



IEEE Standard for Radio over Ethernet Encapsulations and Mappings

STANDARDS

IEEE Communications Society

Developed by the
Mobile Communications Networks Standards Committee

IEEE Std 1914.3™-2023
(Revision of IEEE Std 1914.3-2018)



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Mobile Communications Networks Standards Committee
of the
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IEEE SA Standards Board

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Abstract: The encapsulation and mapping of radio protocols transported over Ethernet frames and Internet Protocol (IP) packets and the operation of the mappers and de-mappers 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 normal and compressed digitized radio in-phase and quadrature (I/Q) payload. Specifications are provided for parameters, control messages, and mechanisms that help operate, administrate, and maintain the mapping and demapping functions. A management model and a YANG data model are defined.

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

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Introduction

This introduction is not part of IEEE Std 1914.3-2023, 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 control
- 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

Previous generation 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 RoE transport networking solution for 5G cellular services.

This standard was first published as IEEE Std 1914.3™-2018.

IEEE Std 1914.3-2023 makes the following general changes:

- Consistent use of the following terms: native frequency domain mode; native time domain mode; structure-aware mode; structure-aware (frequency domain) mode; structure-aware (time domain) mode; structure-agnostic tunneling mode; structure-agnostic line-coding-aware mode; RoE [mapping or functional type] data or control packet; [mapping mode] RoE mapper or de-mapper.
- A new NOTE after each RoE object parameter table to clarify linkage to the RoE object hierarchy.
- “RoE frame” changed to “RoE packet” in much of the standard, both terms now defined in 3.1.

IEEE Std 1914.3-2023 makes the following specific changes:

- 3.1 revises (RoE object) and adds (Ethernet link, RoE, RoE frame, interface, node, packet) definitions.

- 3.2 adds the following acronyms: DM, FTN, LOA, LOF, LOS, NFD, NTD, PCS, PHY, PM, RE, REC, SAG, SAGT, SAGLC, SAW, SAWTD, SAWFD, SERDES, SFD, UDP.
- 4.3 specifies RoE UDP port numbers supporting UDP/IP encapsulation in the underlying network.
- 5.2.1 assumes the (removed) logical connection for timing (LC_T) is part of that for control (LC_C).
- 5.3.1 describes the relationships of RoE objects in an RoE interface for all RoE mapping modes.
- 5.3.1 also corrects the .cpriID and “SA” ranges (from 0 to n and 0 to m, respectively) in Figure 6.
- 5.3.2 specifies and recommends use of an Ethernet link to connect (only) two RoE interfaces.
- 5.3.3 overhauls the description of RoE (de)mappers.
- 5.3.4 clarifies how a CPRI port relates to an RoE interface and to RoE mapping modes.
- 5.3.5 prefixes “subType mapping object” with “RoE” and clarifies it updating Table 3, linking 7.3.8.
- 5.4 includes a UDP/IP encapsulation option and changes “RoE common frame” to “RoE packet”.
- 5.5.2 adds subType support for RoE delay measurement and extended header to Table 4.
- 5.5.3 links the flow identifier to a flow between RoE mapper and de-mapper instead of two nodes.
- 5.5.5.2 adds optional r-sequence and r-subsequence counters, E-bit (new sequence number type).
- 6.1 improves the description of, and terms used for, RoE time measurement.
- 6.2 introduces message timestamp point options, allows internationally recognized time references.
- 6.3 introduces a presentation time offset parameter and RoE delay measurement.
- 6.4 uses a new heading to better describe its content.
- 7.2.1 clarifies the meaning of default value for a read-only parameter.
- 7.2.2 refines parameter sets and uses “enTLV.enParam” instead of “parameter name”.
- 7.2.3 lists all object parameters tables, adds entries 10 through 23, and deprecates entry 64 in Table 7.⁶
- 7.3.3 clarifies link establishment aspects and changes “Ethernet port” to “Ethernet link” in Table 8.
- 7.3.4 uses “CPRI-like” as needed, and adds entries 8 through 13, 16, 17, and relevant modes to Table 9.
- 7.3.5 extracts parameters relevant to RoE de-mappers from Table 10 to a new Table 11.
- 7.3.5 covers the new structure-aware (frequency domain) mode in Table 10 and Table 11.

⁶ Table 7, Table 8, Table 9, and Table 10 were Table 6, Table 7, Table 8, and Table 9, respectively, in IEEE Std 1914.3-2018.

- 7.3.5 adds entries 11, 64, and 65 to Table 10 and entries 11 and 64 through 66 to Table 11.
- 7.3.6 and 7.3.7 are refined and introduce the new **.numCtrl** parameter in Table 12 and Table 13.
- Table 12⁷ enhances entries 1 through 3, 5, 8, and 33; adds entries 11, 64, and 65; and precedes new NOTE 2 through NOTE 4.
- Table 13 enhances entries 1 through 3, 5, 8, and 33; adds entries 11 and 64 through 66; and precedes new NOTE 2 through NOTE 8.
- 7.3.8 references Annex H, updates Table 14 (including a **.mapSubtype** default), and adds NOTE 1 and NOTE 2.
- 8.1 provides a broader description of all RoE mapper types.
- 8.2.1 now describes PCS and sub-PCS functions for the structure-agnostic line-coding-aware mode.
- 8.2.2 now clarifies the optional use of RoE control packets for structure-agnostic modes.
- 8.3.1 refines its introduction, adds entry 6, and revises entries 0 through 1 in Table 15 to resolve conflicts.⁸
- 8.3.2 updates text⁹ that contradicted the intended concept.
- 8.3.3.5 clarifies CPRI control words handling and I/Q samples as being in the time domain.
- 8.3.5 refines its description and changes “L1+Sync” content in Table 16 and Figure 15.¹⁰
- 8.3.6 is refined and describes L1 inband protocol fields carried in mapper status control packets.
- 8.3.9 is refined and addresses a conflict¹¹ in entry 0 and an error¹² in entry 1 in Table 17.
- 8.4.3 expands the description of control data for the native time domain mode.
- 8.5.2 discusses 5G NR, changes entry 0,¹³ adds entries 6 and 7 in Table 20, and precedes new NOTE 2.
- 8.5.3.1 describes the role that **.flowID** plays in structure-aware (frequency domain) mode.
- 8.5.3.6 describes the role that **.allowRB** plays in structure-aware (frequency domain) mode.
- 8.5.3.6 also describes the ordering of the resource blocks and their I/Q samples in RoE packets.
- 8.5.4 expands the description of control data for the native frequency domain mode.

⁷ Table 12 to Table 21 were Table 10 to Table 19, respectively, in IEEE Std 1914.3-2018.

⁸ The original descriptions for entries 0 and 1 in Table 13 of IEEE Std 1914.3-2018 partly conflicted with statements in that standard. These conflicts are addressed in this standard based on the relationships described in 5.3.1.

⁹ The contradicting text in 8.3.2 of IEEE Std 1914.3-2018 was “the **.flowID** typically equates to an AxC that is placed into separate RoE packets/flows.”

¹⁰ Figure 15 was Figure 14 in IEEE Std 1914.3-2018.

¹¹ The description for entry 0 in Table 17 of IEEE Std 1914.3-2018 contradicted with statements in that standard.

¹² The bits and description for entry 2 in Table 17 of IEEE Std 1914.3-2018 incorrectly indicated a 3-bit mask.

¹³ **.fftID** is unique for a **(de)mapperID** but not necessarily unique over an entire RoE interface.

