EPON suitability for Fronthaul

Mark Laubach

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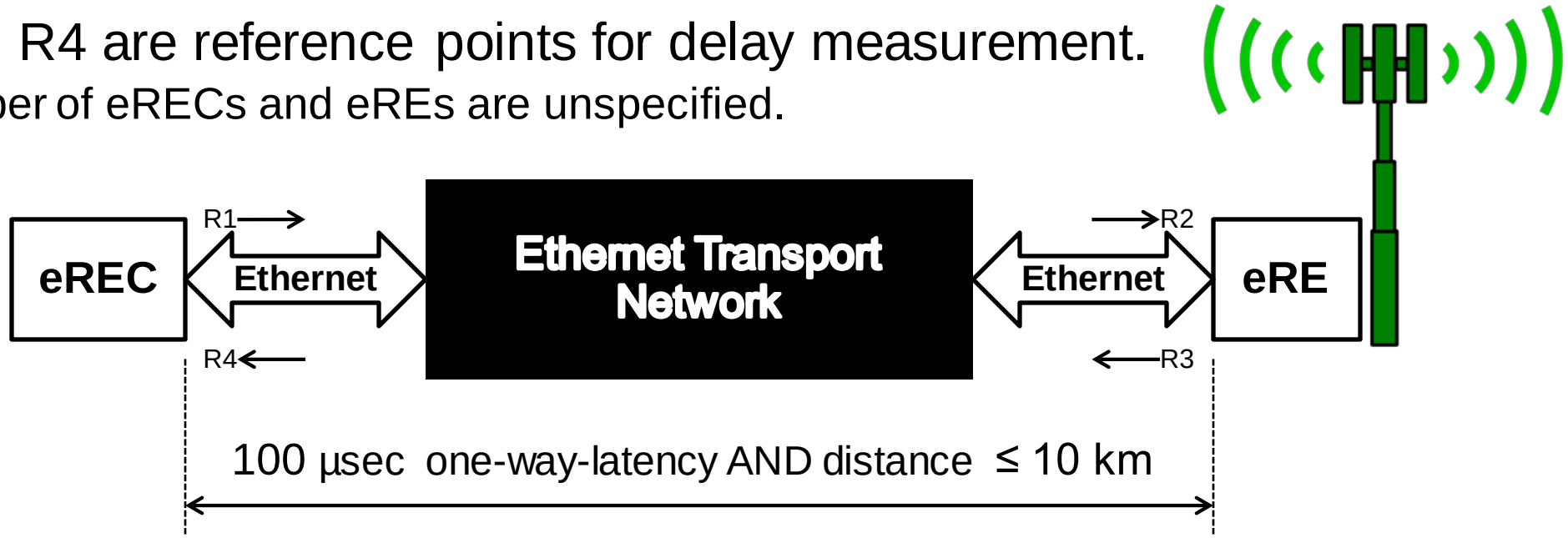
Introduction

- Several contributions have presented information on mobile fronthaul raising the question on applicability of using EPON and highlighting the end-to-end latency requirements of:
  - eCPRI, specifies 100 µsec for the most stringent one-way-latency
  - 3GPP, specifies a 250 µsec one-way-latency
- There is also IEEE 1914.3. Radio Over Ethernet Encapsulations and Mappings.
  - Alternative standard to eCPRI. One way latency is also 100 µsec.
  - Status: IEEE SA sponsor ballot group is forming, invitation closes 1/17/18 at 23:59 ET.
- eCPRI has been published and will be the focus of this presentation.
- There are questions:
  - Q1: Where are the measurement points for the one-way-latency?
  - Q2: What is the nature of the traffic flow(s) in each direction?
  - Q3: What are the delay variation requirements?

Q1: Where are the measurement points for the one-way-latency?

- Hallway conversations with 802.1 TSN eCPRI “folks” in Orlando:
  - Transport is viewed as a “black box” between the eREC (radio equipment control) and eRE (radio equipment).
  - 100 µsec one-way-latency.
    - Measured from first bit transmitted to last bit received.
  - 10 km max distance.
- R1, R2, R3, R4 are reference points for delay measurement.
  - Note: number of eRECs and eREs are unspecified.



