Common Public Radio Interface

eCPRI presentation

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CPRI
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Background 1/2

1. Operator view of CPRI features

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.

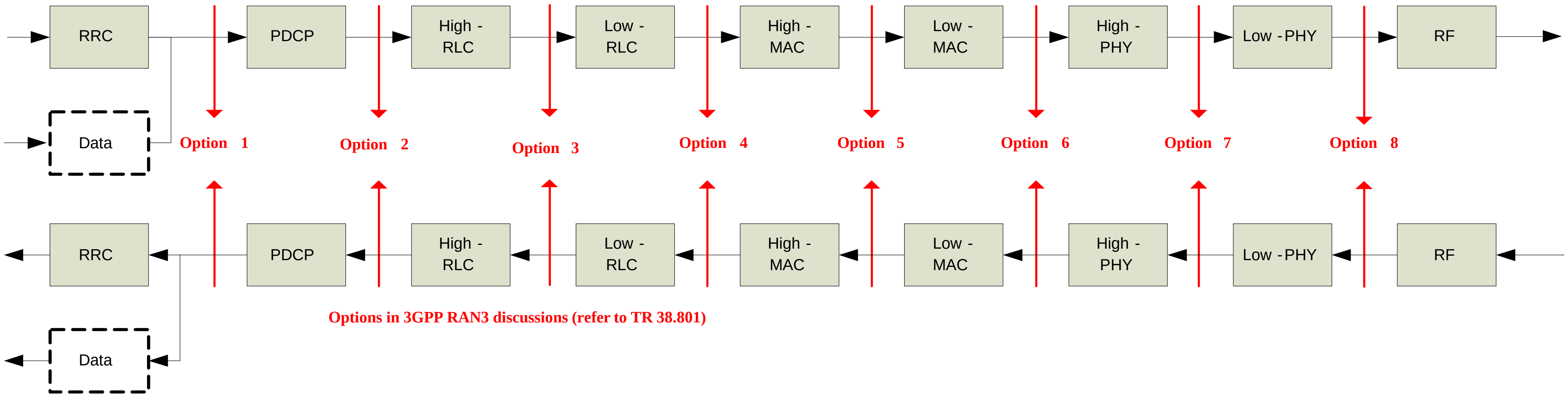
Also advanced networking and OAM features of mainstream packet transport standards were requested.

Background 2/2

2. High risk of Fragmentation for FH Standardization

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.



Options in 3GPP RAN3 discussions (refer to TR 38.801)

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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

CPRI reminder

What is CPRI?

- 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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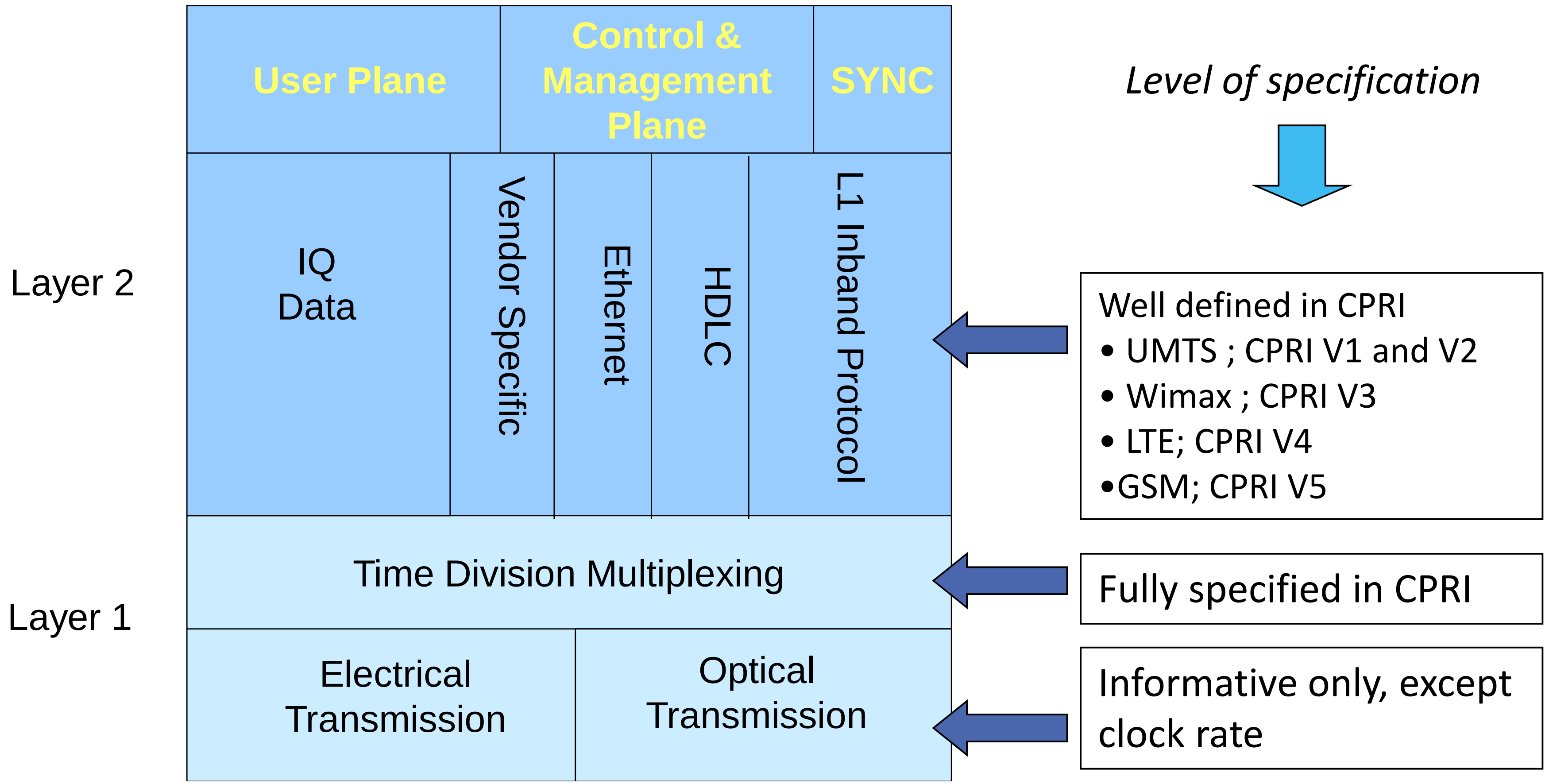
CPRI reminder

CPRI Protocol Stack



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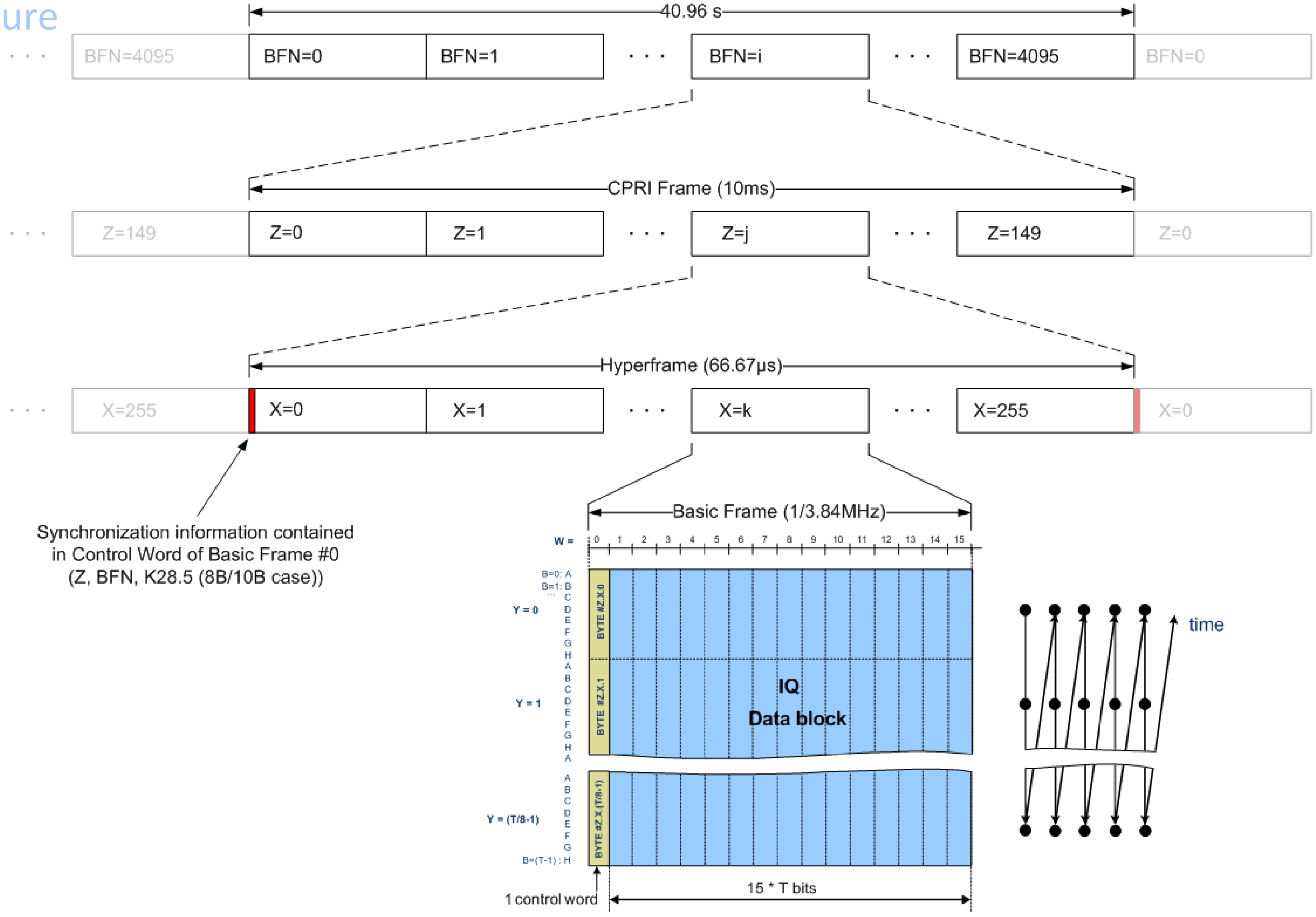
CPRI reminder

CPRI Frame Structure



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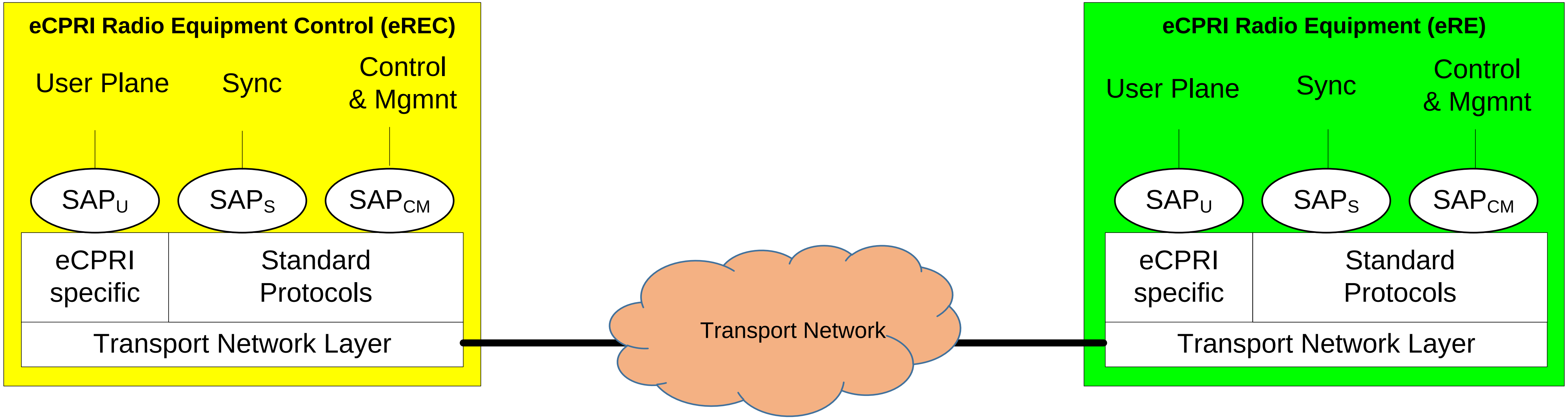
eCPRI introduction

