eCPRI Specification V2.0 (2019-05-10)

Interface Specification

Common Public Radio Interface: eCPRI Interface Specification

Table of Contents

1. Introduction

The Common Public Radio Interface (CPRI) is an industry cooperation aimed at defining publicly available specifications for the key internal interface of radio base stations, such as eCPRI connecting the eCPRI Radio Equipment Control (eREC) and the eCPRI Radio Equipment (eRE) via a so-called fronthaul transport network. The parties cooperating to define the specification are Ericsson AB, Huawei Technologies Co. Ltd, NEC Corporation and Nokia.

<u>Motivation for eCPRI:</u>

Compared to CPRI [1], eCPRI makes it possible to decrease the data rate demands between eREC and eRE via a flexible functional decomposition while limiting the complexity of the eRE.

<u>Scope of Specification:</u>

The necessary items for transport, connectivity and control are included in the specification. This includes User Plane data, Control and Management Plane transport mechanisms, and means for synchronization.

The eCPRI specification supports 5G and enables increased efficiency in order to meet the needs foreseen for 5G Mobile Networks. In contrast to CPRI, the eCPRI specification supports more flexibility in the positioning of the functional split inside the Physical Layer of the cellular base station.

The scope of the eCPRI specification is to enable efficient and flexible radio data transmission via a packet based fronthaul transport network like IP or Ethernet. eCPRI defines a protocol layer which provides various - mainly User Plane data specific - services to the upper layers of the protocol stack.

The specification has the following scope (see Figure 1, Figure 1A and Figure 1B):

1. The internal radio base station interface establishing a connection between "eCPRI Radio Equipment Control" (eREC) and "eCPRI Radio Equipment" (eRE) via a packet based transport network is specified.
2. Three different information flows (eCPRI User Plane data, C&M Plane data, and Synchronization Plane data) are transported over the interface.
3. The specification defines a new eCPRI Layer above the Transport Network Layer. Existing standards are used for the transport network layer, C&M and Synchronization.

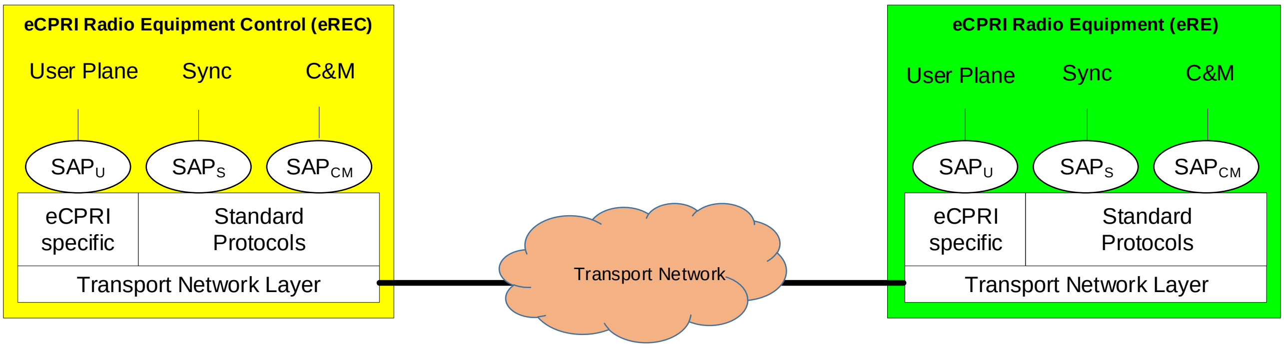


Figure 1: System and Interface Definition

The eCPRI interface can also be used between two eRECs or between two eREs as well as with Interworking Function(s) (IWF) located between the eCPRI transport network and one/several CPRI node(s).

In Figure 1A the Interworking Function is located between the eCPRI transport network and one/several CPRI RE node(s). The SAPs shall be terminated at both eCPRI and CPRI ends and bridged to each other via vendor specific functionality. For this configuration IWF type 0 is used.

In Figure 1B the Interworking Functions are located between the respective CPRI nodes and the transport network. The Interworking Functions bridge the CPRI link over the Fronthaul Transport Network. For this configuration IWF type 1 and type 2 are used.

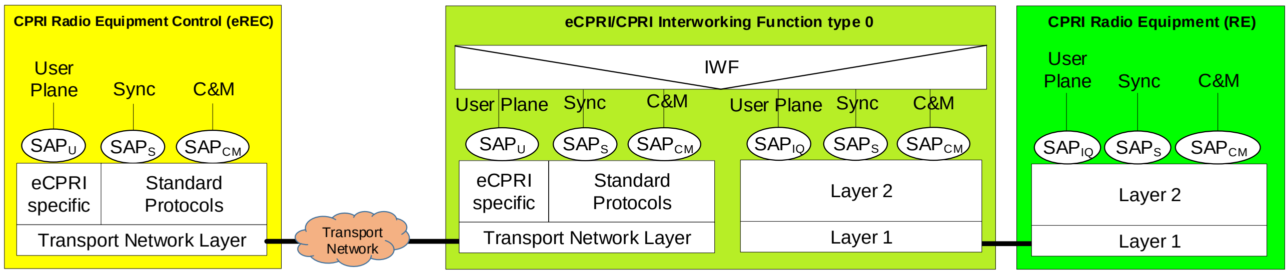


Figure 1A: System and Interface Definition with eCPRI/CPRI IWF type 0

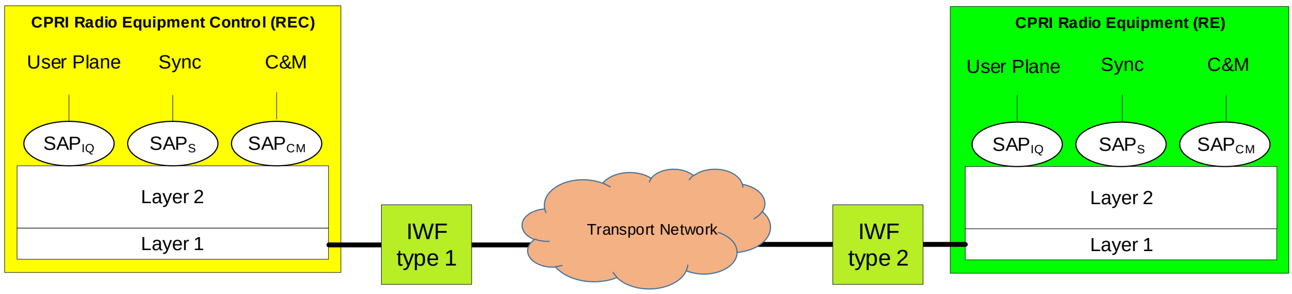


Figure 1B: System and Interface Definition with eCPRI/CPRI IWF type 1 and type 2

2. System Description

This section describes the eCPRI related parts of the basic radio base station system architecture and defines the mapping of the functions to the different nodes. Furthermore, the reference configurations and the basic nomenclature used in the following sections are defined.

The following description is based on the Evolved UMTS Terrestrial Radio Access (E-UTRA) and 5G (NR). However, the interface may also be used for other radio standards.

2.1. Definitions/Nomenclature

This section provides the basic nomenclature that is used in the following sections.

eCPRI node:

The radio base station system is composed of two basic eCPRI nodes, the eCPRI Radio Equipment Control and the eCPRI Radio Equipment (see Figure 1). The eCPRI Radio Equipment Control and the eCPRI Radio Equipment are described in the following chapter. The radio base station system shall contain at least two eCPRI nodes, at least one of each type: eREC and eRE.

eREC / eRE element:

A hardware or software component within an eCPRI node which alone does not constitute a full eCPRI node.

Protocol planes:

The following planes are outlined:

C&M Plane:	Control and Management data flow for the operation, administration and maintenance of the nodes.
User Plane:	Three data flows covered by the User Plane: a) Data flow to be transferred from the radio base station to the User Equipment (UE) and vice versa. b) Real time control data related to a). c) Other eCPRI flows not covered by other protocol planes/flows.
Synchronization Plane:	Data flow for synchronization and timing information between nodes.

eCPRI Protocol Layer:

A Protocol Layer defined by this specification and providing specific services to the upper layers.

Service Access Points:

For all protocol planes except Connection OAM, service access points are defined. These service access points are denoted as SAP_{CM}, SAP_S and SAP_U as illustrated in Figure 1. A service access point is defined on a per logical connection basis.

Logical connection:

A “logical connection” defines the interconnection between SAPs (e.g., SAP_U) across peered eCPRI nodes.

Grandmaster Clock (GM):

Reference clock of a Precision Time Protocol-based Transport network. The GM can be located in the network as well as in the eREC or eRE.

Downlink:

Direction from eNB/gNB to UE.

Uplink:

Direction from UE to eNB/gNB.

Service:

Method to access one or more functionalities via the eCPRI protocol. This method typically involves the transmission/reception of eCPRI messages.

Figure 2 illustrates basic definitions related to service access points.

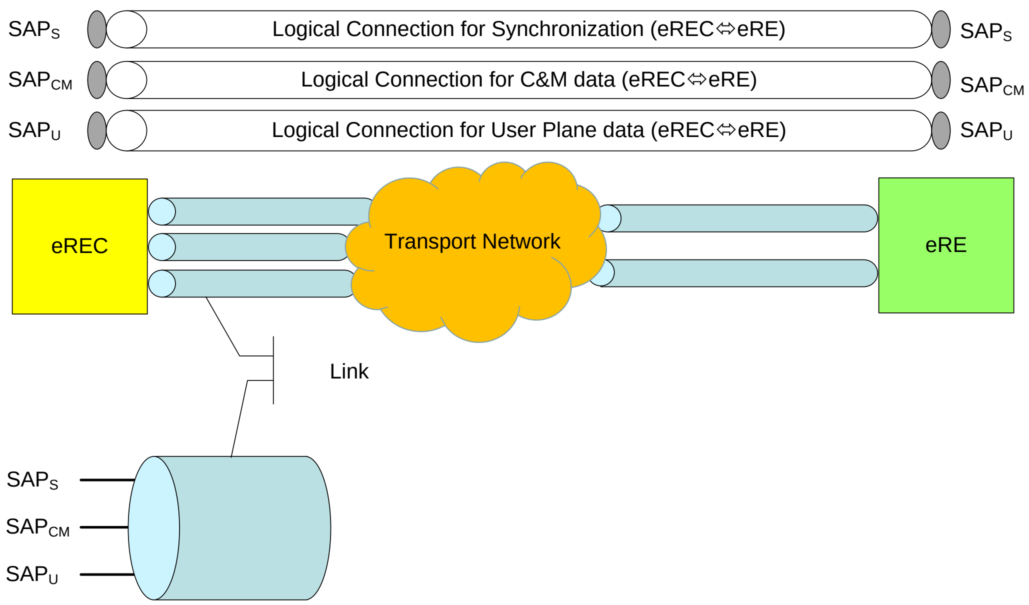


Figure 2: Illustration of basic definitions

eCPRI/CPRI Interworking Function (IWF):

A function providing a bridge between eCPRI and CPRI nodes. The protocol for both eCPRI and CPRI shall be terminated within the IWF and bridged to/from each other. Three types of IWF are defined:

Type 0:

Used in an “eREC ↔ Fronthaul ↔ **IWF type 0** ↔ RE” configuration.

Type 1:

Used in an “REC ↔ **IWF type 1** ↔ Fronthaul ↔ IWF type 2 ↔ RE” configuration, connected to an REC.

Type 2:

Used in an “REC ↔ IWF type 1 ↔ Fronthaul ↔ **IWF type 2** ↔ RE” configuration, connected to an RE.

Interworking Function type 0 is described in sections 6.5.2 and 7, and types 1 and 2 in sections 6.5.3 and 8.

CPRI master port for IWF type 0:

The “CPRI master port for IWF type 0” is fully equivalent to “CPRI master port” described in section 2.1 of the CPRI specification [1] and shall comply with all requirements for CPRI master ports stated in the CPRI specification [1].

CPRI slave port for IWF type 1:

The “CPRI slave port for IWF type 1” is connected to and interacts with a “CPRI master port” and behaves as a “CPRI slave port” when IWF type 1 and 2 are configured as described in this eCPRI specification. However, the configuration and function of the “CPRI slave port for IWF type 1” itself is not equivalent to a “CPRI slave port” and may not behave as a “CPRI slave port” unless operating in conjunction with the IWF type 2 and RE.

CPRI master port for IWF type 2:

The “CPRI master port for IWF type 2” is connected to and interacts with a “CPRI slave port” and behaves as a “CPRI master port” when IWF type 1 and 2 are configured as described in this eCPRI specification.

However, the configuration and function of the “CPRI master port for IWF type 2” itself is not equivalent to a “CPRI master port” and may not behave as a “CPRI master port” unless operating in conjunction IWF type 1 and REC.

2.2. System Architecture

Radio base stations should offer deployment flexibility to mobile network operators, i.e., in addition to an all-in-one radio base station, more flexible radio base station system architectures involving remote radio equipment shall be supported. This may be achieved by a decomposition of the radio base station into two basic building blocks, the so-called eCPRI Radio Equipment Control (eREC) and the eCPRI Radio Equipment (eRE). Both parts may be physically separated (i.e., the eRE may be close to the antenna, whereas the eREC is generally located in a conveniently accessible site) and connected via a transport network.

Typically, the eREC contains part of the PHY layer functions and higher layer functions of the air interface, whereas the eRE contains the other part of the PHY layer functions and the analog radio frequency functions. The basic idea of the functional split between both parts is described in section 2.3.1. Several examples of functional splits are described in informative Annex 6.1.

User Plane data (i.e. information flows between split PHY layer functions in eREC and eRE and their real-time control), control and management and synchronization signals are packetized, multiplexed and transferred over the transport network (fronthaul network) which eREC(s) and eRE(s) are connected to.

eCPRI does not constrain the use of network-layer and data link-layer protocols to form the network, so any type of network can be used for eCPRI provided eCPRI requirements (defined in [15]) are fulfilled. eCPRI also uses existing de-facto/de-jure standard protocols as much as possible where available. The basic idea is illustrated in Figure 1.

Figure 3 shows an example of a system architecture with local eCPRI. eCPRI is used as an internal interface within the eREC and/or eRE (local eCPRI) when the eREC/eRE consists of multiple eREC/eRE elements. In addition, eCPRI and CPRI can coexist in a system. Please note that eCPRI has no backward compatibility with CPRI.

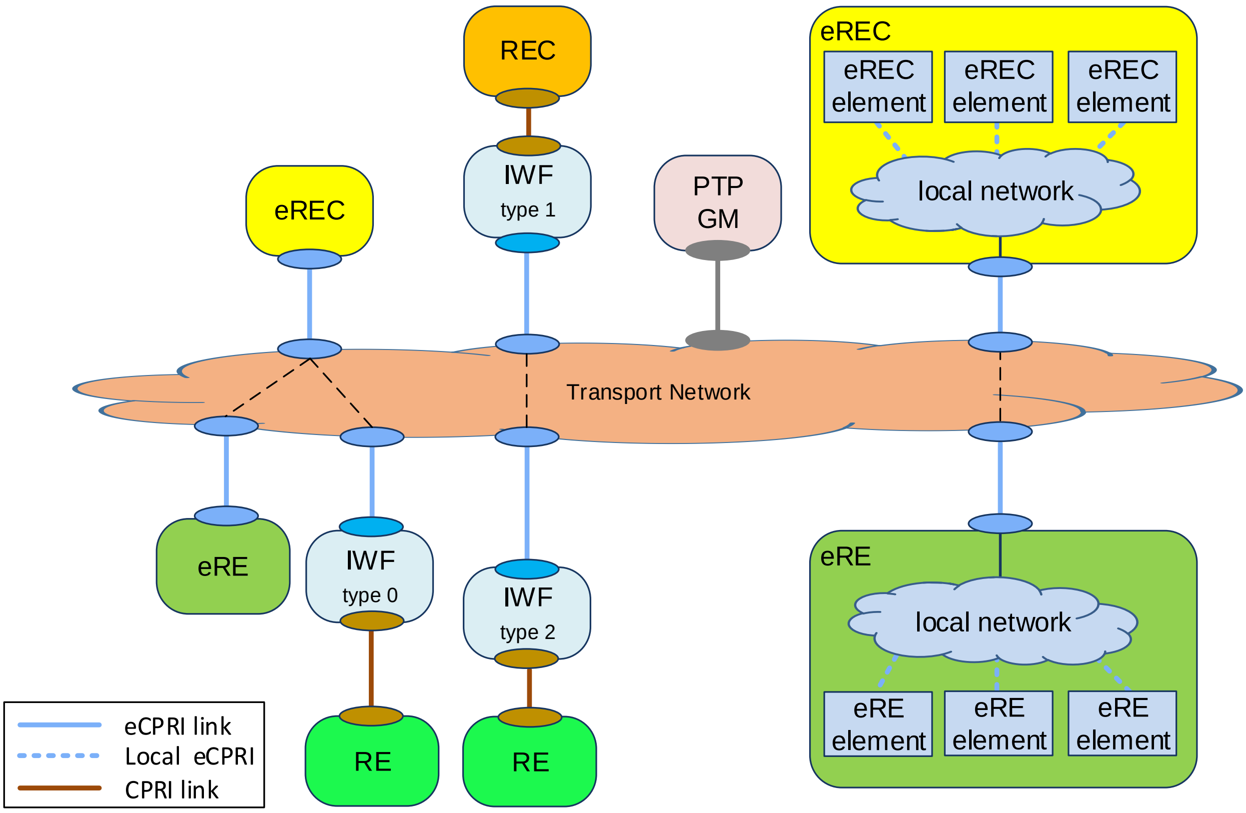


Figure 3: System Architecture example with local eCPRI and IWF types 0, 1 and 2

The eCPRI/CPRI Interworking Functions type 0, 1 and 2 are also illustrated in Figure 3. IWF type 0 allows connection of an RE as if it was an eRE (from the eREC viewpoint). Similarly, it provides REC functionality (from the RE viewpoint). IWF types 1 and 2 combined provide a logical connection between REC and RE nodes.

2.3. Functional Description

This section provides a description of the functional content of an eNB/gNB. The CPRI concept of a radio base station divided into two nodes, one called REC (Radio Equipment Control) and the other called RE (Radio Equipment) is still valid for eCPRI but with the small change of renaming the two nodes to eREC and to eRE. The functional split across these two nodes can be outlined more flexibly than in the CPRI specification. The functional content of an eNB/gNB (eREC and eRE) is listed in Table 1, references to corresponding 3GPP Technical Specifications are included in the table.

Table 1: Functional content of eNB/gNB

Functions and Protocol Stack of eNB/gNB eREC + eRE	3GPP eNB Reference TS 36.nnn [2]	3GPP gNB Reference TS 38.nnn [3]
Radio Base Station Control & Management	-	-
Backhaul transport	-	-
RRC (Radio Resource Control)	331	331
PDCP (Packet Data Convergence Protocol)	323	323
RLC (Radio Link Control)	322	322
MAC (Medium Access Control)	321	321
PHY (Physical)	201 (General description)	201 (General description)
RF (Radio Functions)	104	104, 133
Measurements	214, 314	215

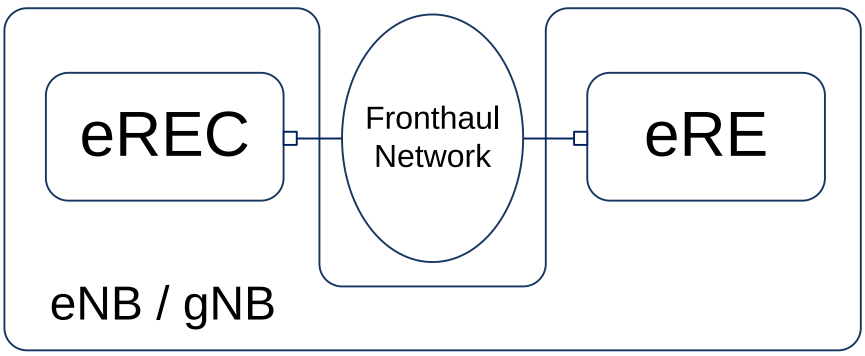


Figure 4: Fronthaul Network definition

Regardless of which functional decomposition between eREC and eRE is selected for a specific implementation, the “Fronthaul Network” is the interface between the two eCPRI nodes eREC and eRE.

The different functions listed in Table 1 can be located either in the eREC or in the eRE. When using eCPRI for either existing or forthcoming radio standards such as the 3GPP 5G (NR) the functional decomposition between eREC and eRE depends on vendor specific choices. Different implementations will be targeting different objectives (radio performance, fronthaul performance adaptions, feature necessity circumstances etc.) leading to a different functional decomposition between eREC and eRE.

2.3.1. Functional Decomposition

Figure 5 shows the protocol stack layers for a 3GPP 4G (LTE) or 5G (NR) radio base station. Five inter-layer functional splits numbered A to E are depicted in the figure. One additional set of intra-PHY splits named "$\{I_D;II_D;I_U\}$" is also shown. For more details of the intra-PHY splits refer to section 6.1.1.

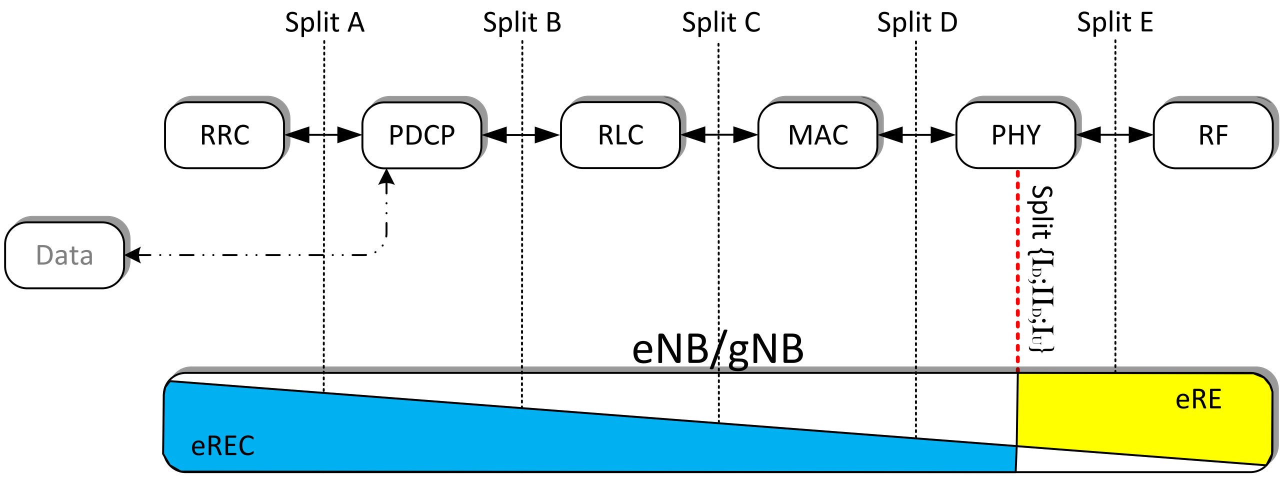


Figure 5: Functional decomposition on RAN layer level

As shown in Figure 5 the eNB/gNB consists of only two units: the eREC and the eRE. For some of the splits an implementation with only two nodes may not be realistic. For instance, Split A with a central RRC and a distributed unit containing the rest of the protocol stack would not support a number of features (such as those requiring cell-coordination) efficiently. eCPRI assumes that the eNB/gNB consists of eREC and eRE(s) only and thus the following text should be read with this in mind. The intra PHY Split is marked with a red line, this is just an example showing how the figure shall be interpreted, the blue and yellow colored areas in a eNB/gNB show what parts are located in eREC and eRE.

The CPRI specification [1] functional decomposition-split for E-UTRA corresponds to split E.

The advantages of the intra-PHY-split are: features such as Carrier Aggregation, Network MIMO, Downlink CoMP, Uplink L1 Comp Joint Processing can be efficiently supported. Some of these features might of course be supported by other splits as well.

Some disadvantages of the intra-PHY-split are: A fronthaul network with "higher" capacity and "lower" latency is required compared to higher layer splits.

Table 2 shows how different splits will set different relative capacity- and latency-requirements on the fronthaul network.

Table 2: Fronthaul requirements vs. splits

Split	Fronthaul capacity needs	Fronthaul latency requirement
A	Low, Scales with # MIMO layers	Relaxed
B	Low, Scales with # MIMO layers	Relaxed
C	Low, Scales with # MIMO layers	Relaxed
D	Low, Scales with # MIMO layers	Very Strict
E	Very High, Scales with # antenna ports	Very Strict
$\{I_D;II_D;I_U\}$	See section 6.1.1	Very Strict

3. Interface Specification

3.1. Protocol Overview

The eCPRI interface includes the following information flows:

1. User Plane:
   - User Data:
     User information (to be transmitted from/to the base station to/from the user equipment) with format depending on the underlying functional decomposition between the eREC and the eRE.
   - Real-Time Control data:
     Time-critical control and management information directly related to the User Data.
   - Other eCPRI services:
     eCPRI services such as User Plane support, remote reset, etc.
2. C&M Plane:
   - Control and management information exchanged between the control and management entities within the eREC and the eRE. This information flow is conveyed to the higher protocol layers and is not considered time critical.
3. Synchronization Plane:
   - Synchronization data used for frame and time alignment.

eCPRI defines a protocol for the transfer of user plane information between eREC and eRE via a packet based fronthaul transport network. For C&M and synchronization information flows, existing protocols and standards are referenced as proposals. The interface supports Ethernet-switched or IP-routed fronthaul networks. Figure 6 provides an overview on the basic protocol hierarchy for Ethernet/IP-based eCPRI transport case.

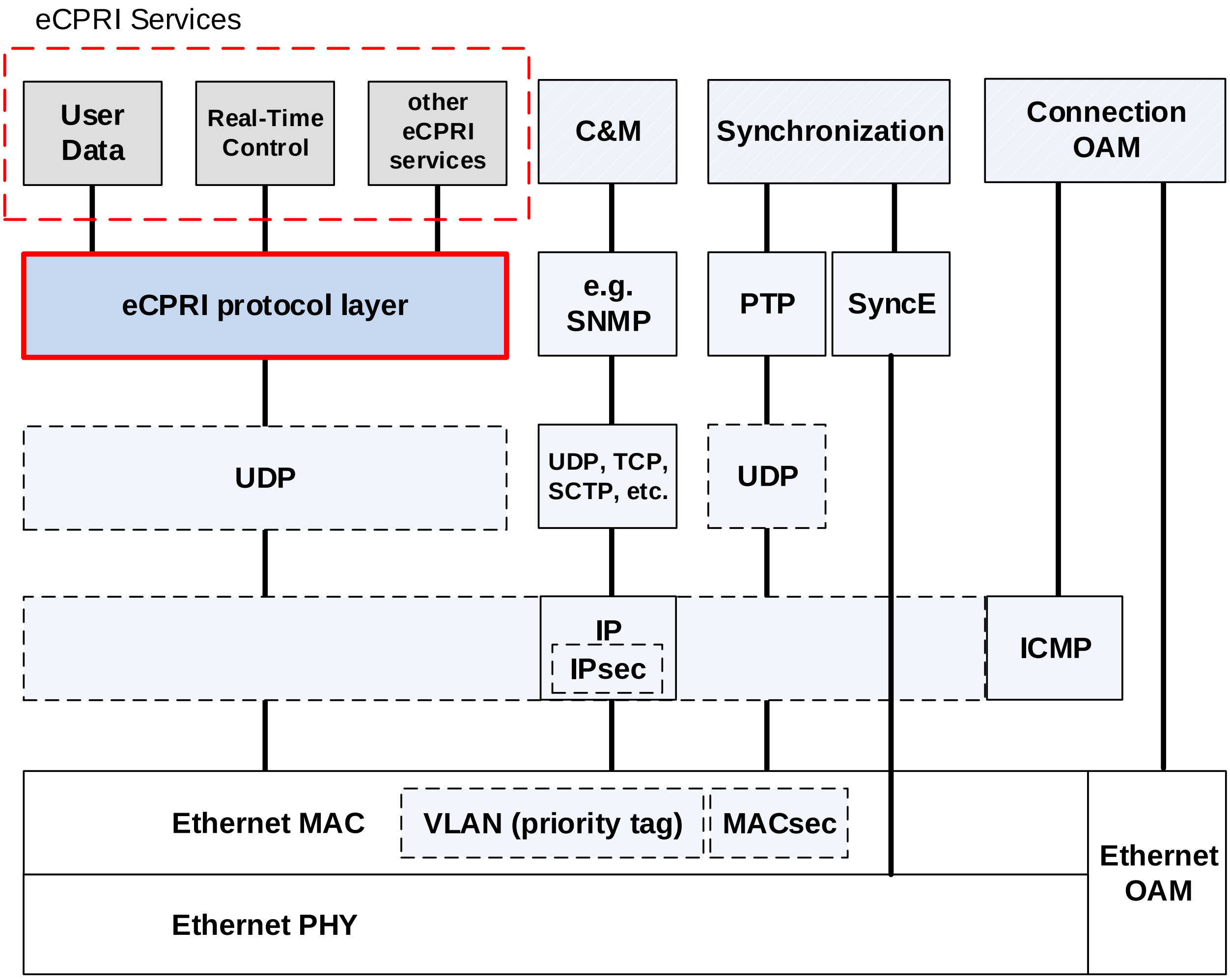


Figure 6: eCPRI protocol stack over IP / Ethernet

For the example of IP/Ethernet based eCPRI transport protocol shown in Figure 6, the following needs to be considered:

- User Plane:
  - In case of eCPRI over Ethernet (refer to section 3.2.1) UDP/IP is not used for the User plane.
  - In case of eCPRI over IP (refer to section 3.2.2), Ethernet might not be used, even though Ethernet is still a typical technology used to transfer IP packets.
  - Message types used by eCPRI are described in section 3.2.3 in detail.
- C&M Plane:
  - Please refer to Section 3.3 “C&M Plane” for more information.
- Synchronization Plane:
  - UDP/IP and VLAN are optional, e.g. the ITU-T PTP telecom profile G.8275.1/Y.1369.1 [4] only defines PTP transport over Ethernet. Insertion of VLAN tag is not allowed in this profile, IP and VLAN are thus not possible.
  - Please refer to Section 3.4 “Synchronization Plane” and Annex 6.2 “Synchronization and Timing” for more information.
- Connection OAM:
  - Please refer to Annex 6.4 “Network Connection Maintenance” for more information.
- Please refer to section 3.1.1 for more information on “Ethernet PHY”.

- Please refer to section 3.5 "QoS" for more information on "VLAN (priority tag)".
- IPsec and MACsec are optional. Please refer to informative Annex 6.8 "Security" for more information.

3.1.1. Physical Layer

The Physical Layer typically follows electrical and optical physical reference standards provided in IEEE 802.3 [5], [6] for the following eCPRI use cases:

1. eCPRI over electrical cable
2. eCPRI over electrical backplane
3. eCPRI over optical fiber

A high flexibility in the choice of connector and transceiver for the optical fiber use case can be achieved by adopting SFP+ [7], [8] and QSFP+ [9], [10].

However, usage of different form factors like CFP, CFP2/4 is not precluded by the eCPRI specification.

The following Table 3 lists typical examples of common Ethernet interface types for 10G, 25G, 40G and 100G Ethernet for the given use cases. Usage of other line rates / interface types is not precluded.

Table 3: Common Ethernet interface types for the given use cases

Use case	Standard / Interface Type	#Lanes	Signal Rate per Lane
Optical	10GBASE-SR/LR/ER ([5], clause 52)	1	10G
	10GBASE-LRM ([5], clause 68)	1	10G
	25GBASE-SR, LR, ER ([5], clauses 112/114)	1	25G
	40GBASE-SR4 LR4/ER4 ([5], clauses 86/87)	4	10G
	100GBASE-SR10 ([5], clause 86)	10	10G
	100GBASE-SR4/LR4/ER4 ([5], clauses 95/88)	4	25G
Electrical	25GBASE-CR/CR-S ([5], clause 110)	1	25G
	40GBASE-CR4 ([5], clause 85)	4	10G
	100GBASE-CR10 ([5], clause 85)	10	10G
	100GBASE-CR4 ([5], clause 92)	4	25G
Backplane	10GBASE-KR ([5], clause 72)	1	10G
	25GBASE-KR/KR-S ([5], clause 111)	1	25G
	40GBASE-KR4 ([5], clause 84)	4	10G
	100GBASE-KR4 ([5], clause 93)	4	25G

3.2. User Plane

3.2.1. User Plane over Ethernet

In this option, eCPRI messages shall be transmitted in standard Ethernet frames[1] [5]. The Ethernet network shall follow the definitions in [15].

The type field of the Ethernet frame shall contain the eCPRI Ethertype ($AEFE_{16}$) [11]. The data field of the Ethernet frame shall contain the eCPRI common header at the beginning, followed immediately by the eCPRI payload. The eCPRI message shall be embedded in the Ethernet frame as a series of octets.

[1] Also, frames with a payload size larger than 1500 octets can be supported

As the minimum size of the data field of an Ethernet frame is 46 octets, if necessary, the eCPRI data field is padded with octets of zero to fill up this minimum size. This padding is not part of the eCPRI message and so is not to be included in the eCPRI payload size field.

An eCPRI node involved in an eCPRI over Ethernet message exchange shall have at least one Ethernet MAC address. All Ethernet MAC addresses within the Ethernet network shall be unique[2]. The assignment of Ethernet MAC addresses to nodes/eCPRI services is out of scope of the eCPRI specification.

The Ethernet MAC header shall provide enough information about the source and the destination of the eCPRI message to deliver the message successfully through the Ethernet network, with the required priority. Further details of the format and definition of the Ethernet frame are out of scope of the eCPRI specification.

3.2.2. User Plane over IP

In this option, eCPRI messages shall be transmitted in UDP/IP packets.

The data field of the UDP datagram contains the eCPRI common header at its beginning, followed immediately by the eCPRI payload. The eCPRI message shall be embedded in the UDP datagram as a series of octets. The UDP datagram shall encapsulate the eCPRI PDU precisely, i.e. without requiring padding octets added to the eCPRI PDU.

An eCPRI node shall have at least one IP address. All IP addresses within the IP network shall be unique [3]. The assignment of IP addresses to nodes/eCPRI services is out of scope of the eCPRI specification.

The header fields of the UDP/IP datagram shall provide enough information about the source and the destination of the eCPRI message to deliver the message successfully through the IP network, with the required priority. Further details of the format and definition of the UDP/IP datagram, and how the IP network is to be maintained are out of the scope of the eCPRI specification.

eCPRI does not specify any range of UDP port values to identify the various eCPRI streams.

3.2.3. eCPRI Message Format

eCPRI messages shall have the format shown in Figure 7 and consist of a four byte eCPRI common header followed by a variable length eCPRI payload.

[2] Both locally unique and globally unique Ethernet MAC addresses are applicable.

[3] There is no restriction on the IP version (IPv4 or IPv6) used in the IP-routed fronthaul network.

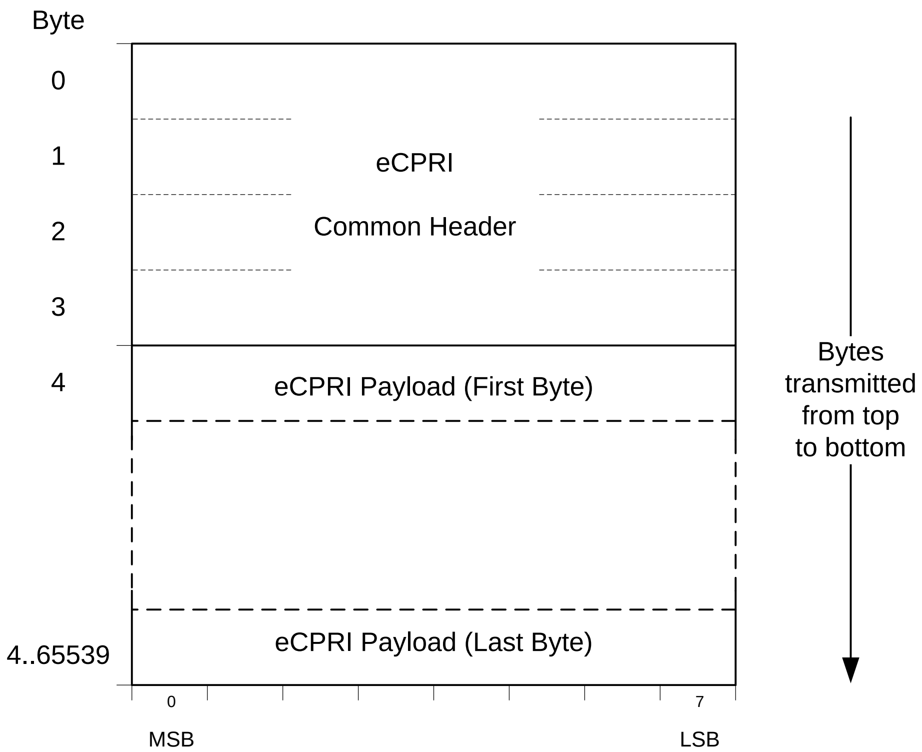


Figure 7: eCPRI message format

3.2.3.1. eCPRI Transmission Byte Order

When the range of a field is too large to fit in a single byte, multiple bytes are used to encode that field. For eCPRI, the transmission byte order follows "network byte order" or "big endian", i.e. the most significant byte is sent first and the least significant byte is sent last (see [12]).

Example:
The hexadecimal number 0xABCD1234 is sent as the byte sequence 0xAB, 0xCD, 0x12, 0x34.

3.2.3.2. Common Header

eCPRI Message Common Header shall have the format shown in Figure 8.

