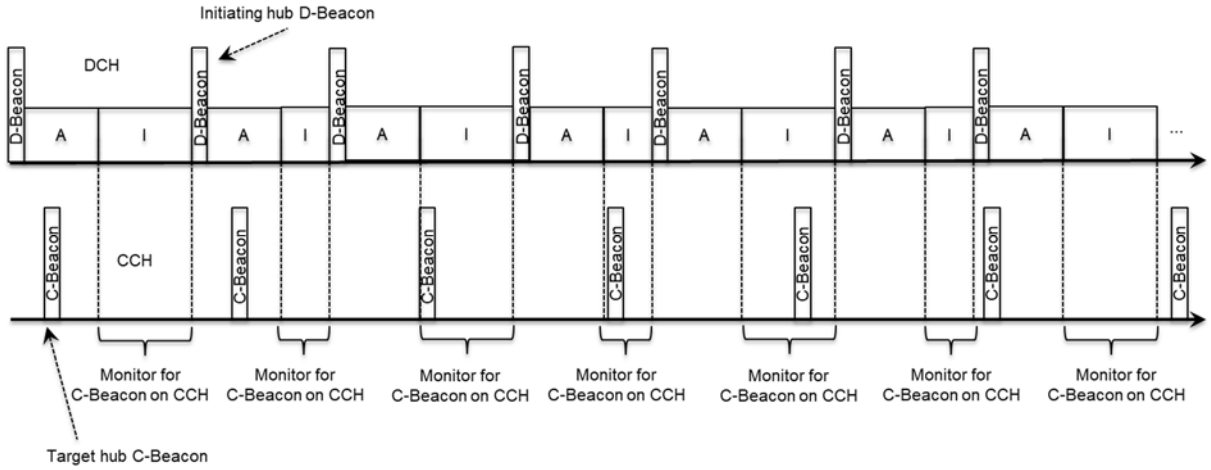

Figure 4: Monitoring the CCHs by the initiating hub during the inactive period of its DCH

6.3 Inter-Beacon Interval Realignment

Using the acquired parameters from the target hub's C-Beacon, the initiating hub may determine the DCH structure of the target hub. The initiating hub shall realign its inter-beacon interval to match with the inter-beacon interval of the target hub. The realignment is performed in order to be able to receive the D-Beacons transmitted by the target hub. The realignment may be performed by the initiating hub by utilizing one or several of the following options:

- Allocation of scheduled period.
- Allocation of control and management period.
- Allocation of inactive period.

The initiating hub checks whether its T_D is of shorter or longer duration than the target hub's T_D. If the initiating hub's T_D does not have exactly the same duration as the target hub's T_D, the initiating hub realigns its inter-beacon interval to fulfil one of the following conditions:

- Integer multiple of initiating hub's forthcoming T_D shall correspond to the target hub's T_D.
- Initiating hub's forthcoming T_D shall correspond to an integer multiple of the target hub's T_D.

An example of the inter-beacon interval realignment is illustrated in Figure 5, where the initiating hub changes its inactive period allocation. After the change, the initiating hub's T_D has a doubled length when compared to the T_D of the target hub.