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



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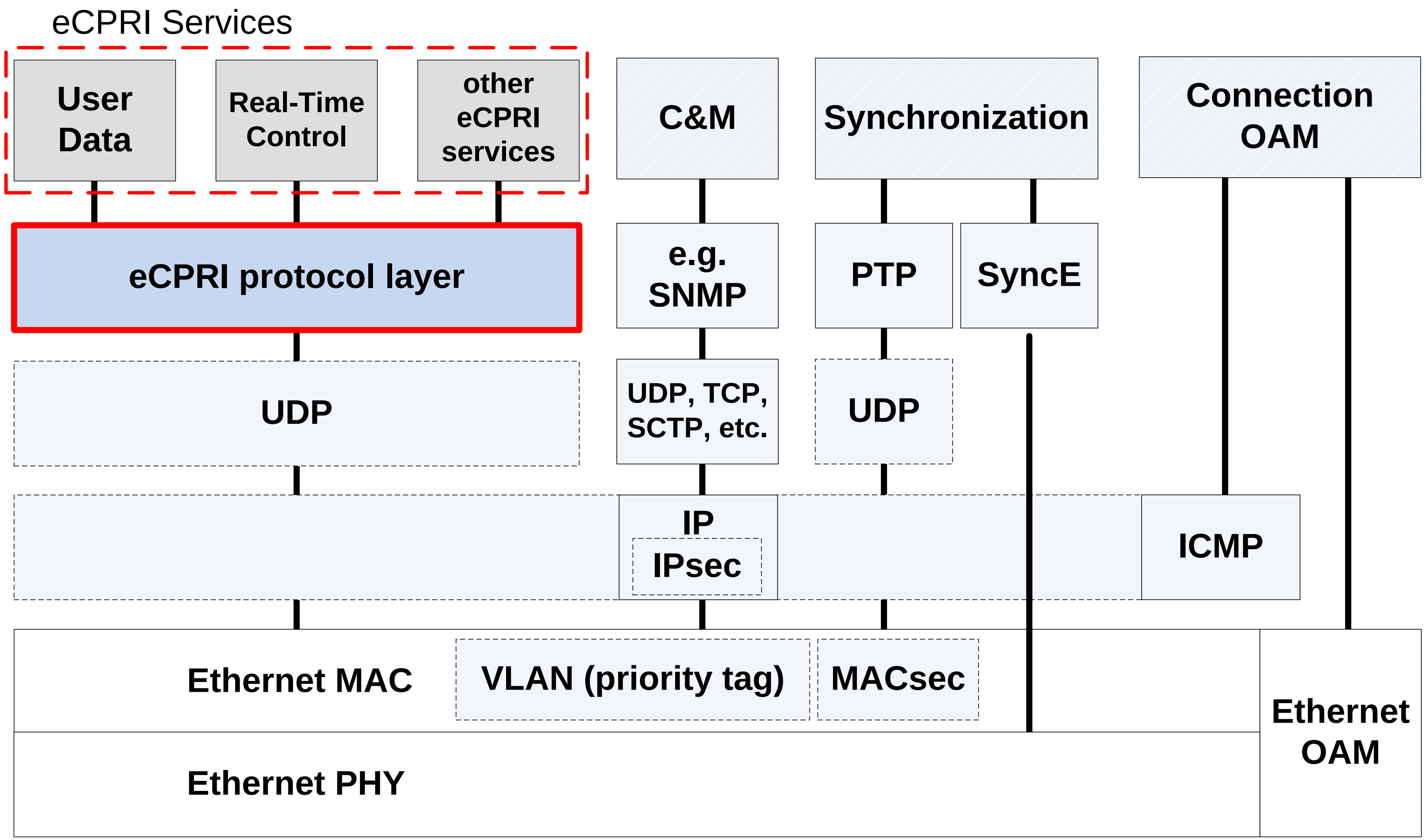
eCPRI introduction

eCPRI main characteristics

- 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 ($AEFE_{16}$)

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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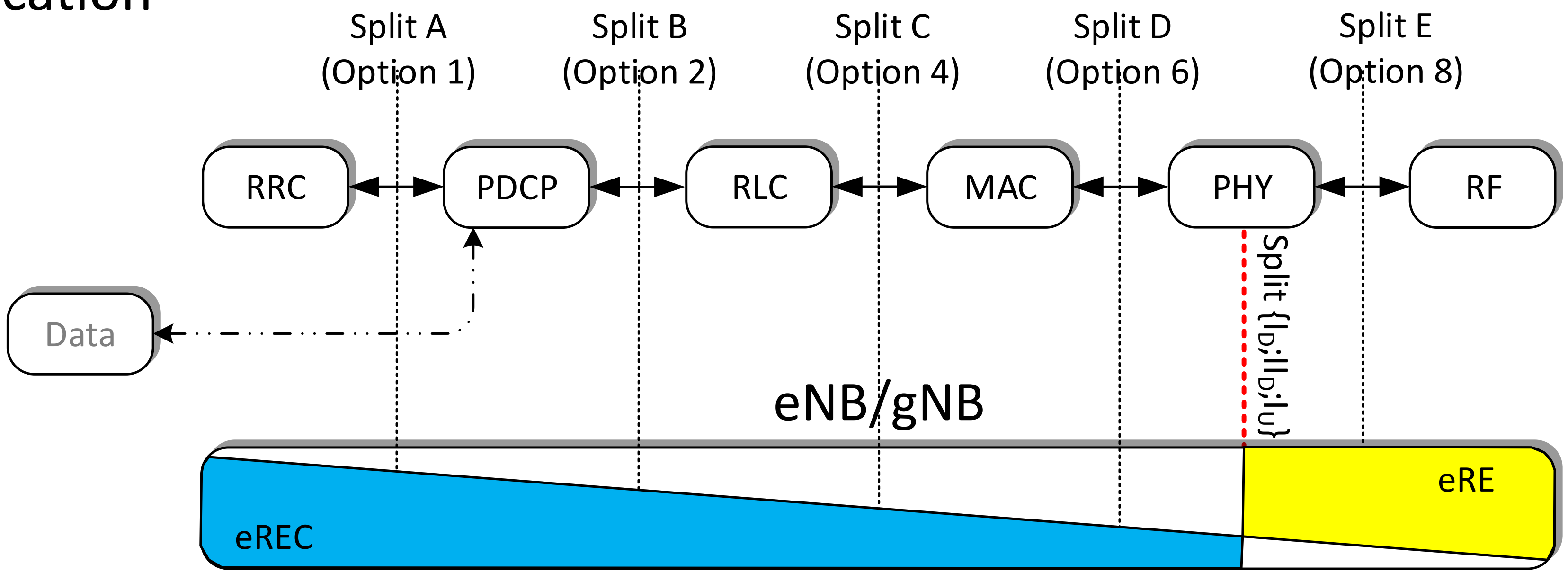
eCPRI introduction

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

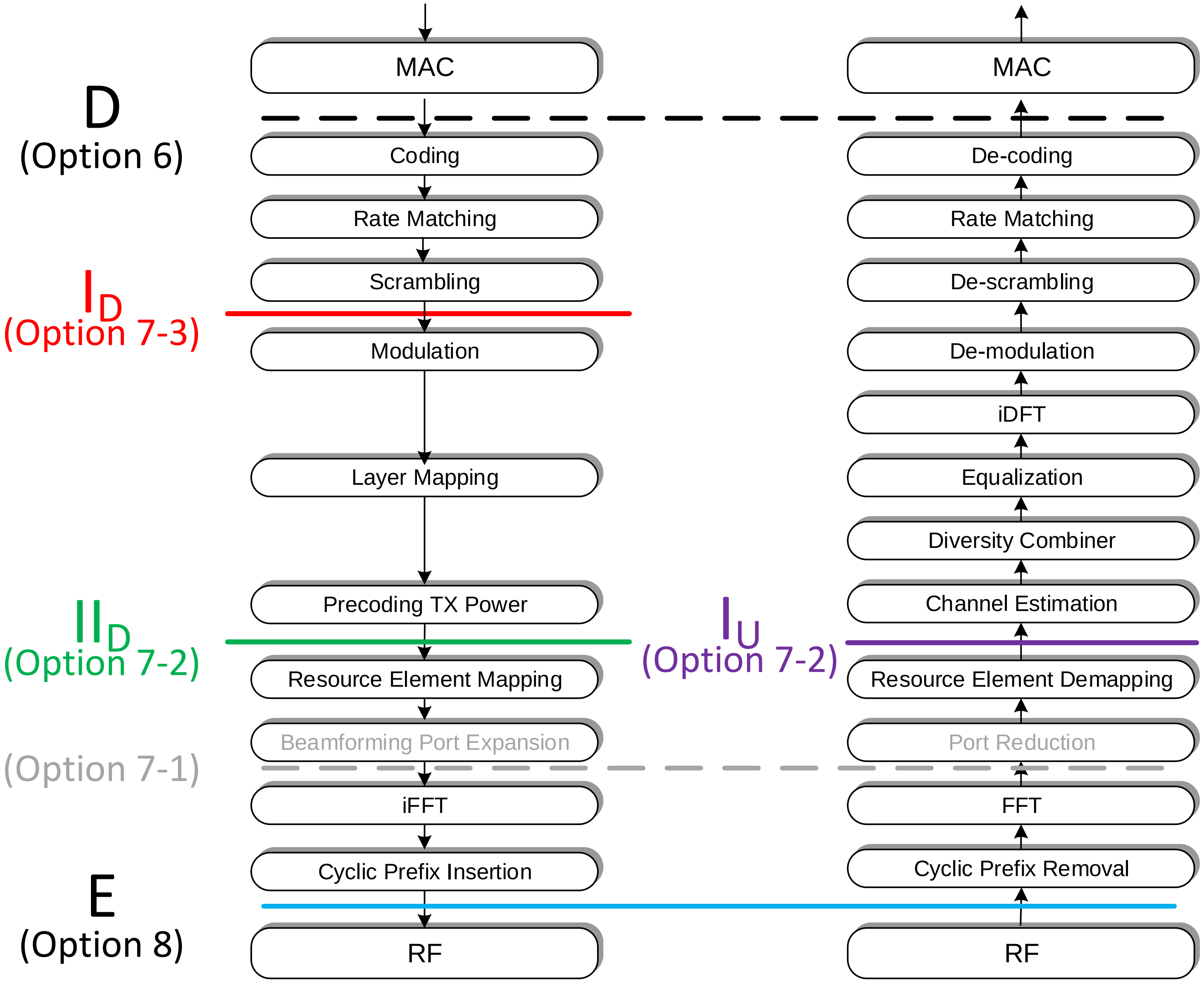


Note: Option 1, 2, 4, 6 and 8 refer to 3GPP split options

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



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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

