Data-rate adaption function for EPoC (baseline proposal)

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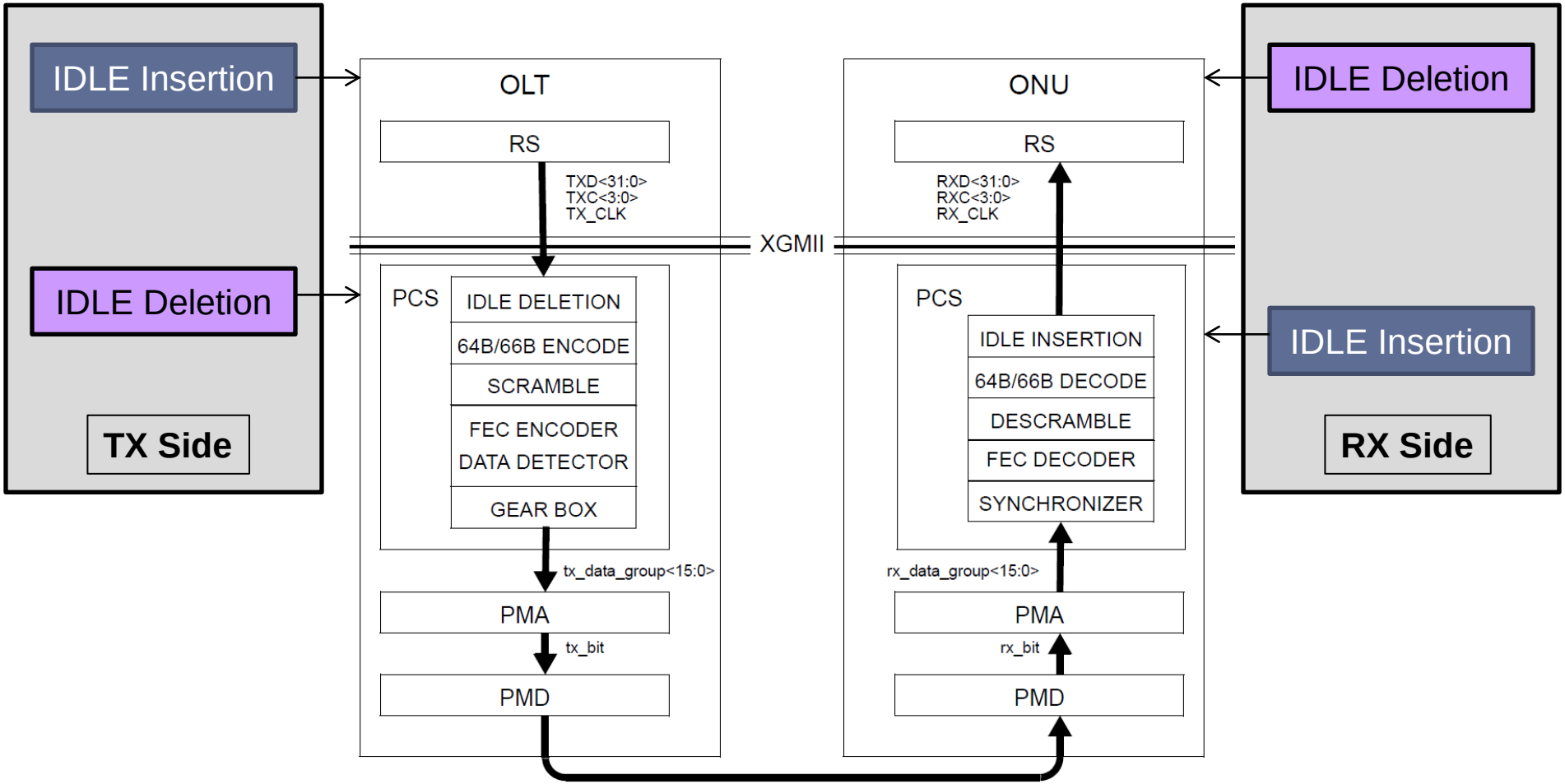
Motivation and Scope

- Data Rate Adaptation (DRA) function is recognized as required for proper operation of EPoC
  - agenda_01b_1112.pdf lists DRA as one of challenge items
- No baseline proposals have been submitted so far
  - We already reviewed 10G-EPON DRA and Clause 61 DRA mechanisms and drew conclusions from these materials
  - 10G-EPON DRA seems more suitable for EPoC (see hajduczenia_02_1112.pdf for more details)
- This contribution provides additional details on DRA implementation and brings in a baseline motion
  - It can be readily incorporated into MPCP for FDD and TDD modes for individual tracks

This presentation focuses on de-rating only and the presented design does not mean to preclude further changes to accommodate additional EPoC functions

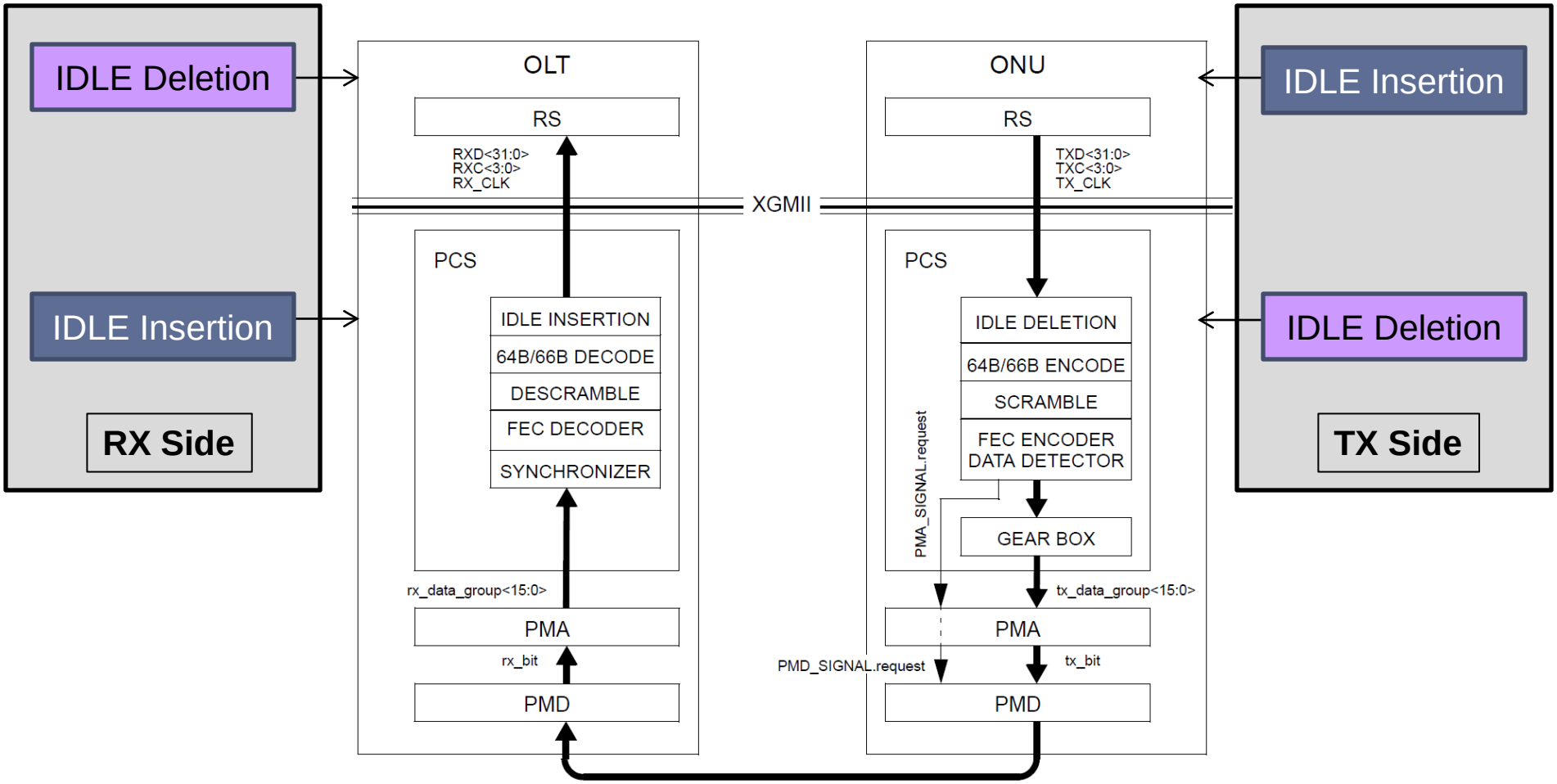
Background – EPON specification review (DS)

