**IEEE P802.15**

**Wireless Specialty Networks**

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| Re: | Contribution to IEEE 802.15.6ma  |
| Abstract | This document provides a proposed text draft for resolving LB210 comments on clause 3 definitions, acronyms and clause 4 general framework elements. |
| Purpose | Support development of technical content for the draft |
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Draft for

1. Overview
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2. Normative references
3. Definitions, acronyms, and abbreviations
	1. Definitions

For the purposes of this document, the following terms and definitions apply. The IEEE Standards Dictionary Online should be consulted for terms not defined in this clause. [[1]](#footnote-2)

**abbreviated address:** A one-octet identifier (ID) selected as an address for a node, coordinatorcoordinator, or body area network (BAN) in frame exchanges.

**active state:** An internal power management state that is ready for frame reception and transmission.

**active superframe:** A superframe in which frame transmission typically occurs within the body area network (BAN) of the coordinator announcing such a superframe.

**allocation:** One or more-time intervals that a node or a coordinator obtains using an access method for initiating one or more frame transactions. An allocation comprises one or more allocation intervals. Reference to allocation of a node means that the node is the sender or recipient in the allocation.

**allocation interval:** A continuous time interval in an allocation, comprising one or more consecutive allocation slots. Reference to allocation interval of a node means that the node is the sender or recipient in the allocation interval.

**allocation slot:** A time unit used to designate the lengths of medium access related time intervals, such as beacon period (superframe) and allocation interval.

**beacon:** A frame transmitted by a coordinator to facilitate network management, such as the coordination of medium access and power management of the nodes in the body area network (BAN) of the coordinator, and to facilitate clock synchronization therein.

**beacon period:** A repetitive time interval to which medium access is referenced and in which a beacon is transmitted when appropriate, comprising the same number of time units (allocation slots) of equal duration.

**bilink:** A communications link for transfer of management and data traffic from a coordinator to a node or/and vice versa.

**bilink allocation:** An allocation with allocation interval(s) in which a coordinator or a node initiates one or more frame transactions to transmit management and data traffic to a node or a coordinator, respectively, and the recipient returns acknowledgment if required, with the provision that the node initiates frame transaction(s) only after receiving a poll from the coordinator.

**connected node:** A node that has a connection with a coordinator.

**connection:** A relationship between a node and a coordinator in a body area network (BAN), substantiated by a connected node identification assigned to the node by the coordinator and by a wakeup arrangement between them, and optionally by one or more scheduled allocations or unscheduled bilink allocations between them.

**contended allocation:** A non-reoccurring time interval, within a random access period (RAP) or a contention access period (CAP), that a node obtains using random access for initiating a frame transaction. A contended allocation is an uplink allocation, suitable for servicing “unpredictable” uplink traffic (for example, due to data rate variations and/or channel impairments).

**contention access:** An access method, based on carrier sense multiple access with collision avoidance (CSMA/CA) or slotted Aloha access but not both, whereby a node obtains a time interval in a contention access period (CAP) for initiating one or more frame transactions. As an access method, contention access is synonymous with random access.

**contention access period (CAP):** A time span set aside by a coordinator and announced via a preceding non-beacon frame for contention access to the medium by the nodes in the body area network (BAN) of the coordinator.

**coordinator:** An entity that possesses a node’s functionality and coordinates the medium access and power management of the nodes in its body area network (BAN).

**coordinator identifier (HID):** An abbreviated address of a coordinator.

**downlink:** A communications link for transfer of management and data traffic from a coordinator to a node.

**downlink allocation:** An allocation with allocation interval(s) in which a coordinator initiates one or more frame transactions to transmit management and data traffic to a node and the node returns acknowledgment if required.

**entity authentication:** Corroboration of the identity of the node or the coordinator in a security association procedure.

**exclusive access period (EAP):** A time span set aside by a coordinator in a beacon period (superframe) for transfer of the traffic of the highest user priority (UP) (for emergency or medical implant event report).

**frame:** An 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 coordinator.

**dependable BAN:** A body area network (BAN) that operates in beacon mode with superframes over IR-UWB PHY and establishes low latency, low jitter, and high update cycle for the time critical medical services of human BAN (H-BAN) and/or for the feedback loop control services of vehicle BAN (V-BAN).

**dependable BAN group:** A group of dependable BANs that are located within interfering range and coordinate each other to coexist.

