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IEEE 802.3ca Channel Bonding And Skew Remediation

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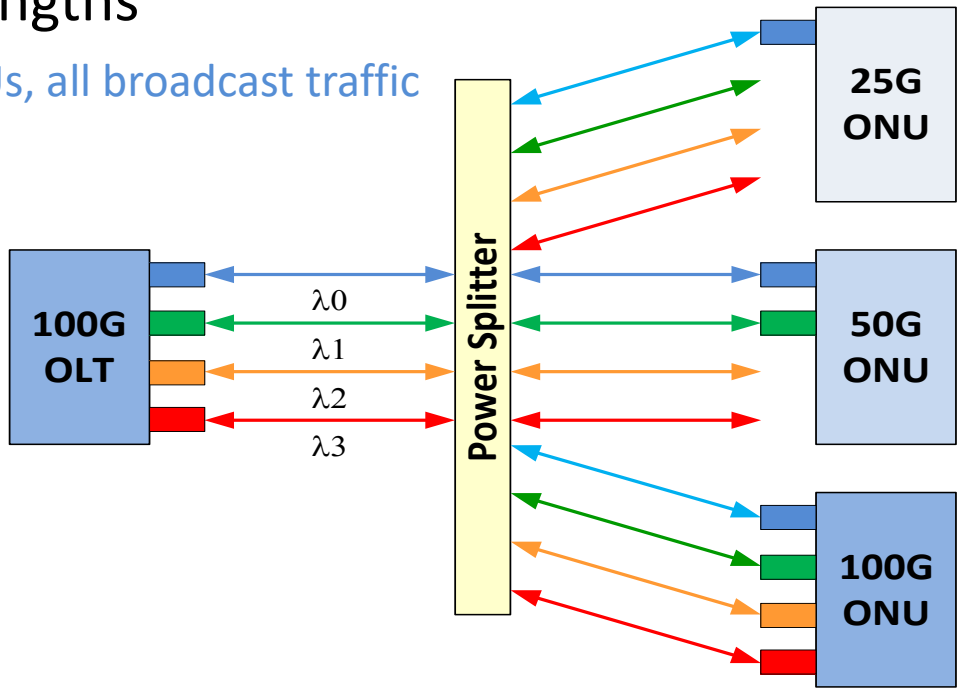
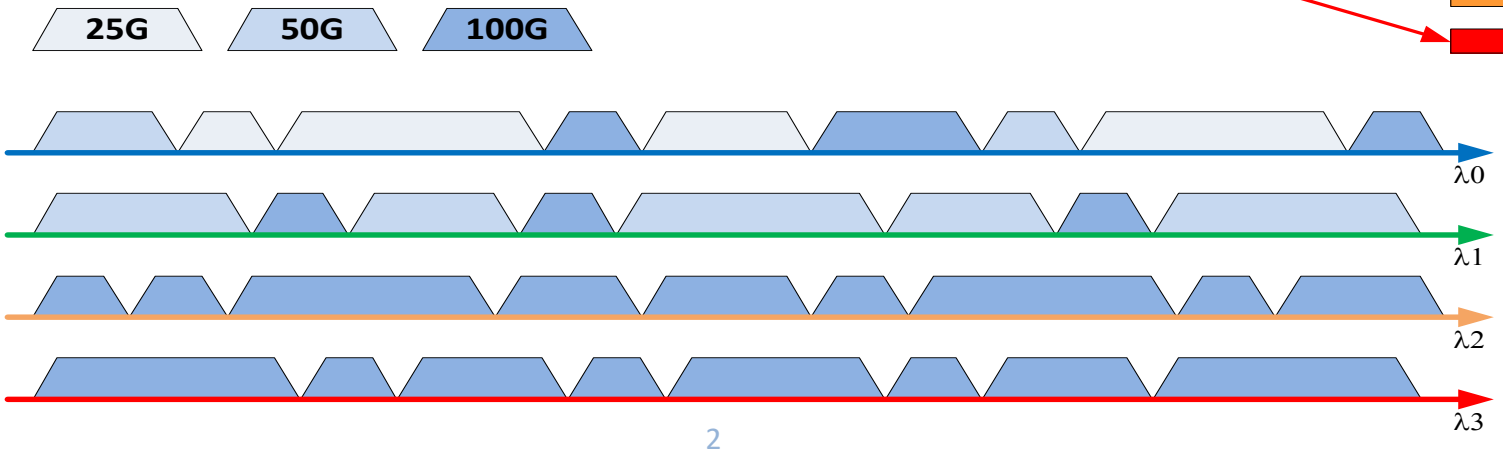
Multi-channel 100G-EPON