eCPRI introduction

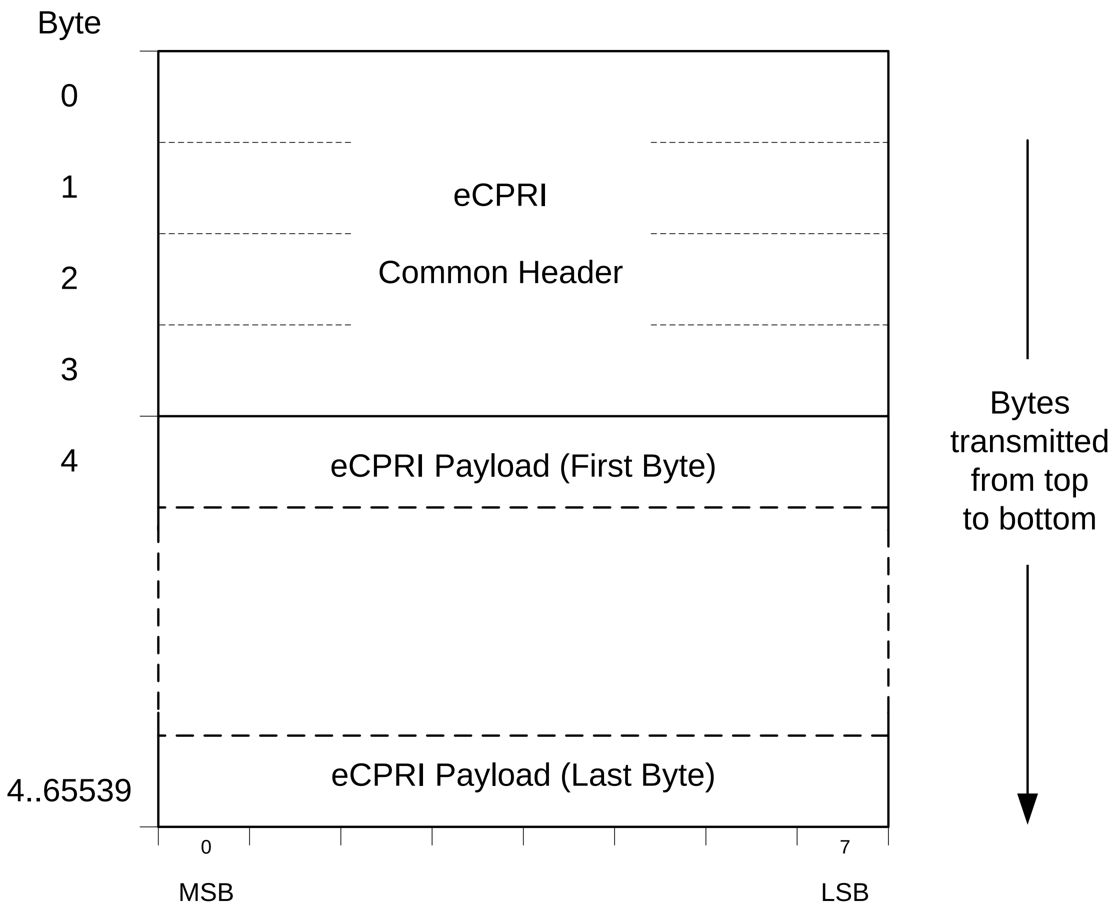
eCPRI typical bandwidth estimations

	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

eCPRI User Plane messages

eCPRI Messages Common Header format

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



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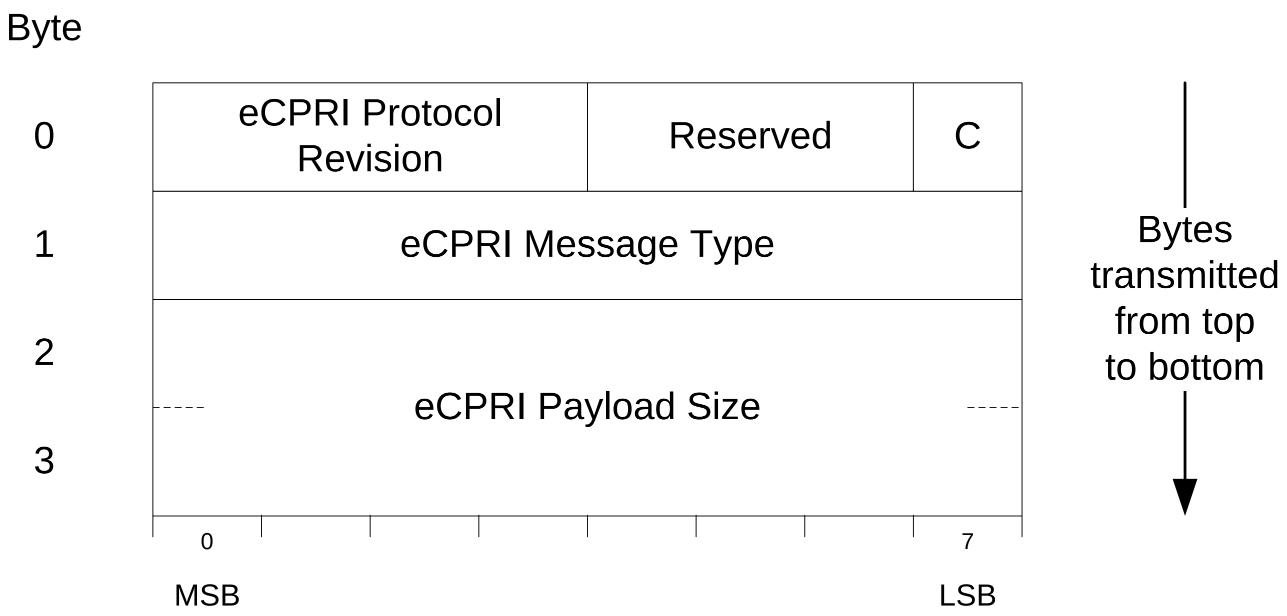
eCPRI User Plane messages