- IDLE Insertion and Deletion included in EPON spec [1] are used to account for data rate adaption due to insertion of FEC parity bits at PCS



Background – EPON specification review (US)

- IDLE Insertion and Deletion included in EPON spec [1] are used to account for data rate adaption due to insertion of FEC parity bits at PCS



Background – EPON specification review

- IDLE characters are used in place of data across XGMII interface [2]
- In the TX direction:
  - Gaps are created by the Multipoint Transmission Control (in MPMC sub-layer) and filled up with IDLEs by the MAC layer below. In this way, a fixed rate is guaranteed for the XGMII interface and space for FEC parity bits in the data stream is created
  - Extra IDLEs are then removed by the IDLE Deletion function inside the PCS (upper PHY stack) and then replaced by FEC parity bits
    - IPG IDLEs remain in the data stream (≥ 96 bits per Ethernet Frame)
- In the RX direction:
  - The PCS inserts IDLEs after FEC decoding to fill in gaps created by the removed FEC parity bits
  - IDLEs are then removed above XGMII interface and complete Ethernet frames are then passed to the MAC and respective upper layer clients

Function of IDLE characters in EPON / EPoC

- In EPON, IDLE characters are transmitted for three reasons:
  - IPG between individual Ethernet frames (like in any P2P link)
    - These IDLEs are FEC encoded and transmitted on the wire
  - To prepare space in data stream for FEC parity bits (10G-EPON specific)
    - These IDLEs are removed in PCS by IDLE Deletion and then replaced with FEC parity data
  - To fill in link when no actual data is transmitted (like in any P2P link)
    - These IDLEs are FEC encoded and transmitted on the wire

- In EPoC, IDLE characters will be used as they are used in EPON, but also:
  - Some amount of IDLEs will be inserted in MPMC to account for de-rating at PHY (recall, PHY has capacity << 10Gb/s). How many IDLEs are inserted per data vector – see next slide
  - Another amount of IDLEs will have to inserted in some fashion to account for TDD switching (We do not focus on TDD switching in these slides)
  - All of these IDLEs will be removed in PCS and not transmitted on the wire

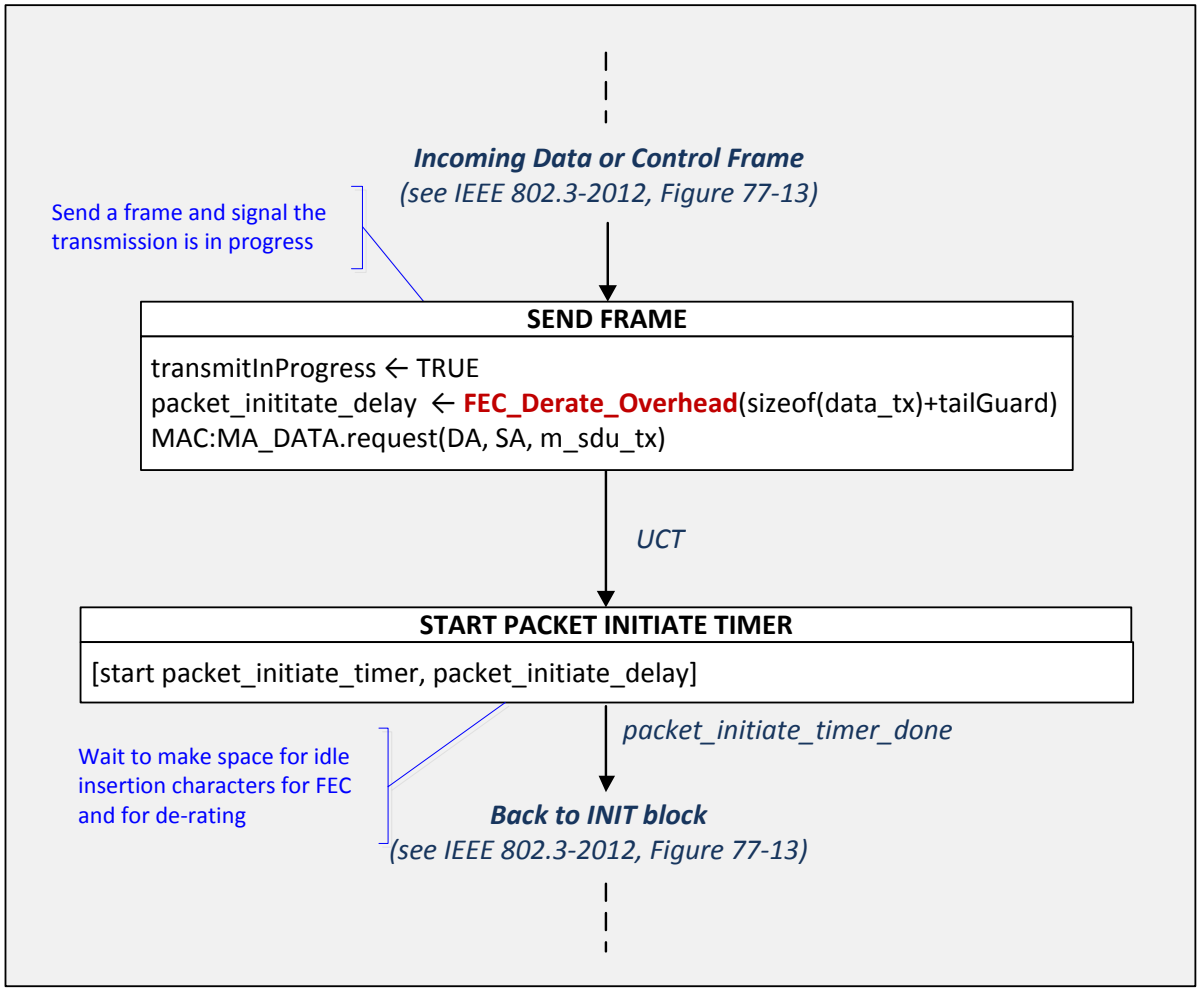
De-rating – EPoC DS TX IDLE insertion (ref. 77.2.2)

