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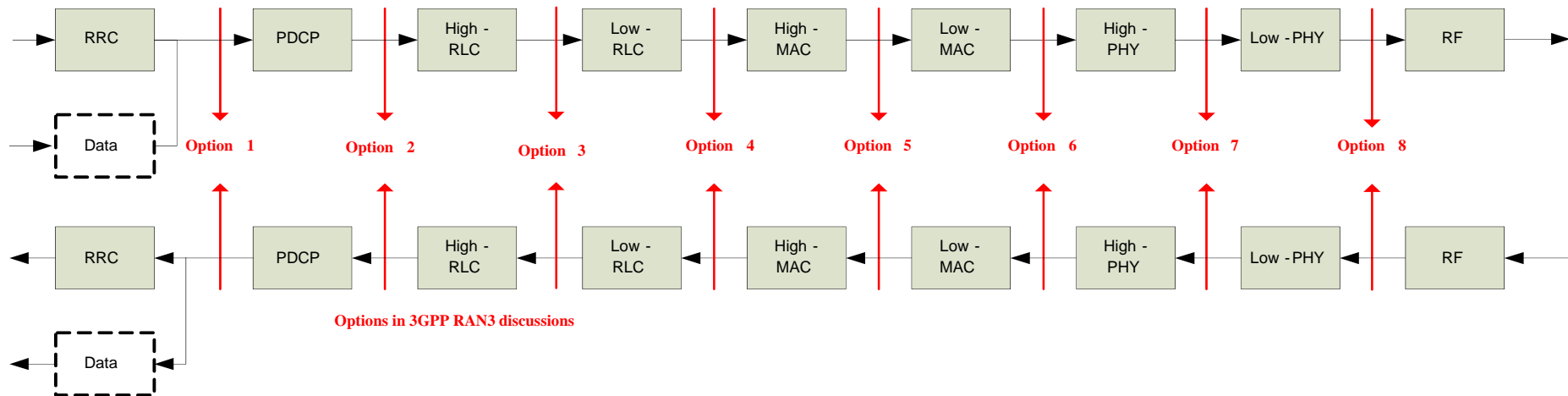
Also advanced networking and OAM features of mainstream packet transport standards were requested.

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Background 2/2

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.

| RRC | PDCP | High - RLC | Low - RLC | High - MAC | Low - MAC | High - PHY | Low - PHY | RF |

Data

Option 1   Option 2   Option 3   Option 4   Option 5   Option 6   Option 7   Option 8

Options in 3GPP RAN3 discussions

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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 Ethernet/IP technologies encouraged
7. eCPRI specification V1.0 published and openly available to download from www.cpri.info
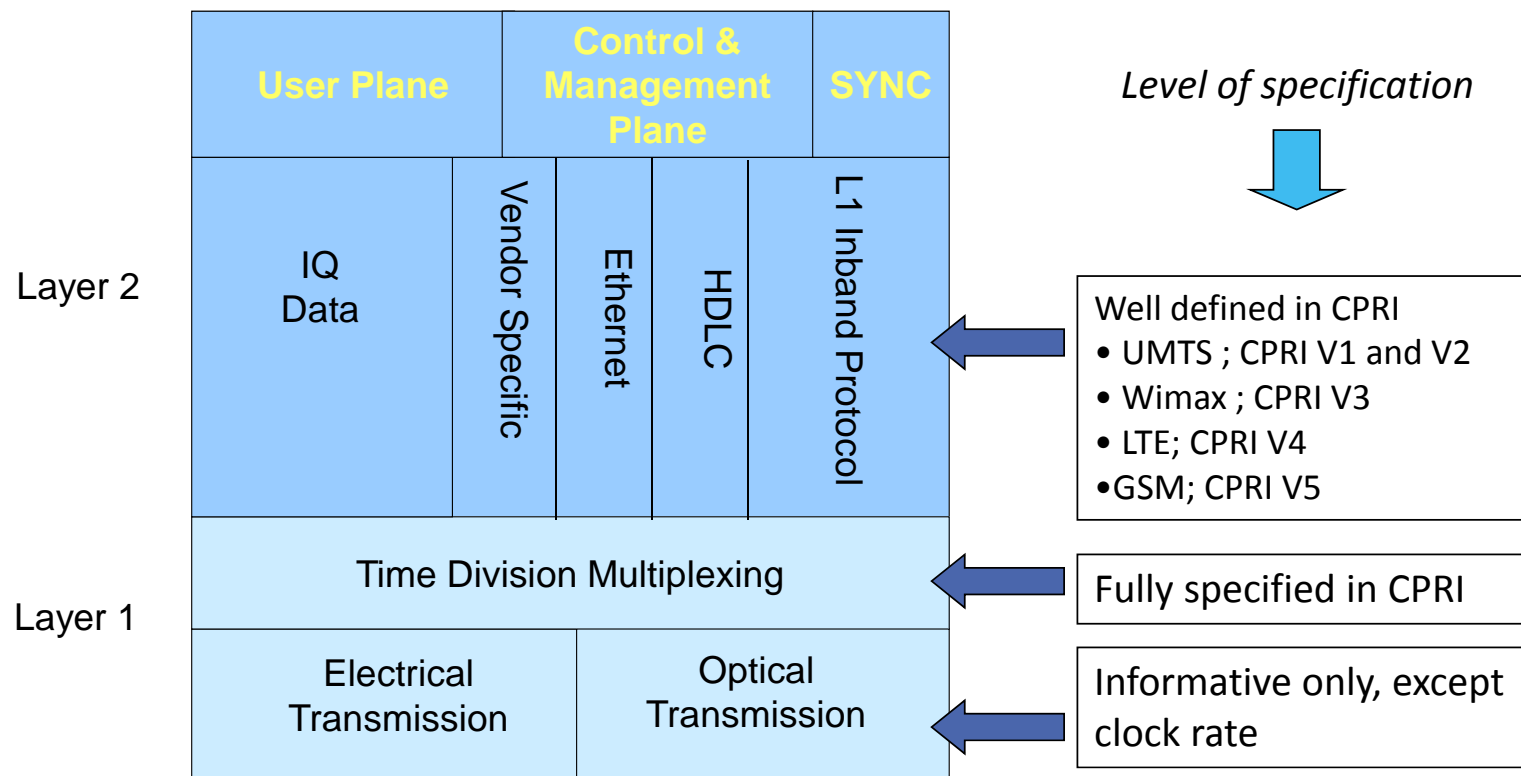
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CPRI reminder
What is CPRI?

- 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
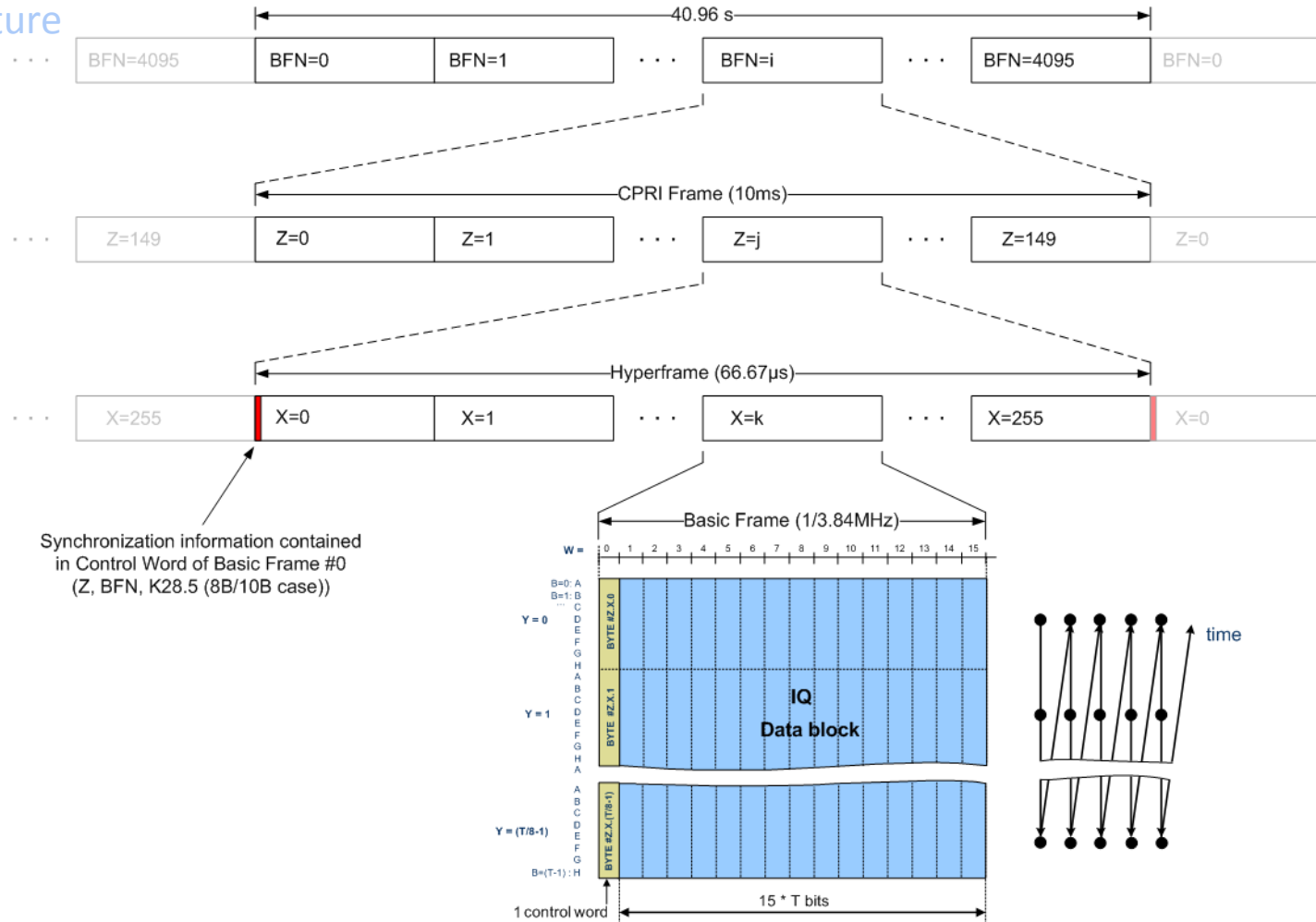
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CPRI reminder
CPRI Protocol Stack