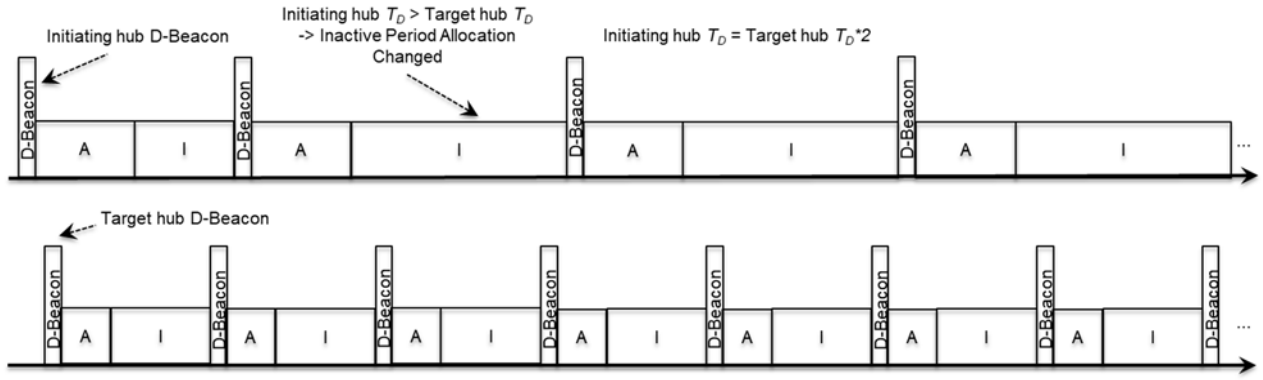

Figure 5: An example of inter-beacon interval realignment performed by the initiating hub

A flowchart describing the inter-beacon interval realignment mechanism is presented in Figure A.2 of Annex A.

6.4 Resource Pre-Allocation

The initiating hub pre-allocates time slots for the destination hub on its own DCH utilizing either one or both of the following periods within the inter-beacon interval:

- Scheduled access period.
- Inactive period.

The initiating hub may have to modify allocation assignments of nodes in its SmartBAN by sending the nodes a Slot Reassignment (S-Ras) frame as described in clause 7.5 of ETSI TS 103 325 [1] to accommodate the time slots for the destination hub.

6.5 Hub to Hub Connection Initialization

Using the acquired parameters from the C-Beacon transmitted by the target hub, the initiating hub may monitor the DCH of the target hub and initiate a connection according to the following procedure:

1) Acquire DCH parameters (e.g. Scheduled Access Period start, C/M Period start) from the D-Beacon transmitted by the target hub.

2) Transmit a Hub to Hub Connection Request (H-Creq) frame during the C/M period of the target hub using the Slotted Aloha Channel Access procedure described in clause 7.3.2 of ETSI TS 103 325 [1].

On successful reception of the H-Creq frame, the target hub shall perform one of the following steps:

1) The target hub shall transmit an Acknowledgment frame, in which the Command Ack field in the Frame Control field is set to '1'. This signals to the initiating hub that the target hub shall process the Hub to Hub Connection Request.

2) The target hub shall transmit an Acknowledgment frame, in which the Command Ack field in the Frame Control field is set to '0'. This signals to the initiating hub that the target hub shall not process the Hub to Hub Connection Request.

3) The target hub shall discard the H-Creq frame (e.g. due to security reasons).

Followed by step 1), the target hub shall transmit either a Hub to Hub Connection Confirmation (H-Conf) frame or a Connection Assignment (C-Ass) frame in the next available time slot of one of the following periods:

1) The Proposed Uplink Allocation Assignment or the Proposed Downlink Allocation Assignment indicated in the H-Creq frame.

2) Control and Management Period of the initiating hub.

3) Inactive Period of the initiating hub.

The initiating hub shall monitor all these periods for a predefined time.

H-Conf frame indicates to the initiating hub that the target hub has confirmed the Proposed Uplink Allocation Assignment and the Proposed Downlink Allocation Assignment defined in the H-Conf frame.

C-Ass frame indicates to the initiating hub that the target hub has not confirmed the Proposed Uplink Allocation Assignment and the Proposed Downlink Allocation Assignment defined in the H-Conf frame. In this case, the target hub proposes an alternative Allocation Assignment indicated in the C-Ass frame to the initiating hub.

Hub to hub connection initialization utilizing the H-Conf frame is illustrated in Figure 6 and utilizing the C-Ass frame in Figure 7.