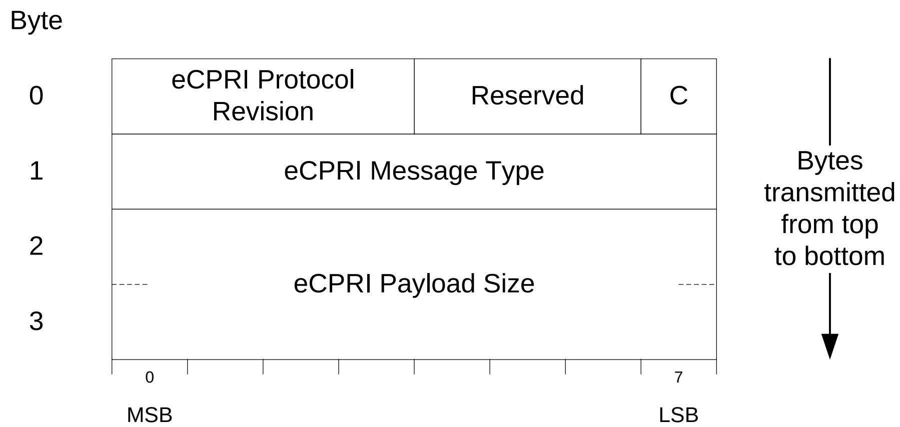


Figure 8: eCPRI Common Header format

Where:

- eCPRI Protocol:

  Revision indicates the protocol version. The eCPRI Protocol Revision is a positive integer value, see section 4.4.

- eCPRI Message Type:
  - indicates the type of service conveyed by the message.
  - see Table 4

- eCPRI Payload Size:

  size in bytes of the payload part corresponding to the eCPRI message. It does not include any padding bytes following the eCPRI message. The maximum supported payload size is 216-1 but the actual size may be further limited by the maximum payload size of the underlying transport network.

- C:
  - eCPRI messages concatenation indicator.
  - "C=0" indicates that the eCPRI message is the last one inside the eCPRI PDU.
  - "C=1" indicates that another eCPRI message follows this one within the eCPRI PDU. In this case, 0 to 3 padding byte(s) shall be added to ensure that the following eCPRI message starts at a 4-byte boundary. Padding byte(s) shall be ignored when received.

- Reserved bits shall be handled according to section 4.2.

3.2.3.3. eCPRI Payload

The payload of eCPRI messages shall follow the format specified in the corresponding eCPRI Message Type sub-section of section 3.2.4. An eCPRI message payload typically includes an eCPRI message header and its associated eCPRI message user data.

3.2.3.4. Mapping Examples

This section explains how eCPRI messages are mapped onto a transport network layer payload with examples.

Figure 9 shows an example in which one eCPRI message is mapped onto a transport network layer payload (e.g. UDP/IP or Ethernet).

Figure 10 shows an example in which two eCPRI messages are concatenated and mapped onto a transport network layer payload (e.g. UDP/IP or Ethernet).

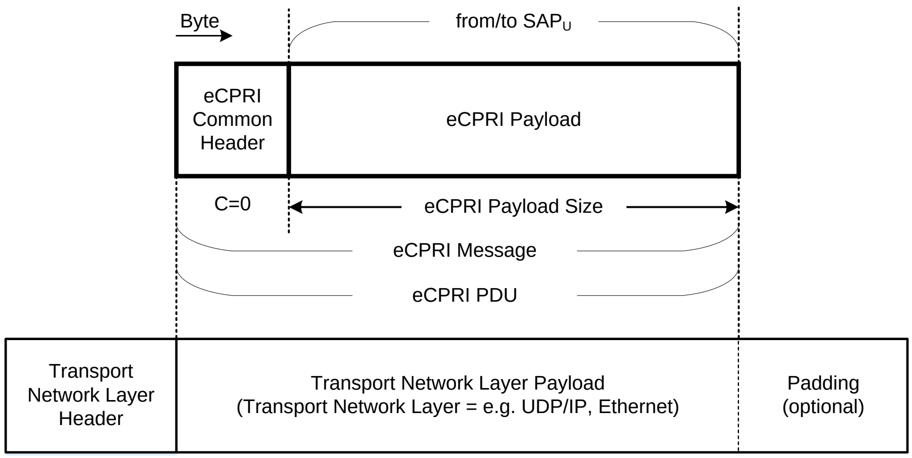


Figure 9: An example of non-concatenated case

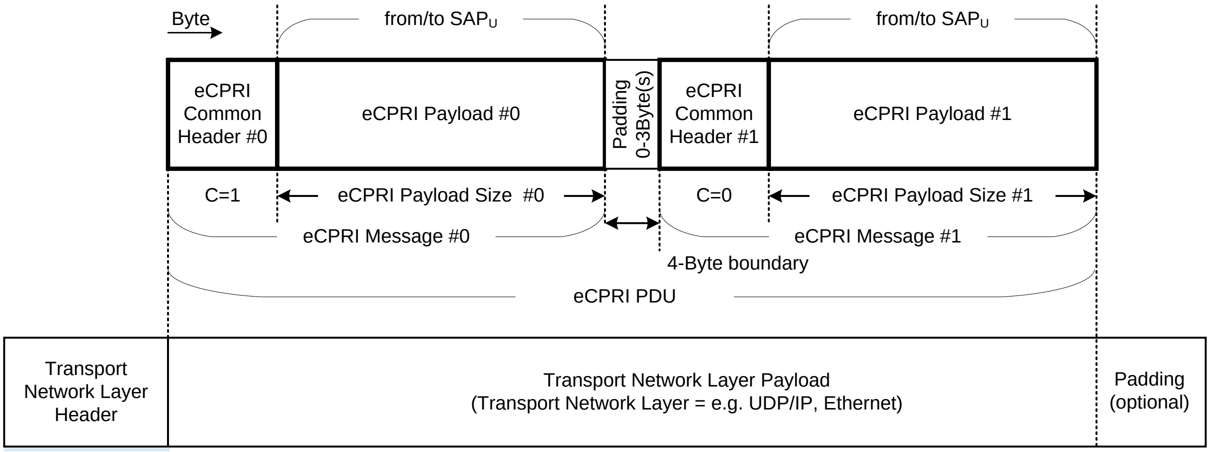


Figure 10: An example of two concatenated eCPRI messages

3.2.4. Message Types

The message types listed in Table 4 are supported by eCPRI. The usage of these types is optional.

Message types #8 - #11 are intended for IWF type 1 ↔ IWF type 2 communication.

Table 4: eCPRI Message Types

Message Type #	Name	Section
0	IQ Data	3.2.4.1
1	Bit Sequence	3.2.4.2
2	Real-Time Control Data	3.2.4.3
3	Generic Data Transfer	3.2.4.4
4	Remote Memory Access	3.2.4.5
5	One-way Delay Measurement	3.2.4.6
6	Remote Reset	3.2.4.7
7	Event Indication	3.2.4.8
8	IWF Start-Up	3.2.4.9
9	IWF Operation	3.2.4.10
10	IWF Mapping	3.2.4.11
11	IWF Delay Control	3.2.4.12
12 - 63	Reserved	3.2.4.13
64 - 255	Vendor Specific	3.2.4.14

3.2.4.1. Message Type #0: IQ Data

3.2.4.1.1. Description/Usage

This message type is used to transfer time domain or frequency domain IQ samples between PHY processing elements split between eCPRI nodes (eREC and eRE).

3.2.4.1.2. Message format

Figure 11 shows IQ Data Transfer message format.

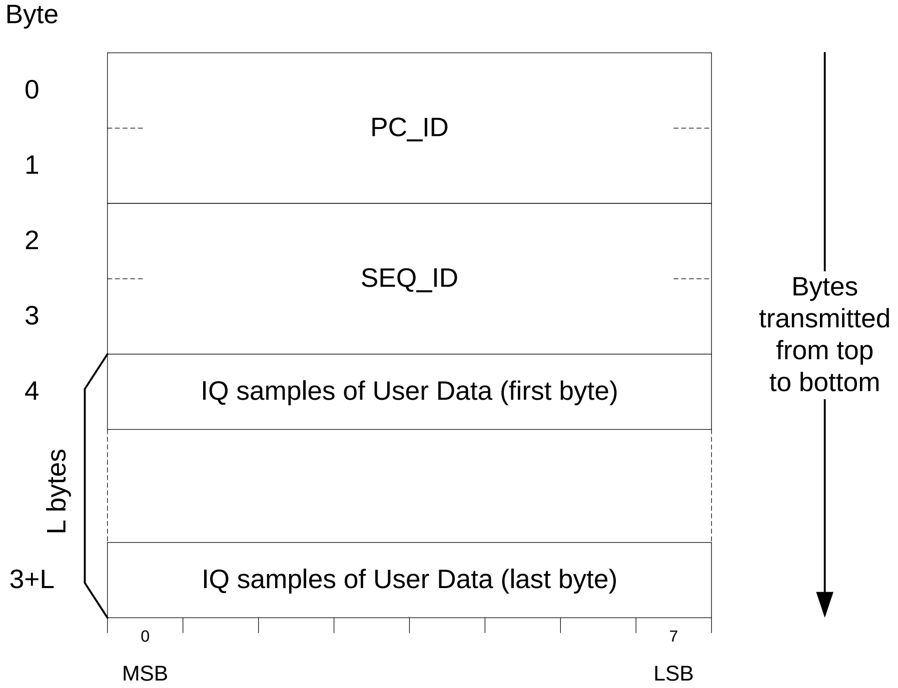


Figure 11: IQ Data Transfer message format

Where:

- PC_ID:
  - An identifier of a series of “IQ Data Transfer” messages.
  - For example, identifier of a physical channel, a user, a layer, an antenna port, etc. which has a common property for PHY processing.
  - How to allocate values to PC_ID is vendor specific.
- SEQ_ID:
  - An identifier of each message in a series of “IQ Data Transfer” messages.
  - For example, identifier of an OFDM symbol, a block of sub-carriers, etc.
  - How to allocate values to SEQ_ID is vendor specific.
- IQ Samples of User Data:
  - A sequence of IQ sample pairs (I, Q) in frequency domain or time domain and associated control information if necessary.
  - Frequency domain IQ or time domain IQ depends on the selected functional split between eCPRI nodes and is vendor specific.
  - The bit width of an IQ sample, the number of IQ sample pairs in a message, and the format of IQ samples (e.g. fixed point, floating point, block floating point), etc. are vendor specific. The actual format is known by the transmit/receive eCPRI nodes in advance.

3.2.4.1.3. Message sequence diagram

Figure 12 shows an example of IQ Data Transfer Sequence. In this example:

- A “Real-Time Control Information” message for PC_ID is transferred before a series of “IQ Data Transfer” messages to inform the remote node how to process IQ samples in following “IQ Data Transfer” messages.

- An “IQ Data Transfer” message with PC_ID is transferred every OFDM symbol period. Each message has a unique SEQ_ID.
- In general, multiple transfer sequence may happen in parallel with different PC_IDs, e.g. for multiple physical channels, users, layers, antenna ports, etc.

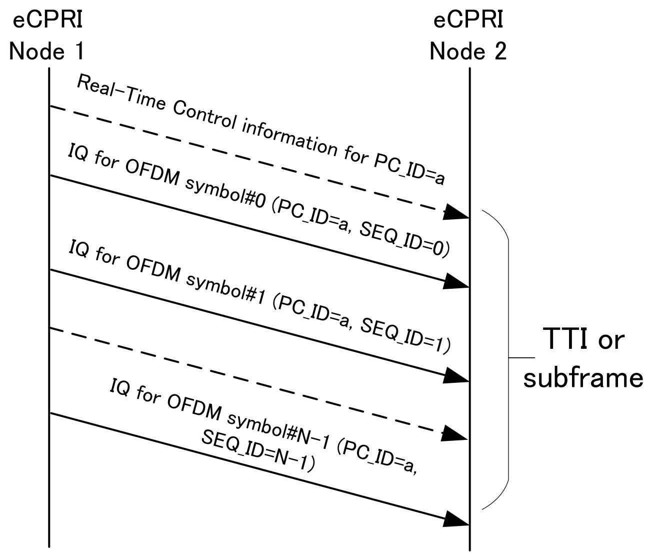


Figure 12: Message sequence diagram (example)

3.2.4.2. Message Type #1: Bit Sequence

3.2.4.2.1. Description/Usage

This message type is used to transfer user data in form of bit sequence between PHY processing elements split between eCPRI nodes (eREC and eRE).

3.2.4.2.2. Message format

Figure 13 shows Bit Sequence Transfer message format.

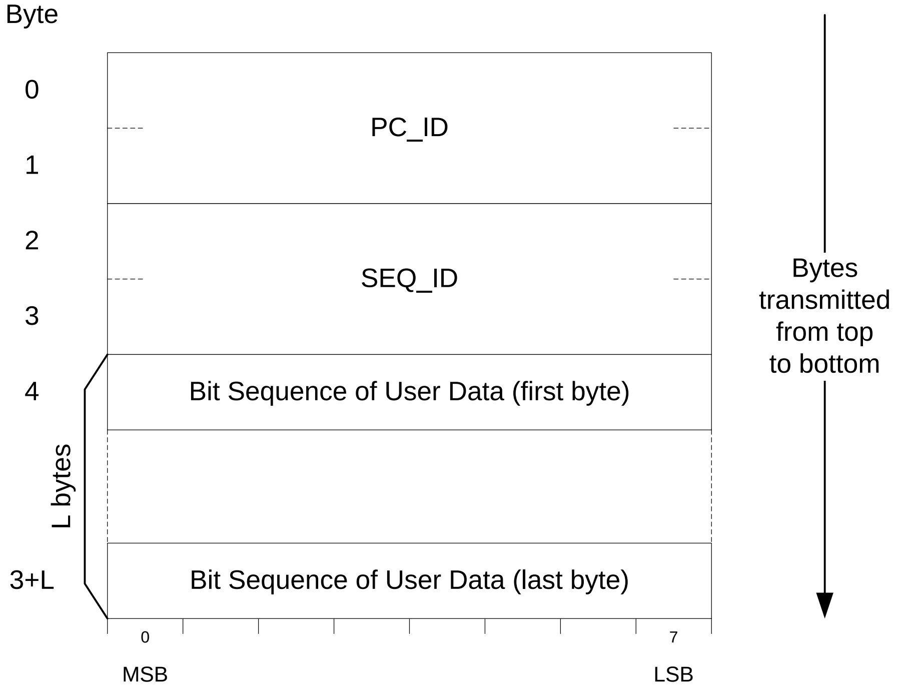


Figure 13: Bit Sequence Transfer message format

Where:

- PC_ID:
  - An identifier of a series of “Bit Sequence Transfer” messages.
  - For example, identifier of a physical channel, a user, a layer, an antenna port, etc. which has a common property for PHY processing.
  - How to allocate values to PC_ID is vendor specific.
- SEQ_ID:
  - An identifier of each message in a series of “Bit Sequence Transfer” messages.
  - For example, identifier of an OFDM symbol, a block of sub-carriers, etc.
  - How to allocate values to SEQ_ID is vendor specific.
- Bit Sequence of User Data:
  - A Bit Sequence of User Data, e.g. channel coded data before modulation mapping.
  - The information carried by the Bit Sequence Transfer message depends on the selected functional split between eCPRI nodes and is vendor specific.
  - The length of a Bit Sequence in a message is vendor specific and known by the transmit/receive node in advance.

3.2.4.2.3. Message sequence diagram

A message sequence example of the Bit Sequence Transfer is shown in Figure 14. In this example:

- A “Real-Time Control Information” message for PC_ID=a is transferred prior to a series of “Bit Sequence Transfer” messages to inform the remote node how to process the user data in bit sequence format in the following “Bit Sequence Transfer” messages.
- A “Bit Sequence Transfer” message with PC_ID is transferred every OFDM symbol period. Each message has a unique SEQ_ID.
- In general, multiple transfer sequences may happen in parallel with different PC_IDs, e.g. for multiple physical channels, users, layers, antenna ports, etc.

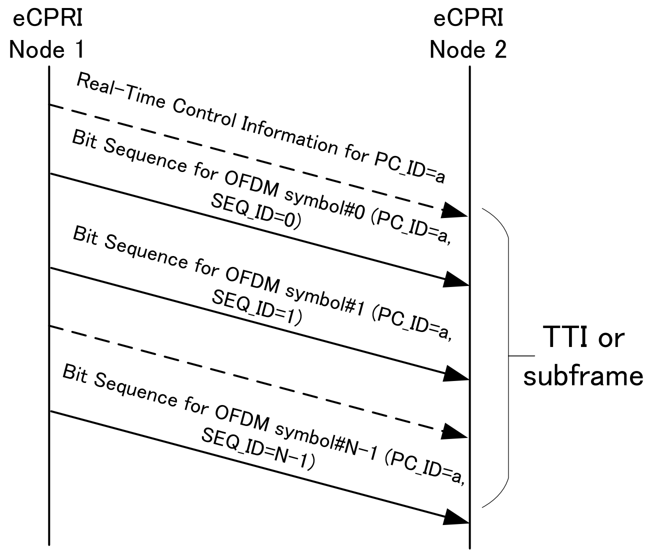


Figure 14: Message sequence diagram (example)

3.2.4.3. Message Type #2: Real-Time Control Data

3.2.4.3.1. Description/Usage

This message type is used to transfer vendor specific real-time control messages between PHY processing elements split between eCPRI nodes (eREC and eRE). This message type addresses the need to exchange various types of control information associated with user data (in form of IQ samples, bit sequence, etc.) between eCPRI nodes in real-time for control/configuration/measurement. However, this type of information highly depends on the selected function split and the actual implementation of these functions. So only the message type for Real-Time Control Data is defined, but not the data format.

3.2.4.3.2. Message format

Figure 15 shows the Real-Time Control Data message format.

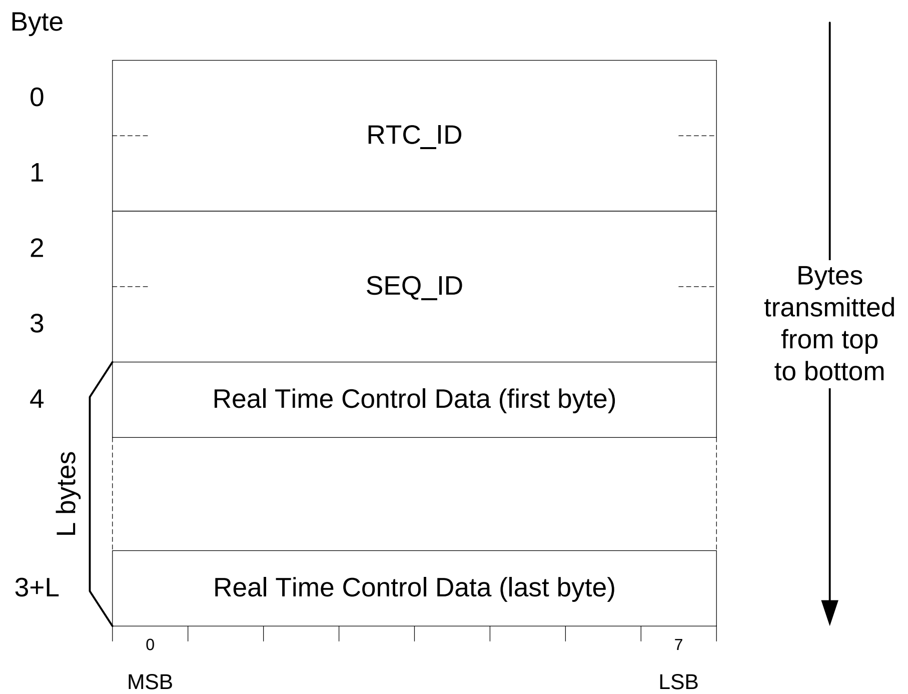


Figure 15: Real-Time Control Data Message format

Where:

- RTC_ID:
    - An identifier of a series of “Real-Time Control Data” messages.
    - For example, identifier for message structures of specific control / configuration / status / measurement and request / response / indication types.
    - How to allocate values to RTC_ID is vendor specific.
- SEQ_ID:
    - An identifier of each message in a series of “Real-Time Control Data” messages.
    - For example, identifier of message sequence, links between request and response messages, etc.
    - How to allocate values to SEQ_ID is vendor specific.
- Real-Time Control Data:
    - The format of this part of the payload is vendor specific.

3.2.4.3.3. Message sequence diagram

Figure 16 shows an example of Real-Time Control Message passing sequence. In this example, Real-Time Control Messages are transferred prior to and/or after the associated user data messages (in form of IQ Data or Bit Sequence).

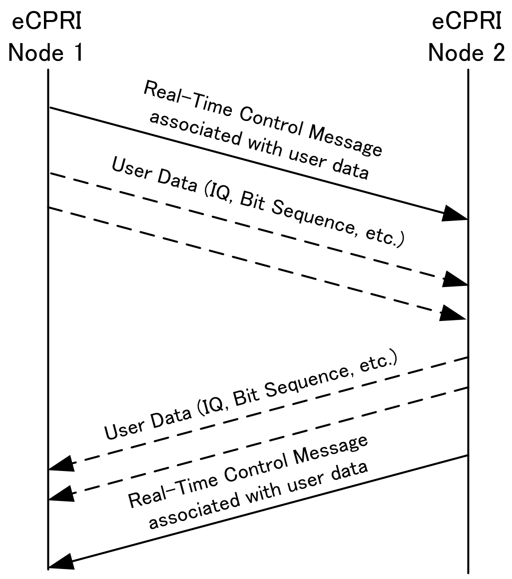


Figure 16: Message Sequence diagram (example)

3.2.4.4. Message Type #3: Generic Data Transfer

3.2.4.4.1. Description/Usage

This message type is used to transfer user plane data or related control between eCPRI nodes (eREC and eRE) providing extended data synchronization support for generic data transfers.

3.2.4.4.2. Message format

Figure 17 shows the Generic Data Transfer message format.

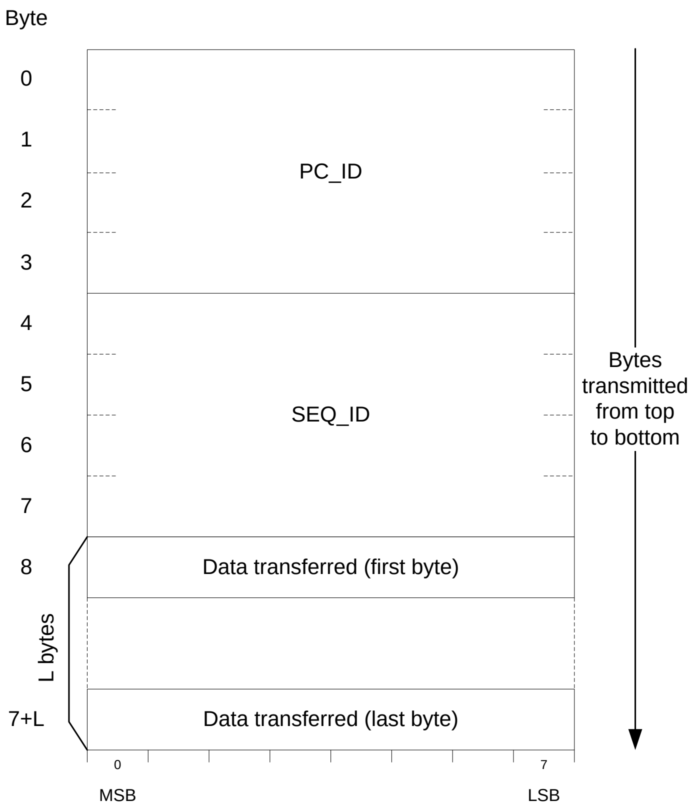


Figure 17: Generic Data Transfer message format

Where:

- PC_ID:
  - An identifier of a series of “Generic Data Transfer” messages.
  - For example, identifier of a physical channel, a user, a layer, an antenna port, etc. or in case of control, an identifier for control / configuration / status / measurement or other indication.
  - How to allocate values to PC_ID is vendor specific.
- SEQ_ID:
  - 4-byte field of each message in a series of “Generic Data Transfer” messages.
  - For example, identifier of
    - message sequence
    - data time relation to frame, OFDM symbol, a block of sub-carriers or sub-carrier etc.
    - identifier for completion of transfer phase
  - How to allocate values to SEQ_ID is vendor specific.
- Data transferred:
  - A sequence of
    - user data samples in frequency or time domain and associated control information if necessary
    - control information
  - User or control data content depends on the selected functional split between eCPRI nodes and is vendor specific.
  - The sample size, the number of samples etc. in a message, and the format of samples (e.g. fixed point, floating point, block floating point), etc. are vendor specific. The actual format is known by the transmit/receive eCPRI nodes in advance.

3.2.4.4.3. Message sequence diagram

Figure 18 shows an example of Data Transfer Sequence. In this example, the Message Type “Generic Data Transfer” is used to transmit “User data”:

- A “Real-Time Control Information” message for PC_ID is transferred before a series of “Generic Data Transfer” messages to inform the remote node how to process Data samples in following “Generic Data Transfer” messages.
- An “Generic Data Transfer” message with PC_ID is transferred e.g. every OFDM symbol period. Each message has a unique SEQ_ID.
  - SEQ_ID does not need to be continuous.
- In general, multiple transfer sequence may happen in parallel with different PC_IDs, e.g. for multiple physical channels, users, layers, antenna ports, etc.

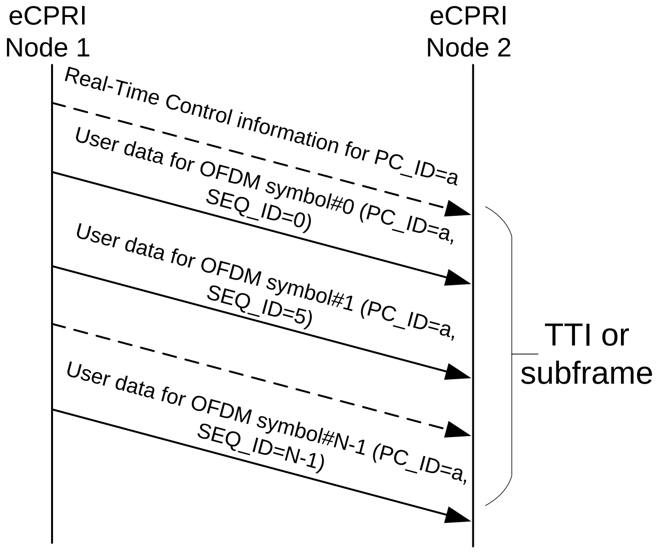


Figure 18: Message sequence diagram (example)

3.2.4.5. Message Type #4: Remote Memory Access

3.2.4.5.1. Description/Usage

The Message Type “Remote Memory Access” allows reading or writing from/to a specific memory address on the opposite eCPRI node. The service is symmetric i.e. any “side” of the interface can initiate the service.

The service is conceived in a generic way to handle different kinds of write and read access that depend on the hardware used in a specific implementation. It is up to the driver routines for an implementation to map a write/read request to its hardware implementation.

A read or write request/response sequence is an atomic procedure, i.e. a requester needs to wait for the response from the receiver before sending a new request to the same receiver. A write request without response is also defined, this procedure is a one-message procedure.

3.2.4.5.2. Message format

The “Remote Memory Access” message format is shown in Figure 19.

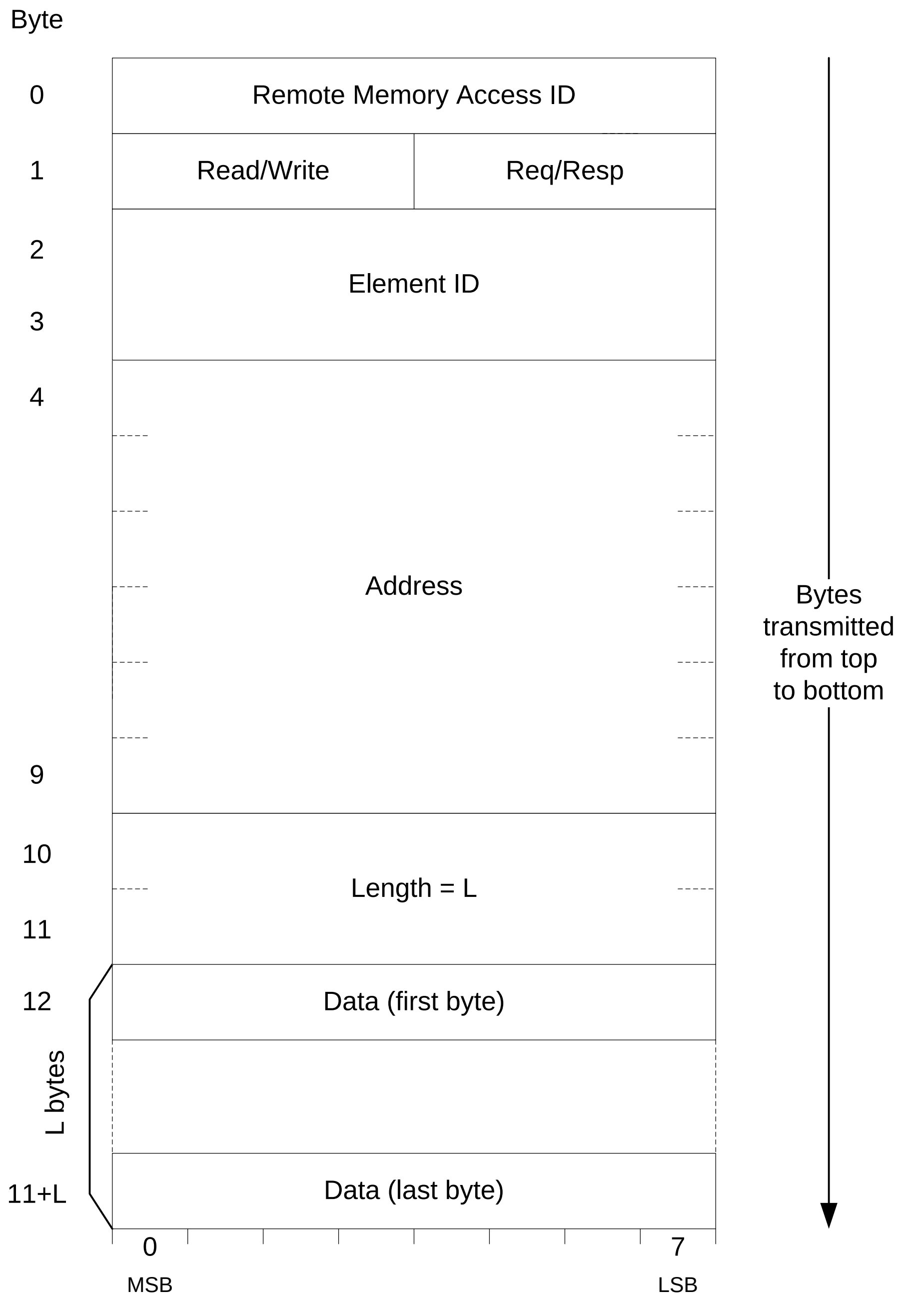


Figure 19: Remote Memory Access message format

Where:

- Remote Memory Access ID:

  The Remote Memory Access ID is used by the initiator of the request when the response is received to distinguish between different accesses.

- Read/Write & Request/Response:

  The field consist of two parts, a read or write indication and a request or response indication.

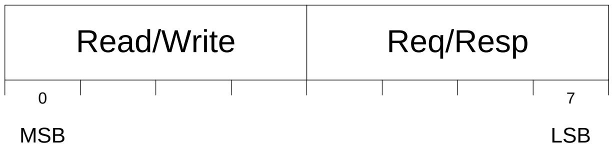


Figure 20: R/W and Req/Resp

The Read/Write and Request/Response fields are coded according to Table 5 and Table 6.

Table 5: Read/Write coding

Value	Read/Write
0000b	Read
0001b	Write
0010b	Write_No_Resp
0011b .. 1111b	Reserved

Table 6: Request/Response coding

Value	Request/Response
0000b	Request
0001b	Response
0010b	Failure
0011b .. 1111b	Reserved

The Response value 0010b (Failure) is used when the receiver of the request is unable to perform the read/write request due to invalid content in received parameters or other faults.

- Element ID:

Depending on implementation the Element ID could be used for instance to point out a specific instance of a generic hardware function.

- Address:

The Address is a 48-bit value. Details such as whether the memory on the opposite node is organized in one or more memory banks or whether an address offset is signaled over the interface etc. are vendor specific. The Element ID could be used for identifying a specific memory hardware instance.

- Length:

For a request, the 2-byte Length field contains the number of bytes that are either to be written to or read from a specific address.

For a response, the 2-byte Length field contains the actual number of bytes that were either written or read. If for some reason it was not possible to either read or write the full length of data, this will be detected via the difference in the length field.

- Data:

  The first Data-byte after the length-field is either the byte that will be written to the memory address given in the write request or it is the byte read from the memory address given in the read request.

3.2.4.5.3. Message sequence diagram

An eCPRI-node can at any time initiate a Remote Memory Access to another node. Depending on if it is a request or a response and whether it is a read or write, different fields will be copied or set according to Table 7.

Table 7: Parameter handling

Action	ID	Read/Write	Req/Resp	Element ID	Address	Length	Data
Read request	Set	Set to Read	Set to Req	Set	Set	Set	No data
Read response	Copied	Copied	Set to Resp	Copied	Copied	Number of read bytes	The read data
Write request	Set	Set to Write	Set to Req	Set	Set	Set	The data to be written
Write response	Copied	Copied	Set to Resp	Copied	Copied	Number of written bytes	No data
Write No response	Set	Set to Write_No_Resp	Set to Req	Set	Set	Set	The data to be written
Failure response	Copied	Copied	Set to Failure	Copied	Copied	Vendor specific	Vendor specific

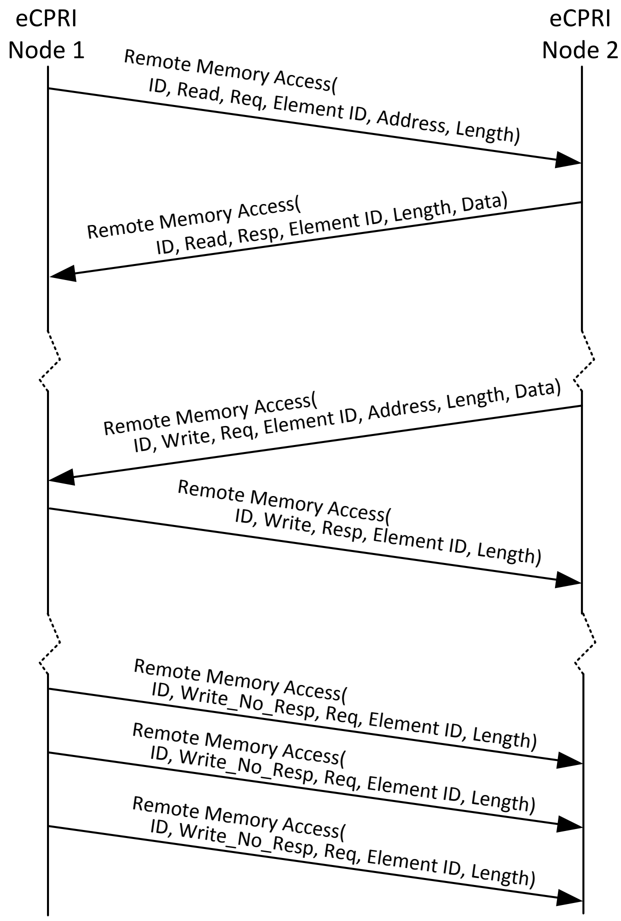


Figure 21: Message sequence diagram (example)

3.2.4.6. Message Type #5: One-Way Delay Measurement

3.2.4.6.1. Description/Usage

The Message Type "One-Way delay measurement" is used for estimating the one-way delay between two eCPRI-ports in one direction. The sender of the message will sample the local time (t_1) and include a compensation value (t_{cv1}) and send it to the receiver. The receiver will time stamp the message when it arrives (t_2) and send that together with an internal compensation value (t_{cv2}) back to the sender. The one-way delay measurement can be performed without or with a Follow_Up message (1-Step and 2-Step versions). The decision of which version to use is vendor specific.

The One-Way delay value is calculated according to equation (1):

$$t_D = (t_2 - t_{CV2}) - (t_1 + t_{CV1}) \quad (1)$$

With the two compensation values, it is possible for a specific implementation to set the reference points for the measurements as suited for a specific implementation. The exact locations of the reference points are vendor specific.

Example: Time sampling according to Clause 90 in IEEE 802.3-2015 [5], in this case the time sampling is in between MAC and PHY layers.

The service assumes that both nodes are time synchronized to a common time with an accuracy sufficient for the eCPRI service.

The usage of eCPRI Message Type "One-Way delay measurement" regarding which node initiates a transmission, the frequency of measurements, response deadline, etc. is vendor specific.

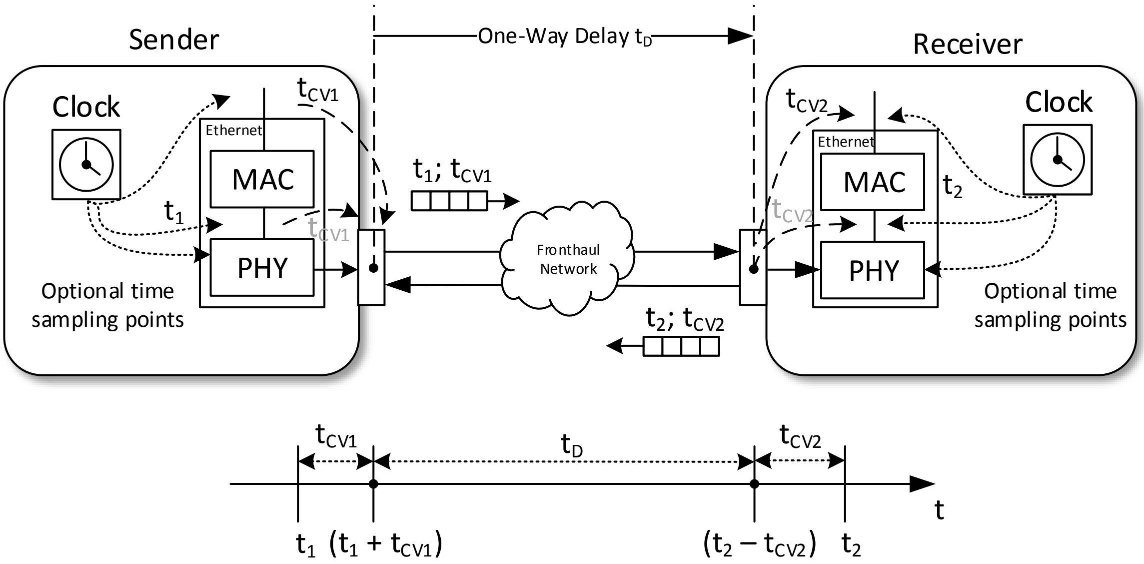


Figure 22: One-Way delay measurement of the delay Sender -> Receiver

3.2.4.6.2. Message format

The “One-Way delay measurement” message format is shown in Figure 23.