**improvised access:** An access method, based on impromptu polling or posting by a coordinator, whereby a coordinator grants to a node or itself a polled or posted allocation, typically outside scheduled downlink and uplink allocations, for initiating one or more frame transactions by the node or coordinator, respectively.

**inactive state:** An internal power management state that is not ready for frame reception and transmission.

**inactive superframe:** A superframe in which no frame transmission occurs within the body area network (BAN) of the coordinator announcing such a superframe.

**information element (IE):** An optional part, with variable but self-identifiable length, of some frames.

**managed access period (MAP):** A time span set aside by a coordinator for improvised access, scheduled access, and unscheduled access to the medium by the coordinator and the nodes in the body area network (BAN) of the coordinator.

**master key (MK):** A secret bit string activated or established between a node and a coordinator in a security association procedure and used to create a pairwise temporal key (PTK) shared between them.

**message authentication:** Corroboration of the origin of a message in a message transfer.

**multi-periodic (m-periodic) allocation:** A scheduled allocation or an unscheduled bilink allocation that has allocation intervals reoccurring in every *m*th beacon period (superframe) with m being an integer larger than one. An m-periodic scheduled allocation is an uplink allocation, a downlink allocation, or a bilink allocation, suitable for servicing low duty cycle periodic or quasi-periodic traffic on a committed schedule. An m-periodic unscheduled allocation is a bilink allocation, suitable for servicing low duty cycle periodic or quasi-periodic traffic on a best-effort basis.

**node:** An entity that contains a medium access control (MAC) sublayer, a physical (PHY) layer, and that optionally provides security services.

**node identifier (NID):** An abbreviated address of a single node or of a logical group of nodes.

**nonce:** A number that is unique per instantiation of a cryptography protocol as part of a measure to thwart cryptanalytic and other cryptographic attacks.

**non-secure frame:** A term that is interchangeable with unsecured frame.

**one-periodic (1-periodic) allocation:** A scheduled allocation that has allocation intervals reoccurring in every beacon period (superframe), or an unscheduled bilink allocation that has allocation intervals reoccurring in every beacon period (superframe) or in round-robin together with the allocation intervals of other 1-periodic unscheduled bilink allocations. A 1-periodic scheduled allocation is an uplink allocation, a downlink allocation, or a bilink allocation, suitable for servicing high duty cycle periodic or quasi-periodic traffic on a committed schedule. A 1-periodic unscheduled bilink allocation is a bilink allocation, suitable for servicing high duty cycle periodic or quasi-periodic traffic on a best-effort basis.

**pairwise temporal key (PTK):** A secret bit string shared between a node and a coordinator and used to secure frames transferred between them.

**pairwise temporal key (PTK) creation:** A procedure used to create a PTK between a node and a coordinator based on a master key (MK) shared between them, and to confirm possession of a shared MK between the node and the coordinator.

**poll:** A control type frame or its variant sent by a coordinator to grant an immediate polled allocation to the addressed node or to inform the node of a future poll or post.

**polled allocation:** A non-reoccurring time interval that a coordinator grants to a node using polling access for initiating one or more frame transactions by the node. A polled allocation is an uplink allocation interval, suitable for servicing “ordinary,” “unexpected,” or “extra” uplink traffic (for example, due to data rate variations and/or channel impairments). A polled allocation is also called a *polled allocation interval.*

**polling access:** An access method, based on impromptu or scheduled polling by a coordinator, whereby a coordinator grants to a node a polled allocation for initiating one or more frame transactions by the node.

**post:** A management or data type frame sent by a coordinator to a node within its body area network (BAN). A post starts a posted allocation.

**posted allocation:** A non-reoccurring time interval that a coordinator grants to itself using posting access for initiating a frame transaction. A posted allocation is a downlink allocation interval, suitable for servicing “unexpected” or “extra” downlink traffic (for example, due to network management needs, data rate variations, and/or channel impairments).

**posting access:** An access method, based on impromptu or scheduled posting by a coordinator, whereby a coordinator grants to itself a posted allocation, typically outside scheduled uplink allocations, for initiating one or more frame transactions by the coordinator.

**random access:** An access method, based on carrier sense multiple access with collision avoidance (CSMA/CA) or slotted Aloha access but not both, whereby a node obtains a time interval in a random access period (RAP) for initiating one or more frame transactions.

**random access period (RAP):** A time span set aside by a coordinator and announced via a beacon frame for random access to the medium by the nodes in the body area network (BAN) of the coordinator.