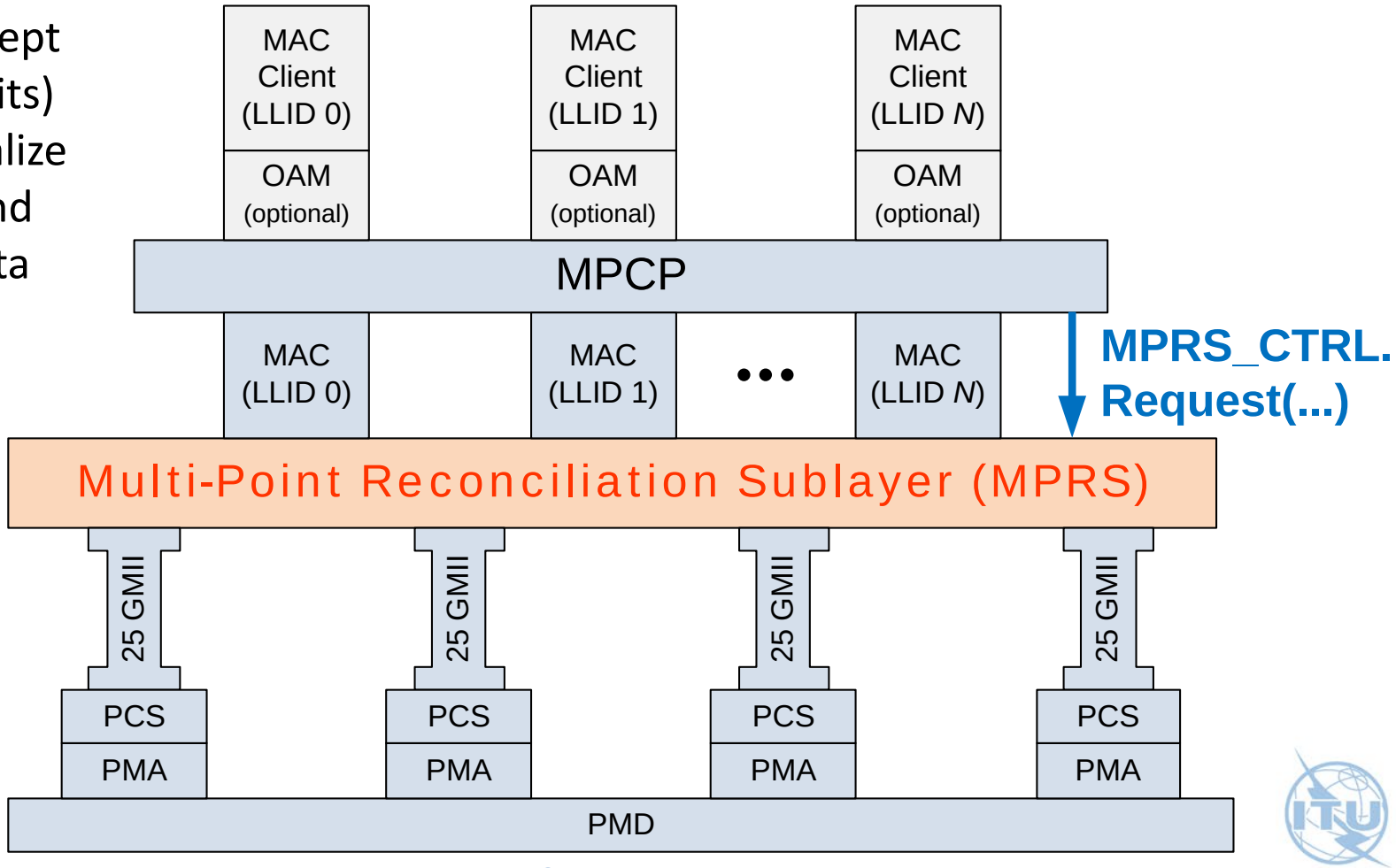
- 100G OLT serves a mix of 25G, 50G, and 100G ONUs
- Four DS and four US wavelengths
  - **λ0:** 25G, 50G, and 100G ONUs, all broadcast traffic
  - **λ1:** 50G and 100G ONUs
  - **λ2, λ3**: 100G ONUs
- Four independent schedulers upstream and downstream





