Common Public Radio Interface

eCPRI presentation

CPRI
Common Public Radio Interface

Background 1/2

Although CPRI has been the main Fronthaul interface standard, many operators started to question its suitability to high bandwidth 5G use cases.

Improvements to efficiency and link capacity utilization were requested.

Also advanced networking and OAM features of mainstream packet transport standards were requested.

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Background 2/2

An increasing number of proposals for a new functional splits between the baseband and radio started to emerge.

Several standardization bodies announced activities to define new Fronthaul Interfaces.

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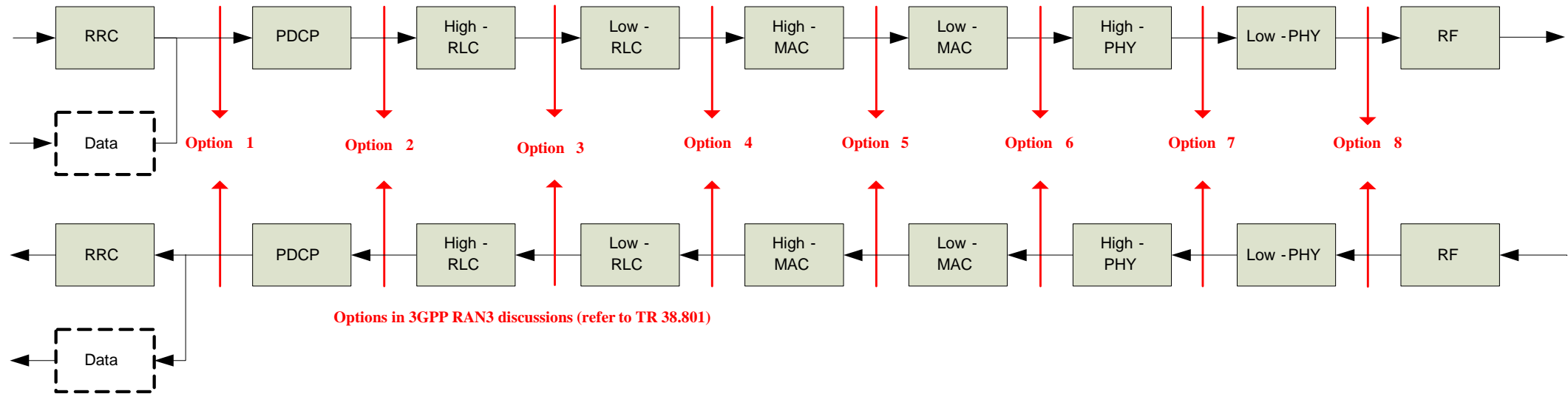
Targets agreed for the new CPRI Specification:

1. Significant reduction of required bandwidth

2. More efficient utilization of available bandwidth

3. Enable evolution for radio processing and support of sophisticated coordination algorithms to guarantee best possible radio performance

4. Carefully select the functionalities of the radio unit in order to enable evolution by SW updates and long life span of the radio units

5. Utilize existing main stream technologies to minimize duplicated specification work

6. Encourage utilization of existing technologies for OAM and networking

7. Be first to the market , becoming the prevailing fronthaul standard and minimizing fronthaul standards fragmentation

eCPRI key Features:

1. ~10 fold reduction of required bandwidth

2. Required bandwidth can scale flexibly according to the user plane traffic

3. Functional split inside PHY layer enables support of sophisticated coordination algorithms

4. Split in PHY keeps most of the functionality in baseband enabling new feature introduction without changes in the radio equipment

5. Encourage utilization of Ethernet and IP , thus guaranteeing future evolution

6. Use of Ethernet/IP technologies encouraged

7. eCPRI specification V1.0 published and openly available to download from www.cpri.info
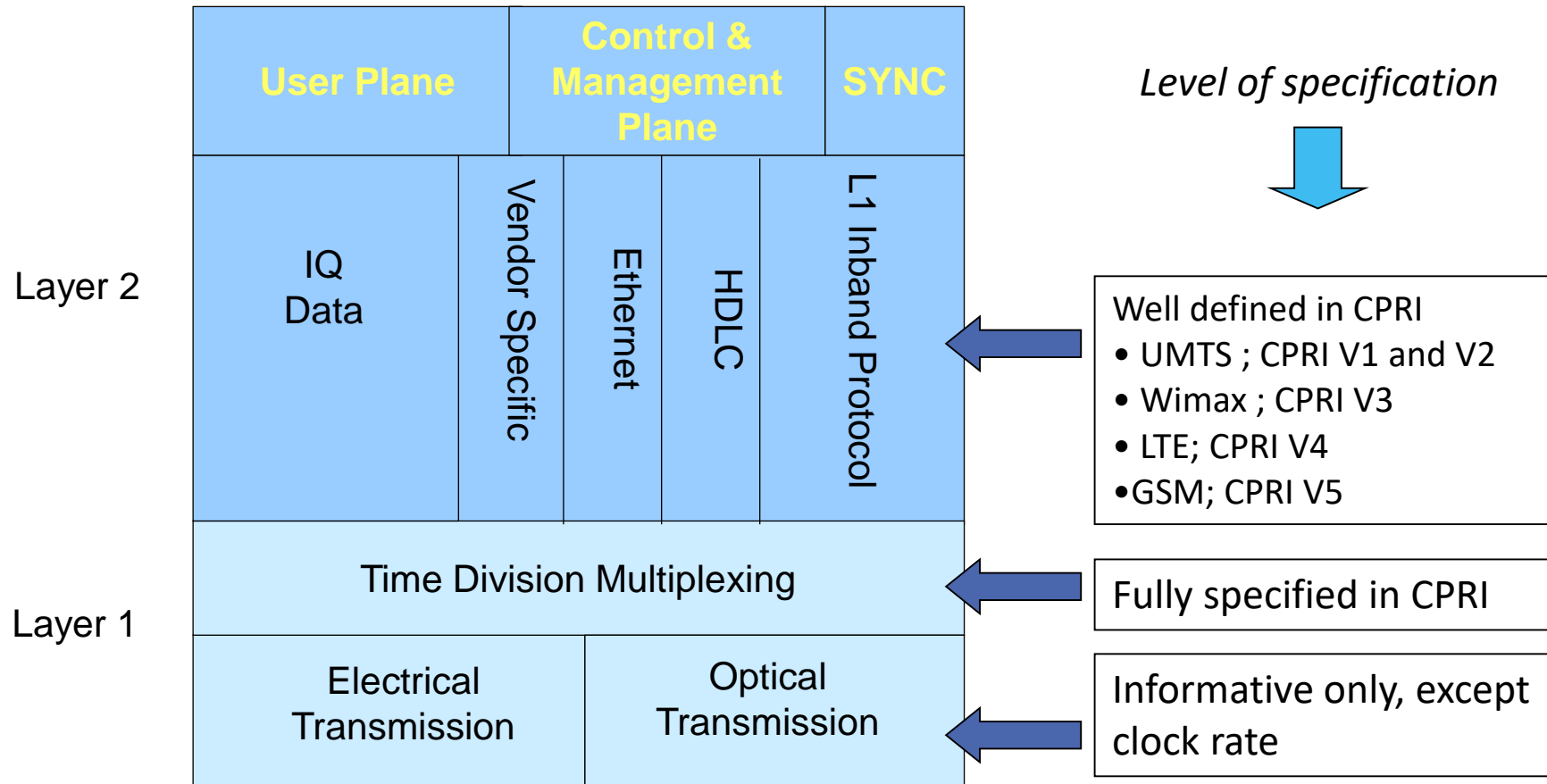
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CPRI reminder

- A digital interface standard to transport antenna samples between a Radio Equipment (RE) and a Radio Equipment Control (REC) performing the digital processing of these signals
- Antennas signals are interleaved in a TDM-like fashion supported by a Constant Bit Rate transport solution
- CPRI v7.0 bit rates range from 614 Mbit/s (Rate 1) up to 24330 Mbit/s (Rate 10)
- Mix of Radio Access Technologies is supported
- Provide time and synchronization information for the Radio Air Interface
- Originally specified for point-to-point topology
- Maximum latency assuming no intermediate nodes
- Multipoint topologies supported but networking management left to the application layer
- Interoperability limited to the low layers covered by the specification
- CPRI define how to exchange the radio signal data not the data content itself nor the associated management plane
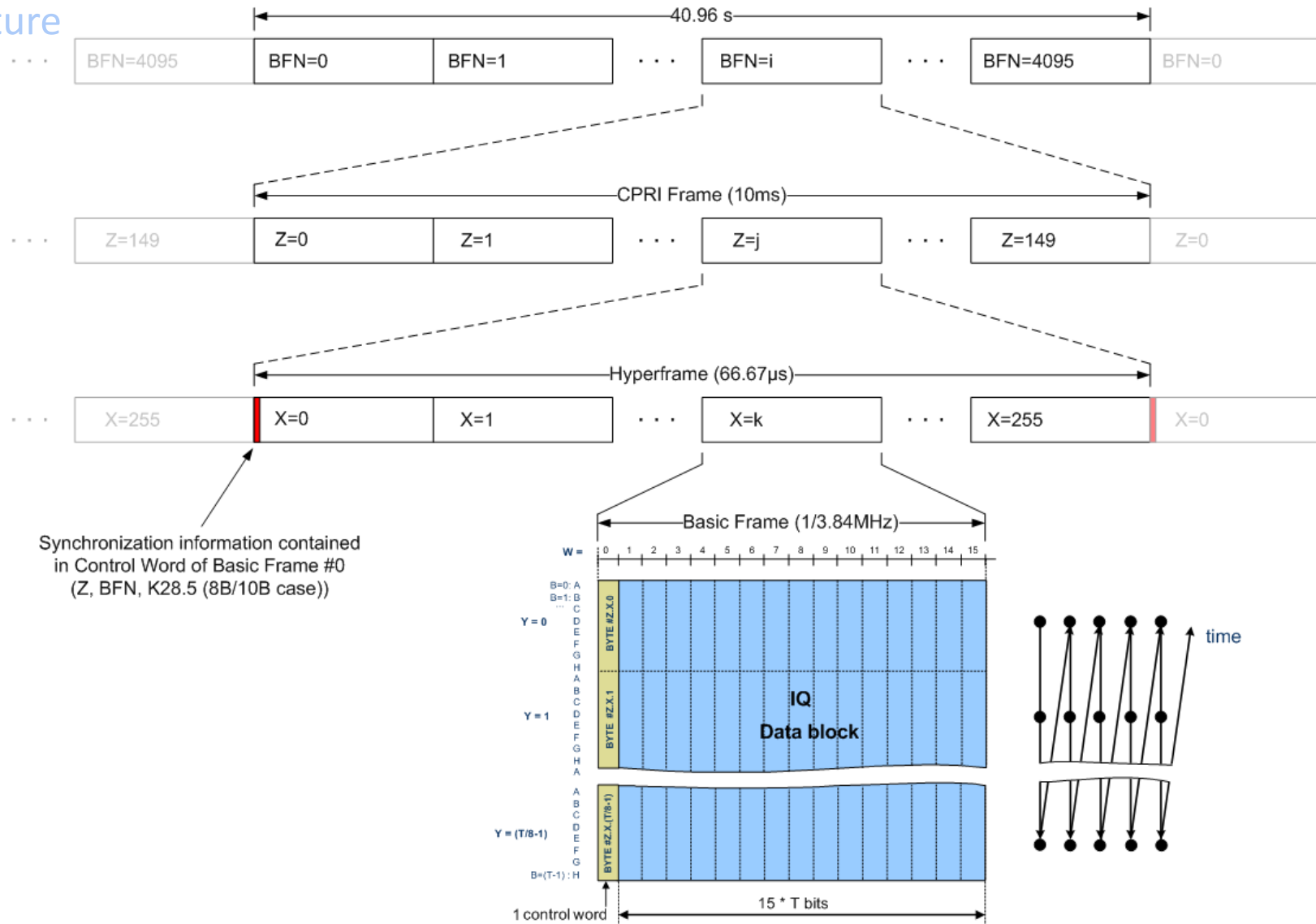
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CPRI reminder
CPRI Protocol Stack

User Plane	Control & Management Plane	SYNC
IQ Data	Vendor Specific	Ethernet	HDLC	L1 Inband Protocol

Layer 2

Layer 1

Time Division Multiplexing

Electrical Transmission | Optical Transmission

Level of specification

Well defined in CPRI
• UMTS ; CPRI V1 and V2
• Wimax ; CPRI V3
• LTE; CPRI V4
•GSM; CPRI V5

Fully specified in CPRI

Informative only, except clock rate

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CPRI reminder
CPRI Frame Structure