- 8.5.5 discusses 5G NR including in entries 1 and 2 of Table 21 that changes entry 0¹⁴ and adds entry 4.
- 8.5.6.6 describes the ordering of the subcarriers and their I/Q samples in RoE packets.
- New 8.6 “Structure-aware (Frequency domain) RoE mapper” including new Table 22.
- New 9.2¹⁵ “RoE control object parameters” including new Table 23 and Table 24.
- Table 25¹⁶ enhanced and aligned to cover new material introduced by this revision.
- 9.5.2¹⁷ **flowID** value changed to ALL_ONES for RoE Ctrl_AxC control packets to align with the changes in 8.3.9.
- 9.6.2¹⁸ **flowID** value changed to ALL_ONES for RoE VSD control packets to align with the changes in 8.3.9.
- 9.7.5 is clarified without any intended change to the operation of the RoE timing control packet.
- New 9.8 “RoE loopback control packet (optional)”.
- New 9.9 “RoE mapper status control packet (optional)”.
- New Clause 10 “RoE delay measurement, DM (optional)” and attendant A.2.8.
- New Clause 11 “RoE performance monitoring (PM) counters (optional)” and attendant A.2.9.
- New Clause 12 “Defect monitoring and consequential actions (optional)” and attendant A.2.10.
- New Clause 13 “Support for auto-negotiation (optional)” and attendant A.2.11 and A.2.12.
- New Clause 14 “YANG data model (optional)” and attendant A.2.13.
- A.2.1 adds items UDPT, MA8, MA9, ANEG, and YANG.
- A.2.2.1 adds item DDM and changes items DCM, DNF, DNP, and DFC.
- A.2.2.2 adds items CLP, CMSTAT, and STDBNC and changes items COAM, CAXC, and CVSD.
- A.2.2.3 loses item RES.
- A.2.3.2 adds items PQCNT and RSCNT and changes items SN and TS.
- A.2.4.2 adds items CPP2, CPP3, CPP4, and CPRP and changes items CID, CPP, and CPS.
- A.2.4.3 adds items PRI, TSTMP, and RPATT.
- A.2.6 adds item ALWRB and changes items NRST, NRSF, NRFF, NRPF, NRNP, and RBM.

¹⁴ **.prachID** is unique for a **.(de)mapperID** but not necessarily unique over an entire RoE interface.

¹⁵ Inserted, along with new 9.1, before 9.1 of IEEE Std 1914.3-2018.

¹⁶ Table 25 was Table 20 in IEEE Std 1914.3-2018.

¹⁷ 9.3.2 in IEEE Std 1914.3-2018 is 9.5.2 in this standard.

¹⁸ 9.4.2 in IEEE Std 1914.3-2018 is 9.6.2 in this standard.

- A.2.7.1 changes items CNM1, CSKP, CLEN, and CMOD.
- A.2.7.2 changes item CFTM.
- New A.2.7.3 “FFT conversion for structure-aware (frequency domain) RoE mapper”.
- New A.2.8 “Delay measurement”.
- New A.2.9 “Performance monitoring counters”.
- New A.2.10 “Defect indication and status”.
- New A.2.11 “Auto-negotiation”.
- New A.2.12 “CPRI port performance at REC Proxy and RE Proxy”.
- New A.2.13 “YANG”.
- Annex B adds sequence number parameter settings and changes **mapper[2,3].seqNumPInc**.
- C.3 and C.4 examples add the effects of the **.msgTstmpPoint** and **.presTimeOffset** parameters.
- New Annex F¹⁹ “R-sequence, R-subsequence, and E-bit example operation”.
- New Annex G “Considerations for delay measurement”.
- New Annex H “Examples of organizations using the RoE subType mapping object”.
- New Annex I “Auto-negotiation time considerations”.
- New Annex J “RoE SAG extended header”.
- New Annex K “CPRI port parameters and defects”.

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¹⁹ Annex F in IEEE Std 1914.3-2018 is Annex L in this standard.

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IEEE Standard for Radio over Ethernet Encapsulations and Mappings

1. Overview

1.1 Scope

This standard defines the encapsulation and mapping of radio protocols transported ~~for transport~~ over Ethernet frames and Internet Protocol (IP) packets and the operation of mappers and de-mappers ~~, 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™).²⁰ Native mode definitions are provided for normal and compressed digitized radio in-phase and quadrature (I/Q) payload. Specifications are provided for parameters, control messages, and mechanisms that are used to operate, administrate, and maintain mappers and de-mappers. A management model and a YANG and data model are defined ~~channels~~.

1.2 Purpose

This standard enables the transfer of radio data (e.g., I/Q user-plane data, vendor-specific data, and control and management (C&M) information) ~~channels~~ across an Ethernet and/or IP-based packet-switched network. The standard fosters interoperability among implementations by defining common information formats, information the framing, the encapsulation, operation, administration, and maintenance processes and mechanisms, and management and YANG data models ~~of the information, and a common Ethernet Type for RoE purposes~~.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{21, 22}

²⁰ CPRI is a trademark of the Nokia Corporation in the United States and/or other countries.

²¹ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

²² The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

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

CPRI™ Specification, V7.0.²³

iana-if-type YANG module, Internet Assigned Numbers Authority.²⁴

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

~~Common Public Radio Interface (CPRI™) Specification, v7.0.^{2,3}~~

²³ CPRI publications are available from the Common Public Radio Interface (<http://www.cpri.info/>).

²⁴ The iana-if-type YANG module is available from the Internet Assigned Numbers Authority (<https://www.iana.org/assignments/iana-if-type/iana-if-type.xhtml>).

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

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

~~³CPRI is a trademark of Nokia.~~

IEEE Std 754™-2008, IEEE Standard for Binary Floating-Point Arithmetic. [25](#), [26](#) ^{4,5}

[IEEE Std 802d™, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture—Amendment 1: Allocation of Uniform Resource Name \(URN\) Values in IEEE 802 Standards.](#)

[IEEE Std 802.1AC™, IEEE Standard for Local and metropolitan area networks—Media Access Control \(MAC\) Service Definition.](#)

[IEEE Std 1588™, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.](#)

[IETF RFC 768, User Datagram Protocol.](#)²⁷

[IETF RFC 791, Internet Protocol, Protocol Specification.](#)

[IETF RFC 7950, The YANG 1.1 Data Modeling Language.](#)

[IETF RFC 8200, Internet Protocol, Version 6 \(IPv6\) Specification.](#)

[IETF RFC 8343, A YANG Data Model for Interface Management.](#)

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this [document](#) ~~standard~~, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. ²⁸ ⁶

²⁵ ⁴ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

²⁶ ⁵ The IEEE standards or products referred to in ~~this~~ Clause [2](#) are trademarks [owned by](#) ~~of~~ The Institute of Electrical and Electronics Engineers, [Incorporated](#) ~~Inc.~~

²⁷ RFC publications are available from the Internet Engineering Task Force (<http://ietf.org/>).