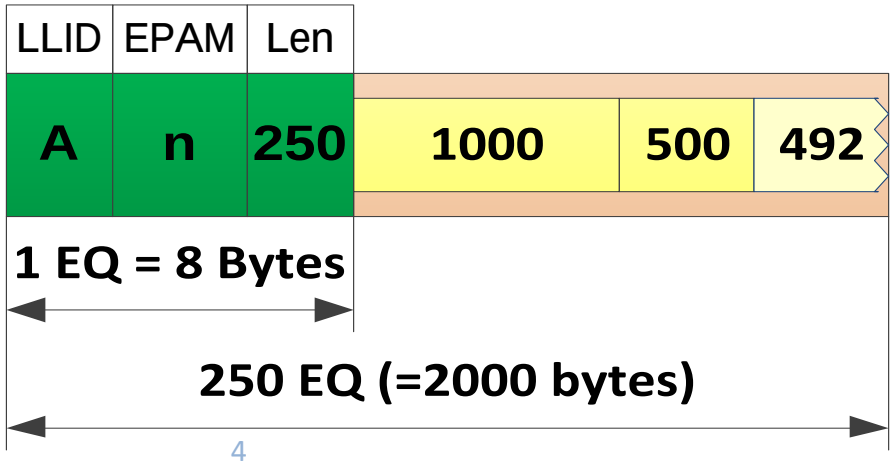
100G ONU Layering Diagram

- Each MAC is a 100 Gb/s MAC
- If not all four lanes are active at a given time, the MPRS will pause the MAC (i.e., not accept more bits) to equalize MAC and PHY data rates