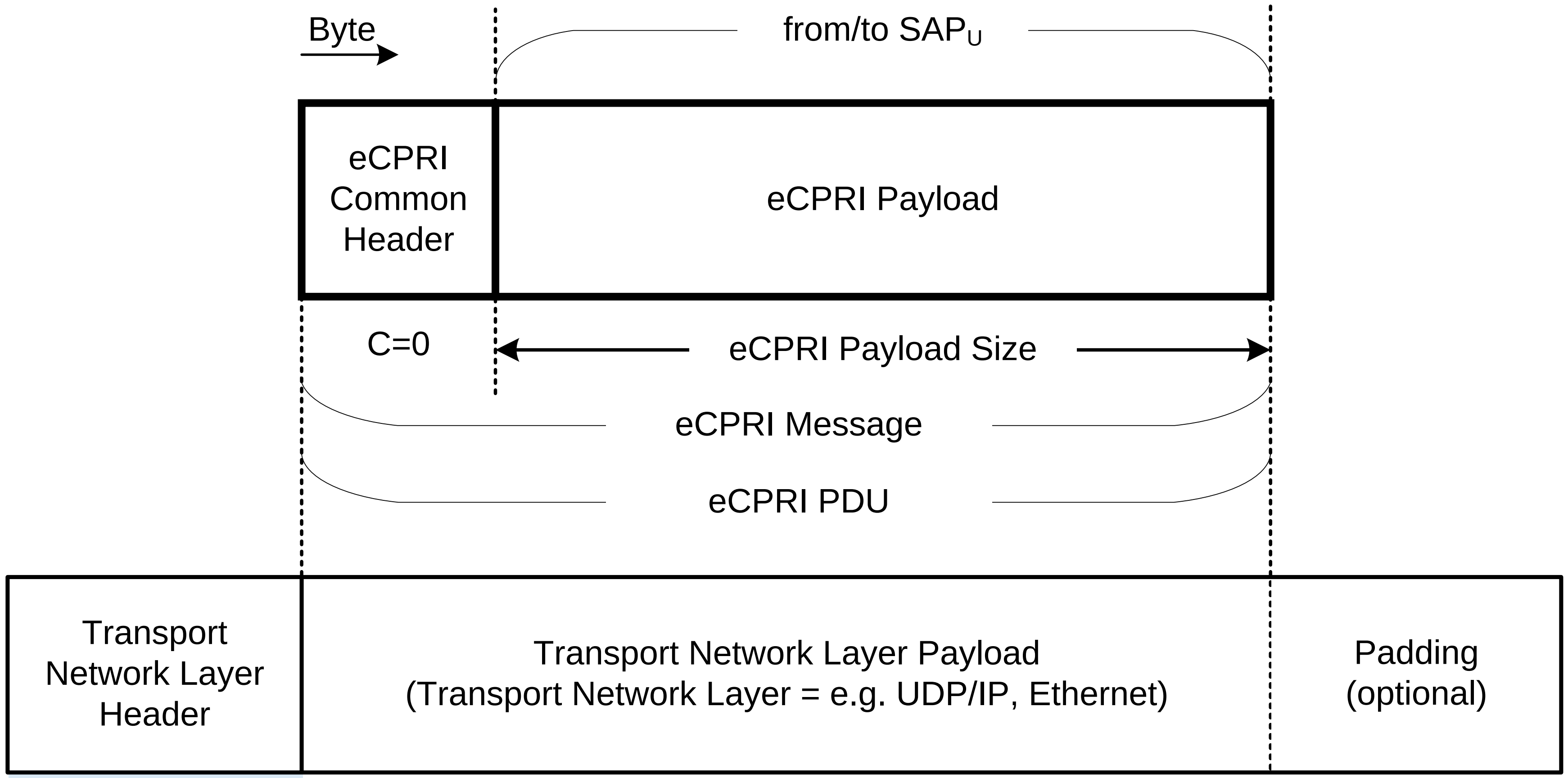
eCPRI Messages Common Header format



- "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

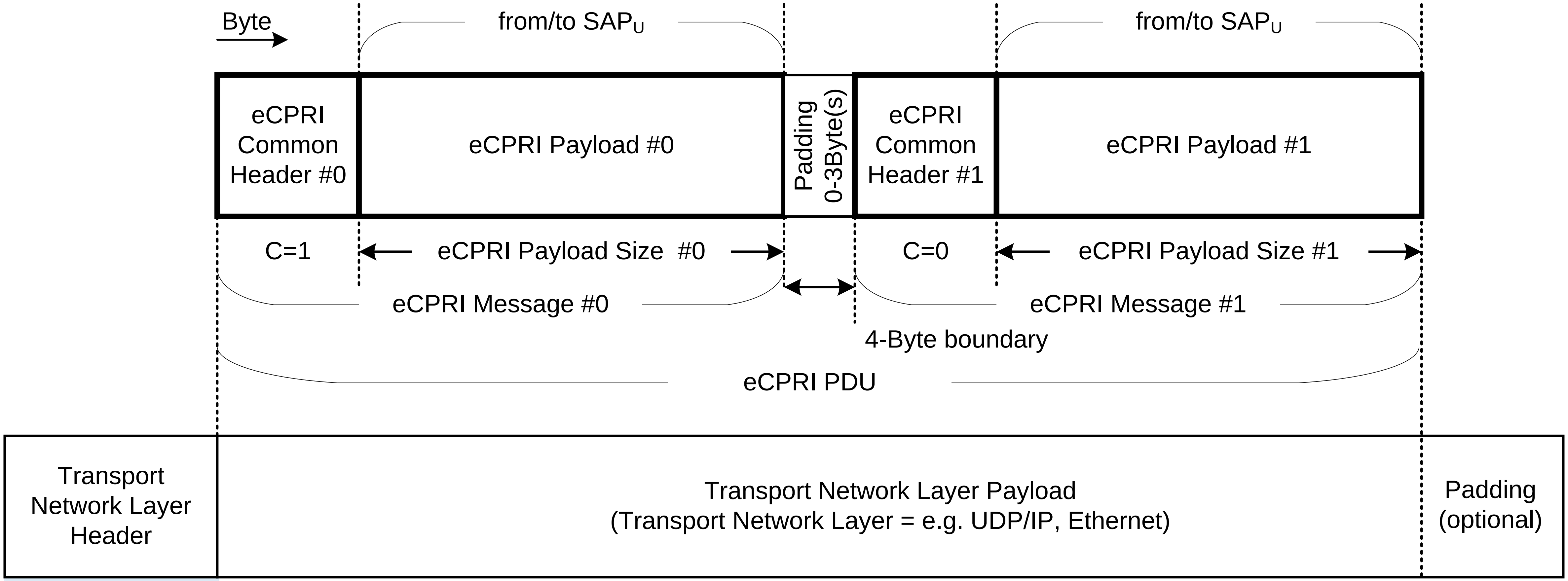
eCPRI User Plane messages

eCPRI Messages Common Header format: concatenation indicator



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

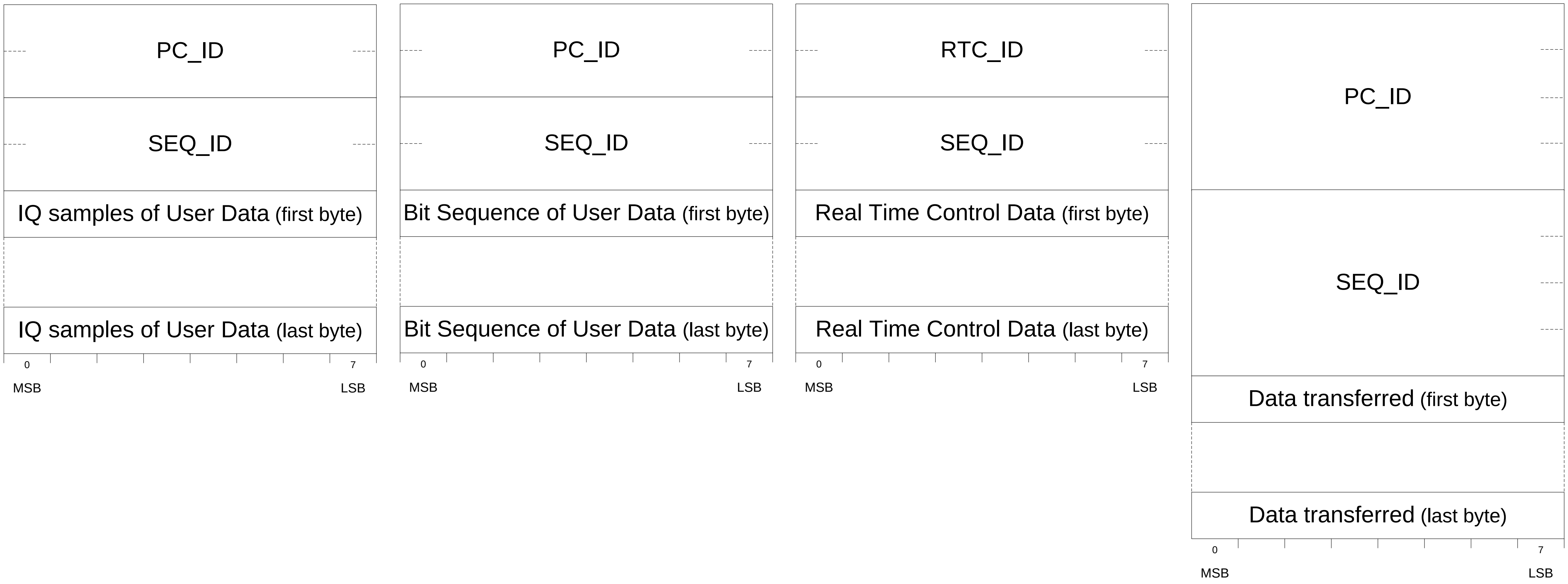
To transfer vendor specific real-time control messages between PHY processing elements split between eCPRI nodes (eREC and eRE). This message type addresses the need to exchange various types of control information associated with user data (in form of IQ samples, bit sequence, etc.) between eCPRI nodes 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.

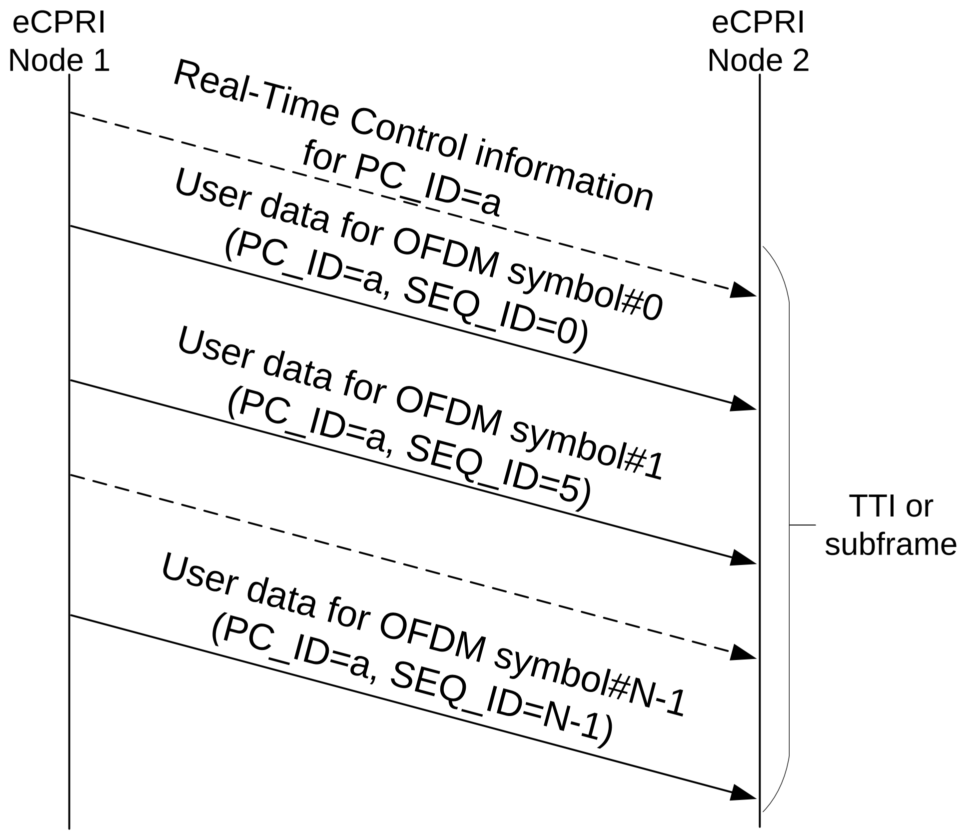
eCPRI User Plane messages

eCPRI User Plane message formats



eCPRI User Plane messages

Message Type #3: Generic Data Transfer sequence diagram example



eCPRI User Plane messages

eCPRI Message types for Remote Memory Access : #4

Message Type #4: Remote Memory Access

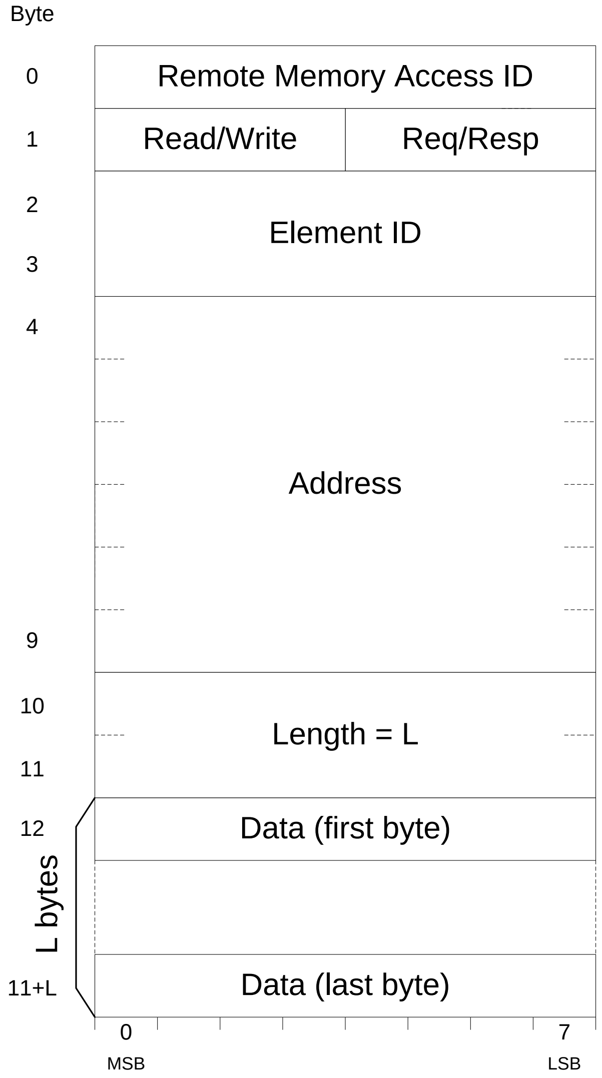
The message type 'Remote Memory Access' allows reading or writing from/to a specific memory address on the opposite eCPRI node. The service is symmetric i.e. any "side" of the interface can initiate the service.