	User Plane	Control & Management Plane	SYNC
Layer 2	IQ Data	Vendor Specific / Ethernet / HDLC	L1 Inband Protocol
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

Synchronization information contained
in Control Word of Basic Frame #0
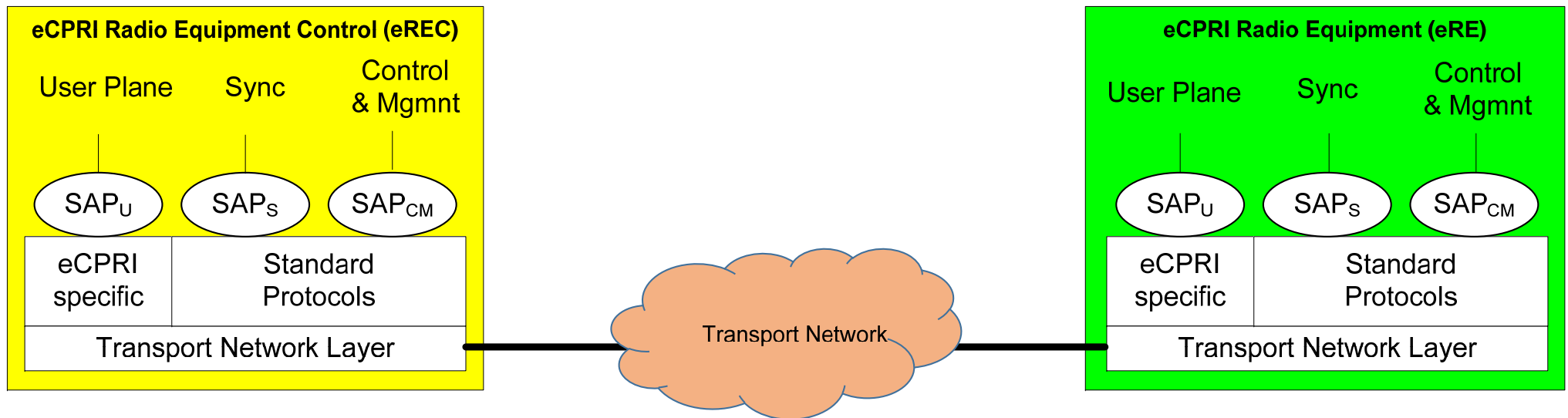(Z, BFN, K28.5 (8B/10B case))

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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

eCPRI Radio Equipment Control (eREC)

User Plane | Sync | Control & Mgmnt

SAP_U | SAP_S | SAP_{CM}

eCPRI specific | Standard Protocols

Transport Network Layer

Transport Network

eCPRI Radio Equipment (eRE)

User Plane | Sync | Control & Mgmnt

SAP_U | SAP_S | SAP_{CM}

eCPRI specific | Standard Protocols

Transport Network Layer
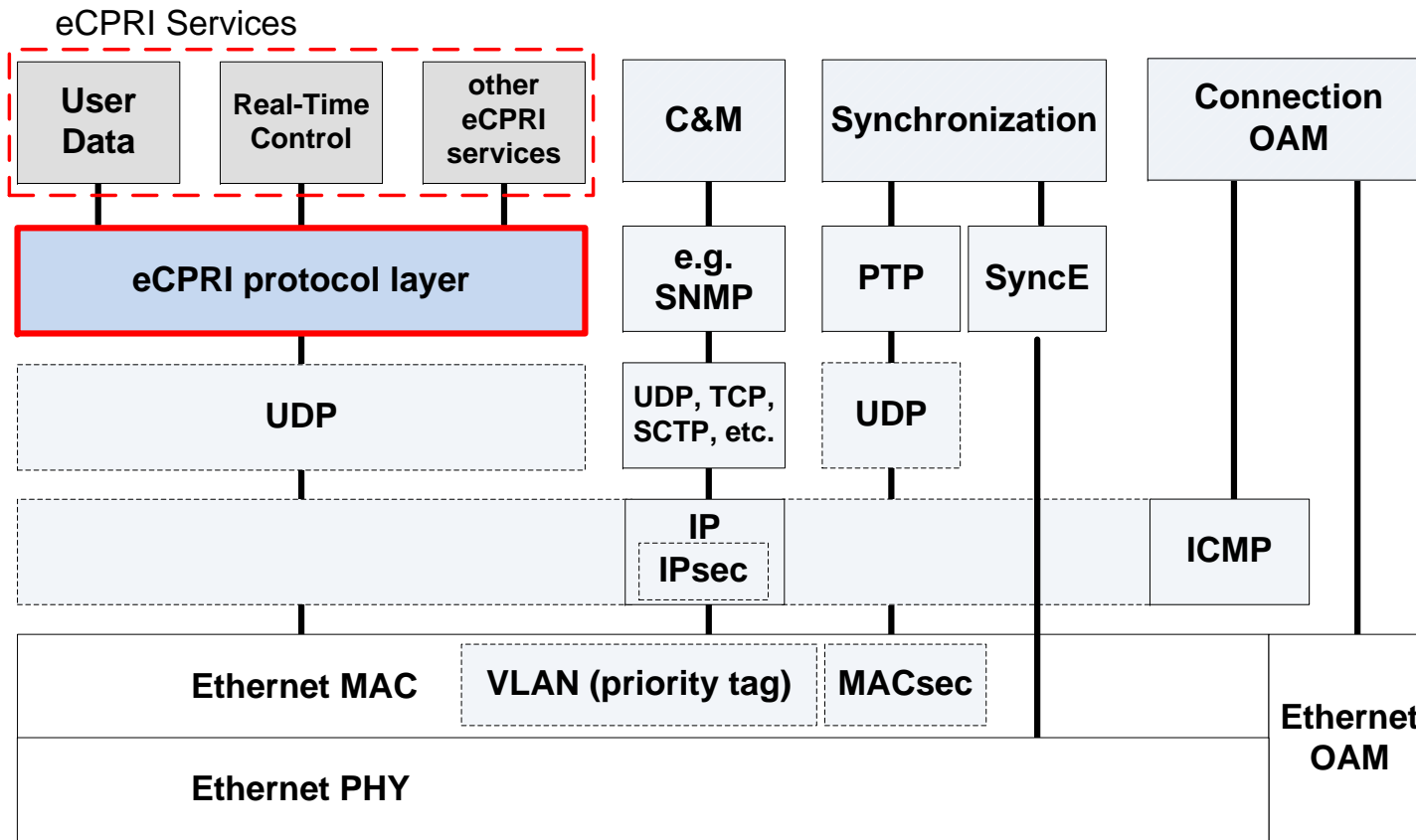
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eCPRI introduction
eCPRI main characteristics

- 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,
      - …
- eCPRI also encourages the use of existing de-facto/de-jure standard protocols as much as possible where available
- In case 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 Services

