

# IEEE Standard for Radio over Ethernet Encapsulations and Mappings

IEEE Communications Society

Sponsored by the  
Mobile Communications Networks Standards Committee

# IEEE Standard for Radio over Ethernet Encapsulations and Mappings

Sponsor

**Mobile Communications Networks Standards Committee**  
of the  
**IEEE Communications Society**

Approved 27 September 2018

**IEEE-SA Standards Board**

**Abstract:** The encapsulation and mapping of radio protocols for transport over Ethernet frames, using radio over Ethernet (RoE), are defined in this standard. Structure-agnostic definitions are provided for any digitized radio data. Structure-aware definitions are provided for the Common Public Radio Interface (CPRI™). Native mode definitions are provided for digitized radio in-phase and quadrature (I/Q) payload.

**Keywords:** IEEE 1914.3™, native RoE, radio over Ethernet, RoE, RoE de-mapper, RoE mapper, structure-agnostic, structure-aware

---

The Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2018 by The Institute of Electrical and Electronics Engineers, Inc.  
All rights reserved. Published 5 October 2018. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

CPRI™ is a trademark of Nokia.

PDF: ISBN 978-1-5044-5038-6      STD23200  
Print: ISBN 978-1-5044-5039-3      STDPD23200

*IEEE prohibits discrimination, harassment, and bullying.*

*For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.*

*No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.*

## **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 US 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. A current 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 10 years. When a document is more than 10 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 IEEE standard was completed, the Next Generation Fronthaul Interface Working Group had the following membership:

**Jinri Huang, *Chair***  
**Abdellah Tazi, *Co-Chair***  
**Richard Tse, *Task Group Chair***  
**Jouni Korhonen, *Former Task Group Chair***  
**Richard Maiden, *Technical Editor***

Khalid Al-Mufti  
Andres Arjona  
Kevin Bross

Lujing Cai  
Aleksandra Checko  
Bomin Li

Vincenzo Sestito  
Stuart Whitehead  
Zhen Zhou

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

Khalid Al-Mufti  
Andres Arjona  
Steinar Bjornstad  
Christian Boiger  
Kevin Bross  
Demetrio Bucaneg Jr.  
Suresh Channarasappa  
Aleksandra Checko  
David Chen  
Keith Chow  
Todor Cooklev  
Rodney Cummings  
Marc Emmelmann  
Yonggang Fang  
Devon Gayle  
Tim Godfrey  
Zhigang Gong  
Randall Groves  
Marco Hernandez  
Werner Hoelzl  
Jinri Huang  
Noriyuki Ikeuchi  
Atsushi Ito  
Raj Jain

SangKwon Jeong  
Piotr Karocki  
Stuart Kerry  
Yongbum Kim  
Jouni Korhonen  
Mark Laubach  
Hyeong Ho Lee  
Hanan Leizerovich  
Bomin Li  
Michael Lynch  
Elvis Maculuba  
Richard Maiden  
Roger Marks  
Jeffery Masters  
John Messenger  
Paul Nikolich  
Robert O'Hara  
Giorgio Parladori  
Bansi Patel  
R. K. Rannow  
Alon Regev  
Maximilian Riegel  
Robert Robinson  
Silvana Rodrigues

Peter Saunderson  
Thomas Starai  
Noel Stott  
Scott Streit  
Walter Struppler  
Bo Sun  
Wu Tao  
Abdellah Tazi  
Richard Tse  
Mark-Rene Uchida  
Alexander Umnov  
Dmitri Varsanofiev  
John Vergis  
Kari Vierimaa  
Khurram Waheed  
Hung-Yu Wei  
Stuart Whitehead  
Scott Willy  
Andreas Wolf  
Jun Xu  
Oren Yuen  
Nader Zein  
Zhen Zhou  
Weihong Zhu

When the IEEE-SA Standards Board approved this standard on 27 September 2018, it had the following membership:

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

Ted Burse  
Guido R. Hiertz  
Christel Hunter  
Joseph L. Koepfinger\*  
Thomas Koshy  
Hung Ling  
Dong Liu

Xiaohui Liu  
Kevin Lu  
Daleep Mohla  
Andrew Myles  
Paul Nikolich  
Ronald C. Petersen  
Annette D. Reilly

Robby Robson  
Dorothy Stanley  
Mehmet Ulema  
Phil Wennblom  
Philip Winston  
Howard Wolfman  
Jingyi Zhou

\*Member Emeritus

## Introduction

This introduction is not part of IEEE Std 1914.3-2018, IEEE Standard for Radio over Ethernet Encapsulations and Mappings.