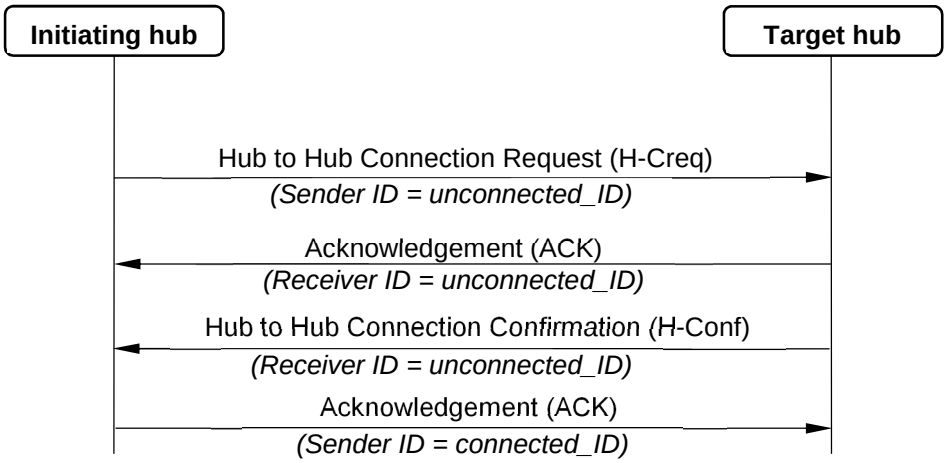

Figure 6: Hub to hub connection initialization utilizing H-Conf frame

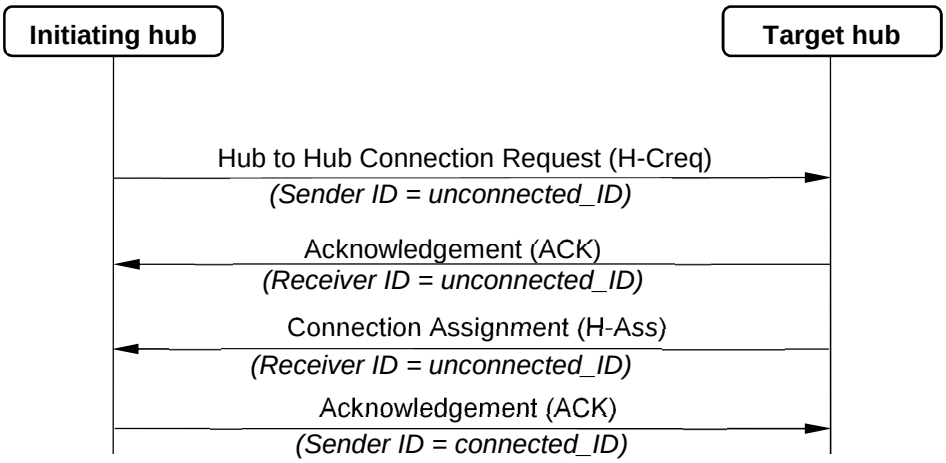

Figure 7: Hub to hub connection initialization utilizing C-Ass frame

6.6 Hub to Hub Channel Access

Upon hub to hub connection initialization, the initiating hub and the target hub may employ Scheduled Access or Multi-use Channel Access defined in clause 7.3 of ETSI TS 103 325 [1] during the Scheduled Access Period and the Inactive Period of the target hub's DCH.

The initiating hub or the target hub may employ Slotted Aloha Channel Access to transmit management frames when it has not been allocated sufficient time slots in the Scheduled Access Period or Inactive Period for its purpose.

6.7 Modifying Hub to Hub Connection

To obtain one or more new scheduled allocation, the initiating hub shall send a Hub to Hub Connection Request (H-Creq) frame to the target hub in the C/M Period of the target hub using Slotted Aloha Channel Access.

To grant scheduled access requested by the initiating hub, the target hub shall send a Connection Assignment (C-Ass) frame in its C/M Period using Slotted Aloha Channel Access to the initiating hub.

The target hub may also modify the hub to hub connection by utilizing the slot re-assignment procedure as described in clause 7.5 of ETSI TS 103 325 [1].