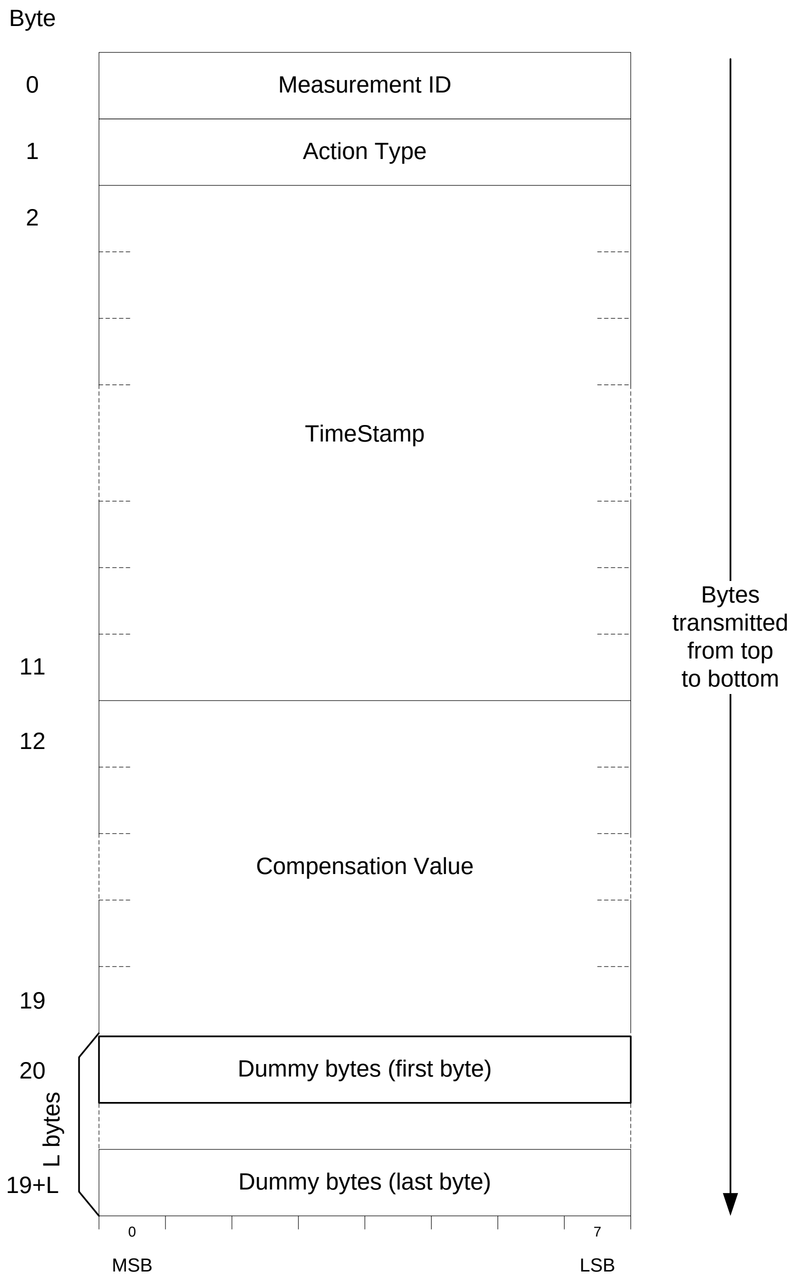


Figure 23: One-Way delay measurement message

Where:

- Measurement ID:

  The Measurement ID is a 1-byte value used by the sender of the request when the response is received to distinguish between different measurements, i.e. the receiver of the request shall copy the ID from the request into the response message.

- Action Type:

  The Action Type is a 1-byte value described in Table 8.

Table 8: Action Type

Action Type	Description
0x00	Request
0x01	Request with Follow_Up
0x02	Response
0x03	Remote Request
0x04	Remote request with Follow_Up
0x05	Follow_Up
0x06 … 0xFF	Reserved

Values 0x00 and 0x01 are used when an eCPRI node initiates a one-way delay measurement in the direction from its own node to another node. Values 0x03 and 0x04 are used when an eCPRI node needs to know the one-way delay from another node to itself. See section 3.2.4.6.3 for usage.

- TimeStamp:

When Action Type is set to 0x00 (Request) in the message this field will contain the time stamp t_1 and when Action Type is set to 0x02 (Response) the time stamp t_2. When action type is set to 0x01 (Request with Follow_Up) the time stamp information fields shall be set to 0b in all bits, the corresponding time information values are sent in the Follow_Up message.

When Action Type is set to 0x03 or 0x04 (Remote Request and Remote Request with Follow_Up) the time stamp information fields shall be set to 0b in all bits.

When using the Follow_Up message (2-Step version) the Follow_Up message (Action Type set to 0x05) the time information values t_1 and t_{CV1} will be set to the TimeStamp field.

The time information values follow the format specified in IEEE 1588-2008 [13] Clause 5.3.3.

The value consists of 2 parts, one “seconds”-part and one “nanoseconds”-part. The first 6 bytes are the seconds and the next 4 bytes are the nanoseconds.

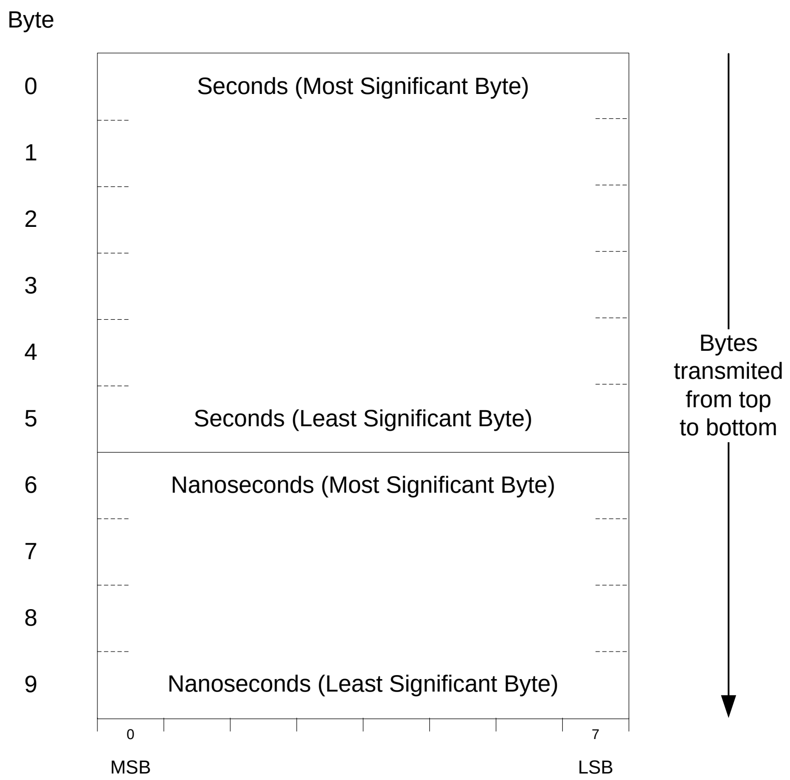


Figure 24: TimeStamp

- Compensation value:

  When Action Type is set to 0x00 (Request), 0x02 (Response) or 0x05 (Follow_Up) in the message, this field will contain the “Compensation Value” which is the compensation time measured in nanoseconds and multiplied by 2^{16} and follows the format for the correctionField in the common message header specified in IEEE 1588-2008 Clause 13.3 [13]. When Action Type is set to 0x03 (Remote Request) or 0x04 (Remote Request with Follow_Up) the time information fields TimeStamp and Compensation Value are set to 0b in all bits.

  A Compensation Value of 0 (zero) is a valid value.

  Example: A Compensation Value of 183.5 ns is represented as $0000000000B78000_{16}$.

- Dummy bytes:

  The number of dummy bytes included in the eCPRI-payload will be defined by the eCPRI payload size field in the eCPRI common header, see section 3.2.3.1

  Due to network characteristics, a small message might take shorter time through the network than a large one, with the dummy bytes the one-way delay estimation can be improved.

  The insertion of dummy bytes is only needed when the Action Type set to 0x00 (Request) or to 0x01 (Request with Follow_Up).

3.2.4.6.3. Message sequence diagram

The message sequence diagram shown in Figure 25 is divided in 2 parts:

Part I shows the sequence when Node 1 initiates a delay measurement in the direction Node 1 to Node 2.

Part II shows the sequence when Node 1 initiates a delay measurement in the direction Node 2 to Node 1.

An eCPRI-node can at any time initiate a one-way delay measurement by setting the Action Type to 0x00 (Request), 0x01 (Request with Follow_Up) 0x03 (Remote Request) or 0x04 (Remote Request with Follow_Up). The Measurement ID received in the request shall be copied in the response.

Figure 26 shows the same sequences as Figure 25 but with the usage of the Follow_Up message.

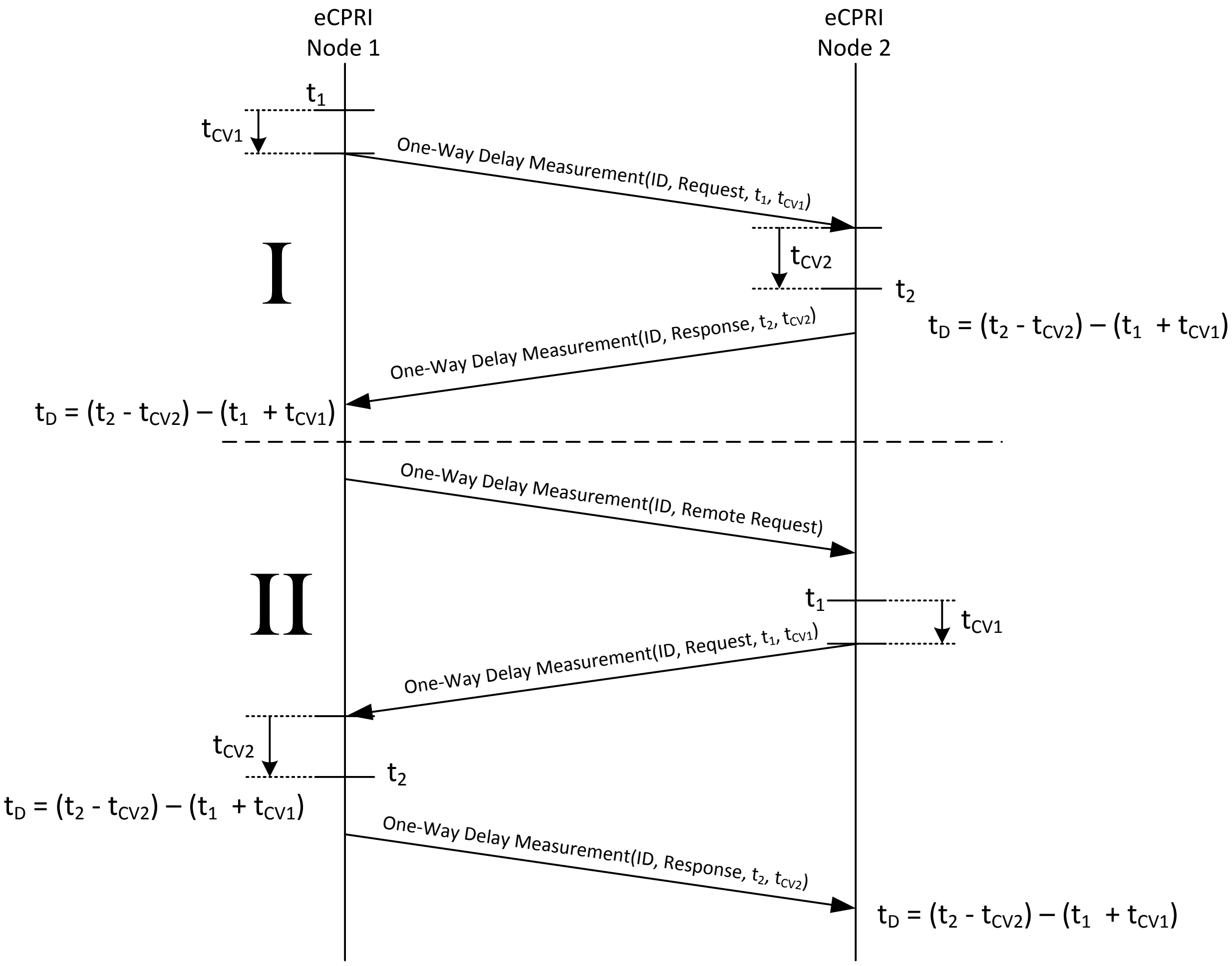


Figure 25: Message sequence diagram without Follow_Up (example)

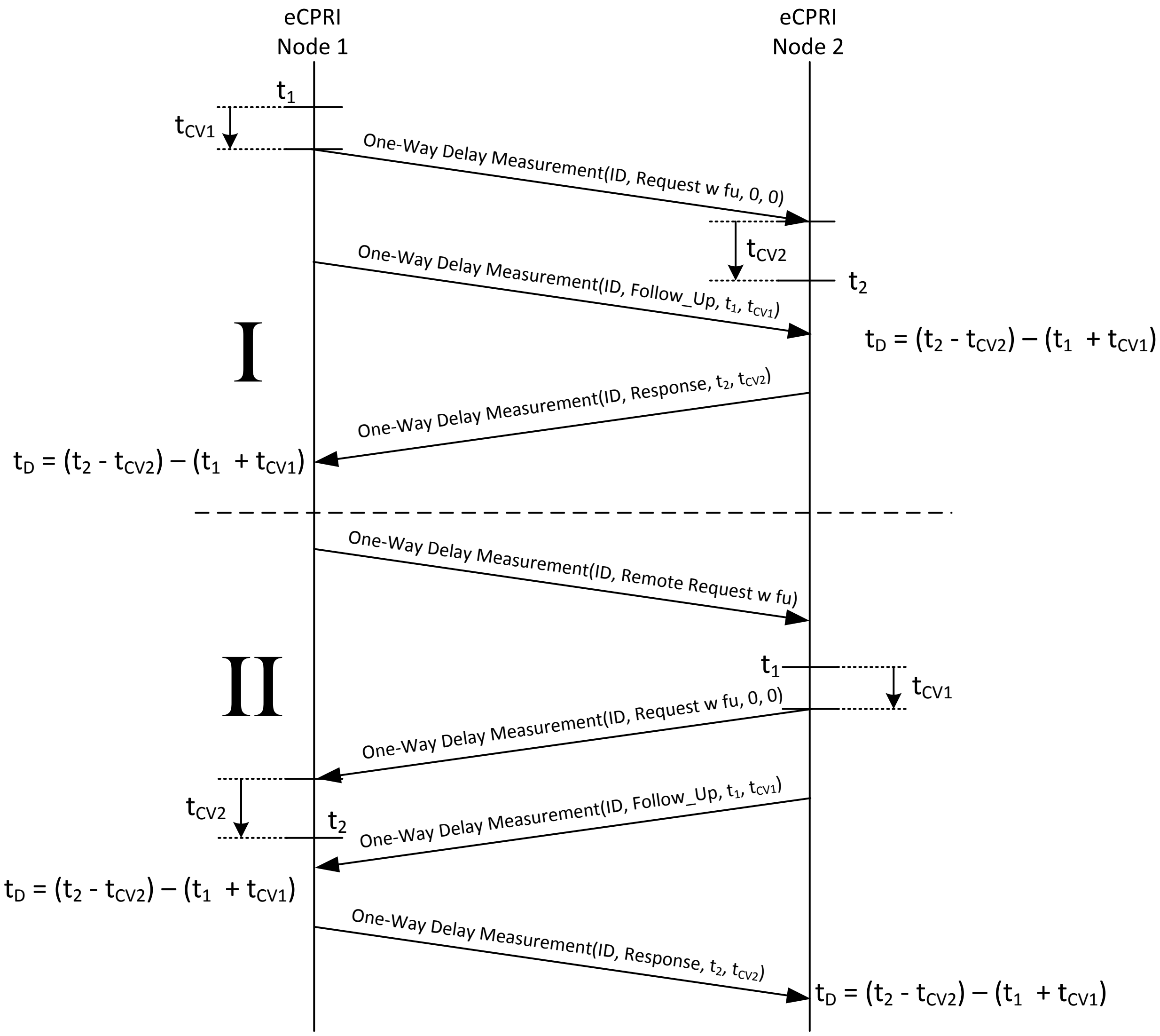


Figure 26: Message sequence diagram with Follow_Up (Example)

3.2.4.7. Message Type #6: Remote Reset

3.2.4.7.1. Description/Usage

This message type is used when one eCPRI node requests reset of another node. A "Remote Reset" request sent by an eREC triggers a reset of an eRE. Upon reception of a valid "Remote Reset" request, the eRE should send a "Remote Reset" indication before performing the requested reset.

Resetting the IWF is recommended to be handled by higher layers to minimize the radio system impact, because all connecting functions including REs may be affected. However, applying Message Type #6 "Remote Reset" to the IWF may be considered as an emergency reset for cases such as the IWF software control not responding or misbehaving. Returning the "Remote reset response" (see Table 9) is recommended but not mandatory.

An eREC can request the IWF type 0 to reset the connected REs by using this "Remote Reset" message. In this case, each RE shall be identified by a vendor specific allocated Reset ID.

3.2.4.7.2. Message format

Figure 27 shows the Remote reset message format.

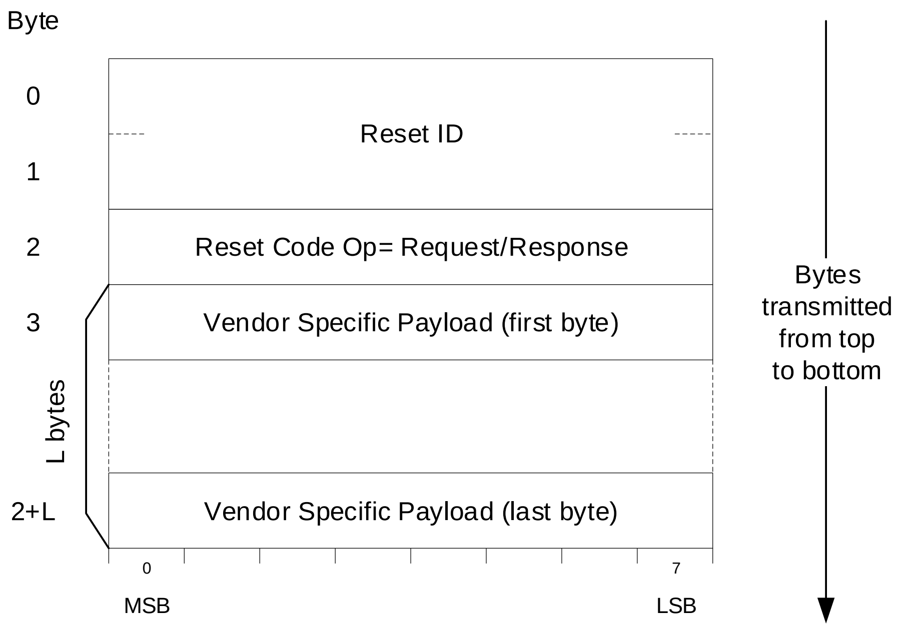


Figure 27: Remote reset message format

Where:

- Reset ID:
    - Depending on implementation the Reset ID could be used for instance to point out a specific instance of a generic hardware function.
    - How to allocate values to Reset ID is vendor specific.
- Reset Code Op:

  The Reset Code Op is a 1-byte value described in Table 9.

Table 9: Reset Code Op

Reset Code Op	Description
0x00	Reserved
0x01	Remote reset request
0x02	Remote reset response
0x03…0xFF	Reserved

- Vendor Specific Payload bytes:

  Vendor Specific Payload bytes are used to carry optional vendor-specific information. The vendor-specific information can contain data items such as authentication parameters or any parameters to select a specific reset behavior. This specification does not detail any concrete reset behavior.

3.2.4.7.3. Message sequence diagram

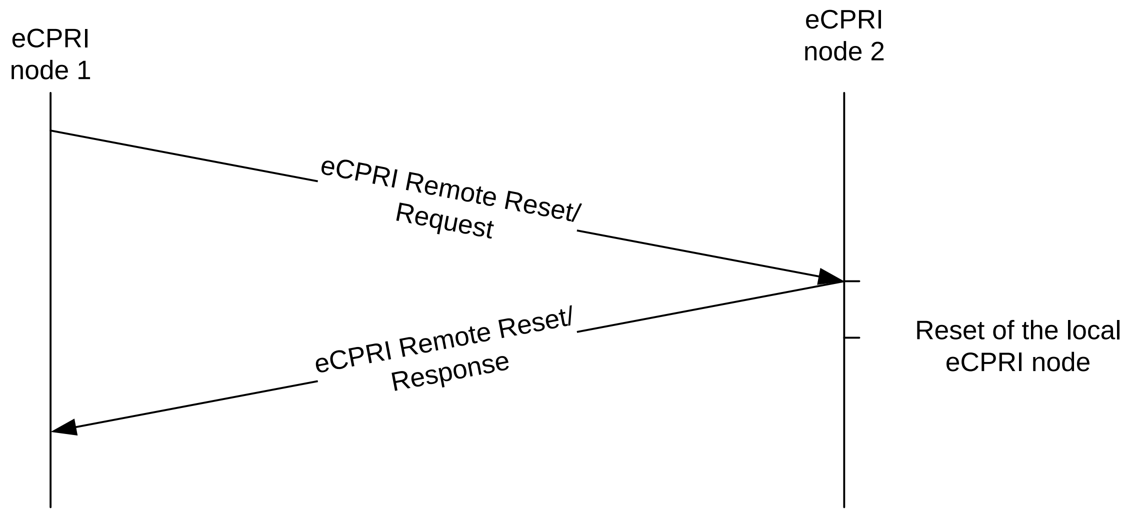


Figure 28: Message sequence diagram (example)

3.2.4.8. Message Type #7: Event Indication

3.2.4.8.1. Description/Usage

The Message Type “Event Indication” is used when either side of the protocol indicates to the other end that an event has occurred. An event is either a raised or ceased fault or a notification. Transient faults shall be indicated with a Notification.

Faults/Notifications sent on eCPRI level should be relevant to the eCPRI services. For instance, faults in the user plane processing, power usage fault situations etc. The faults and notifications should be related to the user data processing.

One Event Indication can either contain one or more faults, or one or more notifications. Faults and notifications cannot be mixed in the same Event Indication message.

Other faults/notifications related to an eCPRI node such as temperature faults, power supervision, etc. would normally be sent via the C&M plane.

An eCPRI node is modelled as consisting of N Elements, a fault or notification is connected to one Element. The detailed mapping of a specific implementation of HW and SW to Elements and their associated faults/notification is vendor specific.

A fault/notification may be connected to the node itself. In that case a predefined Element ID number is used, see Table 11.

The Event/Fault Indication message could be sent from an eCPRI node at any time.

For consistency check a synchronization request procedure is defined. This procedure will synchronize the requester with the current status of active faults. Transient faults will not be synchronized.

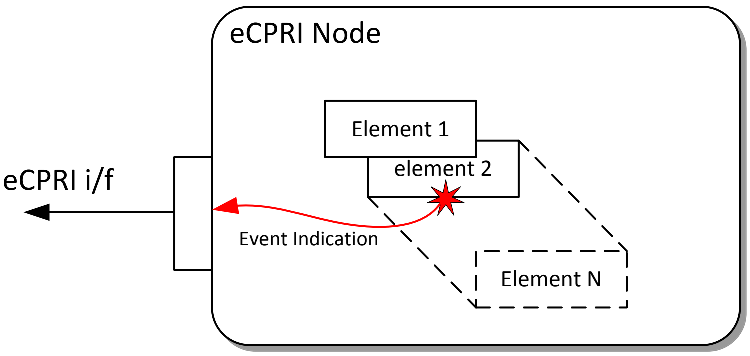


Figure 29: Model for event indications

3.2.4.8.2. Message format

The Event Indication message format is shown in Figure 30.

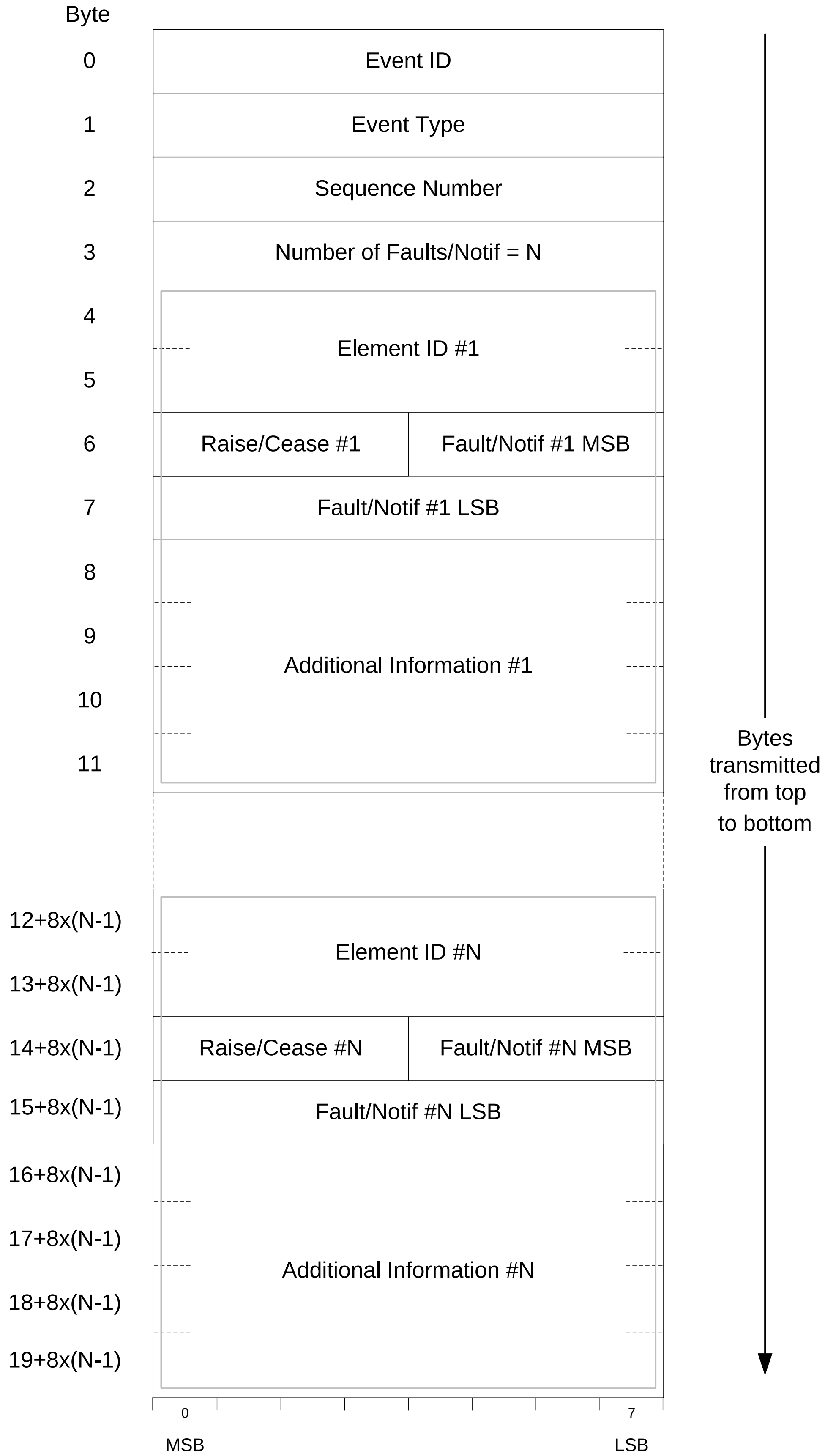


Figure 30: Event indication message

Where:

- Event ID:

A 1-byte value set by the transmitter of an Event Indication or a Synchronization Request to enable identification of the acknowledge response.

- Event Type:

Table 10: Event Type

Event Type	Description
0x00	Fault(s) Indication
0x01	Fault(s) Indication Acknowledge
0x02	Notification(s) Indication
0x03	Synchronization Request
0x04	Synchronization Acknowledge
0x05	Synchronization End Indication
0x06…0xFF	Reserved

- Sequence Number:

The Sequence Number is a 1-byte value that is incremented each time the transmitter sends the “Event Indication” with Event Type set to 0x00 (Fault(s) Indication). The receiver will use the sequence number to ensure that the correct status for a specific combination of {Element-ID; Fault-value} is used. Due to the nature of the packet based fronthaul network, packets might be delivered out of order and a sequence number is needed to handle this scenario. When a fault indication is not acknowledged the transmitter will re-transmit the fault, setting the sequence number to the same value used in the initial transmission.

- Number of Faults/Notifications:

Number of fault indications or notifications attached in the same message.

- Element ID:

Table 11: Element ID

Element ID Number	Usage
0x0000 … 0xFFFE	Vendor specific usage
0xFFFF	A fault or notification applicable for all Elements i.e. the node

- Raise/cease:

First nibble in the same byte as the Fault/Notification Number.

Table 12: Raise/ceased

Raise/Cease	Description
0x0	Raise a fault
0x1	Cease a fault
0x2 … 0xF	Reserved

- Fault/Notification Numbers:

  A 12-bit number indicating a fault or notification divided between 2 bytes.

Table 13: Fault/Notification numbers

Fault Indication and Notification Numbers	Usage
0x000 … 0x3FF	eCPRI reserved Faults
0x400 ... 0x7FF	eCPRI reserved Notifications
0x800 ... 0xFFF	Vendor Specific Fault Indications and Notifications
eCPRI Faults and Notifications	
0x000	General Userplane HW Fault
0x001	General Userplane SW Fault
0x002 ... 0x3FF	eCPRI reserved
0x400	Unknown message type received
0x401	Userplane data buffer underflow
0x402	Userplane data buffer overflow
0x403	Userplane data arrived too early
0x404	Userplane data received too late
0x405 … 0x7FF	eCPRI reserved

- Additional Information:

  If available, additional information regarding the fault/notification for vendor specific usage.

3.2.4.8.3. Message sequence diagram

An eCPRI node can at any time send an Event Indication to the peer node. Depending on what Event Type, different fields will be set or copied according to Table 14.

Table 14: Parameter handling

Event Type	Event ID	Sequence Number	Nbr of Faults or Notifications	Fault/Notification(s)	Raise/Cease	Additional Information
Fault Indication	Set	Increment	> 0	Fault(s)	Raise or Cease	Vendor Specific
Fault Indication Acknowledge	Copied	Copied	0	Not included	Not included	Not Included
Synchronization Request	Set	Set to 0	0	Not included	Not included	Not Included
Synchronization Acknowledge	Copied	Set to 0	0	Not included	Not included	Not Included
Synchronization End Indication	Copied	Set to 0	0	Not included	Not included	Not Included
Notification	Set	Set to 0	>0	Notifications	Set to 0x0	Vendor specific

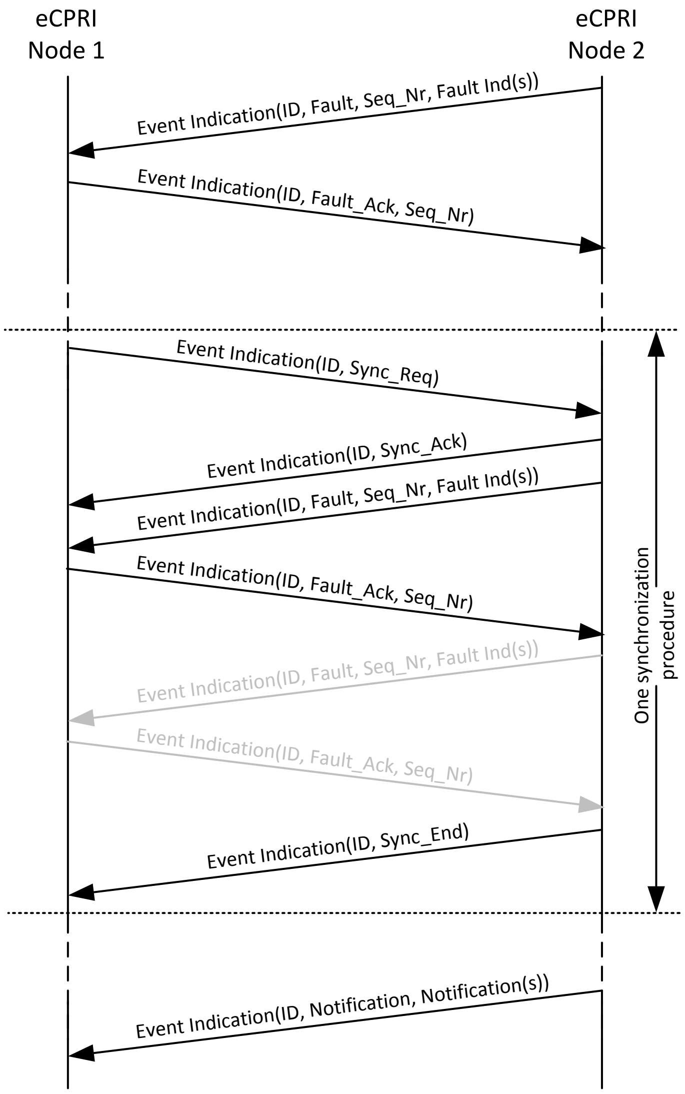


Figure 31: Message sequence diagram (example)

The first part of the sequence above shows when Node 2 detects a fault condition which is signalled to Node 1 and Node 1 acknowledges the reception of the indication.

The middle part of the sequence diagram shows a Synchronization procedure. The procedure is started with a Synchronization-Request sent by Node 1, signals marked in grey might be sent due to number of faults or due to the implementation. The request is acknowledged by Node 2, Node 2 then sends the current list of raised faults to Node 1, the sequence is ended when Node 2 sends the Synchronization-End message. In the Synchronization procedure the “Event ID” set by Node 1 in the request message will be used during the full procedure.

The last part of the sequence shows when Node 2 sends a notification to Node 1, this notification is not acknowledged by Node 1.

3.2.4.9. Message Type #8: IWF Start-Up

3.2.4.9.1. Description/Usage

This message type is used during the start-up sequence to transfer CPRI control words between CPRI nodes (REC and RE). Typically, this message is used during line bit rate negotiation.

This message also instructs the IWFs when to start the CPRI frame structure relative to the IWFs local clocks.

At start-up, IWF type 1 and type 2 will exchange eCPRI Type #8 messages. Please refer to section 8.7 for details on the usage of Message Type #8 during the start-up procedure.

3.2.4.9.2. Message format

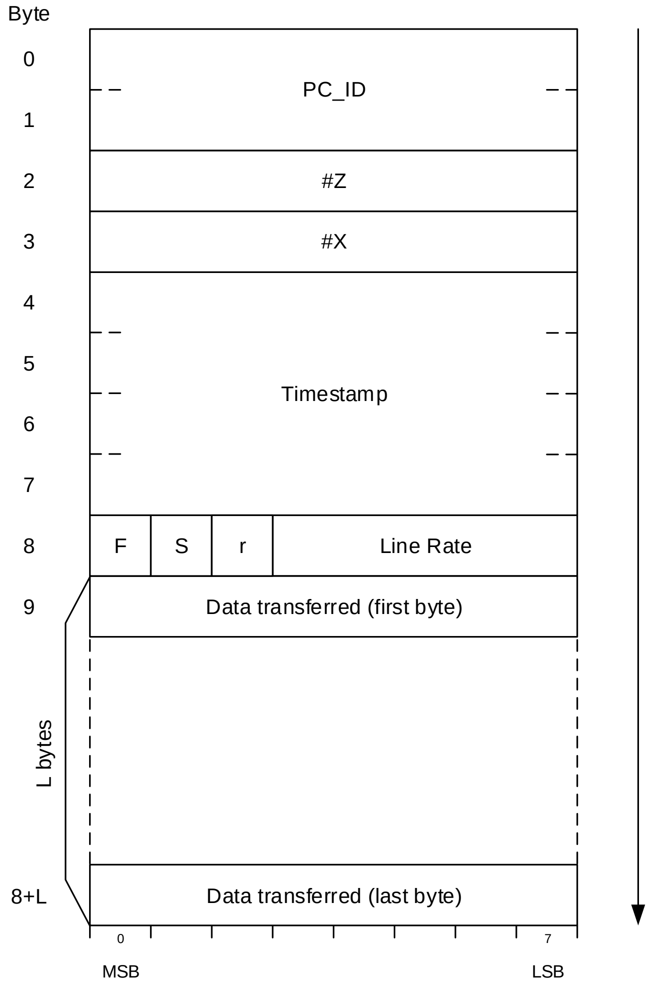


Figure 31A: IWF Start-Up message format

Where:

- PC_ID:
  - 2-byte field identifier of a series of “IWF Start-Up” messages.
  - For example, identifier of destination CPRI node.
  - How to allocate values to PC_ID is vendor specific.
- #Z:

  #Z is the hyperframe number (see [1]) of the corresponding CPRI basic frame.
- #X:

  #X is the basic frame number within the hyperframe (see [1]) of the corresponding CPRI basic frame.
- Timestamp:

  The Timestamp allows the IWF to establish the relation between the CPRI frame structure timing and its local clock. The Timestamp is a value in number of nanoseconds. Only values less than 10^9 shall be used (see [13], section 5.3.3).
  For the IWF type 1 to IWF type 2 direction the Timestamp specifies when the data contents in this message shall start to be transmitted on the IWF type 2 CPRI link. Transmission shall start, when the nanosecond part of IWF type 2 local clock equals this timestamp value.

In the IWF type 2 to IWF type 1 direction this specifies when the CPRI data content was received at IWF type 2.
From this Timestamp the IWFs shall learn when the CPRI hyperframe structure starts relative to the local clocks in the IWFs. The CPRI 10ms frame delimitation is indicated by #Z=0 and #X=0.

See sections 8.7.2 and 8.9 for further details on delay management and Timestamp handling.