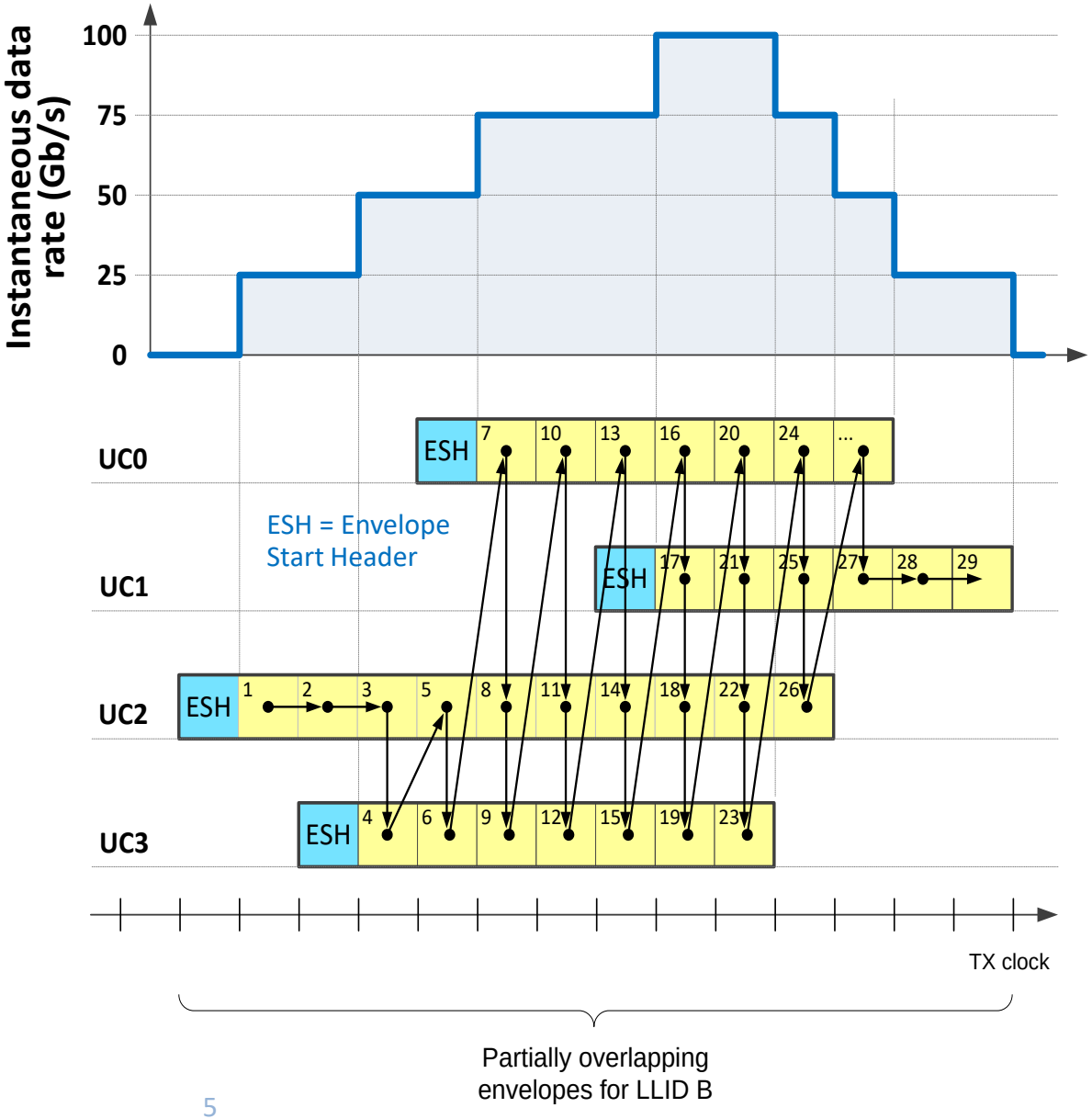
Transmission Envelope

- A grant may allocate bandwidth to multiple LLIDs
- **Envelope** is a continuous transmission by a specific LLID on a specific channel (wavelength)
- Structure of Envelope:
  - Wraps multiple user frames with a common ***Envelope Header***, that includes ***LLID***, ***Envelope Position Alignment Marker (EPAM)***, and ***envelope payload length***.
  - ***Envelope Length*** represents the number of units (***Envelope Quanta - EQ***) granted to a given LLID in a given grant on a given channel. Envelope Length includes the Envelope Header.
  - Beginning of an envelope payload may be a full frame or a tail segment of a frame.
  - End of the envelope payload may be a full frame or a head segment of a frame.