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

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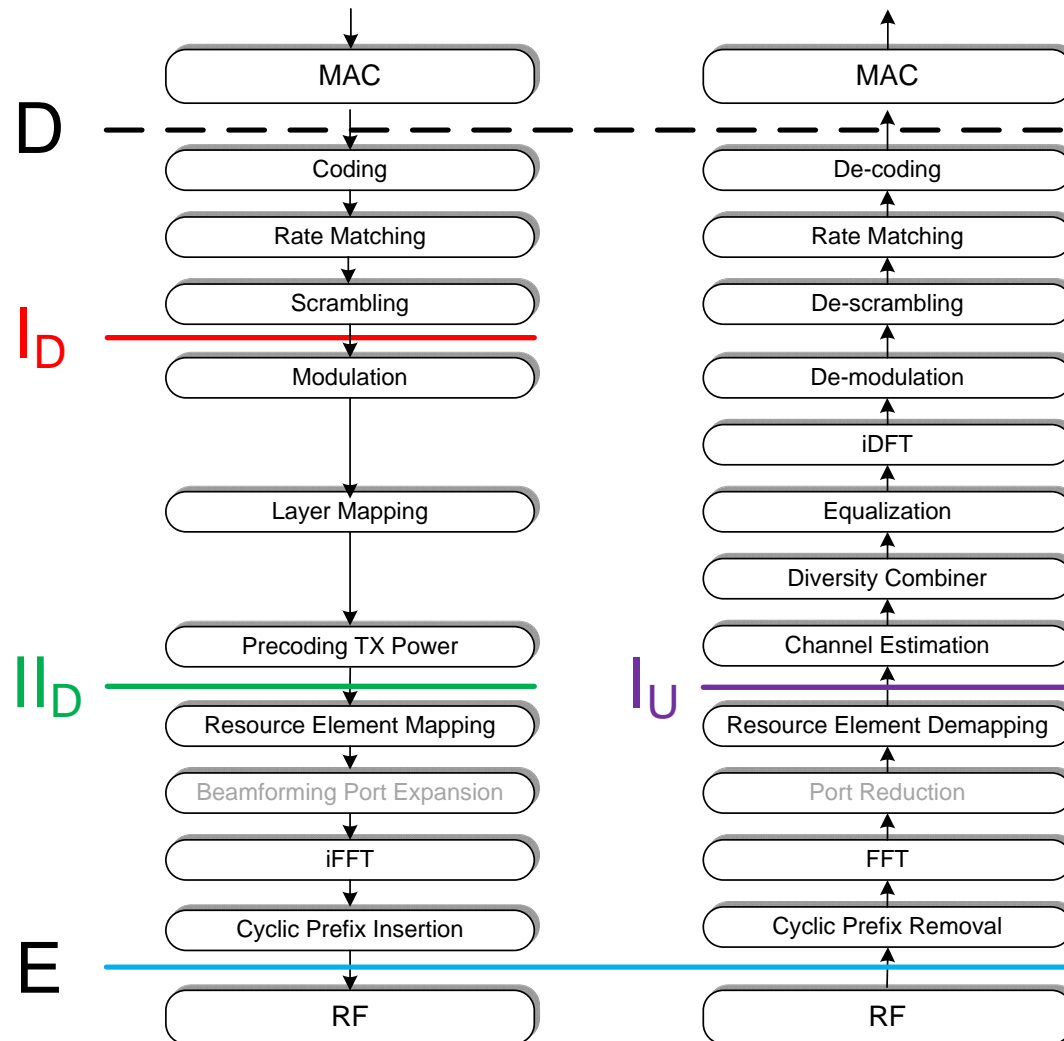# eCPRI introduction

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
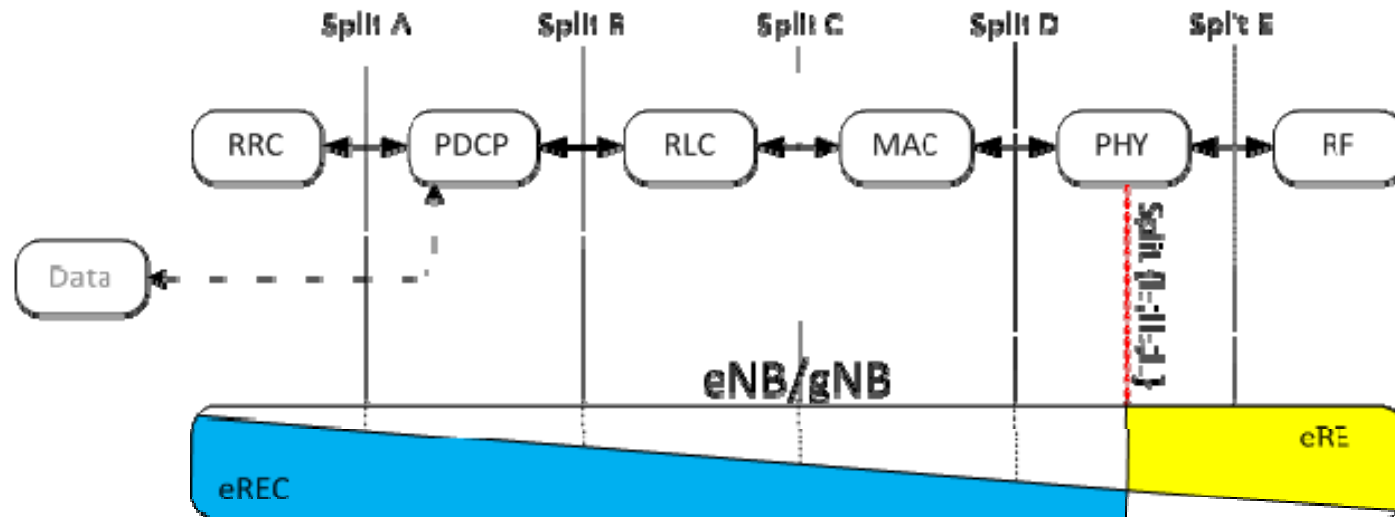
eCPRI introduction

eCPRI functional decomposition

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
- Subcarrier spacing: 15 kHz
- IQ sampling frequency: 122.88 Msps (3.84*32)
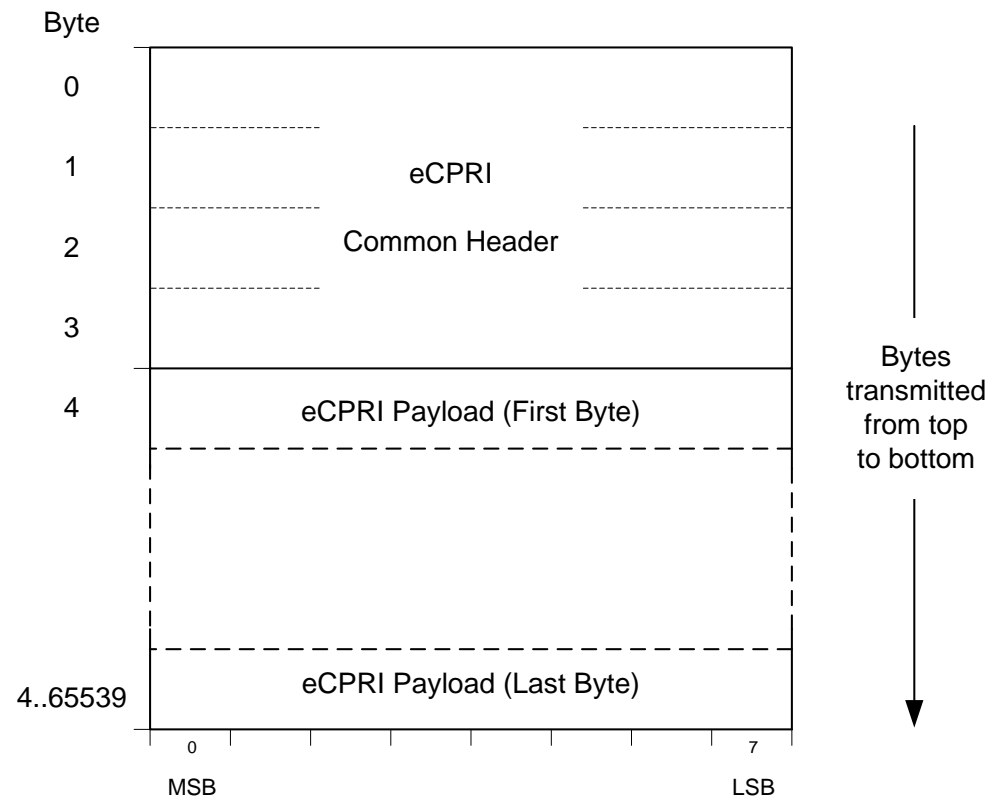- IQ-format: 30 bits per IQ-sample
- No IQ compression

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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			236

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eCPRI User Plane messages
eCPRI Messages Common Header format
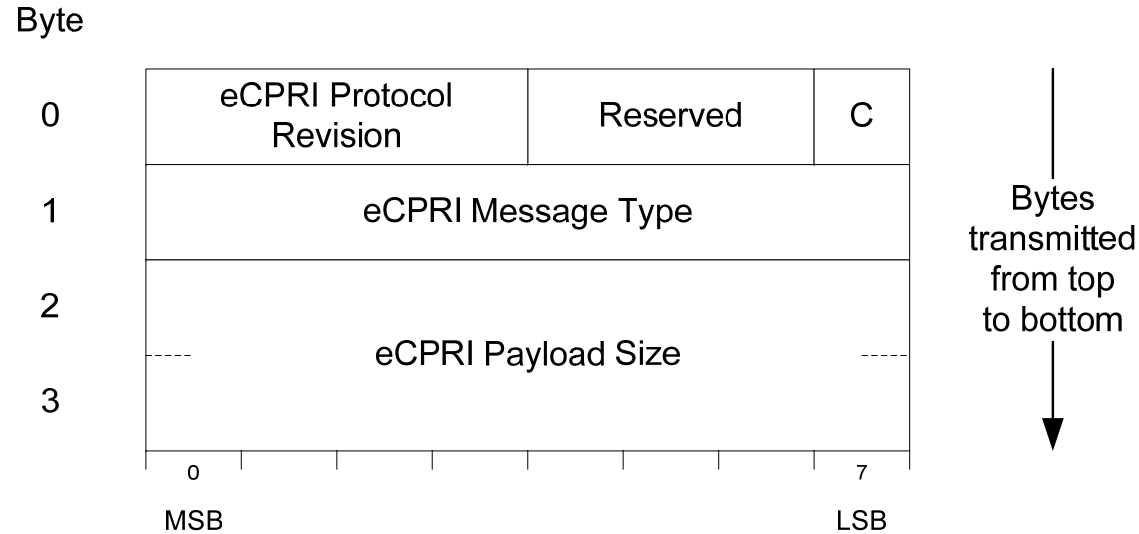
- 4 byte eCPRI common header followed by a variable length eCPRI payload

eCPRI User Plane messages
eCPRI Messages Common Header format

Byte

	eCPRI Protocol Revision	Reserved	C	
0				
1	eCPRI Message Type			
2	eCPRI Payload Size			
3				

