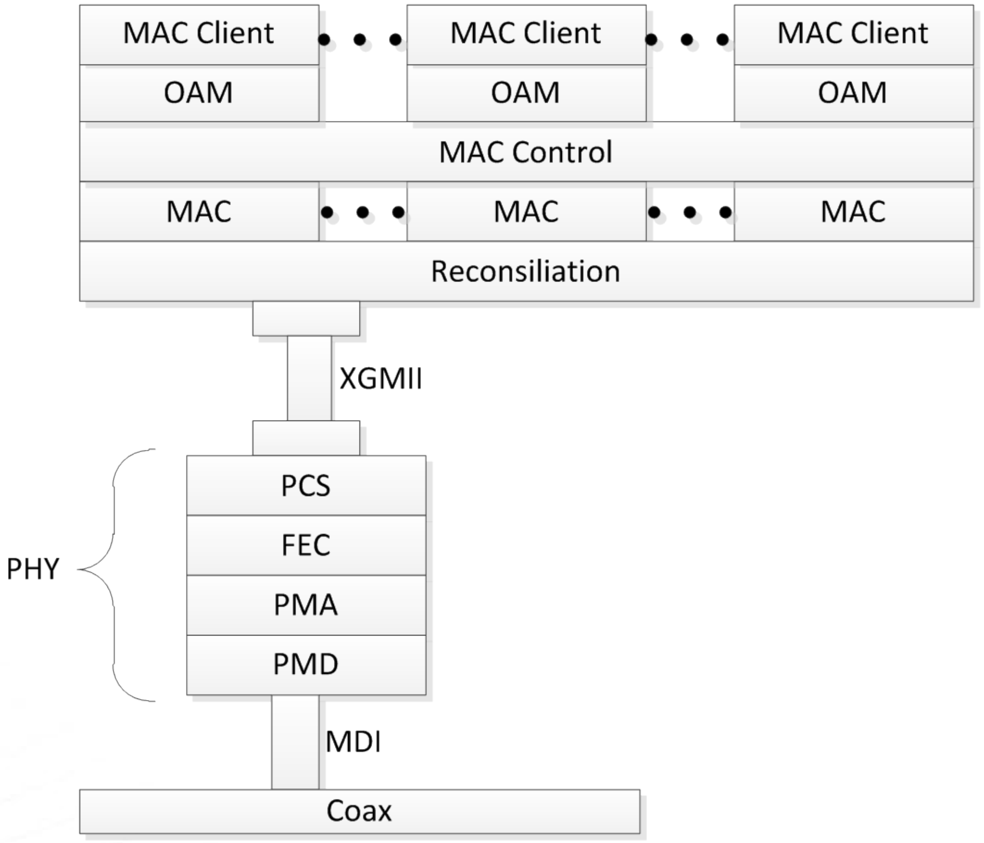
MPCP TIMING IN EPOC

Ryan Hirth, Avi Kliger, Rich Prodan

LAYERING

- **MAC Control has no visibility to PHY**
  - Cannot align to RBs or OFDM frames
  - Does not control PHY ranging or probes
- **MAC operates at 10Gbps**
- **MAC only matches rate to the PHY**
  - IDLE insertion/deletion
  - Rate is a global parameter
- **Layer restricts many options, but ultimately simplifies the solution**



UPSTREAM DATA DETECTOR

- **The Data Detector is used in EPON to enable/disable the Laser**
  - The Data Detector is located in the PCS.
- **EPOC can use a similar data detector to enable transmission on an RB boundary.**
  - Packet data is not aligned to RB boundaries. IDLEs fill unused data on the first and last RB to maintain timing alignment of the packet.