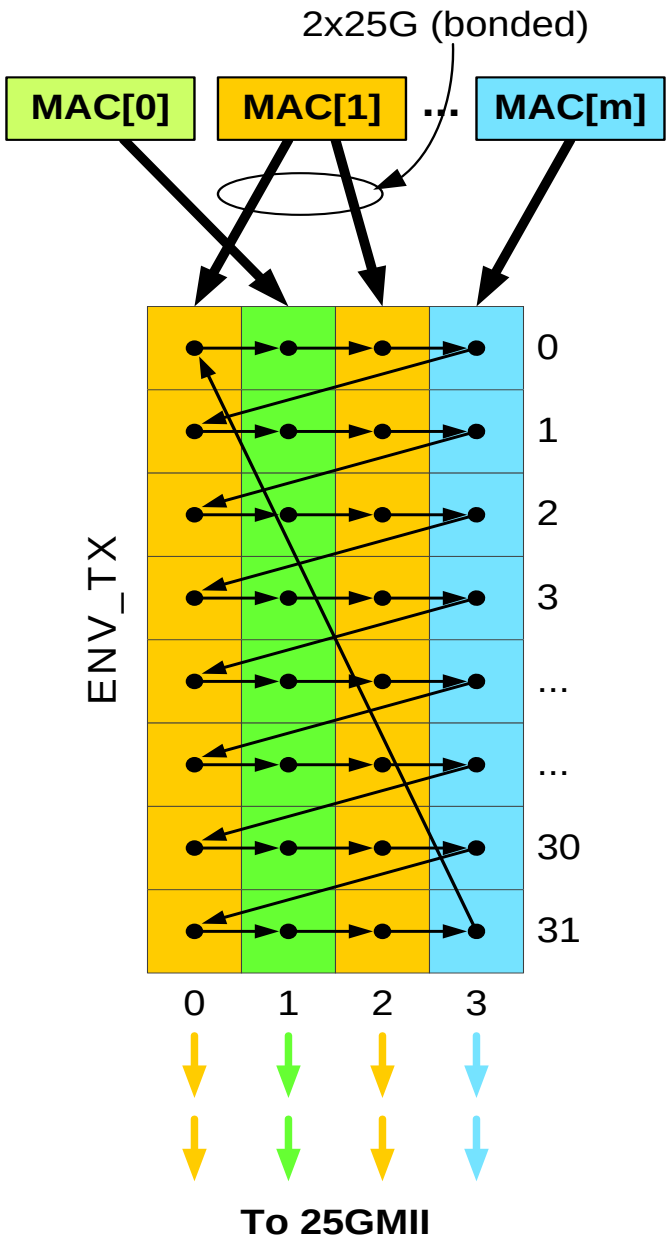
Channel Bonding

- Channel bonding refers to ability of a single LLID (single MAC) to transmit on multiple channels at the same time
- When a MAC transmits on multiple channels, its data stream is demultiplexed into multiple channels
- A unit of demultiplexing is the Envelope Quantum (EQ)
  - EQ represents 64 bits of data (not a fixed duration of time like TQ)
    - At 25GB/s, an EQ takes 2.56 ns
    - At 10Gb/s, an EQ takes 6.4 ns.



