

802.15.1™

**IEEE Standard for
Information technology—
Telecommunications and information
exchange between systems—
Local and metropolitan area networks—
Specific requirements**

**Part 15.1: Wireless medium access control (MAC)
and physical layer (PHY) specifications for
wireless personal area networks (WPANs)**

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee



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of the
IEEE Society**

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Abstract: Methods for communicating devices in a personal area network (PAN) are covered in this standard.

Keywords: Bluetooth™, communications protocol, ISM, personal area network, WPAN

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Introduction

This introduction is not part of IEEE Std 802.15.1-2005, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements: Part 15.1: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs).

This standard defines services and protocol elements that permit the exchange of management information between stations associated in a personal area network (PAN).

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**IEEE Standard for
Information technology—
Telecommunications and information
exchange between systems—
Local and metropolitan area networks—
Specific requirements**

**Part 15.1: Wireless medium access control (MAC)
and physical layer (PHY) specifications for
wireless personal area networks (WPANs)**

1. Overview

Wireless personal area networks (WPANs) are used to convey information over short distances among a private, intimate group of participant devices. Unlike a wireless local area network (WLAN), a connection made through a WPAN involves little or no infrastructure or direct connectivity to the world outside the link. This allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

1.1 Scope

This standard defines physical layer (PHY) and medium access control (MAC) specifications for wireless connectivity with fixed, portable, and moving devices within or entering a personal operating space (POS). A POS is the space about a person or object that typically extends up to 10 m in all directions and envelops the person whether stationary or in motion.

The original goal of the IEEE 802.15.1 Task Group was to achieve a level of interoperability that could allow the transfer of data between a WPAN device and an IEEE 802.11™ device. Although this proved infeasible, IEEE Std 802.15.1-2005 does have mechanisms defined to allow better coexistence with IEEE 802.11b™ class of devices.

Both this standard and the previous version are based upon technology originally developed by the Bluetooth™ Special Interest Group (SIG).

1.2 WPAN definition

The term *WPAN* in this standard refers specifically to a wireless personal area network as used in this standard.

Specifically, this standard describes the following:

- The functions and services required by an IEEE 802.15.1-2005 device to operate within ad hoc networks.

- The following MAC procedures to support the asynchronous connectionless or connection-oriented (ACL) and synchronous connection-oriented (SCO) link delivery services:
 - The baseband (BB) layer, specifying the lower level operations at the bit and packet levels, e.g., forward error correction (FEC) operations, encryption, cyclic redundancy check (CRC) calculations, Automatic Repeat Request (ARQ) Protocol.
 - The link manager (LM) layer, specifying connection establishment and release, authentication, connection and release of SCO and ACL channels, traffic scheduling, link supervision, and power management tasks.
 - The Logical Link Control and Adaptation Protocol (L2CAP) layer, forming an interface to standard data transport protocols. It handles the multiplexing of higher layer protocols and the segmentation and reassembly (SAR) of large packets. The data stream crosses the LM layer, where packet scheduling on the ACL channel takes place. The audio stream is directly mapped on an SCO channel and bypasses the LM layer. The LM layer, though, is involved in the establishment of the SCO link. Between the LM layer and the application, control messages are exchanged in order to configure the IEEE 802.15.1-2005 transceiver for the considered application.
- The 2.4 GHz industrial, scientific, and medical (ISM) band PHY signaling techniques and interface functions that are controlled by the IEEE 802.15.1-2005 MAC. Requirements are defined for two reasons:
 - To provide compatibility between the radios used in the system.
 - To define the quality of the system.

Above the L2CAP layer may reside the Serial Cable Emulation Protocol based on ETSI TS 07.10 (RFCOMM), Service Discovery Protocol (SDP), Telephone Control Protocol specification (TCS), voice-quality channels for audio and telephony, and other network protocols. These protocols are necessary for interoperability for end-user products, but are outside the scope of this standard.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

2.1 IEEE documents

IEEE Std 802®, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.^{1, 2}

IEEE Std 802.15.2™, IEEE Recommended Practice for Telecommunications and Information exchange between systems—Local and metropolitan area networks—Specific Requirements—Part 15.2: Coexistence of Wireless Personal Area Networks with Other Wireless Devices Operating in Unlicensed Frequency Band.