0   7

MSB   LSB

Bytes transmitted from top to bottom

- "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

CPRI
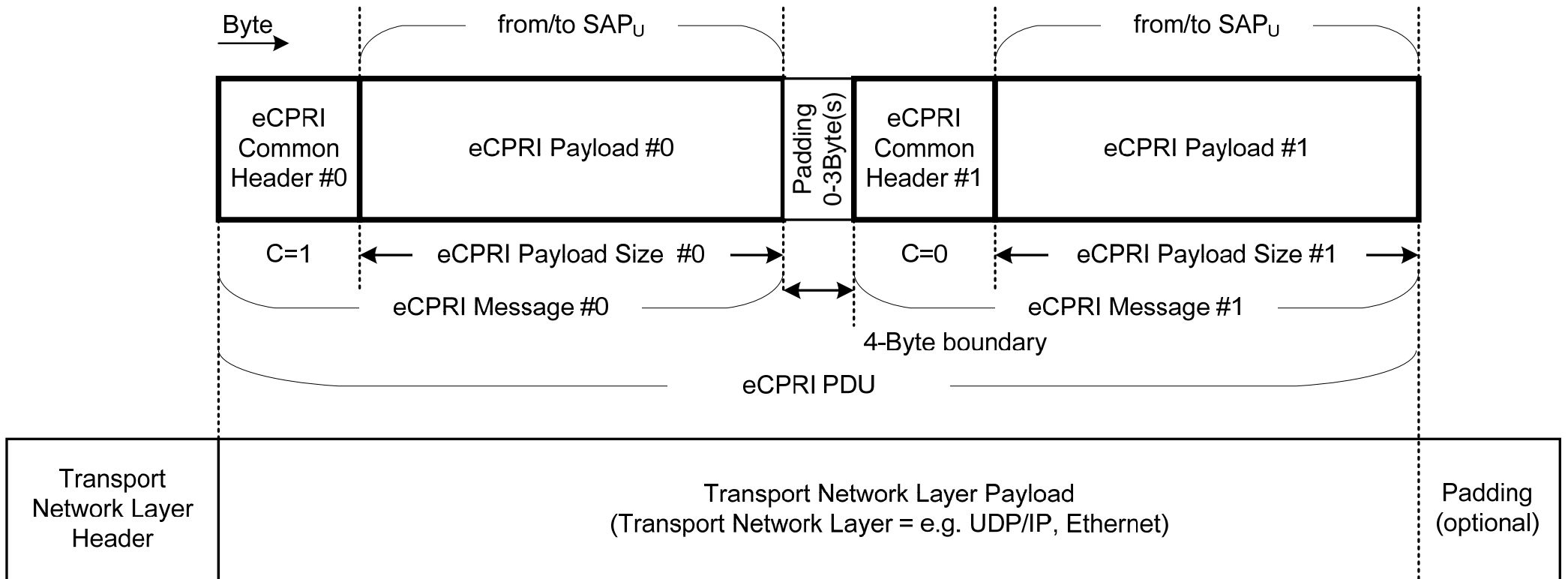Common Public Radio Interface

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

CPRI
Common Public Radio Interface
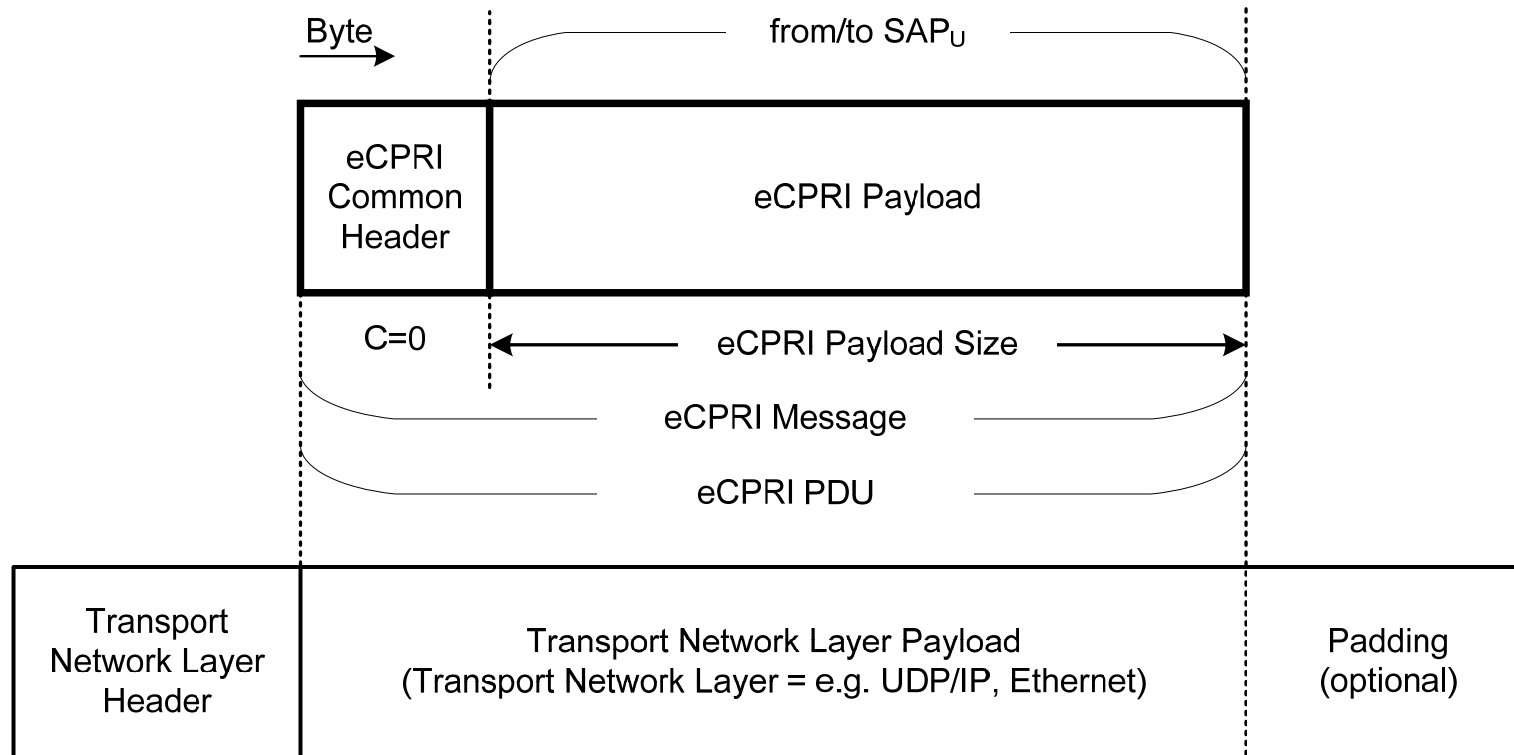
eCPRI User Plane messages
eCPRI Messages Common Header format: concatenation indicator