CPRI
Common Public Radio Interface
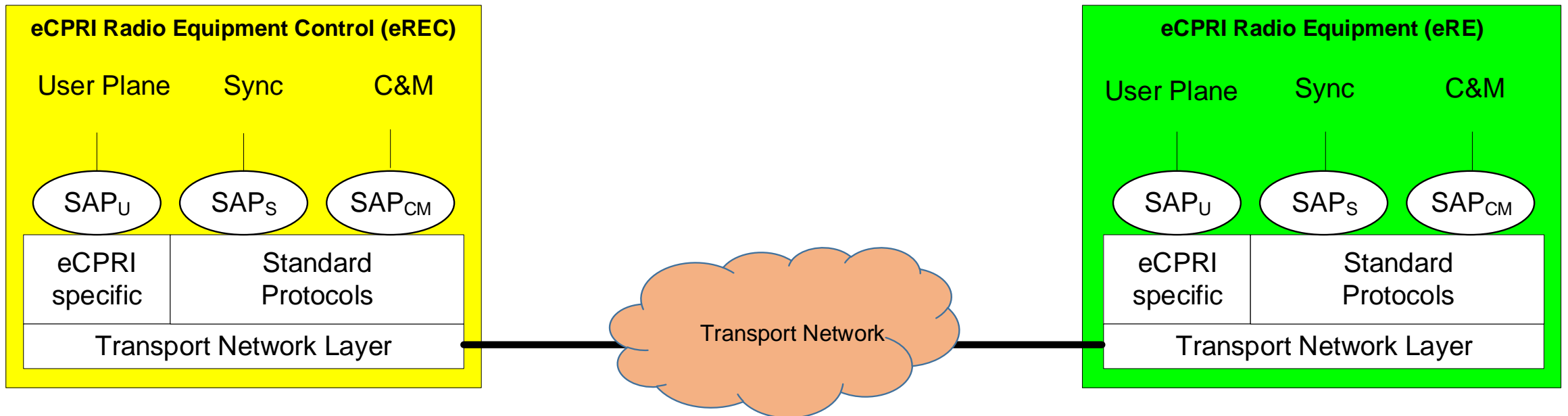
eCPRI introduction
eCPRI system architecture

- eCPRI is packet based fronthaul interface developed by CPRI forum
- Same level of interoperability as CPRI
- Ethernet/IP networking, synchronization and security relying on existing standards
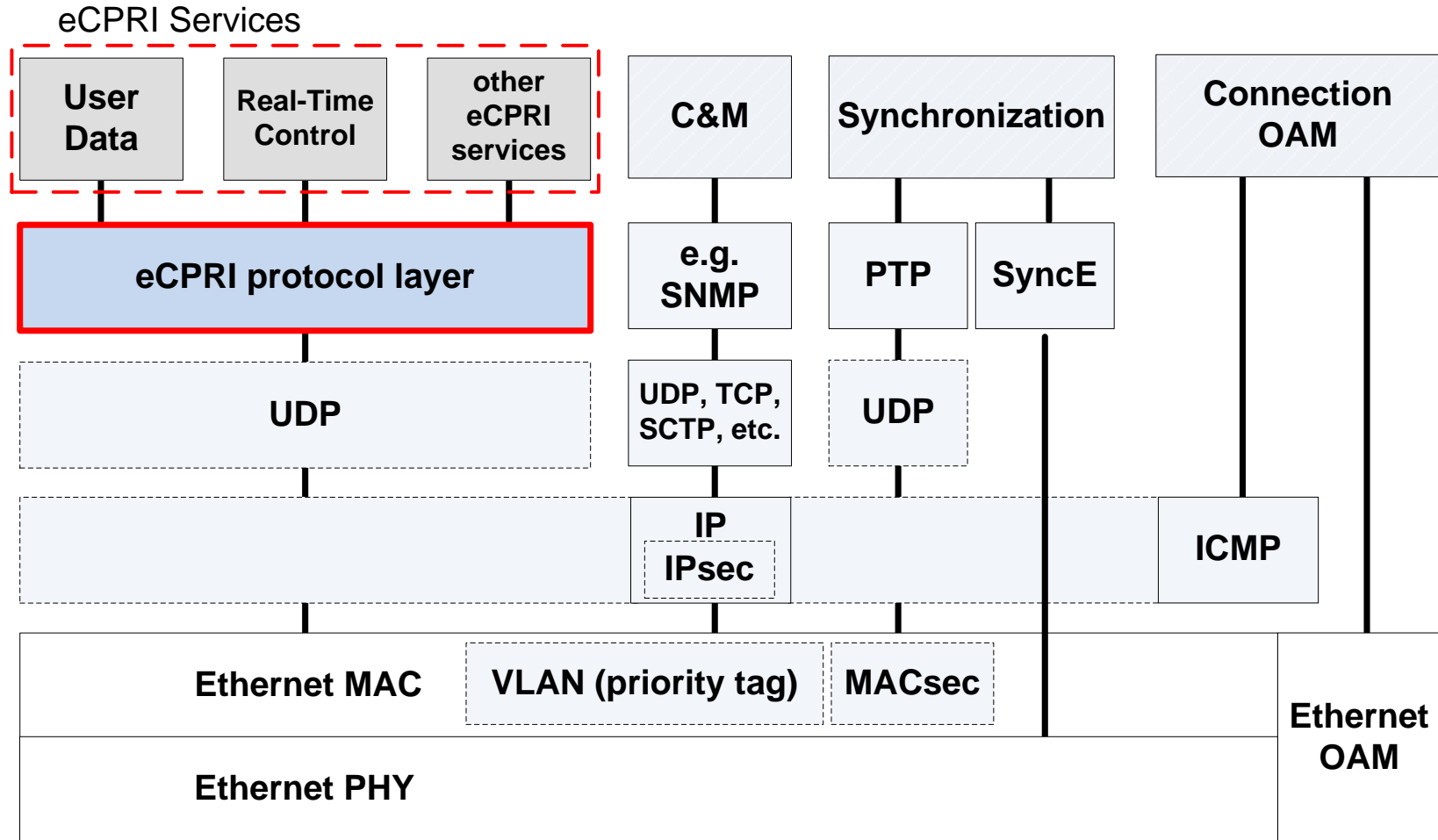
eCPRI introduction

- eCPRI does not constrain the use of specific network- and data link-layer protocols to form the network
  - Any type of network can be used for eCPRI, provided eCPRI requirements are fulfilled.
  - "Requirements for the eCPRI Transport Network" aim to ensure that eCPRI systems can:
    - Use packet based transport network solutions
    - Comply with the requirements associated with the more stringent radio technologies features in terms of:
      - Timing and frequency accuracy
      - Bandwidth capacity,
      - Latency,
      - Packet loss,
      - …
  - eCPRI also encourages the use of existing de-facto/de-jure standard protocols as much as possible where available
  - In case of eCPRI User Plane over Ethernet directly, eCPRI messages shall be transmitted in standard Ethernet frames. The type field of the Ethernet frame shall contain the eCPRI Ethertype (AEFE$_{16}$)

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eCPRI introduction
eCPRI protocol stack over IP / Ethernet

- eCPRI does not restrict the Transport Network to be Ethernet or IP based

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eCPRI introduction
eCPRI node functional decomposition

- eCPRI enables flexible functional decomposition while limiting the complexity of the eRE
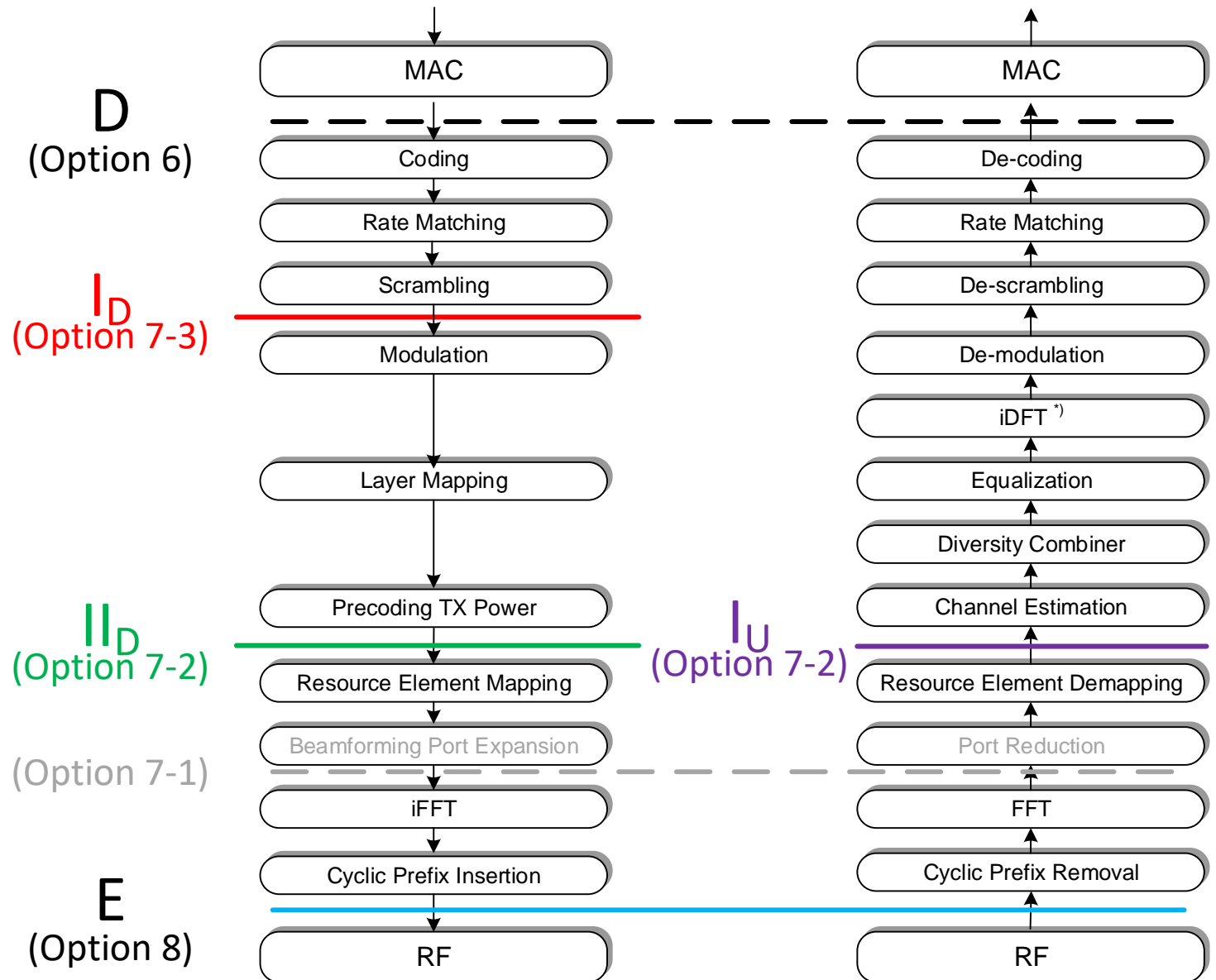- Split points located at the PHY level is one set of examples covered in the eCPRI specification
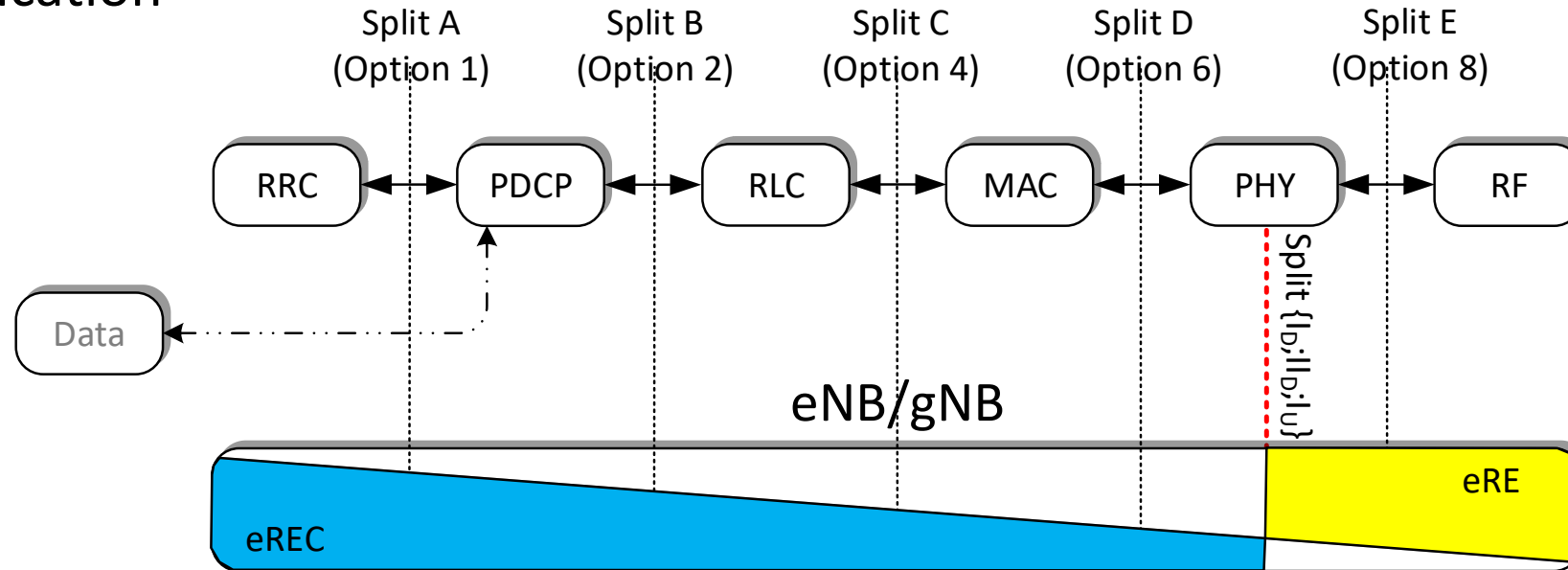
Note: Option 1, 2, 4, 6 and 8 refer to 3GPP split options