- F:
  - CPRI FEC bit indicator of the CPRI link associated with the IWF generating the message.
  - "F=0" indicates that the CPRI FEC is disabled.
  - "F=1" indicates that the CPRI FEC is enabled.
- S:
  - CPRI scrambling bit indicator of the CPRI link associated with the IWF generating the message.
  - "S=0" indicates that the CPRI scrambling is disabled.
  - "S=1" indicates that the CPRI scrambling is enabled.
- Line Rate:
  - Line rate of the CPRI link associated with the IWF generating the message:
  - CPRI line bit rate option 5-bits field (LLLLL):
    - 00000: Reserved
    - 00001: CPRI line bit rate option 1
    - 00010: CPRI line bit rate option 2
    - 00011: CPRI line bit rate option 3
    - 00100: CPRI line bit rate option 4
    - 00101: CPRI line bit rate option 5
    - 00110: CPRI line bit rate option 6
    - 00111: CPRI line bit rate option 7
    - 01000: CPRI line bit rate option 7A
    - 01001: CPRI line bit rate option 8
    - 01010: CPRI line bit rate option 9
    - 01011: CPRI line bit rate option 10
    - 01100…11111: Reserved
- Data transferred:

  The Control Word bytes (T_{CW} bits) of the basic frame #Z, #X.

3.2.4.10. Message Type #9: IWF Operation

3.2.4.10.1. Description/Usage

This message type is used to transfer CPRI basic frames or part of CPRI basic frames between CPRI nodes (REC and RE) after CPRI start-up.

3.2.4.10.2. Message format

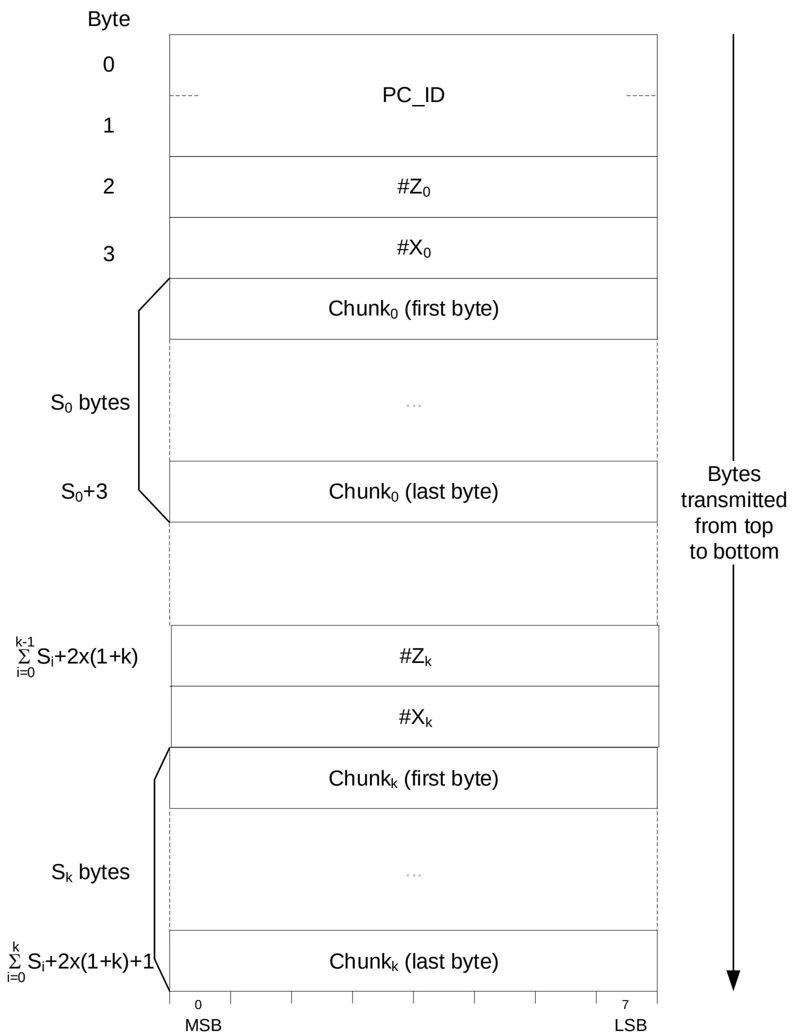
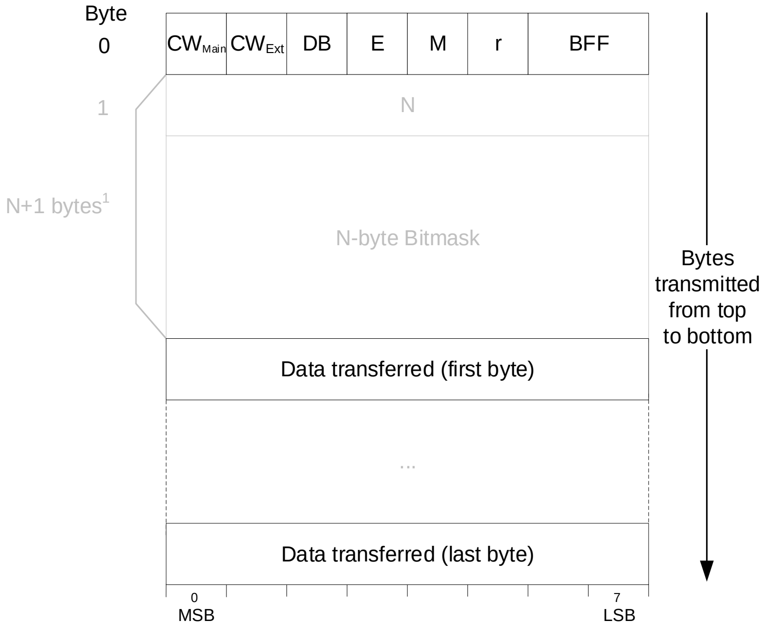


Figure 31B: IWF Operation message format

Where:

- PC_ID:
  - 2-byte field identifier of a series of “IWF Operation” messages.
  - For example, identifier of destination CPRI node.
  - How to allocate values to PC_ID is vendor specific.
- $\#Z_i$:
  - $\#Z_i$ is the hyperframe number (see [1]) of the corresponding CPRI basic frame for chunk #i.
- $\#X_i$:
  - $\#X_i$ is the basic frame number within the hyperframe (see [1]) of the corresponding CPRI basic frame for chunk #i.

The chunk format is defined as follows:



[1]: These N+1 bytes are present if M=1.

Figure 31C: eCPRI Message Type #9 Chunk format

Where:

- CW_{Main}:
  - CPRI Control Word presence bit indicator.
  - “CWMain=0” indicates that the first TCW bits of the CPRI Control Word are not included in the “Data transferred” bytes.
  - “CWMain=1” indicates that the first TCW bits of the CPRI Control Word are included in the “Data transferred” bytes.
- CW_{Ext}:
  - Control Word Extension presence bit indicator.
  - “CWExt=0” indicates that the last T-TCW bits of the word with index W=0 are not included in the “Data transferred” bytes, except if explicitly stated by the sub-part mapping configuration (e.g. by using eCPRI Message Type #10 or higher layer configuration).
  - “CWExt=1” indicates that the last T-TCW bits of the word with index W=0 are included in the “Data transferred” bytes.
- DB:
  - CPRI IQ Data Block presence bit indicator.
  - “DB=0” indicates IQ Data Block bytes are not included in the “Data transferred” bytes.
  - “DB=1” indicates IQ Data Block bytes are included in the “Data transferred” bytes.
- E:
  - Error indicator, indicates if at least one error has been detected during the reception of the CPRI basic frame bytes associated to the “Data transferred” bytes.
- M:
  - N-byte bitmask flag
  - “M=0” indicates that there is no N-byte bitmask descriptor in this chunk.
  - “M=1” indicates that there is an N-byte bitmask descriptor in this chunk.
- N:
  - length in bytes of the N-byte bitmask (N = 0, 1, 2, 4, 8).

- N-byte Bitmask:

  N-byte parameter indicating which sub-part(s) of the previously negotiated CPRI IQ data area configuration (e.g. via eCPRI Message Type #10) are included in the eCPRI message Data transferred field.

  The N-byte bitmask shall be interpreted as follows:

  If the i^{th} bit of the N-byte bitmask is set to 1 then the i^{th} sub-part of the previously negotiated CPRI IQ data area configuration is included in the eCPRI message “Data transferred” field, otherwise this sub-part is not included.

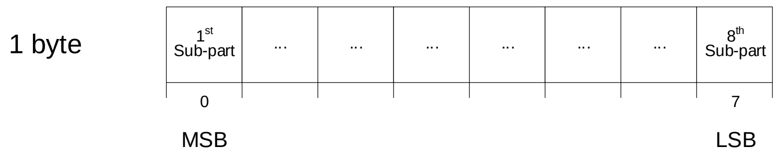


Figure 31D: 1-byte bitmask format

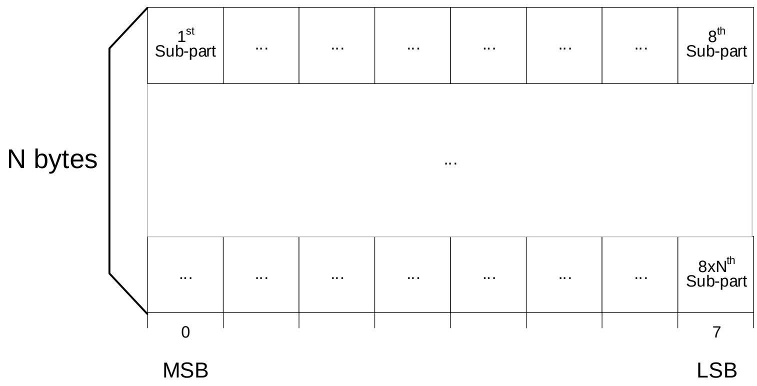


Figure 31E: N-byte bitmask format (N=2, 4, 8)

- BFF:
  - Basic Frame Fragment index of a CPRI basic frame when split over several eCPRI chunks.
  - All fragments of a CPRI basic frame have the same #Z and #X.
  - The main purpose of basic frame fragmentation is to distribute large basic frames over multiple eCPRI messages.
  - BFF shall be set to zero if fragmentation is not used. Otherwise BFF starts at zero for the first fragment of a CPRI basic frame and is incremented by one for subsequent fragments of the same CPRI basic frame.
- Data transferred:
  - The “Data transferred” field bytes correspond to the decoded CPRI basic frame content bytes.
    - M=0:
      Fields shall be created as specified in byte 0 of the chunk (“CW_{Main}”, “CW_{Ext}” and “DB”) in combination the sub-part mapping provided by either:
      - eCPRI Message Type #10: IWF Mapping messages (see section 3.2.4.11)
      - Configured via C&M plane of IWFs
      - Pre-configured
      - Any other vendor-specific method
    - M=1:
      Fields shall be created as specified in byte 0 of the chunk (“CW_{Main}”, “CW_{Ext}” and “DB”) in combination the sub-part mapping provided by either:
      - eCPRI Message Type #10: IWF Mapping messages (see section 3.2.4.11)

- Configured via C&M plane of IWFs
- Pre-configured
- Any other vendor-specific method

Additionally, the sub-part must be set in the corresponding "N-byte bitmask" parameter; otherwise the sub-part shall not be included in "Data transferred".

- “N=0” indicates that there is no N-byte bitmask in this chunk meaning that the current mapping is ignored and the “Data transferred” in the eCPRI message corresponds to the concatenation of the decoded CPRI basic frame content bits indicated by fields “CWMain”, “CWExt” and “DB”.
- “N=1,2,4,8” indicates that there is an N-byte bitmask in this chunk.
- The N-byte bitmask shall be interpreted as follows:
- If the ith bit of the N-byte bitmask is set to 1 then the ith sub-part of the previously negotiated CPRI IQ data configuration shall be included in the eCPRI message “Data transferred” field otherwise this sub-part shall not be included.

  - The “Data transferred” fields in the eCPRI data are padded with bits of zero to fill up to the next byte boundary.

The following examples assume:

- CPRI line bit rate option 2
- IWFs have negotiated a simple mapping, where the first half of the IQ data block is divided in 4 equal sub-parts of 30 bits and the second half (120 bits) is unused, as shown in Figure 31F:

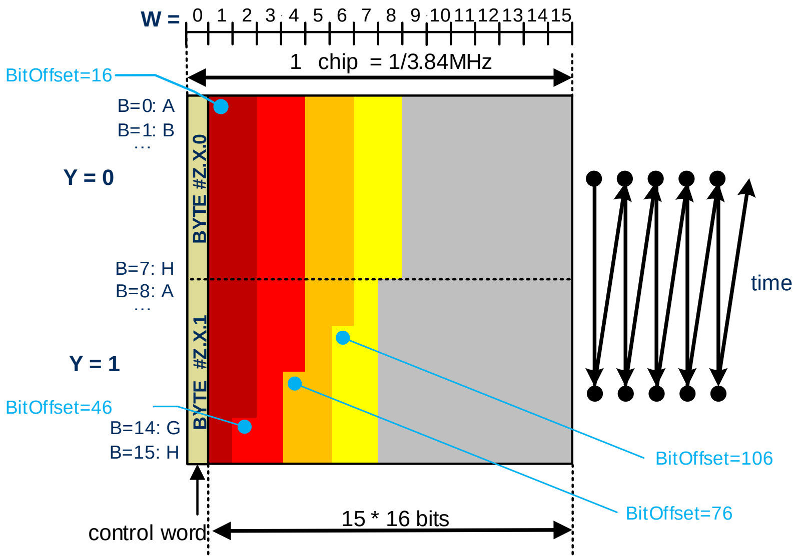


Figure 31F: CPRI basic frame mapping configuration example

With the chunk parameters M=1, N=1 and a 1-byte bitmask = 0xC0, indicating that the first two sub-parts are considered, the corresponding chunk, with CW_{Main}=0 and CW_{EXT}=0 and DB=1, will contain the first 60 bits of the IQ data block and 4 padding bits, as shown in Figure 31G.

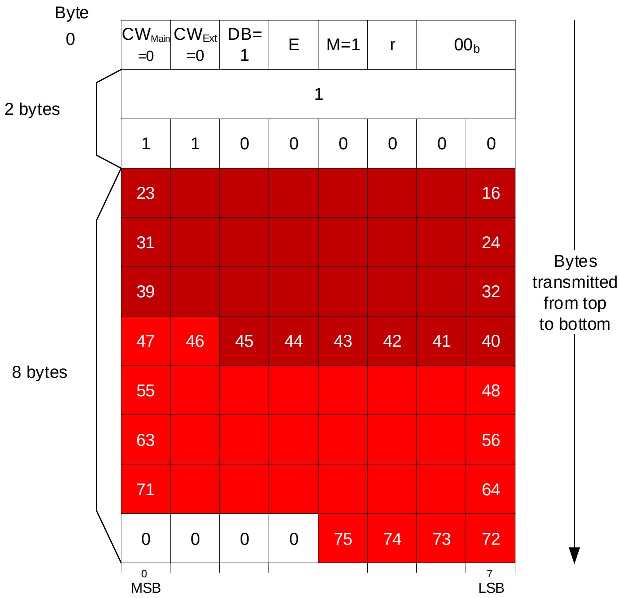


Figure 31G: eCPRI chunk example M=1, N=1 and 1-byte bitmask = 0xC0

With the chunk parameters M=1, N=1 and a 1-byte bitmask = 0x90, indicating that the first and the last sub-parts are considered, the corresponding chunk, with CW_{Main}=0 and CW_{EXT}=0 and DB=1, will contain the first 30 bits and the last 30 bits of the IQ data block and 4 padding bits, as shown in Figure 31H.

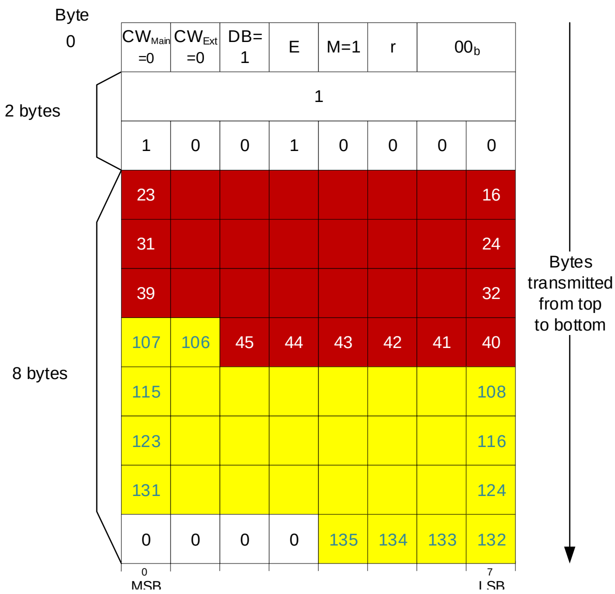


Figure 31H: eCPRI chunk example M=1, N=1 and 1-byte bitmask = 0x90

With the chunk parameter M=0, indicating that there is no N-byte bitmask, the corresponding chunk, with CW_{Main}=0 and CW_{EXT}=0 and DB=1, will contain all four sub-parts with a total size of 120 bits, as shown in Figure 31I.

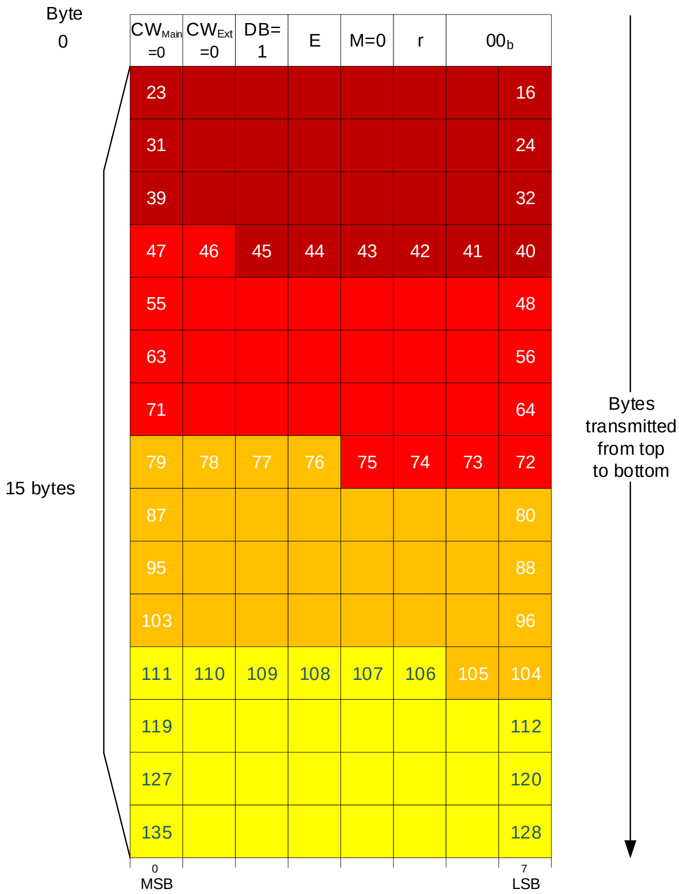


Figure 31I: eCPRI chunk example M=0

With the chunk parameters M=1, N=0, indicating that the whole IQ data block is considered, the corresponding chunk, with CW_{Main}=0 and CW_{EXT}=0 and DB=1, will contain the complete IQ data block of size 240 bits, as shown in Figure 31J:

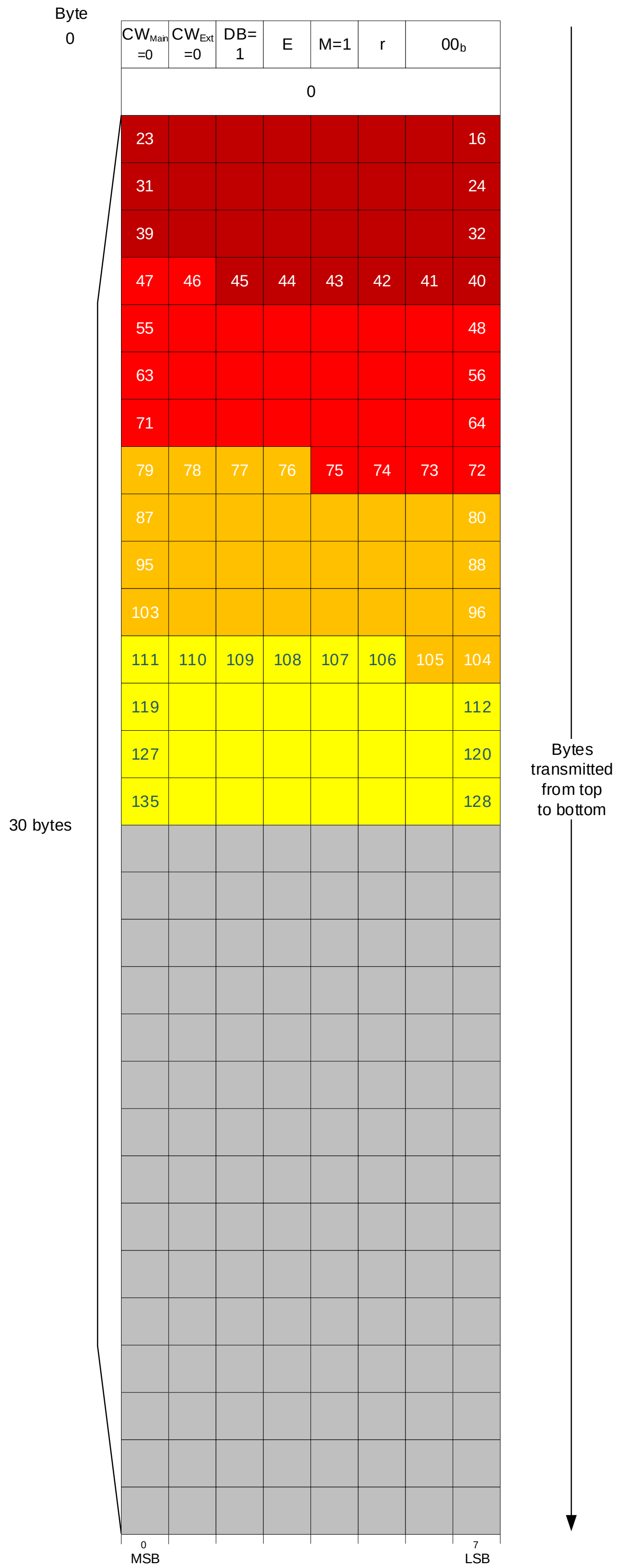


Figure 31J: eCPRI chunk example M=1, N=0

1 3.2.4.10.3. Message sequence diagram

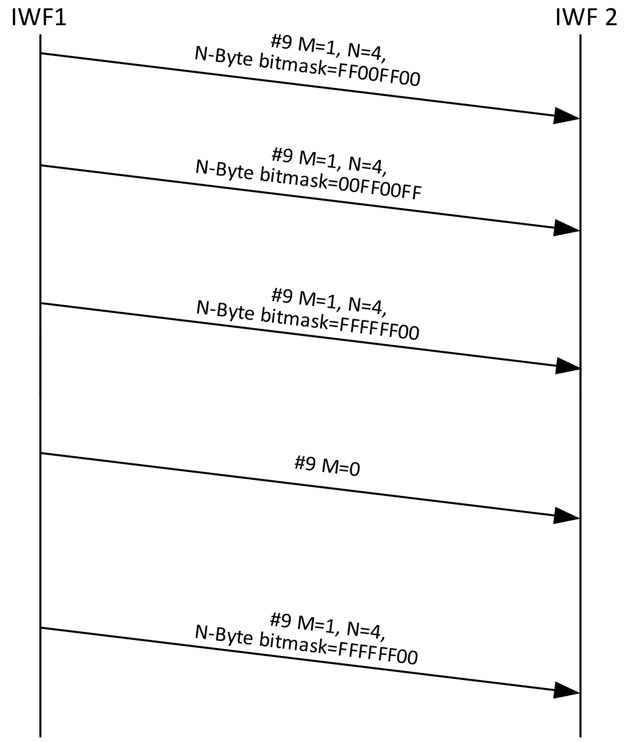


Figure 31K: Message #9 sequence

3.2.4.11. Message Type #10: IWF Mapping

3.2.4.11.1. Description/Usage

This message type is used to negotiate the mapping configuration between two IWFs by defining sub-part locations within the IQ data block area of a CPRI basic frame.

A sub-part may or may not correspond to one or more AxC containers.

Sub-parts may or may not have the same size.

Sub-parts may or may not be contiguous.

In an eCPRI/CPRI interworking scenario, the uplink and the downlink mapping configurations may be different. The downlink mapping configuration request is initiated by IWF type 1, and the uplink mapping configuration request is initiated by IWF type 2.

3.2.4.11.2. Message format

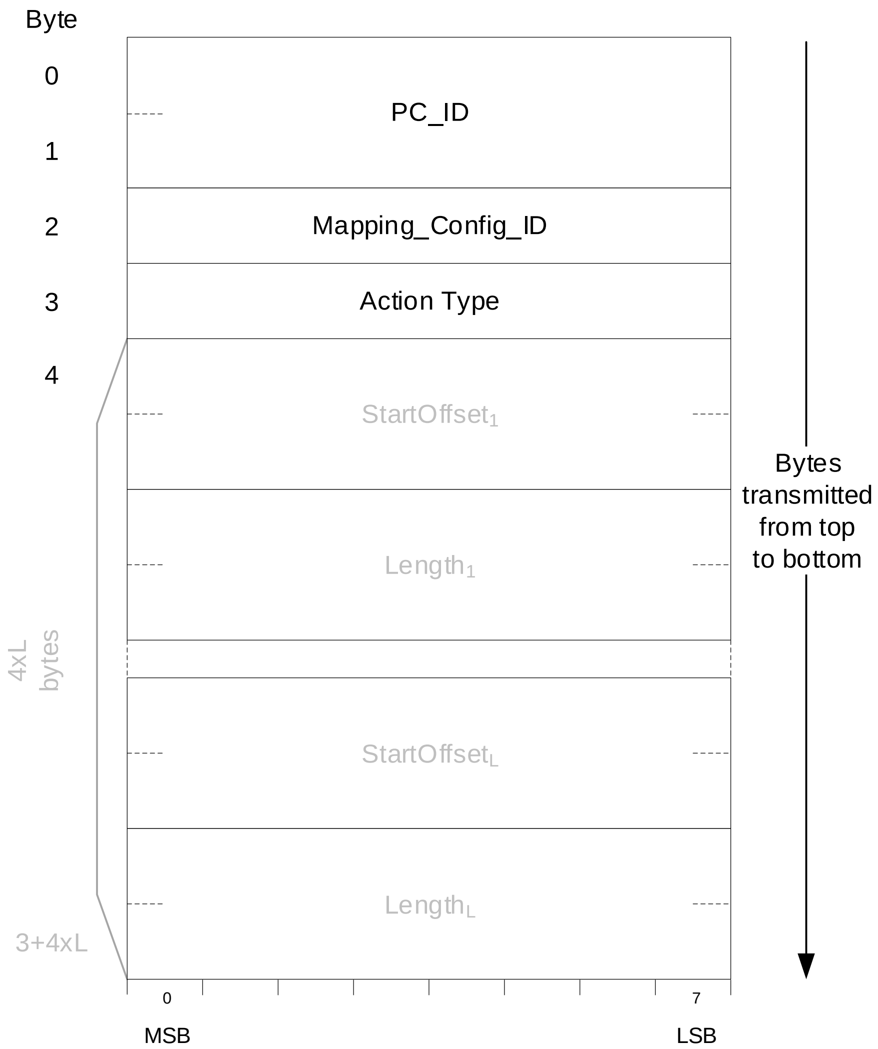


Figure 31L: IWF Mapping message format

Where:

- PC_ID:
  - 2-byte field identifier of a series of “IWF Mapping” messages.
  - For example, identifier of destination CPRI node.
  - For the request message, how to allocate values to PC_ID is vendor specific. For the response message, PC_ID is copied from the request.
- Mapping_Config_ID:
  - 1-byte field identifier of a configuration request.
  - For a request message, how to allocate values to Mapping_Config_ID is vendor specific.
  - For a response message, Mapping_Config_ID is copied from the request. It enables the initiator of the request to distinguish between different configuration requests, when it receives a response.
- Action Type:

  This 1-byte field specifies the type of action associated to the message.

  The Action Type field is coded according to Table 14A.

Table 14A: Action Type

Value	Request/Response
00000000b	SetRxConfigRequest
00000001b	SetRxConfigResponseAccept
00000010b	SetRxConfigResponseReject
00000011b	SetRxConfigResponsePropose
00000100b 11111111b	Reserved

- SetRxConfigRequest:

  This Action Type is used by one IWF to specify the mapping configuration associated to the PC_ID and Mapping_Config_ID in the eCPRI message to be used by the remote IWF.

- SetRxConfigResponseAccept/SetRxConfigResponseReject/SetRxConfigResponsePropose:

  These Action Types are used by one IWF to respond to a SetRxConfigRequest.

  If the requested mapping configuration associated to a SetRxConfigRequest with PC_ID and Mapping_Config_ID parameters is accepted, the request message shall be acknowledged by a SetRxConfigResponseAccept with the same PC_ID and Mapping_Config_ID parameters and no mapping configuration parameters.

  If the requested mapping configuration associated to a SetRxConfigRequest with PC_ID and Mapping_Config_ID parameters is rejected and the receiver does not want to propose an alternative mapping configuration, the request message shall be acknowledged by a SetRxConfigResponseReject with the same PC_ID and Mapping_Config_ID parameters and no mapping configuration parameters.

  If the requested mapping configuration associated to a SetRxConfigRequest with PC_ID and Mapping_Config_ID parameters is rejected, and the receiver wants to propose a mapping configuration, the request message shall be acknowledged by a SetRxConfigResponsePropose with the same PC_ID and Mapping_Config_ID parameters and the proposed mapping configuration parameters. The subsequent SetRxConfigRequest with the proposed mapping shall be accepted by the receiver.

  The mechanisms used to synchronize the IWFs when changing the configuration are out of the scope of the eCPRI specification and are vendor specific.

- StartOffset$_i$/Length$_i$:

These fields specify the location of a sub-part in a CPRI basic frame.

The value of StartOffset$_i$ corresponds to the first bit index of the ith sub-part in a CPRI basic frame. The bit offset StartOffset$_i$ is given by the following equation:

$$\text{StartOffset}_i = B + W \times T$$

where B, W and T are defined by the CPRI specification [1] nomenclature as:

- T is the number of bits per word in a CPRI basic frame (The length T of the word depends on the CPRI line bit rate).
- W is the word index in the CPRI basic frame (W=0…15).
- B is the bit index within a CPRI word (B=0…T-1).

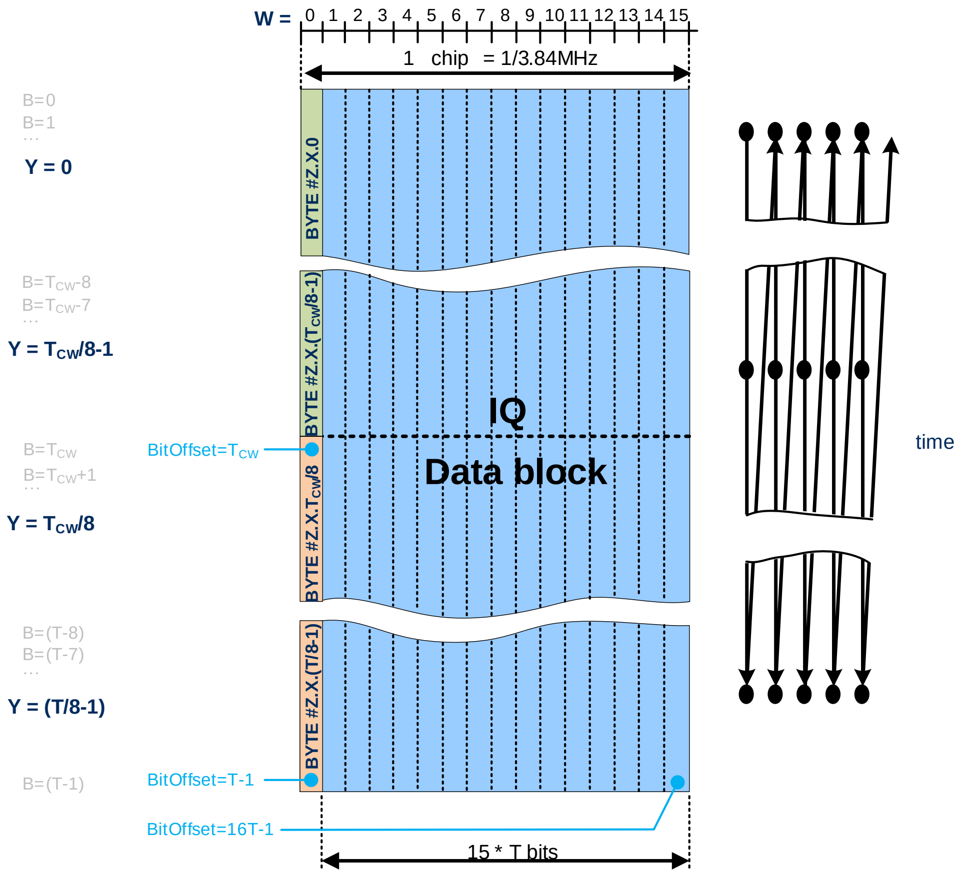


Figure 31M: CPRI Basic bit offsets

The value of $Length_i$ corresponds to the number of bits of the i[th] sub-part of a CPRI basic frame. A $Length_i$ equal to 0 indicates that the sub-part is defined as a Null sub-part, meaning that this sub-part is defined but it is not associated to any actual content.

As the sub-parts are in the IQ data block of a CPRI basic frame, the following inequalities shall be ensured:

$$T_{CW} \leq StartOffset_i$$

$$StartOffset_i + Length_i < 16 \times T$$

Restricted by the maximum N-byte bitmask size of N=8, the number of sub-parts L is less than or equal to 64. Thus, the value of i shall be in the following range:

$$1 \leq i \leq L \leq 64$$

The whole configuration shall be carried in only one message. In each message, i is always numbered from 1. If there are remaining sub-parts not covered in one message, i.e. the number of sub-parts is less than the length of bitmask in Message Type #9, they shall be interpreted as Null sub-parts.

If there are overlapping sub-parts, the corresponding bitmask entries in Message Type #9 shall not be enabled simultaneously in order to avoid that the subsequent sub-part would overwrite the previous sub-part at the receiving end.

The negotiation process of the mapping configuration must be completed before the sub-parts can be used in Message Type #9. During the mapping negotiation process, the bitmasks associated with the changed or added sub-parts must not be enabled.

If there is no valid mapping configuration, only Message Type #9 with DB=1, M=1 and N=0 can be used.

Depending on whether the Action Type is a request or a response, different fields shall be copied or set according to Table 14B.

Table 14B: Parameter handling

Action Type	PC_ID	Mapping_Config_ID	ConfigParameter (StartOffset$_i$/Length$_i$)
SetRxConfigRequest	Set	Set	Set
SetRxConfigResponseAccept	Copied	Copied	No data
SetRxConfigResponseReject	Copied	Copied	No data
SetRxConfigResponsePropose	Copied	Copied	Proposed configuration

3.2.4.11.3. Message sequence diagram

The message sequence diagram shown in Figure 31N is divided in three parts.

The first part of the sequence shows the case where the IWF type 1 initiates a mapping configuration and IWF type 2 accepts the configuration.

The second part of the sequence shows the case where the IWF type 1 initiates a mapping configuration and IWF type 2 rejects the configuration.

The last part of the sequence shows the case where the IWF type 1 initiates a mapping configuration and IWF type 2 rejects the configuration but proposes another configuration instead. Then IWF type 1 initiates a new mapping configuration with the one proposed by IWF type 2, and IWF type 2 accepts the new configuration.

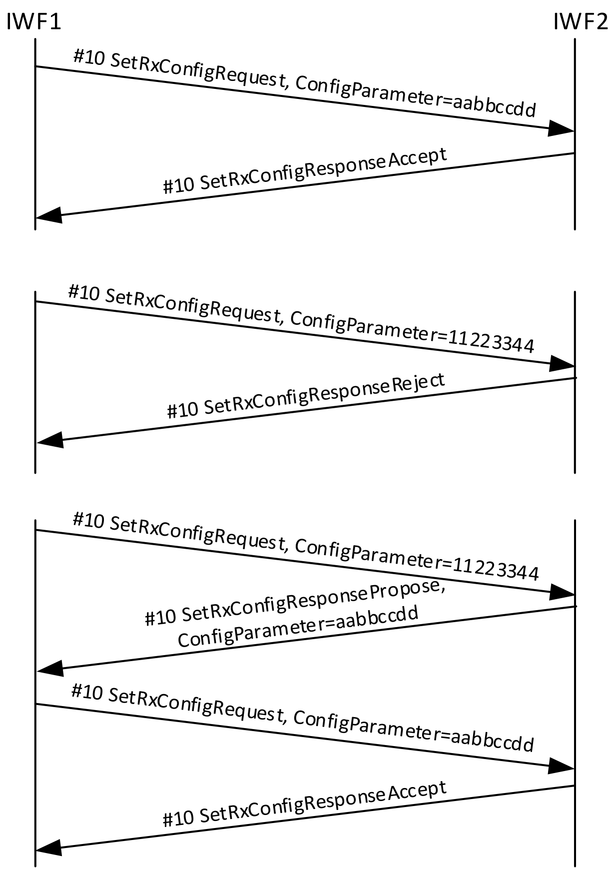


Figure 31N: Mapping configuration negotiation sequence examples

3.2.4.12. Message Type #11: IWF Delay Control

3.2.4.12.1. Description/Usage

The Message Type “IWF Delay Control” is used to retrieve/report delay values from a remote device. A typical use is to assist in the delay management of IWFs type 1 and type 2 in an eCPRI/CPRI interworking scenario. The use of this message type is though not limited to this case.

In an eCPRI/CPRI IWF type 1 and type 2 scenario the IWF type 1 needs delay values from IWF type 2 to be able to calculate required operational parameters. By these calculated parameters and the “Timestamp” in the “IWF Start-Up” messages the IWF type 1 can establish the CPRI frame timing. See section 8.7.2 and section 8.9 for details on how and what IWF type 2 shall respond back to IWF type 1.