**relayed node:** A node that communicates with a coordinator through another node.

**relaying node:** A node through which another node communicates with a coordinator.

**scheduled access:** An access method, based on advance reservation and committed scheduling, whereby a node and a coordinator obtain scheduled reoccurring time intervals for initiating frame transactions.

**scheduled allocation:** One or more scheduled reoccurring time intervals that a node and a coordinator obtains using scheduled access for initiating frame transactions. A scheduled allocation is an uplink allocation, a downlink allocation, or a bilink allocation, suitable for servicing high or low duty cycle periodic or quasi-periodic traffic on a committed schedule.

**scheduled-polling access:** A combination of scheduled access and polling access, whereby a node and a coordinator obtain scheduled reoccurring time intervals, wherein the coordinator grants to the node and/or itself non-reoccurring time intervals for initiating frame transactions on uplink and/or downlink.

**secure frame:** A term that is interchangeable with secured frame.

**secured communication:** Exchange of secured frames.

**secured frame:** A frame that is secured with authenticity, integrity, confidentiality if required, and replay protection.

**security association:** A procedure used to identify a node and a coordinator to each other and establish a new master key (MK) shared between them or activate an existing MK pre-shared between them.

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

**superframe:** A term that is interchangeable with beacon period used especially when no beacons are transmitted.

**type-I polled allocation:** A polled allocation the length of which is specified in terms of the duration of time granted for transmission.

**type-I polling access:** Polling access that provides type-I polled allocations.

**type-II polled allocation:** A polled allocation the length of which is specified in terms of the number of frames granted for transmission.

**type-II polling access:** Polling access that provides type-II polled allocations.

**unconnected node:** A node that does not have a connection with a coordinator in a body area network (BAN).

**unscheduled access:** A combination of best-effort scheduled access and polling access, whereby a node and a coordinator obtain unscheduled reoccurring time intervals, wherein the coordinator grants to the node and/or itself non-reoccurring time intervals for initiating frame transactions in an uplink and/or downlink.

**unscheduled bilink allocation:** One or more unscheduled reoccurring time intervals that a node and a coordinator obtains using unscheduled access for initiating frame transactions. An unscheduled bilink allocation is a bilink allocation, suitable for servicing high or low duty cycle periodic or quasi-periodic traffic in an uplink and/or downlink on a best-effort basis.

**unsecured communication:** Exchange of unsecured frames.

**unsecured frame:** A frame that is not secured with authenticity, integrity, confidentiality, or replay protection.

**uplink allocation:** An allocation with allocation interval(s) in which a node initiates one or more frame transactions to transmit management and data traffic to a coordinator and the coordinator returns acknowledgment if required.

**uplink:** A communications link for transfer of management and data traffic from a node to a coordinator.

* + 1. Special terms

**association:** A term synonymous to security association in absence of the qualifier “security.”

**appropriate:** Subject to the rules specified in the clauses of the standard.

**frame transaction:** All management or data type frames of the same frame subtype, and an acknowledgment frame if required, that are separated in time by an appropriate interframe space and transmitted between a node and a coordinator. Examples of a frame transaction: (a) a management type frame and an immediate acknowledgment frame; (b) all data type frames of the same frame subtype after a block acknowledgment frame, and the block acknowledgment frame that follows; (c) a management or data type frame, which is followed by another management or data type frame of a different frame subtype; (d) a management or data type frame, which is separated by more than an appropriate interframe space by another management or data type frame of the same frame subtype.

**implant:** An entity that is placed inside a human body for medical purposes.

**low power low duty cycle (LP/LDC):** Power, duty cycle, and transmission (transmissions/per hour) limits defined by standards and regulations for implants transmitting within the band 403.5 MHz to 403.8 MHz without coordination with a coordinator.

**medical implant event:** A term referenced in regulatory documents governing the use of the Medical Device Radiocommunication Service (MedRadio), which includes the Medical Implant Communications Service (MICS) from 402 MHz to 405 MHz.