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eCPRI introduction
eCPRI functional decomposition

- Split points D, I_D, II_D, I_U and E are examples covered in the eCPRI specification
- Split points Option 6, 7-1, 7-2, 7-3 and 8 are 3GPP split options and sub-options

*) Mandatory processing stage for 4G, optional for 5G

D
(Option 6)

I_D
(Option 7-3)

II_D
(Option 7-2)

I_U
(Option 7-2)

(Option 7-1)

E
(Option 8)

TX chain	RX chain
MAC	MAC
Coding	De-coding
Rate Matching	Rate Matching
Scrambling	De-scrambling
Modulation	De-modulation
	iDFT *)
Layer Mapping	Equalization
	Diversity Combiner
Precoding TX Power	Channel Estimation
Resource Element Mapping	Resource Element Demapping
Beamforming Port Expansion	Port Reduction
iFFT	FFT
Cyclic Prefix Insertion	Cyclic Prefix Removal
RF	RF

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eCPRI introduction
eCPRI typical bandwidth estimations assumptions

- Throughput: 3/1.5 Gbps (DL/UL, 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)
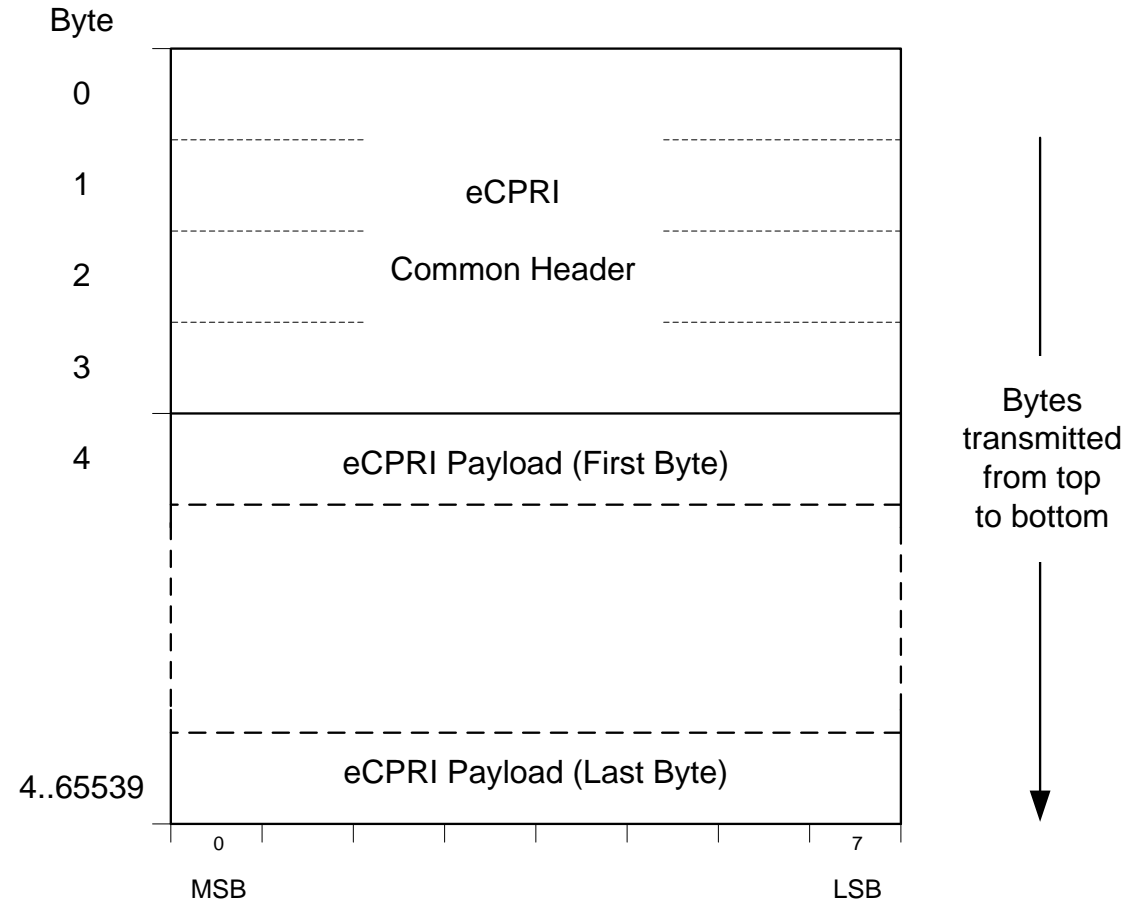- IQ-format: 30 bits per IQ-sample
- No IQ compression

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eCPRI introduction
eCPRI typical bandwidth estimations

	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

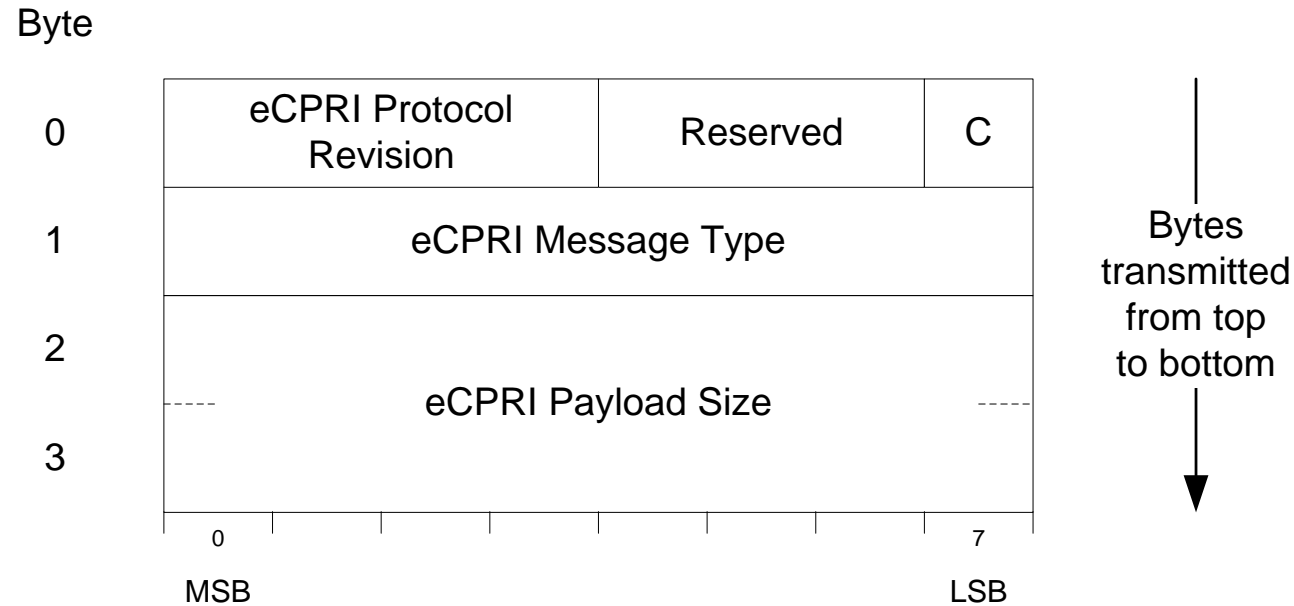|	Split D		Split I_U				Split E
eRE→ eREC	1.5 (assumption)	<< 1	~ 20	<10	~ 20	<10	236

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eCPRI User Plane messages
eCPRI Messages Common Header format

- 4 byte eCPRI common header followed by a variable length eCPRI payload

Byte

0	
1	eCPRI
2	Common Header
3	
4	eCPRI Payload (First Byte)
4..65539	eCPRI Payload (Last Byte)

Bytes transmitted from top to bottom

0   7

MSB   LSB

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eCPRI User Plane messages

eCPRI Messages Common Header format

Byte

| | eCPRI Protocol Revision | Reserved | C |
| 0 | | | |

eCPRI Message Type — Byte 1

eCPRI Payload Size — Bytes 2, 3

Bytes transmitted from top to bottom

0   7

MSB   LSB

- "C" is the eCPRI messages concatenation indicator:
  - "C=0" indicates that the eCPRI message is the last one inside the eCPRI PDU
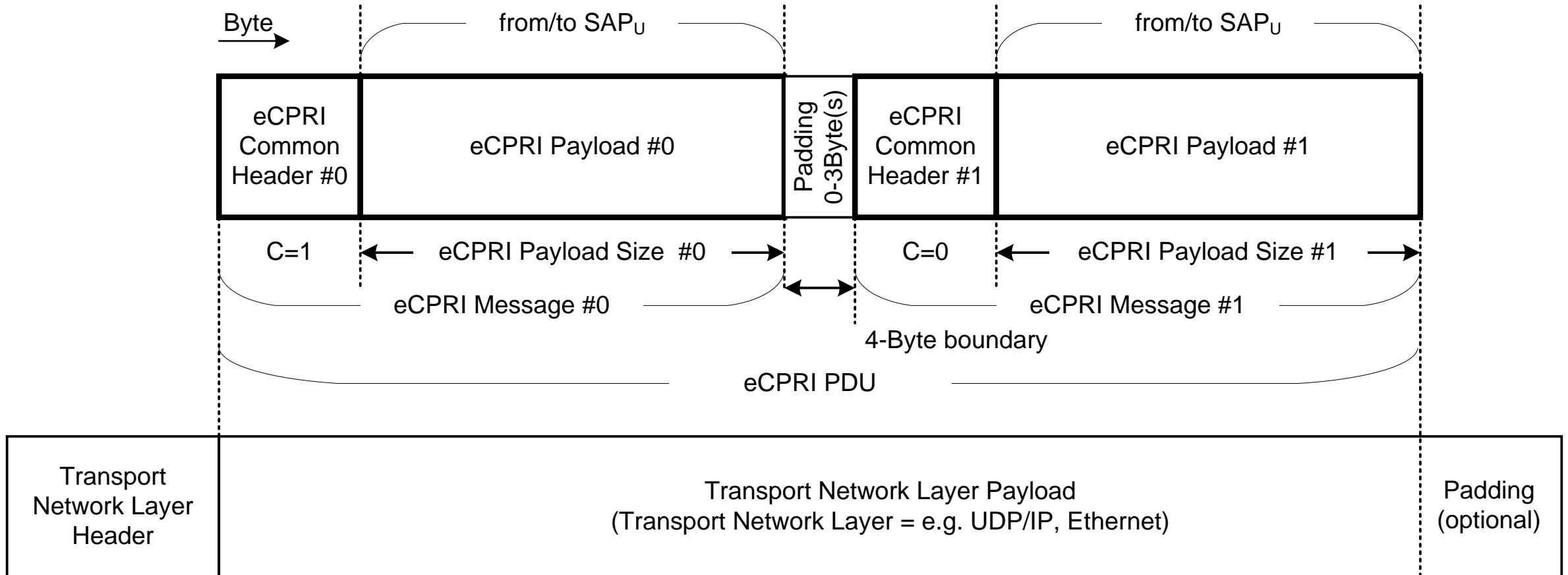 - "C=1" indicates that another eCPRI message follows this one within the eCPRI PDU

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eCPRI User Plane messages
eCPRI Messages Common Header format: concatenation indicator