3.2.4.12.2. Message format

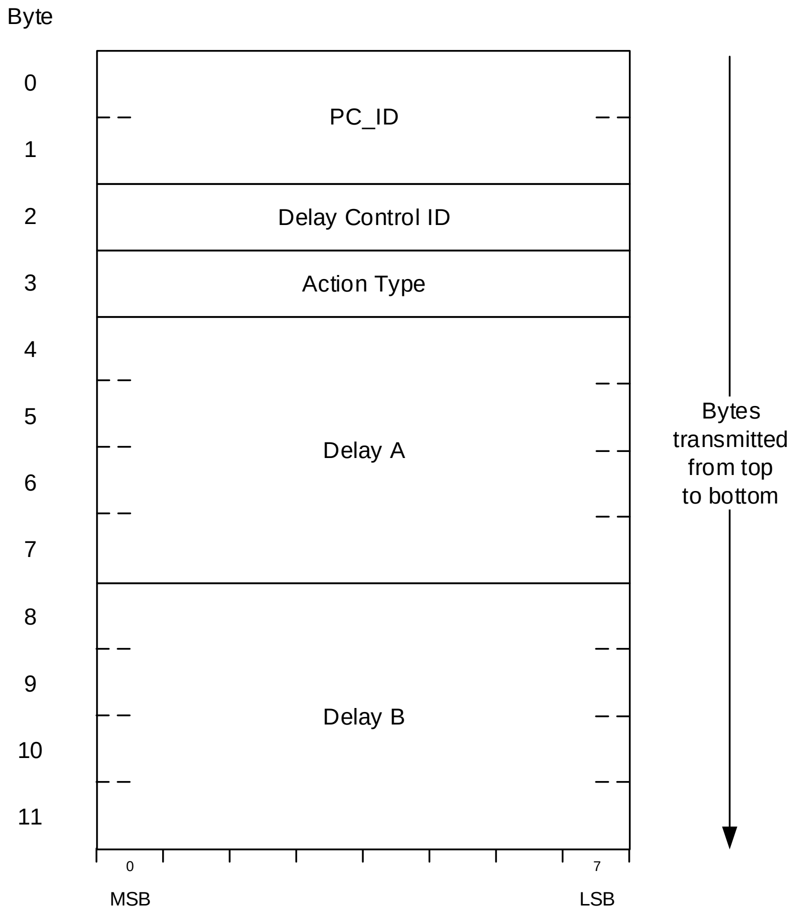


Figure 31O: IWF Delay Control message format

Where:

- PC_ID:
    - 2-byte field identifier of a series of “IWF Delay Control” messages.
    - For example, identifier of destination CPRI node.
    - How to allocate values to PC_ID is vendor specific.
- Delay Control ID:

    The Delay Control ID is a 1-byte value used by the sender of the request when the response is received to distinguish between different Delay Control signals, i.e. the receiver of the request shall thus copy the ID from the request into the response message.
- Action Type:

The Action Type is a 1-byte value described in Table 14C.

Table 14C: Action Type

Action Type	Description
0x00	Request get delays
0x01	Response get delays
0x02 … 0xFF	Reserved

- Delay A/Delay B:

  When Action Type is set to 0x00 (“Request get delays”) or 0x01 (“Response get delays”) the “Delay A” and “Delay B” fields are 4-byte values. The unit of the values is 1/16 ns. For example, a value of 15.5ns will be represented as 0x000000F8. For Action Type 0x00 (“Request get delays”) both “Delay A” and “Delay B” are set to zero.

3.2.4.12.3. Message sequence diagram

A message sequence diagram is shown in Figure 31P. It shows the sequence when IWF type 1 requests delay values from IWF type 2.

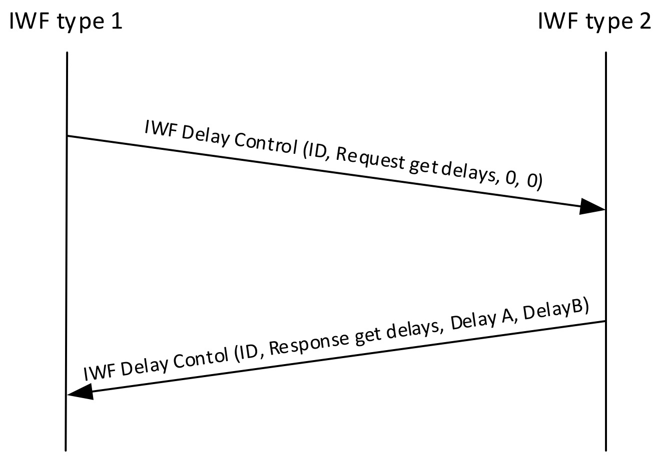


Figure 31P Message sequence diagram for IWF Delay Control

3.2.4.13. Message Type #12 - #63: Reserved

eCPRI Message Types from 12 to 63 are reserved for future eCPRI specifications.

3.2.4.14. Message Type #64 - #255: Vendor Specific

eCPRI Message Types from 64 to 255 are not defined in eCPRI. These are for vendor specific usage. Vendor specific message types shall not be reserved (before any specific usage is defined) by any 3rd parties (other than CPRI and vendors).

Vendor specific usage shall be guaranteed.

3.3. C&M Plane

Control and management information will be exchanged between eCPRI entities (eREC and eRE) on any commonly used transport protocols. The C&M information will not be transmitted via the eCPRI specific protocol. The details of this information flow are out of the scope of the eCPRI specification. This information can use protocols (e.g. TCP) over the IP protocol but any other solution is not precluded.

The C&M information flow will be considered as non-time-critical and utilize a small part of the total bandwidth between eCPRI entities. The majority of this information flow will be considered as background traffic, the rest are interactive traffic that is needed to keep control of the eCPRI node. See section 6.5.2 for considerations regarding priority for C&M data.

3.4. Synchronization Plane

The eCPRI nodes shall recover the synchronization and timing from a synchronization reference source, and the air interface of the eRE shall meet the 3GPP synchronization and timing requirements. The synchronization information will not be transmitted via the eCPRI specific protocol. The details of this information flow are out of the scope of the eCPRI specification. This information flow can use existing protocols (e.g. SyncE, PTP) but any other solution is not precluded.

The synchronization information flow will be considered as time-critical and will utilize a small part of the total bandwidth between eCPRI nodes.

3.5. QoS

The quality of service (QoS) control for eCPRI is implemented by setting different priority for different traffic flows depending of the needed quality of service. If the eCPRI fronthaul network is Ethernet-switched the priority field (PCP field) in the VLAN-tag shall be used for QoS of eCPRI, see further details below. If the eCPRI fronthaul network is IP-routed the Differentiated Services (DiffServ) can be used.

3.5.1. VLAN Tagging for Ethernet-switched fronthaul networks

For an Ethernet network with Ethernet bridges a VLAN tag according to the IEEE 802.1Q-2014 [14] shall always be added by the eRE or eREC and provided to the Ethernet network. The VLAN ID does not need to be set if only the priority is used in the VLAN tag. In that case the VLAN ID (VID field) is set to zero (the null VID). The priority is set in the PCP field of the VLAN tag.

Normally a C-tag with a priority in the PCP field is set by the eCPRI nodes (VID is optional), but other cases may exist depending on the network type and what kind of customer service interface to the network is used. For further details and options see [14].

The use of the VLAN ID (VID field), including the null VID, is fully vendor specific and agreed with the network provider.

How to use the priority field (PCP field) is vendor specific. See section 6.5.2.

3.5.2. QoS for IP-routed fronthaul networks

QoS for IP-routed fronthaul network can be done by DiffServ. The DiffServ uses the DSCP field in the differentiated services field (DS field) in the IP header for classification purposes. How to use the DSCP field for QoS in an IP-routed fronthaul network is fully vendor specific.

Other ways to implement QoS in an IP-routed fronthaul network are possible.

4. Forward and Backward Compatibility

In order to allow for forward and backward compatibility of eCPRI, the following requirements are introduced.

4.1. Fixing eCPRI Protocol Revision Position

For forward and backward compatibility, the eCPRI Protocol Revision field in the common header shall be fixed in all revisions. This is in order to find the eCPRI protocol revision correctly.

4.2. Reserved Bits and Value Ranges within eCPRI

Within the eCPRI message format some data parts are reserved for future use by the CPRI specification group. These parts may be used in future releases of the eCPRI specification to enhance the capabilities or to allow the introduction of new features in a backward compatible way. The reserved data parts are of two different types:

1. Reserved bits in the eCPRI common header or reserved bits within a specific message payload.
2. Reserved value ranges in both eCPRI common header and within a specific message payload.

Reserved data parts of type 1: the transmitter shall send 0's for the reserved bits, and the receiver shall not interpret the reserved bits.

Reserved data parts of type 2: the transmitter is only allowed to use values that are defined by this specification or as defined within a vendor specific range. The receiver shall discard the message when receiving a message with illegal values.

4.3. eCPRI specification release version

The eCPRI specification release version is indicated by two digits (version A.B). The following text defines the digits:

- The first digit A is incremented to reflect significant changes (modification of the scope, new section…).
- The second digit B is incremented for all changes of substance, i.e. technical enhancements, corrections, updates etc.

4.4. Specification release version mapping to eCPRI protocol revision

The eCPRI common header field “eCPRI Protocol revision” indicates the protocol version number, which will be denoted by 1, 2, 3, … The protocol revision number will be incremented only when a new specification release version includes changes that lead to incompatibility with previous specification release versions.

The simple sequence and the well-defined rule for non-compatibility between different specification release versions allows for a simple, efficient and fast start-up procedure. The following table provides the mapping between specification release version and protocol revision number.

Table 15: Specification release version and protocol revision numbering

Specification release version	Available eCPRI protocol revision values	Comment
1.0, 1.1, 1.2, 2.0	0001b	The interpretation of the eCPRI message shall follow eCPRI specification versions up to 2.0.
	0010b-1111b; 0000b	Reserved for future eCPRI protocol revisions. Unallocated values can temporarily be used for vendor specific extensions until allocated.

This table shall be updated when new specification release versions become available.

5. Compliance

An eCPRI compliant interface shall fulfill the following requirements:

- An eCPRI compatible interface shall follow the normative parts of this specification.
- One or more eCPRI Message Types are used over the interface for eREC and eRE communication.
- eCPRI Message Types in use are implemented as per their defined requirements.

An eCPRI compliant IWF type 1/2 implementation shall in addition follow section 8 of this specification.

6. Annex A - Supplementary Specification Details (Informative)

6.1. Functional Decomposition

6.1.1. eCPRI Functional Decomposition

The functional content of the PHY layer and a typical processing order is shown in Figure 32. Process stages marked with grey text are optional, i.e. in a non-massive antenna configuration those stages are not present. The eCPRI specification focuses on three different reference splits, two splits in downlink and one split in uplink (Split I_D, II_D and I_U). Any combination of the different downlink/uplink splits is possible.

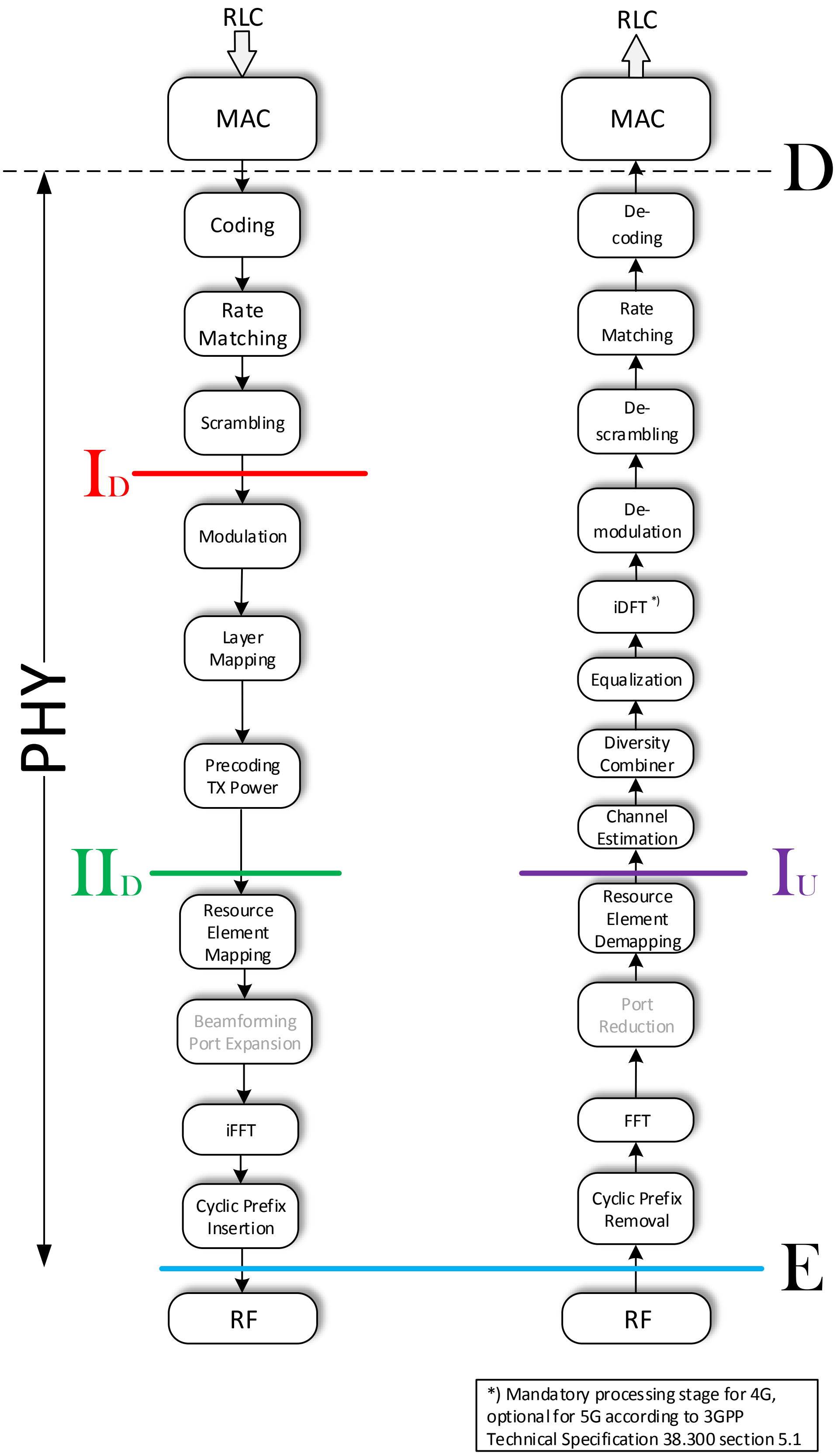
Nevertheless, any other split within the PHY layer (and also any other inter/intra layer split) is not precluded to be used with the eCPRI specification.

The major difference between Split I_D and II_D is that the data in Split I_D is bit oriented and the data in split II_D and I_U is IQ oriented.

In Figure 32 only the data plane processing stages are shown, but in parallel to this, a user data real time control flow also exists. Depending on where the split is, this real-time control data is e.g. modulation scheme, Tx power, beamforming information etc. The bit rate of this real-time control flow differs between different splits. As a rule of thumb the closer to the MAC layer the split is, the more real time control data needs to be sent between the two eCPRI nodes eREC and eRE.

It is possible to implement e.g. a PRACH preamble detection process in the eRE and handling of SRS in the eRE thus lowering the bit rate needs in the uplink direction, these options/possibilities are however not shown in Figure 32. Also, in the downlink direction the reference signals and synchronization signals could be generated internally on the eRE with just an initial configuration by the eREC, this is not shown in the figure either.

One of the major objectives of a new functional split between eREC and eRE compared to the classical CPRI functional split is to lower the bit rates on the fronthaul interface. When looking at the different processing stages performed in the PHY-layer (see Figure 32) in downlink direction, three processes will mostly increase the bit rate. These three processes are modulation, the port-expansion being done in combination with the beamforming process and the IFFT+cyclic-prefix-process (i.e. going from the frequency domain to the time domain). By moving the split upwards in the figure the fronthaul bit rate will be lowered and vice versa. But conversely the bit rate for the user plane real-time control data will increase when moving the split point towards the MAC layer and vice versa.



1

2 Figure 32: PHY layer and eCPRI splits

6.1.2. Bit Rate Calculations / Estimations

When making the decision for what split to implement one major issue will be the bit rate capacity on the link between the eREC and the eRE. When moving the split point from the MAC-PHY boundary towards the RF layer the bit rate will increase for each step. This applies for the user data, the opposite is true for the control data needed to process the data on the eRE, i.e. the bit rate for the control data will decrease when moving the split towards the RF layer. However, the sum of the bit rates for the user data and the control data will not remain the same.

It is assumed that the control algorithm for e.g. beamforming resides in the eREC and that control data for these stages must be transmitted from eREC to eRE.

When going to a split that is above the split E there are many factors that will have an impact on the final needed bit rate of the link between eREC and eRE. The most relevant factors are:

- Throughput (closely related to the available and used air bandwidth)
- Number of MIMO-layers
- MU-MIMO support (y/n)
- Code rate
- Modulation scheme
- Beamforming algorithm
- Number of antennas

When making a comparison of the needed bit rate between an eCPRI split and the classical CPRI split (split E) one needs to set a specific use case.

Among the abovementioned factors, only the “Number of antennas” has an impact on the bit rate for split E.

There are on the other hand other factors that have an impact on the needed bit rate for a split E implementation as well which are not mentioned in the bullet list above. These factors are mainly: sample frequency for the IQ-data, used IQ-format (number of bits per IQ-sample) and the presence of IQ compression algorithms or not.

6.1.2.1. Bit Rate Calculation Example

eCPRI has no limitation with respect to the factors mentioned in the previous section.

As an example, the following values are used for the forthcoming bit rates calculations:

- Throughput: 3/1.5 Gbps (downlink/uplink, end-user data rate, transport block from/to MAC)
- Air bandwidth: 100 MHz (5 * LTE20) -> 500 PRB
- Number of downlink MIMO-layers: 8
- Number of uplink MIMO-layers: 4 (with 2 diversity streams per uplink MIMO layer)
- MU-MIMO: No
- TTI length: 1 ms
- Digital beamforming where BF-coefficients calculation is performed in eREC.
- Rate matching assumptions: Code rate: ~0.80
- Modulation scheme (Downlink & Uplink): 256 QAM
- Number of antennas: 64
- Sub-carrier spacing: 15 kHz
- IQ sampling frequency: 122.88 Msps (3.84*32)
- IQ-format: 30 bits per IQ-sample
- No IQ compression

Table 16: PHY layer splits bit rate estimations for the example use case above

	Split D		Split I_D		Split II_D		Split E
	User Data [Gbps]	Control [Gbps]	User Data [Gbps]	Control [Gbps]	User Data [Gbps]	Control [Gbps]	User Data [Gbps]
eREC→ eRE	3 (assumption)	<< 1	< 4	< 10	~ 20	< 10	236
			Split I_U				
eRE → eREC	1.5 (assumption)	<< 1	~ 20	< 10	~ 20	< 10	236

6.2. Synchronization and Timing

An eCPRI node shall recover the frequency and time/phase from its synchronization reference source (see Figure 3). In an eCPRI installation all eCPRI nodes (eRECs and eREs) need to be time synchronized to a common time reference, see sections 6.2.1 and 6.2.2 for more information.

Different solutions exist for synchronization of eREC and eRE.

6.2.1. Synchronization of eRE

Depending on which 3GPP features a specific eCPRI installation supports, different timing accuracy requirements are applicable for the eRE node. [15] defines four different timing synchronization requirement categories each one targeting different timing accuracy requirements for different use cases. The different categories will supply different timing accuracy at the edge of the fronthaul network, i.e. "almost" at the input-port on the eRE. With the knowledge of the expected supplied timing accuracy it will be possible to implement an eRE that will fulfill the final timing accuracy requirement on the air interface according to the 3GPP requirements.

The eRE shall also fulfill requirements set by 3GPP on the transmission frequency accuracy and the phase noise (implicit requirement).

6.2.2. Synchronization of eREC

The timing accuracy requirement on the eREC is relaxed compared to the requirement set on the eRE (see 6.2.1). Actually, the eREC does not need to have a high quality frequency available since it is the eRE that will generate the frequency for air transmission locally. Nevertheless, there will be a vendor specific requirement set on the eREC regarding the eREC timing accuracy. Such a requirement is needed to be able to send data at correct time to the eRE from the eREC thus to give the eRE time for its processing of the data before being transmitted on the air interface and for buffer handling due to network latency variation. The requirement value depends on vendor specific choices related to desired performance for the wireless network, expected delay variation in fronthaul network etc.

6.2.3. Synchronization of IWFs

The synchronization requirements for IWF type 0 are similar to (or may be tighter than) those of an eRE, see Section 7.4.

The synchronization requirements for IWF types 1 and 2 are for further study.

6.3. Link Delay Management

The following section provides a description of the link delay management in eCPRI. Figure 33 shows an example of an eREC and eRE connected via an eCPRI network. Both eREC and eRE clocks are synchronized to a common grand master clock (in this example via PTP).

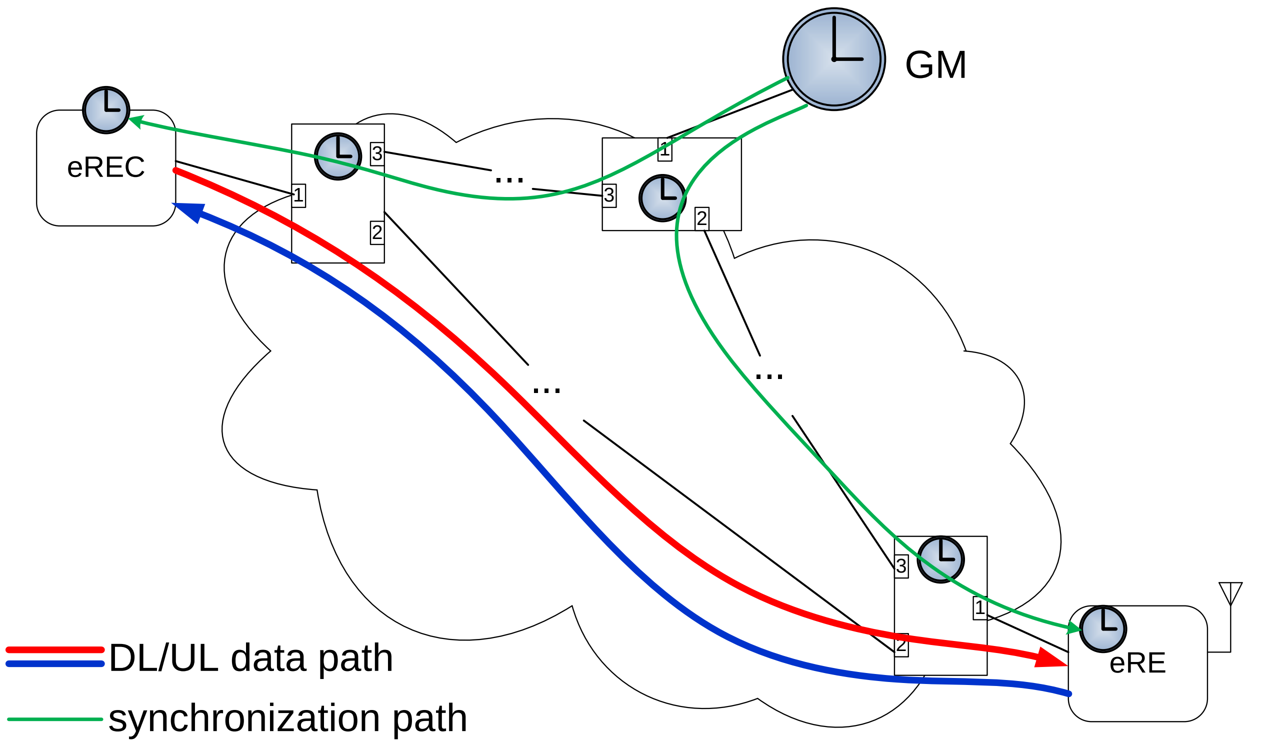


Figure 33: eCPRI topology example with synchronization via PTP

6.3.1. Reference Points for Delay Measurement

The reference points for delay management are the input and the output points of the equipment, i.e. the connectors of eREC and eRE as shown in Figure 34.

Reference points R1 to R4 correspond to the output point (R1) and the input point (R4) of the eREC, and the input point (R2), and the output point (R3) of an eRE. The antenna is shown as “Ra” for reference.

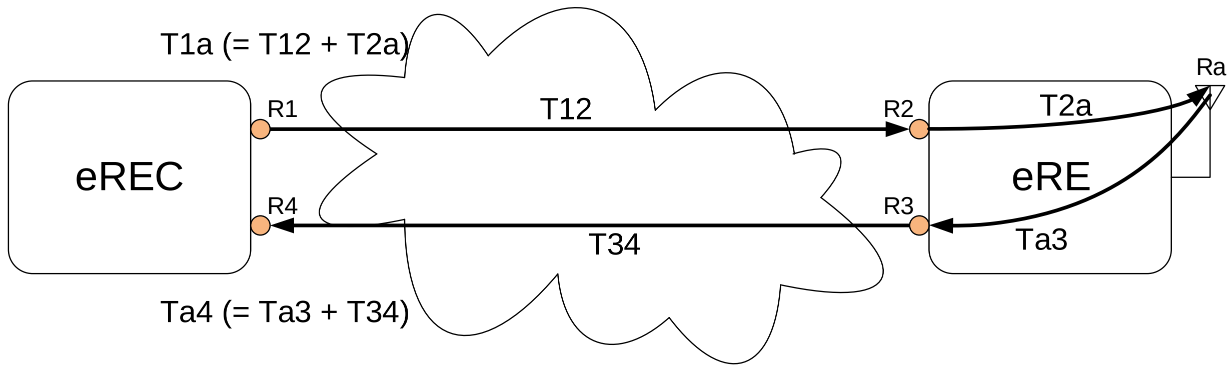


Figure 34: Definition of reference points for delay management

The definitions for the different delays are given in the remaining of this section.

Note: The eRE delay definitions refer to the delay between the transmission/reception of an IQ sample at the antenna Ra and the reception/transmission of data packets containing the corresponding information at the fronthaul interface R1/R4 (eREC) and R2/R3 (eRE). In case of time domain IQ functional split, the assignment is straight forward since an eCPRI message carries IQ samples. In case of frequency domain functional split, the information associated to an IQ sample is contained in a set of N packets, e. g. frequency domain IQ data for one OFDM symbol + related control information or user data for one OFDM symbol + related control information.

Please note that N can vary per symbol/TTI according to the number of users/used resource blocks.

- T12 is the transport network delay of a user data packet between eREC (R1) and eRE (R2) in DL direction. T12 may not be constant for every data packet and shows a statistical variation, but its range is limited by e.g. the profile of deployed transport network:

$$0 \leqq T12\ min \leqq T12 \leqq T12\ max$$

  Where:

  - T12 max is given as the maximum one-way end-to-end latency, see e.g. [15].
  - T12 min is 0 in general, but in case the minimum latency of some or all network elements are known, it can be determined by the sum of all fiber delays and minimum forwarding delays of the network nodes along the DL data path.

- T34 is the transport network delay of a user data packet between eRE (R3) and eREC (R4) in UL direction. T34 may not be constant for every data packet and shows a statistical variation, but its range is limited by e.g. the profile of deployed transport network:

$$0 \leqq T34\ min \leqq T34 \leqq T34\ max$$

  Where:

  - T34 max is given as the maximum one-way end-to-end latency, see e.g. [15].
  - T34 min is 0 in general, but in case the minimum latency of some or all network elements are known, it can be determined by the sum of all fiber delays and minimum forwarding delays of the network nodes along the UL data path.

- T1a is the timing difference between the transmission of a user data packet at the output point R1 of the eREC and the transmission of IQ samples at the antenna Ra of the eRE. The transmission of the earliest IQ sample which is generated from the transmitted user data is used as the reference timing at the antenna Ra. T1a may not be constant but its range is limited by e.g. eREC design specification:

$$0 \leqq T1a\ min \leqq T1a \leqq T1a\ max$$

  Where:

  - Both T1a min and T1a max are vendor specific values; in general, T1a min is related to the best case processing time of user data and T1a max is related to the worst case processing time and the output buffer size.

- T2a is the timing difference between the reception of a user data packet at the input point R2 of eRE and the transmission of IQ samples at the antenna Ra. The transmission of the earliest IQ sample which is generated from the received user data is used as the reference timing at the antenna Ra. T2a may not be constant but its range is limited by e.g. eRE design specification:

$$0 \leqq T2a\ min \leqq T2a \leqq T2a\ max$$

  Where:

  - Both T2a min and T2a max are vendor specific values; in general, T2a min is related to the worst case eRE processing time of user data and T2a max is related to the input buffer size and the worst case eRE processing time.
  - If a user data packet arrives outside of this reception window (i.e. earlier than T2a max or later than T2a min), the user data packet may not be used and consequently IQ samples related to this user data packet may not be generated correctly.

- Ta3 is the timing difference between the reception of IQ samples at the antenna Ra and the transmission of a user data packet at the output point R3 of eRE. The reception timing of the earliest IQ sample necessary to generate the user data packet is used as the reference timing at the antenna Ra. Ta3 may not be constant but its range is limited by e.g. eRE design specification:

$$0 \leqq Ta3\ min \leqq Ta3 \leqq Ta3\ max$$

Where:

- Both Ta3 min and Ta3 max are vendor specific values; in general, Ta3 min is related to the best case eRE processing time of user data and Ta3 max is related to the worst case eRE processing time and the output buffer size.

- Ta4 is the timing difference between the reception of IQ samples at the antenna Ra of the eRE and the reception of a user data packet at the input point R4 of the eREC. The reception timing of the earliest IQ sample necessary to generate the user data packet is used as the reference timing at the antenna Ra. Ta4 may not be constant but its range is limited by e.g. eRE design specification:

$$0 \leqq \text{Ta4 min} \leqq \text{Ta4} \leqq \text{Ta4 max}$$

Where:

- Both Ta4 min and Ta4 max are vendor specific values; in general, Ta4 min is related to the input buffer size and the worst case eREC processing time. Ta4 max is related to the eREC worst case processing time of user data.
- If a user data packet arrives outside of this reception window (i.e. earlier than Ta4 min or later than Ta4 max), the user data packet may not be used and (a part of) the UL user data may be lost or degraded.

The DL timing relations are shown in Figure 35. eREC and eRE clocks are synchronized to a common GM and it is assumed that both eREC and eRE know the timing relation between air frame start and their clocks. The time point when the first IQ sample of a DL air frame has to be transmitted at the antenna is indicated by the red line on the right.

By definition, the following equation has to be satisfied:

$$\text{T1a} = \text{T12} + \text{T2a}$$

This equation implies that fluctuation of transport network latency and the eREC transmission timing has to be absorbed by the input buffer of eRE; moreover the minimum/maximum limits of these three variables are not independent; i.e. the following conditions have to be met in order not to lose DL user data.

$$\text{T1a min} \geqq \text{T12 max} + \text{T2a min}$$

$$\text{T1a max} \leqq \text{T12 min} + \text{T2a max}$$

“Tx window size at R1” $\leqq$ “Rx window size at R2” - “max fluctuation of transport network latency”

Where:

“Tx window size at R1” = T1a max - T1a min

“Rx window size at R2” = T2a max - T2a min

“Max fluctuation of transport network latency” = T12 max - T12 min

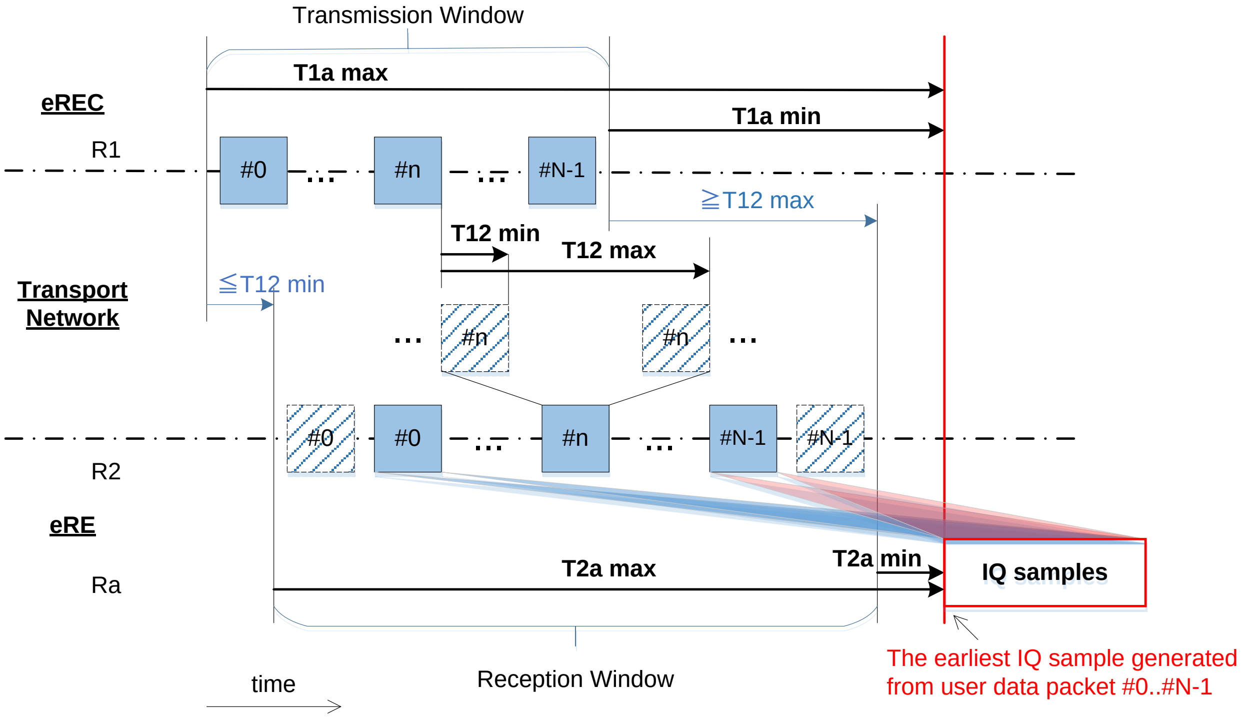


Figure 35: Timing relations in DL direction

The UL timing relations are shown in Figure 36. The time point when the first IQ sample of a UL air frame to be received at the antenna is indicated by the red line on the left.

By definition, the following equation has to be satisfied:

$$Ta4 = Ta3 + T34$$

Therefore the minimum/maximum limits of these three variables are not independent; i.e. the following conditions have to be met in order not to lose UL user data.

$$Ta4\ min \leqq Ta3\ min + T34\ min$$

$$Ta4\ max \geqq Ta3\ max + T34\ max$$

“Rx window size at R4” ≧ “Tx window size at R3” + “max fluctuation of transport network latency”

Where:

“Tx window size at R3” = Ta3 max – Ta3 min

“Rx window size at R4” = Ta4 max – Ta4 min

“Max fluctuation of transport network latency” = T34 max – T34 min

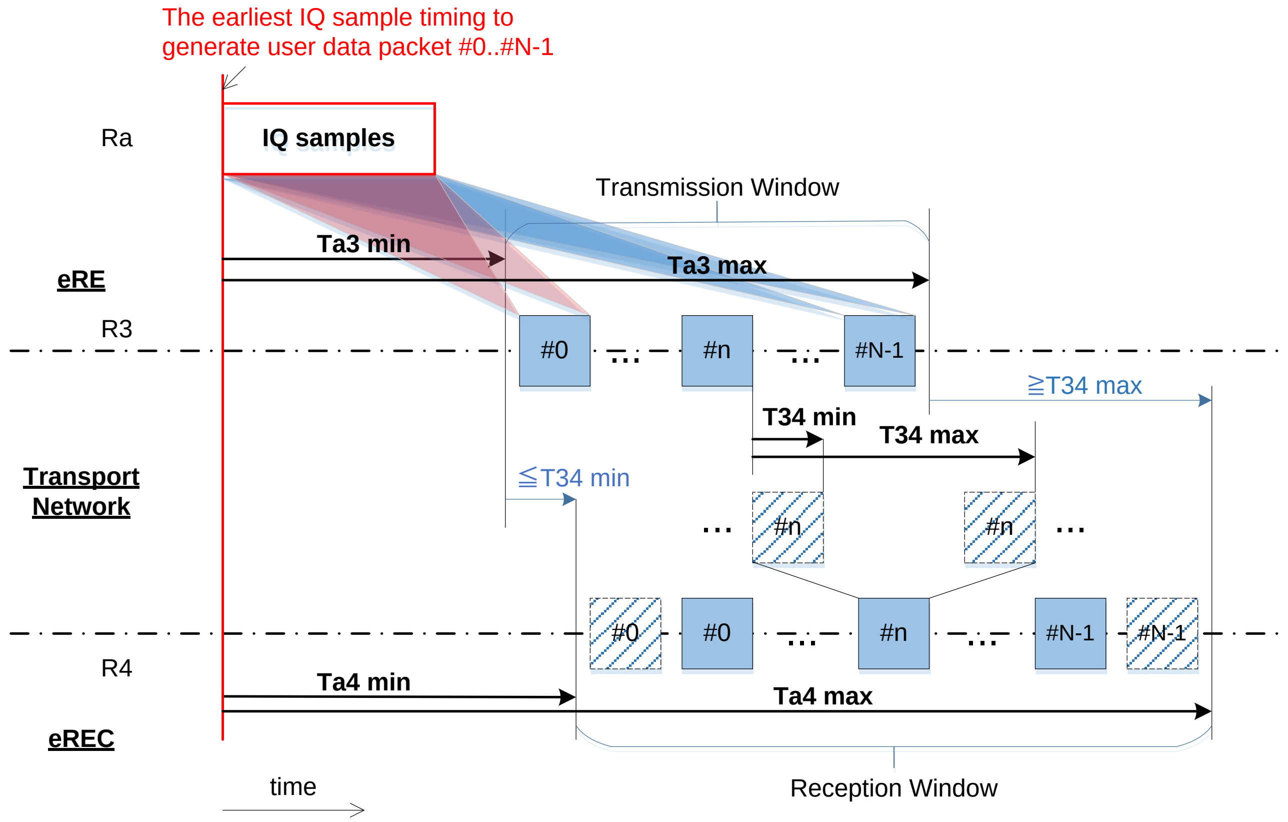


Figure 36: Timing relations in UL direction

6.3.2. Delay Management example

Figure 37 shows a model of UL/DL eCPRI user data transmission between eCPRI nodes (eREC and eRE). Both transmitter and receiver side of eCPRI nodes have buffer memories to absorb the fluctuation of transport network delay as well as the variation of processing time in eCPRI nodes which depends on the traffic and processing load. The goal of delay management is to avoid the overflow/underflow of buffer memories and to decrease the overall delay, the necessary size of buffer memories, etc. at the same time. Additionally, a sort of traffic shaping may be necessary at the transmitter side to avoid unnecessary traffic congestion. Flow control with fast feedback loop is not considered in this example.