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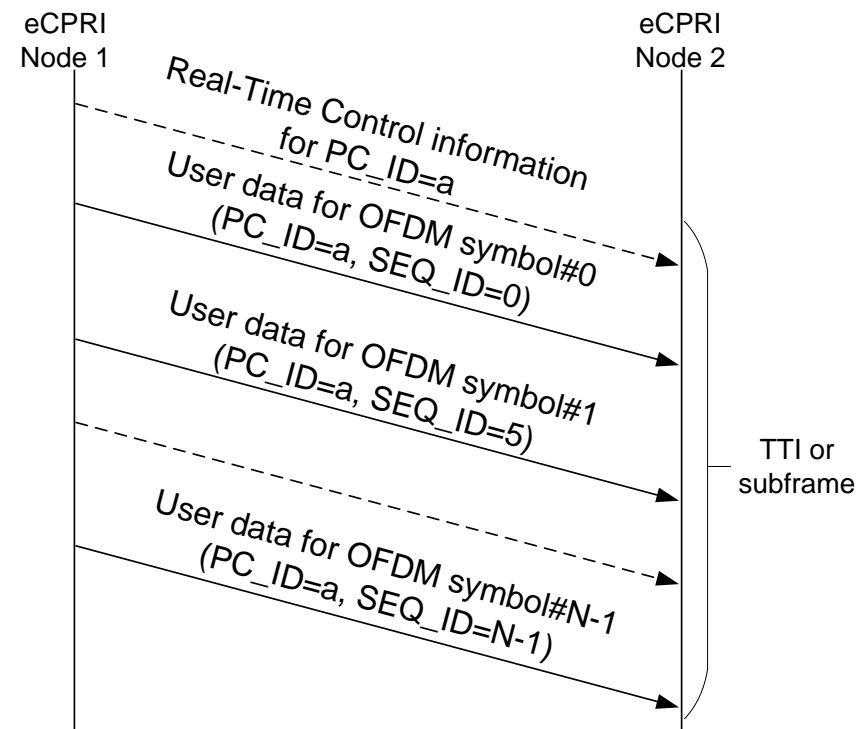
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eCPRI User Plane messages
eCPRI User Plane message formats
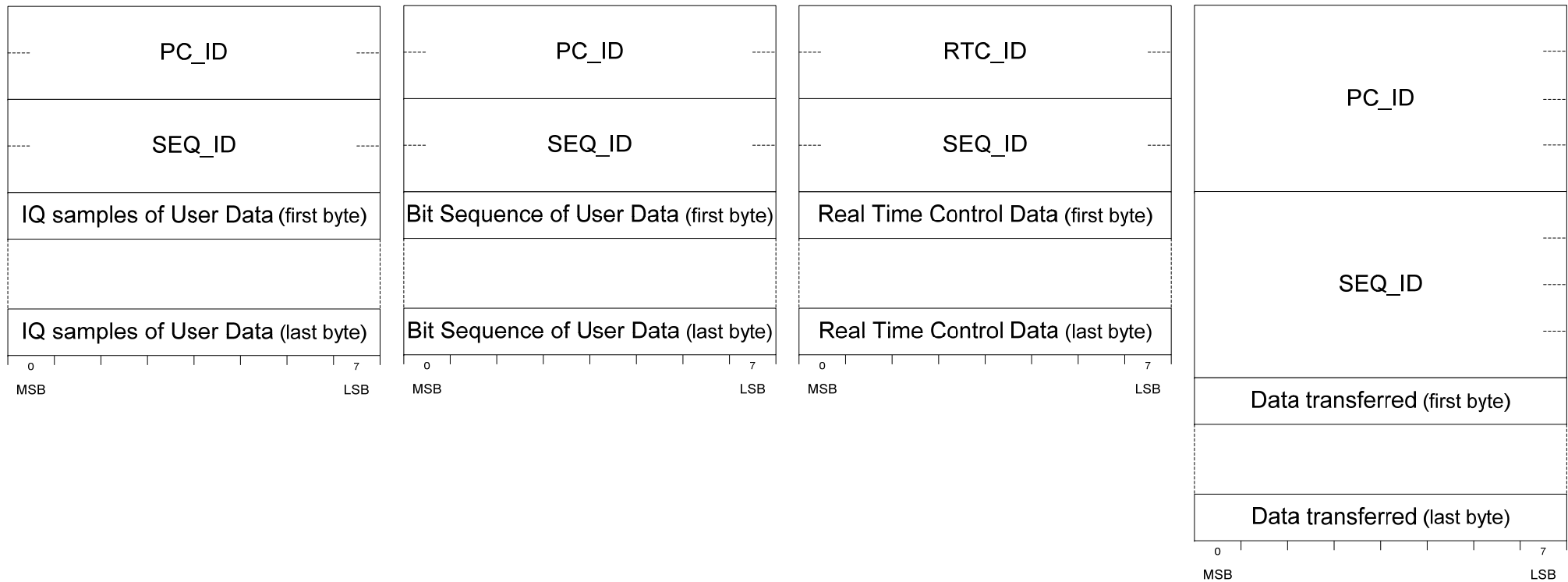
eCPRI User Plane messages
Message Type #3: Generic Data Transfer sequence diagram example

eCPRI Node 1

eCPRI Node 2

Real-Time Control information for PC_ID=a

User data for OFDM symbol#0 (PC_ID=a, SEQ_ID=0)

User data for OFDM symbol#1 (PC_ID=a, SEQ_ID=5)

User data for OFDM symbol#N-1 (PC_ID=a, SEQ_ID=N-1)

TTI or subframe

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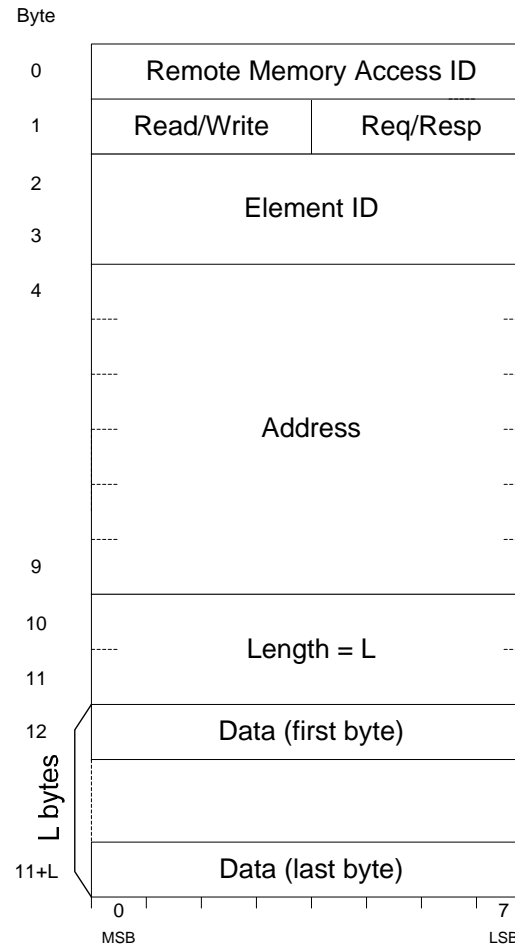
Message Type #4: Remote Memory Access

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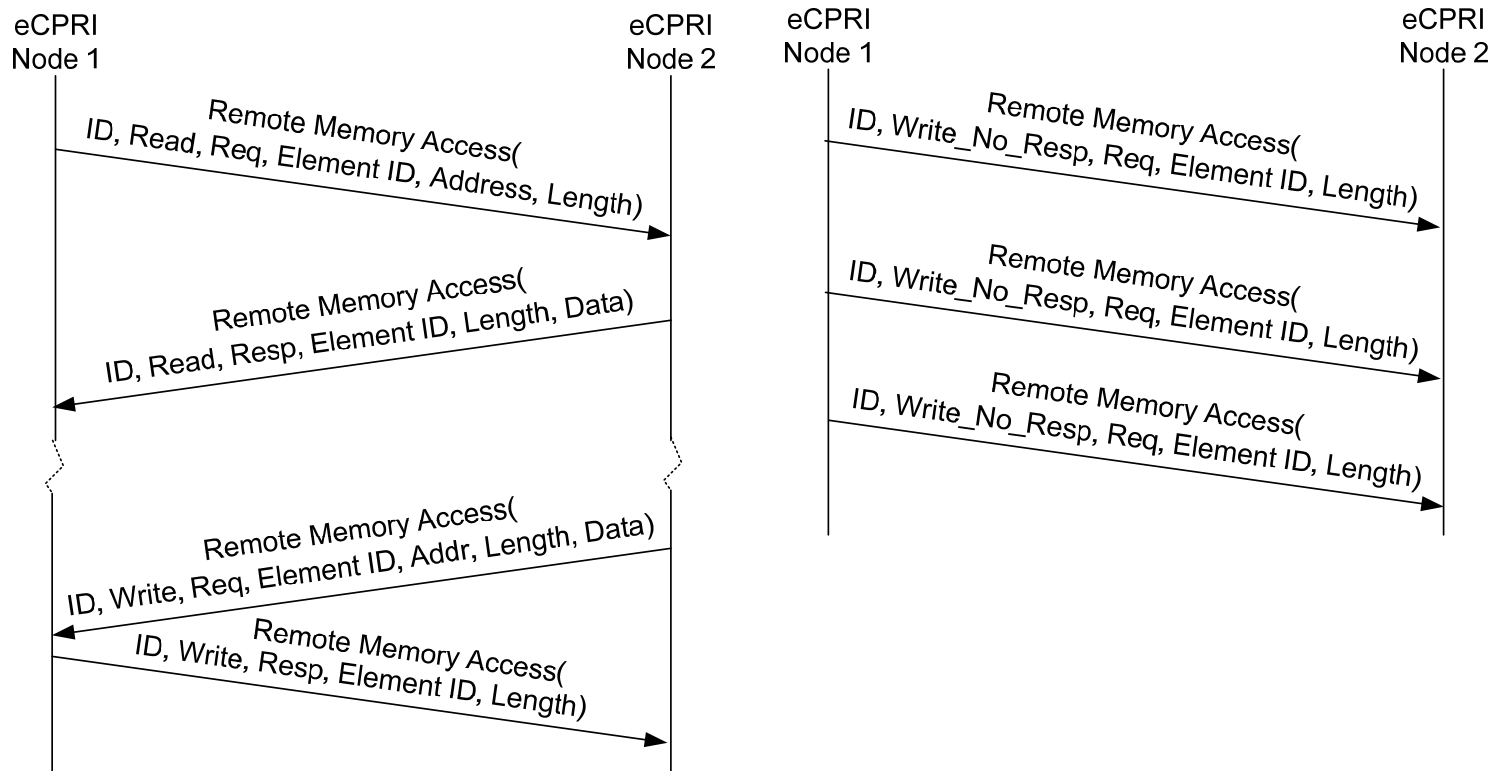
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eCPRI User Plane messages
Message Type #4: Remote Memory Access

Byte

Bit	0 (MSB)	7 (LSB)

```
0      ┌─────────────────────────────────┐
       │    Remote Memory Access ID      │
1      ├─────────────────┬───────────────┤
       │   Read/Write    │    Req/Resp   │
2      ├─────────────────┴───────────────┤
       │                                 │
       │           Element ID            │
3      │                                 │
4      ├─────────────────────────────────┤
       │                                 │
       │                                 │
       │                                 │
       │            Address              │
       │                                 │
       │                                 │
9      │                                 │
10     ├─────────────────────────────────┤
       │          Length = L             │
11     ├─────────────────────────────────┤
12     │        Data (first byte)        │
       ├─────────────────────────────────┤
       │                                 │
       ├─────────────────────────────────┤
11+L   │        Data (last byte)         │
       └─────────────────────────────────┘
        0                               7
       MSB                             LSB
```