This standard defines the encapsulation and mapping of radio protocols for transport over Ethernet frames, using radio over Ethernet (RoE). It is an integral part of the IEEE 1914™ family of standards, which facilitates the implementation of key technologies for next generation (5G) cellular services, from a transport networking perspective.

The transport networking solution for these cellular services is expected to provide, at least, the following:

- High link capacity
- High link efficiency
- Load balancing for pooled resources (Cloud-RAN)
- Latency guarantees
- Phase alignment of radio data
- Flexible mapping (e.g., different functional splits of radio data) of radio traffic for transport between radio units, aggregation points, and/or centralized baseband unit pools

Today's transport networking solutions cannot satisfy all these expectations. On the other hand, Ethernet technology has experienced steady and cost-efficient speed and capacity growth, driven by the enterprise, access, and data-center markets, and has inherent characteristics that allow it to satisfy the other expectations.

IEEE Std 1914.3 specifies details that allow Ethernet to partake in the new RoE transport networking solution for 5G cellular services.

## Contents

1. Overview .....	14
1.1 Scope .....	14
1.2 Purpose .....	14
2. Normative references .....	14
3. Definitions, acronyms, and abbreviations .....	15
3.1 Definitions .....	15
3.2 Acronyms and abbreviations .....	15
4. Type conventions .....	16
4.1 General .....	16
4.2 RoE Ethernet type .....	16
4.3 Bit, octet ordering, and numerical presentation .....	17
5. Radio over Ethernet (RoE) .....	17
5.1 General .....	17
5.2 RoE architecture .....	18
5.3 RoE objects .....	21
5.4 RoE traffic types .....	22
5.5 RoE common frame format .....	23
6. Timing and synchronization considerations .....	28
6.1 General .....	28
6.2 General assumptions .....	28
6.3 RoE presentation time .....	28
6.4 Presentation time measurement points .....	29
7. RoE parameters .....	29
7.1 General .....	29
7.2 Parameter introduction .....	29
7.3 Parameter lists .....	30
8. RoE mappers .....	35
8.1 General .....	35
8.2 Structure-agnostic RoE mapper .....	35
8.3 Structure-aware RoE mapper .....	37
8.4 Native RoE time domain packet mapper .....	45
8.5 Native RoE frequency domain packet mapper .....	46
9. RoE control packet header format .....	50
9.1 General .....	50
9.2 OAM TLV control packet .....	51
9.3 Ctrl_AxC control packet .....	54
9.4 VSD control packet .....	54
9.5 Timing control packet .....	55
Annex A (normative) Protocol Implementation Conformance Statement (PICS) proforma .....	57
Annex B (informative) Structure-aware examples .....	65
Annex C (informative) Presentation time usage .....	69
Annex D (informative) Sequence number example code .....	72

Annex E (informative) RoE OAM TLV example .....	74
Annex F (informative) Bibliography .....	75

## List of Figures

Figure 1—Bit ordering and numbering within an octet .....	17
Figure 2—Bit and octet ordering and numbering within a 32-bit double word.....	17
Figure 3—RoE endpoints and supported functions .....	18
Figure 4—RoE nodes and supported functions .....	19
Figure 5—RoE topology examples: a) single point-to-point, b) multiple point-to-point, c) point-to-multipoint, d) chain, e) ring, f) tree .....	20
Figure 6—RoE objects and hierarchy.....	21
Figure 7—RoE encapsulation in Ethernet frames .....	22
Figure 8—RoE encapsulation common frame format—the RoE header.....	23
Figure 9—Sequence number composition .....	25
Figure 10—Format of the timeStamp field.....	27
Figure 11—Presentation time measurement points .....	28
Figure 12—Example of how a CPRI basic frame appears in a structure-agnostic packet: a) originating CPRI basic frame, b) common header (first 8 B in the packet), c) remainder of packet with I/Q samples .....	38
Figure 13—Example mapping CPRI basic frame using structure-aware packet: a) originating CPRI basic frames (total series of four), b) common header (first 8 B in the packet), c) remainder of packet with I/Q samples (assuming total four basic frames of 15-bit samples).....	40
Figure 14—CPRI basic frame and “control process” interaction .....	41
Figure 15—A simple example of CPRI fast C&M transport over native Ethernet .....	42
Figure 16—Example RoE packet for transporting CPRI Slow C&M flow.....	43
Figure 17—Native RoE time domain packet example with I/Q sample payload: a) common header (first 8 B in the packet), b) remainder of packet (only two complete 15-bit i/Q sample pairs are shown) .....	46
Figure 18—Native RoE frequency domain packet example with I/Q sample payload: a) common header (first 8 B in the packet), b) remainder of packet (only two complete 15-bit I/Q sample pairs are shown).....	48
Figure 19—Native RoE PRACH packet example: a) Common header (first 8 B in the packet), b) Remainder of packet (only two complete 15-bit I/Q sample pairs are shown).....	50
Figure 20—RoE control packet common frame format .....	50
Figure 21—OAM TLV packet format .....	51
Figure 22—Basic TLV format.....	51
Figure 23—OAM TLV write control packet (without child ID).....	52
Figure 24—OAM TLV read request control packet for Mapper PRACH parameter values.....	53
Figure 25—OAM TLV read response control packet for Mapper PRACH parameter values .....	53