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.

eCPRI User Plane messages

Message Type #4: Remote Memory Access



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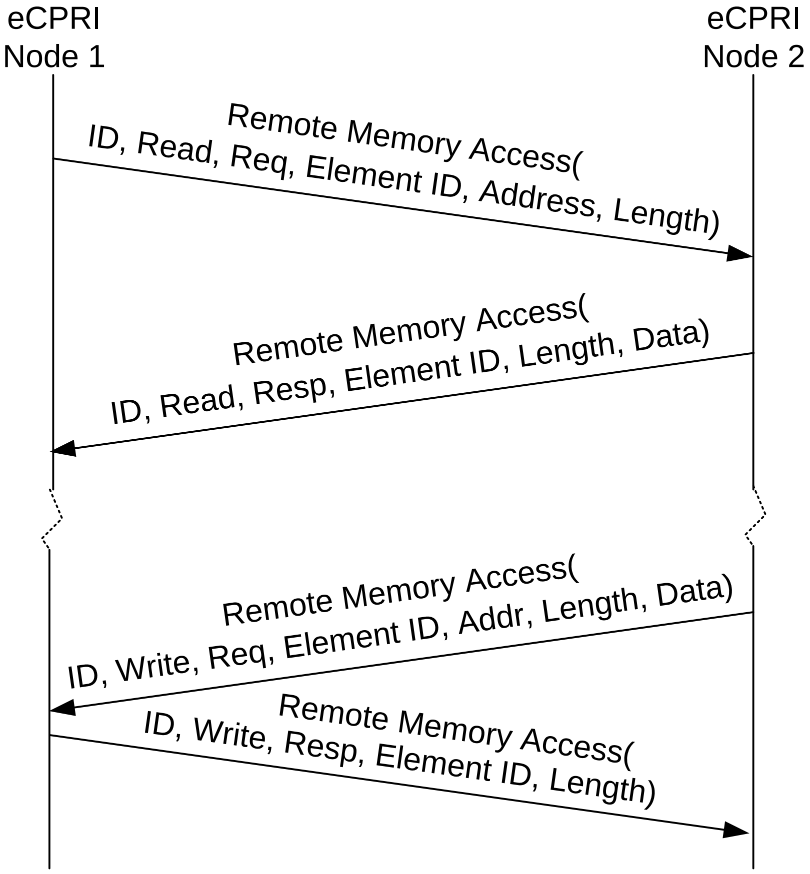
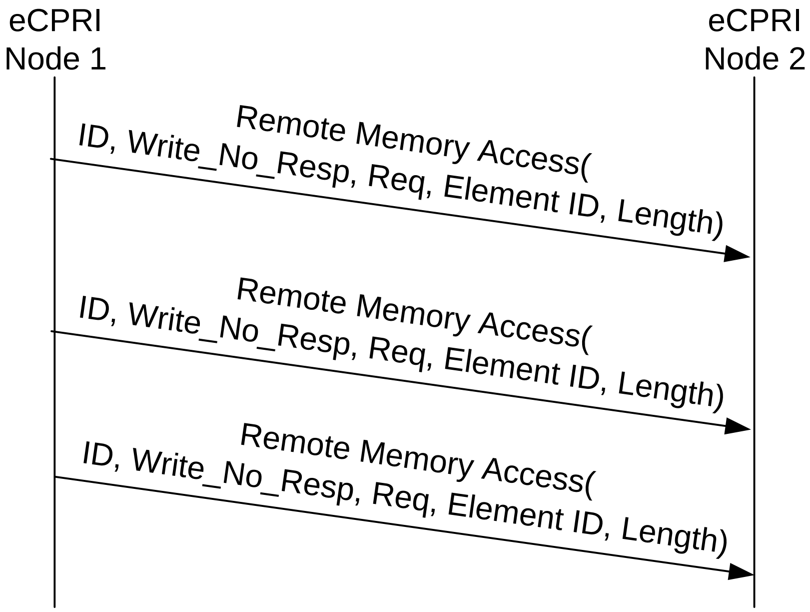
eCPRI User Plane messages

Message Type #4: Remote Memory Access sequence diagram example





eCPRI User Plane messages

eCPRI Message types for One-Way Delay Measurement: #5

Message Type #5: One-Way Delay Measurement

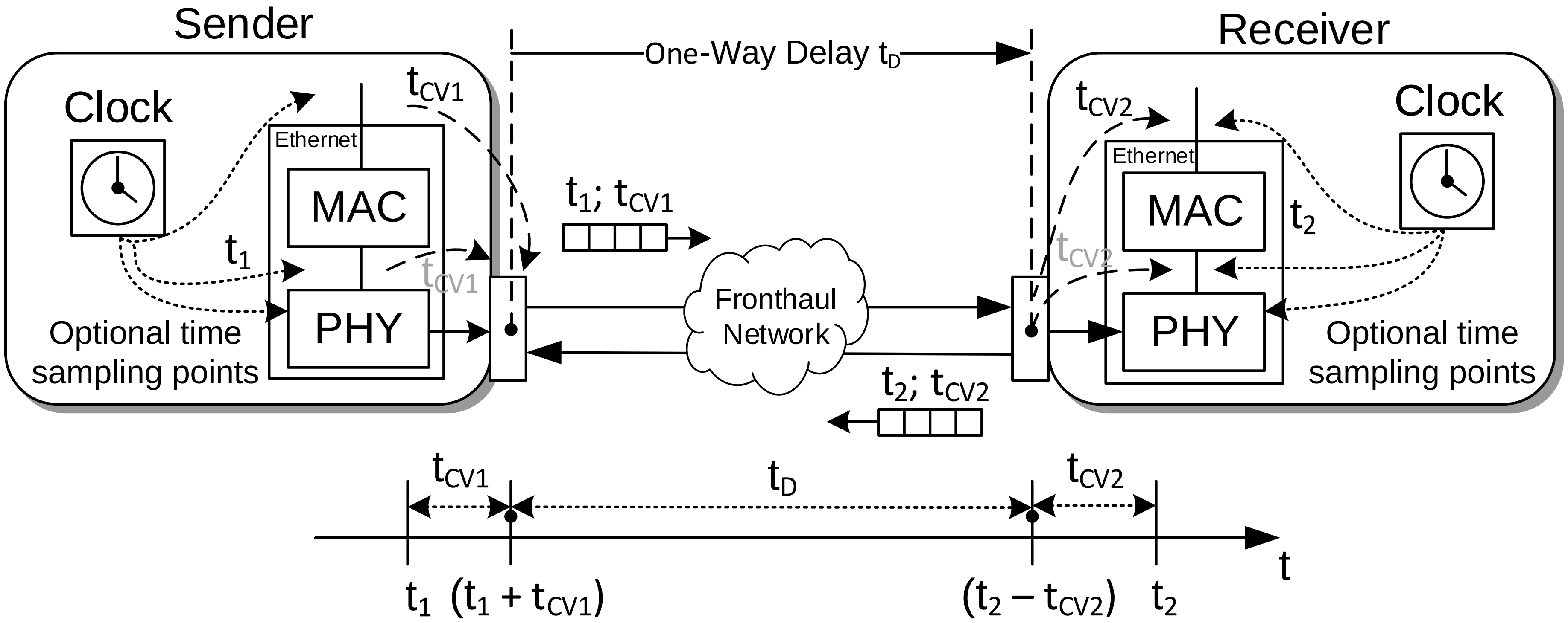
The message type 'One-Way delay measurement' is used for estimating the one-way delay between two eCPRI-ports in one direction. The one-way delay measurement can be performed without or with a Follow_Up message (1-Step and 2-Step versions). The decision of which version to use is vendor specific.

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.

eCPRI User Plane messages

eCPRI Message types for One-Way Delay Measurement: #5



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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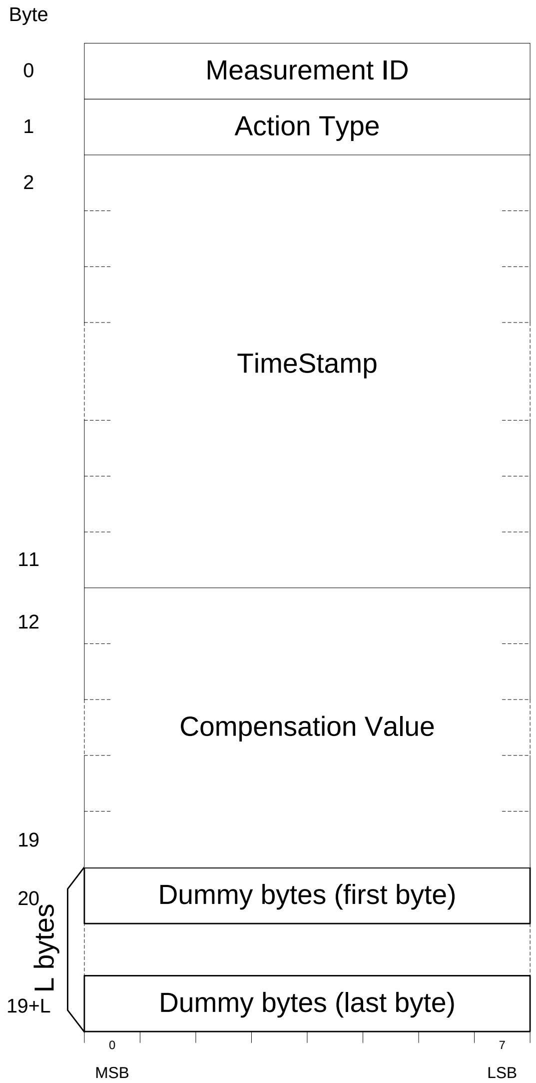
Message Type #5: One-Way Delay Measurement