2.2 ISO documents

ISO/IEC 3309, Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures — Frame structure.³

ISO/IEC 7498-1, Information technology — Open Systems Interconnection — Basic Reference Model: The Basic Model.

ISO/IEC 8802-2, Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements — Part 2: Logical link control.

ISO/IEC 10039, Information technology — Open Systems Interconnection — Local Area Networks — Medium Access Control (MAC) service definition.

ISO/IEC 15802-1, Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Common specifications — Part 1: Medium Access Control (MAC) service definition.

2.3 ITU documents

ITU-T Recommendation G.711, Pulse code modulation (PCM) of voice frequencies.⁴

ITU-T Recommendation O.150, Digital test patterns for performance measurements on digital transmission equipment.

ITU-T Recommendation O.153, Basic parameters for the measurement of error performance at bit rates below the primary rate.

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²IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

³ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO/IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁴ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>).

ITU-T Recommendation X.200, Information technology—Open systems interconnection—Basic reference model: The basic model.

2.4 Other documents

IETF RFC 1363, A Proposed Flow Specification.⁵

IETF RFC 1661, The Point-to-Point Protocol (PPP).

IrDA Object Exchange Protocol (IrOBEX), Version 1.2.⁶

⁵ IETF documents are available from Internet Engineering Task Force (<http://www.ietf.org/>).

⁶ IrDA documents are available from the Infrared Data Association (<http://www.irda.org/>).

3. Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B7]⁷, should be referenced for terms not defined in this clause.

3.1 active slave broadcast (ASB): The logical transport that is used to transport Logical Link Control and Adaptation Protocol (L2CAP) user traffic to all active devices in the piconet.

3.2 ad hoc network: A network typically created in a spontaneous manner. An ad hoc network requires no formal infrastructure and is limited in temporal and spatial extent.

3.3 authenticated device: A device whose identity has been verified during the lifetime of the current link, based on the authentication procedure.

3.4 authentication: A generic procedure based on link management profile authentication that determines whether a link key exists or, on Link Manager Protocol (LMP) pairing, whether no link key exists.

3.5 authorization: A procedure where a user of a device grants a specific (remote) device access to a specific service. Authorization implies that the identity of the remote device can be verified through authentication.

3.6 authorize: The act of granting a specific device access to a specific service. It may be based upon user confirmation or given the existence of a trusted relationship.

3.7 baseband (BB): The part of the system that specifies or implements the medium access control (MAC) layer and physical layer (PHY) procedures to support the exchange of real-time voice, data information streams, and ad hoc networking between devices.

3.8 beacon train: A pattern of reserved slots within a basic or adapted piconet physical channel. Transmissions starting in these slots are used to resynchronize parked devices.

3.9 Bluetooth device address (BD_ADDR): The address used to identify a device conforming to this standard.

3.10 Bluetooth wireless technology: The general term used to describe the technology originally developed by the Bluetooth Special Interest Group (SIG). It defines a wireless communication link, operating in the unlicensed industrial, scientific, and medical (ISM) band at 2.4 GHz using a frequency hopping transceiver. The link protocol is based on time slots.

3.11 bond: A relation between two devices defined by creating, exchanging, and storing a common link key. The bond is created through the bonding or Link Manager Protocol (LMP) pairing procedures.

3.12 channel: Either a physical channel or an Logical Link Control and Adaptation Protocol (L2CAP) channel, depending on the context.

3.13 connect (to service): The establishment of a connection to a service. If not already done, this also includes establishment of a physical link, logical transport, logical link, and Logical Link Control and Adaptation Protocol (L2CAP) channel.

3.14 connectable device: A device in range that periodically listens on its page scan physical channel and will respond to a page on that channel.

⁷The numbers in brackets correspond to the numbers of the bibliography in Annex A.