L bytes

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

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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

eCPRI Message types for One-Way Delay Measurement: #5
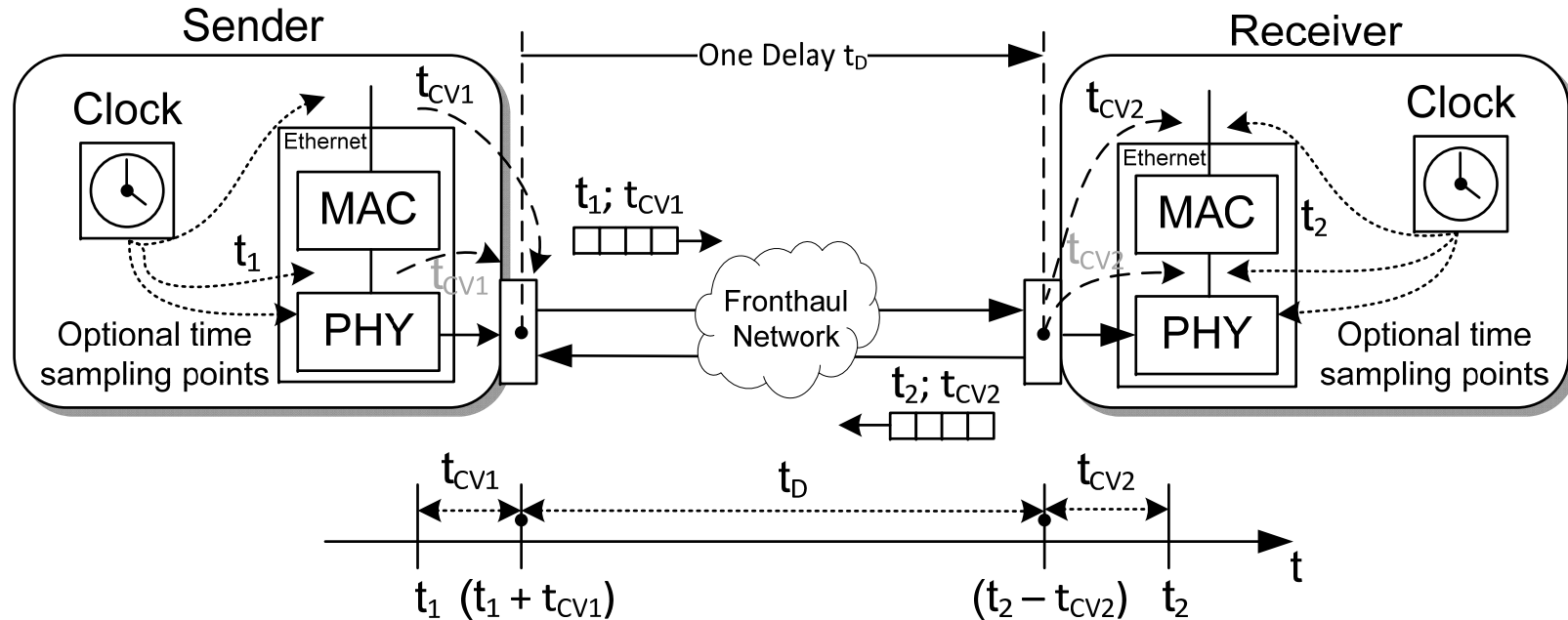
Two compensation values are used to set the measurements reference points as suited for a specific implementation. The exact locations of the reference points are vendor specific.
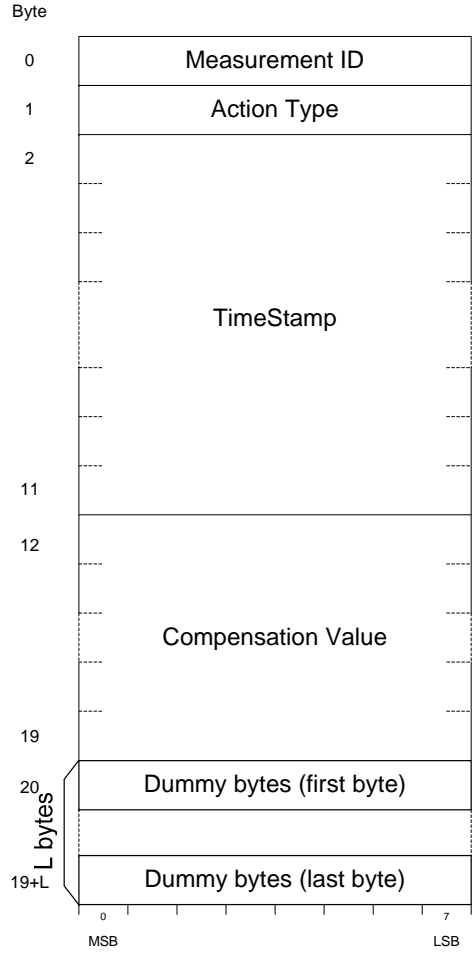
The One-Way delay value is calculated according to following equation:

$$t_D = (t_2 - t_{CV2}) - (t_1 + t_{CV1})$$
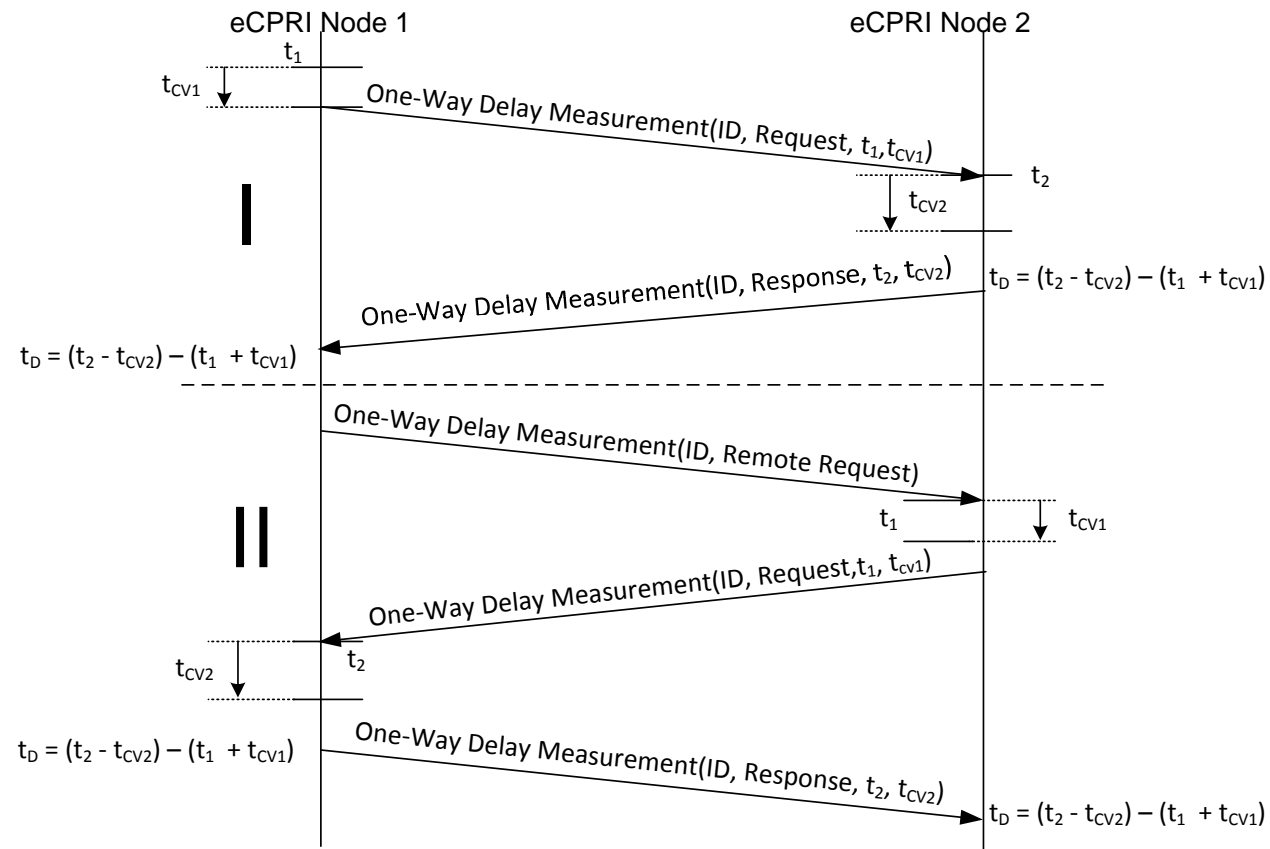
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eCPRI User Plane messages
## Message Type #5: One-Way Delay Measurement