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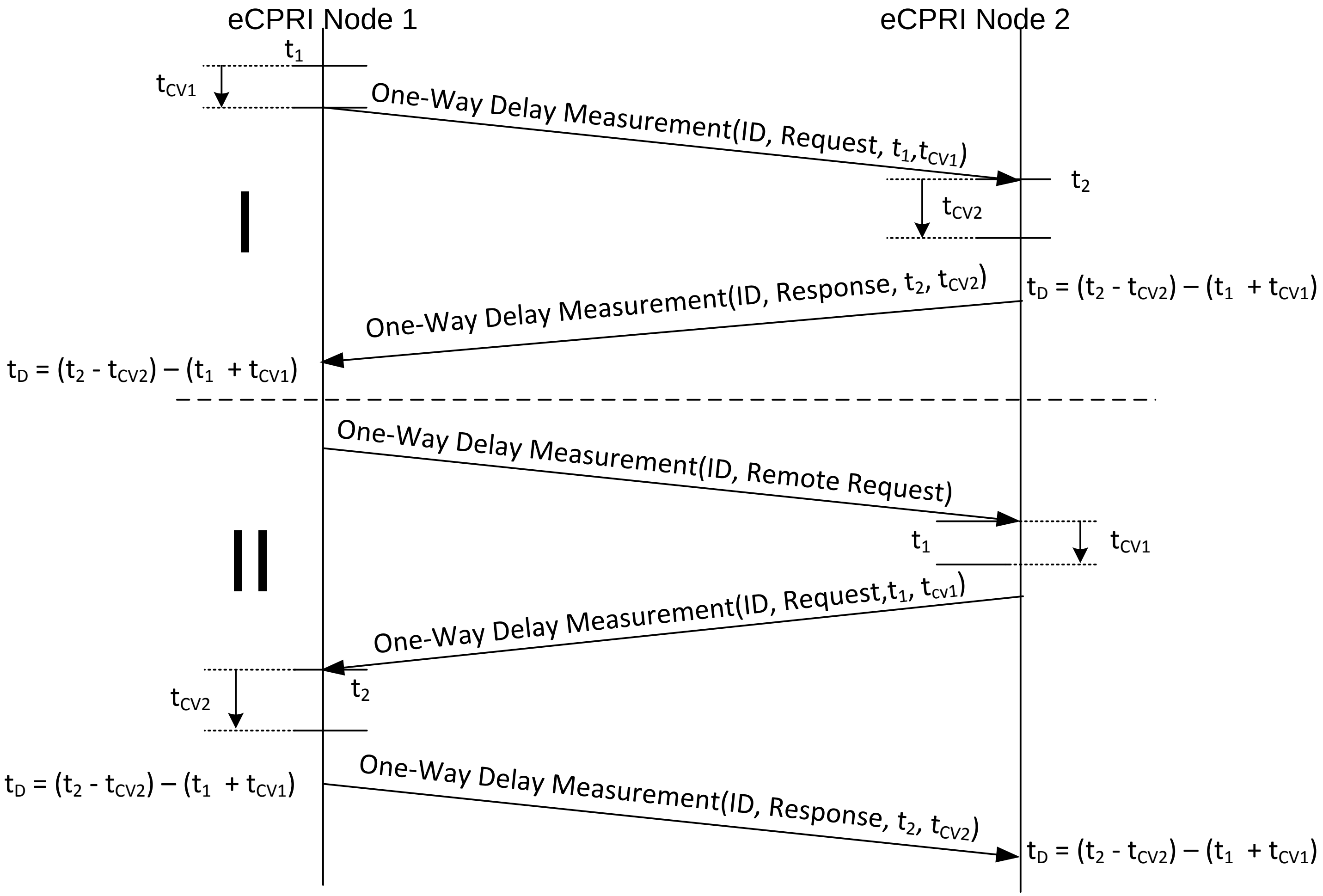
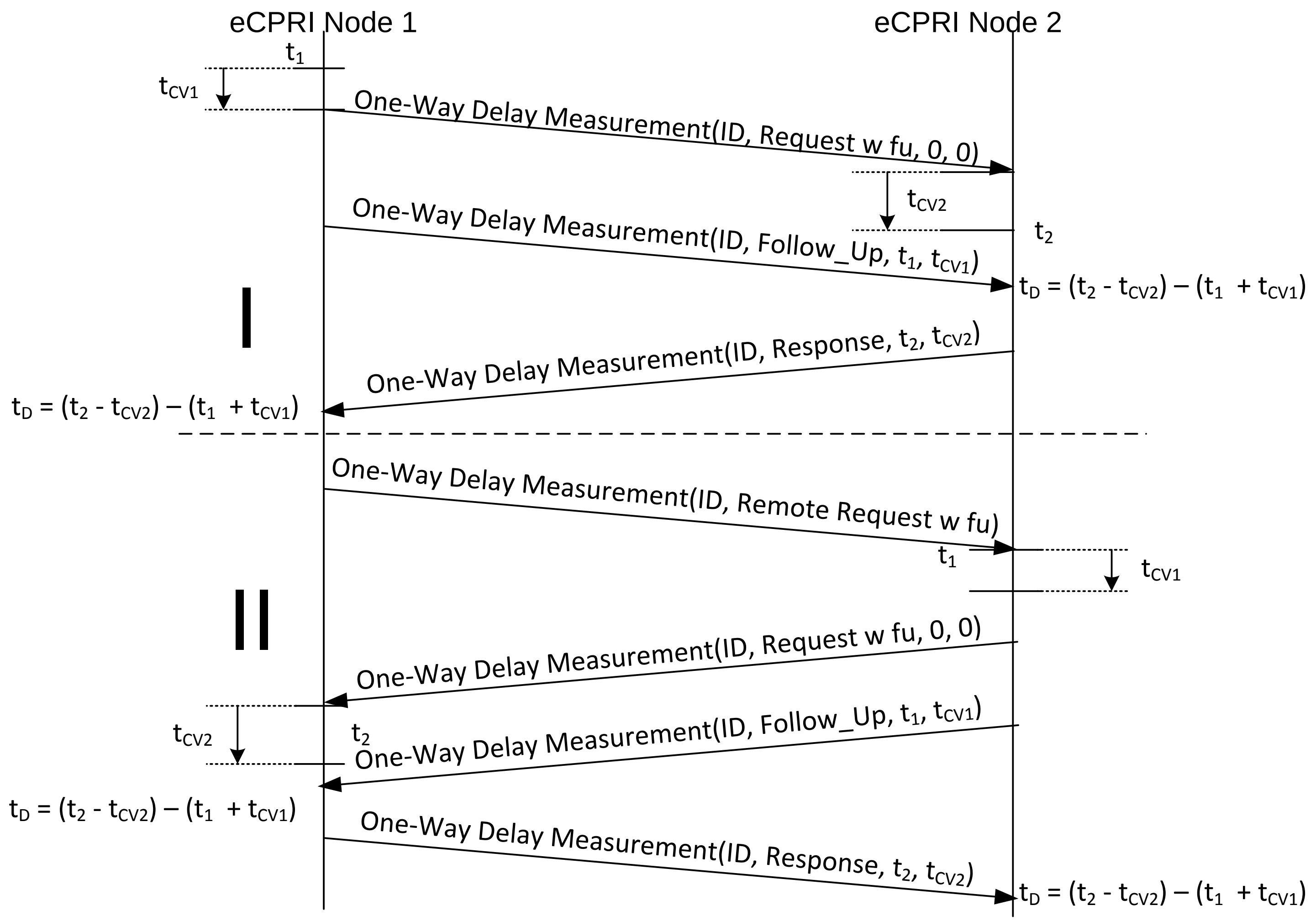
eCPRI User Plane messages

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



eCPRI User Plane messages

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



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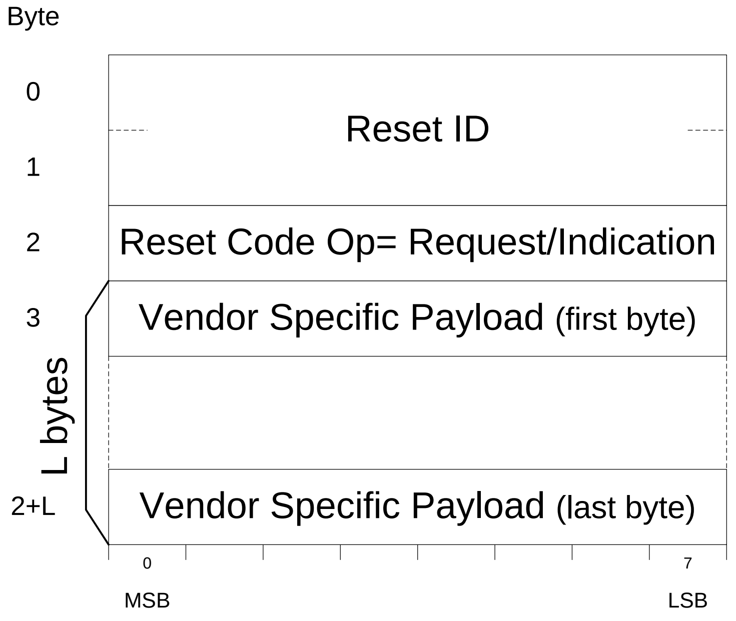
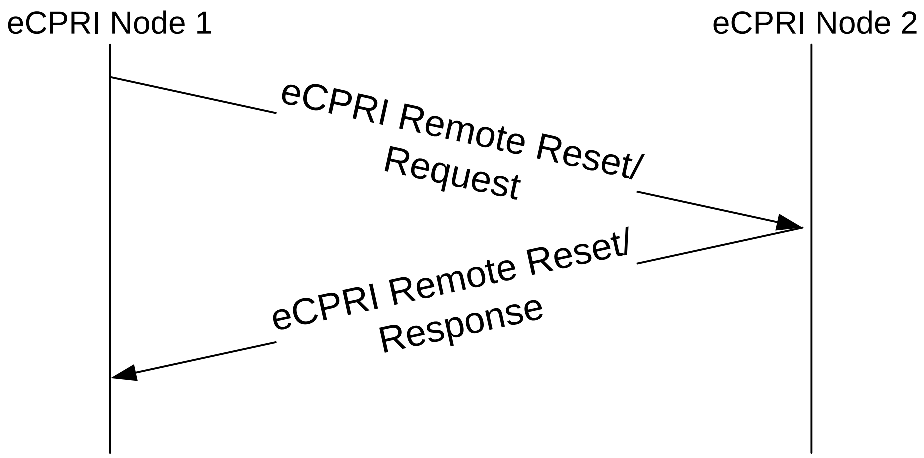
eCPRI User Plane messages

eCPRI Message types for Remote Reset: #6

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.





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.

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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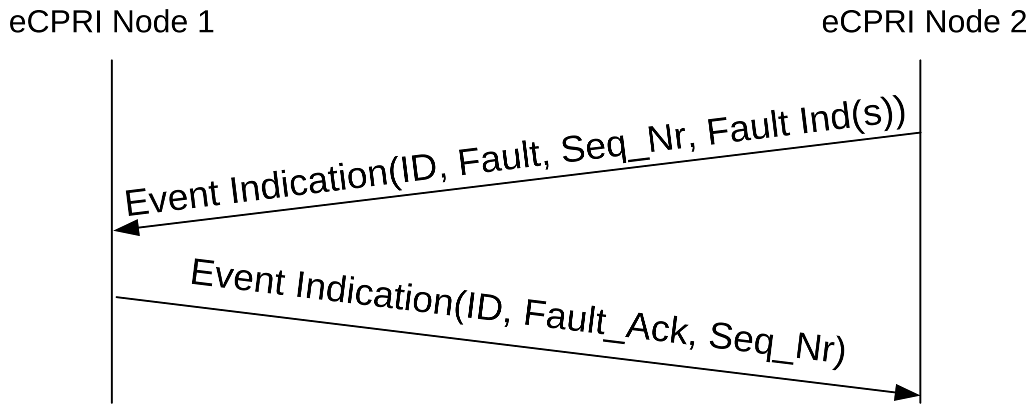
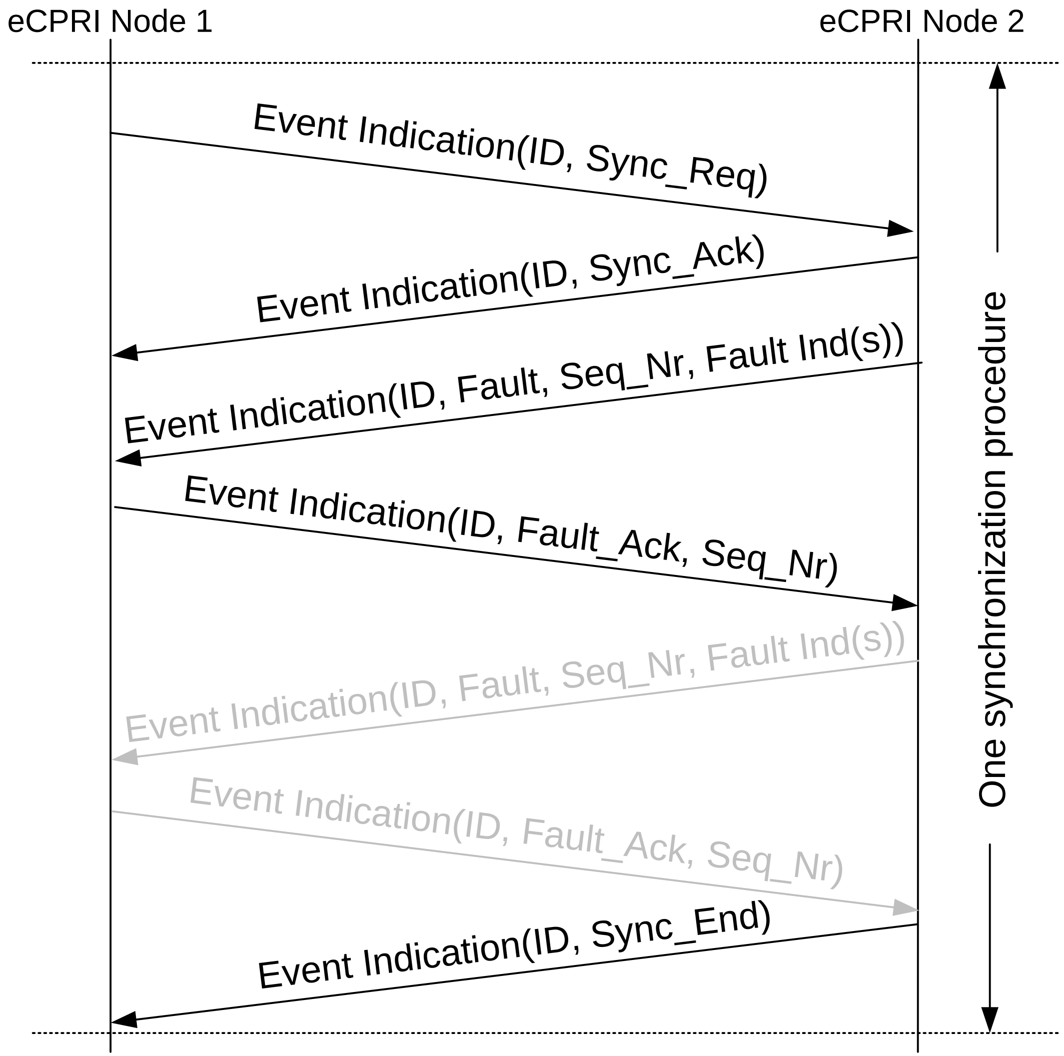
eCPRI User Plane messages

Message Type #7: Event Indication sequence diagram example





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.

eCPRI Synchronization

Synchronization Service Access point

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.