* 1. Acronyms and abbreviations

AES Advanced Encryption Standard

ARQ automatic repeat request

AWGN additive white Gaussian noise

B-Ack block acknowledgment

BAN body area network

BCH code Bose, Ray-Chaudhuri, Hocquenghem code

BPSK binary phase shift keying

CAP contention access period

CBC cipher block chaining

CCA clear channel assessment

CCM counter mode for message encryption and cipher block chaining (CBC) mode for message authentication

CFP contention free period

CMAC (block) cipher-based message authentication code algorithm

CP contention probability

CP-BFSK continuous-phase binary frequency shift keying

CRC cyclic redundancy check

CSMA/CA carrier sense multiple access with collision avoidance

CW contention window (for carrier sense multiple access with collision avoidance)

D8PSK differential 8-phase-shift keying

DBPSK differential (or differentially encoded) binary phase-shift keying

DQPSK differential (or differentially encoded) quadrature phase-shift keying

DRF data rate field

EAP exclusive access period

ED energy detection

EFC electric field communication

EIRP equivalent isotropically radiated power

EUI extended unique identifier

EVM error vector magnitude

FCS frame check sequence

FEC forward error correction code

FSDT frequency selective digital transmission

FS-Spreader frequency selective spreader

G-Ack group acknowledgment

GAP group allocation period

GBI group beacon interval

GCP group coordination period

GF Galois field

GFSK Gaussian frequency-shift keying

GPPM group pulse position modulation

GT guard time

GTK group temporal key

HARQ hybrid automatic repeat request

HBAN human body area network

VBAN vehicle body area network

HCS header check sequence

HID coordinator identifier

HME coordinator management entity

HRP high repetition pulse

I-Ack immediate acknowledgment

IE information element

IR-UWB impulse radio ultra-wideband

ISM industrial scientific medical

ISO International Organization for Standardization

KCK key confirmation key

KMAC key message authentication code

L-Ack late acknowledgment (acknowledgment later)

LFSR linear feedback shift register

LP/LDC low power low duty cycle

LSB least significant bit

MAC media access control

MAP managed access period

MCU micro controller unit

MIC message integrity code

MICS medical implant communications service

MIFS minimum interframe space

MK master key

MPDU medium access control protocol data unit

MSB most significant bit

MSDU media access control service data unit

MUX multiplexer

N-Ack no acknowledgment

NID node identifier

NME node management entity

OSI open systems interconnection

PER packet error rate

PHR physical layer header

PHY physical or physical layer

PLCP physical layer convergence protocol

PN pseudo-random noise

PPDU physical layer protocol data unit

P.PRF peak pulse repetition frequency

PRF pulse-repetition-frequency

PSD power spectral density

PSDU physical layer service data unit

PSK phase shift keying

PTK pairwise temporal key

QPSK quadrature phase shift keying

RAP random access period

RI rate indicator

RX receive or reception

S2P serial-to-parallel

SAP service access point

SAR specific absorption rate

SD superframe duration

SF spreading factor

SFD start-of-frame delimiter

SHR synchronization header

SIFS short interframe spacing

SRRC square-root raised cosine

TK temporal key

TX transmit or transmission

UP user priority

UWB ultra wideband

1. General framework elements
	1. General

This clause provides the basic framework of nodes and coordinators. The framework serves as a prerequisite to supporting the functions of nodes and coordinators and their interactions specified later in detail. It covers the following aspects: the network topology used for medium access, the reference model used for functional partitioning, the time base used for access scheduling, the state diagrams used for frame exchange, the security paradigm used for message protection, and the coexisting dependable BANs.

* 1. Network topology

All nodes and coordinators are to be organized into logical sets, referred to as *body area networks* (BANs) in this specification, and coordinated by their respective coordinators for medium access and power management as illustrated in Figure 1. There is to be one and only one coordinator in a BAN, whereas the number of nodes in a BAN is to range from zero to mMaxBANSize. In a one-hop star BAN, frame exchanges are to occur directly between nodes and the coordinator of the BAN. In a two-hop extended star BAN, the coordinator and a node are to exchange frames optionally via a relay-capable node.

Optional mechanisms for coexistence and interference mitigating between adjacent or overlapping BANs are provided (in 6.13). Nodes referenced in this standard are in the context of a given BAN, unless noted otherwise.



1. —Network topology

Optional mechanisms for coexistence and interference mitigating between adjacent or overlapping BANs include Coordinator-to-Coordinator (C2C) communication and ranging in PHY and MAC. To identify if communication ranges of multiple BANs are overlapped or not, each coordinator keeps broadcasting beacons periodically every superframe to range distance with neighboring BANs, so-called C2C ranging.

C2C Ranging is applied to identify status of no, partial, or full overlapping coverage, and its dynamism of approaching, fixed, or leaving each other (in 6.5.1.3). C2C Ranging is performed more accurate by two way ranging(TWR) in UWB PHY than RSSI with received power only in narrowband PHY in general.