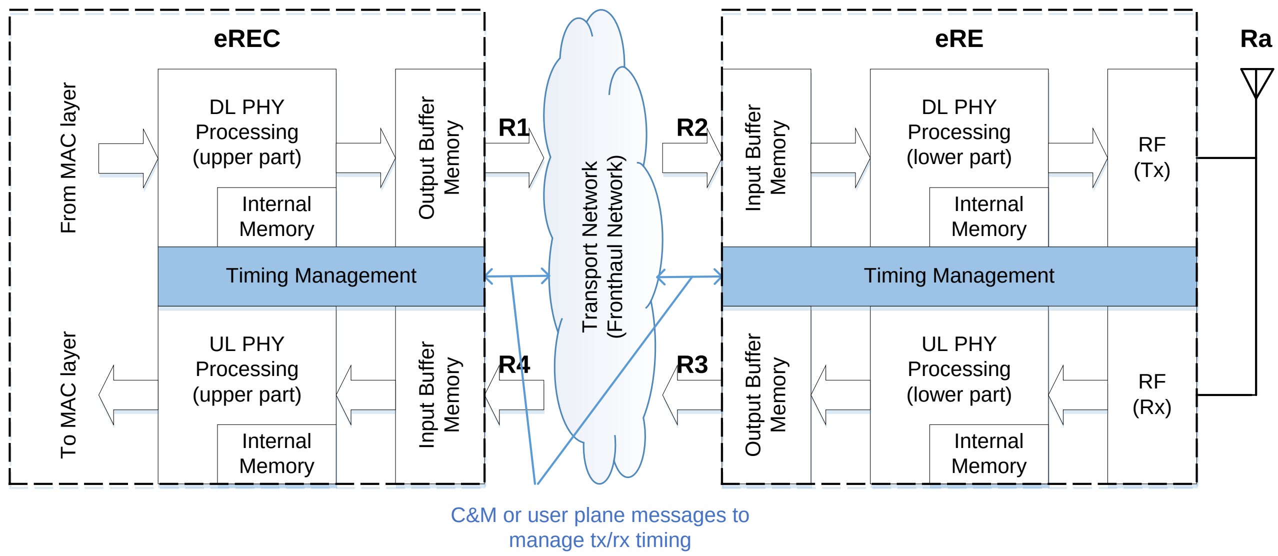


Figure 37: Delay management model example

eREC functions:

- Measure the actual typical/maximum/minimum one-way delay between the eREC and the eRE (UL and DL direction) in addition to the nominal maximum/minimum transport network delay and allocate the optimum delay budget to the eREC, the eRE and the transport network.
    - eCPRI service “one-way E2E delay measurement” is used.
    - Measure the delay periodically if necessary.
- Manage the transmission timing of UL/DL user plane messages in order to ensure that messages arrive at the eRE properly (i.e. within the reception windows at the eRE), considering:
    - UL/DL frame timing at the antenna of the eRE (strictly defined by 3GPP specification)
    - Deadline of each user plane message (or a group of messages) for the eRE to start/complete UL/DL processing to avoid buffer underflow.
    - The maximum size of the input buffer at the eRE as well as the remaining size to avoid buffer overflow.
    - The actual delay of the transport network and processing time in the eRE based on reports from the eRE.
- Declare the allowable reception window timing for each (or a group of) UL user plane message(s) relative to the air interface frame timing.
    - The end of the window (deadline) depends on the processing time in the eREC (vendor specific), especially the HARQ related processing.
    - The beginning of the window depends on the input buffer size in the eREC (vendor specific)
- Monitor the actual reception timing of (critical) user plane message and the input buffer status and request the eRE to adapt the transmission timing if necessary.

eRE functions:

- Manage the transmission timing of UL user plane messages in order to ensure that messages arrive at the eREC properly (i.e. within the reception windows at the eREC).
- Declare the allowable reception window timing for each (or a group of) UL/DL user plane message(s) relative to the air interface frame timing.
    - The end of the window (deadline) depends on the processing time in the eRE (vendor specific).
    - The beginning of the window depends on the input buffer size in the eRE (vendor specific).
- Monitor the actual reception timing of (critical) user plane messages and the input buffer status and report them to the eREC.
    - At least, the occurrence of buffer overflow/underflow (late delivery) should be reported.
    - Reports may be transferred by C&M plane or eCPRI services (“Real-Time Control Data” or “Event Indication”) depending on its time criticality.
- Additionally, traffic shaping of UL user data may be necessary to avoid unnecessary transport network congestion, especially in case the transport network bandwidth is shared by multiple synchronized TDD eREs.

Figure 38 shows an example of DL user data transmission timing between the eREC and the eRE.

In this example, we assume:

- The eREC transmits user data each OFDM symbol interval (e.g. 67usec for LTE).
- The eRE has an input buffer large enough to store full messages for 3 OFDM symbols.
- Only worst cases (regarding min/max delay of transport network, maximum processing time in the eRE) are considered.
- The transmission timing of the first IQ sample of OFDM symbol #n at the eRE antenna Ra is used as the reference timing. This timing is strictly defined by 3GPP specification, so fluctuation is not allowed.

- The eREC transmits all user data packets which are necessary to generate OFDM symbol #n within the transmission window [T1a max, T1a min] before its first IQ sample is transmitted from the eRE antenna.
- The eRE receives all user data packets which are necessary to generate OFDM symbol #n within the reception window [T2a max, T2a min] before its first IQ sample is transmitted from the eRE antenna.

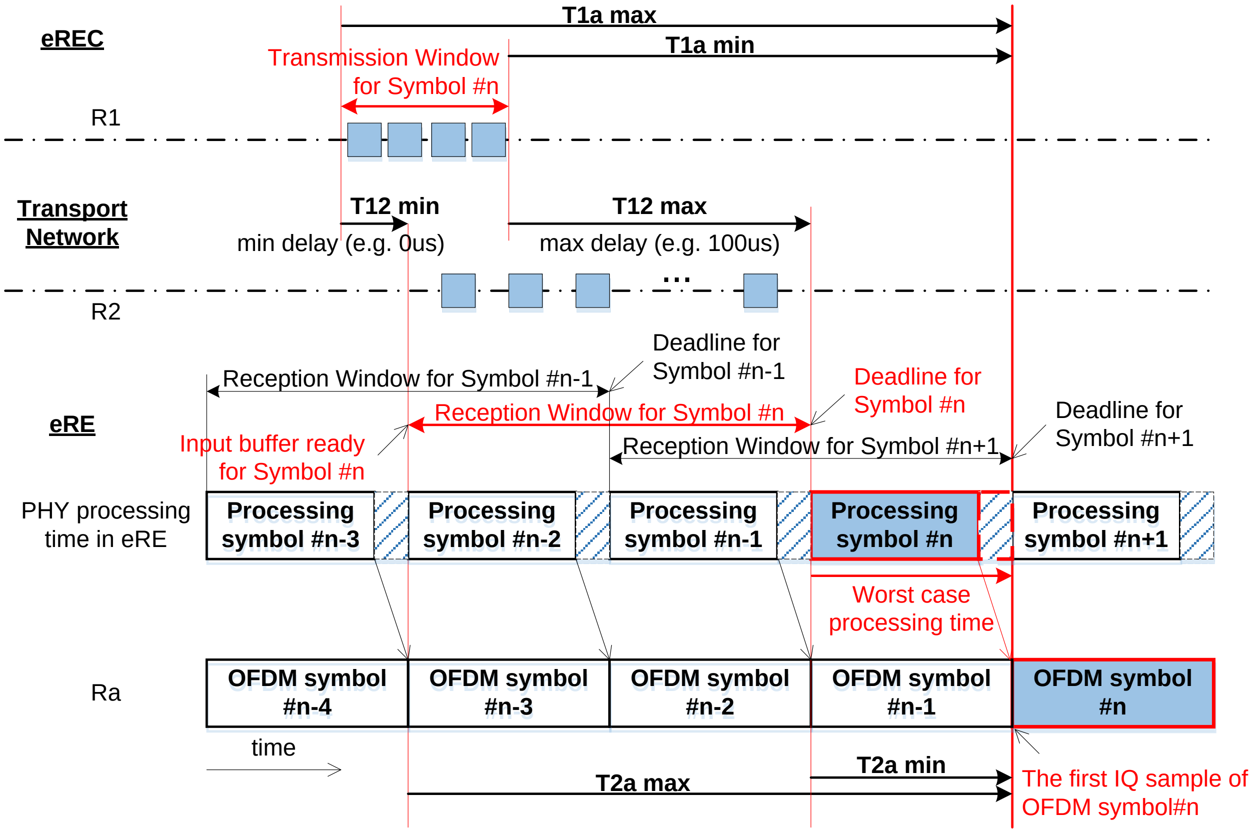


Figure 38: DL user data transmission timing example

6.4. Network Connection Maintenance

Network connection maintenance and network connection control is out of scope of the eCPRI specification. There are a number of different methods and standards that can be used.

For the Ethernet parts of eCPRI (if applicable for the User plane data and for IP over Ethernet), the Ethernet OAM can be used. Ethernet OAM is a common name for the IEEE 802.1Q [14] and ITU-T Recommendation G.8013/Y.1731 [16]. The IEEE 802.1Q Ethernet CFM (Connectivity Fault Management) defines three protocols, Continuity Check Protocol (CC), Link Trace (LT) and Loop-back (LB). ITU-T defines the same functions and tools in Y.1731 by the Ethernet continuity check (ETH-CC), Ethernet remote defect indication (ETH-RDI), Ethernet link trace (ETH-LT) and Ethernet loopback (ETH-LB), and also adds more OAM functions like Ethernet alarm indication signal (ETH-AIS), Ethernet loss measurement (ETH-LM) or synthetic loss measurement (ETH-SLM), and Ethernet delay measurement (ETH-DM).

For the IP parts of the eCPRI (e.g. the C&M flow), the Internet Control Message Protocol (ICMP) can be used. ICMP for IPv4 is defined in RFC 792 [17] and for IPv6 it is defined in RFC 4443 [18].

An eCPRI node needs to have either a unique MAC address or a unique IP address. How to assign or get these addresses is out of scope of the eCPRI specification.

6.5. Networking

6.5.1. Difference between eCPRI and CPRI

This subsection describes the major differences between eCPRI and CPRI (e.g. CPRI v7.0). The main audience of this section is anyone familiar with CPRI and who would like to understand the difference between eCPRI and CPRI networking quickly. So it may not be of any use to new readers of eCPRI who are not interested in CPRI.

Figure 39 shows an example network by CPRI. CPRI has the following characteristics:

- CPRI is a point-to-point interface by nature.
- There is a master-port and a slave-port connected directly by optical/electrical cable(s) (a hop).
- Networking functions are application layer functions and not supported by the CPRI interface itself.
- Supported topologies depend on REC/RE functions.
- Supported logical connections include:
    - Point-to-point (one REC – one RE).
    - Point-to-multi-point (one REC – several REs).
- Redundancy, QoS, security, etc. are REC/RE functions (if required).

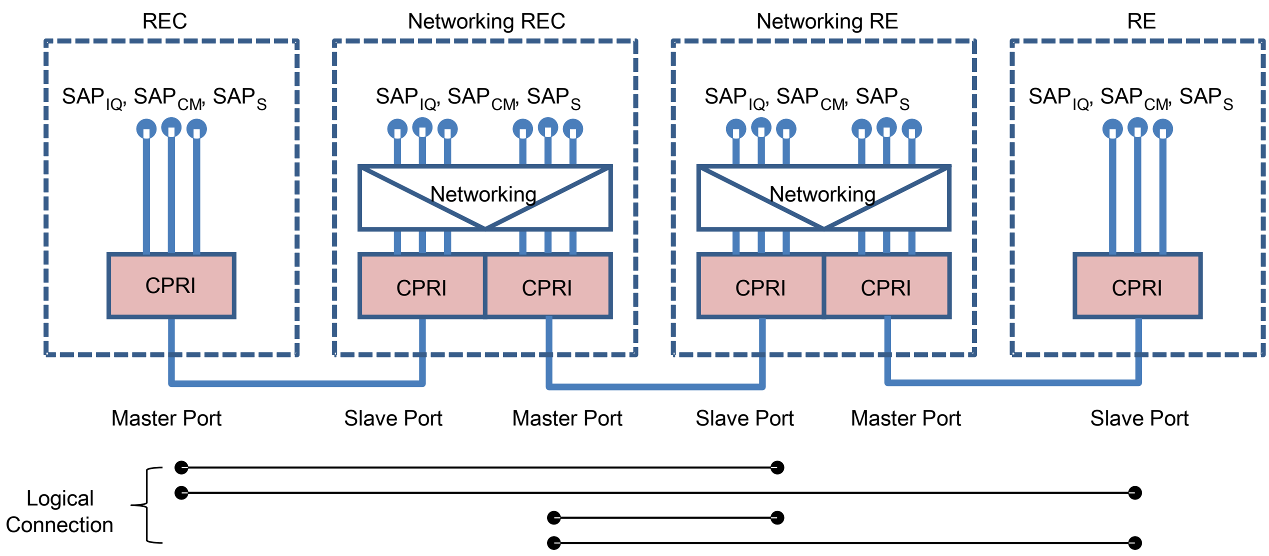


Figure 39: Network by CPRI

Figure 40 shows an example network by eCPRI. eCPRI has the following characteristics:

- An eCPRI network consists of eCPRI nodes (eRECs and eREs), transport network, as well as other network elements not shown in Figure 40 (including GM/BC for timing, EMS/NMS for management).
- There is no longer a master port/slave port classification at physical level.
    - SAP_S: master of PTP and Synchronous Ethernet is not a eREC in general.
    - SAP_{CM}: some of M-plane may be managed by EMS/NMS.
- The eCPRI layer is above the transport networking layer.
- The eCPRI layer does not care about the actual transport network layer topology.
- The transport network may include some local network, e.g. local switch(es) provided by the eREC/eRE vendors.

- Supported logical connections include:
    - Point-to-point (one eREC – one eRE), same as CPRI.
    - Point-to-multi-point (one eREC – several eREs), same as CPRI
    - Multi-point-to-multi-point (eRECs – eREs, eRECs – eRECs, eREs - eREs), new for eCPRI but not always necessary.
- Redundancy, QoS, security, etc. are mainly transport network functions; eCPRI nodes need to implement proper transport network layer protocols to support these capabilities if required.

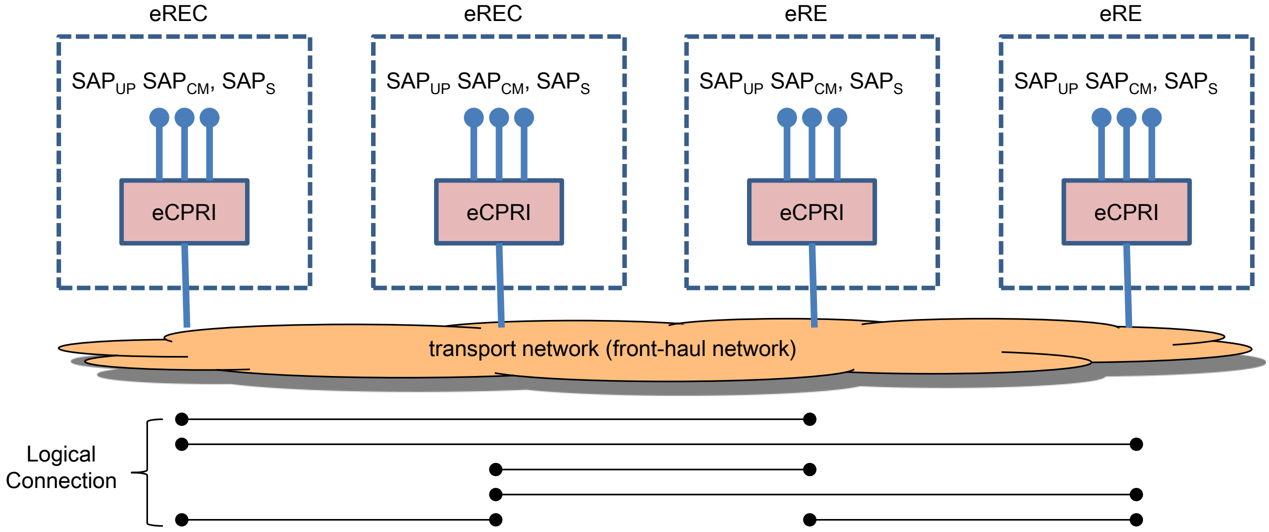


Figure 40: Network by eCPRI

6.5.2. eCPRI/CPRI networking with eCPRI/CPRI IWF type 0

This subsection describes a networking example of how CPRI REs can be connected to an eCPRI network and eREC via eCPRI/CPRI Interworking Function (IWF) type 0. The eCPRI protocol is terminated by the IWF. The IWF implements the master port of the CPRI interface. All information flows (User Plane, C&M Plane and Synchronization and Timing) are bridged or routed at the higher layer over the eCPRI and CPRI protocols. This is similar to the concept of the networking function of the CPRI Networking REC/RE.

Supported logical connections include:

- eREC and (networking) RE
- eREC and IWF, for the eREC to control and manage the IWF
- IWF and (networking) RE, for the IWF to control and manage the (networking) RE as a proxy of the eREC.

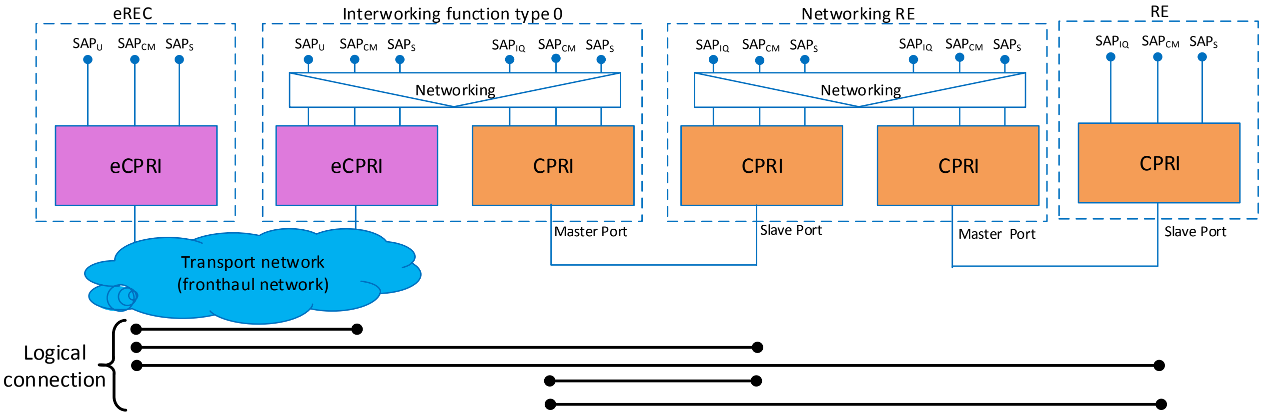


Figure 41: Networking with eCPRI/CPRI Interworking Function type 0

6.5.3. eCPRI/CPRI networking with eCPRI/CPRI IWF type 1 and type 2

This subsection describes a networking example of how a CPRI REC can be connected to a CPRI RE via an eCPRI based transport network by using eCPRI/CPRI IWF type 1 and 2. The CPRI protocol is terminated by the IWF, the IWF implements a “CPRI slave” and “CPRI master” port respectively, that are not fully compliant with [1]. Further information regarding these special ports can be found in section 8. The CPRI information flows (User Plane, C&M Plane and Synchronization Plane) are after transmitted over the eCPRI Network and subsequently reconstructed by the IWF nodes. This tunneling, or pseudo wire concept is indicated in the figure as an aggregation of the different SAPs.

The supported logical connection is:

- ○ REC and RE
- ○ IWF type 1 and IWF type 2, to control and manage functionality between the IWFs

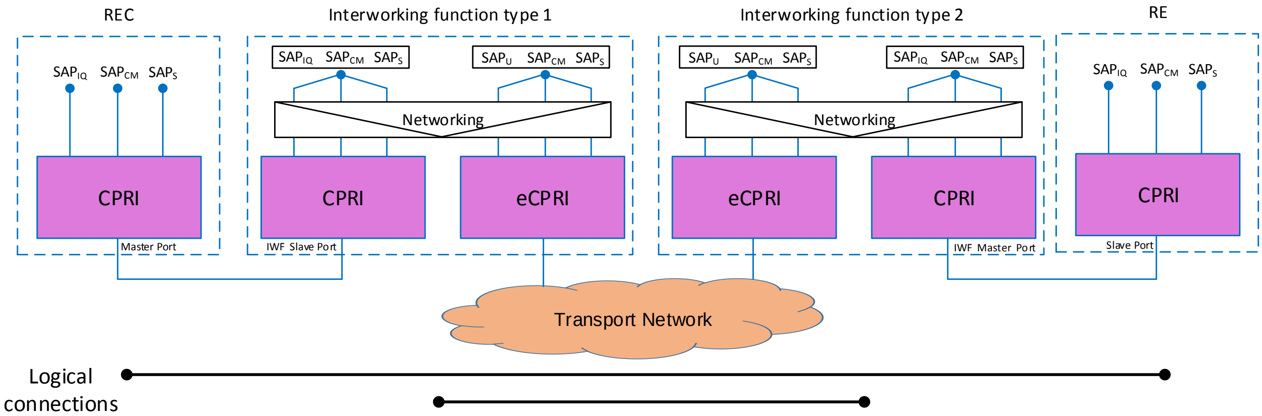


Figure 42: Networking with eCPRI/CPRI Interworking Function type 1 and type 2

Figure 43 shows a more detailed diagram of the functions typically implemented in IWF type 1 or type 2.

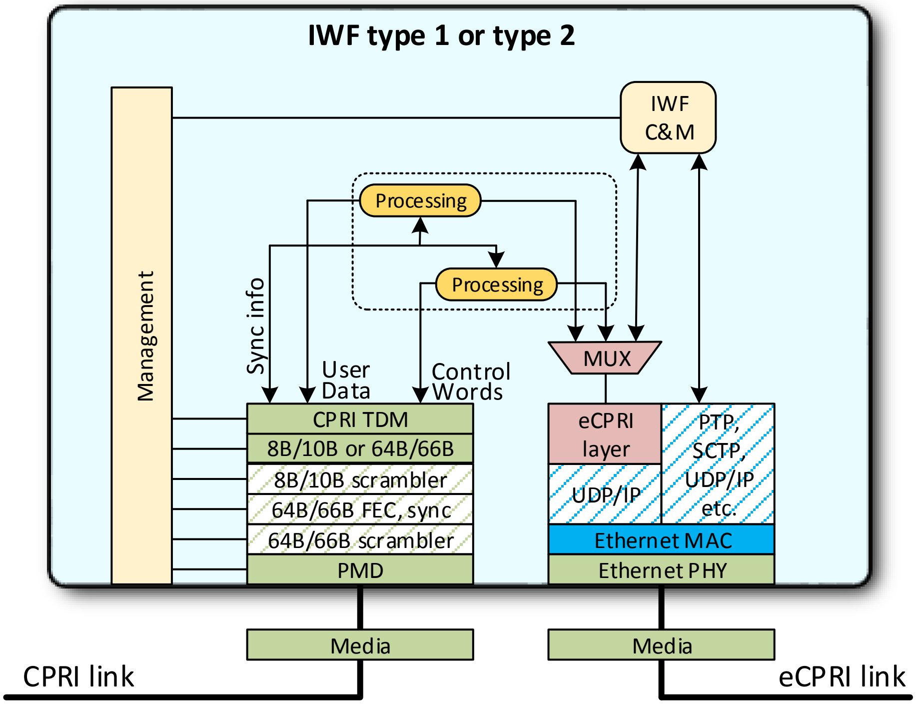


Figure 43: Protocol stack of Interworking Function type 1 or type 2

In the CPRI to eCPRI direction, IQ data and control word flows are extracted and combined with the CPRI synchronization information (hyperframe boundary) to create eCPRI interworking messages to be transmitted over the fronthaul packet network.

6.6. Priority considerations

The User data and Real-Time Control data are the most time sensitive flows and normally require a high priority. The traffic on the User Plane can in many cases be split into different kinds of traffic with different need of QoS. In that case, it might be good, to have several priorities for the User Plane Data.

The C&M data flow is normally not time sensitive and can be set to a low priority. But it may be wise to have two different priorities for C&M. One with lower priority than the User Plane Data that can be used for C&M considered as background traffic, and one with higher priority than the User Plane Data for the interactive traffic. The interactive traffic (including critical operation and emergency) needs to come through even if the amount of User Plane Data exceeds the available network bandwidth.

Note that for an Ethernet-switched fronthaul network there are only up to eight priorities available and in a provider network other traffic might need at least one priority. So even if there are many traffic streams with different QoS needs (e.g. for the User Plane Data) it will be good to keep down the total number of QoS levels.

6.7. Message Ordering Considerations

The eCPRI transport network may not guarantee preservation of the eCPRI messages order (i.e. the order in which a sequence of eCPRI messages is transmitted by the source node may be different from the order in which the sequence is received at the destination node). Order preservation may not be guaranteed even assuming the same priority, type of message, source node and destination node.

This is partially addressed by the inclusion of a sequence related ID field for some of the eCPRI Message Types.

6.8. Security

This section covers security considerations related to eCPRI traffic. If the transport network is not safe for a particular flow then an eCPRI network end-to-end security system should be implemented in the eREC node and eRE node for that flow.

6.8.1. eCPRI Network Security Protocol

eCPRI Network Security Protocol suites include IPsec in IP traffic and MACsec in Ethernet traffic， IPsec and MACsec are designed to provide interoperable, high quality, cryptography-based security for IP and Ethernet traffic. The set of security services offered includes access control, connectionless integrity, data origin authentication, protection against replays (a form of partial sequence integrity), confidentiality (encryption), and limited traffic flow confidentiality. These services are provided at the IP or Ethernet layer, offering protection for Ethernet or IP and/or upper layer protocols.

The details of IPsec and MACsec usage is vendor specific.

6.8.2. eCPRI Network Security Specification

Vendors can choose e.g. IPsec or MACsec to ensure security of transmission.

6.8.2.1. User plane

User plane over IP:

- IPsec or MACsec are both optional solutions to provide transmission security.

User plane over Ethernet:

- MACsec is an optional solution to provide transmission security.

6.8.2.2. C&M plane

TLS, IPsec or MACsec are optional solutions to provide transmission security and access control for eCPRI C&M plane.

6.8.2.3. Synchronization plane

There is no eCPRI recommendation for security aspects related to the synchronization plane.

7. Annex B – eCPRI/CPRI Interworking with IWF type 0 (Informative)

The main purpose of IWF type 0 is allowing REs to be connected to an eREC via an eCPRI network and reused as eREs to support new services, e.g. 5G NR. In this informative section, a functionality to bridge eCPRI and CPRI (eCPRI/CPRI Interworking Function, IWF) is described. There are different examples of IWF type 0 use cases, such as:

- IWF type 0 is a functionality, not necessarily in an independent node, i.e. it could be in eRECs/eREs or transport network nodes (e.g. bridges/routers) as well as in independent nodes. If it is within an eRECs/eREs, the concept is similar to networking CPRI REC/RE where networking function is within the CPRI REC/RE.
- IWF type 0 could be located at the cell-site close to CPRI REs, then the general packet-based transport network can be used (including the access link from the edge of the central network to the cell-site).
- IWF type 0 could be located at the edge of the central network, e.g. at the central office, then the new services by eREC could be added without changing the original CPRI access link and CPRI REs.

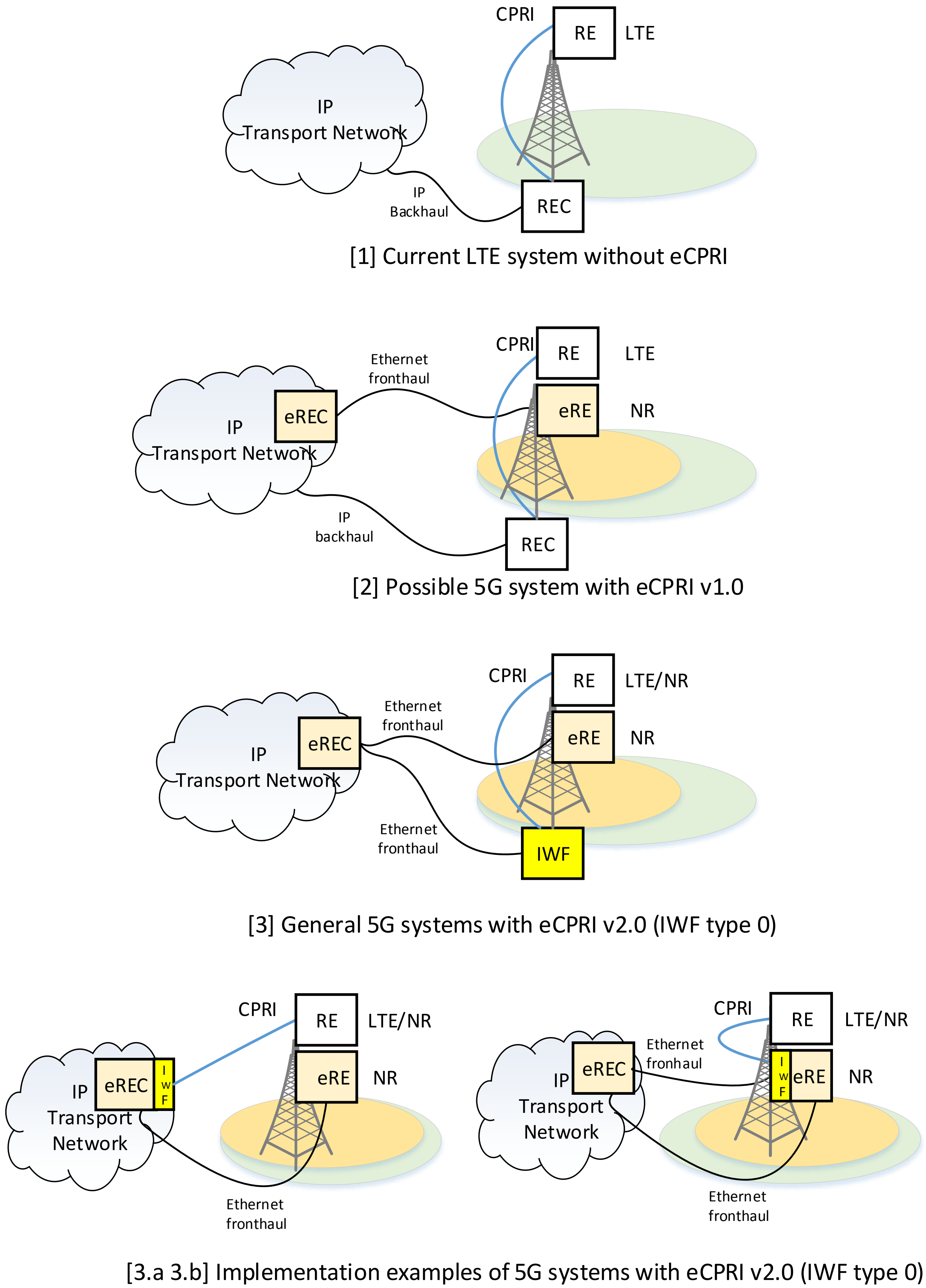


Figure 44: eCPRI/CPRI IWF type 0 possible migration scenarios

7.1. Concept

The IWF type 0 acts as a proxy for the REC and eRE.

- From the eREC viewpoint, “IWF type 0 and an RE connected via CPRI link” is considered as an eRE. Exceptions are C&M plane and Connection OAM. Independent Control & Management may be necessary for each node and link.
- From the RE viewpoint, “IWF type 0 connected to an eREC via eCPRI network” is considered as an REC.
- The bridging of information flows between the eCPRI and the CPRI within the IWF type 0 is implemented at the higher layers of the eCPRI and CPRI protocol stacks.
- As the definitions of higher layer protocols are vendor specific, only guidelines of how eCPRI information flows are mapped from/to CPRI information flows are provided.
- This concept is similar to the CPRI networking REs (e.g. daisy chained REs).

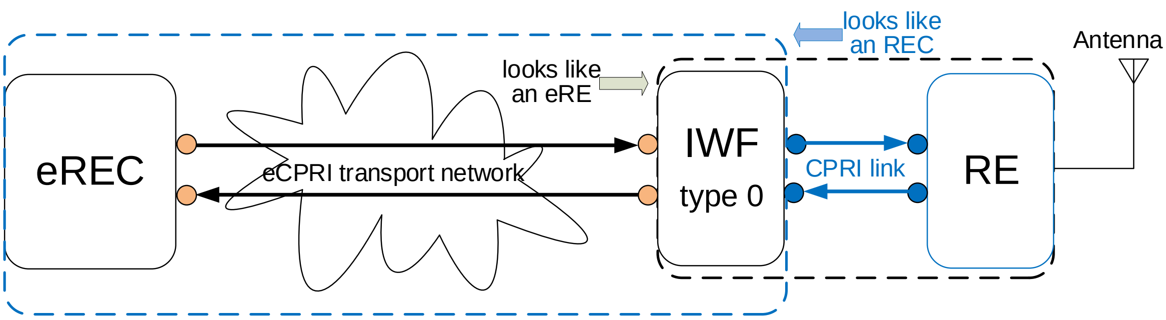


Figure 45: Concept of eCPRI/CPRI IWF type 0

Table 17 shows how information flows over eCPRI and CPRI can be mapped.

Table 17 An example of mapping between eCPRI and CPRI information flows

eCPRI			CPRI		
Section	SAP & Plane	Contents	Section	SAP & Plane	Contents
3.2	User Plane	Message Type #0: IQ data Message Type #1: Bit Sequence	4.2.7.2	User Plane	AxC Container IQ
3.2	User Plane (real time control)	Message Type #2: Real-Time Control Data	4.2.7.9 4.2.7.10	User Plane	Vendor Specific Data Control AxC Data
3.3	C&M Plane	(standard protocols)	4.2.7.7	C&M Plane	Slow C&M or Fast C&M
3.4 6.2	Synchronization	(standard protocols like PTP and SyncE)	4.2.7.5 4.2.8	Synchronization and Timing	Frame Timing HFN, BFN
3.2	User Plane (other eCPRI services)	Message Type #5 ,6, 7: One-way delay Measurement Remote reset Event indication	4.2.7.6 4.2.10	L1 inband Protocol Link maintenance of Physical Layer	Protocol Version Start-up (HDLC bit rate) LOS, LOF, RAI, SDI Reset Req/Ack Pointer p
6.4	Connection OAM	(standard protocols like Ethernet OAM)			

7.2. Bridging of User Plane

Downlink IQ data in CPRI AxC containers is generated from eCPRI Message Type #0 (time-domain or frequency-domain IQ Data) and/or eCPRI Message Type #1 (Bit Sequence). If data rate reduction of transport network is not an essential requirement (this may be the case if the RE has neither many antenna elements nor a wide radio bandwidth) and if the eREC can generate time-domain IQ, then time-domain IQ Data is transferred by eCPRI Message Type #0, (function decomposition “E” in Figure 32). If data rate reduction is required and/or the eREC does not generate time-domain IQ data, then eCPRI Message Type #0 (frequency-domain IQ, the function decomposition II_D in Figure 32) or eCPRI Message Type #1 (Bit Sequence, the function decomposition I_D in Figure 32) are used. In this case, the IWF must include additional functions (e.g. functions included between I_D/II_D and E). These additional functions are assumed as the simple and open methods of data rate reduction.

Uplink IQ data in AxC containers are converted to eCPRI Message Type #0. Similar to the downlink case, IQ data, time-domain IQ (function decomposition E) or frequency-domain IQ (function decomposition I_U) can be used depending on the requirements.

eCPRI Message Type #2 is also used if associated information (real-time control) to IQ Data or Bit Sequence is necessary.

If CPRI Vendor Specific Data and/or CPRI Control AxC Data are used, they are generated/converted from/to eCPRI Message Type #2 (real-time control data). The timing relation between CPRI AxC containers and CPRI Vendor Specific Data/Control AxC Data can be maintained by the SEQ_ID in eCPRI Message Type #0, #1 and #2. In the CPRI specification [1], example use cases of Control AxC Data are shown such as: GSM frequency hopping information, UMTS RTWP measurement report. Such information can be easily carried by eCPRI Message Type #2 and associated with IQ Data by SEQ_ID.

Figure 46 shows two examples of protocol stacks in IWF type 0. The left part shows an example where time-domain IQ data is bridged across and the right part shows an example where frequency-domain IQ data is bridged across.

