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IEEE Std 802.15.6™-2012

IEEE Standard for Local and metropolitan area networks—

Part 15.6: Wireless Body Area Networks

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Approved 6 February 2012

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Abstract: Short-range, wireless communications in the vicinity of, or inside, a human body (but not limited to humans) are specified in this standard. It uses existing industrial scientific medical (ISM) bands as well as frequency bands approved by national medical and/or regulatory authorities. Support for quality of service (QoS), extremely low power, and data rates up to 10 Mbps is required while simultaneously complying with strict non-interference guidelines where needed. This standard considers effects on portable antennas due to the presence of a person (varying with male, female, skinny, heavy, etc.), radiation pattern shaping to minimize the specific absorption rate (SAR) into the body, and changes in characteristics as a result of the user motions.

Keywords: BAN, body area network, IEEE 802.15.6

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Introduction

This introduction is not part of IEEE Std 802.15.6-2012, IEEE Standard for Local and metropolitan area networks—Part 15.6: Wireless Body Area Networks.

With the decreasing size and increasing capability of electronic devices, thanks to the Moore's Law, it was inevitable that small and portable devices would be developed for communications around human bodies. Some devices are wearable and some are implementable for medical purposes. These devices need to communicate with their remote controllers. IEEE Std 802.15.6-2012 is a standard for short-range, wireless communications in the vicinity of, or inside, a human body (but not limited to humans). It uses ISM and other bands as well as frequency bands in compliance with applicable medical and communication regulatory authorities. It allows devices to operate on very low transmit power for safety to minimize the specific absorption rate (SAR) into the body and increase the battery life. It supports quality of service (QoS), for example, to provide for emergency messaging. Since some communications can carry sensitive information, it also provides for strong security.

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1. Overview

1.1 Scope

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1.2 Purpose

The purpose is to provide an international standard for a short-range (i.e., about human body range), low power, and highly reliable wireless communication for use in close proximity to, or inside, a human body. Data rates, typically up to 10Mbps, can be offered to satisfy an evolutionary set of entertainment and healthcare services. Current *personal area networks* (PANs) do not meet the medical (proximity to human tissue) and relevant communication regulations for some application environments. They also do not support the combination of reliability, QoS, low power, data rate, and noninterference required to broadly address the breadth of body area network (BAN) applications.

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NIST Special Publication 800-38B (2005), Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication. [6]

NIST Special Publication 800-38C (2004), Recommendation for Block Cipher Modes of Operation: The CCM Mode for Authentication and Confidentiality.

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms & Definitions* [B1] should be consulted for terms not defined in this clause.[7, 8]

3.1 Definitions

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

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

[1] ETSI publications are available from the European Telecommunications Standards Institute (http://www.etsi.org).
[2] FIPS publications are available from the National Technical Information Service (http://www.ntis.gov/).
[3] IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org).
[4] The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.
[5] ISO/IEC publications are available from the ISO Central Secretariat (http://www.iso.org/). ISO publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).
[6] NIST publications are available from the National Institute of Standards and Technology (http://www.nist.gov/).
[7] The *IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at http://shop.ieee.org/.
[8] The numbers in brackets correspond to those of the bibliography in Annex A.

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

allocation: One or more time intervals that a node or a hub 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 hub 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 hub, 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 hub to a node or/and vice versa.

bilink allocation: An allocation with allocation interval(s) in which a hub or a node initiates one or more frame transactions to transmit management and data traffic to a node or a hub, 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 hub.

connected node: A node that has a connection with a hub.

connection: A relationship between a node and a hub in a body area network (BAN), substantiated by a connected node identification assigned to the node by the hub 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 phase (RAP) or a contention access phase (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 phase (CAP) for initiating one or more frame transactions. As an access method, contention access is synonymous with random access.

contention access phase (CAP): A time span set aside by a hub 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 hub.

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

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

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

exclusive access phase (EAP): A time span set aside by a hub 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 hub.

hub: 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).

hub identifier (HID): An abbreviated address of a hub.

improvised access: An access method, based on impromptu polling or posting by a hub, whereby a hub 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 hub, 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 hub announcing such a superframe.

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

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

master key (MK): A secret bit string activated or established between a node and a hub 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

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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 hub 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 hub based on a master key (MK) shared between them, and to confirm possession of a shared MK between the node and the hub.

poll: A control type frame or its variant sent by a hub 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 hub 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 hub, whereby a hub 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 hub to a node within its body area network (BAN). A post starts a posted allocation.

posted allocation: A non-reoccurring time interval that a hub 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 hub, whereby a hub grants to itself a posted allocation, typically outside scheduled uplink allocations, for initiating one or more frame transactions by the hub.

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 phase (RAP) for initiating one or more frame transactions.

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

relayed node: A node that communicates with a hub through another node.

relaying node: A node through which another node communicates with a hub.

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

scheduled allocation: One or more scheduled reoccurring time intervals that a node and a hub 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.

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scheduled-polling access: A combination of scheduled access and polling access, whereby a node and a hub obtain scheduled reoccurring time intervals, wherein the hub 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 hub 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 hub and zero or more nodes whose medium access and power management are coordinated by the hub.

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 hub in a body area network (BAN).

unscheduled access: A combination of best-effort scheduled access and polling access, whereby a node and a hub obtain unscheduled reoccurring time intervals, wherein the hub 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 hub 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 hub and the hub returns acknowledgment if required.

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

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3.2 Special terms

association: A term synonymous to security association in absence of the qualifier "security."

appropriate: Subject to the rules specified in Clause 5, Clause 6, and Clause 7.

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 hub. 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 hub.

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.

3.3 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 phase
CBC	cipher block chaining
CCA	clear channel assessment
CCM	counter mode for message encryption and cipher block chaining (CBC) mode for message authentication
CMAC	(block) cipher-based message authentication code algorithm
CP	contention probability
CP-BFSK	continuous-phase binary frequency shift keying
CRC	cyclic redundancy check

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