C2C communications is applied to decide a group BAN coordinator which is a master coordinator of coexisting multiple BANs, and to synchronize and control packet access among multiple BANs in MAC (6.5.1.3).

BAN1

Node

BAN2

Node

desired signal

desired signal

BAN1

Node

BAN

Node

BAN1

Coordinator

BAN2

Coordinator

**Coordinator-to-Coordinator(C2C)**

**Ranging and Communic ation**

BAN1

Node

BAN2

Node

1. —Coordinator-to-Coordinator(C2C) Communication and Ranging
	1. Reference model

All nodes and coordinators are internally partitioned into a physical (PHY) layer and a medium access control (MAC) sublayer, in accordance with the IEEE 802® reference model, as shown in Figure 3. Direct communications between a node and a coordinator are to transpire at the PHY layer and MAC sublayer as specified in this standard; the PHY layer and MAC sublayer of a node or a coordinator are to use only one operating channel at any given time. Message security services are to occur at the MAC sublayer, and security key generations are to take place inside and/or outside the MAC sublayer.



1. ―Reference model

Within a node or a coordinator, the MAC provides its service to the MAC client (higher layer) through the MAC service access point (SAP) located immediately above the MAC sublayer, while the PHY provides its service to the MAC through the PHY SAP located between them. On transmission, the MAC client passes MAC service data units (MSDUs) to the MAC sublayer via the MAC SAP, and the MAC sublayer passes MAC frames (also known as MAC protocol data units or MPDUs) to the PHY layer via the PHY SAP. On reception, the PHY layer passes MAC frames to the MAC sublayer via the PHY SAP, and the MAC sublayer passes MSDUs to the MAC client via the MAC SAP. Both MAC SAP and PHY SAP are not exposed and their specifications are beyond the scope of this standard.

There may be a logical node management entity (NME) or coordinator management entity (HME) that exchanges network management information with the PHY and MAC as well as with other layers. The HME is a superset of the NME in terms of the management functionality they each support. However, the presence of the NME or HME and the partitioning between the NME or HME and the MAC or the PHY is not mandated, nor is the behavior of the NME or HME specified, in this standard.

* 1. Time base

All nodes and coordinators are to establish a time reference base, as shown in Figure 4, if their medium access is to be scheduled in time, where the time axis is divided into beacon periods (superframes) of equal length and each beacon period (superframe) is composed of allocation slots of equal length and numbered from *0, 1, ..., s,* where *s* ≤ 255*.* An allocation interval may be referenced in terms of the numbered allocation slot comprising it, and a point of time may be referenced in terms of the numbered allocation slots preceding or following it as appropriate.



1. —Time reference base

If time reference is needed for access scheduling in its BAN, the coordinator is required to choose the boundaries of beacon periods (superframes) and hence of the allocation slots therein. In beacon mode operation for which beacons are transmitted, the coordinator needs to communicate such boundaries by transmitting beacons at the start or other specified locations of beacon periods (superframes), and optionally timed frames (T-Poll frames) containing their transmit time relative to the start time of current beacon period (superframe). In non-beacon mode operation for which beacons are not transmitted but time reference is needed, the coordinator is required to communicate such boundaries by transmitting timed frames (T-Poll frames) also containing their transmit time relative to the start time of current superframe.

A node requiring a time reference in the BAN needs to derive and recalibrate the boundaries of beacon periods (superframes) and allocation slots from reception of beacons or/and timed frames (T-Poll frames).

A frame transmission may span more than one allocation slot, starting or ending not necessarily on an allocation slot boundary.

* 1. MAC and security state diagrams

Overview

* 1. Security paradigm
	2. Revision overview

The main changes and features in the standard respect to the IEEE Std 802.15.6-2012 are as follows:

* The standard focuses on enhanced dependability of data transmission and ranging of BAN networks operating in unlicensed environments shared with other wireless networks.
* Human BAN and the new use case of vehicle BAN with a revised UWB PHY and MAC are tested using new and conventional channel models for medical and automotive applications with enhanced dependability.
* The standard supports backward compatibility with the IEEE Std 802.15.6-2012, except for deprecated FM-UWB PHY and HBC.

The revised UWB PHY introduces a new modulation scheme compatible with other IEEE Std 802.15.4 and amendments to facilitate the implementation of radio interfaces and new FEC mechanisms. The revised MAC is specially tailored for the revised UWB PHY with simplifications for the channel access in contrast to MAC in IEEE Std 802.15.6-2012.