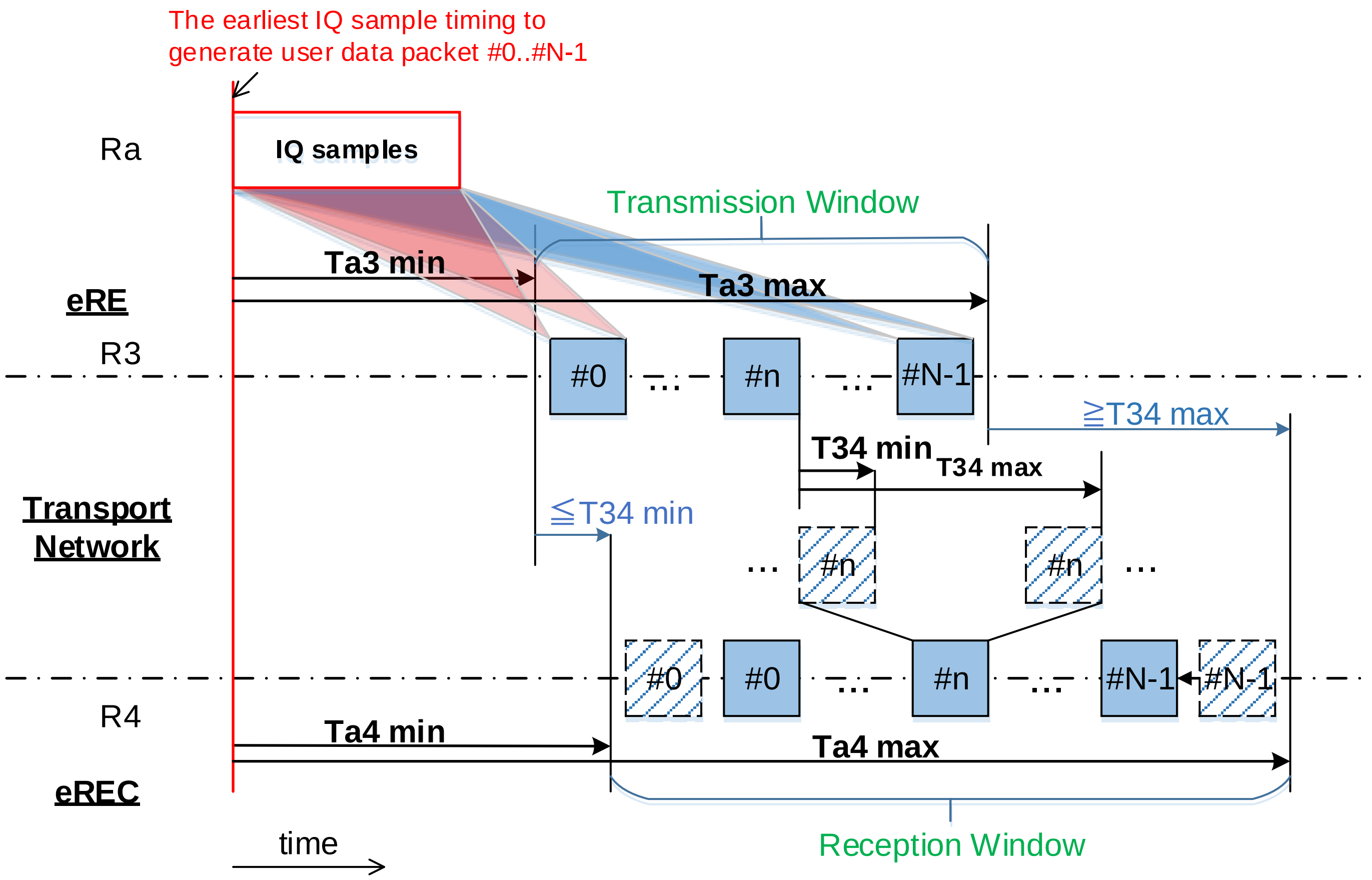
The synchronization information flow will be considered as time-critical and will utilize a small part of the total bandwidth between eCPRI nodes.

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.



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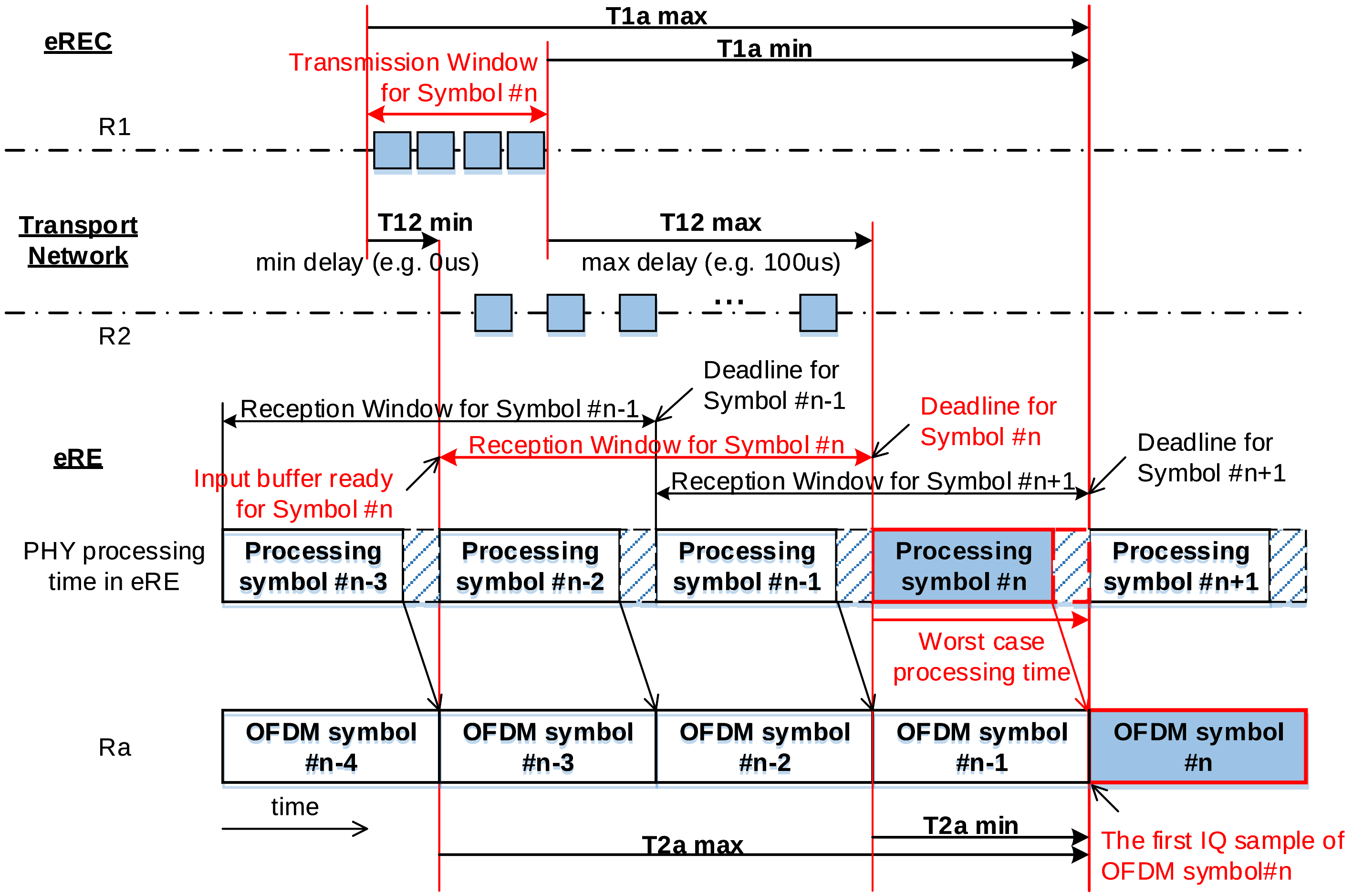
eCPRI Timing

DL user data transmission timing relations

Accurate delays enable correct setup of eREC transmission and eRE reception windows.