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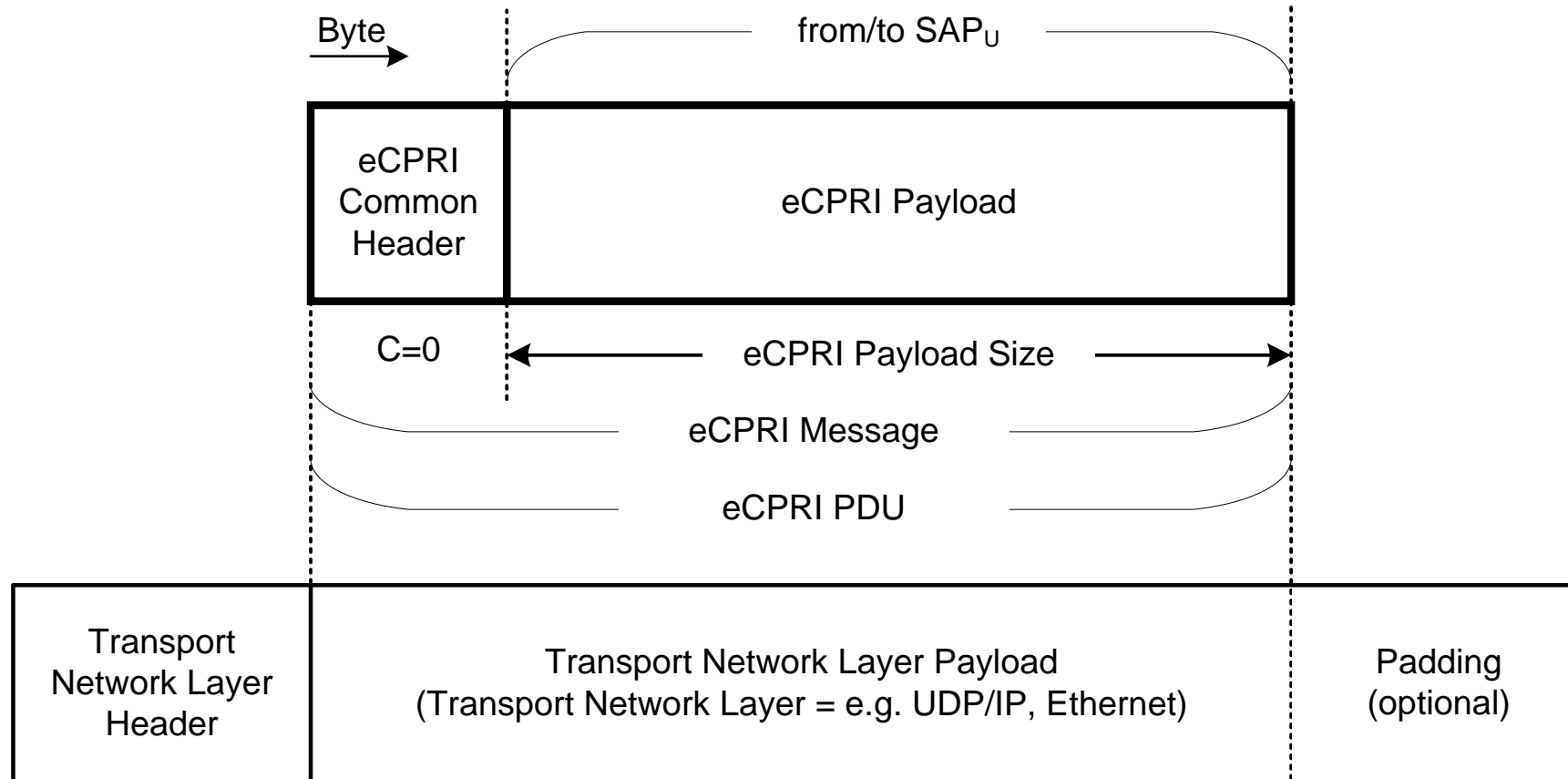
eCPRI User Plane messages

eCPRI Messages Common Header format: concatenation indicator

eCPRI User Plane messages
eCPRI Message types

Message Type #	Name
0	IQ Data
1	Bit Sequence
2	Real-Time Control Data
3	Generic Data Transfer
4	Remote Memory Access
5	One-way Delay Measurement
6	Remote Reset
7	Event Indication
8 – 63	Reserved
64 – 255	Vendor Specific

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eCPRI User Plane messages

eCPRI Message types for data transfer: #0, #1 , #2 and #3

Message Type #0: IQ Data

To transfer time domain or frequency domain IQ samples between PHY processing elements split between eCPRI nodes

Message Type #1: Bit Sequence

To transfer user data in form of bit sequence between PHY processing elements split between eCPRI nodes

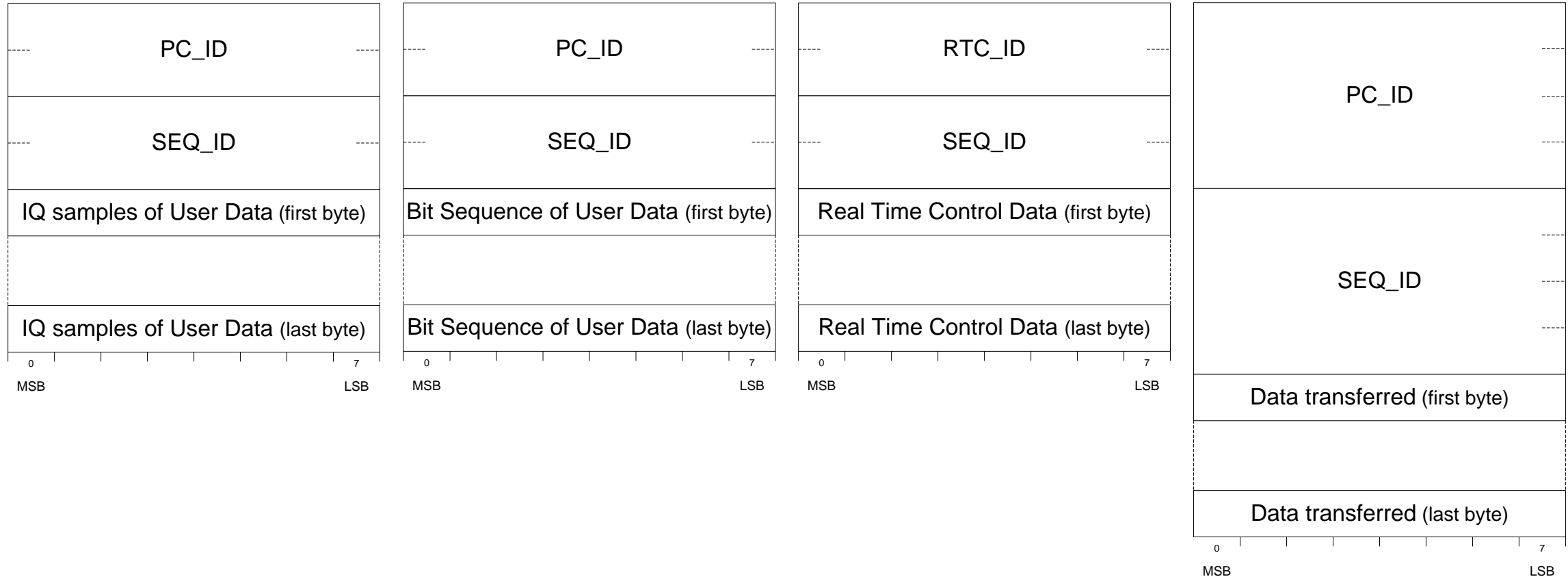## Message Type #2: Real-Time Control Data

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

Message Type #3: Generic Data Transfer

To transfer user plane data or related control between eCPRI nodes (eREC and eRE) providing extended data synchronization support for generic data transfers.
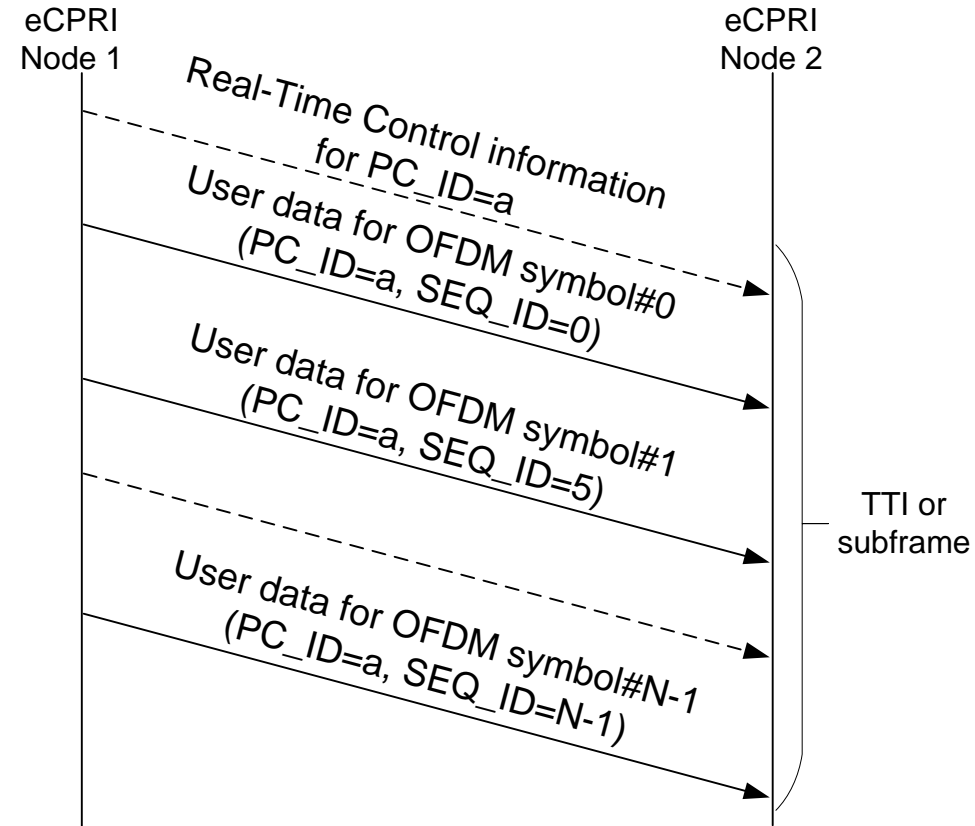
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eCPRI User Plane messages

eCPRI User Plane message formats

PC_ID
SEQ_ID
IQ samples of User Data (first byte)
IQ samples of User Data (last byte)

0 MSB — 7 LSB

PC_ID
SEQ_ID
Bit Sequence of User Data (first byte)
Bit Sequence of User Data (last byte)

0 MSB — 7 LSB

RTC_ID
SEQ_ID
Real Time Control Data (first byte)
Real Time Control Data (last byte)

0 MSB — 7 LSB

PC_ID
SEQ_ID
Data transferred (first byte)
Data transferred (last byte)

0 MSB — 7 LSB

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eCPRI User Plane messages
Message Type #3: Generic Data Transfer sequence diagram example

eCPRI User Plane messages
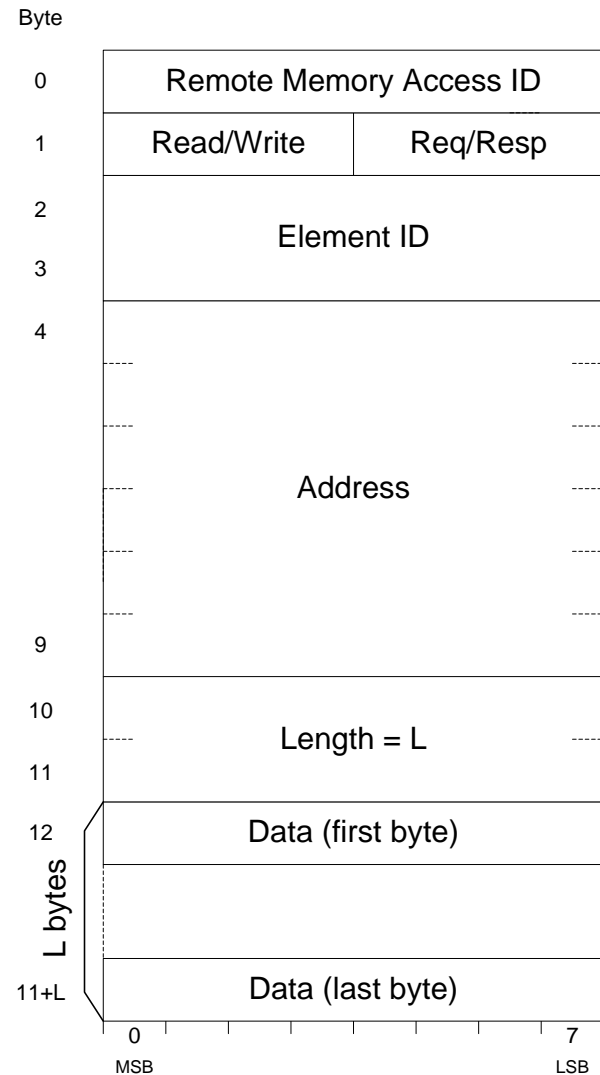
Message Type #4: Remote Memory Access