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Ethernet Transport Network and Latency

- The Ethernet Transport Network includes all network devices and interfaces:
  - Bridges, switches, access network equipment, etc.
- For one-way latency for either endpoints R1 to R2 or R3 to R4:
  - Physics: 10 km of fiber consumes 50 µsec propagation delay of the 100 µsec budget.
  - 50 µsec remains for the Ethernet Transport Network.
    - Includes all latency contributions from standards and vendor implementations.

For more information:

- Work is ongoing in IEEE 802.1CM Time Sensitive Networking for Fronthaul:
  - http://www.ieee802.org/1/pages/802.1cm.html
  - eCPRI related presentations in 802.1CM.
  - References to MEF 10.3 one-way frame delay for Carrier Ethernet Network.

What is eCPRI data and rates?

- Different messages are traffic classes are defined (see Backup Material).
- Real-time radio encapsulated data sent as Ethernet frames, constant bit rate:
  - Continuous (Class 1).
  - With an on/off mask (Class 2) with additional control channel data.
- Examples in eCPRI use the same scenario for a 64 antenna site and IQ sampling (assuming Class 1):
  - ~3 Gb/s in downlink (downstream)
  - ~1.5 Gb/s in uplink (upstream)
  - Observation: 2:1 asymmetry ratio

  Note: unclear from examples how many eRE units are assumed.

Q3: What are the delay variation requirements?

- From eCPRI Spec, Section 6.2.2: “The requirement value depends on vendor specific choices related to desired performance for the wireless network, expected delay variation in fronthaul network etc.”
- From eCPRI Spec, Section 6.3.1:
  - DL (downstream link) from eREC (R1) to eRE (R2) for one-way “T12”:
    - Statistical variation, range limited between $0 \le T12_{min} \le T12 \le T12_{max}$.
  - UL (upstream link) eRE (R3) to eREC (R4) for T34.
    - Statistical variation, range limited between $0 \le T34_{min} \le T34 \le T34_{max}$.
  - $T12_{max}$ and $T34_{max}$ are referenced to “Table 1 Split E and splits ID, IID, IU requirements” in the document Requirements for the eCPRI Transport Network (eCPRI Transport Network D0.1 (2017-08-30)). For the “High” Class of Services (CoS) the value is 100 µsec.
- Generally, a maximum one-way packet delay variation ≤ 100 µsec.

Along comes EPON

- Discovery processing (802.3 Clause 64.3.3) impact on upstream latency:
  - OLT periodically makes available Discovery Time Windows to register off-line ONUs.
    - The periodicity and Discovery Length are unspecified and up to the vendor.
    - All on-line (registered) ONUs are held off from transmitting during a Discovery Time Window.
  - Also, there may exist situations when the OLT requires that an ONU go through the discovery sequence again and reregister and there may be situations where an ONU needs to inform the OLT of its desire to deregister.
    - Forces ONU to go through discovery again; i.e., can't discover once and then never again offer future Discovery Time Windows.
  - Discovery length is typically > 1 round-trip time as it also includes sync time and laser on/off considerations for multiple ONUs transmitting non-overlapping Register Requests in the window.
- For 10 km of fiber a frame ready to go but just held for a Discovery Time Window:
  - Experiences a ≥ 100 µsec wait for Discovery Time Window + 50 µsec one-way propagation delay + all other "black box" delays resulting in ≥ 150+ µsec wait.
  - Exceeds fronthaul one-way latency, may also break maximum allowed packet delay variation.

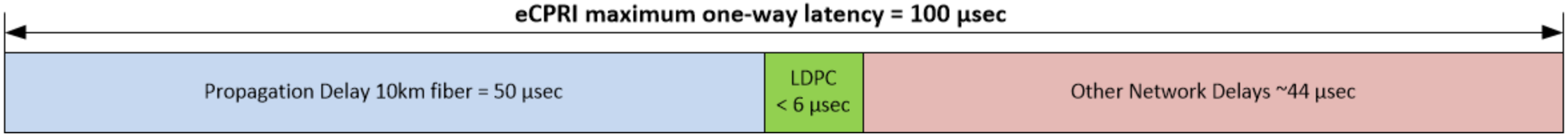
P802.3ca provides a workable solutions!