- In case of EPoC, extra IDLEs are added for de-rating purposes
- Compared to EPON, some modification to state diagram (slide 9) are needed:
  a) For FEC, the same function can be reused with adjusted parameters:
     - *(FEC_PAYLOAD_SIZE + FEC_PARITY_SIZE) = FEC_CODEWORD_SIZE*
     - *FEC_PAYLOAD_SIZE / FEC_CODEWORD_SIZE = coding rate ≤ 1*

  b) For de-rating, extra IDLEs are added in proportion to the PHY rate of the coax Rcoax with respect to the XGMII data rate *Rxgmii* – this account of a ratio of R = *(Rxgmii/Rcoax – 1) ≥ 0* between IDLEs and data
     - *Example: Rcoax = 2 Gb/s → R = 4 → every D data, 4D IDLEs are added, whereby D includes both information and parity bits (i.e. de-rating shall be applied to both payload and parity sizes)*

The two components can be easily merged together in a new *FEC_Derate_Overhead* function, to compute the time the next packet can be transmitted (see next slide)

EPoC DS TX IDLE insertion in CLT (ref. Figure 77-13)



data_tx
is the payload of tx PDU

tailGuard

PDU overhead: preamble, Ethernet Frame header and IPG

FEC_Derate_Overhead(length)

is a function that calculates the amount of time that the MPCP control multiplexer waits following the transmission of a frame of size 'length' for the insertion of FEC parity bits at PHY and for scaling factor due to data rate adaption to the coax

Note: the variable *transmitInProgress* is reset to FALSE in the INIT block, thus returning the control to the Multi-Point Transmit Controller to allow transmission of next packet

EPoC DS TX IDLE insertion in CLT - functions

The **FEC_Derate_Overhead** function can be based on similar operations as included in the *FEC_Overhead* function of EPON (here below – see clause 77.2.2.4) and includes FEC, a scaling factor of about *Rxgmii/Rcoax* for rate adaption and appropriate rounding – the detailed definition can be finalized once PHY parameters are available

Note: For the state diagram (slide 9) to work properly, the variable *fecOffset* shall advance at the pace of coax transmission rate Rcoax (otherwise it will scroll also during the time of inserted de-rating IDLEs, which would result in incorrect FEC calculations:

"fecOffset advances by 1 every 8 bit times on coax"

(EPON FEC_Overhead function, clause 77.2.2.4)

packet length

fecOffset advances by 1 every 8 bit times.

Variable tracking time passed in octets – start at 0 and get reset to 0 when reaching code word size

FEC_Overhead(length) = 12 + FEC_PARITY_SIZE * floor[(fecOffset + length)/FEC_PAYLOAD_SIZE]

FEC parity bits

FEC information bits

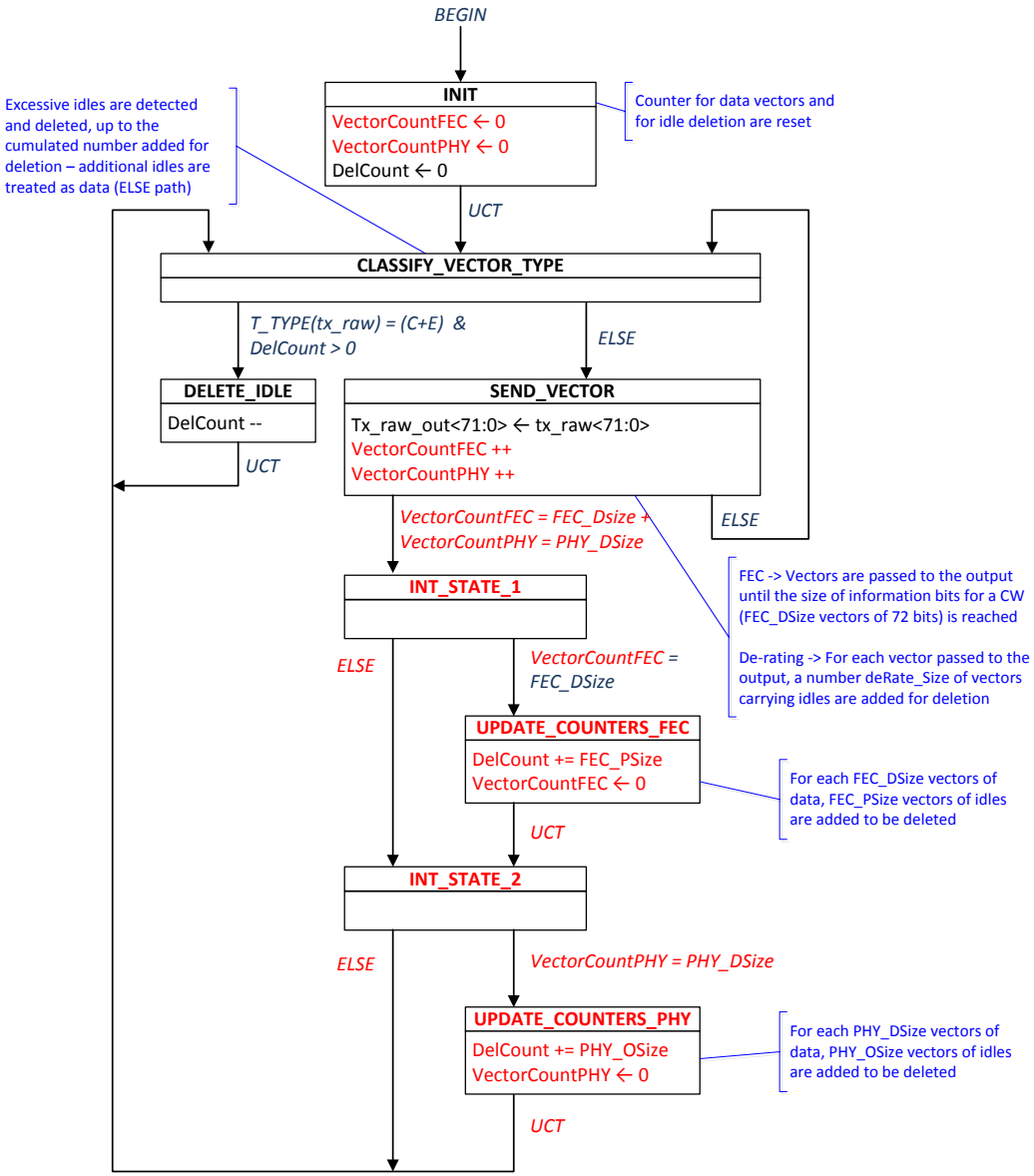
EPoC DS TX IDLE deletion in CLT

- In case of EPoC, extra IDLEs added for de-rating purposes shall be deleted
- Compared to EPON, some modification to state diagram (slide 12) are needed:
  a) For FEC, the same function can be reused with adjusted parameters:
     - *(FEC_DSize + FEC_PSize) = CW_Size*
     - *FEC_DSize / CW_Size = coding rate ≤ 1*