²⁸ ⁶ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page. ~~<https://dictionary.ieee.org/>~~

Ethernet link: Ethernet connectivity between two radio over Ethernet (RoE) interfaces.

radio over Ethernet (RoE): The encapsulation and mapping of radio protocols for transport over Ethernet frames, with or without additional Internet Protocol (IP) and user datagram protocol (UDP) encapsulations.

radio over Ethernet (RoE) de-mapper: A de-mapper that performs the task of extracting radio data from Ethernet frames.

radio over Ethernet (RoE) field: A field that refers to a value within an RoE header.

radio over Ethernet (RoE) flow: ~~An~~ Individual connectivity connection, identified by a flow identifier, between ~~an~~ ~~two specific~~ RoE mapper and a corresponding RoE de-mapper ~~nodes~~.

radio over Ethernet (RoE) frame: An RoE packet encapsulated in an Ethernet frame, with or without additional Internet Protocol (IP) and user datagram protocol (UDP) encapsulations.

radio over Ethernet (RoE) interface: The interconnection of a Common Public Radio Interface (CPRI™) (or CPRI-like) port and an Ethernet port using RoE objects.

radio over Ethernet (RoE) mapper: A mapper that performs the task of forming Ethernet frames from radio data sources.

radio over Ethernet (RoE) node: A network element comprising up to 65 536 RoE interfaces.

radio over Ethernet (RoE) object: One of: ~~An RoE mapper, RoE de-mapper,~~ Ethernet link; , Common Public Radio Interface (CPRI™) port; RoE mapper; RoE mapper Fast Fourier transform (FFT); RoE de-mapper; RoE de-mapper , ~~forward and/or~~ inverse Fast Fourier transform (iFFT); RoE mapper/de-mapper container, control function, CPRI control word, defect indication and status, performance monitoring, [(i)FFT] or physical random access channel (PRACH), sequence number, or structure-aware FFT conversion; RoE auto-negotiation; subType mapping ~~function~~.

radio over Ethernet (RoE) packet: The concatenation of an RoE header and its associated RoE payload.

radio over Ethernet (RoE) parameter: A [parameter value](#) that describes how [part of](#) an RoE [object connection](#) operates [and/or that provides state information for an RoE object](#). ~~Parameters are enumerated to facilitate operation, administration, and maintenance (OAM) type-length-value (TLV) control.~~

3.2 Acronyms and abbreviations

1PPS	one pulse per second
AxC	antenna carrier
BFN	Node B frame number
CID	Company ID ~~IEEE company identifier~~
~~C&M~~	~~control and management~~
C-plane	term used in the CPRI Specification v7.0 for the control plane ²⁹
CPRI	Common Public Radio Interface
DA	destination address
DM	delay measurement
E-UTRA	evolved universal terrestrial radio access (3GPP)
eNB	evolved Node B
FCS	frame check sequence
FDD	frequency division duplex
FDV	frame delay variation
FEC	forward error correction

²⁹ [Information on references can be found in Clause 2.](#)

FFT	Fast Fourier transform
FTD	frame transfer delay
FTN	fronthaul transport node
GNSS	Global Navigation Satellite System
HFN	hyper-frame number
HFNSYNC	hyper-frame number synchronized
I	in-phase
iFFT	inverse Fast Fourier transform
(i)FFT	forward and/or inverse Fast Fourier transform
IP	Internet Protocol
I/Q	in-phase and quadrature
LOA	loss of line-code alignment
LOF	loss of frame
LOS	loss of signal
LCC	logical connection for control (packet)
LC _D	logical connection for data (packet)
~~LC_T~~	~~logical connection for timing (packet)~~
LSB	least significant bit
MSB	most significant bit
NFD	native frequency domain mode

NTD	native time domain mode
OAM	operation, administration, and maintenance
OUI	IEEE organizationally unique identifier
PCS	physical coding sublayer
PHY	physical layer
PM	performance monitoring
PPS	pulse per second
PRACH	physical random access channel
PTP	Precision Time Protocol
Q	quadrature
RE	radio equipment REC radio equipment controller
RoE	radio over Ethernet
SA	source address
SAG	structure-agnostic mode
SAGT	structure-agnostic tunneling mode
SAGLC	structure-agnostic line-coding-aware mode
SAP	service access point SAW structure-aware modes
SAWTD	structure-aware (time domain) mode
SAWFD	structure-aware (frequency domain) mode
SERDES	serializer deserializer

[SFD](#) [start of frame delimiter](#)

SoF start of frame

TLV type-length-value

ToD time of day

[UDP](#) [user datagram protocol](#)

UE user equipment

VSD vendor-specific data

4. Type conventions

4.1 General

Within this standard, names of parameters are shown in bold typeface and prefixed with a period, for example, **.seqNumPMax**. Fields names are shown in bold typeface without a prefixed period, for example, **length**. When parameters are described/assigned with their associated RoE object, the RoE object, its index, and the parameter are shown in bold typeface, for example, **mapper[1].destID = 4**. Multiple indexes can be described together by using a comma separator, for example, **mapper[2,3].lenPack = 8**.

4.2 RoE Ethernet type

All RoE packets shall use the EtherType value shown in Table 1 [when encapsulated in an Ethernet frame, without optional IP and UDP encapsulations](#).

Table 1—RoE EtherType

Purpose	EtherType
RoE packet	0xFC3D

4.3 RoE UDP port number (optional)

All RoE packets shall use a dynamic UDP port number from the range shown in Table 2 when encapsulated in an Ethernet frame, with optional IP and UDP encapsulations. How the dynamic UDP port number is assigned is out of the scope of this standard.

Table 2—RoE UDP port number

Purpose	UDP Port Number
RoE packet	a value in the range 0xC000 to 0xFFFF

(New)

4.4 Bit, octet ordering, and numerical presentation

For Ethernet frames, this standard assumes network byte ordering (i.e., most significant byte first ~~big-endian~~). Figure 1 illustrates the bit ordering and numbering within an octet. Similarly, Figure 2 illustrates the bit and octet ordering and the corresponding numbering within a 32-bit double word.

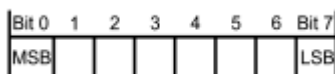


Figure 1—Bit ordering and numbering within an octet

For structure-aware and native RoE mappers, I/Q samples are transported without their bits interleaved.

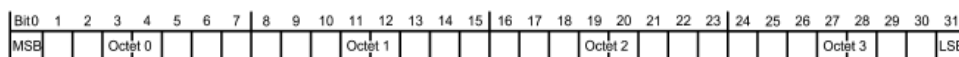


Figure 2—Bit and octet ordering and numbering within a 32-bit double word

The following numerical notations are used in this standard:

- Decimal or base 10 value has no specific notation, for example, 763.

- Hexadecimal or base ~~16~~ 8 value has a prepended “0x”, for example, 0x02FB. Every 4 hexadecimal digits are separated by a space, for example: 0x1 001F.
- Binary or base 2 value has a trailing “b”, for example, 10 1111 1011b. Every 4 binary digits are separated by a space, for example, 1 0000 0000 0001 1111b.
- “~~ALL_ONES~~” is the value with all bits set. This translates to –1 for signed values, 0xFF for 8-bit unsigned values, 0xFFFF for 16-bit unsigned values, etc.