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.
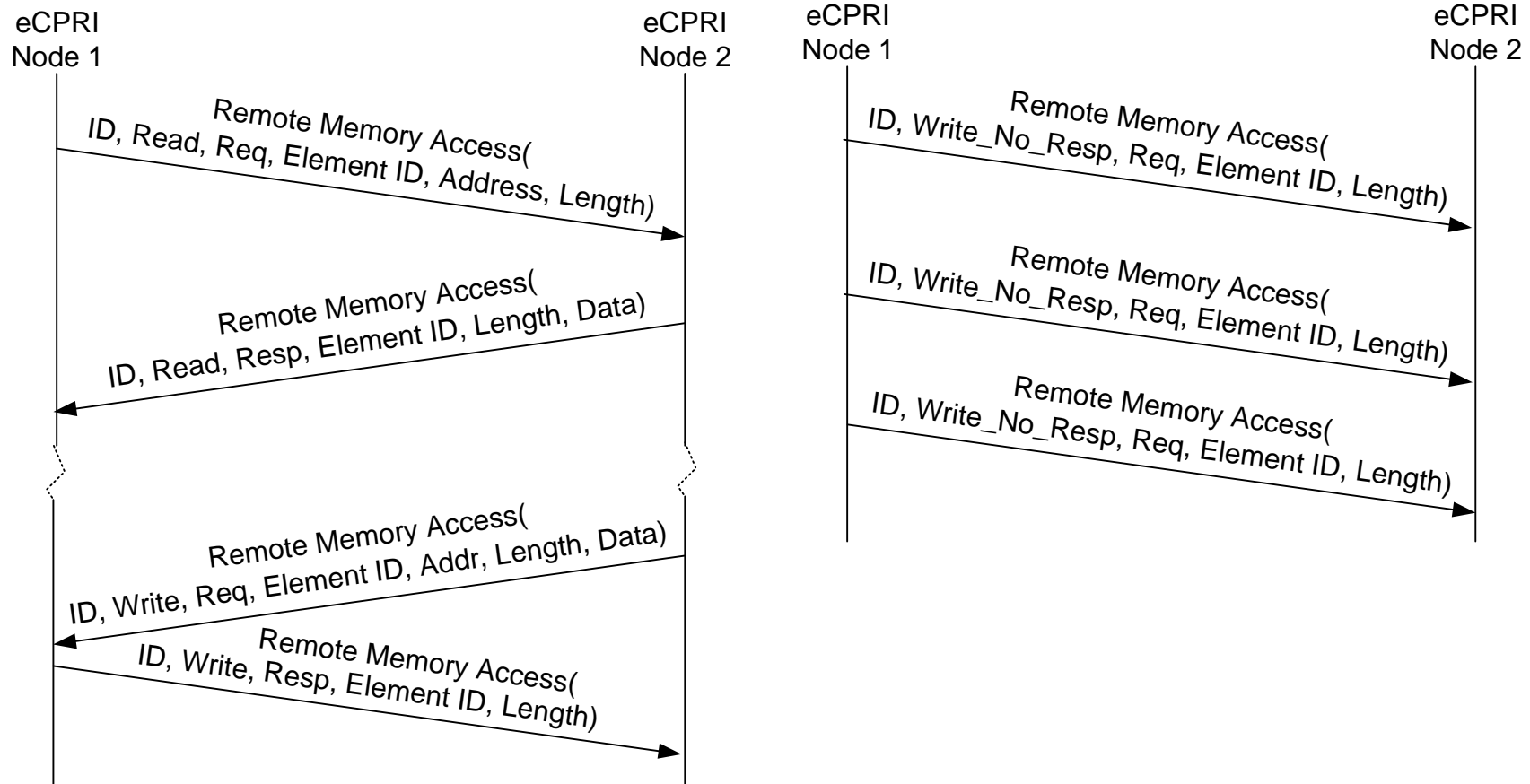
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eCPRI User Plane messages
Message Type #4: Remote Memory Access

Byte

0	Remote Memory Access ID
1	Read/Write · Req/Resp
2–3	Element ID
4–9	Address
10–11	Length = L
12	Data (first byte)
...	L bytes
11+L	Data (last byte)

0 MSB   7 LSB

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eCPRI User Plane messages
Message Type #4: Remote Memory Access sequence diagram example

eCPRI User Plane messages

Message Type #5: One-Way Delay Measurement

The message type 'One-Way delay measurement' is used for estimating the one-way delay between two eCPRI-ports in one direction. 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 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.

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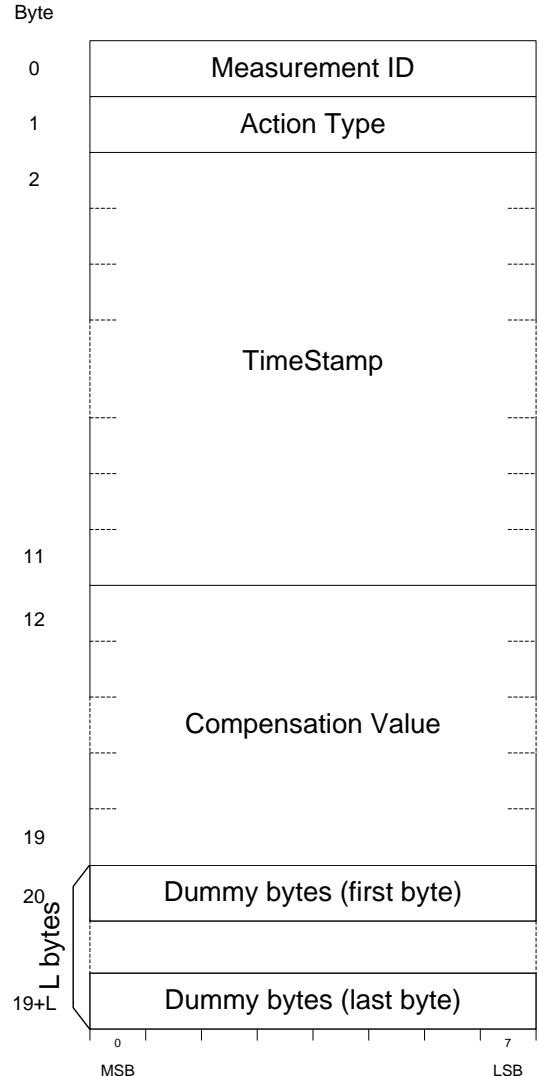
eCPRI User Plane messages
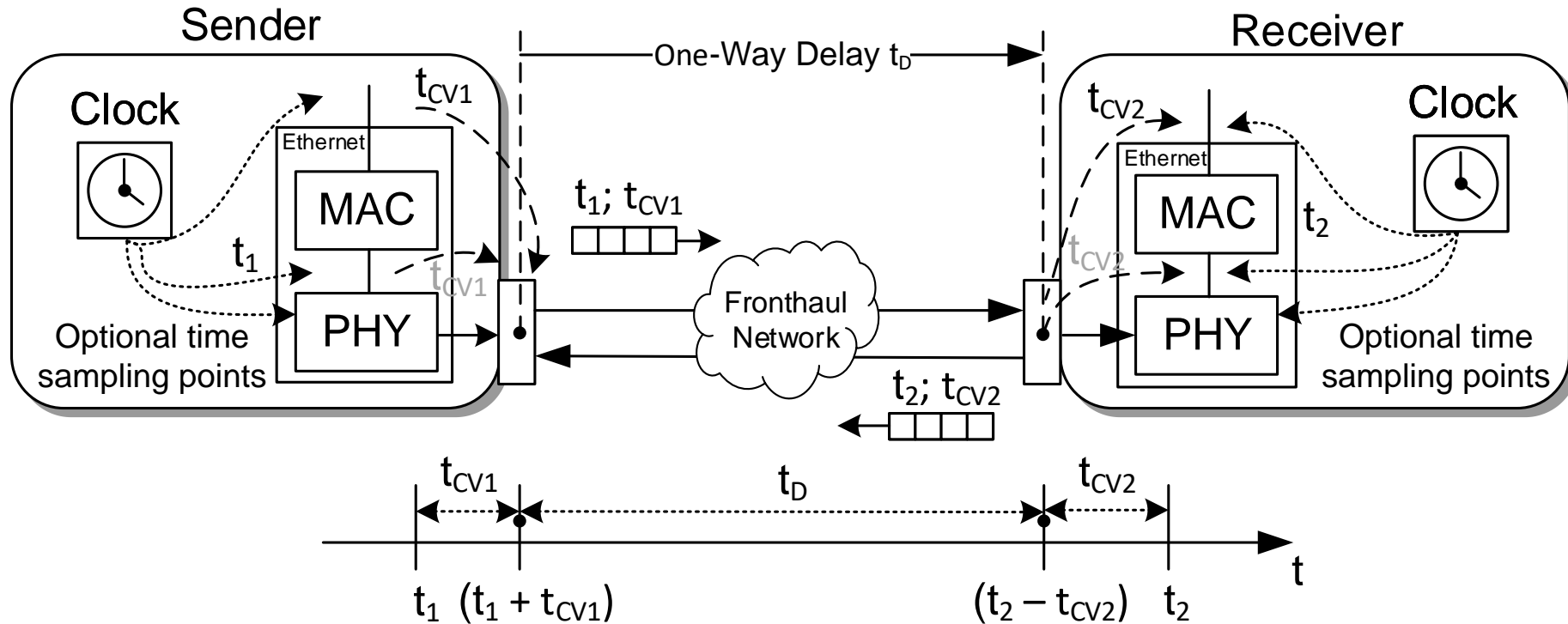
Two compensation values are used to set the measurements reference points as suited for a specific implementation. The exact locations of the reference points are vendor specific.

The One-Way delay value is calculated according to following equation:
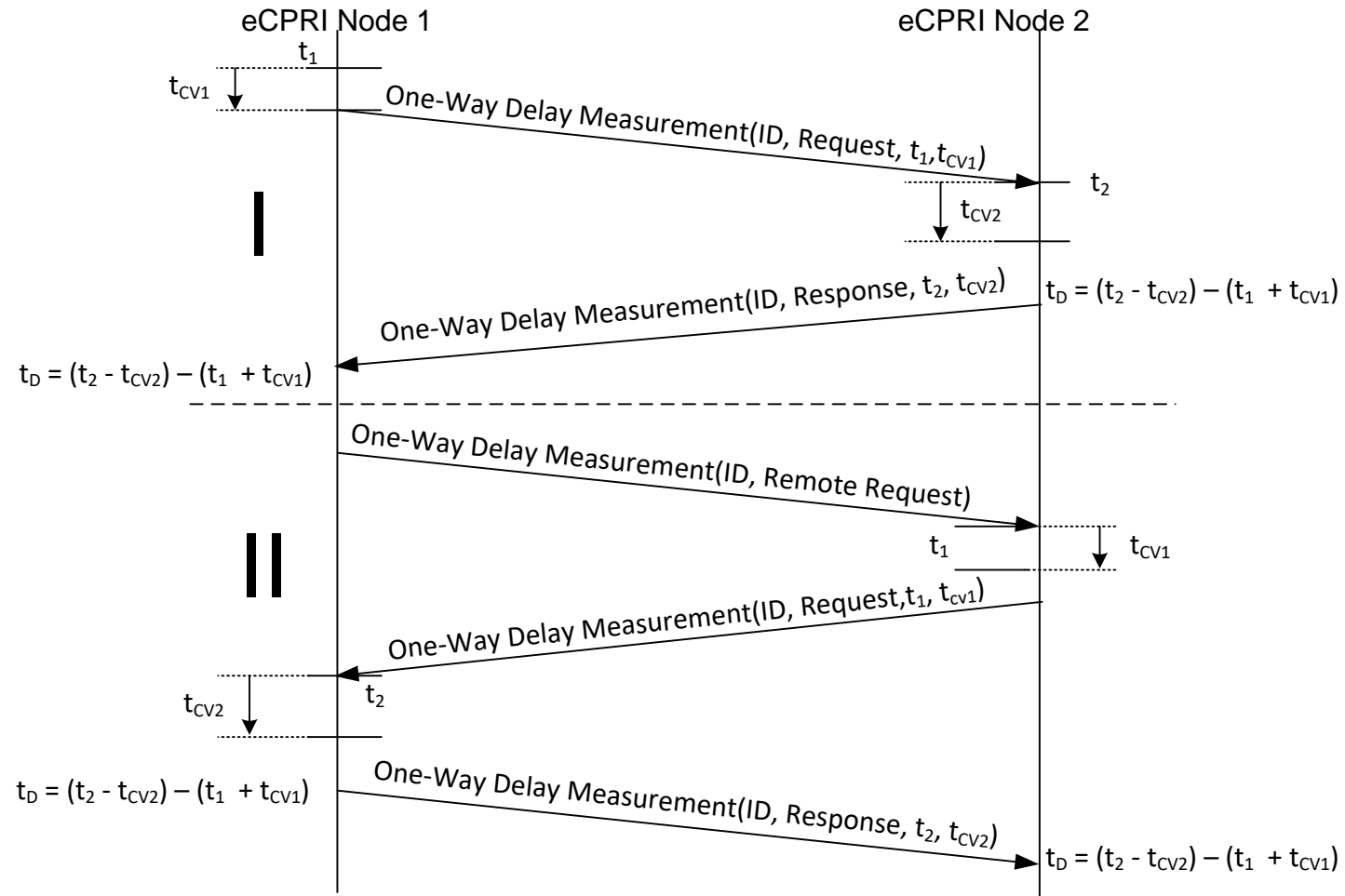
$$t_D = (t_2 - t_{CV2}) - (t_1 + t_{CV1})$$