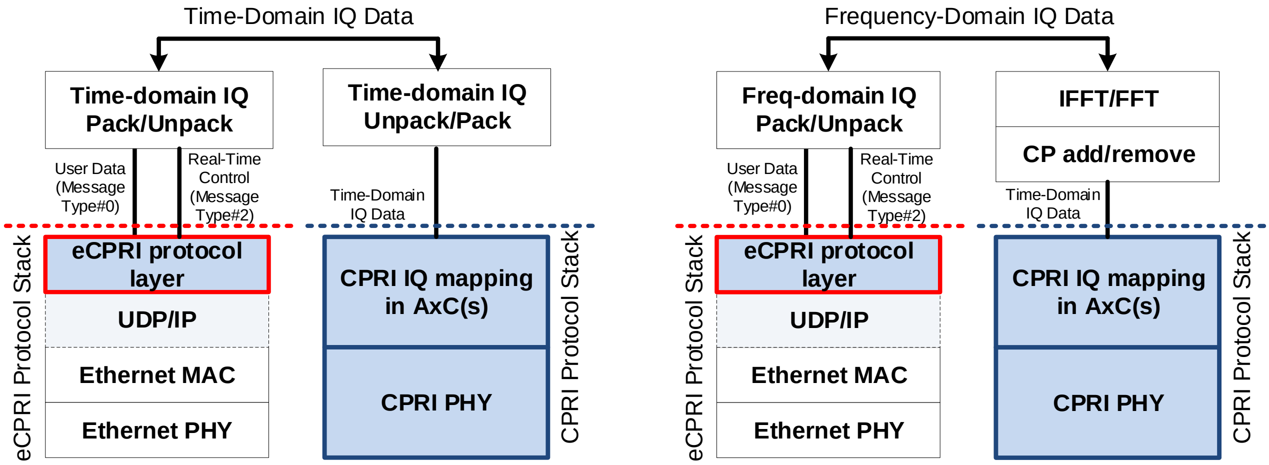


Figure 46: Example of User Plane Bridging in IWF type 0

7.3. Bridging/Routing of C&M Plane

In CPRI, two transport protocols are defined for C&M plane, namely slow C&M (HDLC based) and fast C&M (Ethernet based). However, any higher protocols over HDLC or Ethernet can be used.

In eCPRI, no protocols are defined for C&M plane as it is easy to use any existing standard protocols over IP/Ethernet.

If there is no strong motivation to use different higher layer protocols over IP for eCPRI and CPRI, IP routing is the functionality required for IWF C&M plane routing. C&M plane for the IWF itself (eREC-IWF) is terminated at the IWF and C&M plane for the CPRI REs (eREC-RE) is routed to CPRI SAP_{CM}. Additionally, a C&M plane between the IWF and the CPRI RE may also be necessary. Figure 47 shows an example of the protocol stacks in the IWF type 0 for this IP routing scenario.

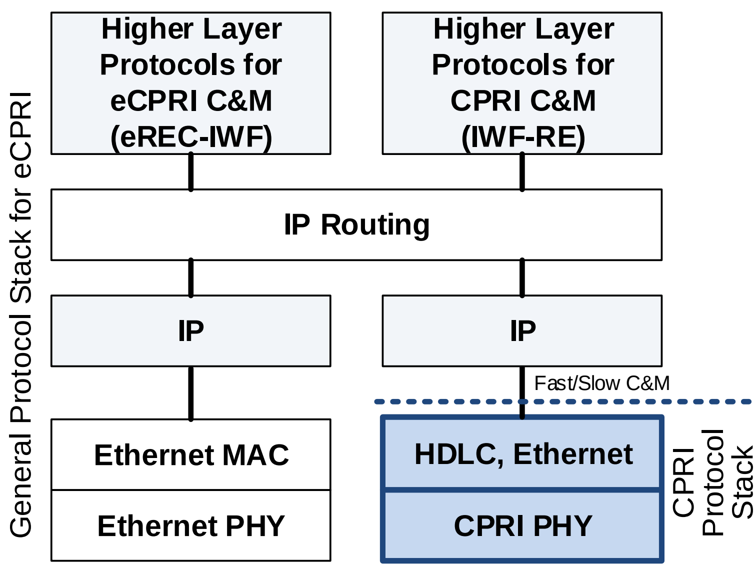


Figure 47: Example of C&M plane Routing in IWF type 0

7.4. Bridging of Synchronization Plane

All eCPRI nodes (eRECs, eREs and IWFs) are assumed to be time and frequency synchronized to one master time clock (e.g. UTC), whereas CPRI does not assume all CPRI nodes are synchronized but slave ports have to be synchronized to their master ports.

In the case where CPRI REs are connected to an eCPRI network via IWF, all nodes including CPRI REs shall be time and frequency synchronized to one master time clock (e.g. UTC). This can be easily achieved because all IWFs are time and frequency synchronized to one master clock and each CPRI RE (CPRI slave port) is time and frequency synchronized to an IWF type 0 CPRI master port.

The one-way delay between the IWF and the RE (CPRI link) can be measured by CPRI standard method and is constant. So, the overall delay between eCPRI interface points (R2 and R3) in the IWF and the antenna ports in the RE is equal to the internal delay T2a and Ta3 within the assumed eRE (IWF + CPRI link + RE).

If the time relation between radio frames at the antenna ports of the eREs/REs and the master time clock (e.g. UTC) is pre-defined, the IWF can generate the radio frame timing (including HFN and BFN).

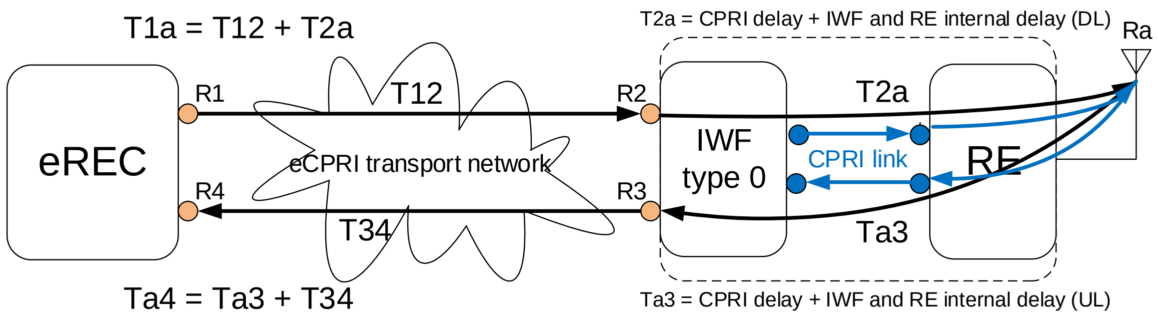


Figure 48: Definition of Reference Points for Delay Management of eCPRI/CPRI IWF type 0

7.5. Bridging of L1 inband protocol

CPRI L1 inband protocol is classified into three categories. The mapping between eCPRI and CPRI is explained per category.

- Information necessary to establish CPRI link and C&M plane (start-up Sequence). This category is terminated at link-by-link level. There is no direct relation with eCPRI network (similarly to Ethernet bit rate negotiation):
    - Protocol version
    - HDLC bit rate
    - Pointer p (Ethernet bit rate)
- Information necessary to monitor CPRI link status (alarms). The CPRI link status is monitored by the master port of the IWF type 0 and reported to the eREC by C&M plane between eREC and the IWF type 0 via eCPRI Message Type #7 “Event Indication”:
    - LOF
    - LOS
    - RAI
    - SDI
- Information necessary for emergency control. If only the RE is out-of-control by CPRI C&M plane, reset of the RE is managed by the eREC via the eCPRI C&M plane between the eREC and the IWF type 0. If the IWF itself is out-of-control, eCPRI Message Type #6 may be used to reset the IWF. In this case the master port of the IWF type 0 shall reset the RE and hence stop transmission of the RF signal, e.g. automatically generating CPRI reset bit (other methods are also possible):

- Reset

7.6. Start-up Sequence

- eCPRI connection between eREC and IWF type 0 is established via transport network.
  - IWF is time- and frequency-synchronized to the master time clock (e.g. UTC).
  - C&M plane between eREC and IWF type 0 is established.
  - eREC knows the one-way delay between eREC and IWF type 0 via transport network. In the case where several REs are controlled by one IWF type 0 the Tx/Rx time windows at the eREC could be managed per RE (not per IWF type 0).
- eREC configures the CPRI master port(s) in IWF type 0.
  - All necessary information for CPRI master port(s) is sent to IWF type 0 via the C&M plane between the eREC and the IWF type 0.
  - CPRI master port in IWF type 0 is now ready to start "CPRI start-up sequence".
- eREC requests IWF type 0 to start "CPRI start-up sequence".
  - C&M plane between eREC and RE as well as between IWF type 0 and RE is established if "CPRI start-up sequence" is successfully completed.
  - eREC or IWF type 0 may request to optimize the CPRI line bit rate.
  - One-way delay of CPRI link between IWF type 0 and RE is measured. This delay is considered as a part of internal delay T2a and Ta3 in the assumed eRE (IWF type 0 + CPRI link + RE).
  - eREC has now all necessary information of the assumed eRE configuration including the internal delays T2a and Ta3.
  - The assumed eRE (IWF type 0 + CPRI link + RE) is now ready to start operation.
- eREC requests IWF type 0 and RE to start operation.

8. Annex C – eCPRI/CPRI Interworking with IWF type 1 and type 2

Being able to re-use existing CPRI-based RAN equipment when migrating to an Ethernet-based fronthaul configuration is of great value.

These sections describe the use case when a CPRI link connected between a REC and RE is bridged over an eCPRI based fronthaul network by the usage of an Interworking Function (IWF).

8.1. Concept

In the IWF type 1 and 2 configuration suitable sub-parts will be extracted from the CPRI protocol by the near end IWF, packed to eCPRI messages and transported over the network to the far end IWF, where the CPRI stream is reconstructed and transmitted to the connected CPRI node, as defined in IWF specific eCPRI Message Type sections 3.2.4.9 - 3.2.4.12.

Depending on the need for a bit rate reduction, this extraction, packing, signaling and reconstruction process can be more or less complex. C&M of both IWF types shall be performed by a specific C&M entity and shall not be performed via the CPRI link(s).

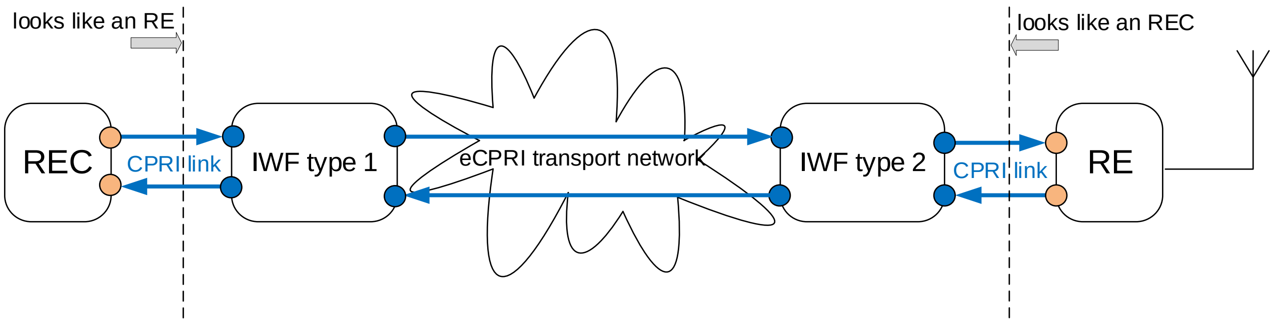


Figure 49: Concept of eCPRI/CPRI bridge with IWFs type 1 and type 2

8.2. Definition of IWF type 1 and IWF type 2 CPRI ports

This section specifies the IWF type 1 and 2 CPRI ports.

An IWF type 1 CPRI port shall implement all mandatory parts of the eCPRI specification related to the IWF type 1 CPRI port and the appropriate sub-sections of the CPRI specification related to CPRI slave port as per Table 18.

An IWF type 2 CPRI port shall implement all mandatory parts of the eCPRI specification related to the IWF type 2 CPRI port and the appropriate sub-sections of the CPRI specification related to CPRI master port as per Table 18.

In Table 18, the term “Applicable” means that the IWF type 1/2 CPRI port shall be fully compliant with the referenced CPRI section, while the term “N/A” means that the referenced CPRI section is irrelevant for the IWF CPRI port, which instead shall comply with the referenced eCPRI section.

Table 18: IWF type 1 and type 2 CPRI protocol compliance

CPRI section	Status	eCPRI related section
4.2.1 Line Bit Rate	Applicable	
4.2.2 Physical Layer Modes	Applicable	
4.2.3 Electrical Interface	Applicable	
4.2.4 Optical Interface	Applicable	
4.2.5 Line Coding	Applicable	
4.2.6 Bit Error Correction/Detection	Applicable	
4.2.7 Frame Structure	Applicable	8.3 Bridging of User Plane
4.2.8 Synchronization and Timing	N/A	7.4 Bridging of Synchronization Plane 8.8 Synchronization
4.2.9 Link Delay Accuracy and Cable Delay Calibration	N/A	8.7.2 Start-up Delay Management 8.9 Delay Management
4.2.10 Link Maintenance of Physical Layer	Applicable	8.6 Bridging/handling of CPRI sub-channels 0 and 2
4.3 Data Link Layer (Layer 2) Specification for Slow C&M Channel	Applicable	8.4 Bridging/Routing of CPRI Control Words
4.4 Data Link Layer (Layer 2) Specification for Fast C&M Channel	Applicable	8.4 Bridging/Routing of CPRI Control Words
4.5 Start-up Sequence	N/A	8.7 Start-up Sequence
6.5 Scrambling	Applicable	
6.7 64B/66B line coding	Applicable	
6.9 Reed-Solomon Forward Error Correction	Applicable	

8.3. Bridging of User Plane

The bridging of the user plane is performed via eCPRI specified message types described in section 3.2.4.

8.4. Bridging/Routing of CPRI Control Words

The bridging of the CPRI control words, as shown in Figure 43, is performed via eCPRI specified message types described in section 3.2.4. Except subchannels 0 and 2 (see section 8.6) all CPRI control words are expected to be tunneled, i.e. copied over and not interpreted by the IWFs.

8.5. Bridging of Synchronization Plane

In an eCPRI/CPRI interworking configuration with IWFs type 1 and type 2, the IWFs are assumed to be time and frequency synchronized to one master time clock. The CPRI node REC needs to be time synchronized to avoid bit slips on the IWF's CPRI port.

The delay between R1 and R2 shall be kept constant. Likewise, the delay between R3 and R4 shall be kept constant. For further details see section 8.8 and section 8.9.

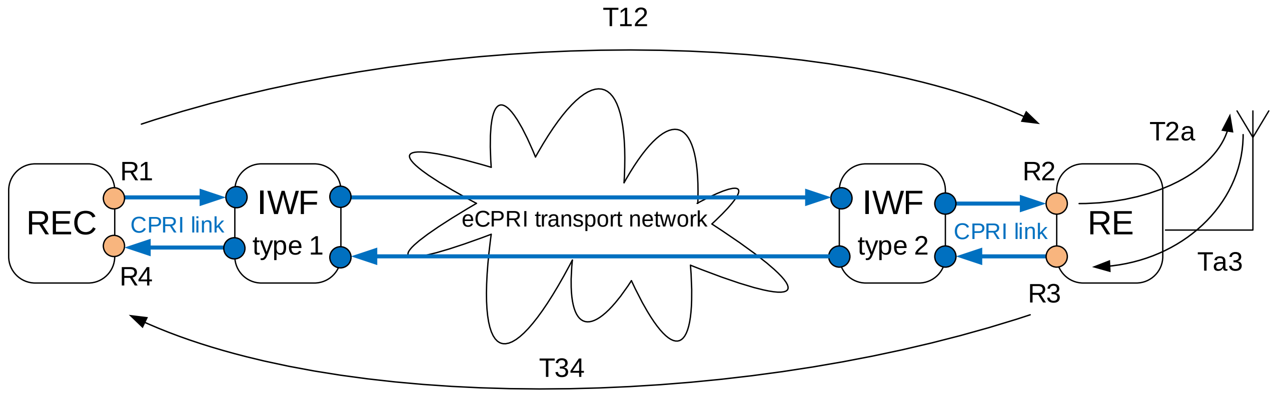


Figure 50: Definitions of Reference Points for Delay Management of eCPRI/CPRI IWF type 1 and type 2

8.6. Bridging/handling of CPRI sub-channels 0 and 2

IWF type 1 or 2 must take special care of CPRI control word sub-channels 0 and 2 in the received eCPRI messages. Table 19 below describes how each information element in these sub-channels shall be handled in normal operation case. For details about error handling please refer to section 8.11.

When generating and transmitting eCPRI messages, all these information elements shall be tunneled from CPRI to eCPRI messages except for the Sync byte which needs special handling according to the eCPRI messages definitions.

Table 19: Sub-channel 0 and 2 handling in eCPRI to CPRI direction

Sub-channel	Information	Normal operation handling
0	Sync byte	Based on IWF local counters
0	HFN	Based on IWF local counters
0	BFN-low and BFN-high	Opt BFN. 1: Tunneled Opt BFN. 2: Based on IWF local counters
2	Version	Opt Ver. 1: Tunneled Opt Ver. 2: Based on IWF capabilities
2	Start-up	Tunneled
2	LOS, LOF	Tunneled, might be overwritten with local IWF status, see section 8.11 (Fault Management)
2	RAI, SDI, Reset	Tunneled
2	p pointer	Tunneled
0 and 2	Reserved bits	Opt res. 1: Tunneled Opt res. 2: Zeroed

Clarification of terms used in Table 19:

Tunneled: The information received in the eCPRI message is copied to the CPRI link.

Zeroed: Used when no information is available and IWF needs to re-create it, in this case the bit or bits are set to zero.

8.7. Start-up Sequence

8.7.1. eCPRI/CPRI IWF Start-up sequence overview

Figure 51 shows a high-level flow chart for the IWF type 1/type 2 start-up sequence.

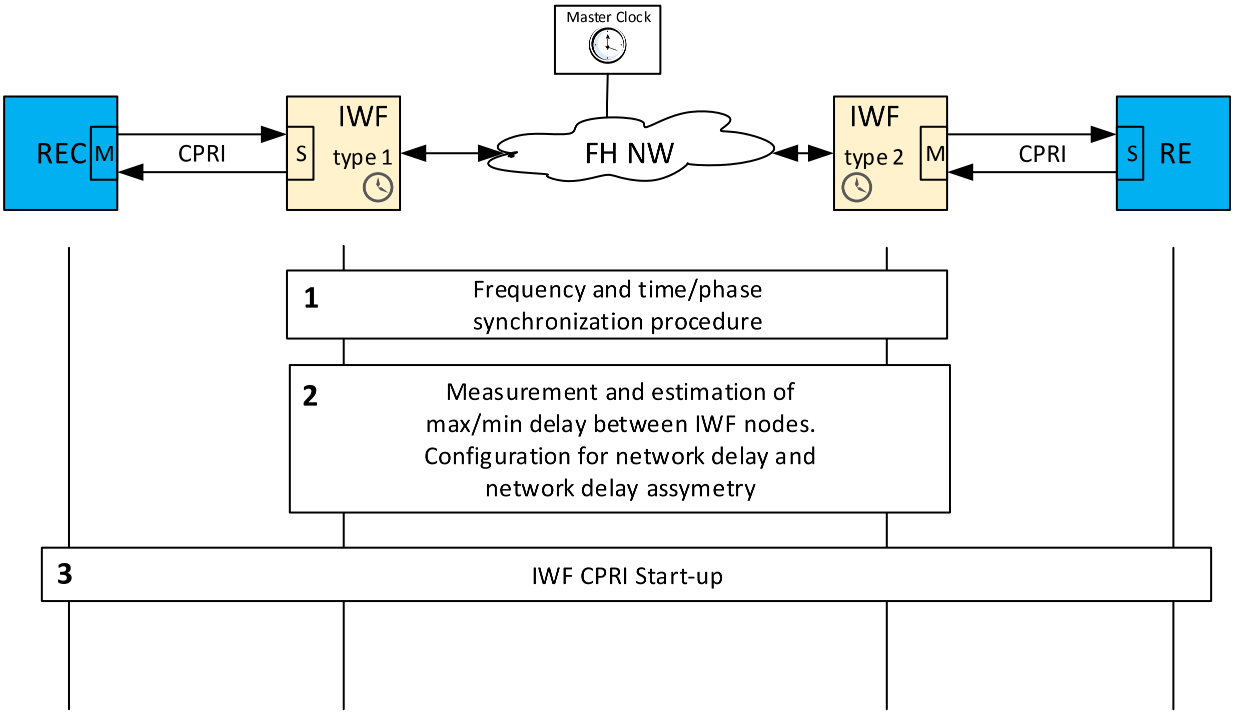


Figure 51: eCPRI/CPRI IWF Start-up sequence overview

Step 1:

The IWF nodes acquire frequency and time/phase synchronization via e.g. IEEE 1588v2 protocol. The start-up sequence cannot continue until both nodes reach locked state.

Step 2:

To prepare for the CPRI data to be transmitted over the fronthaul packet network and get an estimate of the delay variation, the IWF nodes measure the delay in both directions via the eCPRI one-way delay measurement procedure defined in section 3.2.4.6. If applicable, necessary steps are taken to handle any network delay asymmetries. These steps are described in more detail in section 8.7.2.

Step 3:

The IWF nodes apply the IWF CPRI start-up procedure as specified in section 8.7.3, while the behavior of the CPRI nodes (REC, RE) is assumed to fully comply with the CPRI start-up sequence specified in section 4.5 of [1].

8.7.2. Start-up Delay Management

Figure 52 shows the steps taken during the IWF start-up sequence regarding delay management.

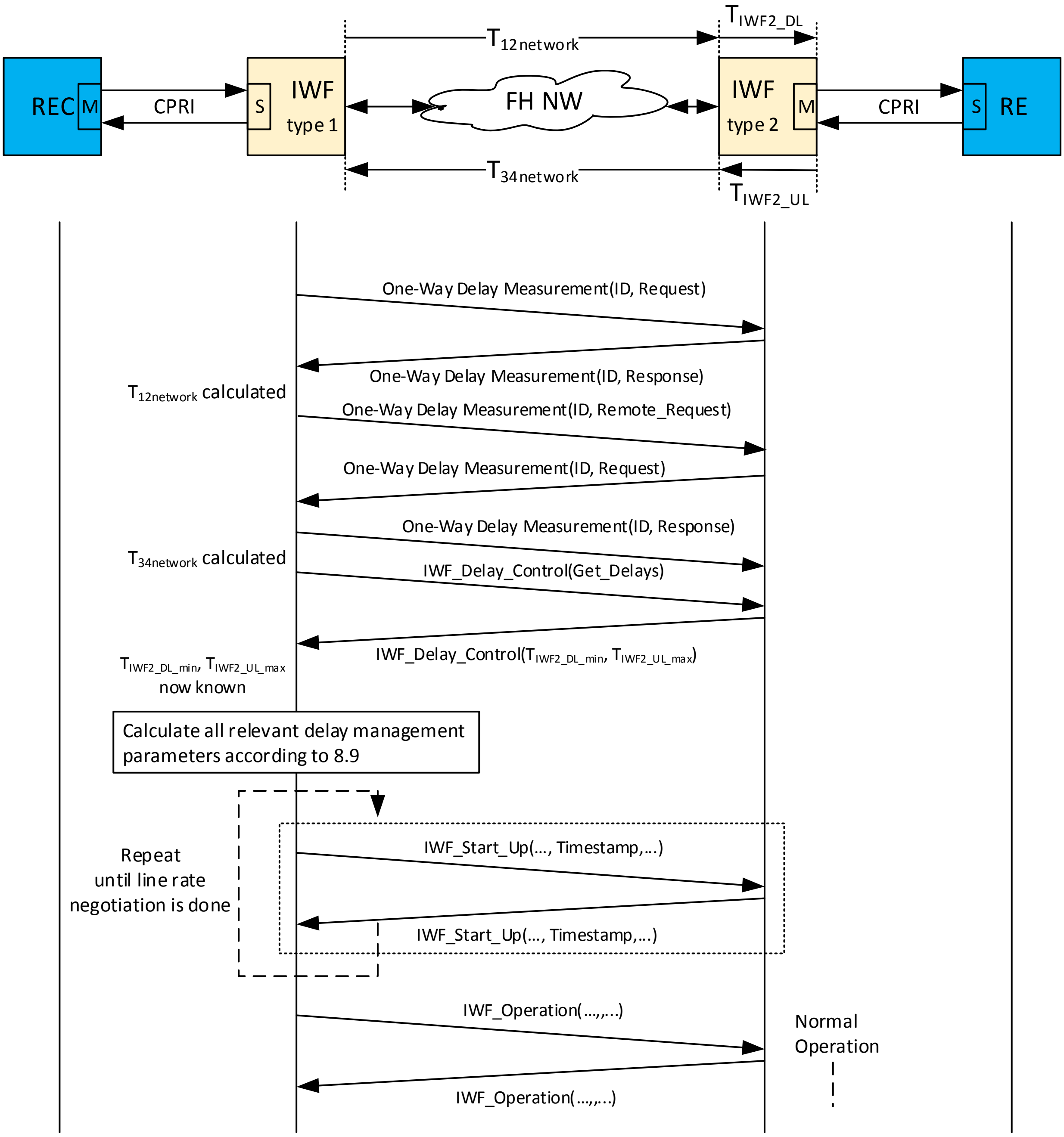


Figure 52: eCPRI/CPRI IWF type 1/type 2 delay management start-up sequence

- IWF type 1 determines the network delays by using the eCPRI one-way delay measurement procedure described in section 3.2.4.6. In general, several measurements are needed to properly estimate T12network_max and T34network_max.
- The IWF type 1 sends a Delay Control message (eCPRI Message Type #11, see section 3.2.4.12) with “Request get delays”. IWF type 2 responds with a Delay Control message with “Response get delays”. “Delay A” shall contain $T_{IWF2\_DL\_min}$ and “Delay B” shall contain $T_{IWF2\_UL\_max}$.
- IWF type 1 calculates all parameters needed for delay management, see section 8.9 on how to calculate the parameters.
    - Based on the calculated parameters IWF type 1 knows how to set the Timestamp field in the eCPRI Message Type #8 (IWF Start-Up).
    - IWF type 2 will set the Timestamp field in the eCPRI Message Type #8 (IWF Start-Up) indicating the CPRI frame reception time. Based on the calculated parameters and Timestamp received from IWF type 2, IWF type 1 will compute the transmission time of the CPRI frame towards the REC.

8.7.3. IWF CPRI port start-up sequence

This section defines the sequence of actions to be performed by IWF type 1 and type 2 CPRI ports to start-up their relevant CPRI links (to/from REC and RE respectively), assuming that the latter fully comply with the CPRI start-up sequence as specified in section 4.5 of [1].

When both connected CPRI ports are in state F, the link is in normal operation.
After a reset, all CPRI ports shall enter state A.

8.7.3.1. General

The start-up procedure accomplishes two main things:

- Layer 1 synchronization: byte alignment and hyperframe alignment.
- Alignment of capabilities of the RE/REC CPRI ports and the IWF type 1/2 CPRI ports: line bit rate and protocol.

Since there is no mandatory line bit rate, the CPRI master/slave port and IWF type 1/2 CPRI port shall, during the start-up procedure, try different configurations until a common configuration is detected. The common configuration does not have to be optimal – it shall be considered as just a first contact where capabilities can be exchanged for a proper configuration to be used in the following communication.

For all states, it is mandatory to always transmit information consistent with the protocol indicated in #Z.2.0 in all control words in subchannel 1 and subchannels 3 to 15.

When changing the line bit rate of the transmitted CPRI, the interruption of transmission shall be less than 0.1s. When changing the line bit rate of the received CPRI, the interruption of reception shall be less than 0.1s. The time to reach HFNSYNC for the receiving unit shall be less than 0.2s, given the precondition that the far-end transmitter is on, they use the same line bit rate and no bit errors occur.

In the negotiation steps in state C the IWF type 1/2 CPRI port shall sample and evaluate the received protocol version at least every 0.1 s. As the remote end IWF and CPRI node may be involved in the evaluation, it may not be possible to update the transmitted protocol version within 0.2 s after the evaluation as specified for the CPRI port in [1], section 4.5.1. In that case, Transition 13 of the CPRI start-up sequence would be triggered (see section 8.7.3.4.7 of [1]) impacting the start-up time and associated timers.

8.7.3.2. Layer 1 Start-up Timer

The start-up procedure may be endless due to:

- Fault in one of the units.
- No common layer 1 configuration found.

The supervision may be done per state and per cause, but the start-up procedure also specifies a generic start-up timer which shall be set upon entry of the start-up procedure and shall be cleared when state F is entered.

If the timer expires the start-up procedure shall be restarted.

The “layer 1 start-up timer” is activated in transitions 2 and 13.

The “layer 1 start-up timer” is cleared in transitions 3, 10 and 11.

If the “layer 1 start-up timer” expires, transition 16 shall take place and state B is entered, possibly modifying the available set of line bit rates and protocols.

The “layer 1 start-up timer” expiration time is vendor specific.

Following Figure 53 shows the start-up state diagram for the IWF type 1/2 CPRI ports.

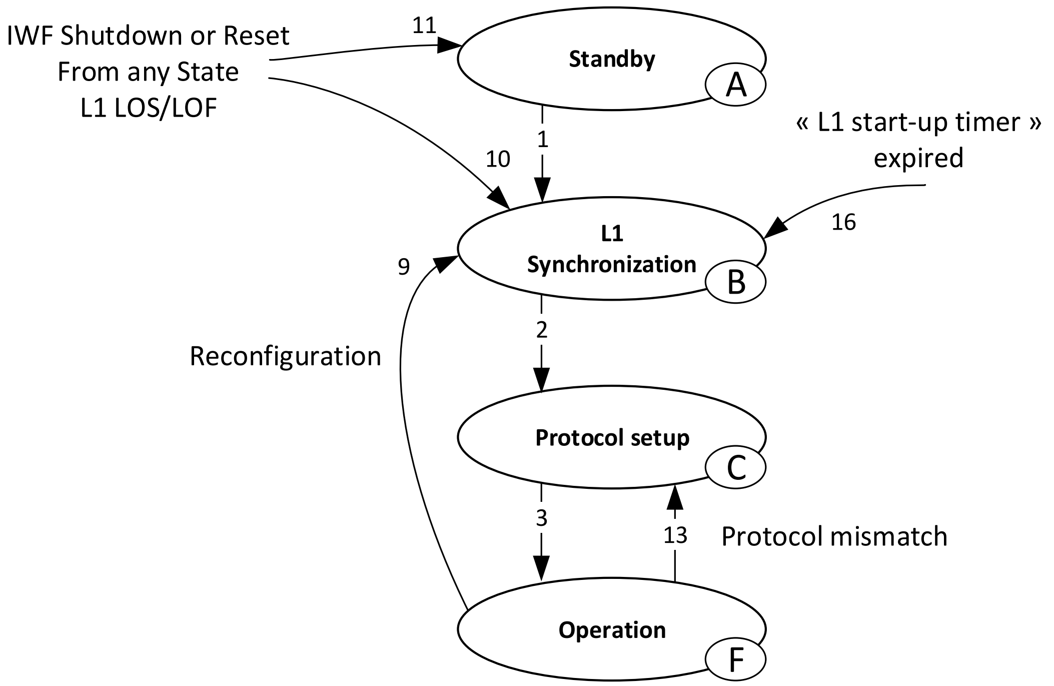


Figure 53: Start-up states and transitions

8.7.3.3. State Description

8.7.3.3.1. State A – Standby

<u>Prerequisites:</u>
None

<u>Description:</u>
Waiting to be configured to start-up CPRI. No transmission or reception of CPRI. The operator may set up a suitable start-up configuration (line bit rate). The IWF type 1/2 CPRI ports may also have knowledge of a previous successful configuration.

8.7.3.3.2. State B – L1 Synchronization and Rate Negotiation

<u>Prerequisites</u>:
The set of available line bit rate, protocol versions and C&M plane characteristics is known. This may be the complete set of the unit or a subset based on operator configuration or previous negotiation between the units.

<u>Description</u>:
During this state, the line bit rate of the interface is determined and both CPRI master port (REC) and IWF type 1 CPRI port as well as CPRI slave port (RE) and IWF type 2 CPRI port reach layer 1 synchronization up to state HFNSYNC.

<u>Interpreted control BYTES:</u>
For 8B/10B line coding protocol version 1 and 2; #Z.0.0, #Z.64.0
For 8B/10B line coding protocol version 2; #Z.0.2 … #Z.0.T/8-1
For 64B/66B line coding; #Z.0.8, #Z.64.0

<u>IWF type 2 CPRI port actions</u>:

While in this state, upon reception of eCPRI start-up message from the remote end (i.e. IWF type 1), IWF type 2 shall:

- Opt Ver. 1: start transmitting CPRI on the line bit rate of the received eCPRI start-up message with the protocol version in #Z.2.0, RS-FEC and scrambling mode set to the lower between the IWF type 2 maximum capability and the received eCPRI start-up message setting and also start attempting to receive CPRI at the same line bit rate.
- Opt Ver. 2: start transmitting CPRI on the line bit rate of the received eCPRI start-up message with the protocol version in #Z.2.0, RS-FEC and scrambling mode set according to the IWF type 2 configuration[4] and also start attempting to receive CPRI at the same line bit rate.

IWF type 1 CPRI port actions:
The IWF type 1 CPRI port shall start attempting to receive CPRI at the highest available line bit rate directly when entering the state. If the IWF type 1 CPRI port does not reach synchronization state HFNSYNC it shall select another line bit rate for CPRI reception after T1’ from entering the state, given that another line bit rate is available. T1’ is 3.9-4.1s. Each following T1’ interval, a new reception line bit rate shall be selected for reception, given that another line bit rate is available. The line bit rates shall be selected from the available set in a round robin fashion, i.e. first highest, the second highest, …, the slowest, and then restarting from the highest line bit rate. An IWF type 1 CPRI port which supports both RS-FEC enabled/disabled modes shall check both modes in parallel.

When entering this state, the IWF type 1 CPRI port shall turn off its CPRI transmitter. If this state was entered with transition 10 the IWF type 1 CPRI port may optionally transmit for a maximum of 5 hyperframes to indicate to far-end equipment (i.e. REC) the layer 1 link maintenance control BYTE #Z.130.0. When the IWF type 1 CPRI port reaches synchronization state HFNSYNC, it shall

- Opt Ver. 1: start forwarding the received CPRI basic frames by means of eCPRI start-up message #8 to the remote IWF (i.e. IWF type 2) with the protocol version in #Z.2.0, RS-FEC and scrambling mode set to the lower between the IWF type 1 maximum capability and the REC proposed setting.
- Opt. Ver. 2: start forwarding the received CPRI basic frames by means of eCPRI start-up message #8 to the remote IWF (i.e. IWF type 2) with the protocol version in #Z.2.0, RS-FEC and scrambling mode set according to the IWF type 1 configuration[4].

Upon reception of eCPRI start-up message from the remote end (i.e. IWF type 2) corresponding to the expected line bit rate, it shall stop trying to select other line rates even if not in the HFNSYNC state and it shall

- Opt Ver. 1: start forwarding the CPRI basic frames received from the remote IWF (i.e. IWF type 2) with the protocol version in #Z.2.0, RS-FEC and scrambling mode set to the lower between the IWF type 1 maximum capability and the received eCPRI start-up message #8 setting.
- Opt Ver. 2: start forwarding the CPRI basic frames received from the remote IWF (i.e. IWF type 2) with the protocol version in #Z.2.0, RS-FEC, scrambling according to IWF configuration[4].

Comments:
While in this state, no timer to detect hanging-up is provided by the start-up procedure. Such a hanging-up will occur in case of HW fault or may also occur for configurations with an IWF type 2 CPRI port supporting more than 4-line bit rates for auto-negotiation. Such a hanging-up shall be detected and managed by vendor specific means. For more information see also Annex 6.8 in [1].

Figure 54 shows the line rate negotiation between two CPRI nodes in an eCPRI/CPRI type 1/ type 2 interworking configuration.

[4] How to set up the IWF configuration is out of the scope of this specification.

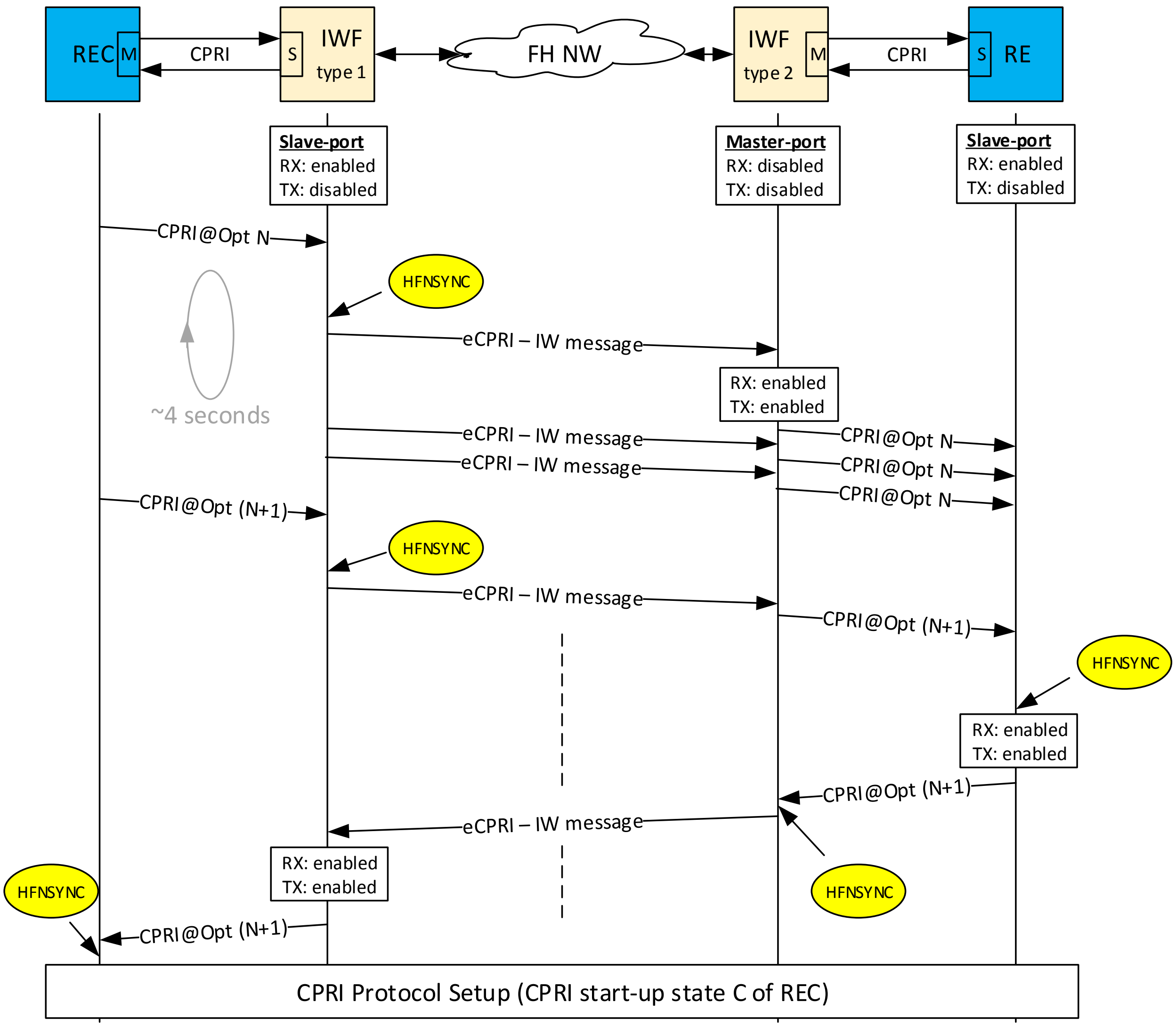


Figure 54: Line bit rate negotiation sequence diagram

Assumptions in the sequence diagram (Figure 54):

- Both IWF type 1 and IWF type 2 support at least one common CPRI line rate option of REC and RE.
- REC in the example above supports at least CPRI line rate options N and (N+1), the RE only supports the (N+1) option.
- The line-rate auto-negotiation turn-around times are fulfilled (i.e. the T1 (0.9…1.1 seconds) and T1´ (3.9…4.1 seconds) in the CPRI Specification).