  Note: these are expressed in vectors of 72 bits

  b) For de-rating, extra IDLEs added in proportion to the PHY rate of the coax *Rcoax* with respect to the XGMII data rate *Rxgmii* needs to be deleted – this results in a ratio R = *(Rxgmii/Rcoax – 1) ≥ 0* between IDLEs and data
     - *Example: Rcoax = 2 Gb/s → R = 4 → every D data, 4D IDLEs are deleted, whereby D includes both information and parity bits*
     - *We can define a parameter **deRate_Size = R/coding_rate**, which accounts for the number of IDLE vectors to be deleted for each data vector transmitted over the XGMII interface*

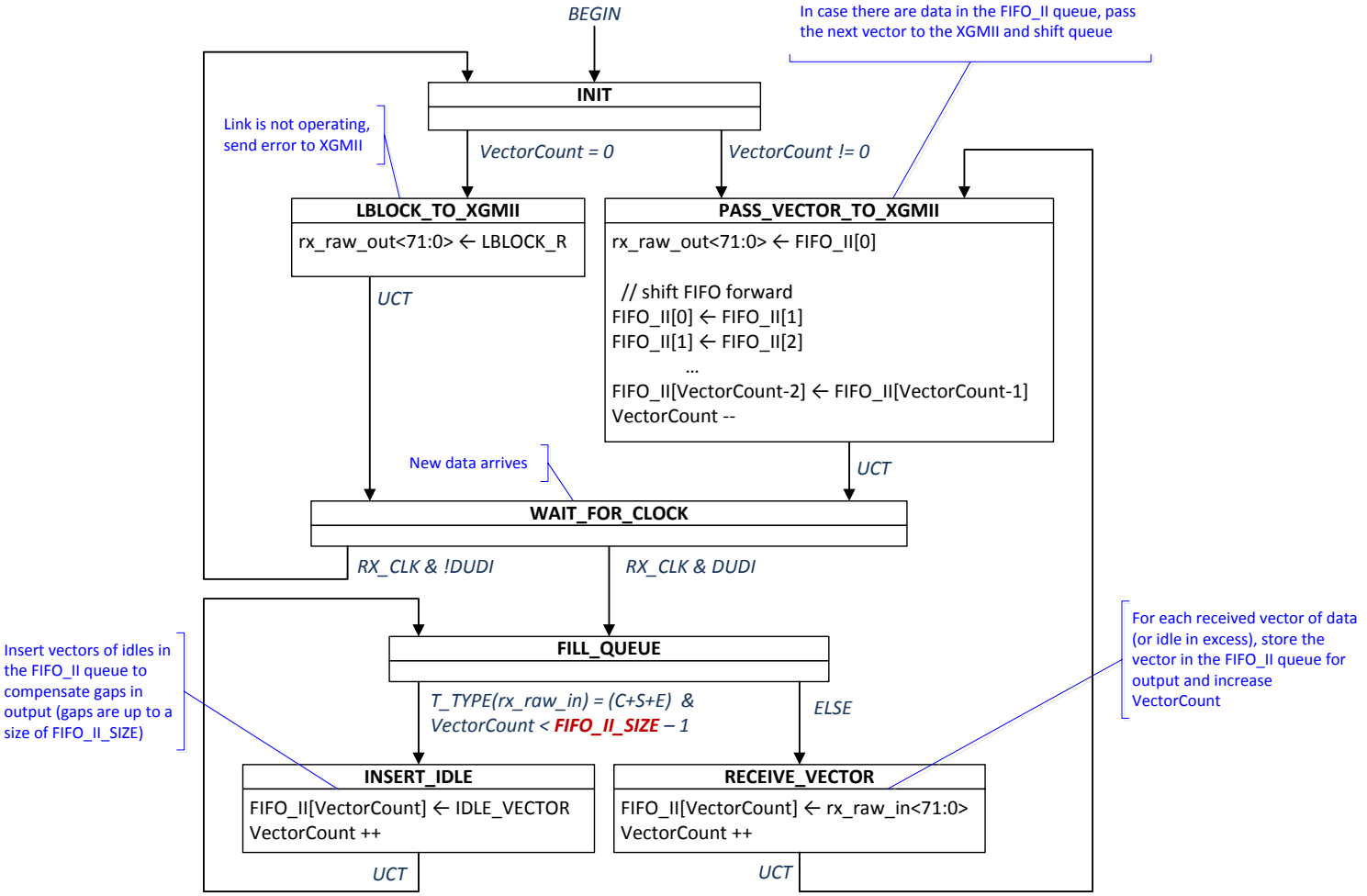
EPoC DS TX IDLE deletion in CLT (ref. Figure 76-9)



In **red** the change due to de-rating from the original chart – final format and proper rounding can be defined once know PHY parameters

- FEC_PSize vectors of IDLEs are deleted every (FEC_DSize + FEC_PSize) vectors
- Enough IDLEs to cover DelayBound are transmitted
- **PHY_OSize vectors of IDLEs are deleted every (PHY_OSize + PHY_DSize) vectors**

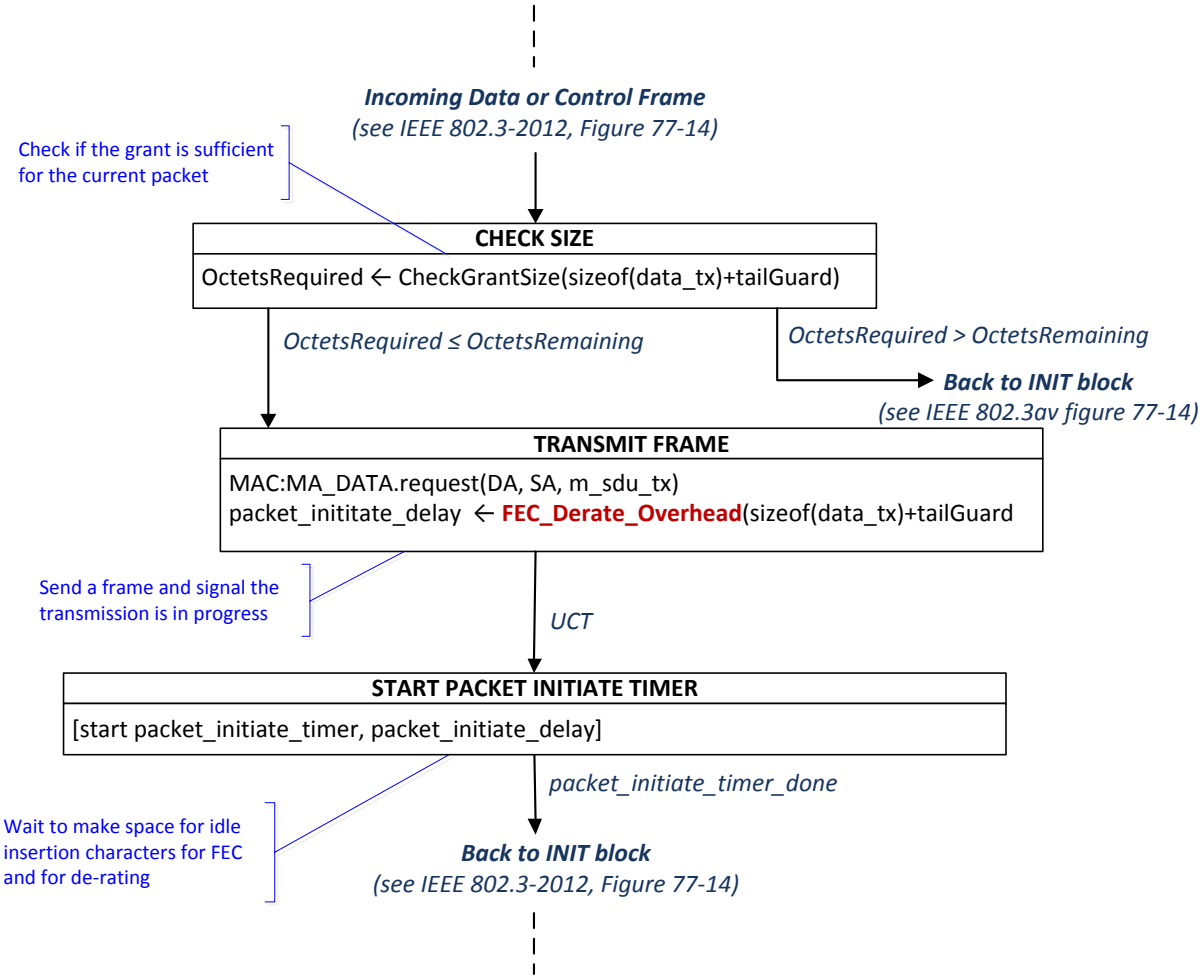
EPoC DS RX IDLE insertion in CLT (ref. Figure 76-23)