5. Radio over Ethernet (RoE)

5.1 General

This clause describes the ~~RoE encapsulation transport format. Subclauses 5.2 through 5.5 also describe the~~ following [RoE principles](#):

- ~~Overall~~ RoE architecture, [topologies, and networks](#)
- [RoE nodes, interfaces, and objects](#)
- [RoE encapsulations](#)
- [RoE packet format](#)
- ~~Encapsulation and de-encapsulation functions and locations~~
- ~~RoE mapper functions and locations~~
- ~~Underlying assumptions of an RoE-enabled network~~

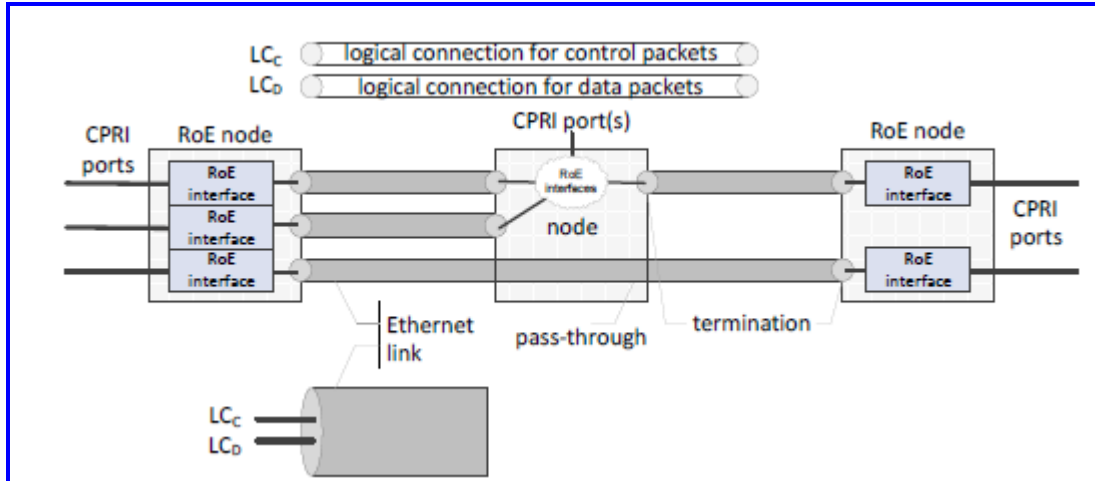
5.2 RoE architecture

5.2.1 General

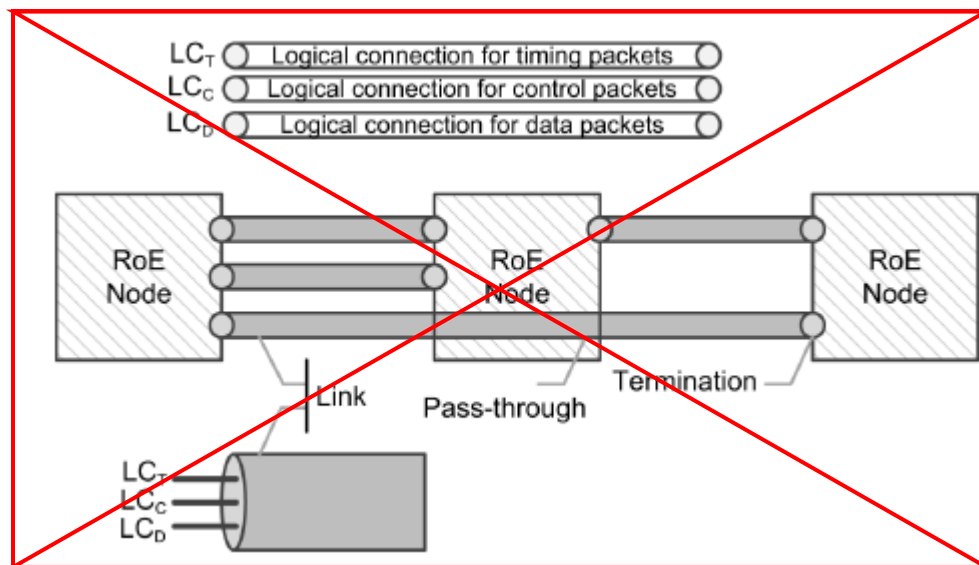
The RoE interface carries ~~two~~ ~~three~~ types of traffic over ~~Ethernet~~ ~~physical~~ links, as ~~described in 5.3.2~~ ~~and illustrated~~ ~~shown~~ in Figure 3. These ~~Ethernet links~~ ~~physical connections~~ carry the following:

- Logical connection for control (LC_C) packets, which carry control ~~and/or CPRI control word~~ information. See ~~8.3.4, 8.3.5, 8.3.6, 8.3.7, 8.3.8, 8.3.9, 8.4.3, 8.5.4, 8.6.3, and~~ Clause 9.
- Logical connection for data (LC_D) packets, which carry I/Q data. See 8.2, 8.3, ~~and~~ 8.4, ~~8.5, and~~ ~~8.6.~~
- ~~— Logical connection for timing (LC_T) packets, which carry timing control information. See 9.5. Note that LC_T is a subset of LC_C.~~

The ~~two~~ ~~three~~ logical connections may be carried over the same physical links or over different physical links. This standard uses ~~the~~ terms *node*, *RoE node*, and *RoE interface*, ~~node, both meaning an RoE-capable networking instance that is either the originator or the receiver of an~~ RoE communication link. ~~RoE nodes can be endpoints, where RoE traffic is terminated, or pass-through points, where the traffic is forwarded to a following node. A given node can support a mixture of~~ ~~terminated~~ and ~~RoE interface~~ are defined in 3.1. A node is a network element that can contain RoE node(s), and hence, RoE interface(s), and/or can be a pass-through or switching/routing point for RoE traffic. As shown in Figure 3, ~~pass-through traffic~~, there may be zero or more intermediate ~~networking~~ nodes, acting as ~~RoE~~ pass-through ~~points or switching/routing points~~, between RoE endpoints, ~~as shown in Figure 3.~~



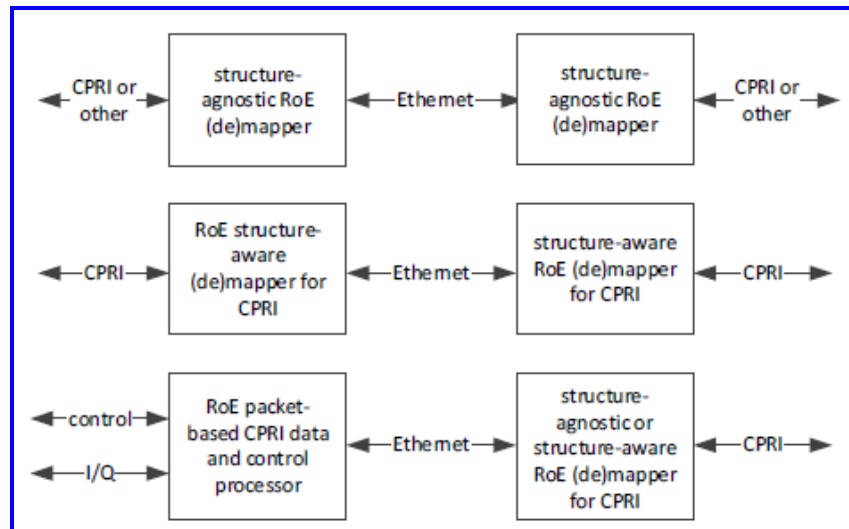
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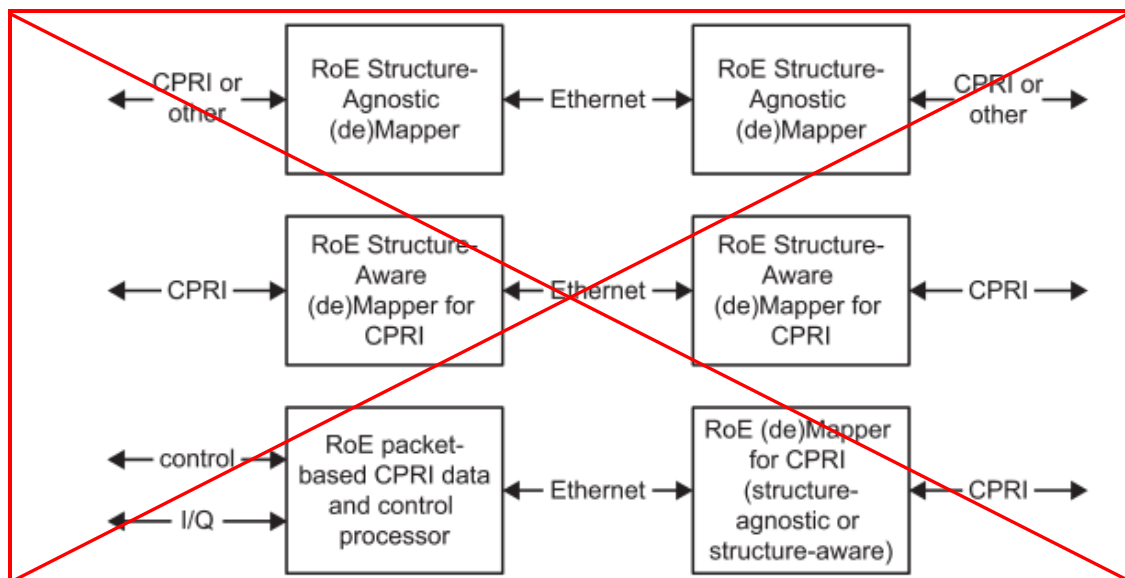
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Figure 3—RoE endpoints and supported functions