Figure 26—Timing packet format .....	56
Figure B.1—Packed position AxC Container mapping in the I/Q data block .....	65
Figure B.2—Flexible position AxC Container mapping in the I/Q data block .....	65
Figure B.3—Example of CPRI mapping method #3 .....	66
Figure B.4—Example of using modulo rules and the structure-aware RoE mapper.....	66
Figure B.5—Example of configuration parameter sets.....	67
Figure E.1—RoE OAM TLV Example.....	74

## List of Tables

Table 1—RoE EtherType .....	17
Table 2—subType mapping table .....	22
Table 3—RoE subType values .....	23
Table 4—RoE flowID values.....	24
Table 5—Sequence number related parameters.....	26
Table 6—Object type enumeration.....	30
Table 7—Ethernet link parameters .....	30
Table 8—CPRI port parameters .....	31
Table 9—RoE mapper/de-mapper parameter relevance.....	31
Table 10—RoE mapper parameters.....	32
Table 11—RoE de-mapper parameters.....	34
Table 12—subType mapping object parameters.....	35
Table 13—Parameters under RoE.Container branch.....	38
Table 14—Control process RoE mappers for CPRI control words.....	41
Table 15—CPRI control word RoE mapper container parameters .....	43
Table 16—Subchannel word bit masks .....	44
Table 17—Hyper-frame filtering options .....	44
Table 18—Parameters under mapper[mapperID].[fftID] branch .....	47
Table 19—Parameters mapper[mapperID].[fftID].[PRACH] branch .....	49
Table 20—RoE control packet opCode values .....	50

# IEEE Standard for Radio over Ethernet Encapsulations and Mappings

## 1. Overview

### 1.1 Scope

This standard defines the encapsulation and mapping of radio protocols for transport over Ethernet frames, using radio over Ethernet (RoE). Structure-agnostic definitions are provided for any digitized radio data. Structure-aware definitions are provided for the Common Public Radio Interface (CPRI™). Native mode definitions are provided for digitized radio in-phase and quadrature (I/Q) payload and control data channels.

### 1.2 Purpose

This standard enables the transfer of I/Q user-plane data, vendor-specific data, and control and management (C&M) information channels across an Ethernet-based packet-switched network. The standard fosters interoperability among implementations by defining the framing, the encapsulation of the information, and a common Ethernet Type for RoE purposes.

## 2. Normative references

The following referenced documents are indispensable for the application of this standard (i.e., they must be understood and used; therefore, each referenced document is cited in text, and its relationship to this standard 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.

3GPP Specification TS 36.211, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation.<sup>1</sup>

Common Public Radio Interface (CPRI™) Specification, v7.0.<sup>2,3</sup>

IEEE Std 754™-2008, IEEE Standard for Binary Floating-Point Arithmetic.<sup>4,5</sup>

---

<sup>1</sup>The 3GPP specification is available from the 3GPP Website, <http://www.3gpp.org/specifications/releases>.

<sup>2</sup>The CPRI specification is available from the CPRI Website, <http://www.cpri.info/>.

<sup>3</sup>CPRI is a trademark of Nokia.

<sup>4</sup>IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

<sup>5</sup>The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.