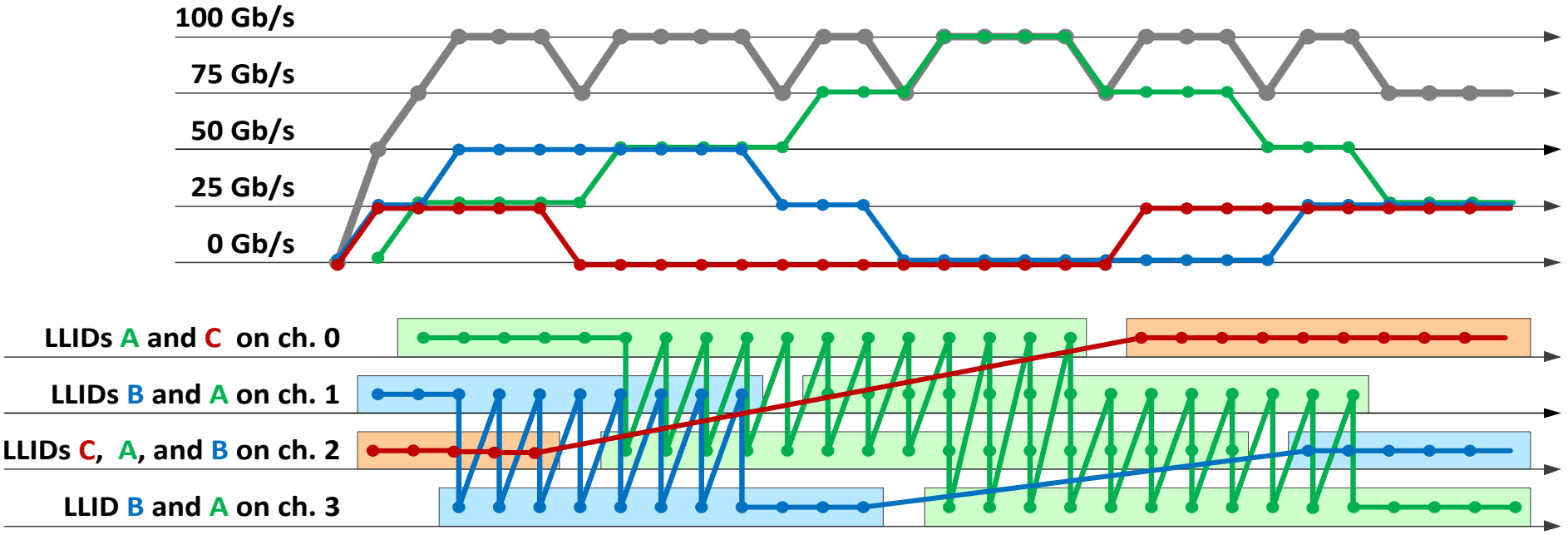
2D Alignment Buffer

- MPRS Channel Bonding is built around the 2D Envelope Alignment buffer (called **ENV_TX** at the transmitting end and **ENV_RX** at the receiving end)
  - Each cell in the buffer stores one EQ
  - The buffer has N columns and M rows.
    - ***N*** – number of channels (***N***=4 for 100 Gb/s ONU, ***N***=2 for 50 Gb/s ONU, ***N***=1 for 25 Gb/s ONU)
    - ***M*** - should be twice as large as the maximum skew / propagation delay variability (in 802.3ca, ***M***=32)
  - The buffer is filled and read in cyclic pattern row-by-row
- When four LLIDs transmit in parallel on separate channels, the source for each cell in a row would be a different LLID (MAC)
- When one LLID transmits over 4 channels (channel bonding), the source for each cell in a row is that LLID (MAC)
- Many other combinations are also possible (2+2, 3+1, 2+1+1)