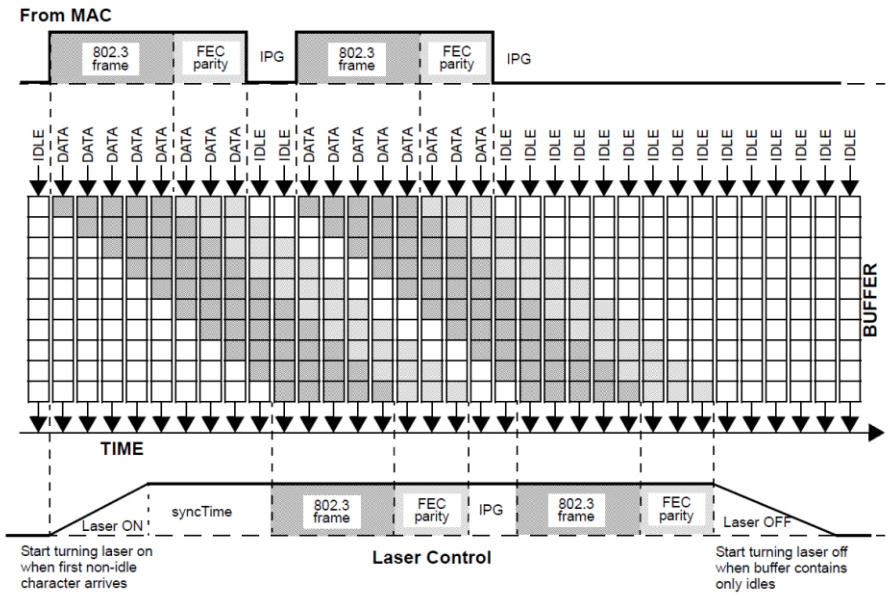
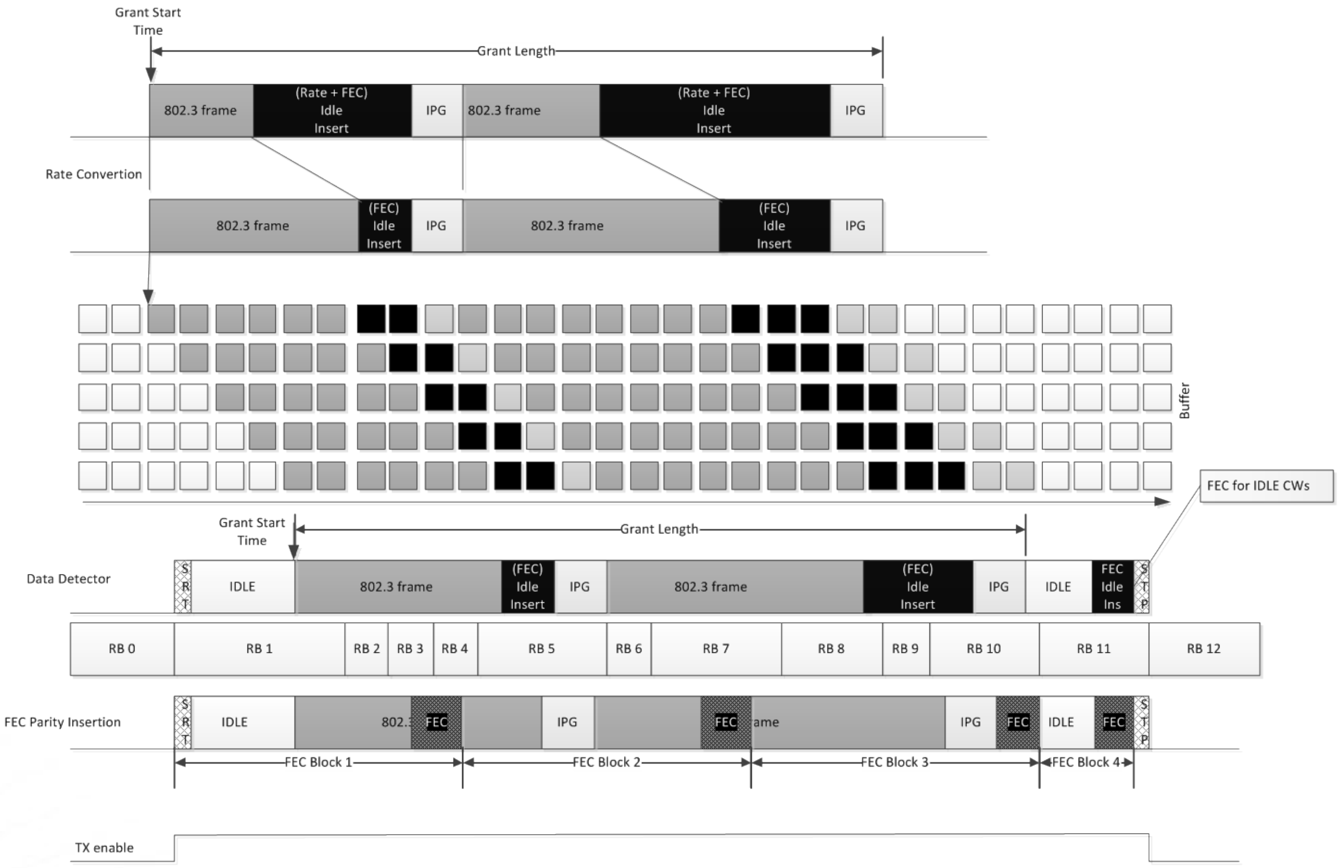