- 3.15 connected devices:** Two devices in the same piconet and with a physical link between them.
- 3.16 connecting:** A phase in the communication between devices when a connection between them is being established. (Connecting phase follows after the link establishment phase is completed.)
- 3.17 connection:** A connection between two peer applications or higher layer protocols mapped onto a Logical Link Control and Adaptation Protocol (L2CAP) channel.
- 3.18 connection establishment:** A procedure for creating a connection mapped onto a channel.
- 3.19 controller:** A subsystem containing the physical layer (PHY), baseband (BB), resource controller, link manager (LM), device manager, and a host controller interface (HCI) conforming to this standard.
- 3.20 coverage area:** The area where two devices can exchange messages with acceptable quality and performance.
- 3.21 creation of a secure connection:** A procedure of establishing a connection, including authentication and encryption.
- 3.22 creation of a trusted relationship:** A procedure where the remote device is marked as a trusted device. This includes storing a common link key for future authentication and pairing (if the link key is not available).
- 3.23 device:** A device that is capable of short-range wireless communications using this standard.
- 3.24 device address:** A 48-bit address used to identify each device.
- 3.25 device discovery:** A procedure for retrieving the device address, clock, class-of-device field, and used page scan mode from discoverable devices.
- 3.26 discoverable device:** A device in range that periodically listens on an inquiry scan physical channel and will respond to an inquiry on that channel. Discoverable devices are normally also connectable.
- 3.27 estimated clock (CLKE):** Estimate of another device's clock. CLKE may be a slave's estimate of a master's clock, a paging devices's estimate of the paged device's clock, or other such use.
- 3.28 host:** A computing device, peripheral, cellular telephone, access point to public switched telephone network (PSTN) or local area network (LAN), etc. A host attached to a controller may communicate with other hosts attached to their controllers as well.
- 3.29 host controller interface (HCI):** A command interface to the baseband (BB) controller and link manager (LM) that provides access to hardware status and control registers and provides a uniform method of accessing the BB capabilities.
- 3.30 idle:** Description of a device, as seen from a remote device, when no link is established between the devices.
- 3.31 inquiring device:** A device that is carrying out the inquiry procedure.
- 3.32 inquiry:** A procedure where a device transmits inquiry messages and listens for responses in order to discover the other devices that are within the coverage area.
- 3.33 inquiry scan:** A procedure where a device listens for inquiry messages received on its inquiry scan physical channel.

3.34 isochronous data: Information in a stream where each information entity in the stream is bound by a time relationship to previous and successive entities.

3.35 known device: A device for which at least the Bluetooth device address (BD_ADDR) is stored.

3.36 link: Shorthand for a logical link.

3.37 link establishment: A procedure for establishing the default ACL link and hierarchy of links and channels between devices.

3.38 link key: A secret key that is known by two devices and is used in order to authenticate each device to the other.

3.39 LMP authentication: A procedure on the Link Manager Protocol (LMP) level for verifying the identity of a remote device. The procedure is based on a challenge-response mechanism using a random number, a secret key, and the Bluetooth device address (BD_ADDR) of the noninitiating device. The secret key used can be a previously exchanged link key.

3.40 LMP pairing: A procedure that authenticates two devices, based on a personal identification number (PIN), and subsequently creates a common link key that can be used as a basis for a trusted relationship or a (single) secure connection. The procedure consists of the following steps: creation of an initialization key (based on a random number and a PIN), creation and exchange of a common link key, and Link Manager Protocol (LMP) authentication based on the common link key.

3.41 logical channel: Identical to a Logical Link Control and Adaptation Protocol (L2CAP) channel, but deprecated due to inconsistent usage in IEEE Std 802.15.1-2002.

3.42 logical link: The lowest architectural level used to offer independent data transport services to clients of the system.

3.43 logical transport: Used to represent commonality between different logical links due to shared acknowledgment protocol and link identifiers.

3.44 L2CAP channel: A logical connection on the Logical Link Control and Adaptation Protocol (L2CAP) level between two devices serving a single application or higher layer protocol.

3.45 L2CAP channel establishment: A procedure for establishing a logical connection on the Logical Link Control and Adaptation Protocol (L2CAP) level.

3.46 master clock (CLK): Native clock of the piconet's master.

3.47 mode: A set of directives that defines how a device will respond to certain events.

3.48 name discovery: A procedure for retrieving the user-friendly name (the device name) of a connectable device.

3.49 native clock (CLKN): A 28-bit clock internal to a controller subsystem that ticks every 312.5 μ s. The value of this clock defines the slot numbering and timing in the various physical channels.

3.50 packet: Format of aggregated bits that are transmitted on a physical channel.

3.51 page: The initial phase of the connection procedure where a device transmits a train of page messages until a response is received from the target device or a timeout occurs.

3.52 page scan: A procedure where a device listens for page messages received on its page scan physical channel.

3.53 paging device: A device that is carrying out the page procedure.

3.54 paired device: A device with which a link key has been exchanged (either before connection establishment was requested or during connecting phase).