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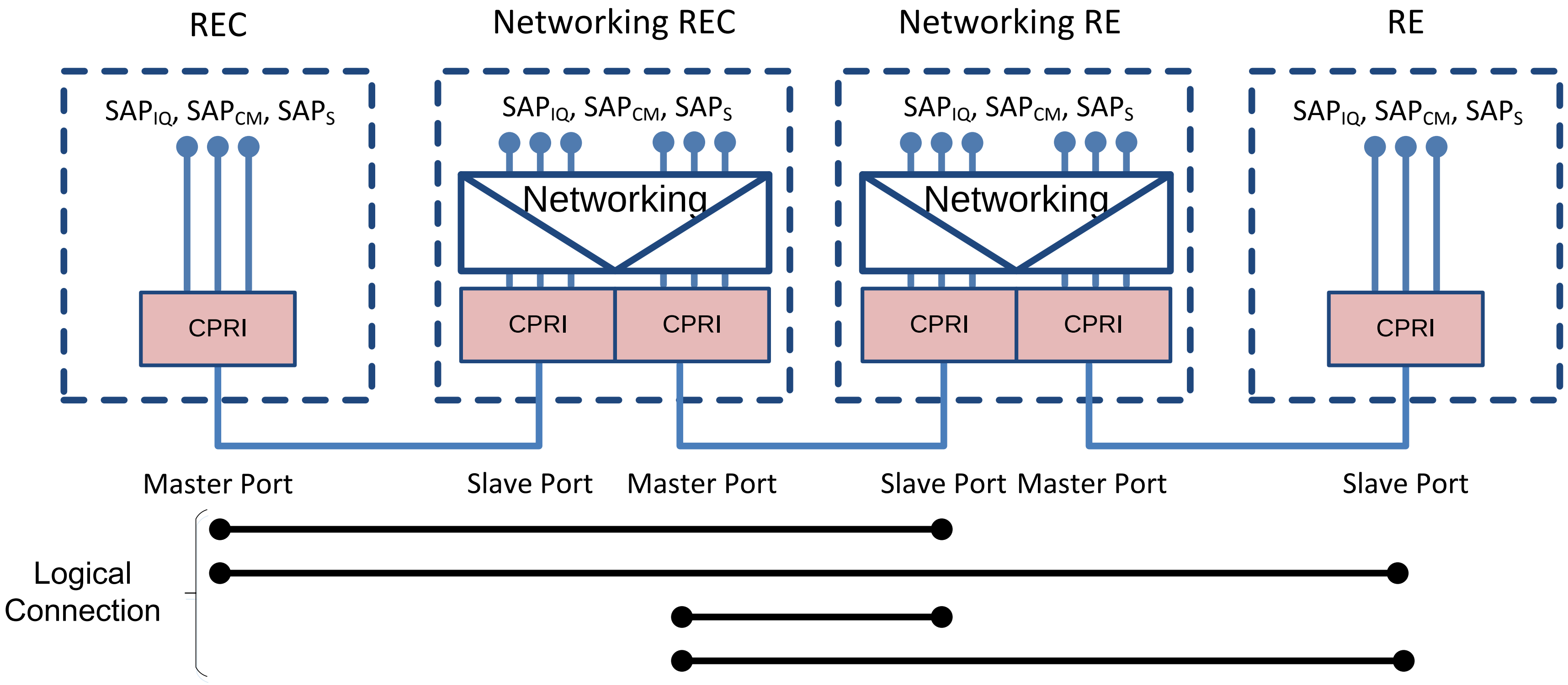
eCPRI Networking (1/2)

CPRI networking reminder

CPRI networking example



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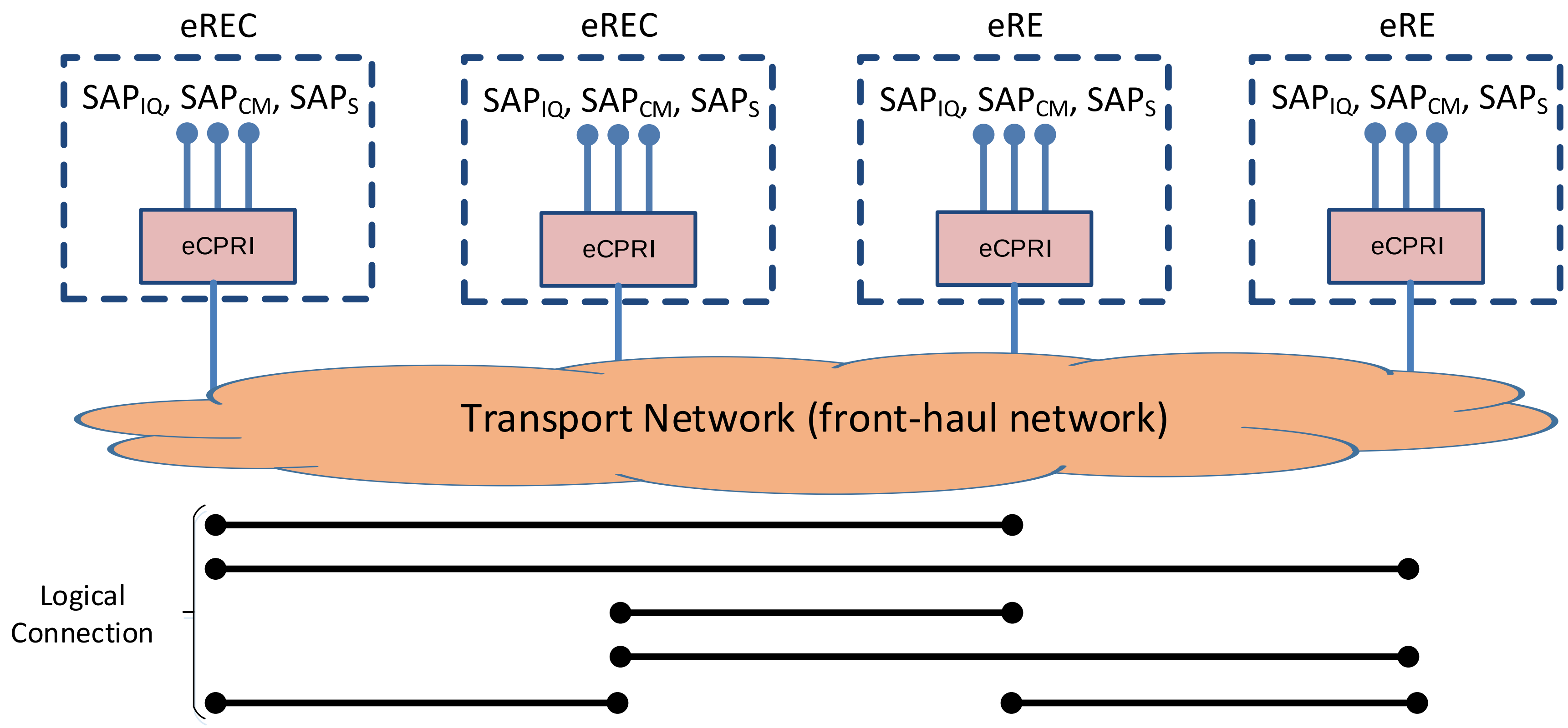
eCPRI Networking (2/2)

eCPRI networking principle

eCPRI networking example



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.

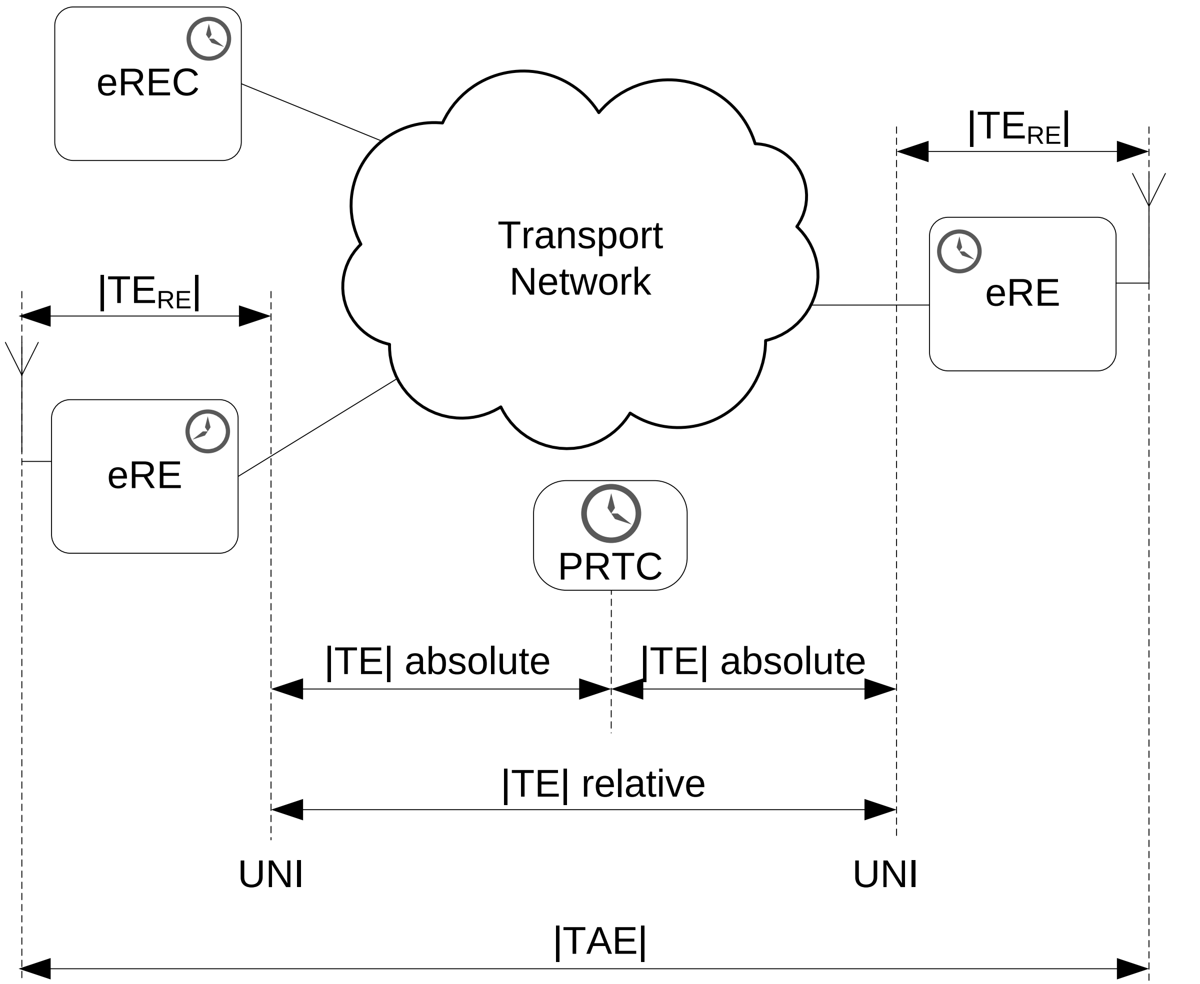
- User Plane:
  - User Plane over IP
    - IPsec or MACsec are both optional solutions to provide transmission security.
  - User Plane over Ethernet
    - MACsec is an optional solution to provide transmission security.
- C&M Plane
  - TLS, IPsec or MACsec are optional solutions to provide transmission security and access control for eCPRI C&M plane.
- Synchronization Plane
  - There is no eCPRI recommendation for security aspects related to the synchronization plane.

eCPRI Transport Network requirements

Timing accuracy requirements (1/3)

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.



eCPRI Transport Network requirements

Timing accuracy requirements (2/3)

Category (note 1)	Time error requirements at UNI, |TE|			Typical applications and time alignment error (TAE) requirements at antenna ports of eREs (for information)	
	Case 1 (note 2)		Case 2 (note 3)	Typical applications	TAE
	Case 1.1 (note 4)	Case 1.2 (note 5)			
A+	N.A.	N.A.	20 ns (relative)	MIMO or TX diversity transmissions, at each carrier frequency	65 ns (note 6)
A	N.A.	60 ns (relative) (note 7)	70 ns (relative)	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	130 ns (note 6)
B	100ns (relative) (note 7)	190 ns (relative) (note 7)	200 ns (relative)	Intra-band non-contiguous carrier aggregation, with or without MIMO or TX diversity, and Inter-band carrier aggregation, with or without MIMO or TX diversity	260 ns (note 6)
C (note 8)	1100 ns (absolute) (note 9)		1100 ns (absolute) (note 9)	3GPP LTE TDD	3 us (note 10)

eCPRI Transport Network requirements

Timing accuracy requirements (3/3)

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]

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], |TE| at the antenna ports shall be less than TAE/2

eCPRI Transport Network requirements

Per flow requirements - Split E and splits ID, IID, IU when running E-UTRA

CoS Name	Example use	Maximum One-way Frame Delay Performance	Maximum One-way Frame Loss Ratio Performance
High	User Plane (fast)	100 µs	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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