IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

IEEE Power and Energy Society

Sponsored by the
Power System Relaying Committee

and the

Substations Committee

IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

Sponsor

Power System Relaying Committee
and
Substations Committee
of the
IEEE Power and Energy Society

Approved 23 March 2017

IEEE-SA Standards Board

Abstract: An extended profile is specified for the use of Precision Time Protocol of IEEE Std 1588-2008 in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

Keywords: grandmaster clock, IEEE 1588™, IEEE C37.238™, power substation, precise time synchronization, Precision Time Protocol, PTP, sample synchronization, slave-only clock, synchrophasors, transparent clock

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notices and Disclaimers Concerning IEEE Standards Documents." They can also be obtained on request from IEEE or viewed at http://standards.ieee.org/IPR/disclaimers.html.

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE Standards are documents developed through scientific, academic, and industry-based technical working groups. Volunteers in IEEE working groups are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE Standards do not guarantee or ensure safety, security, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

> Secretary, IEEE-SA Standards Board
> 445 Hoes Lane
> Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Xplore at http://ieeexplore.ieee.org/ or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the IEEE 1588 Profile for Power System Applications Working Group had the following membership:

Galina S. Antonova, *Chair*
William Dickerson, *Vice Chair*

Mark Adamiak	Didier Giarratano	R. Jay Murphy
Alex Apostolov	Herb Falk	Markus Renz
Christoph Brunner	Richard Harada	Greg Rzepka
James Bougie	Christopher R. Huntley	Veselin Skendzic
Michael Dood	David M. E. Ingram	Timothy Tibbals
Roman Graf	Hubert Kirrmann	Sergiu Zimath
	Bruce Muschlitz	

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

William Ackerman	Roman Graf	Donald Platts
Mark Adamiak	Randall Groves	Farnoosh Rahmatian
Ali Al Awazi	Ajit Gwal	Michael Roberts
M. Victoria Alonso	James Hackett	Silvana Rodrigues
Galina S. Antonova	Roger Hedding	M. Sachdev
Douglas Arnold	Werner Hoelzl	Bartien Sayogo
Roberto Asano	Yi Hu	Thomas Schossig
Philip Beaumont	Richard Hunt	Maik Seewald
Robert Beresh	C. Huntley	Veselin Skendzic
William Bloethe	David M.E. Ingram	Brian Smellie
Klaus Brand	Innocent Kamwa	John Spare
Gustavo Brunello	Piotr Karocki	Walter Struppler
William Byrd	Yuri Khersonsky	Stefan Svensson
Paul Cardinal	Hubert Kirrmann	David Tepen
Randall Crellin	Jim Kulchisky	Eric Thibodeau
Ratan Das	Marc Lacroix	Timothy Tibbals
William Dickerson	Chung-Yiu Lam	Joe Uchiyama
Michael Dood	John Mackay	Eric Udren
Neal Dowling	Pierre Martin	Benton Vandiver
Denis Dufournet	William McBride	John Vergis
Dan Dwyer	David Mcginn	Stephen Webb
Lee Eccles	R. Murphy	Karl Weber
John Egan	Bruce Muschlitz	Roger Whittaker
Christian Frei	Michael Newman	Philip Winston
Fredric Friend	Lorraine Padden	Oren Yuen
Frank Gerleve	Charles Petras	Daidi Zhong
Jalal Gohari		Sergio Zimath

When the IEEE-SA Standards Board approved this standard on 23 March 2017, it had the following membership:

Jean-Philippe Faure, *Chair*
Gary Hoffman, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams	Thomas Koshy	Robby Robson
Masayuki Ariyoshi	Joseph L. Koepfinger*	Dorothy Stanley
Ted Burse	Kevin Lu	Adrian Stephens
Stephen Dukes	Daleep Mohla	Mehmet Ulema
Doug Edwards	Damir Novosel	Phil Wennblom
J. Travis Griffith	Ronald C. Petersen	Howard Wolfman
Michael Janezic	Annette D. Reilly	Yu Yuan

*Member Emeritus

Introduction

This standard specifies a profile that extends the capabilities of IEC/IEEE 61850-9-3 profile for the use of the IEEE 1588 Precision Time Protocol (PTP) in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

This revision was generated to respond in a timely manner to comments brought forward by IEC Technical Committee 57 Working Group 10 and others after publication of IEEE Std C37.238-2011, as a result of first implementations.

To provide base-level interoperability, IEEE Std C37.238-2011 was divided into a base profile specified in IEC/IEEE 61850-9-3:2016 and the profile that extends the capabilities of the IEC/IEEE 61850-9-3 profile, which is specified in this standard. As a result, this standard is compliant with the IEC/IEEE 61850-9-3:2016 standard.

The following main changes are incorporated into this revision:

— PTP parameters and performance specifications that are part of the base profile were replaced with references to IEC/IEEE 61850-9-3:2016. Refer to 5.2 to 5.11 and Annex B of IEEE Std C37.238-2011.

— Definitions were revisited; some definitions were removed and replaced with references. Refer to 3.1.

— New Clause 5 was added to explain the relationship between different standards, namely IEEE Std 1588-2008, IEC/IEEE 61850-9-3:2016, and this standard.

— The Best Master Clock Algorithm (BMCA) requirement to check for the presence of profile-specific type, length, and value (TLV) was removed, to keep the BMCA as specified in 9.3 of IEEE Std 1588-2008. Refer to 5.12 of IEEE Std C37.238-2011 and new subclause 6.2 of this standard.