3.55 parked device: A device operating in a basic mode piconet that is synchronized to the master, but has given up its default ACL logical transport.

3.56 parked slave broadcast (PSB): The logical transport that is used for communications from the master to parked slave devices. These communications may also be received by active devices.

3.57 participant in multiple piconets: A device that is concurrently a member of more than one piconet. It achieves this status using time division multiplexing (TDM) to interleave its activity on each piconet physical channel.

3.58 personal identification number (PIN): A user-friendly number that can be used to authenticate connections to a device before pairing has taken place.

3.59 physical channel: A channel characterized by synchronized occupancy of a sequence of radio frequency (RF) carriers by one or more devices. A number of physical channel types exist with characteristics defined for their different purposes.

3.60 physical link: A connection on the baseband (BB) level between two devices established using paging.

3.61 piconet: A collection of devices occupying a shared physical channel where one of the devices is the piconet master and the remaining devices are connected to it.

3.62 piconet physical channel: A channel that is divided into time slots in which each slot is related to a radio frequency (RF) hop frequency. Consecutive hops normally correspond to different RF hop frequencies and occur at a standard hop rate of 1600 hop/s. These consecutive hops follow a pseudo-random hopping sequence, hopping through a 79-RF channel set, or optionally fewer channels when adaptive frequency hopping (AFH) is in used.

3.63 piconet master: The device in a piconet whose clock and device address are used to define the piconet physical channel characteristics.

3.64 piconet slave: Any device in a piconet that is not the piconet master, but is connected to the piconet master, and that controls piconet timing and access by its transmissions to slaves.

3.65 prepared device: A device with which a link key was exchanged and stored before link establishment.

3.66 scatternet: Two or more piconets that include one or more devices participating in more than one piconet.

3.67 service discovery (SD): Procedures for querying and browsing for services offered by or through another device.

3.68 service layer protocol: A protocol that uses a Logical Link Control and Adaptation Protocol (L2CAP) channel for transporting protocol data units (PDUs).

3.69 silent device: A device appears as silent to a remote device if it does not respond to inquiries made by the remote device.

3.70 trusted device: A paired device that is explicitly marked as trusted.

3.71 unknown device: A device for which no information (e.g., device address, link key) is stored.

3.72 unpaired device: A device for which there was no exchanged link key available before connection establishment was requested.

4. Acronyms and abbreviations

This clause contains two classes of acronyms and abbreviations. The first class is based on this and other standards and is the type usually found in IEEE standards. The second class refers to acronyms and abbreviations from the Bluetooth specification that are used by this standard. This second class is included in this standard as an aid to the reader.

4.1 Standard-based acronyms and abbreviations

ACK	acknowledge
ACL	asynchronous connection-oriented [logical transport]
ACL-C	ACL control [logical link] (LMP)
ACL-U	ACL user [logical link] (L2CAP)
ACO	authenticated ciphering offset
AFH	adaptive frequency hopping
AHS	adapted hop sequence
AR_ADDR	access request address
ARQ	automatic repeat request
ARQN	acknowledgment indication
ASB	active slave broadcast [logical transport]
ASB-U	active slave broadcast user [logical link] (L2CAP)
BB	baseband
BCH	Bose, Chaudhuri, and Hocquenghem
BD_ADDR	device address
BER	bit error rate
BT	bandwidth time
CAC	channel access code
CID	channel identifier
CL	connectionless
CLK	master clock
CLKE	estimated clock
CLKN	native clock
CODEC	coder decoder
COF	ciphering offset
CQDDR	channel quality-driven data rate
CRC	cyclic redundancy check
CVSD	continuous variable slope delta [modulation]
DA	destination address [field]

DAC	device access code
DCI	default check initialization
DH	data-high rate [packet]
DIAC	dedicated inquiry access code
DLL	data link layer
DM	data-medium rate [packet]
DUT	device under test
DV	data-voice [packet]
EN RAND	encryption random number
ERP	ear reference point
eSCO	extended synchronous connection-oriented [logical transport]
eSCO-S	stream extended synchronous connection-oriented
EV	extended voice [packet]
ERTX	extended response timeout expired [timer]
FCS	frame check sequence
FEC	forward error correction
FHS	frequency hop synchronization
FHSS	frequency hopping spread spectrum
FIFO	first in first out
GAP	generic access profile
GFSK	Gaussian frequency shift keying
GIAC	general inquiry access code
HCI	host controller interface
HEC	header error check
HID	human interface device
HV	high-quality voice [packet]
IAC	inquiry access code
IN RAND	initialization random number
IP	Internet Protocol
ISDN	integrated services digital network
ISM	industrial, scientific, and medical
L2CAP	Logical Link Control and Adaptation Protocol
LAP	lower address part
LC	link control [logical link]
LCID	local channel identifier
LCP	Link Control Protocol