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eCPRI User Plane messages

Message Type #5: One-Way Delay Measurement

Byte

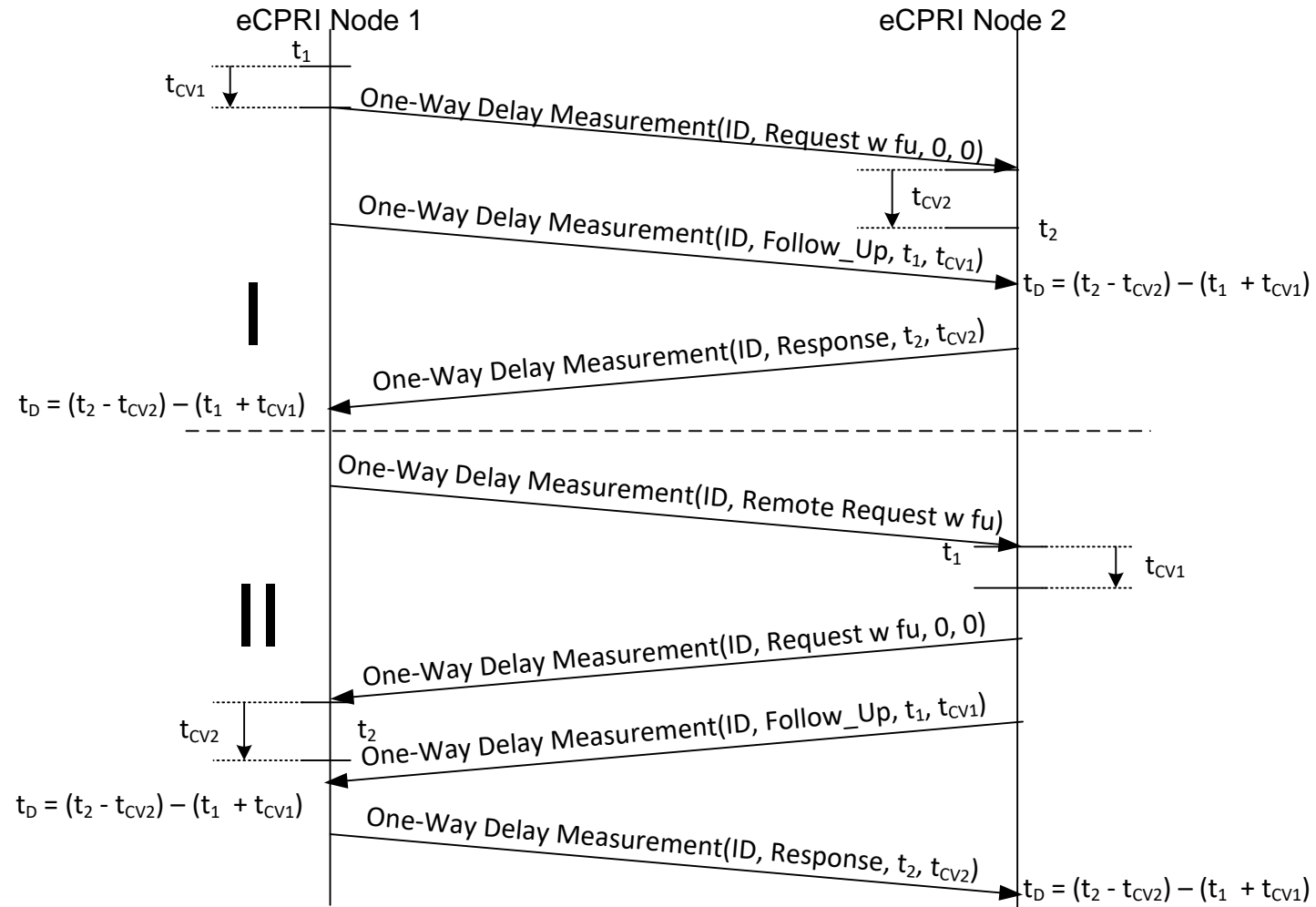|	Measurement ID
0	
1	Action Type
2	
	TimeStamp
11	
12	
	Compensation Value
19	
20	Dummy bytes (first byte)
19+L	Dummy bytes (last byte)

L bytes

0   MSB   7   LSB

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eCPRI User Plane messages
eCPRI Message Type #5: One-Way Delay Measurement sequence diagram example

eCPRI Node 1   eCPRI Node 2

t_1

t_{CV1}

One-Way Delay Measurement(ID, Request, t_1, t_{CV1})

t_2

t_{CV2}

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

One-Way Delay Measurement(ID, Response, t_2, t_{CV2})

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

One-Way Delay Measurement(ID, Remote Request)

t_1 t_{CV1}

One-Way Delay Measurement(ID, Request, t_1, t_{CV1})

t_{CV2} t_2

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

One-Way Delay Measurement(ID, Response, t_2, t_{CV2})

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

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eCPRI User Plane messages
eCPRI Message Type #5: One-Way Delay Measurement sequence diagram example

eCPRI Node 1

eCPRI Node 2

t_1

t_{CV1}

One-Way Delay Measurement(ID, Request w fu, 0, 0)

t_{CV2}

One-Way Delay Measurement(ID, Follow_Up, t_1, t_{CV1})

t_2

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

I

One-Way Delay Measurement(ID, Response, t_2, t_{CV2})

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

One-Way Delay Measurement(ID, Remote Request w fu)

t_1

t_{CV1}

II

One-Way Delay Measurement(ID, Request w fu, 0, 0)

One-Way Delay Measurement(ID, Follow_Up, t_1, t_{CV1})

t_{CV2}

t_2

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

One-Way Delay Measurement(ID, Response, t_2, t_{CV2})

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

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eCPRI User Plane messages

Message Type #6: Remote Reset

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.

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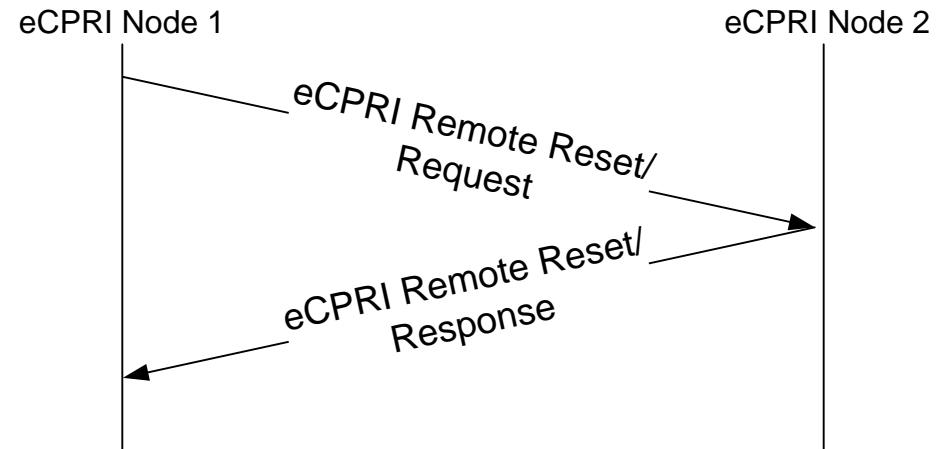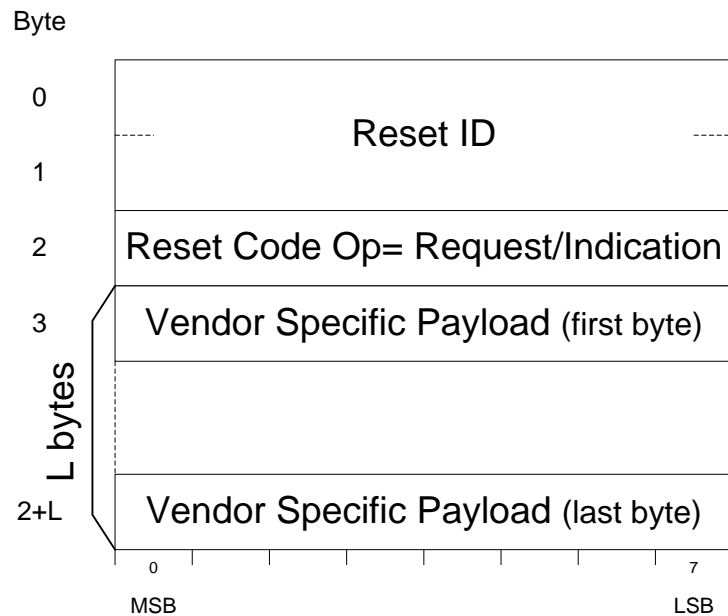
eCPRI User Plane messages

eCPRI Message types for Event Indication: #7

Message Type #7: Event Indication

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.

One Event Indication can either contain one or more faults, or one or more notifications.

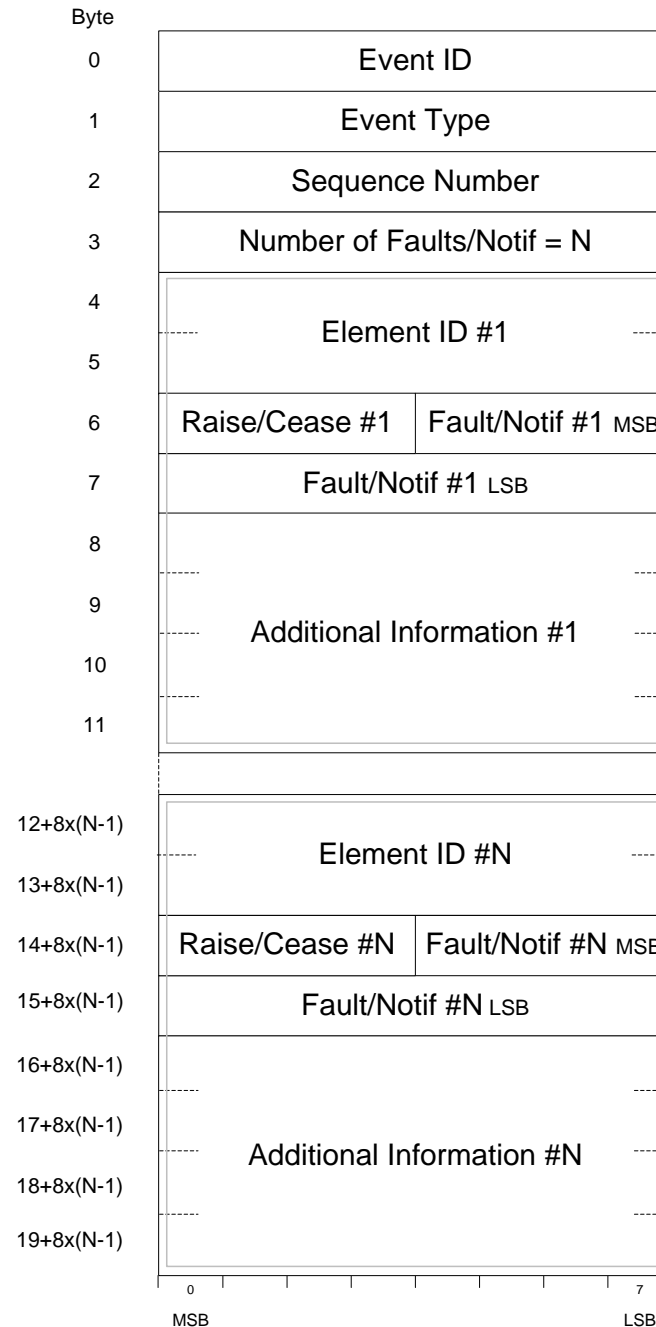The Event/Fault Indication message could be sent from an eCPRI node at any time.

An eCPRI node is modelled as consisting of N Elements, a fault or notification is connected to 1 Element. The detailed mapping of a specific implementation of HW and SW to Elements and their associated faults/notification is vendor specific.

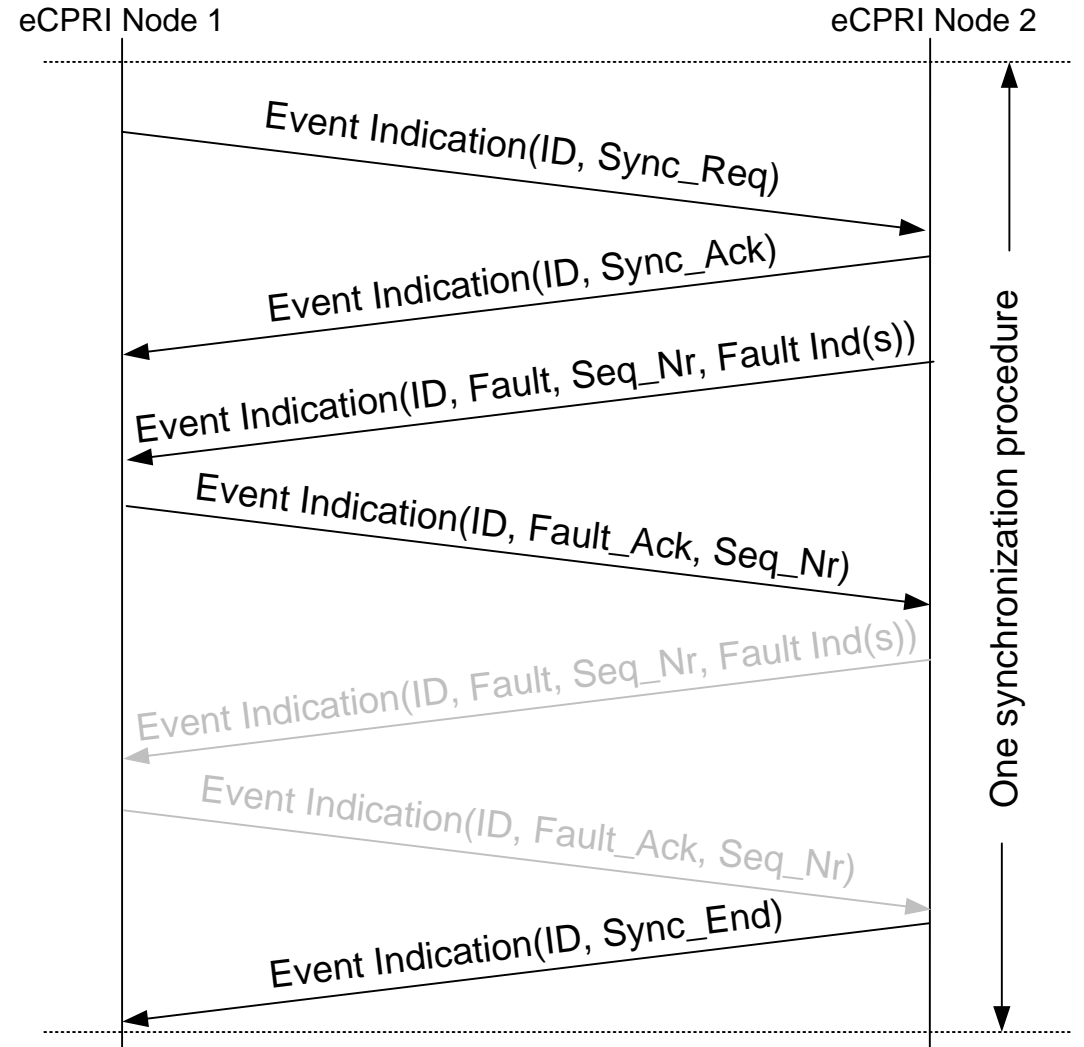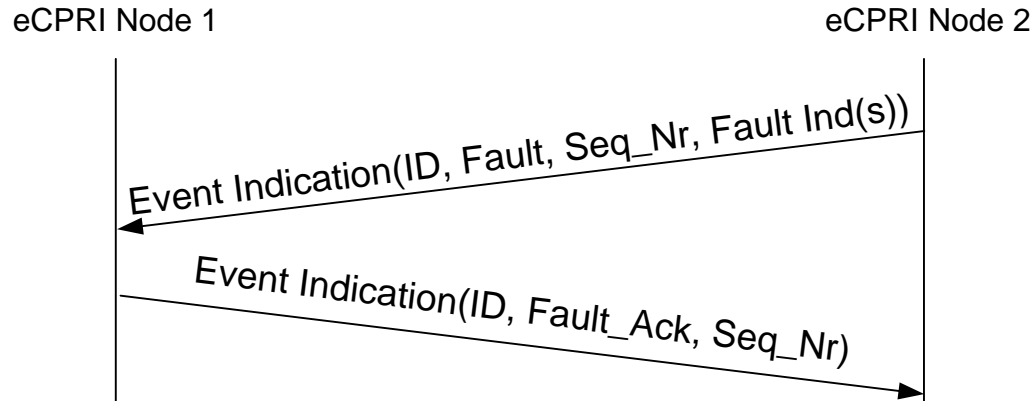For consistency check a synchronization request procedure is defined.