Figure 65–5—Laser control as a function of buffer fill

EPON Example

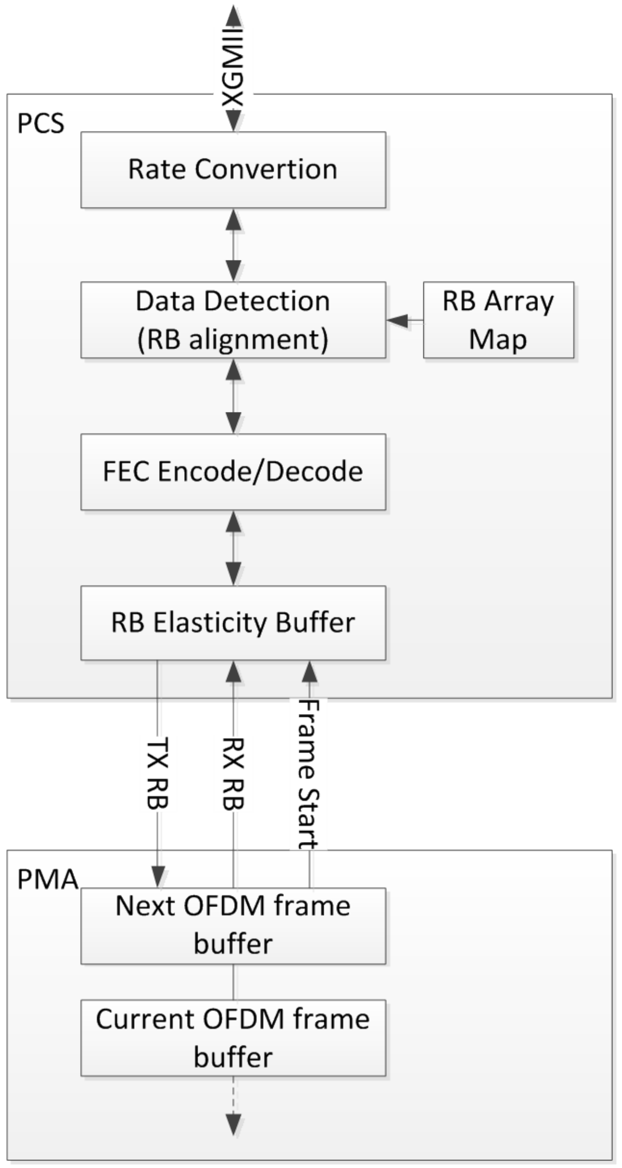


- Bytes per RB ~ 10B to 160B
- 0<->1 RB of IDLE at start
- 0<->1 RB of IDLE plus FEC parity at end
- 0<->N RB of grant spacing
- Data detector pipe delay is a maximum size RB

BLOCK OVERVIEW

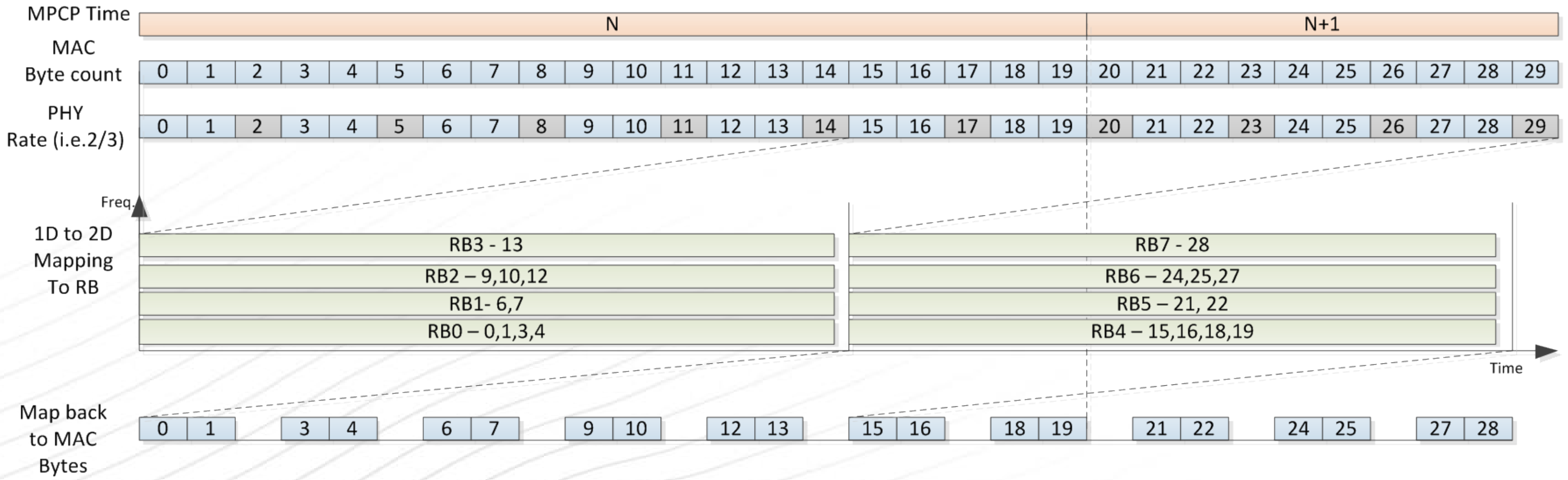
New page

- **Rate conversion**
  - removes IDLEs and adjusts for average bit rate
  - Converts to PHY clock domain
- **Data Detector**
  - Aligns to RBs and maintains MPCP timing
  - Inserts Idles at end of burst to align to FEC codeword block size
  - Inserts start and end markers
- **FEC**
  - TX - removes IDLEs for FEC and inserts parity
  - RX- Performs correction and inserts IDLEs per frame
- **RB Elasticity Buffer**
  - Allows for probe frames and PHY discovery to be inserted without distorting time
  - Aligns RBs to OFDM frame