- Two channel DS and US:
  - Very workable.
  - Example:
    - Ch 0 for “vanilla” EPON, non-eCPRI traffic, maybe eCPRI non-real-time traffic, etc.
    - Ch 1 for eREC and eRE Class 1 and Class 2 traffic only, no upstream discovery processing. Should also work for alternative Radio Over Ethernet standards.

- Can single DS and US be made to work?
  - 802.3av provided a mechanism for unicast (directed) registration, so should P802.3ca.
    - If delays are measured at the time of ODN deployment and ONU MAC addresses are known, discovery process can be avoided all-together.
  - Other implementations are possible.

Summary

- The physics of propagation and impact on Discovery processing remain as the largest contributor to latency for any TDM PON.
- Is P802.3ca EPON suitable for fronthaul?
  - Yes. One method: two channel DS and US, removing discovery processing from one channel.
    - 25/25 Gb/s or 25/10 Gb/s would be available for fronthaul traffic; e.g. eCPRI Class 1 & 2.
- Is there sufficient latency budget for EPON in the Ethernet Transport Network?
  - Propagation delay of 50 µsec and total LDPC latency of < 6 µsec leaves ~44 µsec for other network delays.



- What about network delay variation?
  - Maximum delay variation never exceeds frame delay and can always be made smaller with playout buffer.

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Thank you

eCPRI Backup Material

eCPRI General Background on message types

- **eCPRI Specification V1.0 (2017-08-22)** http://www.cpri.info/spec.html
  - **For User Plane over Ethernet (Section 3.2.1, page 12)**
    - eCPRI Ethertype (AEFE16) http://standards-oui.ieee.org/ethertype/eth.txt
      - Expect VLAN tagging on all frames for all Ethernet-switched fronthaul.
    - Contents: eCPRI common header followed by payload.
    - Message types (8-bit type #):
      - 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
    - IQ Data is for the transfer of time domain or frequency domain IQ samples between the PHY processing elements split between eCPRI nodes (eREC and eRE). Actual IQ sample details, e.g. bit width, number of sample pairs in a message, and format are vendor specific.
    - Bit Sequence is for channel coded data before modulation mapping, vendor specific.
    - Real-Time Control Data is for vendor specific real-time control and management.
    - Generic Data Transfer , user data or control information, vendor specific.

Q2: What is the nature of the traffic flow(s) in each direction?

- Reference from 802.1CM cm-farkas-eCPRI-support-0917-v01.pdf
- Air interface traffic samples, transmitted via fronthaul:
  - Class 1 : Classical CPRI split, which is referred to as Split E for E-UTRA (Evolved Universal Terrestrial Radio Access) in eCPRI specification.
    - CPRI IQ data traffic, CBR, not correlated with the traffic of the User Equipment (UE), e.g. smart phone.
    - Same amount of data is sent each "fronthaul period" (T_F).
    - Single or multiple Ethernet frames per one period T_F .
    - Maximum Frame Loss Ratio = 10^{-7}.
    - MEF terms: CBR (CIR) with Excess Information Rate (EIR) = 0, green frames
  - Class 2 : Split {I D;II D;I U} for E-UTRA; split within the PHY layer.
    - User Data is correlated with UE traffic, e.g. (approximately) no data transmitted via fronthaul if UE does not transmit/receive data
    - On/Off mask on CBR traffic (periodic traffic with empty periods), on/off times not specified
    - User data of one period (T_F) may be carried in multiple Ethernet frames.
    - Downlink Class 2 User Data may have two components: UE data, E-UTRA control channel data
      - Control channel CBR , period $T_{E\text{-}UTRA\text{-}ctrl}$.
    - MEF terms: CBR (CIR) with EIR=0, or CIR with EIR>0 and some frames may be marked yellow


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