IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications

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IEEE Communications Society

Approved 30 September 2010

IEEE-SA Standards Board

Abstract: A standard for high-speed communication devices via electric power lines, so called broadband over power line (BPL) devices, is defined. Transmission frequencies below 100 MHz are used. All classes of BPL devices can use this standard, including BPL devices used for the first-mile/last-mile connection to broadband services as well as BPL devices used in buildings for local area networks (LANs), Smart Energy applications, transportation platforms (vehicle) applications, and other data distribution. The balanced and efficient use of the power line communications channel by all classes of BPL devices is the main focus of this standard, defining detailed mechanisms for coexistence and interoperability between different BPL devices, and ensuring that desired bandwidth and quality of service may be delivered. The necessary security questions are addressed to ensure the privacy of communications between users and to allow the use of BPL for security sensitive services.
Keywords: access devices, adaptive power management, broadband over power lines (BPLs), coexistence protocol (CXP), convolutional turbo code, cosine modulated filter banks, fast Fourier transform orthogonal frequency division multiplexing (FFT OFDM), in-home devices, intersystem protocol (ISP), low-density parity check code (LDPC), medium access control (MAC), power line communication (PLC), physical layer (PHY), privacy, quality of service (QoS), security, sine modulated filter banks, wavelet orthogonal frequency division multiplexing (OFDM)

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PDF: ISBN 978-0-7381-6472-4 STD97024
CDROM: ISBN 978-0-7381-6473-1 STDCD97024

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Introduction

This introduction is not part of IEEE Std 1901-2010, IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications.

This standard was developed on requirements collected from a large diversity of entities (semiconductors, integrators, consumer electronics (CE) companies, utilities, telcos, IT companies, and transportation companies) that participated in the project. It provides a flexible architecture supporting integrated access, Smart Grid, building, in-home, and transportation platforms (vehicle) applications. It addresses a large diversity of topologies. It operates both on alternating (AC) and direct (DC) current lines.

The standard provides efficient medium access control (MAC) procedures that support quality of service (QoS), security, and privacy requirements.

The physical layer (PHY) procedures specify either a wavelet orthogonal frequency division multiplexing (wavelet OFDM) or a fast Fourier transform orthogonal frequency division multiplexing (FFT OFDM) modulation scheme, which are both capable of more than 500 Mbps.

The coexistence procedures allow the fair and efficient coexistence of the broadband over power line (BPL) systems. The intersystem protocol (ISP) enables various BPL systems to share power line communication resources in time (time domain multiplex), in frequency (frequency domain multiplex), or both.

This standard includes diagnostics and management capabilities as needed by the end users.

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IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications

1 Overview

1.1 Scope

The project defines a standard for high-speed (>100 Mbps at the physical layer) communication devices via electric power lines, so-called broadband over power line (BPL) devices. This standard uses transmission frequencies below 100 MHz. It is usable by all classes of BPL devices, including BPL devices used for the first-mile/last-mile connection (<1500 m to the premise) to broadband services as well as BPL devices used in buildings for local area networks (LANs), smart energy applications, transportation platform (vehicle) applications, and other data distribution (<100 m between devices). This standard focuses on the balanced and efficient use of the power line communications channel by all classes of BPL devices, defining detailed mechanisms for coexistence and interoperability between different BPL devices, and assuring that desired bandwidth and quality of service may be delivered. The standard addresses the necessary security questions to provide privacy of communications between users and allow the use of BPL for security-sensitive services. It is limited to the physical layer and the medium access sublayer of the data link layer, as defined by the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Basic Reference Model.

1.2 Purpose

New modulation techniques offer the possibility to use the power lines for high-speed communications. This new high-speed medium is open and locally shared by several BPL devices. Without an independent, openly defined standard, BPL devices serving different applications will conflict with one another and provide unacceptable service to all parties. The standard will provide a minimum implementation subset that allows fair coexistence of the BPL devices. The full implementation will provide interoperability among BPL devices, as well as interoperability with other networking protocols, such as bridging for seamless interconnection via IEEE Std 802.1X™-2010.[1] It is also the intent of this effort to progress quickly toward a robust standard so power

[1] Information on references can be found in Clause 2.

line applications may begin to impact the marketplace. The standard also complies with electromagnetic compatibility (EMC) limits set by national regulators, so as to enable successful coexistence with wireless and telecommunications systems.

1.3 Protocols

The defined protocols provide connectivity over power lines to automatic machinery, equipment, or stations that are connected to power lines, including:

- Functions and services required by an IEEE-1901-conformant device to operate within networks as well as the aspects of station portability (relocation) within those networks.
- Medium access control (MAC) procedures to support the asynchronous MAC service data unit (MSDU) delivery services.
- Physical layer (PHY) signaling techniques and interface functions that are controlled by the IEEE 1901 MAC.
- Operation of an IEEE-1901-conformant device within a power line network that coexists with multiple other overlapping IEEE 1901 power line networks, automatically and without user intervention. Two modes of coexistence operation are defined:
  1) Inter-system protocol (ISP) allows IEEE-1901-conformant devices, ITU-T G.hn devices, and low-rate wideband service devices to coexist.
  2) Coexistence protocol (CXP) allows non–IEEE-1901-conformant devices to coexist with IEEE-1901-conformant devices or non–IEEE-1901-conformant devices.
- Requirements and procedures to enable security, data integrity and confidentiality of user information being transferred over the power line and authentication of IEEE-1901-conformant devices.
- Mechanisms for dynamic notching (DN), dynamic frequency selection (DFS), and transmit power control (TPC).
- Mechanisms for shaping the power spectral density (PSD).
- MAC procedures to support network applications with quality-of-service (QoS) requirements.
- Complete set of variables that govern the conditional requirements of this standard (see Annex A).