MPCP RATE ADAPTATION

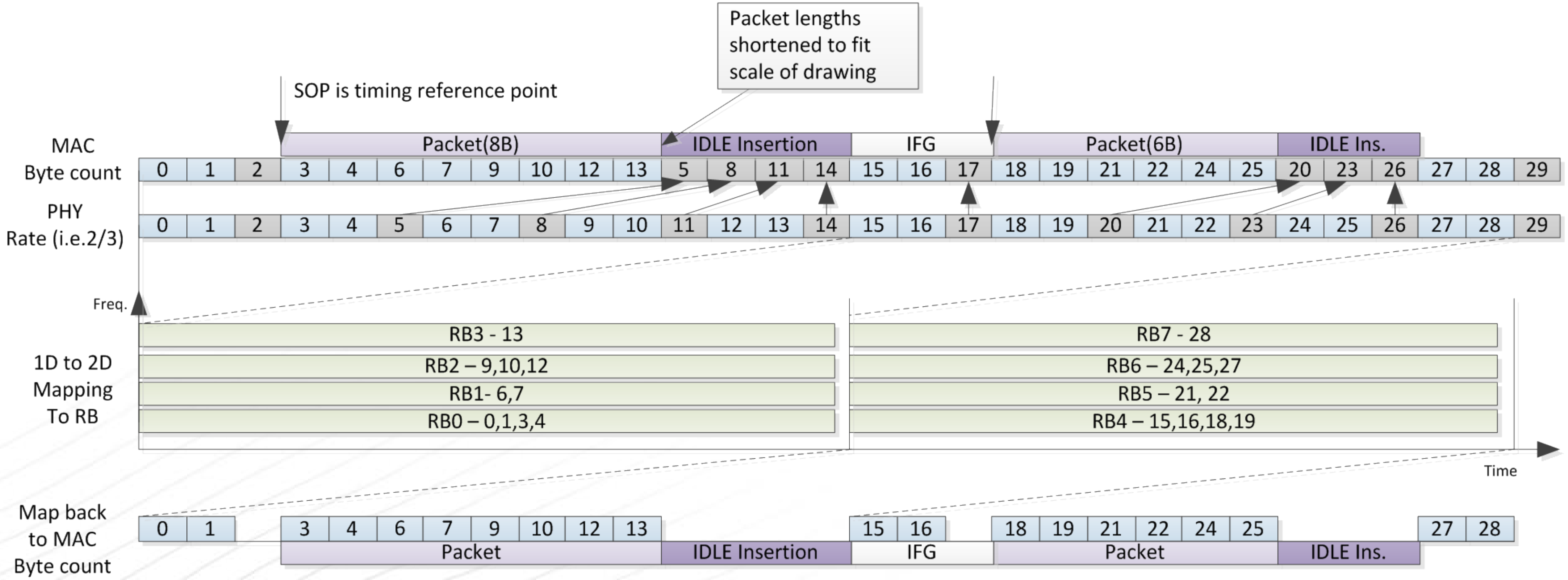
- **At MAC Control layer 1TQ=16ns. At PHY layer TQ is not defined.**
- **CNU and CLT follow the same 1D-to-2D-to-1D mapping**
  - Byte sequence and thus time reference is maintained
    - Loss of MPCP timestamp fidelity will occur only when PHY rate is less than 500Mbps (<1TQ).
    - Below 500Mbps uncertainty will start to impact 12TQ jitter budget



- **Example part 1 (Byte ordering):**
  - The PHY rate in this example is 2/3 *10Gbps.
    - For illustration the every 3rd byte is eliminated. No line coding is shown for simplicity.
  - Byte sequence timing is maintained after 1D-2D-1D mapping

RATE CONVERSION WITH IDLE INSERTION

- **Idle insertion/deletion is used to match the MAC to the PHY rates**
  - Eliminated bytes are moved and accounted for at the end of a packet