The same state diagram (see above) can be reused with proper changes of FIFO_II_SIZE:

- FIFO_II_SIZE needs to accommodate the FEC and de-rating for the largest possible gap
- This corresponds to the maximum size frame at lowest coax rate and largest parity

EPoC US TX IDLE insertion in CNU (ref. Figure 77-14)



Note: For the state diagram (slide 9) to work properly, the variable *fecOffset* shall advance at the pace of coax transmission rate Rcoax (otherwise it will scroll also during the time of inserted de-rating IDLEs, which would result in incorrect FEC calculations – *the same may apply to the counter localTime.*

data_tx

is the payload of tx PDU

tailGuard

PDU overhead: preamble, Ethernet Frame header and IPG

FEC_Derate_Overhead(length)

is a function that calculates the amount of time that the MPCP control multiplexer waits following the transmission of a frame of size 'length' for the insertion of FEC parity bits at PHY and for scaling factor due to data rate adaption to the coax

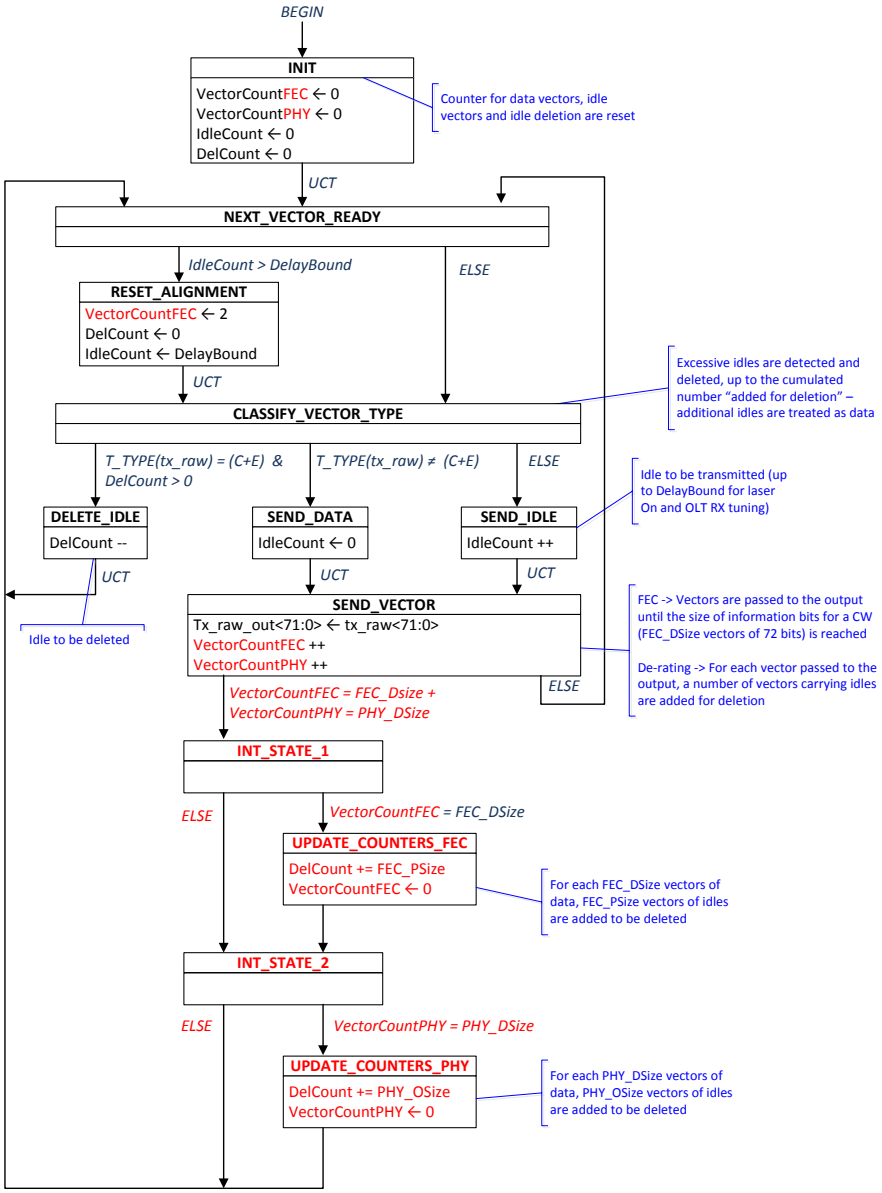
CheckGrantSize(length)

is a function that calculates the future time at which the transmission of the current frame (including the FEC parity overhead) is completed

OctetsRemaining

Number of octets that can be transmitted between the current time and the end of the grant