LFSR	linear feedback shift register
LIAC	limited inquiry access code
LLC	logical link control
LLID	logical link identifier
LM	link manager
LMP	Link Manager Protocol
LPO	low-power oscillator
LR	loudness rating
LSB	least significant bit
LT_ADDR	logical transport address
M	master or mandatory
MAC	medium access control
MPS	maximum PDU payload size
MSB	most significant bit
MSC	message sequence chart
MSDU	MAC service data unit
MTU	maximum transmission unit
NAK	negative acknowledge
NAP	nonsignificant address part
NOP	no operation
O	optional
OBEX	Object Exchange Protocol
OCF	opcode command field
OGF	opcode group field
PCM	pulse code modulation
PDU	protocol data unit
PGA	programmable gain amplifier
PHT	pseudo-Hadamard transform
PIN	personal identification number
PM_ADDR	parked member address
PN	pseudo-random noise
POS	personal operating space
ppm	parts per million
PRBS	pseudo-random bit sequence
PSB	parked slave broadcast [logical transport]
PSB-C	parked slave broadcast control [logical link] (LMP)

PSB-U	parked slave broadcast user [logical link] (L2CAP)
PSM	protocol/service multiplexer
PSTN	public switched telephone network
QoS	quality of service
RAND	random number
RF	radio frequency
RFCMode	retransmission and flow control mode
RFCOMM	Serial Cable Emulation Protocol based on ETSI TS 07.10
RLR	receive loudness rating
RSSI	received signal strength indication
RX	receive
RTX	response timeout expired [timer]
S	slave
SA	source address [field]
SAP	service access point
SAR	segmentation and reassembly
SCO	synchronous connection-oriented [logical transport]
SCO-S	stream synchronous connection-oriented (unframed)
SD	service discovery
SDAP	service discovery applicaiton profile
SDP	Service Discovery Protocol
SDU	service data unit
SEQN	sequence number
SLR	send loudness rating
SRES	signed response
TCS	Telephony Control Protocol specification
TDD	time-division duplex
TDM	time-division multiplexing
TX	transmit
UAP	upper address part
u_int	unsigned integer
USB	universal serial bus

4.2 Bluetooth specification names

References to upper layer Bluetooth protocols use the abbreviations in Table 1.

Table 1—Abbreviations of the Bluetooth specification names

Name	Reference	Placement in Bluetooth specification
A2DP	Advanced Audio Distribution Profile Specification	vol 10 part C
AVCTP	A/V Control Transport Protocol Specification	vol 10 part F
AVDTP	A/V Distribution Transport Profile Specification	vol 10 part A
AVRCP	A/V Remote Control Profile Specification	vol 10 part G
BB	Baseband Specification	vol 2 part B
BIP	Basic Imaging Profile	vol 8 part E
BNEP	Bluetooth Network Encapsulation Protocol Specification	vol 6 part A
BPP	Basic Printing Profile Specification	vol 8 part F
CIP	Common Integrated Services Digital Network (ISDN) Access Profile Specification	vol 12 part A
CTP	Cordless Telephony Profile Specification	vol 9 part B
DUN	Dial-Up Networking Profile Specification	vol 7 part C
ESDP / UPNP	Extended Service Discovery Profile	vol 6 part D
FAX	Fax Profile Specification	vol 7 part D
FTP	File Transfer Profile Specification	vol 8 part C
GAP	Generic Access Profile Specification	vol 3 part C
GAVDP	Generic A/V Distribution Profile Specification	vol 10 part B
GOEP	Generic Object Exchange Profile Specification	vol 8 part A
HCI (1)	Host Controller Interface Functional Specification	vol 2 part E
HCI (2)	Host Controller Interface Transport Layers Specification	vol 4 part A-C
HCRP	Hardcopy Cable Replacement Profile Specification	vol 11 part B
HFP	Hands-Free Profile Specification	vol 7 part E
HID	Human Interface Device Profile Specification	vol 11 part A
HSP	Headset Profile Specification	vol 7 part F
ICP	Intercom Profile Specification	vol 9 part C
L2CAP	Logical Link Control and Adaptation Protocol Specification	vol 3 part A
LAP	LAN Access Profile Specification	deprecated
LMP	Link Manager Protocol Specification	vol 2 part C
MSC	Message Sequence Charts	vol 2 part F
OPP	Object Push Profile Specification	vol 8 part B
PAN	Personal Area Networking Profile Specification	vol 6 part B
RF	Radio Specification	vol 2 part A