8.7.3.3.3. State C – Protocol Setup

Prerequisites:
Layer 1 is synchronized, i.e., CPRI master port (REC) to IWF type 1 and IWF type 2 to CPRI slave port (RE) hyperframe structures are aligned.

Description:
During this state, a common protocol version of CPRI is determined.

Interpreted control BYTES:
For 8B/10B line coding; #Z.0.0, #Z.64.0, #Z.2.0
For 64B/66B line coding; #Z.0.8, #Z.64.0, #Z.2.0

IWF type 2 CPRI master port actions:

When entering this state, the IWF type 2 CPRI master port shall:

- Opt Ver. 1: set the protocol version in #Z.2.0 to the lower between the IWF type 2 maximum capability and the received eCPRI start-up message #8 setting. If the currently received protocol version from the RE CPRI slave port is equal to the current protocol version sent by the IWF type 2 CPRI master port, the protocol setup is achieved.
- Opt Ver. 2: set the protocol version in #Z.2.0 according to the IWF type 2 configuration.

The IWF type 2 CPRI master port shall decode the received protocol version by looking at #Z.2.0. When the IWF type 2 CPRI master port receives a valid or an updated protocol version from the CPRI slave port,

- If the currently received protocol version is equal to the current protocol version sent by the IWF type 2 CPRI master port, the protocol setup is achieved
- If the currently received protocol version differs from the current protocol version sent by the IWF type 2 CPRI master port, it shall reselect the protocol version. The new protocol version shall be selected according to the rule:

  New IWF type 2 CPRI master port protocol version = highest available protocol version which is less or equal to received CPRI slave port protocol version (received in #Z.2.0)

  Error case: If no such protocol exists:

  New IWF type 2 CPRI master port protocol version = lowest available protocol version

  Note that the reselection may choose the already transmitted protocol version. The new selected protocol version shall be stated in #Z.2.0. If the currently received protocol version is equal to the new protocol version sent by the IWF type 2 CPRI master port, the protocol setup is achieved.

While in this state, the IWF type 2 shall forward the received CPRI basic frames by means of eCPRI start-up message #8 to the remote IWF (i.e. IWF type 1) with the protocol version in #Z.2.0 set to the lower between the IWF type 2 maximum capability and the RE proposed setting.

IWF type 1 CPRI slave port actions:

While in this state, the IWF type 1 shall forward the received CPRI basic frames by means of eCPRI start-up message #8 to the remote IWF (i.e. IWF type 2) with the protocol version in #Z.2.0 set to the lower between the IWF type 1 maximum capability and the REC proposed setting.

While in this state,

- Opt Ver. 1: the IWF type 1 shall forward the received eCPRI start-up message #8 setting to the REC CPRI master port with the protocol version in #Z.2.0 set to the lower between the IWF type 1 maximum capability and the eCPRI start-up message #8 setting.
- Opt Ver. 2: the IWF type 1 shall forward the received eCPRI start-up message #8 setting to the REC CPRI master port with the protocol version in #Z.2.0 set to the IWF type 1 configuration.

The IWF type 1 CPRI slave port shall decode the received protocol version by looking at #Z.2.0. When the IWF type 1 CPRI slave port receives a valid or an updated protocol version from the CPRI master port,

- If the currently received protocol version is equal to the current protocol version sent by the IWF type 1 CPRI slave port, the protocol setup is achieved
- If the currently received protocol version differs from the current protocol version sent by the IWF type 1 CPRI slave port, the IWF type 1 CPRI slave port shall reselect the protocol version. The new proposed protocol version shall be selected according to the rule:

  New IWF type 1 CPRI slave port protocol version = highest available protocol version which is less or equal to received CPRI master port protocol version (received in #Z.2.0)

  Error case: If no such protocol exists:

  New IWF type 1 CPRI slave port protocol version = lowest available protocol version

  Note that the reselection may choose the already transmitted protocol version. The new selected protocol version shall be stated in #Z.2.0. If the currently received protocol version is equal to the new protocol version sent by the IWF type 1 CPRI slave port, the protocol setup is achieved.

Comments:
If the IWF type 2 CPRI master port does not receive a new protocol version before the layer 1 start-up timer

expires, it can assume that there are no common protocol versions. Such a detection can be made faster but then the application must take into account the case where the CPRI slave port enters the state later than the IWF type 2 CPRI master port.

8.7.3.3.4. State F – Operation

Prerequisites:
The protocol is agreed upon.

Description:
Normal operation.

Interpreted control words:
All

IWF type 2 CPRI master port actions:
While in this state, the IWF type 2 CPRI master port shall check that #Z.2.0 is equal in both directions. If it is not equal it shall enter state C.

While in this state, the IWF type 2 CPRI master port shall detect any change in the received protocol version value #Z.2.0 from the remote IWF. If this protocol value changes it shall enter state C.

IWF type 1 CPRI slave port actions:
The IWF type 1 CPRI slave port shall check that #Z.2.0 is equal in both directions. If it is not equal it shall enter state C.

Comments:

- In normal operation, the C&M plane has been established and all further setup of HW, functionality, user plane links, IQ format, etc. is conducted using procedures outside the scope of the CPRI and eCPRI specifications. If the CPRI is subject to a failure state, B is entered.
- IWF type 1 will stop sending Message Type #8 when IWF type 1 CPRI port get into operation state F. The IWF type 1 will at this point start sending Message Type #9.
- IWF type 2 will stop sending Message Type #8 when receiving Message Type #9 from the remote IWF type 1. IWF type 2 will at this point start sending Message Type #9.

While in this state the IWF type 1 and 2 ports shall manage the CPRI SAPs as specified in the following sections:

- 8.3 Bridging of User Plane
- 8.4 Bridging/Routing of CPRI Control Words
- 8.5 Bridging of Synchronization Plane
- 8.6 Bridging/handling of CPRI sub-channels 0 and 2

8.7.3.4. Transition Description

8.7.3.4.1. Transition 1

Trigger:
The trigger is out of the scope of the eCPRI specification. But it is required for the CPRI circuit initiation to be completed.

A set of available line bit rates and protocol versions shall be available. This may be the equipment full capabilities, or a subset determined by the equipment configuration (manual) or knowledge from previous successful configurations. Such a subset will shorten the time in state B and C.

Actions:
None

8.7.3.4.2. Transition 2

Trigger:

- IWF type 1: HFNSYNC synchronization state and eCPRI message #8 reception from remote end IWF type 2.
- IWF type 2: First time the synchronization state HFNSYNC is entered. Received CPRI line bit rate is equal to transmitted CPRI line bit rate.

Actions:
The “layer 1 start-up timer” is set.

8.7.3.4.3. Transition 3

Trigger:
Protocol is agreed on. First time transmitted #Z.2.0 is equal to received #Z.2.0.

Actions:
The “layer 1 start-up timer” is cleared.

8.7.3.4.4. Transition 9

Trigger:
Out of the scope of the eCPRI specification. The capability negotiation by the application proposes a new CPRI protocol or line bit rate.

Actions:
The transition carries information about the agreed available set of line bit rates and protocol versions.

8.7.3.4.5. Transition 10

Trigger:
First time LOS or LOF has been found faulty as defined in [1], section 4.2.10.

Actions:
The “layer 1 start-up timer” is cleared.

8.7.3.4.6. Transition 11

Trigger:
The IWF type 1 or 2 CPRI ports are initiated.

Actions:
The “layer 1 start-up timer” is cleared.

8.7.3.4.7. Transition 13

Trigger:
First time the received protocol version in #Z.2.0 is changed while in state F.

Actions:
The “layer 1 start-up timer” is set.

8.7.3.4.8. Transition 16

Trigger:
When “layer 1 start-up timer” expires.

Actions:
None

8.8. Synchronization

eCPRI/CPRI interworking synchronization assumptions:

- The internal time clocks of IWF type 1 and IWF type 2 are frequency and phase/time synchronized to a common reference.
- REC is (at least) frequency synchronized[5] to the same reference as IWF type 1 and IWF type 2.
- RE is synchronized to the IWF type 2 CPRI master port.

8.9. Delay Management

In order to support eCPRI/CPRI interworking for CPRI REC and RE, it is necessary to ensure that the CPRI delay management process can be used by REC and RE. This can be achieved by providing constant and symmetrical[6] DL and UL link delays between REC and RE, which can be measured by REC via T14 measurement and Toffset provided by RE.

Figure 55 shows the definition of the timing reference points for the eCPRI/CPRI interworking delay management:

- T12'/T34' denotes the DL and UL CPRI link delays between REC and IWF type 1, assumed to be constant and symmetric in DL and UL.
- T12''/T34'' denotes the DL and UL CPRI link delays between IWF type 2 and RE, assumed to be constant and symmetric in DL and UL.
- T12network denotes the transport network delay of a user data packet between IWF type 1 and IWF type 2. T12network may not be constant for every packet and may show a statistical variation limited by the profile of the transport network:

  $$0 \le \text{T12network\_min} \le \text{T12network} \le \text{T12network\_max}$$

- T34network denotes the transport network delay of a user data packet between IWF type 2 and IWF type 1. T34network may not be constant for every packet and may show a statistical variation limited by the profile of the transport network:

  $$0 \le \text{T34network\_min} \le \text{T34network} \le \text{T34network\_max}$$

- T_{IWF1_DL} denotes the DL forwarding delay for user data in IWF type 1 between the reception of a basic frame at the CPRI port of IWF type 1 and the transmission of the corresponding user data packet at the eCPRI port of IWF type 1. T_{IWF1_DL} may not be constant for every packet and may show a statistical variation:

  $$0 \le T_{IWF1\_DL\_min} \le T_{IWF1\_DL} \le T_{IWF1\_DL\_max}$$

- T_{IWF2_DL} denotes the DL forwarding delay for user data in IWF type 2 between the reception of a user data packet at the eCPRI port of IWF type 2 and the transmission of the corresponding basic frame at the CPRI port of IWF type 2. T_{IWF2_DL} includes extra buffering of user data which is needed for achieving a constant DL delay and symmetrical DL/UL delays. The worst case zero buffer forwarding delay is denoted as $T_{IWF2\_DL\_min}$, and the worst case zero buffer forwarding delay + maximum buffering delay is denoted as $T_{IWF2\_DL\_max}$.
- T_{IWF2_UL} denotes the UL forwarding delay for user data in IWF type 2 between the reception of a basic frame at the CPRI port of IWF type 2 and the transmission of the corresponding user data packet at the eCPRI port of IWF type 2. T_{IWF2_UL} may not be constant for every packet and may show a statistical variation:

  $$0 \le T_{IWF2\_UL\_min} \le T_{IWF2\_UL} \le T_{IWF2\_UL\_max}$$

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[5] Frequency synchronized means that the average frequency difference is zero, which is equivalent to phase locked, i. e. the average phase difference is arbitrary but constant.

[6] in cases where time synchronization at the antenna ports is not needed (e. g. asynchronous UTRA FDD), a symmetrical DL and UL delay is not essential

- T_{IWF1_UL} denotes the UL forwarding delay for user data in IWF type 1 between the reception of a user data packet at the eCPRI port of IWF type 1 and the transmission of the corresponding basic frame at the CPRI port of IWF type 1. T_{IWF1_UL} includes extra buffering of user data which is needed for achieving a constant UL delay and symmetrical DL/UL delays. The worst case zero buffer forwarding delay is denoted as $T_{IWF1\_UL\_min}$, and the worst case zero buffer forwarding delay + maximum buffering delay is denoted as $T_{IWF1\_UL\_max}$.
- T12 denotes the overall DL delay between transmission of a CPRI basic frame at the REC and reception of this basic frame at the RE. IWF type 1 and IWF type 2 shall ensure by additional buffering of user data that T12 is constant and equal to T34.
- T34 denotes the overall UL delay between transmission of a CPRI basic frame at the RE and reception of this basic frame at the REC. IWF type 1 and IWF type 2 shall ensure by additional buffering of user data that T34 is constant and equal to T12.
- Toffset denotes the CPRI frame offset between the input signal and the output signal at the input point (R2), and the output point (R3) of an RE terminating a particular logical connection between SAP_{IQ} as specified by CPRI specification [1]. Toffset is constant, value is user specific.
- T14 denotes the CPRI frame delay between REC DL and UL CPRI ports. IWF type 1 and IWF type 2 shall ensure by additional buffering of user data that T14 is constant and equal to T12 + Toffset + T34.

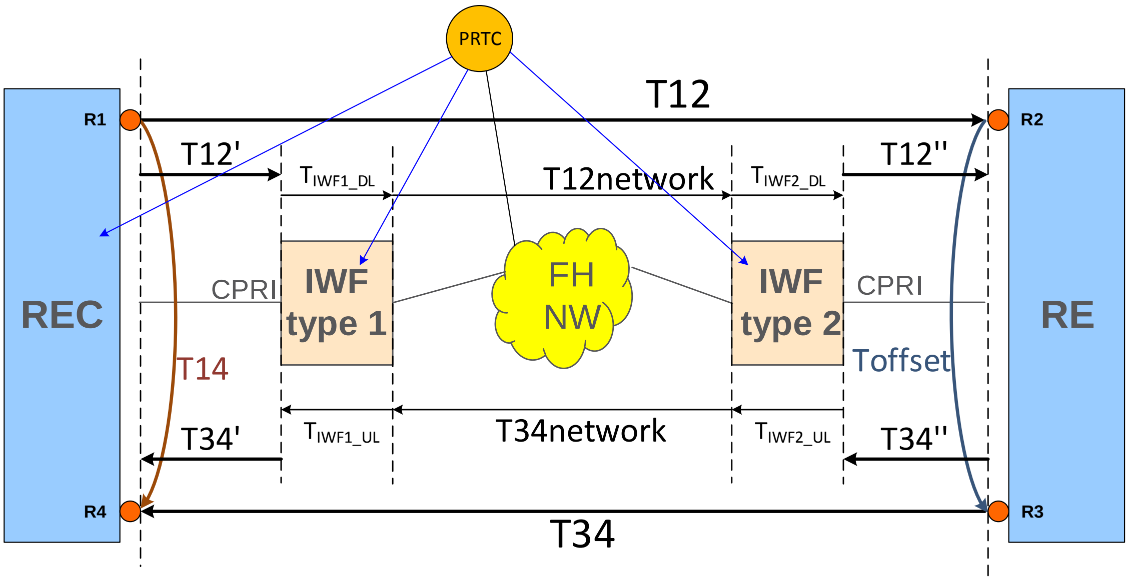

Figure 55: Definition of reference points for eCPRI/CPRI interworking delay management

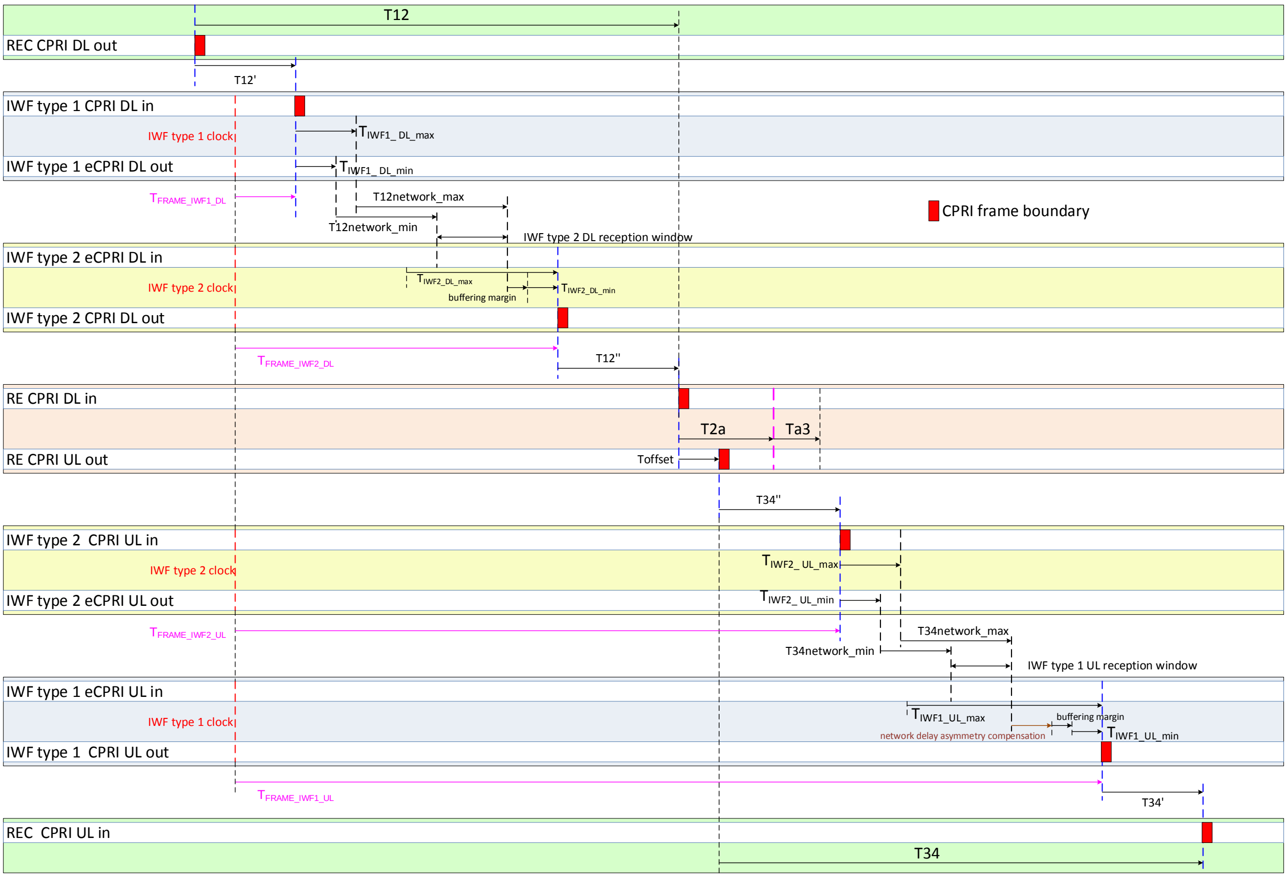

Figure 56: eCPRI/CPRI interworking timing diagram

A detailed timing diagram for eCPRI/CPRI interworking is shown in Figure 56.

Where:

- $T_{FRAME\_IWF1\_DL}$ denotes the reception time of the DL CPRI frame boundary at IWF type 1 relative to the internal timing reference.
- $T_{FRAME\_IWF2\_DL}$ denotes the transmission time of the DL CPRI frame boundary at IWF type 2 relative to the internal timing reference.
- $T_{FRAME\_IWF2\_UL}$ denotes the reception time of the UL CPRI frame boundary at IWF type 2 relative to the internal timing reference.
- $T_{FRAME\_IWF1\_UL}$ denotes the transmission time of the UL CPRI frame boundary at IWF type 2 relative to the internal timing reference.

Please note that the internal time references of IWF type 1 and IWF type 2 are phase/time synchronized to a common reference and thus synchronous (within a suitable synchronization accuracy), see section 8.8.

The goal of the IWF delay management is to achieve a constant and symmetrical delay:

$T_{FRAME\_IWF2\_DL} - T_{FRAME\_IWF1\_DL} = T_{FRAME\_IWF1\_UL} - T_{FRAME\_IWF2\_UL} =$ constant,

by managing the delays T_{IWF2_DL} and T_{IWF1_UL} with extra buffers in IWF type 1 and IWF type 2, as well as selecting for a suitable “constant” value, where:

$T_{FRAME\_IWF2\_DL} - T_{FRAME\_IWF1\_DL} = T_{IWF1\_DL} + T12network + T_{IWF2\_DL}$

$T_{FRAME\_IWF1\_UL} - T_{FRAME\_IWF2\_UL} = T_{IWF2\_UL} + T34network + T_{IWF1\_UL}$

To achieve constant and symmetric delay, the value for “constant” shall be selected to fulfill the following relation:

$T_{FRAME\_IWF2\_DL} - T_{FRAME\_IWF1\_DL} = T_{FRAME\_IWF1\_UL} - T_{FRAME\_IWF2\_UL} = \text{constant} \geq$
$\geq \max(T_{IWF1\_DL\_max} + T12network\_max + T_{IWF2\_DL\_min}, T_{IWF2\_UL\_max} + T34network\_max + T_{IWF1\_UL\_min})$

In case DL/UL delay symmetry is not needed the value for “constant” can be different in DL and UL and the following relations apply:

$T_{FRAME\_IWF2\_DL}$ - $T_{FRAME\_IWF1\_DL}$ = constant_DL ≥ $T_{IWF1\_DL\_max}$ + T12network_max + $T_{IWF2\_DL\_min}$

$T_{FRAME\_IWF1\_UL}$ - $T_{FRAME\_IWF2\_UL}$ = constant_UL ≥ $T_{IWF2\_UL\_max}$ + T34network_max + $T_{IWF1\_UL\_min}$

Any user data packet with a DL delay lower than $T_{FRAME\_IWF2\_DL}$ - $T_{FRAME\_IWF1\_DL}$ has to be buffered in IWF type 2 and any user data packet with an UL delay lower than $T_{FRAME\_IWF1\_UL}$ - $T_{FRAME\_IWF2\_UL}$ has to be buffered in IWF type 1

In order to avoid a buffer overflow in IWF type 1 or IWF type 2, the value for “constant” has to fulfill the following additional relations:

In case DL/UL delay symmetry is required:

$T_{FRAME\_IWF2\_DL}$ - $T_{FRAME\_IWF1\_DL}$ = $T_{FRAME\_IWF1\_UL}$ - $T_{FRAME\_IWF2\_UL}$ = constant ≤
≤ min($T_{IWF1\_DL\_min}$ + T12network_min + $T_{IWF2\_DL\_max}$, $T_{IWF2\_UL\_min}$ + T34network_min + $T_{IWF1\_UL\_max}$)

In case DL/UL delay symmetry is not needed:

$T_{FRAME\_IWF2\_DL}$ - $T_{FRAME\_IWF1\_DL}$ = constant_DL ≤ $T_{IWF1\_DL\_min}$ + T12network_min + $T_{IWF2\_DL\_max}$

$T_{FRAME\_IWF1\_UL}$ - $T_{FRAME\_IWF2\_UL}$ = constant_UL ≤ $T_{IWF2\_UL\_min}$ + T34network_min + $T_{IWF1\_UL\_max}$

T12network_max and T34network_max are either known from guaranteed network performance or have to be measured by IWF type 1 and IWF type 2 (e. g. by using eCPRI one-way-delay measurement) before the CPRI link start-up.

This delay management procedure requires IWF type 1 to know IWF type 2 delays. This can be achieved using Message Type #11 Delay Control. IWF type 1 requests the IWF type 2 delays $T_{IWF2\_DL\_min}$ (Delay A) and $T_{IWF2\_UL\_max}$ (Delay B) via Message Type #11 and calculates constant_DL/UL.

The timing configuration of the CPRI framer in IWF type 2 DL and IWF type 1 UL is carried out during start-up by sending Message Type #8 (IWF Start-Up):

- In DL IWF type 1 measures the reception time $T_{Z.X\_IWF1\_DL}$ of each DL CPRI basic frame Z.X relative to its internal clock, adds constant_DL and sends it to IWF type 2 via the time stamp field of the corresponding Message Type #8. This indicates the transmission time of CPRI basic frame Z.X at IWF type 2 CPRI output port.
- In UL IWF type 2 measures the reception time $T_{Z.X\_IWF2\_UL}$ of each UL CPRI basic frame Z.X relative to its internal clock and sends it to IWF type 1 via the time stamp field of the corresponding Message Type #8. IWF type 1 adds constant_UL to the time stamp, which indicates the transmission time of CPRI basic frame Z.X at IWF type 1 CPRI output port.

Please note that $T_{FRAME\_IWF1\_DL}$ = $T_{0.0\_IWF1\_DL}$ and $T_{FRAME\_IWF2\_UL}$ = $T_{0.0\_IWF2\_UL}$.

Once established, timing is kept by IWF type 1 and IWF type 2 after switching from start-up to operation (Message Type #9 IWF Operation).

8.10.Handling of eCPRI Remote Reset and CPRI Reset

The CPRI Reset bit sent in CPRI control word #Z.130.0 shall have no effect on and shall be tunneled by IWF type 1 or IWF type 2.

How and when to reset the IWF nodes is vendor specific, it can be performed with the Remote Reset message specified in section 3.2.4.7.

8.11.Link and Fault Management

The CPRI link between a CPRI master (normally a REC) and CPRI slave (normally a RE) should behave as a normal CPRI link even if there are Inter Working Function nodes in between. Figure 57 shows a reference model for link and fault management. Depending on the fault nature and location, special measures should be put in place to ensure the CPRI links between the REC and RE behave as normal CPRI links.

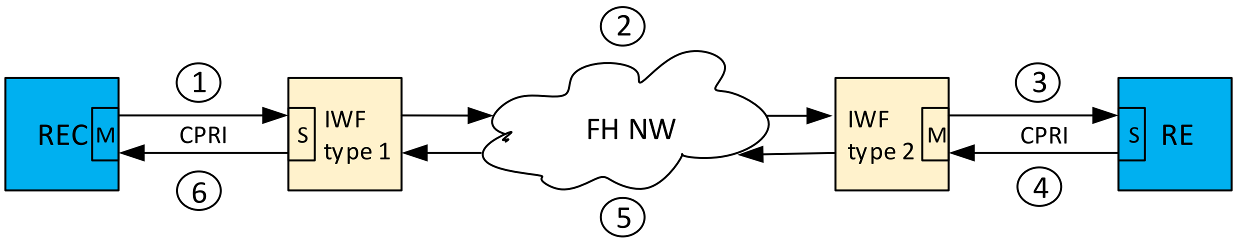

Figure 57: Reference model for link and fault management

During operation, line code errors detected at the CPRI receivers of the IWFs shall be indicated by an error indication bit “E” in the eCPRI Message Type #9. This indicates that at least one “line code error” is detected for a basic frame (or part of basic frame in some cases). This bit is transferred to the other IWF. What to do with this error indicator in the other IWF is out of scope for this eCPRI specification.

Table 20 shows a summary of link faults and the actions that shall be performed. Faults and actions corresponding to links 3 and 6 in Figure 57 are not listed in the table since they are covered by normal CPRI link and fault management [1].

Table 20: Summary of link faults

Link	**Fault detected by**	**Fault detected via**	**Recovery action on/by same node as detected the fault**
1	IWF type 1	Link Supervision (detected LOS/LOF)	Stop sending “link 1 related eCPRI packets” on link 2. (Note: IWF type 2 will detect packet loss.) Discard all received eCPRI packets related from link 5. Set LOS/LOF on Link 6 according to [1]. Disable transmission on link 6 (the transmitting may continue for up to maximum of 5 hyperframes to inform the L1 status). Return to line-rate negotiation (transition 10 in 8.7.3.4.5) See section 8.11.1 for details
		Received RAI	No action (L1 inband will be sent to the CPRI master over eCPRI)
2	IWF type 2	Ethernet supervision Link down Ethernet PCS link down or MAC fault	Disable CPRI link transmission on link 3. Return to start-up. It is recommended to report this to the IWF type 2’s C&M.
		Ethernet supervision No received “link 3 related eCPRI packets” or packets received outside of the reception window for longer than a vendor specific timeout (timeout recommended to be between 1-5 hyperframes)	Disable CPRI link transmission on link 3. Return to start-up. It is recommended to report this to the IWF type 2’s C&M.
		Ethernet supervision No reception or packets received outside of the reception window for “Link 3 related eCPRI packets” but within a vendor specific timeout.	IWF type 2 shall continue sending the CPRI data on link 3 with correct CPRI frame structure but replacing the missing parts with zeros. For exceptions and further details see section 8.11.2.
4	IWF type 2	Link Supervision (detected LOS/LOF)	Stop sending “link 4 related eCPRI packets” on link 5 (Note: IWF type 1 will detect packet loss.) Set LOS/LOF on Link 3 according to [1]. See section 8.11.1 for further details

		Received RAI	No action (L1 inband shall be sent to the CPRI master over eCPRI)
5	IWF type 1	Ethernet supervision Link down Ethernet PCS link down or MAC fault	Disable CPRI link transmission on link 6. Return to start-up. It is recommended to report this to the IWF type 1's C&M.
		Ethernet supervision No received "link 6 related eCPRI packets" or packets received outside of the reception window for longer than a vendor specific timeout (timeout recommended to be between 1 and 5 hyperframe)	Disable CPRI link transmission on link 6. Return to start-up. It is recommended to report this to the IWF type 1's C&M.
		Ethernet supervision No reception or packets received outside of the reception window for "Link 6 related eCPRI packets" but within a vendor specific timeout.	IWF type 1 shall continue sending the CPRI data on link 6 with correct CPRI frame structure but replacing the missing parts with zeros. For exceptions and further details see section 8.11.2.

CPRI L1 reset does not need any special handling because it shall be transferred transparently between the CPRI master and CPRI slave.

Depending on the functionality implemented by and the ambition level of the IWF-node vendor, KPIs regarding the link quality could be accessed by an external management system. Details regarding this KPI reporting are out of scope of this specification.

8.11.1. IWF CPRI transmitter fault recovery/actions for CPRI detected faults

Only two bits shall be treated separately: LOF and LOS bit in the #Z.130.0.

Normally the LOF and LOS bits are forwarded as is from the received eCPRI messages. Special handling is required when locally detecting LOS and LOF errors.

When the CPRI receiver detects LOF, the LOF bit shall be set in the CPRI transmitter. The locally-detected LOF shall be OR-ed with the LOF bit reported in the received eCPRI message.

When the CPRI receiver detects LOS, the LOS bit shall be set in the CPRI transmitter. The locally-detected LOS shall be OR-ed with the LOS bit reported in the received eCPRI message.

8.11.2. IWF CPRI transmitter fault recovery/actions for Ethernet detected faults

Upon detection of Ethernet errors following actions shall be performed:

- For control word 0 (including the "sync byte"), the affected CPRI byte(s) shall be filled with:
  - The generated value based on the local CPRI TX frame structure counter.
- For HFN (#Z.64.0), the affected CPRI byte(s) shall be filled with:
  - The value based on the local HFN counter in the IWF.
- For BFN (#Z.128.0 and #Z192.0), the affected CPRI byte(s) shall be filled with:
  - Opt BFN. 1: zeros.
  - Opt BFN. 2: the value based on the local BFN counter in the IWF.
- For "protocol version" (#Z.2.0), the affected CPRI byte(s) shall be filled with:
  - Opt err prot. 1: zeros.
  - Opt err prot. 2: the same value as before the Ethernet error.

- For “start-up” (#Z.66.0), the affected CPRI byte(s) shall be filled with:
  - Opt err prot. 1: zeros.
  - Opt err prot. 2: the same value as before the Ethernet error.
- For LOF in #Z.130.0, the affected CPRI bit shall be filled with the locally-detected LOF.
- For LOS in #Z.130.0, the affected CPRI bit shall be filled with the locally-detected LOS.
- For SDI, RAI, Reset in the in #Z.130.0, the affected CPRI bits shall be filled with zeros.
- For “pointer p” (#Z.194.0), the affected CPRI byte(s) shall be filled with:
  - Opt err prot. 1: zeros.
  - Opt err prot. 2: the same value as before the Ethernet error.
- For all CPRI “reserved” control words/bits:
  - Opt err prot. 1: the affected CPRI byte(s) shall be filled with zeros.
- For all other CPRI sub channels, the affected CPRI byte(s) shall be filled with zeros.
- For IQ data block, the affected CPRI bits shall be filled with zeros.

9. List of Abbreviations

3GPP	3rd Generation Partnership Project
BC	Boundary Clock
BFF	Basic Frame Fragment
C&M	Control and Management
CFM	Connectivity Fault Management
CoMP	Coordinated Multipoint
CCP	Continuity Check Protocol
CFP	C Form-factor Pluggable
CPRI	Common Public Radio Interface
DiffServ	Differentiated Services
DL	Downlink
DSCP	Differentiated Services Code Point
EMS	Element Management System
eNB	Evolved NodeB
eRE	eCPRI Radio Equipment
eREC	eCPRI Radio Equipment Control
ETH-CC	Ethernet Continuity Check
ETH-AIS	Ethernet Alarm Indication Signal
ETH-LT	Ethernet Link Trace
ETH-LB	Ethernet Loopback
ETH-RDI	Ethernet Remote Defect Indication
ETH-LM	Ethernet Loss Measurement
E-UTRA	Evolved Universal Terrestrial Radio Access
FFT	Fast Fourier Transform
GM	Grandmaster
gNB	5G base station name
GPS	Global Positioning System
HW	Hardware
ICMP	Internet Control Message Protocol
iDFT	inverse Discrete Fourier Transformation
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
IP	Internet Protocol
IPsec	Internet Protocol Security
IQ	In-phase and Quadrature
IWF	eCPRI/CPRI Interworking Function
L1	Layer 1
LT	Link Trace
LLC	Logical Link Control

LB	Loop-Back
LSB	Least Significant Bit
LTE	Long Term Evolution
MAC	Media Access Control
MACsec	Media Access Control Security
MIMO	Multiple Input, Multiple Output
MSB	Most Significant Bit
Msps	Mega sample per second
MU-MIMO	Multi-User MIMO
N/A	not applicable
NMS	Network Management System
NR	New Radio Access Technology (for 5G)
OAM	Operations, Administration and Maintenance
OFDM	Orthogonal Frequency-Division Multiplexing
PCP	Priority Code Point
PDCP	Packet Data Convergence Protocol
PDU	Protocol Data Unit
PHY	Physical Layer
PRACH	Physical Random Access Channel
PTP	Precision Time Protocol
QoS	Quality of Service
QSFP	Quad Small Form-factor Pluggable
RE	Radio Equipment
REC	Radio Equipment Control
Req	Request
Resp	Response
RF	Radio Frequency, Radio Functions
RLC	Radio Link Control
RRC	Radio Resource Control
Rx	Receive
SAP	Service Access Point
SCTP	Stream Control Transmission Protocol
SFP	Small Form-factor Pluggable
SNMP	Simple Network Management Protocol
SRS	Sounding Reference Signal
SW	Software
t_1	Timestamp 1
t_2	Timestamp 2
TCP	Transmission Control Protocol
t_{cv1}	Compensation Value 1
t_{cv2}	Compensation Value 2

t_D	One-Way Delay
TLS	Transport Layer Security
TTI	Transmission Time Interval
Tx	Transmit
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
VID	VLAN Identifier
VLAN	Virtual LAN

10. References

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11. History

Version	Date	Description
V 1.0	2017-08-22	First eCPRI specification
V 1.1	2018-01-10	Editorial corrections
V 1.2	2018-06-25	Section 1: • "The eCPRI interface can also be used between two eREC units or between two eRE units" added below figure 1 Section 2.3: • Table 1: Reference to 38.133 added for RF functions in NR case Section 3.1.1: • Table 3: 25GBase LR/ER added with reference [19] Section 3.2.4.7.1: • "shall" replaced by "should": "Upon reception of a valid "Reset request", the eRE *should* send a "Remote Reset" Indication before performing the requested reset." Section 6.1.1: • Figure 32 updated (legend added for iDFT UL processing block) • Footnote 4 removed Section 6.1.2: • Reworked and new subsection 6.1.2.1 "Bit Rate Calculation Example" introduced Section 8: • New reference [19] added

V2.0	2019-05-10	• Editorial corrections • Introduction of eCPRI/CPRI Interworking function (IWF) resulting in the following list of detailed modifications: o Section 1: System configurations with eCPRI/CPRI IWF type 0 and IWF types 1 and 2 added (new Figures 2 and 3) o Section 2.1: new definitions added: ▪ eCPRI/CPRI Interworking Function (IWF) ▪ CPRI master port for IWF type 0 ▪ CPRI slave port for IWF type 1 ▪ CPRI slave port for IWF type 2 o Section 2.2: Figure 6 (System Architecture example with local eCPRI) added together with associated description. o Section 3.2.4: Table 4 updated to cover IWF related eCPRI Message Types #8...#11. Explicit statement added, that eCPRI Message Types #8...#11 intended IWF type 1 ↔ IWF type 2 communication o Section 3.2.4.7.1 (Remote Reset) updated to cover IWF impact o New section 3.2.4.9 “Message Type #8: IWF Start-Up” o New section 3.2.4.10 “Message Type #9: IWF Operation” o New section 3.2.4.11 “Message Type #10: IWF Mapping” o New section 3.2.4.12 “Message Type #11: IWF Delay Control” o Section 4.4, Table 15 updated o New section 6.2.3 “Synchronization of IWFs” o New section 6.5.2 “eCPRI/CPRI networking with eCPRI/CPRI IWF type 0” o New section 6.5.3 “eCPRI/CPRI networking with eCPRI/CPRI IWF type 1 and type 2” o New Annex B (section 7) “eCPRI/CPRI Interworking with IWF type 0 (Informative)” o New Annex C (section 8) “eCPRI/CPRI Interworking with IWF type 1 and type 2 (Normative)” o Section 9: Abbreviations updated o Section 10: References updated o Section 11: History updated