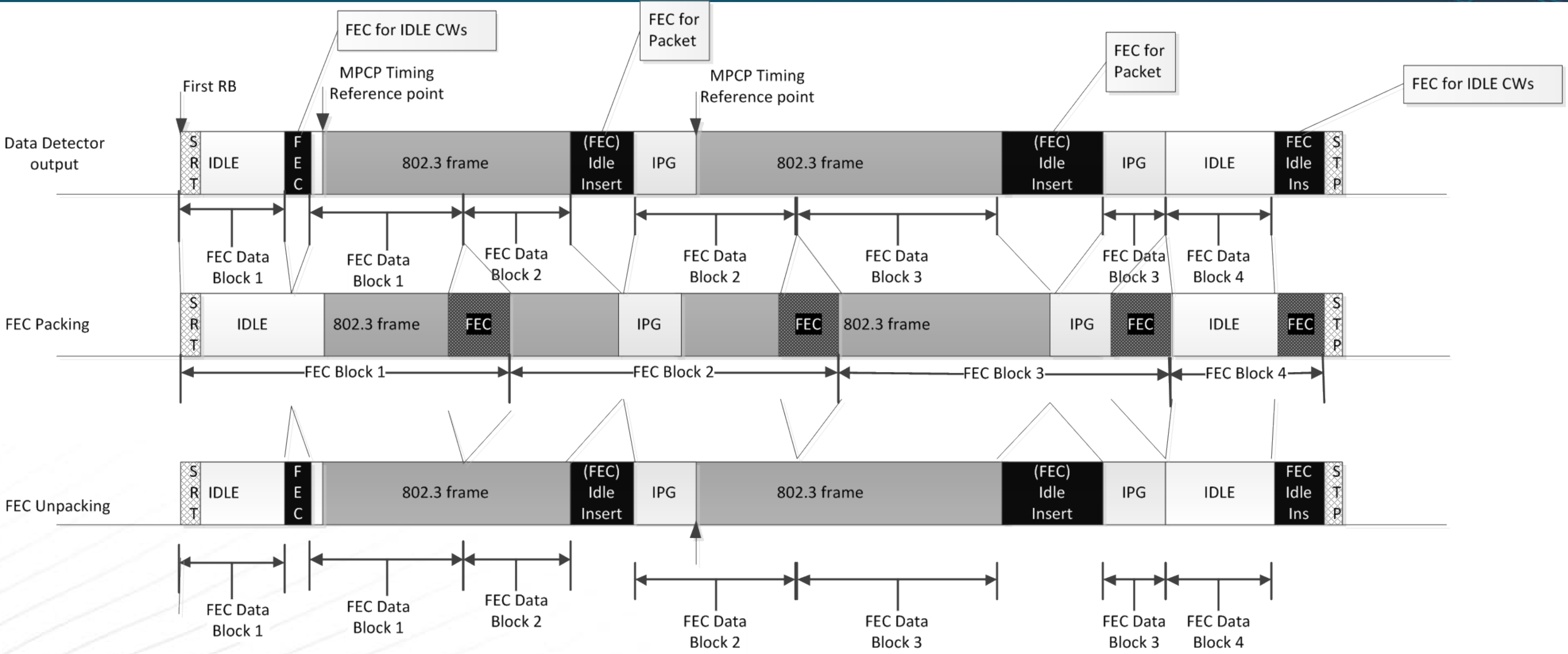
- **Example part 2(Idle insertion for rate difference):**
  - *Notes:*
    - *Packet lengths are shortened for scale. Actual packets length are standard IEEE 802.3. FEC is not shown.*
  - Eliminated bytes within packet time are accumulated and transferred as Idles at end of packet
  - The Start of Packet is the timing reference point. The timing is maintained after 1D-2D-1D mapping.

CLOCK ADAPTATION

New page

- **The PMA and MAC may all operate on different clock domains.**
- **Conventional methods of IFG compression and expansion may be used to compensate for small differences in clock rates. (100PPM typically)**
- **The Rate parameter needs to be accurate to this tolerance.**
- **TX Clock adaption should not decrease an IPG to less than 12B average.**
- **IFG timing adjustments also allows for rate parameter changes. This simplifies the synchronization of dynamic adjustments.**
- **Clock adaption must be done above FEC due to IDLE deletions.**
- **The maximum TQ error without clock compensation is 7TQ over a maximum size burst (100ppm). Clock adaptation can reduce this to 1TQ.**