The combination of technologies for the revised UWB PHY and MAC depends on traffic priority (QoS) and the coexistence scenario with other BANs and wireless networks operating in the same spectrum. Hence, a classification of coexistence classes and QoS is defined.

The main changes of the revised UWB PHY are as follows:

* New UWB modulation to accommodate high data rate and precise ranging. New FEC schemes: Binary Convolutional Code (BCC), LDPC, and a concatenation with Reed-Solomon codes. Also, HARQ based on decomposable BCC and LDPC codes is introduced.
* Interference mitigation schemes according to various environments of coexistence classes.

The main changes of the revised MAC are as follows:

* Transmission in an alternative radio channel for exclusive control and management of BAN coordinators. The exchange of messages in the coordination channel enables the creation of a group-based MAC superframe structure for the allocation of users in their respective BANs, optimizing coexistence.
* The revised MAC is simplified to address the revised UWB PHY operating in coexistence scenarios with enhanced dependability.
	+ 1. Coexistence environments

The standard supports BANs operating with high reliability in dense environments coexisting with intra-interference and inter-interference due to other wireless systems in the same frequency band. Table 1 shows the different coexistence environments considered in the standard.

1. —Coexistence environments

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coexistence environment class** | **15.** | **15.6-2012** | **Non-UWB (Wi-Fi, unlicensed 5G)** | **IEEE Stds 802.15 UWB (15.4, 15.8)** | **Non-IEEE Std 802.15 UWB (ETSI)** | **Note** |
| 0 | ⎯ | ⎯ | ⎯ | ⎯ | ⎯ | A single BAN |
| 1 | 🗸 | ⎯ | ⎯ | ⎯ | ⎯ | Multiple BANs |
| 2 | 🗸 | 🗸 | ⎯ | ⎯ | ⎯ |
| 3 | 🗸 | ⎯ | 🗸 | ⎯ | ⎯ | Non-UWB systems |
| 4 | 🗸 | ⎯ | ⎯ | 🗸 | ⎯ | Multiple UWB systems |
| 5 | 🗸 | ⎯ | ⎯ | ⎯ | 🗸 |
| 6 | 🗸 | ⎯ | ⎯ | 🗸 | 🗸 |
| 7 | 🗸 | 🗸 | 🗸 | 🗸 | 🗸 | Multiple: BANs, non-UWB and UWB systems |

The configuration of the revised UWB PHY and MAC depends on the coexistence environment and the QoS traffic type.

The coexistence environment classes in Table 1 are summarized as follows:

* Class 0 defines the operation of a single BAN, either HBAN or VBAN. This type of configuration enables the radio interface to be similar to IEEE Std 802.15.4 UWB PHY radio interface for harmonizing implementations.
* Class 1 defines the operation of multiple BANs. This environment triggers the coordinator-to-coordinator protocol for the formation of a group superframe for coexistence and enhanced dependability.
* Class 2 defines the operation of multiple BANs and IEEE Std 802.15.6-2012 BANs. As in class 1, this environment triggers the coordinator-to-coordinator protocol for the formation of a group superframe and interference mitigation of IEEE Std 802.15.6-2012 15.6 BANs.
* Class 3 defines the operation of BANs with other wireless systems without an UWB PHY operating in the same frequency band such as IEEE Std 802.11, unlicensed 5G, radio location and so on. The standard supports interference mitigation and higher reliability via FEC mechanisms.
* Class 4 defines the operation of BANs with other IEEE Std 802.15 standards with a UWB PHY. BANs support interference mitigation and higher reliability via FEC mechanisms.
* Class 5 defines the operation of BANs with other wireless systems with a UWB PHY such as ETSI standards. BANs support interference mitigation and higher reliability via FEC mechanisms.
* Class 6 defines the operation of BANs with other IEEE Std 802.15 standards with a UWB PHY and other wireless systems with a UWB PHY. BANs support interference mitigation and higher reliability via FEC mechanisms.
* Class 7 defines the operation of BANs with other wireless systems (worst-case scenario) operating in the same frequency band. BANs support interference mitigation and higher reliability via FEC mechanisms.

The difference in the different class environments is the possibility of identifying the interferer system to apply prescribed interference mitigation techniques as described in 9.1. Hence, the transition between coexistence classes depends on interference detection, which is implementation dependent. Once an environment class is identified, the group coordinator shall start a procedure to transition to a new Class environment.