This standard supports scenarios where RoE-enabled nodes are connected to traditional legacy CPRI streams nodes and/or endpoints. Some of these scenarios, using the RoE structure-agnostic and CPRI structure-aware RoE mappers, are shown in Figure 4. For the first two scenarios, a the CPRI stream is mapped into RoE by an RoE mapper and then de-mapped back into CPRI regenerated by an RoE de-mapper. In the third scenario, a serial CPRI stream exists only at one end. A packet-based RoE processor, which negates the need for a regenerated serial CPRI stream, exists at the other end.



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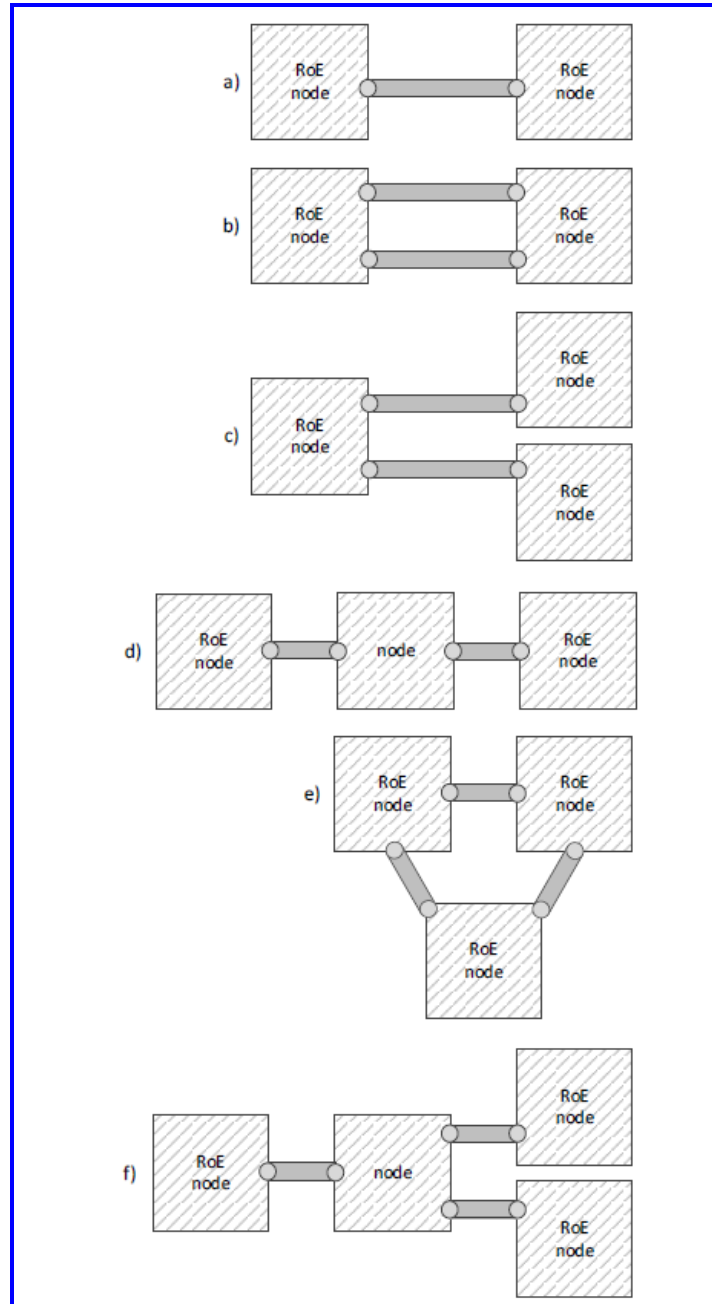


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Figure 4—RoE nodes and supported functions

5.2.2 Topologies

RoE supports many different topologies. Figure 5 shows some examples.



(New)

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

5.2.3 Underlying network (informative)

For RoE to work successfully, the underlying network needs to be provisioned appropriately. While the need for a network that is time sensitive is clear, this RoE specification does not specify how this provisioning is to be achieved. Several other standards, including ITU-T [Recommendation](#) G.8275 [B22 B7] and IEEE Std 802.1CM™-2018 [B9 B3] as amended by IEEE Std 802.1CMde™-2020 [B10], address provisioning.^{30 7} In general, the underlying network [needs](#) ~~will need~~ to fulfill the following requirements:

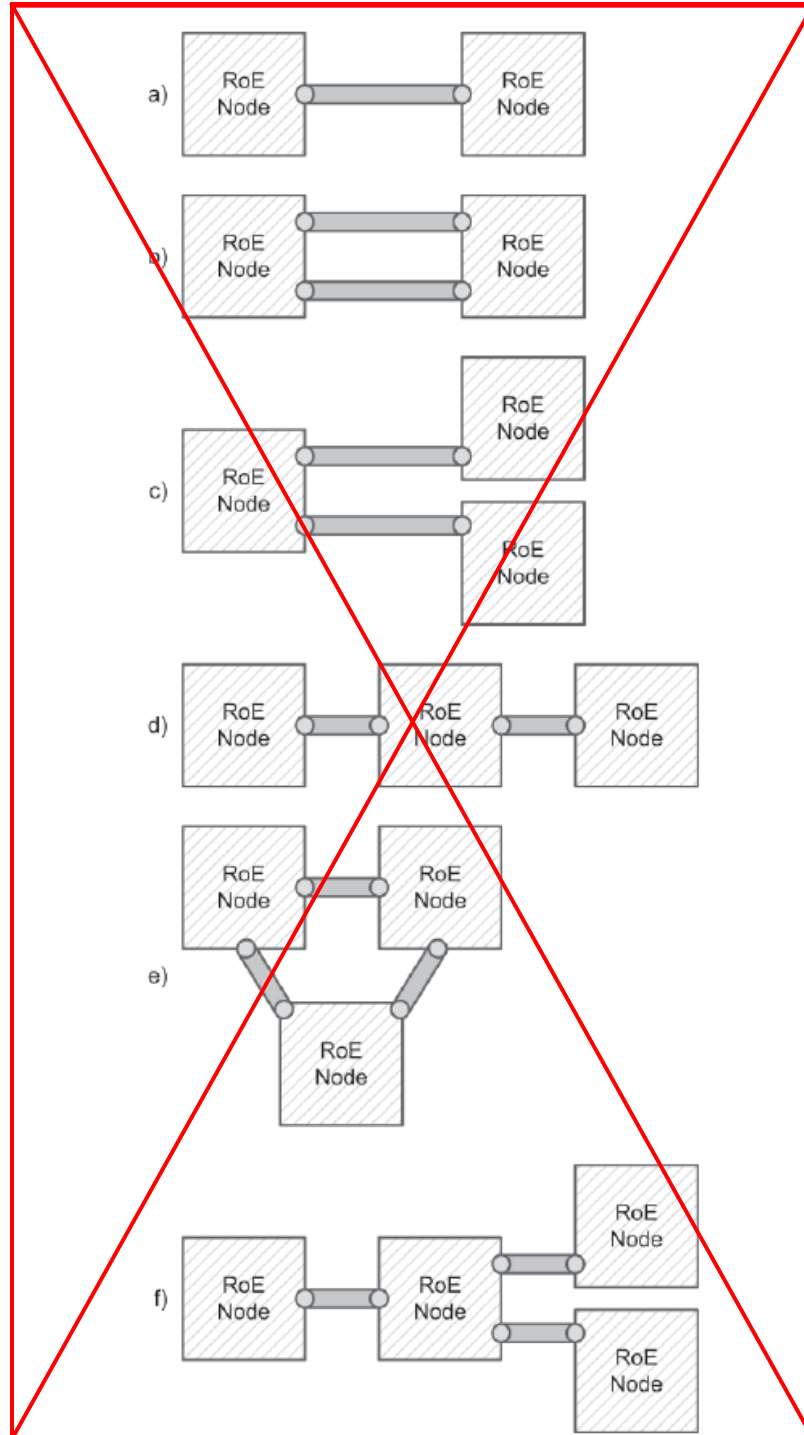
- a) A network comprises bridges/[routers](#) and point-to-point Ethernet links.
- b) The number of actual links and nodes are not specified in this standard; however, the frame transfer delay (FTD) and the frame delay variation (FDV) should meet the application's requirements.
- c) The network [needs](#) ~~will need~~ management for FTD and FDV.
- d) [The](#) managed network should not be oversubscribed (at least for traffic at the same/higher priority as RoE). [The](#) ; network is required to have sufficient bandwidth to carry all the RoE traffic. Peak bandwidth, latencies, and FDV are known in advance.
- e) Time-of-day (ToD) distribution is supported.
- f) Both the transmitting and receiving endpoints need to share the same understanding of the ToD for the information to be presented at the desired time.
- g) No retransmission of RoE traffic is performed.
- h) The maximum one-way transmission time needs to satisfy the application's requirements and needs to be less than the time quantity represented by a presentation time or sequence number in the RoE **orderInfo** field.

³⁰ [The](#) ⁷ numbers in ~~square~~ brackets correspond to [those of the numbers in](#) the bibliography in Annex [L](#) F.

- i) The Ethernet network needs to maintain the frame source address (SA), ~~and~~ destination address (DA), and, if used, VLAN ID (VID).
- j) If the optional IP and UDP encapsulation is used, the IP network needs to maintain the source IP address and destination IP address.

NOTE—The actual method and characteristics of synchronizing RoE nodes are not specified in this standard. Methods such as the Global Navigation Satellite System (GNSS) and IEEE Std 1588~~TM-2008~~ ~~[B5]~~ could be used to synchronize nodes. For example, see the network synchronization requirements and time distribution methods in IEEE Std 1914.1 [B13].^{31 8}

^{31 8}Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.



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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

5.3 RoE nodes, interfaces, and objects

5.3.1 General

An RoE node is a network element comprising up to 65 536 RoE interfaces.

An RoE interface interconnects a CPRI (or CPRI-like) port and an Ethernet port using RoE objects.

The RoE interface is modeled by the YANG data model in Clause 14.

All RoE objects and their identifying enumerations (**enTLV**) are listed in Table 7.

The arrangement of RoE objects in an RoE interface is as follows:

- One RoE object for the CPRI (or CPRI-like) port, identified by **.cpriID**.
 - o Optional auto-negotiation object (only for structure-agnostic and structure-aware modes).
- RoE objects for mapping and de-mapping, as follows:
 - o For structure-agnostic mode (SAG):
 - One RoE (de)mapper, identified by **.(de)mapperID**:
 - Handling a flow (identified by a given **.flowID** value) of RoE data packets carrying the data of the CPRI (or CPRI-like) port.
 - Containing **.numCtrl** control objects, each handling a flow (identified by a **.flowID** of ALL ONES) of optional RoE control packets (i.e., timing control or mapper status control).

- o For structure-aware (time domain) mode (SAWTD):
 - One to 255 RoE (de)mappers, each identified by **.(de)mapperID**, and each:
 - Handling a flow (identified by a given **.flowID** value) of RoE data packets that consist of containers of time domain I/Q data or CPRI control word data from the CPRI port and/or optional flow(s) of RoE control packets (each identified by a **.flowID** value of ALL ONES and an **.opCode** value) that consist of containers of CPRI control word data from the CPRI port.
 - o Each RoE (de)mapper has **.numContainers** container objects.
 - o Of these **.numContainers** container objects, only those that are assigned the given **.flowID** value are (de)mapped as RoE data packets.
 - o Of these **.numContainers** container objects, those that are assigned a **.flowID** value of ALL ONES are passed to the “control process” described in 8.3.4, 8.3.5, 8.3.6, 8.3.7, 8.3.8, and 8.3.9 to handle CPRI Slow C&M, CPRI Fast C&M, Ctrl AxC, and vendor specific data VSD control words and are potentially (de)mapped as RoE control packets.
 - The value of **.numCtrlConts** determines the number of optional RoE Ctrl AxC control packet and/or RoE VSD control packet flows that are (de)mapped by the “control process”.

- o To service all the desired containers from a CPRI port, multiple RoE (de)mappers, each handling a given flow, might be needed.
- Containing **.numCtrl** control objects, each handling a flow (identified by a **.flowID** of ALL ONES) of optional RoE control packets (i.e., timing control or mapper status control).
- o For structure-aware (frequency domain) mode (SAWFD):
 - One to 255 RoE (de)mappers, each identified by **.(de)mapperID**, and each:
 - Handling a flow (identified by a given **.flowID** value) of RoE data packets that consist of FFT objects (where each FFT object is a stream of frequency domain I/O data from one AxC) from the CPRI port and/or optional flow(s) of RoE control packets (each identified by a **.flowID** value of ALL ONES and an **.opCode** value) that consist of containers of CPRI control word data from the CPRI port.
 - o Each RoE (de)mapper has **.numFFT** FFT objects.
 - o Of these **.numFFT** FFT objects, only those that are assigned the given **.flowID** value are (de)mapped as RoE data packets.
 - o Each FFT object in an RoE (de)mapper utilizes a (i)FFT conversion object.
 - o Each RoE (de)mapper has **.numContainers** container objects.