FEC PARITY PACKING

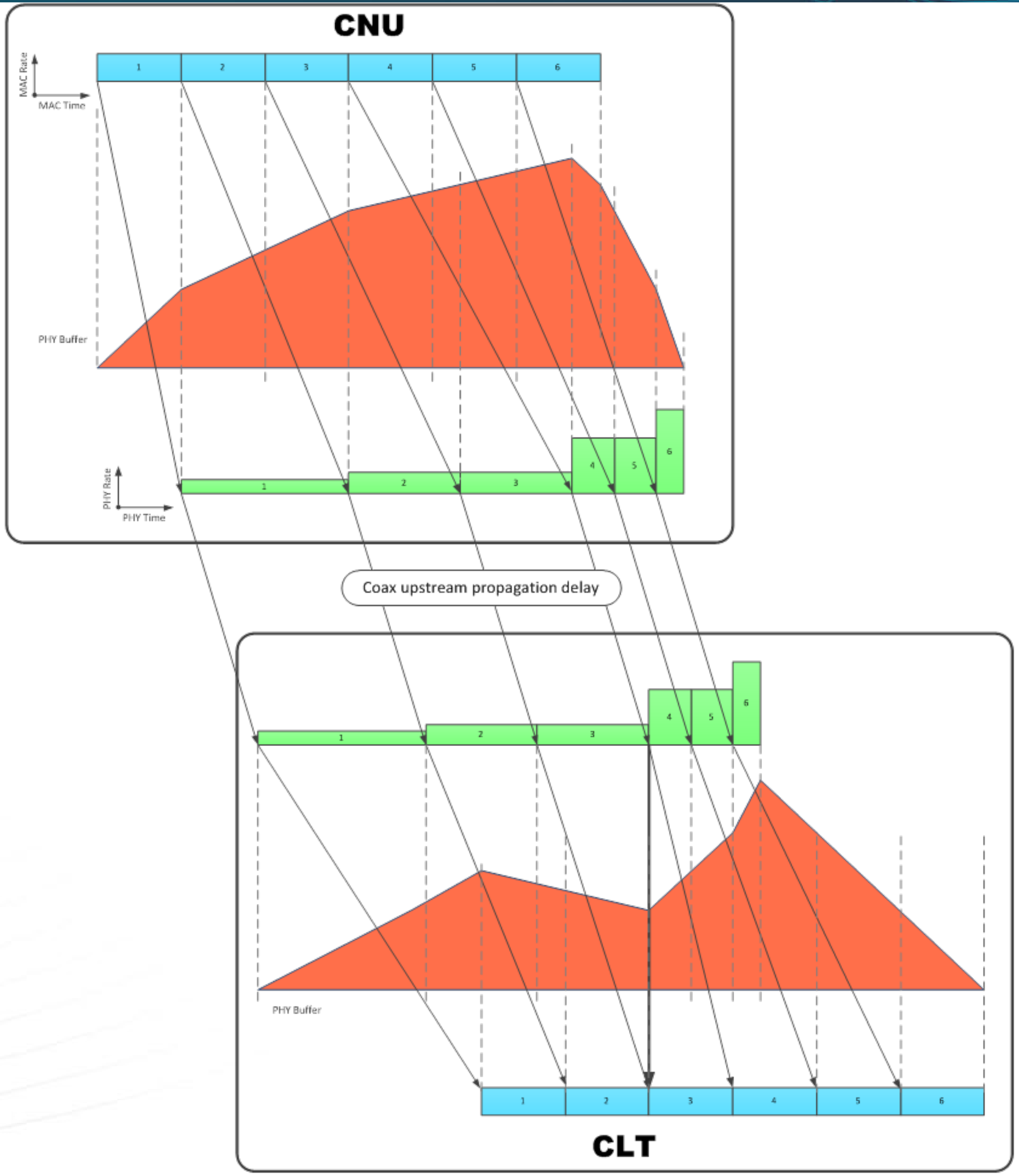


- A “FEC IDLE” is generated based on the FEC parity overhead
- “FEC IDLEs” within a frame are stored until the end of the frame
- A running accumulator maintains count of how many and when FEC IDLEs are inserted
- The last FEC block is a shortened block. FEC may occur on bit level boundaries.
- FEC Packing removes FEC IDLEs and replaces them with FEC Parity on block boundaries.
- The inverse function is used to unpack the FEC parity and insert FEC IDLEs
- Timing is maintained before and after FEC

ELASTIC BUFFER

- **The PHY requires an elastic buffer to adapt a constant MAC input rate to a variable PHY rate.**
- **Buffer must be sized to accommodate the largest capacity variation throughout an OFDM frame.**
  - The MAC fills the buffer based on a Rate Parameter, FEC parity, and burst overhead.
  - The PHY pulls from the buffer to fill RBs.
- **Rate is a global parameter shared between the MAC and PHY**
  - Minor adjustments due to clocking can be accommodated by IFG adjustments

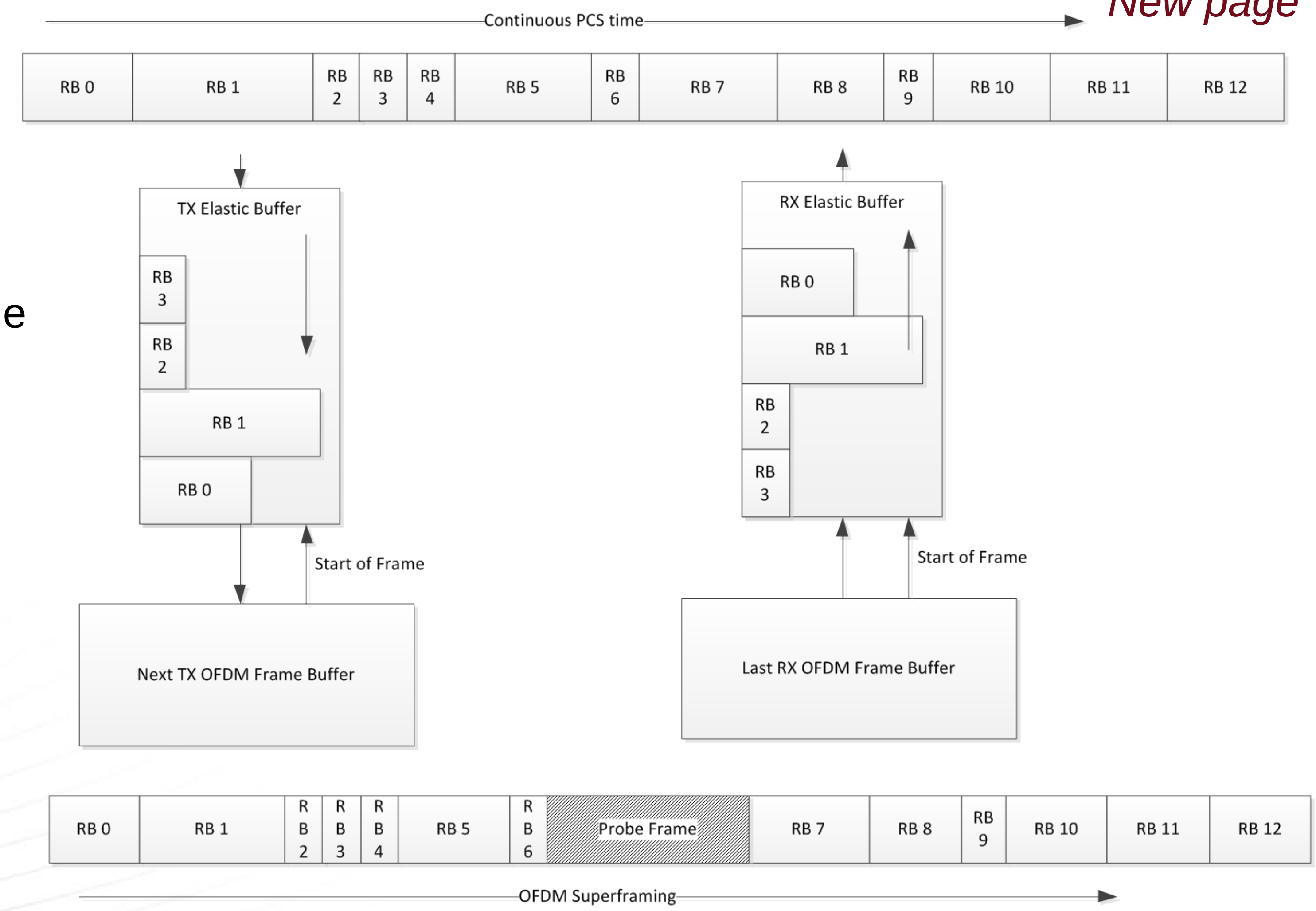
At MAC level blocks are all of the same size because MAC sends at a constant rate. AT PHY level, they grow or shrink in time depending on the rate of a given block. The picture shows blocks ordered by increasing capacity (rate). Red graphs show corresponding buffer dynamics in the CNU and the CLT.