6.8 Ending Hub to Hub Connection

The initiating hub may, at any time, end hub to hub connection by sending an H-Creq frame to the target hub that contains Allocation Request fields with the corresponding Allocation Length field set to 0.

The target hub may, at any time, end hub to hub communication by signalling downlink data in the D-Beacon, and sending a C-Ass frame that contains Allocation Assignments fields with the Interval End field set to 0.

Annex A (normative): Hub to hub communications

Figures A.1 and A.2 describe the neighbour hub discovery and inter-beacon interval realignment mechanisms in the hub to hub communications, respectively.

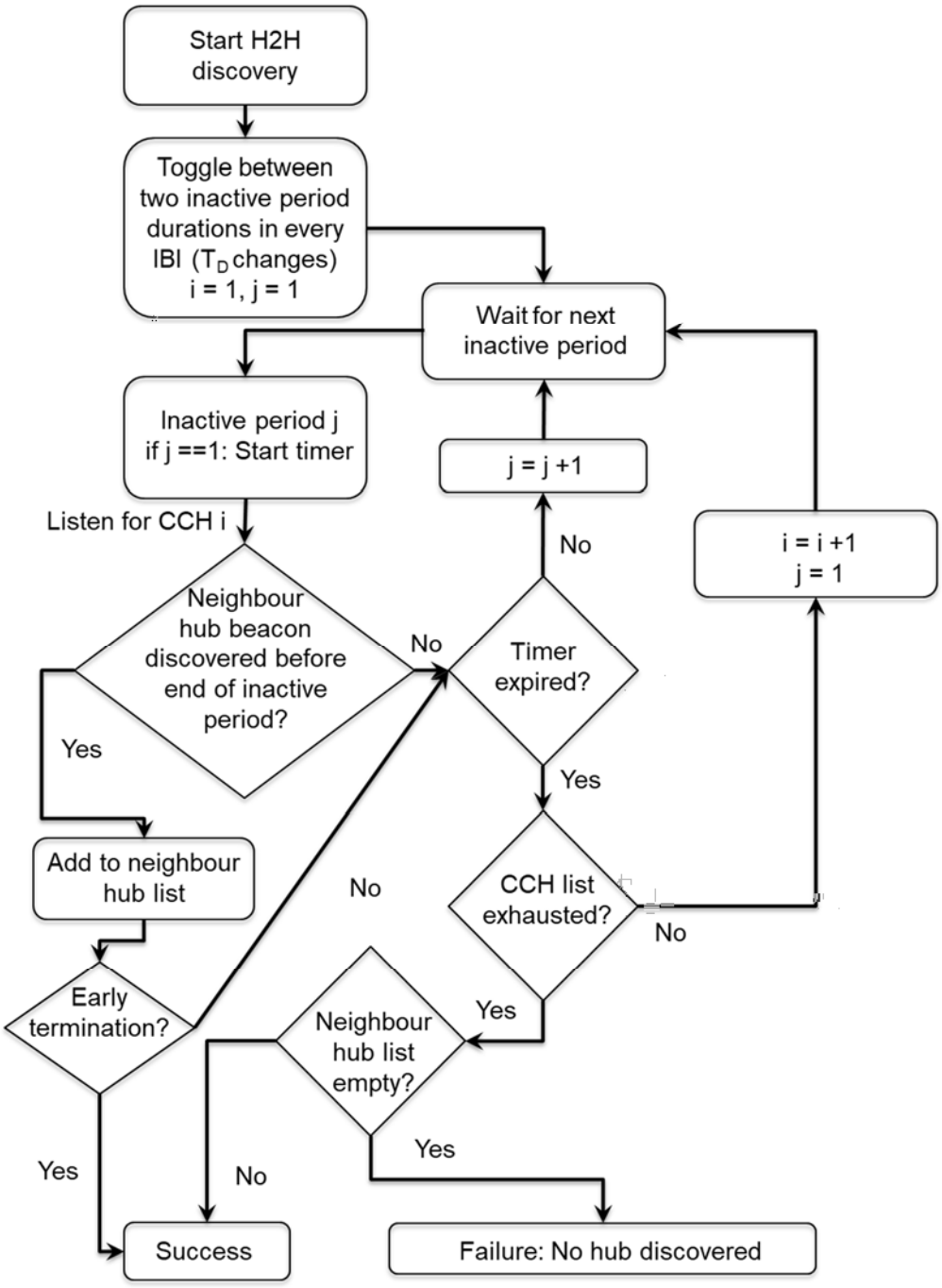

Figure A.1: Flowchart of neighbour hub discovery

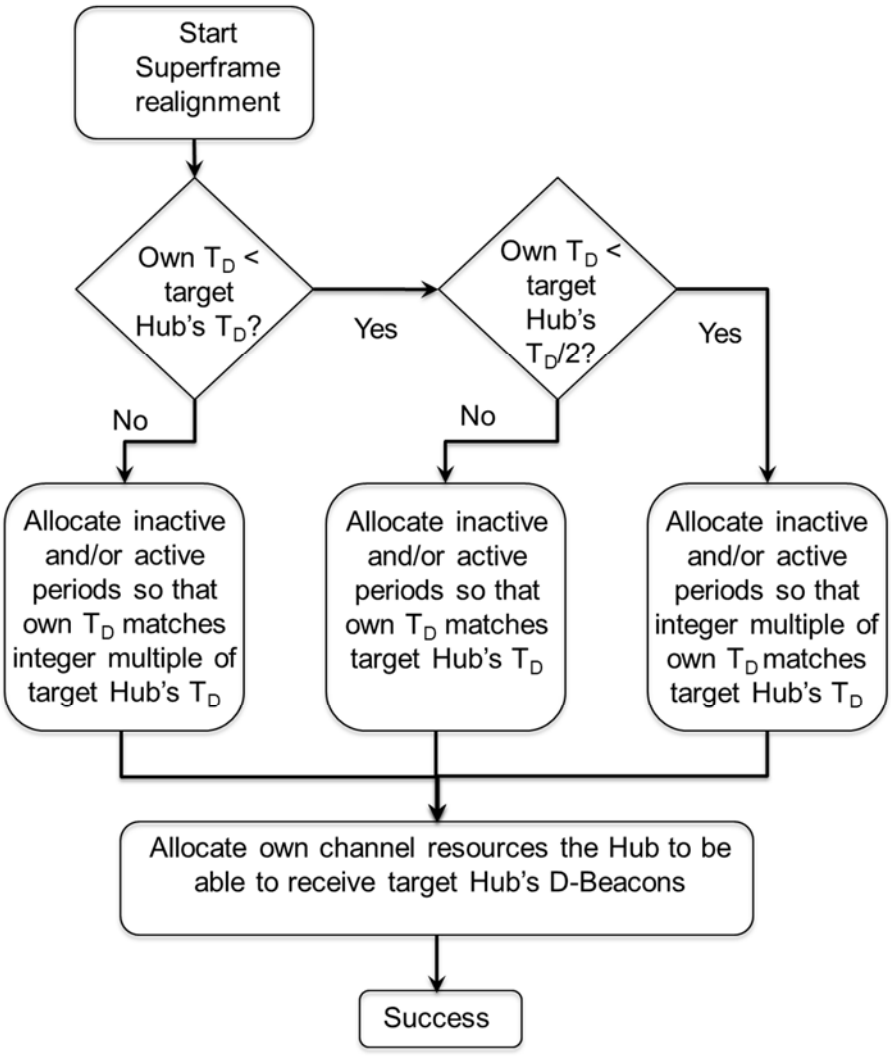

Figure A.2: Flowchart of inter-beacon interval realignment mechanism

History

Document history		
V1.1.1	November 2023	Publication