However, the transition to a new Class environment depends of devices support the FEC configurations and interference estimation, which are implementation dependent.

Coexistence environments Class 1, Class 2, and Class 4 shall be supported by the identification of their respective beacons.

* + 1. Coexistence Class States Transition

The standard supports BANs operating with high reliability (coexistence class 0) and coexisting in dense environments with intra-interference and inter-interference (coexistence class 1 to 7). Figure 7 shows the state transition between several classes of coexistence environments defined in Table 1.



1. —Diagram of state transitions for coexistence class environments.
* The standard focuses on the dependability mechanisms for a single HBAN or VBAN (Class 0) and the scenario with multiple HBANs or VBANS (Class 1).
* Class 2 supports compatibility with IEEE Std 802.15.6-2012 BANs.
* Class 4 supports coexistence with other IEEE Std 802.15 with UWB PHY via the PHY and MAC specification.
* Classes 3, 5, 6, and 7 support coexistence with other wireless systems via interference mitigation technology at the receiver side.

During CCA and beacon periods, a BAN coordinator may analyze the type of synchronization preamble detected from a given standard operating in the UWB band.

In Figure 6, the state transition probabilities are approximated in consecutive superframes. Furthermore, the duration of the CAP and CFP are determined by the type of QoS associated with every superframe, or group frame and available resources to avoid congestion.

The standard supports BANs operating with high reliability in dense environments coexisting with intra-interference and inter-interference due to other wireless systems in the same frequency band. Figure 7 shows state transition among several classes of coexistence environment defined in Table 1.

As shown in Figure 7, coexistence environment classes 0, 1, 2, and 4 perform enhanced dependability. These classes are relatively easy to detect as those use a UWB PHY, whose beacons are known and radios are compatible. Coexistence environment classes 3, 5, 6, and 7 deal with interference from other radios.

* + 1. Communication in a dependable BAN

A dependable BAN may exist other dependable BANs within interfering range. For coexisting multiple dependable BANs, a dependable BAN coordinates other dependable BANs to avoid interference or to mitigate interference by forming a dependable group BAN.

A node of a dependable BAN may become a coordinator that maintains a dependable BAN. A coordinator of a dependable BAN may become a group coordinator that maintains a dependable group BAN. The capability of a node may set as coordinator disabled, coordinator enabled, or group coordinator enabled prior to start a node.The dependable BAN shall operate in beacon mode with superframes over IR-UWB PHY. A coordinator of a BAN forms a superframe structure which contains beacon period, contention access period (CAP), contention free period (CFP), and inactive period. A coordinator broadcasts a beacon frame on beacon period. A coordinator and nodes of a BAN communicate on CAP with contention access mode for transmitting frames. A coordinator may assign timeslots of CFP for reserving up or down preemptive communication with requesting from a node.

A group coordinator of a dependable group BAN forms a group superframe structure which contains group coordination period (GCP) and group allocation period (GAP), as shown in Figure 73. GCP contains a group beacon slot, group coordination slots, and a group notification slot. GAP contains active superframe duration of BANs in a group BAN that contains beacon period, CAP, and CFP of each BANs.

GCP is a control channel for coordinators of a dependable group BAN. A group coordinator broadcasts a group beacon frame on the group bacon slot and a group allocation map frame on the group notification slot of GCP for maintaining a dependable group BAN. A group coordinator and coordinators of a dependable group BAN may use group coordination slots with contention access mode for transmitting management frames such as group association request/response frame, group disassociation frame, group migration frame, group disband frame, group merged frame which come to and from a group coordinator and coordinators of a group BAN.

The length of a group superframe is specified with the number of time slot. A time slot is fixed length of a time that is enough for a pair of devices to exchange a frame and an acknowledgment. A group superframe duration, group beacon interval (GBI), is varied according to the number of BANs in a group BAN. The group coordination period consists of one time slot for a group beacon, one time slot for a group notification, and multiple timeslots for group coordination which are the two times number of BANs in a BAN group. The length of group allocation period is varied according to the length of CAP and CFP of each BAN in a group BAN. For a BAN joined in a group BAN, the length of beacon interval and inactive period of the superframe are varied, whenever group superframe of a group BAN is changed.



1. **—Group superframe structure for a dependable group BAN**
1. IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page. [↑](#footnote-ref-2)