  • The field definition in the IEEE_C37_238_TLV was modified while keeping backwards compatibility with the previous version's data fields. Refer to 5.12.2 of IEEE Std C37.238-2011 and new subclause 6.2.1 of this standard.

    — organizationSubType has been changed from 1 to 2.

    — GrandmasterTimeInaccuracy is replaced with Total time inaccuracy.

    — grandmasterID field field's range restriction has been removed (all 16 bits are now usable), for the following reasons:

      — IEC 61850 applications will now be using the 64-bit grandmaster clock identity, so they do not require a short grandmasterID.

      — For applications that use Inter-Range Instrumentation Group B (IRIG-B), keeping this field, with an expansion to 16 bits, provides compatibility with IEEE Std C37.238-2011, a user-settable ID that does not change when the clock's hardware is replaced (see C.4, C.4.2, and D.3.3), and the use of grandmasterID field is now optional (zero if unused).

— The fields of the IEEE 1588 Alternate Time Offset Indicator TLV are clarified for providing the local time. TLV support is mandatory and use is optional. Refer to 6.2.2.

— Description of TimeInaccuracy concept is expanded and terms are redefined for clarity. Refer to 5.13 of IEEE Std C37.238-2011, new subclause 6.3 of this standard, and Clause 3 of IEC/IEEE 61850-9-3:2016.

- Guidance on compatibility with the previous version of this standard is provided in new Annex B.

- Additional guidance is provided on mapping between IEEE Std C37.238 and IRIG-B formats (see Annex C).

- Appropriate changes are made to Annex C and Annex D to include a new profile-specific TLV format.

- Guidance on the use of multiple PTP profiles in a single timing network, particularly, using IEC/IEEE 61850-9-3 slave devices in an IEEE C37.238 network, can be found in Annex E.

Necessary definitions are provided. Typical Ethernet-based time distribution architecture consists of a reference clock, bridges, and end devices. Bridges with boundary clock functionality may also be used at interconnection points between different PTP domains or PTP profiles.

In addition to distributing global time that is traceable to a recognized standard time source, for the cases when connectivity to recognized standard time sources is lost, a timing island is formed. The master clock is now in holdover mode and continues to distribute its time to the local area (all devices receiving the same time can be construed as being on a timing island), with the master clock's ID (64-bit globally unique and 16-bit user-configurable choices are available) allowing verification of which subsequent timestamps may be correctly compared.

The profile can be used for precise time synchronization of the devices in a substation, and between substations in a larger geographical area, if performance requirements of this standard are met.

The use of different physical layer communication technologies to carry Ethernet frames, including SONET/SDH and wireless technologies, is not precluded if they can meet performance requirements of this standard.

Time distribution specified in this standard is based on the following basic assumptions:

- All devices that participate in time distribution support this standard (except that slave devices may be IEC/IEEE 61850-9-3).

- All devices are in the same time distribution domain.

- All devices have point-to-point connections to their neighbors.

- Transmit and receive cable delay for each point-to-point connection is assumed to be symmetrical. Known asymmetry in cable delay can be configured and corrected.

Cyber security is important in power system design. The scope of this standard does not include that topic. However, other standards and works in progress do address these concerns. For instance, the IEEE 1588 Revision Working Group at the time of this publication was actively investigating methods to secure PTP. Other standards regarding this subject include IEEE Std C37.240™, IEEE Std 1686™-2013, and IEC 62351-6.

Redundancy is an important consideration; some applications recommend or mandate support for different time distribution technologies, e.g., Global Positioning System (GPS) and IRIG-B. Support for multiple time distribution technologies at the same time is out of scope for this standard. Redundancy may be provided using this standard (multiple grandmasters and/or diverse network paths) using domains.

Specific environmental requirements are out of scope for this profile. However, devices conforming to this profile may also follow environmental standards such as IEEE Std 1613™ and IEC 61850-3. Vendors are encouraged to provide information regarding the effect of environmental influences on device performance, perhaps including the pass/fail criteria used when determining environmental compliance.

Contents

IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

1. Overview

1.1 Scope

This standard specifies an extended profile for the use of IEEE Std 1588-2008[1] in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

The profile specifies a well-defined subset of IEEE 1588 mechanisms and settings aimed at enabling device interoperability, robust response to network failures, and deterministic control of delivered time quality. It is compliant with IEC/IEEE 61850-9-3:2016, which specifies the preferred physical layer, Ethernet; the higher level protocol used for message exchange, Precision Time Protocol (PTP); and the PTP protocol configuration parameters. Special attention is given to ensuring consistent and reliable time distribution within substations, between substations, and across wide geographic areas. As such, this profile extends IEC/IEEE 61850-9-3:2016 with continuous monitoring of time inaccuracy, and optionally local time based on Coordinated Universal Time (UTC).

1.2 Purpose

The purpose of this standard is to facilitate adoption of IEEE Std 1588-2008 for power system applications requiring high-precision time synchronization. IEC/IEEE 61850-9-3:2016 and this standard specify a common subset of PTP parameters and options to provide global time availability, device interoperability, and failure management. This set of PTP parameters and options allows IEEE 1588-based time synchronization to be used in mission critical power system protection, control, automation, and data communication applications.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the 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.

IEC/IEEE 61850-9-3:2016, Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation.[2]

---

[1]Information on references can be found in Clause 2.
[2]IEC/IEEE publications are available from the International Electrotechnical Commission (http://www.iec.ch) and The Institute of Electrical and Electronics Engineers (http://standards.ieee.org).