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eCPRI User Plane messages
Message Type #7: Event Indication

Byte	
0	Event ID
1	Event Type
2	Sequence Number
3	Number of Faults/Notif = N
4	Element ID #1
5	
6	Raise/Cease #1 | Fault/Notif #1 MSB
7	Fault/Notif #1 LSB
8	Additional Information #1
9	
10	
11	
12+8x(N-1)	Element ID #N
13+8x(N-1)	
14+8x(N-1)	Raise/Cease #N | Fault/Notif #N MSB
15+8x(N-1)	Fault/Notif #N LSB
16+8x(N-1)	Additional Information #N
17+8x(N-1)	
18+8x(N-1)	
19+8x(N-1)	

0 MSB   7 LSB

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eCPRI User Plane messages
Message Type #7: Event Indication sequence diagram example

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eCPRI C&M
Control and Management Service Access point

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 flow 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 is interactive traffic needed to keep control of the eCPRI node.

The eCPRI specification highlights some considerations regarding relative priorities of the different flows.

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eCPRI Synchronization

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 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.

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eCPRI Timing

UL user data transmission timing relations

Accurate delays enable correct setup of eRE transmission and eREC reception windows to:
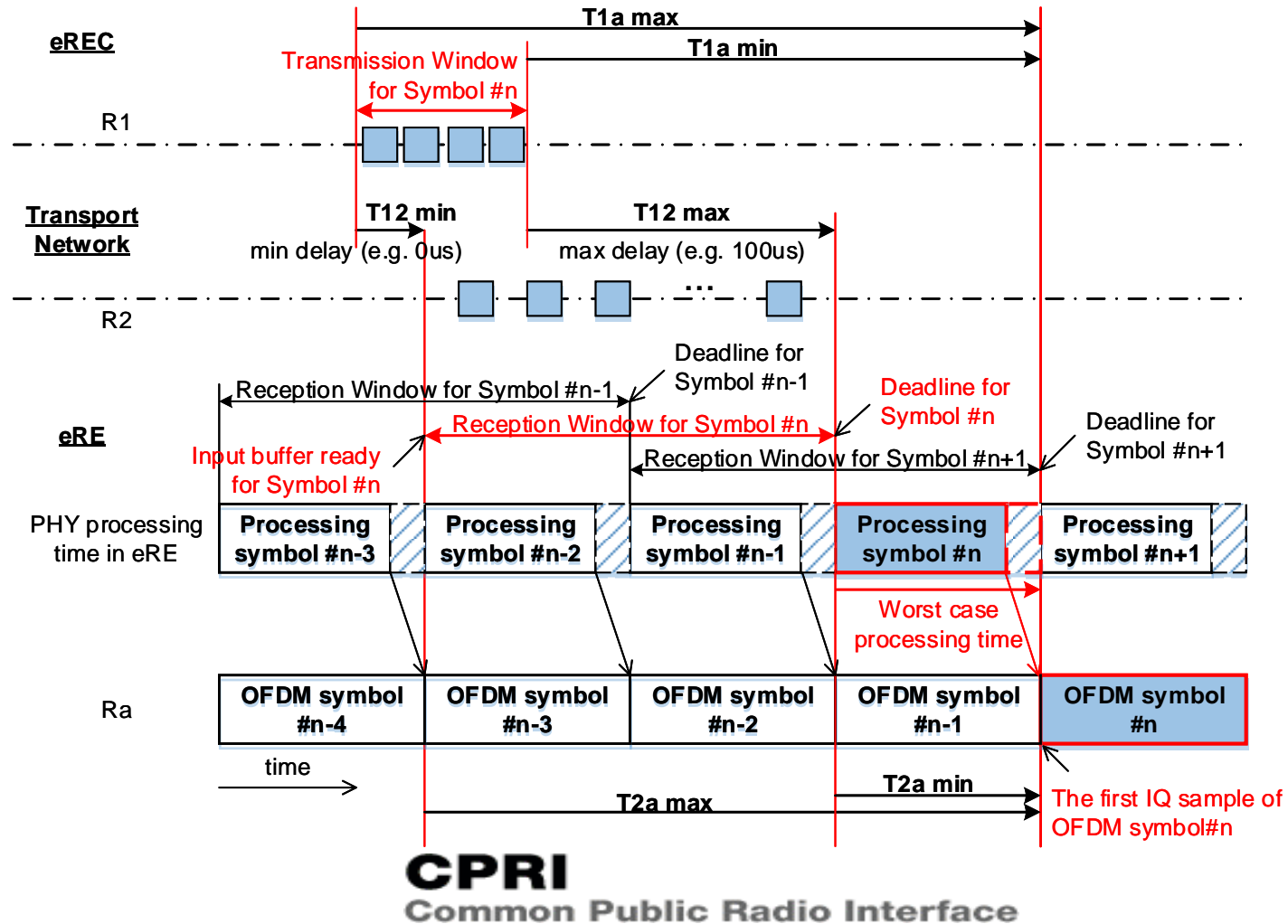
- Avoid overflow/underflow of buffer memories

- decrease the overall delay, dimension size of buffer memories, etc.
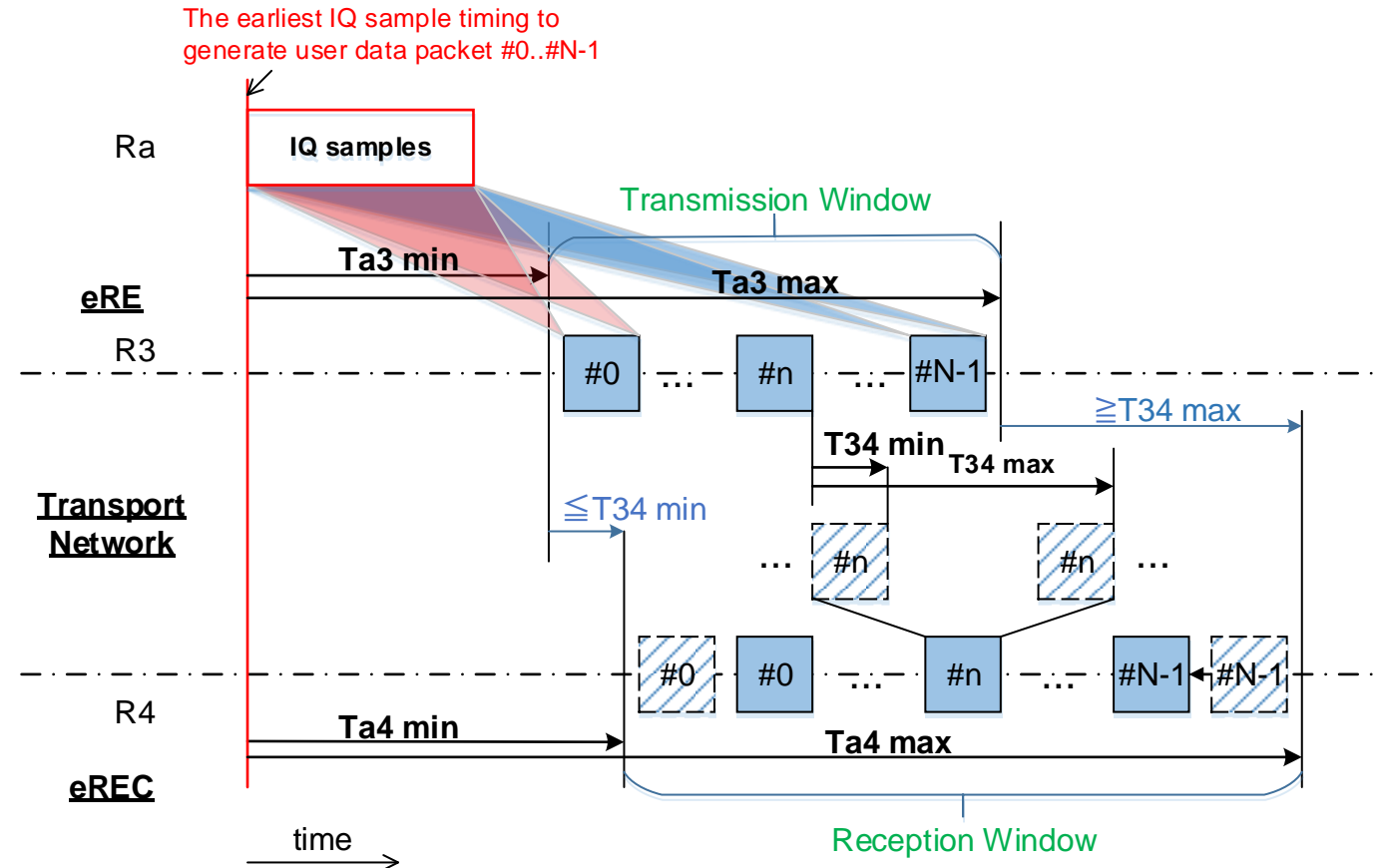
eCPRI Timing
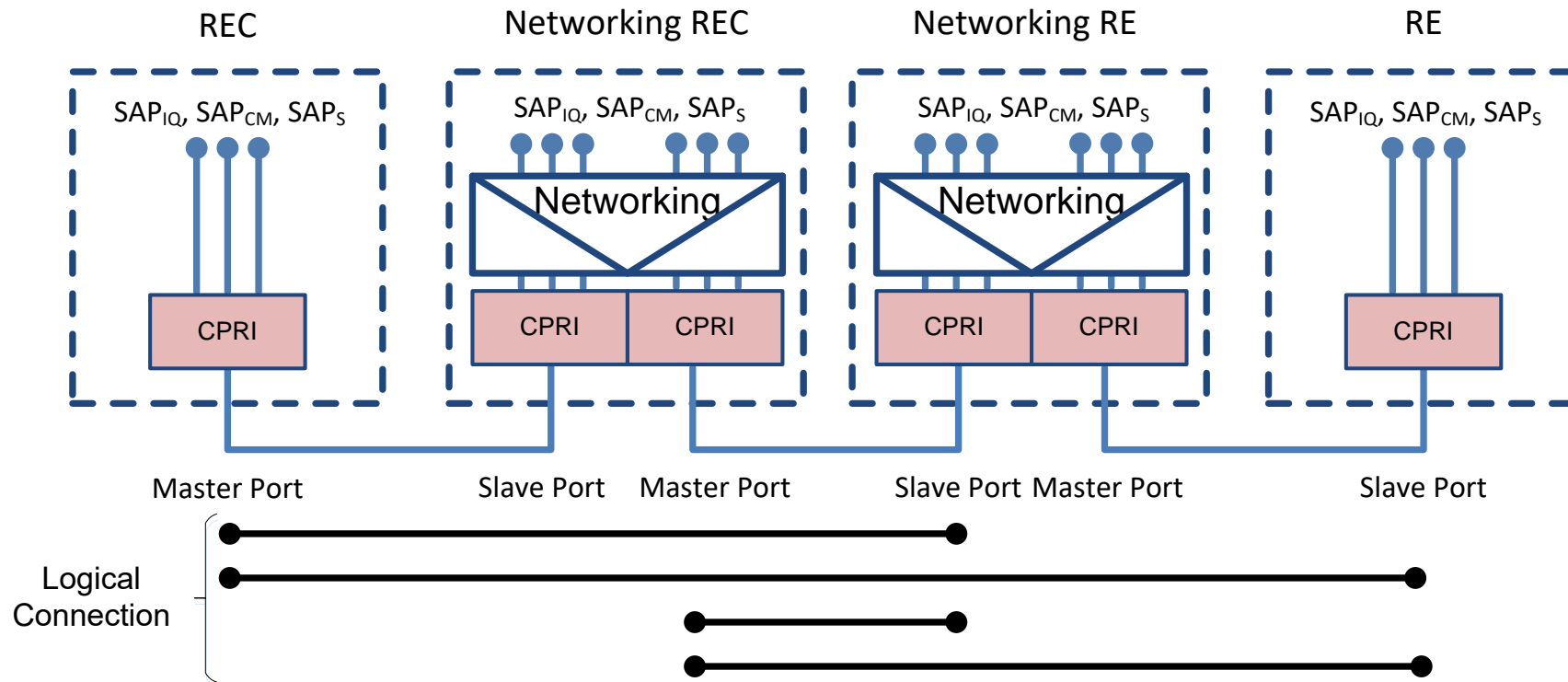DL user data transmission timing relations