1.4 Overview of annexes

This subclause lists all of the annexes contained in this standard:

- Annex A (normative) List of the IEEE 1901 MAC and PHY management variables: provides a list of MAC and PHY management information base (MIB)-capable variables. See IETF RFC 1213.
- Annex B (normative) Optional filters for the bandpass wavelet OFDM: contains some normative tables that were placed in the annexes because of their size.
- Annex C (informative) Beacon-triggered TDMA scheduling examples: provides examples of beacon-triggered, time division multiple access (TDMA) scheduling used for different types of traffic streams.
- Annex D (informative) RSNA reference implementations and test vectors: provides test vectors for robust security network association (RSNA) implementation for pseudo-random function (PRF) and counter mode (CTR) with CBC message authentication code (CBC-MAC) protocol (CCMP).
- Annex E (informative) Integration function: describes an integration service between a non–IEEE-802.3 network and a IEEE 1901 portal and comparison with IEEE 802.1 bridging functionality.

— Annex F (informative) Channel and noise analysis and models for BPL systems: provides informative material regarding BPL channel and noise models.

— Annex G (informative) Priority mapping: provides the recommended mapping between user priority identifiers (IDs) and user applications.

— Annex H (informative) DSN in-home security—user experiences (UEs): describes the typical user experience with IEEE 1901 station (STA) in a basic service set (BSS) implementing a device-based security network (DSN).

— Annex I (informative) DSN in-home security—state transition diagrams: describes a state machine for DSN in-home security and key management.

— Annex J (informative) DSN in-home security—test vectors: provides test vectors for DSN in-home implementation for hashed network membership key (NMK), hashed network identifier (NID) and NMK provisioning management message entry (MME) using device access key (DAK).

— Annex K (informative) Bridging and routing that use 1901 FFT stations as one or more of their portals: provides an explanation and examples for IEEE 1901 end-to-end bridging and station-to-station routing in both in-home and access segments.

— Annex L (informative) FFT parameters: describes FFT parameters for PHY and MAC and multiple networks scenarios for different network modes.

— Annex M (informative) 1901 FFT and TIA-1113 coexistence: describes coexistence between IEEE 1901 FFT STAs and legacy TIA-1113 STAs.

— Annex N (informative) Fair share between 1901 access and 1901 in-home using the same PHY: describes fair medium sharing between the IEEE 1901 access network and the IEEE 1901 in-home network, which are using the same PHY.

— Annex O (informative) 1901 access and 1901 in-home synchronization and interoperability: describes a method for IEEE 1901 access and IEEE 1901 in-home to synchronize on the same PHY scheme for achieving full interoperability.

— Annex P (normative) Optional coexistence protocol: specifies an optional coexistence protocol (CXP) between IEEE-1901-conformant systems and systems that implement only CXP but are not IEEE 1901-conformant.

— Annex Q (informative) Resource request and allocation: describes coexistence resource request and allocation between in-home systems and between in-home systems and access systems.

— Annex R (informative) Resynchronization examples: describes coexistence protocol resynchronization scenarios.

— Annex S (informative) Examples of the coexistence protocol handling hidden node systems: provides examples for coexistence protocol handling of hidden node systems.

— Annex T (informative) Flowcharts of CX Protocol: provides examples of detailed flowcharts for the CXP.

— Annex U (informative) Zero-cross point detection circuit: describes a recommended zero-cross point detection circuit.

— Annex V (informative) Transmit spectrum mask example: shows a transmit spectrum mask example of the upper bound of the power spectral density (PSD).

— Annex W (informative) CDCF signals: description and definition of CXP;s commonly distributed coordination function (CDCF) signal generation and reception

— Annex X (informative) Bibliography: identifies informative references cited in this standard.

2 Normative references

The following referenced documents and URLs are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

FIPS PUB 180-2:2002, Secure Hash Signature Standard (SHS), (including the change notice dated February 25, 2004, concerning truncation).[2]

FIPS PUB 197-2001, Advanced Encryption Standard (AES).

FIPS PUB 198-2002, The Keyed-Hash Message Authentication Code (HMAC).[3]

FIPS SP 800-38A:2001, Recommendation for Block Cipher Modes of Operation—Methods and Techniques.

IEC CISPR 16-1:2003, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1: Radio Disturbance and Immunity Measuring Apparatus.[4]

IEC CISPR 16-1-1:2009, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus —Measuring Apparatus.

IEC CISPR 16-2-1:2005, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 2-1: Methods of Measurement of Disturbances and Immunity—Conducted Disturbance Measurements (withdrawn).

IEC CISPR 22, Information Technology Equipment—Radio Disturbance Characteristics—Limits and Methods of Measurement.

IEEE Std 802™-2001, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.[5,6,7]

IEEE Std 802.1ad™, IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks, Amendment 4: Provider Bridges.

IEEE Std 802.1D™-2004, IEEE Standard for Local and Metropolitan Area Networks Media Access Control (MAC) Bridges.

IEEE 802.1H™-1997 Edition (ISO/IEC TR11802-5:1997), IEEE Technical Report and Guidelines—Part 5: Media Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks.

IEEE Std 802.1Q™-1998, IEEE Standard for Local and Metropolitan Area Network—Virtual Bridged Local Area Networks.

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[2] FIPS publications are available from the National Technical Information Service (NTIS), U.S. Dept. of Commerce, 5285 Port Royal Rd., Springfield, VA 22161, USA (http://www.ntis.org/).

[3] At the time of publication, this document is available at http://csrc.nist.gov/publications/fips/fips198/fips-198a.pdf.

[4] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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