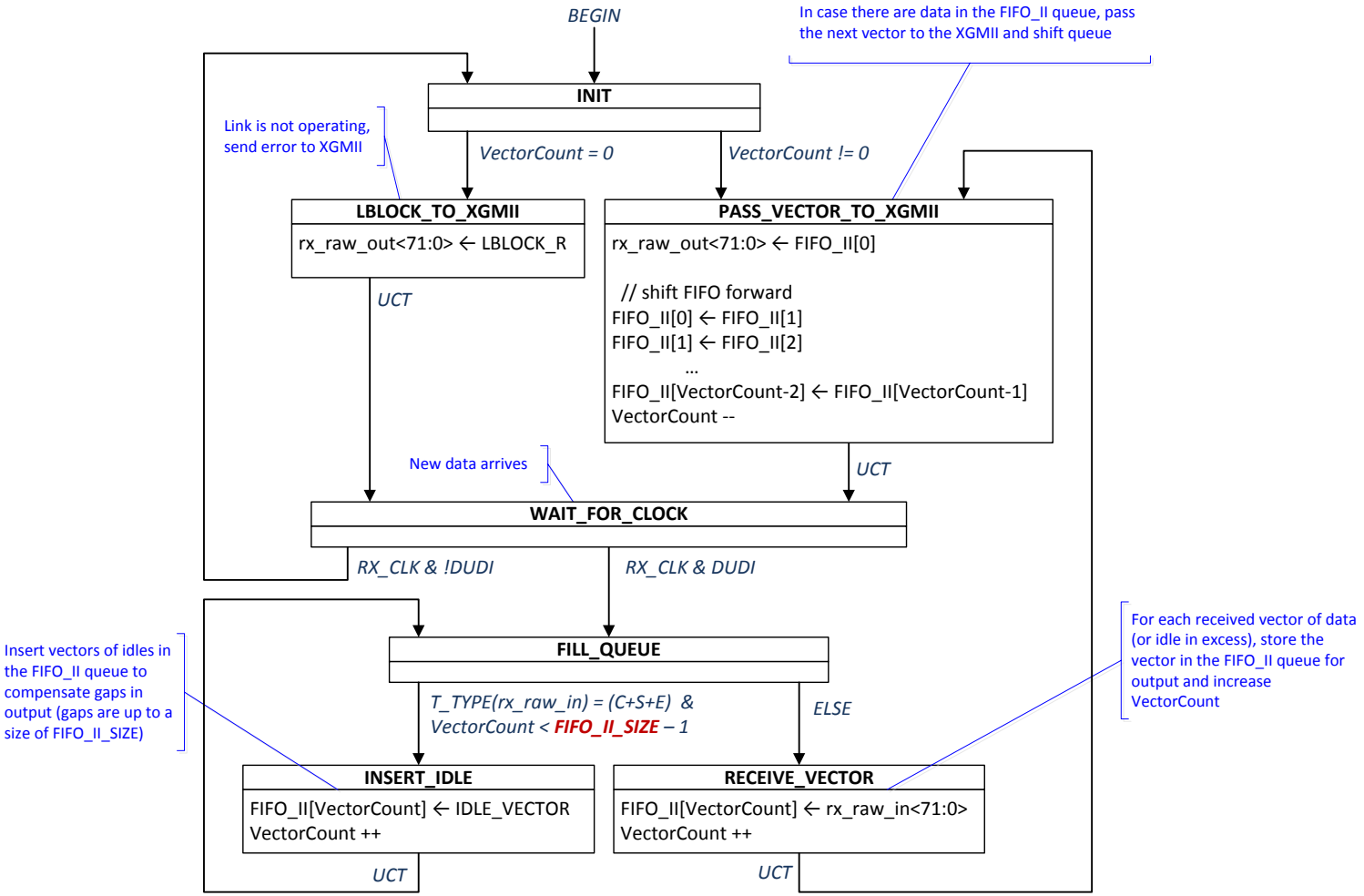
EPoC US TX IDLE deletion in CNU (ref. Figure 76-10)



In **red** the change due to de-rating from the original chart – final format and proper rounding can be defined once know PHY parameters

- FEC_PSize vectors of IDLEs are deleted every (FEC_DSize + FEC_PSize) vectors
- Enough IDLEs to cover DelayBound are transmitted
- **PHY_OSize vectors of IDLEs are deleted every (PHY_OSize + PHY_DSize) vectors**

EPoC US RX IDLE insertion in CNU (ref. Figure 76-23)



The same state diagram (see wbove) can be reused with proper changes of FIFO_II_SIZE:

- FIFO_II_SIZE needs to accommodate the FEC and de-rating for the largest possible gap
- This corresponds to the maximum size frame at lowest coax rate and largest parity

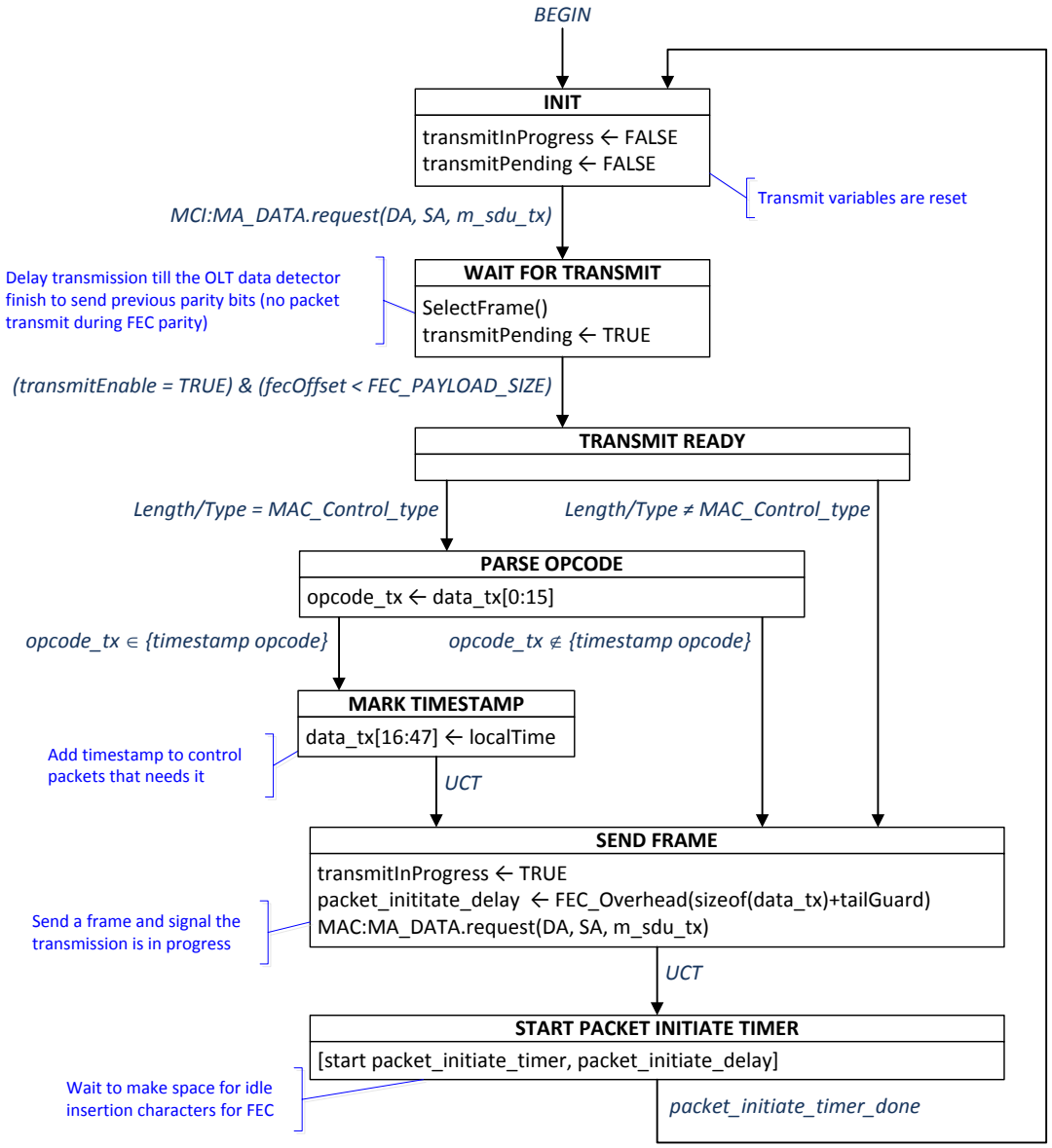
Reference

[1] IEEE 802.3-2012 Specification – Clauses 76 and 77

[2] IEEE 802.3-2012 Specification – Clause 36

Backup Material (from IEEE 802.3-2012)

EPON DS TX IDLE insertion (clause 77.2.2.4)



Key remarks:

- A MAC Control instance gives back control after completing transmission
- A transmission includes the packet and could include additional space for parity
- The parity is added on a code word size base (not necessarily after each packet), by FEC_Overhead function
- A packet is delayed till end of FEC parity transmission in case popping up outside FEC payload transmission (in order to avoid jitter after timestamp)

EPON DS TX IDLE insertion - functions

fecOffset advances by 1 every 8 bit times.