Accurate delays enable correct setup of eREC transmission and eRE reception windows.
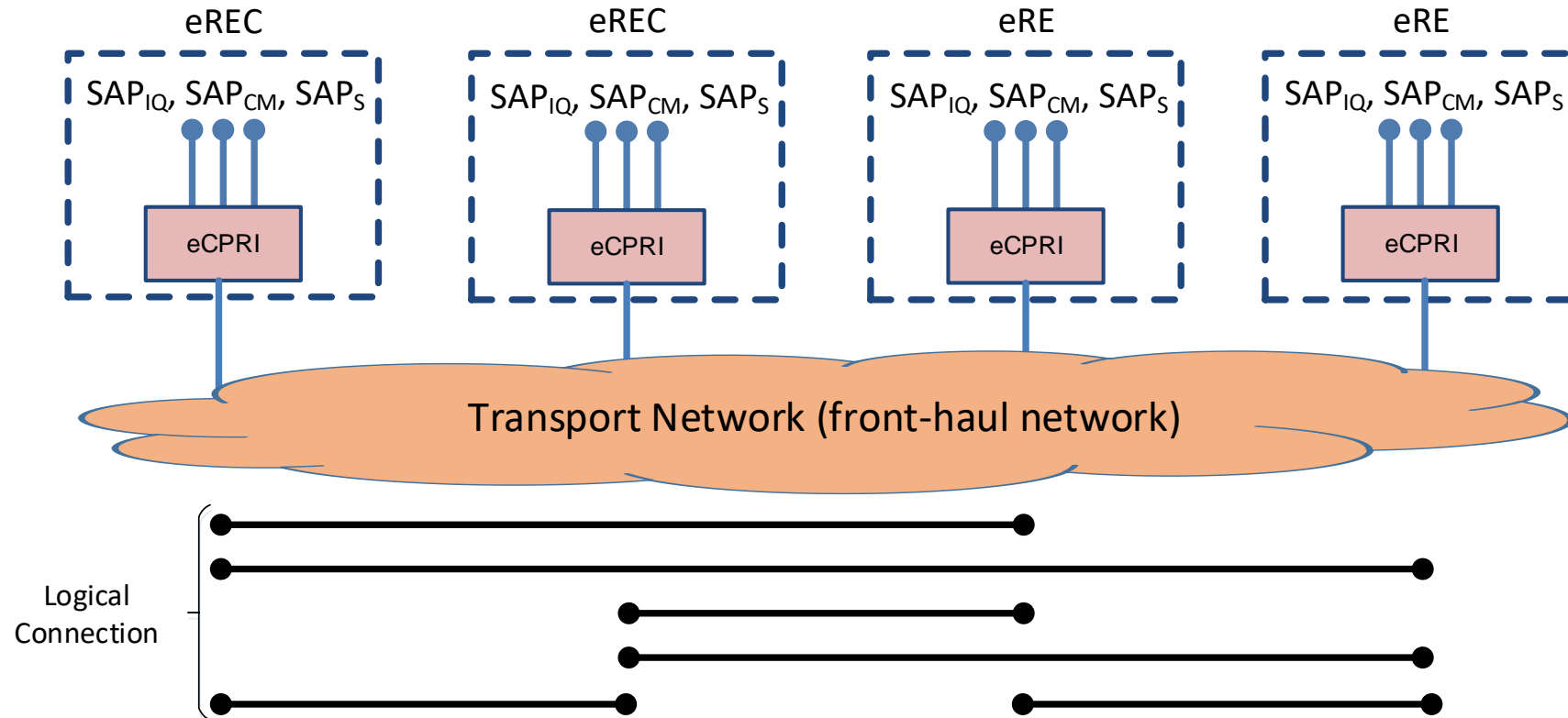
eCPRI Networking (1/2)

CPRI networking reminder

CPRI networking example

eCPRI Networking (2/2)

eCPRI networking principle

eCPRI networking example

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eCPRI Security
eCPRI Network Security

eCPRI Network Security Protocol suites include IPsec in IP traffic and MACsec in Ethernet traffic

The details of IPsec and MACsec usage is vendor specific.

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

    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.

    C&M Plane

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

    Synchronization Plane

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

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eCPRI Transport Network requirements

For category A+/A/B, the requirements are expressed as relative requirements between two UNIs, instead of relative to a common clock reference.

For category C, the requirement is expressed as an absolute requirement at the UNI as in ITU-T G.8271.1.

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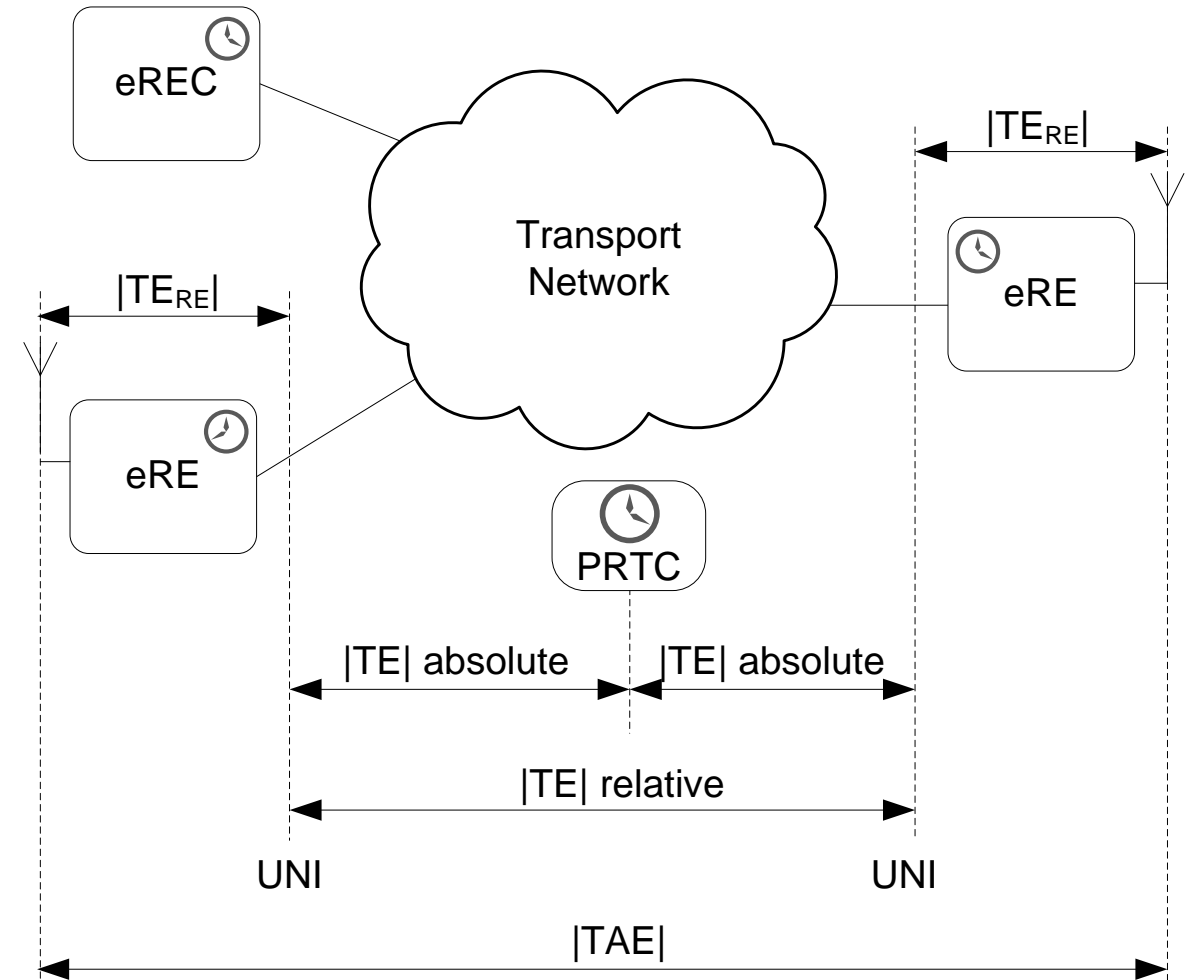
eCPRI Transport Network requirements

Timing accuracy requirements (2/3)

Category (note 1)	Time error requirements at UNI, |TE|			3GPP Time alignment error (TAE) requirements at antenna ports
	Case 1 (note 2)		Case 2 (note 3)	
	Case 1.1 (note 4)	Case 1.2 (note 5)		
A+	N.A.	N.A.	20 ns (relative)	65 ns (note 6)
A	N.A.	60 ns (relative) (note 7)	70 ns (relative)	130 ns (note 6)
B	100ns (relative) (note 7)	190 ns (relative) (note 7)	200 ns (relative)	260 ns (note 6)
C (note 8)	1100 ns (absolute) (note 9)		1100 ns (absolute) (note 9)	3 us (note 10)

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Note 1) In most cases, the absolute time error requirements (Category C) are necessary in addition to the relative time error requirements (Category A+, A and B)

Note 2) Interface conditions for Case 1

•T-TSC is integrated in eRE, i.e. PTP termination is in eREs

•Refer to "deployment case 1" in Figure 7-1 of [ITU-T G.8271.1],

•Note 3) Interface conditions for Case 2

•T-TSC is not integrated in eREs, i.e. PTP termination is in T-TSC at the edge of transport network

•The phase/time reference is delivered from the T-TSC to the co-located eREs via a phase/time synchronization distribution interface (e.g. 1PPS and ToD)

•Refer to "deployment case 2" in Figure 7-1 of [ITU-T G.8271.1]

Note 4) In this case the integrated T-TSC requirements are the same as standalone T-TSC Class B as defined in [ITU-T G.8273.2].

Note 5) In this case the enhanced integrated T-TSC requirements assume a total maximum absolute time error of 15 ns.

Note 6) TAE, section 6.5.3.1 of [3GPP TS36.104] and section 6.5.3/9.6.3 of [3GPP TS38.104]

Note 7) Network access link delay asymmetry error is included

Note 8) The same requirements as "class 4" listed in Table 1 of [ITU-T G.8271]

Note 9) The same value as the network limits at the reference point C described in chapter 7.3 of [ITU-T G.8271.1]

Note 10) Cell phase synchronization requirement for wide area BS (TDD), Table 7.4.2-1, section 7.4.2 of [3GPP TS36.133] and section 7.4.2 of [3GPP TS38.133], |TE| at the antenna ports shall be less than TAE/2

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CoS Name	Example use	Maximum One-way Frame Delay Performance	Maximum One-way Frame Loss Ratio Performance
High	User Plane (fast)	See following table	10^{-7}
Medium	User Plane (slow), C&M Plane (fast)	1 ms	10^{-7}
Low	C&M Plane	100 ms	10^{-6}

User Plane:

- User Plane (fast): Any User Plane data with stringent latency requirements.

- User Plane (slow): Any User Plane data with relaxed latency requirements.

C&M Plane:

- C&M Plane (fast): Interactive traffic that is needed to keep control of the eCPRI node

- C&M Plane : Other non-time-critical information exchanged between eCPRI entities

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eCPRI Transport Network requirements
Maximum One-way Frame Delay Performance for fast User Plane

To enable usage of Transport Networks with different characteristics (different number of switching hops, different length of fiber links, …), four different latency classes for CoS 'High' are defined in Table 1A.

The maximum one-way frame delay requirement value includes fiber propagation delay and switching delay (see section 2.3.1).

A Transport Network supplier needs either to comply with per data-flow requirements or to state which latency classes for data flows the Network supports for a given average bandwidth usage.

Latency Class	Maximum One-way Frame Delay Performance (see section 2.3.1)	Use case
High25	25µs	Ultra-low latency performance
High100	100µs	For full E-UTRA or NR performance
High200	200µs	For installations where the lengths of fiber links are in the 40 km range
High500	500µs	Large latency installations

For latency classes High25 and High100, a transport network delay budget larger than the one specified (thus a smaller delay budget for the eREC/eRE) may degrade the mobile network performance.

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