- o Of these **.numContainers** container objects, those that are assigned a **.flowID** value of ALL ONES are passed to the “control process” described in 8.3.4, 8.3.5, 8.3.6, 8.3.7, 8.3.8, and 8.3.9 to handle CPRI Slow C&M, CPRI Fast C&M, Ctrl AxC, and vendor specific data VSD control words and are potentially (de)mapped as RoE control packets.
 - The value of **.numCtrlConts** determines the number of optional RoE Ctrl AxC control packet and/or RoE VSD control packet flows that are (de)mapped by the “control process”.
- o To service all the desired FFTs from a CPRI port, multiple RoE (de)mappers, each handling a given flow, might be needed.

OR

Handling a flow (identified by a given **.flowID** value) of RoE data packets that consist of PRACH objects (where each PRACH object is a stream of PRACH I/Q data from one AxC) from the CPRI port and/or optional flow(s) of RoE control packets (each identified by a **.flowID** value of ALL ONES and an **.opCode** value) that consist of containers of CPRI control word data from the CPRI port.

- o Each RoE (de)mapper has **.numPRACH** PRACH objects.

- o Of these **.numPRACH** PRACH objects, only those that are assigned the given **.flowID** value are (de)mapped as RoE data packets.
- o Each PRACH object in an RoE (de)mapper utilizes a (i)FFT conversion object.
- o Each RoE (de)mapper has **.numContainers** container objects.
- o Of these **.numContainers** containers objects, those that are assigned a **.flowID** value of ALL_ONES are passed to the “control process” described in 8.3.4, 8.3.5, 8.3.6, 8.3.7, 8.3.8, and 8.3.9 to handle CPRI Slow C&M, CPRI Fast C&M, Ctrl AxC, and vendor specific data VSD control words and are potentially (de)mapped as RoE control packets.
 - The value of **.numCtrlConts** determines the number of optional RoE Ctrl_AxC control packet and/or RoE VSD control packet flows that are (de)mapped by the “control process”.
- o To service all the desired PRACH objects from a CPRI port, multiple RoE (de)mappers, each handling a given flow, might be needed.
- Containing **.numCtrl** control objects, each handling a flow (identified by a **.flowID** of ALL_ONES) of optional RoE control packets (i.e., timing control or mapper status control).
- o For native time domain mode (NTD):

- One RoE (de)mapper, identified by **.(de)mapperID**:
 - Handling a flow (identified by a given **.flowID** value) of RoE data packets that carry time domain I/Q data samples from an AxC from the CPRI-like port.
 - Containing **.numCtrl** control objects, each handling a flow (identified by a **.flowID** of ALL ONES) of optional RoE control packets (i.e., timing control or mapper status control).

o For native frequency domain mode (NFD):

- One RoE (de)mapper, identified by **.(de)mapperID**:
 - Handling a flow (identified by a given **.flowID** value) of RoE data packets that consist of FFT objects (where each FFT object is a stream of frequency domain I/Q data from one AxC) from the CPRI-like port.
- o Each RoE (de)mapper has **.numFFT** FFT objects.
- o Of these **.numFFT** FFT objects, only those that are assigned the given **.flowID** value are (de)mapped as RoE data packets.
- o To service all the desired FFT objects from a CPRI-like port, multiple RoE (de)mappers, each handling a given flow, might be needed.

OR

Handling a flow (identified by a given **.flowID** value) of RoE data packets that consist of PRACH objects (where each PRACH object is a stream of PRACH I/Q data from one AxC) from the CPRI-like port.

- o Each RoE (de)mapper has .numPRACH PRACH objects.
- o Of these .numPRACH PRACH objects, only those that are assigned the given .flowID value are (de)mapped as RoE data packets.
- o To service all the desired PRACH objects from a CPRI-like port, multiple RoE (de)mappers, each handling a given flow, might be needed.
- Containing .numCtrl control objects, each handling a flow (identified by a .flowID of ALL ONES) of optional RoE control packets (i.e., timing control or mapper status control).
- o Optional performance monitoring (PM) object that covers each (de)mapper in the RoE interface.
- o Optional defect indication and status object that covers each (de)mapper in the RoE interface.
- One or more RoE objects for the Ethernet link(s), each identified by .ethID and associated with a unique SA/DA pair.

NOTE 1— This standard does not specify how many individual I/Q data streams exist within one CPRI or CPRI-like port.

~~As shown in Figure 6, an RoE node has the following objects:~~

- ~~a) Ethernet link(s). Each has unique SA/DA pairs, and at least one is mandatory for all RoE implementations.~~

- b) ~~RoE mapper/RoE de-mapper. An RoE mapper packetizes data while an RoE de-mapper de-~~
~~packetizes data. Both are mandatory for all RoE implementations. Figure 6 shows objects~~
~~related to RoE mappers/RoE de-mappers.~~
- c) ~~CPRI port(s). CPRI ports are required for structure-aware and structure-agnostic RoE~~
~~mapper.~~

NOTE 2— For structure-agnostic modes, the term *CPRI* (or *CPRI-like*) port is used even if the protocol being mapped/de-mapped is ~~a~~ not CPRI.

NOTE 3— While RoE (de)mappers and flows are mentioned in this subclause as being identified by .(de)mapperID and .flowID, respectively, these identifiers may be used as shortcuts in the remainder of this standard to refer to these RoE (de-)mappers or flows. This is to allow more concise descriptions.

An example of an RoE node, with multiple CPRI ports, multiple Ethernet links, and corresponding RoE (de)mappers, is shown in Figure 6.

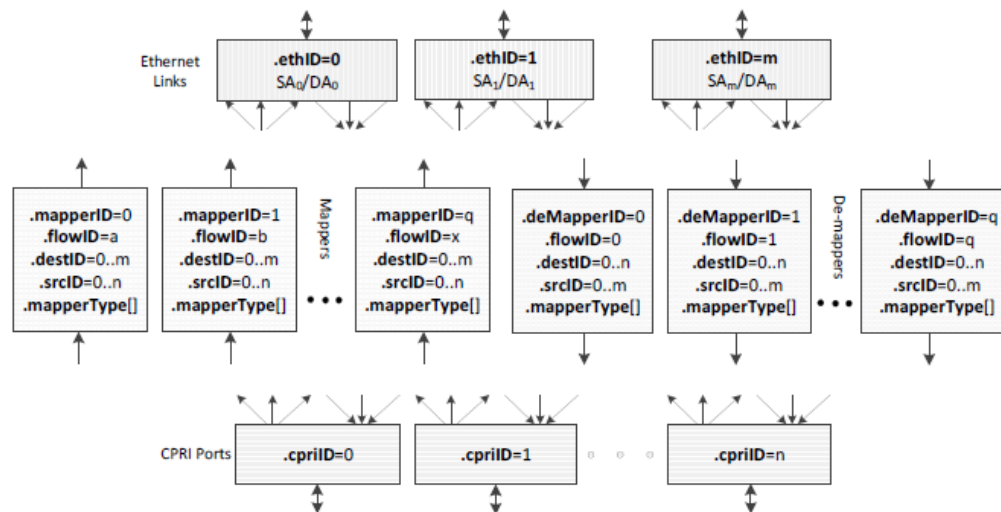


Figure 6— Example of RoE node, objects, and hierarchy

5.3.2 Ethernet link

In this standard, an Ethernet link is [Ethernet connectivity between only two RoE interfaces. In each direction between two RoE interfaces, an Ethernet link is associated](#) ~~defined as a connection~~ with a particular SA and DA. An RoE [interface is connected to an Ethernet port and terminates](#) ~~node shall have~~ at least one Ethernet link. An Ethernet link can accept (and provide) packets of data from multiple flows and RoE mappers. Ethernet links are assumed to be bidirectional; however, this standard does not preclude the option for just one direction to be used.