SUPER FRAME MAPPING

New page

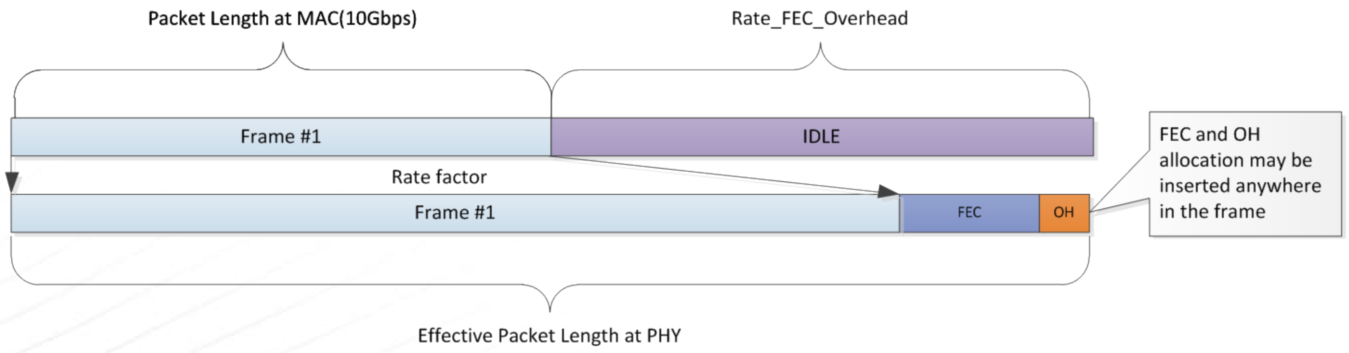
- **Superframe allows Probe frames and PHY discovery to be periodically inserted.**
  - Does not jitter MPCP time
  - Does not require P-frame scheduling at the MPCP layer
- **Data is not moved between RBs**
- **Data is stored in the TX Elastic buffer until the OFDM frame starts**
  - It will then fill the Frame Buffer
- **The RX elastic buffer will store received RBs and play them out at PCS line rate**
- **The number of bits transferred in a superframe is equal at the PCS and PMA layers**



IDLE INSERTION FORMULA

- **The** FEC_Overhead(length) **formula in Clause 77 needs to be updated to include rate as well as EPoC FEC.**
  - Packet example:

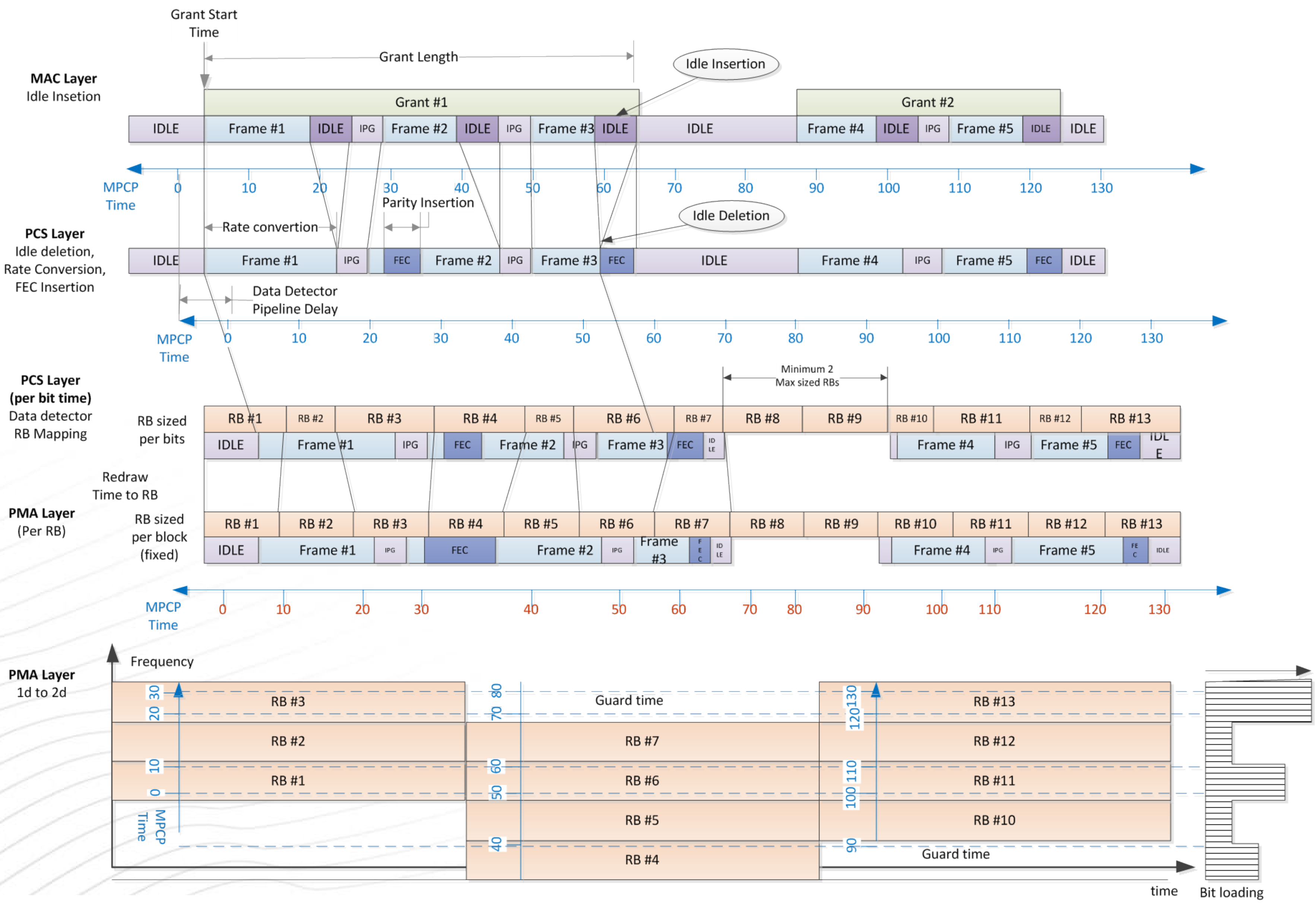
    *Rate_FEC_Overhead(length) = ((length + FEC parity + grant OH)*10Gbps/rate)-length*



  - IDLE code words are also covered by FEC. FEC Idles for parity must also be inserted whenever the percent of FEC OH is greater than a code word or at the end of the burst.

MPCP TIME SUMMARY

- **Rate adaption and FEC packing may be combined and MPCP timing is maintained.**
- **Idle insertion is used to match MAC and PHY rates over a frame.**
- **The Data Detector is used to align to RB boundaries.**
- **An elastic buffer in the PHY is used to absorb the variation in bit rates.**



MPCP DISCOVERY

- **MPCP discovery operates above the PHY layer**
  - PHY will first perform Initial and Fine Ranging to calibrate and align OFDM symbols
  - MPCP discovery is independent of PHY ranging.
- **MPCP discovery aligns MPCP timestamps and measures the RTT at the MAC layer**
- **MPCP discovery GATE is not aligned to OFDM frames.**
  - Discovery Grant may cross one or more OFDM frames
- **MPCP discovery GATE time is sized based on the RTT to provide guard time from data GATEs.**

IMPACTS TO DBA

- **CNU Reports queue length without overhead**
  - DBA may use the reported queue lengths to determine grant length
  - Follows the same model at 10G EPON
- **GATEs may adjust for Grant overhead for RATE, FEC, markers, …**
  - Overhead follows same function as the IDLE insertion rate
- **RATE variation over a OFDM frame profile is covered by the elastic buffer**
  - PHY average rate may be used by DBA calculations.
  - Grants may cross multiple OFDM frames.

SUMMARY

- IEEE layering is maintained between the MAC and PHY
- MPCP Timing can be maintained through 1D-to-2D mapping
- Data detector will align upstream grants to RB boundaries
- IDLE insertion will account for overheads including RATE and FEC
- The PHY will have an elasticity buffer to adapt rate across an OFDM frame