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

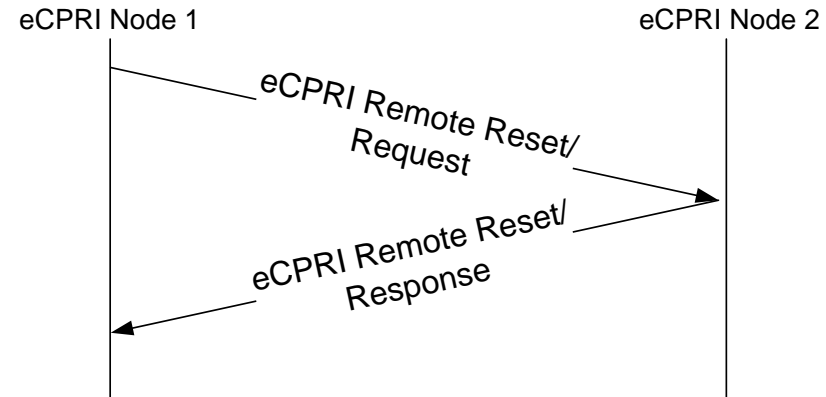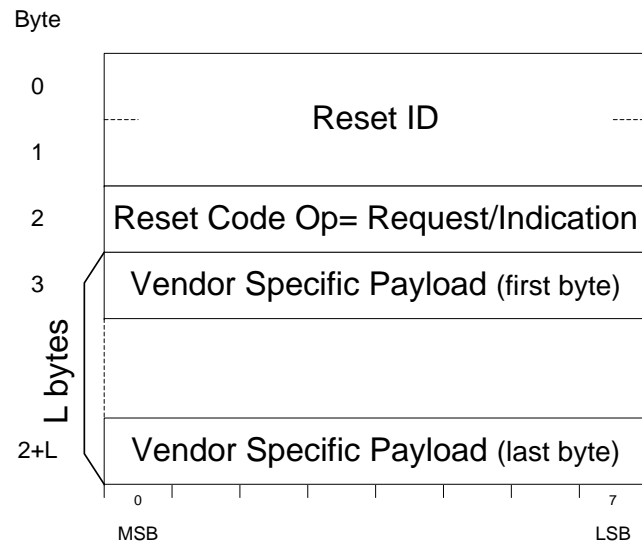**CPRI**
Common Public Radio Interface
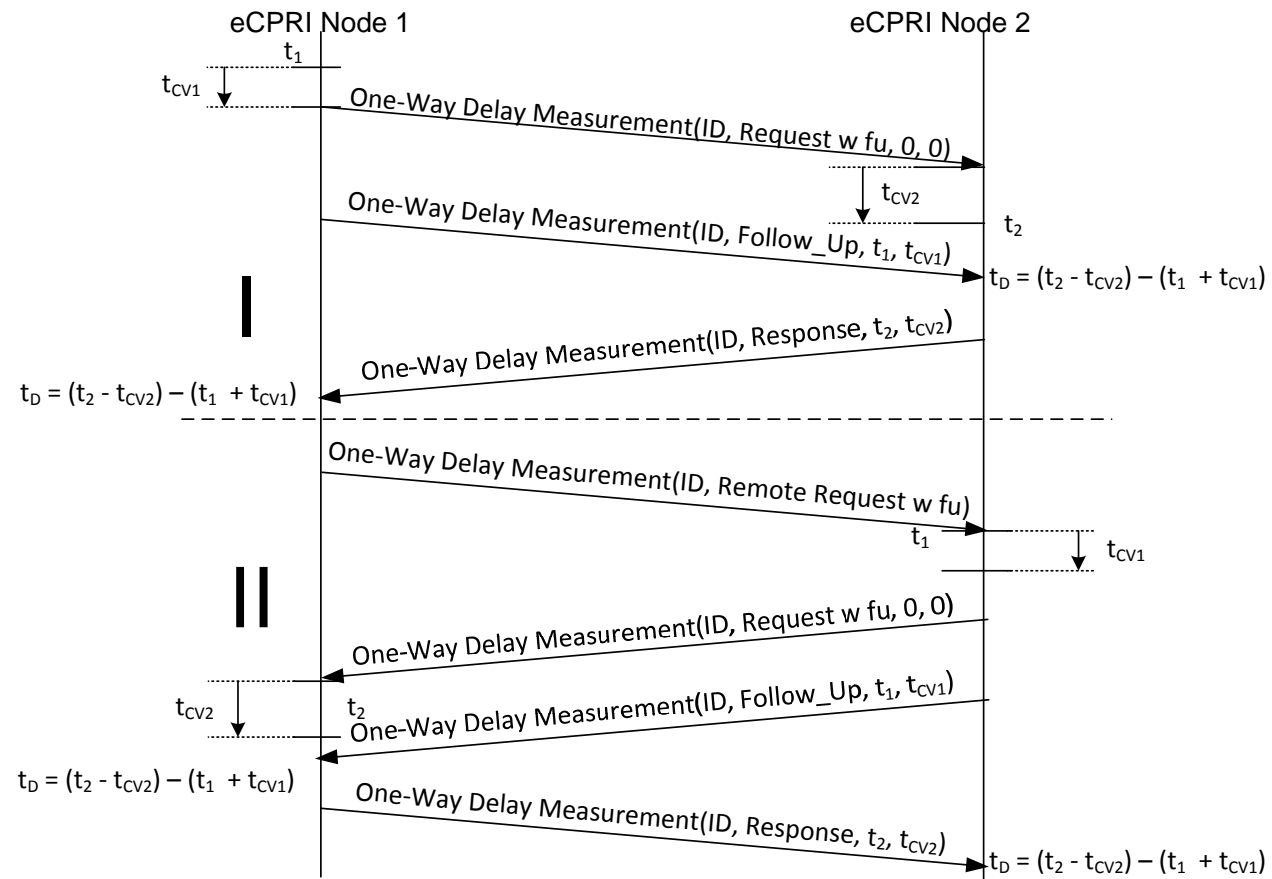
eCPRI User Plane messages

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.

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eCPRI User Plane messages

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.

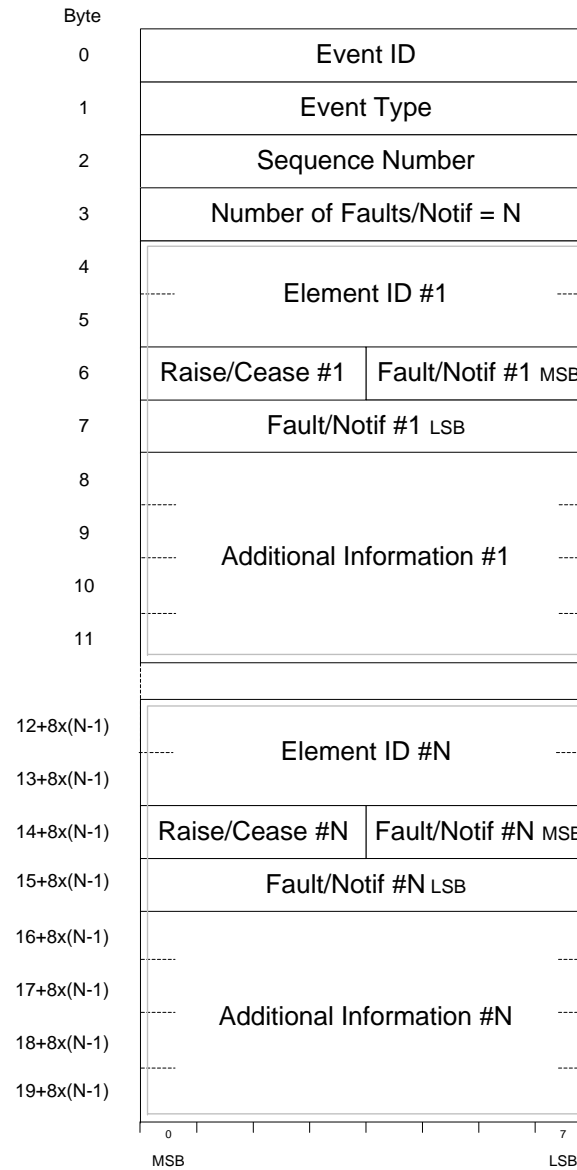One Event Indication can either contain one or more faults, or one or more notifications.

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.