5.3.3 RoE mappers/RoE de-mappers

An RoE mapper is a function/process that converts other transport framing formats [into to an RoE packets framing format](#), and an RoE de-mapper performs the opposite function. ~~This specification describes different flavors of RoE mappers. Structure-aware and native RoE mappers separate control data and sample data into different channels. Control data is fed to a block known as the “control process” in this specification (see 8.3.4). On the RoE de-mapper direction, the RoE control packets received by the control process are fed to RoE demappers with the .flowID set to ALL_ONES flowID and the .deMapperID set to appropriate values by the control process.~~

The chief function of an RoE mapper is to select the appropriate input data from the input data stream (e.g., a CPRI port) and ~~then~~ packetize it. [RoE mappers also generate or select control information and packetize it.](#) The RoE mapper [is](#) also ~~generates or selects control information.~~ ~~Individual subclauses in this specification describe the operation of RoE mappers and RoE de-mappers. The RoE mapper is~~ responsible for generating the [RoE packet's](#) ordering information. [This](#) ~~The functionality of the~~ ordering information is described in 5.5.5.

[This standard describes different types of RoE mappers.](#)

- Structure-agnostic RoE mappers [encapsulate](#) ~~do not have control packets because~~ the entire [CPRI \(or CPRI-like\)](#) data stream (including [CPRI](#) control [word](#) information) [into is encapsulated as](#) a single LCD data channel [with an identifying flowID.](#)

- Structure-aware RoE mappers separate CPRI control word data and time domain or frequency domain I/Q data into different channels, each with an identifying flowID. The CPRI control word data are fed to a block known as the “control process” in this specification (see 8.3.4) and are identified by an ALL ONES flowID.
- Native RoE mappers encapsulate individual time domain or frequency domain I/Q data streams into individual channels, each with an identifying flowID.

For all these mappers, RoE-layer control information (e.g., parameter read/write, timing, loopback, mapper status) can be mapped into RoE control packets and are identified by an ALL ONES flowID.

RoE packets with an ALL ONES flowID are fed to control RoE de-mappers and then to appropriate control processes. RoE data packets are fed to corresponding data RoE de-mappers to recover the radio data.

Individual subclauses in this standard describe the operation of the different RoE mappers and RoE de-mappers.

5.3.4 CPRI ports

CPRI (or CPRI-like) ports are physical interfaces ~~connections. In structure-aware and structure-agnostic mapping modes,~~ An RoE node has one or more CPRI (or CPRI-like) ports. An RoE interface has one CPRI (or CPRI-like) port. In structure-aware (see 8.3 and 8.6) modes, this CPRI port carries a CPRI stream. In structure-agnostic (see 8.2) mapping modes, this CPRI (or CPRI-like) port can carry a CPRI stream or a stream of another protocol. In native time domain (see 8.4) and native frequency domain (see 8.5) mapping modes, the CPRI-like port could, for example, be passing an I/Q data stream. CPRI (or CPRI-like) ports are assumed to be bidirectional.

5.3.5 [RoE](#) subType mapping object

The [RoE](#) subType mapping object ([.mapSubtype](#)) is ~~a table~~ used to maintain and assign mapped [RoE](#) subTypes (as specified in Table [3 2](#)) from the RoE subtype space to particular organizationally unique identifier (OUI) or Company [ID identifier](#) (CID) [assignees entities](#) and their specified subType/payload [formats structures](#). RoE [\(de\)mappers nodes](#) process mapped subTypes, the corresponding payload [format structure](#), and [the](#) optional reserved bits in [seqNum](#) as specified by the [organization holding the](#) OUI or CID [assignment entity](#).

OUI [and](#) ~~or~~ CID values are obtained through IEEE registration. ³² ~~An implementation can pre-populate the mapping table with implementation specific default values. Unused/un-mapped OUI/CID subTypes are indicated by setting the .mapSubtype bits 15 to 0 to ALL_ONES.~~

[See 7.3.8 for more information on the .mapSubtype parameters.](#)

Table 3—[RoE](#) subType mapping [object table](#)

RoE subType	RoE subType mapping object (.mapSubtype)	
	OUI/CID value (3 bytes) bit39 bit16	Payload format identification value (2 bytes) bit 15 bit0
128–191	The OUI or CID value held by the organization that is defining this RoE subType mapping	The identification value, assigned by the organization, for the payload format that is associated with this RoE subType mapping. An ALL_ONES value indicates that the RoE subType is not defined by the corresponding RoE subType mapping object.

[\(New\)](#)

RoE subType	OUI/CID subType mapping table (.mapSubtype)	
	OUI/CID mapping (3 B) bit39	Payload structure mapping (2 B) bit0
128–191	OUI/CID identifier	payload structure identifier

~~(Deleted)~~

³² [The IEEE Registration Authority provides a tutorial \[B7\] explaining OUIs and CIDs and providing guidelines for their use.](#)

5.4 RoE encapsulations traffic types

RoE packets are encapsulated in Ethernet frames with or without optional IP and UDP encapsulations.

An RoE packet that is encapsulated in an Ethernet frame without optional IP and UDP encapsulations is shown in Figure 7. Note that the basic Ethernet frame format shown in Figure 7 is not necessarily representative of how an Ethernet frame is transported. For example, the VLAN tag defined in IEEE Std 802.1Q might be added.

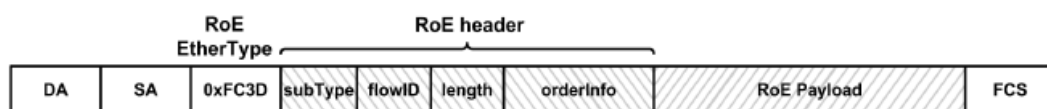
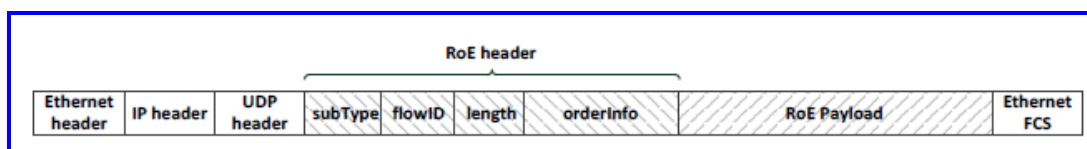


Figure 7—RoE packet encapsulation in an Ethernet frame without optional IP and UDP encapsulations frames

RoE frames are encapsulated in Ethernet frames as shown in Figure 7. For this standard, the SA, DA, and frame check sequence (FCS) are implicit to all RoE frames packets. The RoE EtherType value is specified in 4.2. This standard focuses on the fields contained in the RoE header and RoE payload which, together, constitute an RoE packet fields.

An RoE packet that is encapsulated in an Ethernet frame with optional IP and UDP encapsulations is shown in Figure 8. Note that the basic Ethernet frame format shown in Figure 8 is not necessarily representative of how an Ethernet frame is transported. For example, the VLAN tag defined in IEEE Std 802.1Q might be added.



(New)

Figure 8—RoE packet in an Ethernet frame with optional IP and UDP encapsulations