Table 1—Abbreviations of the Bluetooth specification names (continued)

Name	Reference	Placement in Bluetooth specification
RFCOMM	Serial Cable Emulation Protocol based on ETSI TS 07.10	vol 7 part A
SAP	SIM Access Profile Specification	vol 12 part C
SDAP	Service Discovery Application Profile Specification	vol 5 part B
SDP (1)	Service Discovery Protocol Specification (server)	vol 3 part B
SDP (2)	Service Discovery Protocol Specification (client)	vol 5 part A
SPP	Serial Port Profile Specification	vol 7 part B
Synch	Synchronization Profile Specification	vol 8 part D
TCI	Test Control Interface	vol 3 part D, section 2
TCP	Telephony Control Protocol Specification	vol 9 part A
UDI	Unrestricted Digital Information Profile Specification	vol 12 part B

5. General description

5.1 New features

Several new features are introduced in IEEE Std 802.15.1-2005. The major areas of improvement are as follows:

- Architectural overview
- Faster connection
- Adaptive frequency hopping (AFH)
- Extended SCO links
- Enhanced error detection and flow control
- Enhanced synchronization capability
- Enhanced flow specification

These feature descriptions are incorporated into the text within this standard.

5.2 Changes in wording

Two general classes of changes to the wording of IEEE Std 802.15.1-2002 have been done in IEEE Std 802.15.1-2005. They are a conformance to the formalization of the language by using conventions established by the IEEE and a regularization of Bluetooth wireless technology-specific terms.

5.2.1 IEEE language update

Many portions of IEEE Std 802.15.1-2002 used imprecise or inaccurate terms to describe attributes of the protocol. This standard now conforms to the correct usage of the key verbs that describe requirements. Table 2 is a summary of the verbs whose usage was regularized based on the “IEEE Style Guide” [B8].

Table 2—IEEE nomenclature

<i>shall</i>	is required to – used to define requirements
<i>must</i>	is a natural consequence of – used only to describe unavoidable situations
<i>will</i>	it is true that – used only in statements of fact
<i>should</i>	is recommended that – used to indicate that among several possibilities one is recommended as particularly suitable, but not required
<i>may</i>	is permitted to – used to allow options
<i>can</i>	is able to – used to relate statements in a causal fashion
<i>is</i>	is defined as – used to further explain elements that are previously required or allowed
<i>note</i>	<informational text only>

5.2.2 Nomenclature changes

The nomenclature used to describe the protocol has also been changed in IEEE Std 802.15.1-2005. Several terms were used more than once, for different concepts in IEEE Std 802.15.1-2002. The text has been updated to regularize this standard-specific usage. The nomenclature is introduced together with the new features in the new architecture subclause (see 6.2).

5.3 Structure changes

This standard has been significantly restructured for better consistency and readability. The most important structure changes have been performed in BB, Link Manager Protocol (LMP), host controller interface (HCI), and L2CAP. The text in these clauses have been rearranged to provide the following:

- Presentation of the information in a more logical progression
- Removal of redundant text and requirements
- Consolidation of BB-related requirements (e.g., moving the BB timers and audio subclauses into Clause 8 about the BB)

5.4 Deprecated features

As this standard and the Bluetooth specification continue to evolve, some features, protocols, and profiles are replaced with new ways of performing the same function. Often these changes reflect the evolution of the communications industry. Some of the changes merely reflect an evolved understanding of the WPAN environment itself.

The functions no longer recommended are being deprecated. The term *deprecation* does not mean that these functions are no longer allowed, but that they are no longer recommended as the best way of performing a given function.

Features deprecated in IEEE Std 802.15.1-2005 are as follows:

- The use of unit keys for security
- Optional paging schemes
- The 23-channel hopping sequence