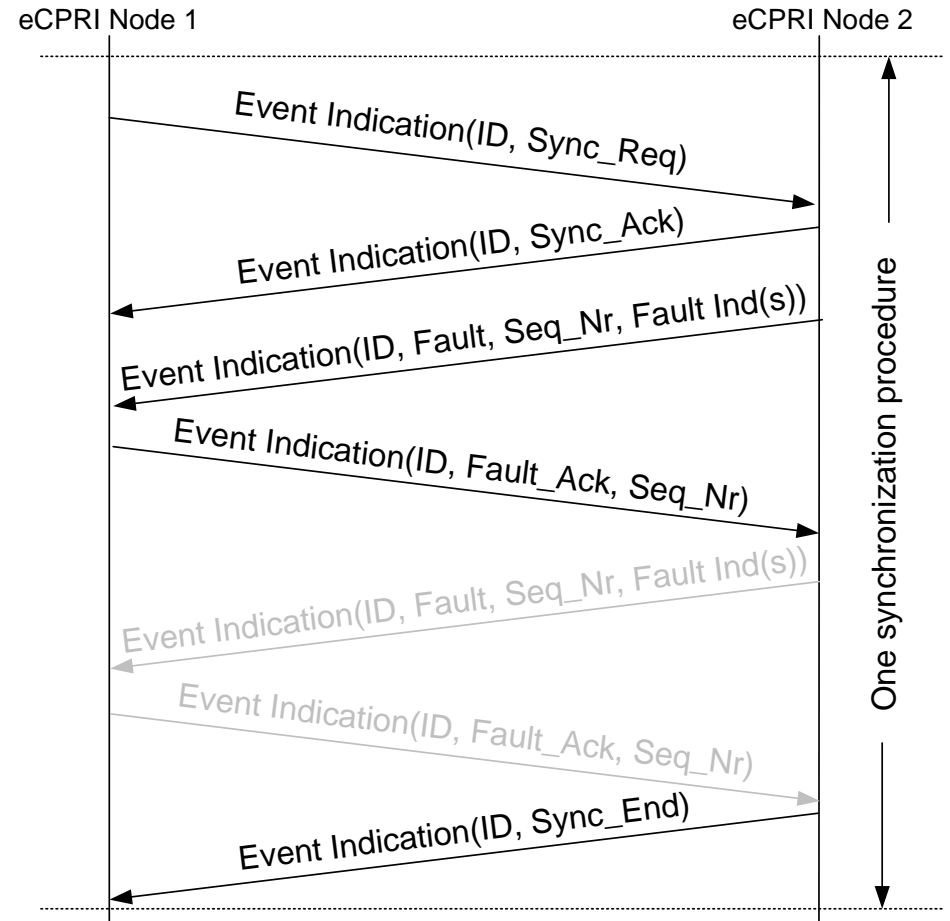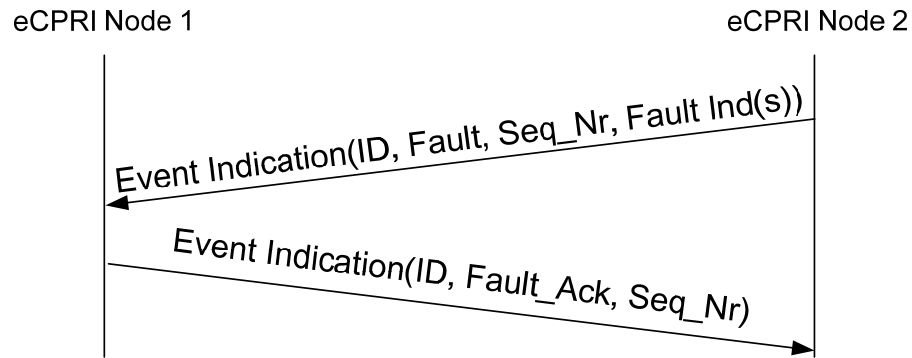For consistency check a synchronization request procedure is defined.

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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

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
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.
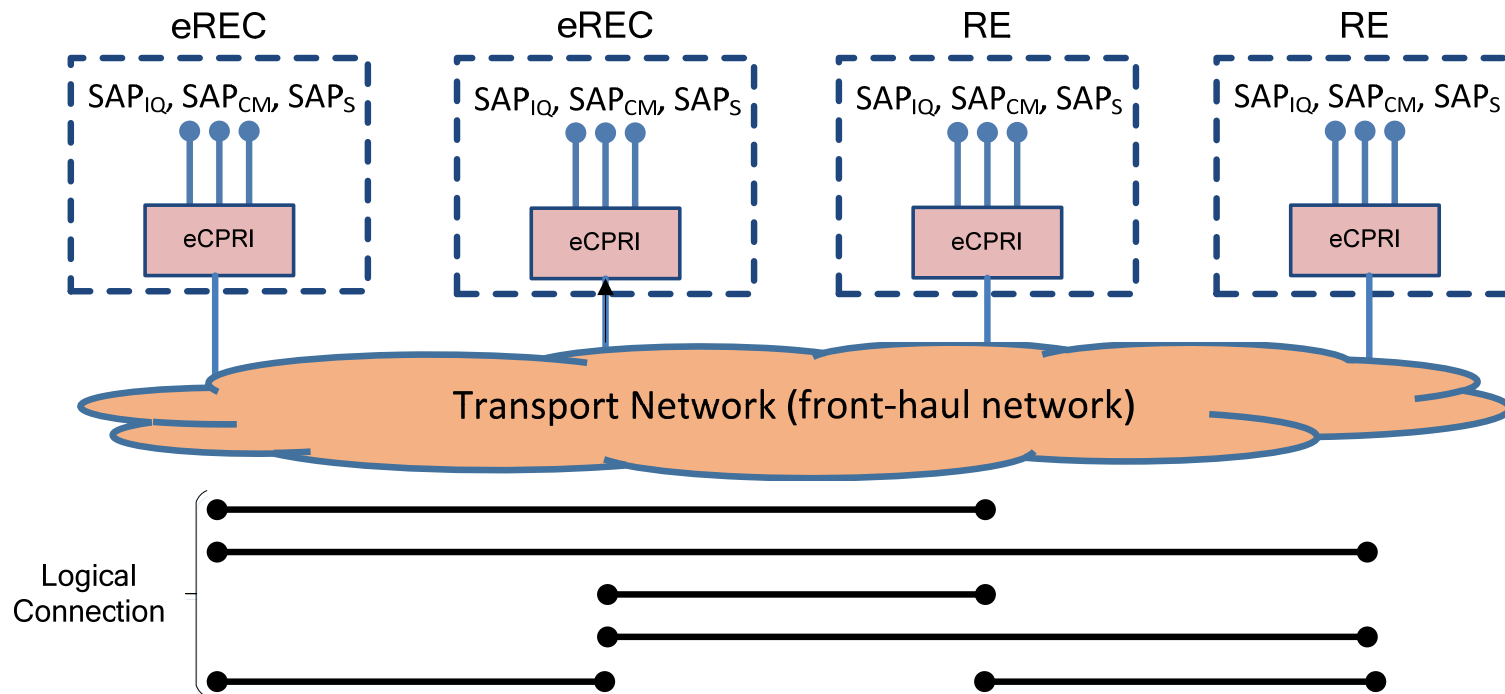
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eCPRI Networking (1/2)
CPRI networking reminder

CPRI networking example
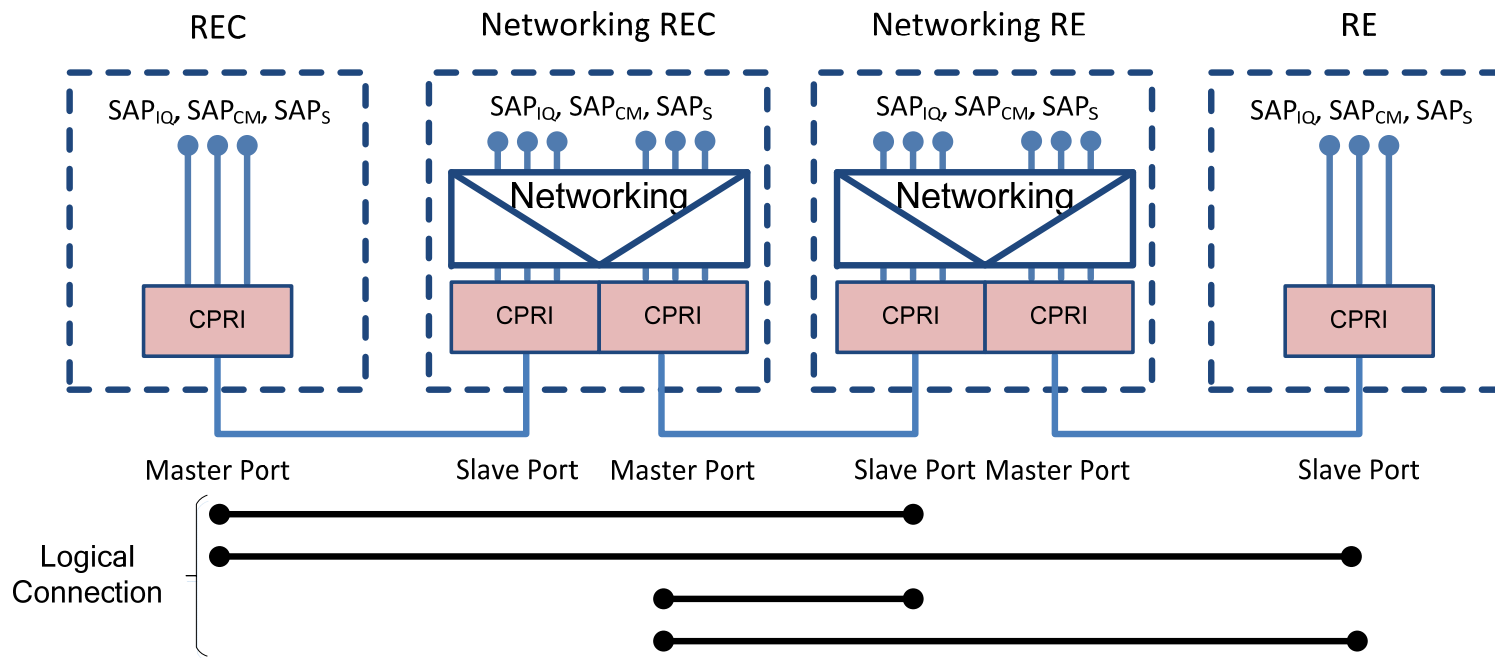
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eCPRI Networking (2/2)

eCPRI networking principle

eCPRI networking example