Variable tracking time passed in octets – start at 0 and get reset to 0 when reaching code word size

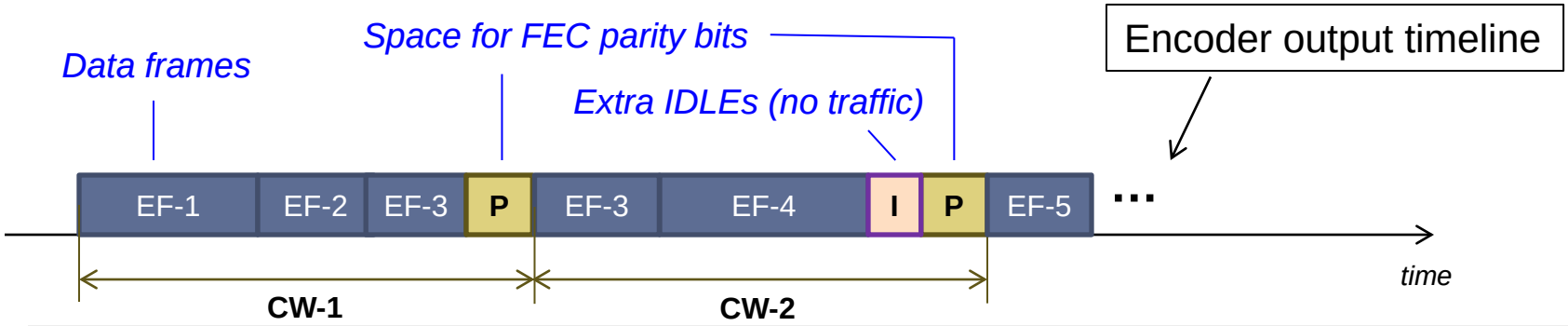
packet length

FEC_Overhead(length) = 12 + FEC_PARITY_SIZE * floor[(fecOffset + length)/FEC_PAYLOAD_SIZE]

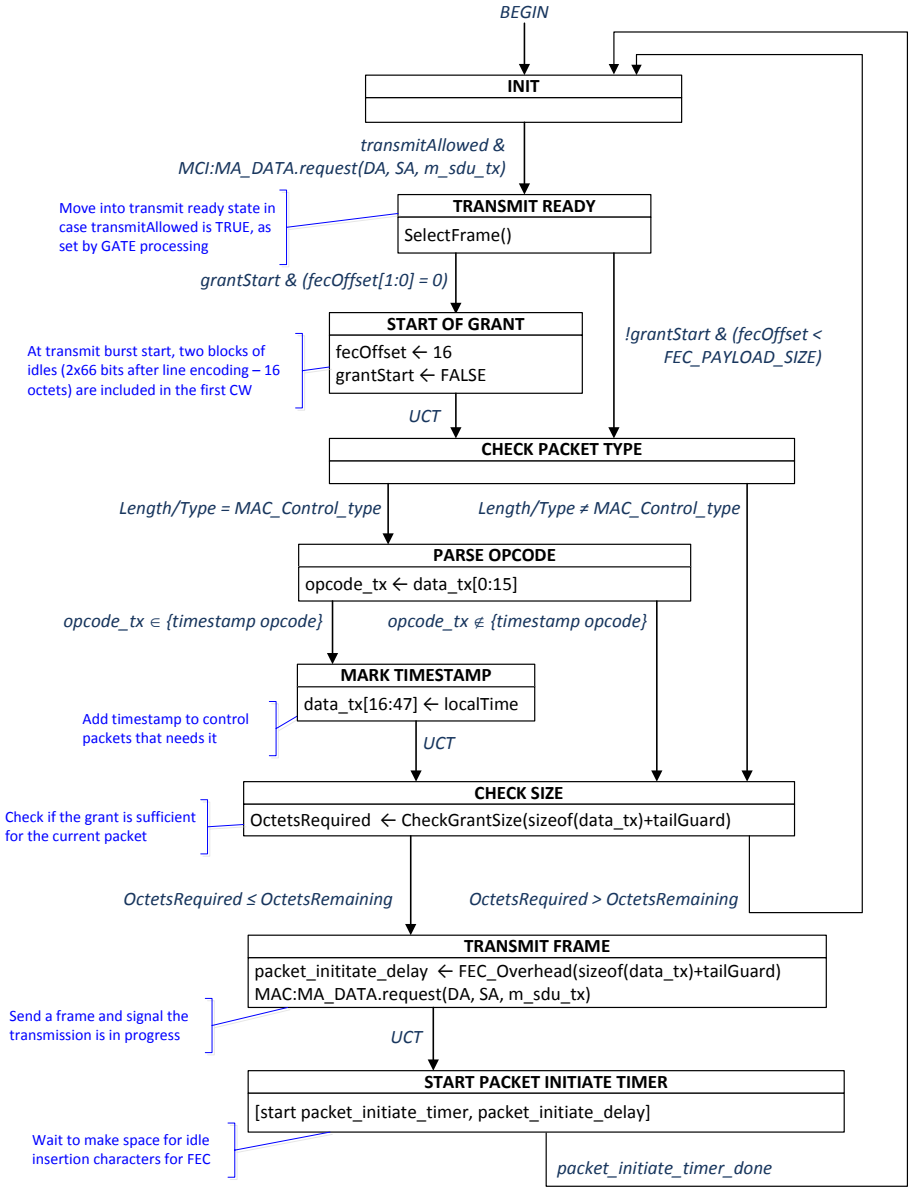
FEC parity bits

FEC information bits

The function returns the length of the data to transmit and cumulates information bits (tracked by the variable *fecOffset*) - when the cumulated data exceeds the FEC_PAYLOAD_SIZE, a FEC_PARITY_SIZE interval is also included to space for parity