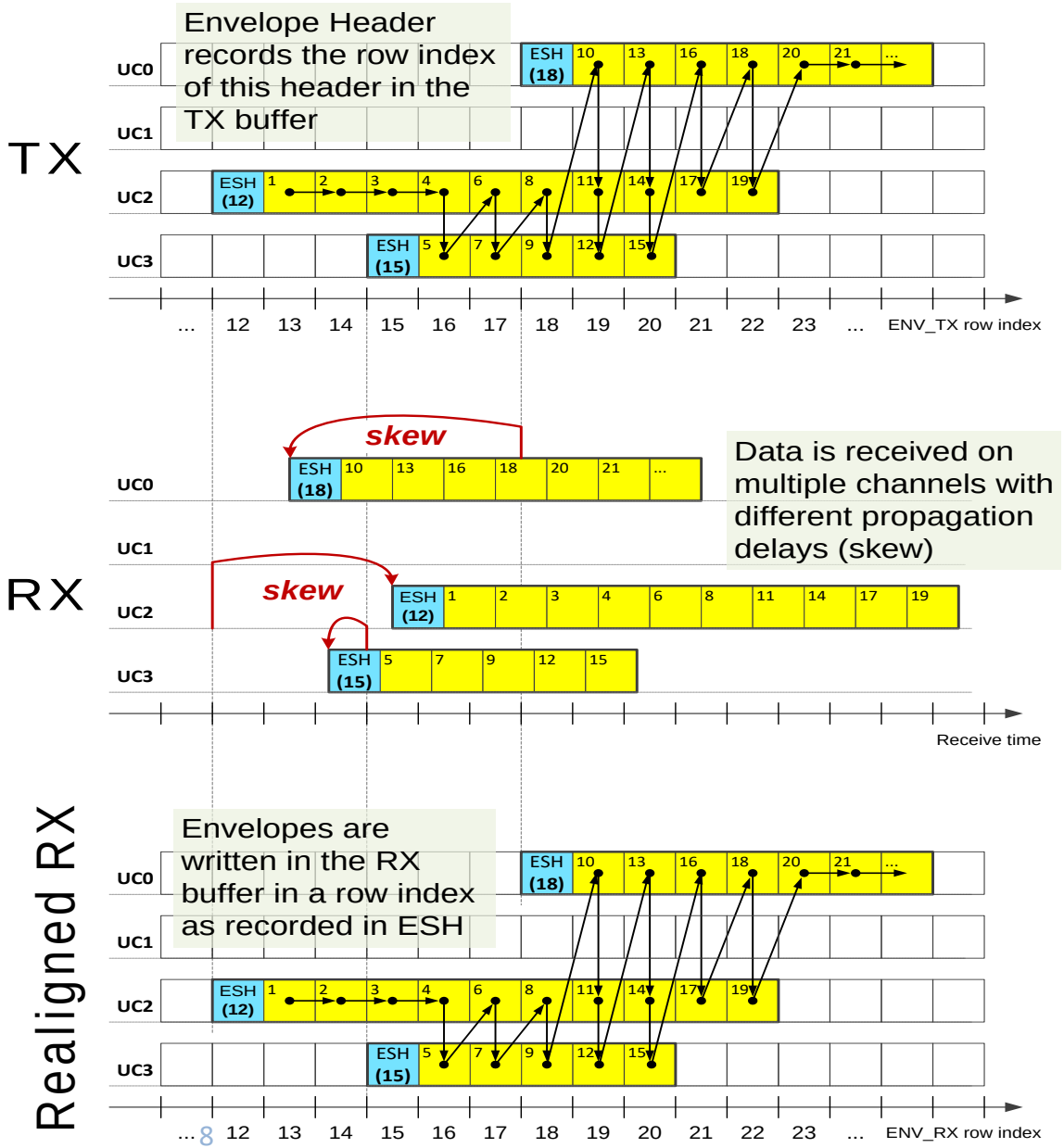
Independent Schedule on Each Channel

- Envelopes for different LLIDs can be scheduled independently on different channels
- MPRS will automatically interleave the EQs to fully utilize granted envelopes.



Skew Remediation

- No matter at what time a particular EQ is received, it is written in ENV_RX buffer in the same location (row) that it had in the ENV_TX buffer.
- Thus, the relative alignment of envelopes in the ENV_RX buffer is identical to the alignment these envelopes had in the ENV_TX buffer.
- As a result, EQs are passed to the receiving MAC in exactly the same order that they were sourced by the transmitting MAC



Conclusion

- 802.3ca standard will support channel bonding
- The problem of skew remediation was solved in space domain, rather than in time domain.
  - Dealing with time is hard -- Requires infinite timing resolution since skew may take values on a continuous timing scale.
  - Dealing with space is much easier -- Just need to determine the proper location to store each received data unit in the RX buffer.
- Skew remediation mechanism equalizes all delays between transmitting and receiving MPRS Service Interfaces on all channels
  - Propagation delays
  - Jitter in any sublayers below MPRS (25GMII, PCS, PMA, PMD)