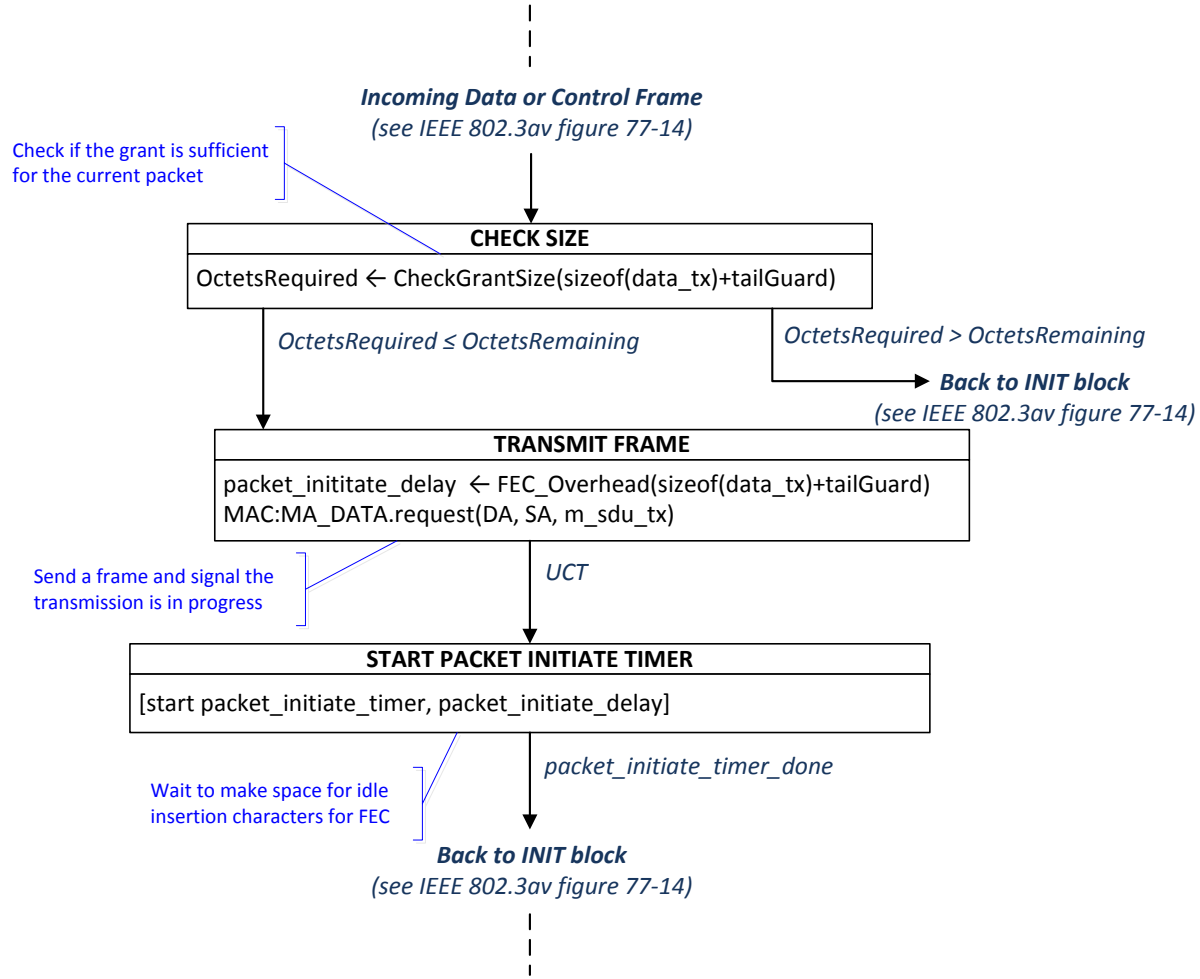
EPON US TX IDLE insertion (clause 77.2.2.4)



Key remarks:

- Transmission is controlled by GATE message content, which results in setting *transmitAllowed* variable
- A MAC Control instance gives back control after completing transmission
- A transmission includes the packet and could include additional space for parity – two IDLEs blocks are including in the first CW of a burst
- The parity is added on a code word size base (not necessarily after each packet), by FEC_Overhead function
- A packet is delayed till end of FEC parity transmission in case popping up outside FEC payload transmission (in order to avoid jitter after timestamp)

EPON US TX IDLE insertion - details



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is the payload of tx PDU

tailGuard

PDU overhead: preamble, Ethernet Frame header and IPG

FEC_Overhead(length)

is a function that calculates the amount of time that the MPCP control multiplexer waits following the transmission of a frame of size 'length' for the insertion of FEC parity at PHY

CheckGrantSize(length)

is a function that calculates the future time at which the transmission of the current frame (including the FEC parity overhead) is completed

OctetsRemaining

Number of octets that can be transmitted between the current time and the end of the grant

EPON US TX IDLE insertion - functions

FEC code word bits

packet length

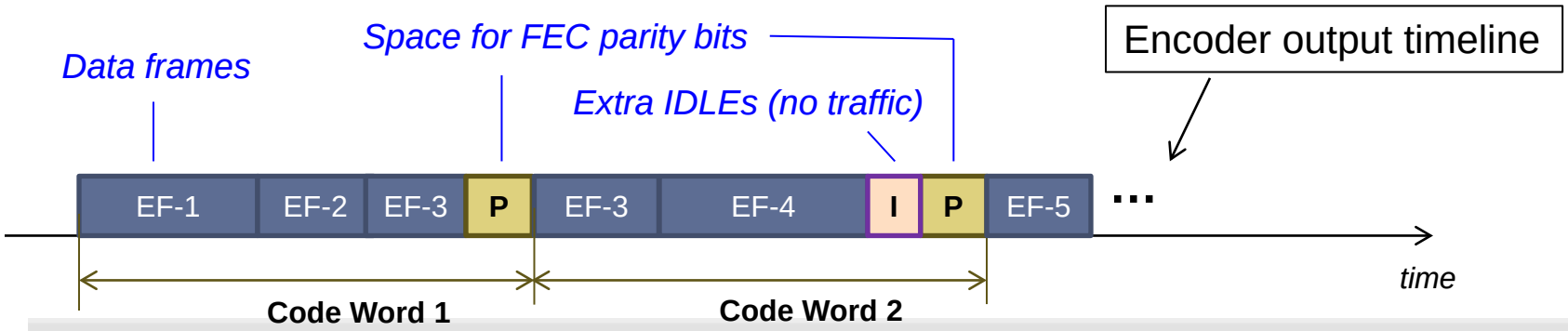
CheckGrantSize(length) = FEC_CODEWORD_SIZE * ceiling[(fecOffset + length)/FEC_PAYLOAD_SIZE] - fecOffset

fecOffset advances by 1 every 8 bit times.

Variable tracking time passed in octets – start at 0 and get reset to 0 when reaching code word size

FEC information bits

The function returns the future time at which the transmission of the current frame (including FEC parity overhead) is completed - when the cumulated data (tracked by the variable *fecOffset*) exceeds the FEC_PAYLOAD_SIZE, a new FEC Code Word is started



EPON US TX IDLE insertion – functions (cont.)

End of grant (from GATE) expressed in number of TQ

Time quanta in bytes (20 bytes @ 10 Gb/s)

OctetsRemaining = [(stopTime – localTime) * tqSize] – tqOffset

The variable holds the value of the local timer used to control MPCP operation. This variable is advanced by a timer at 62.5 MHz and counts in TQ and it is reloaded at ONU with the received timestamp value (from OLT).

This variable denotes the offset (in octet times) of the current actual time from the localTime variable (which maintain the current time in units of TQ)

OctetsRemaining is a variable that denotes the number of octets that can be transmitted between the current time and the end of the grant.