Data Rate Adaptation in EPoC

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Summary

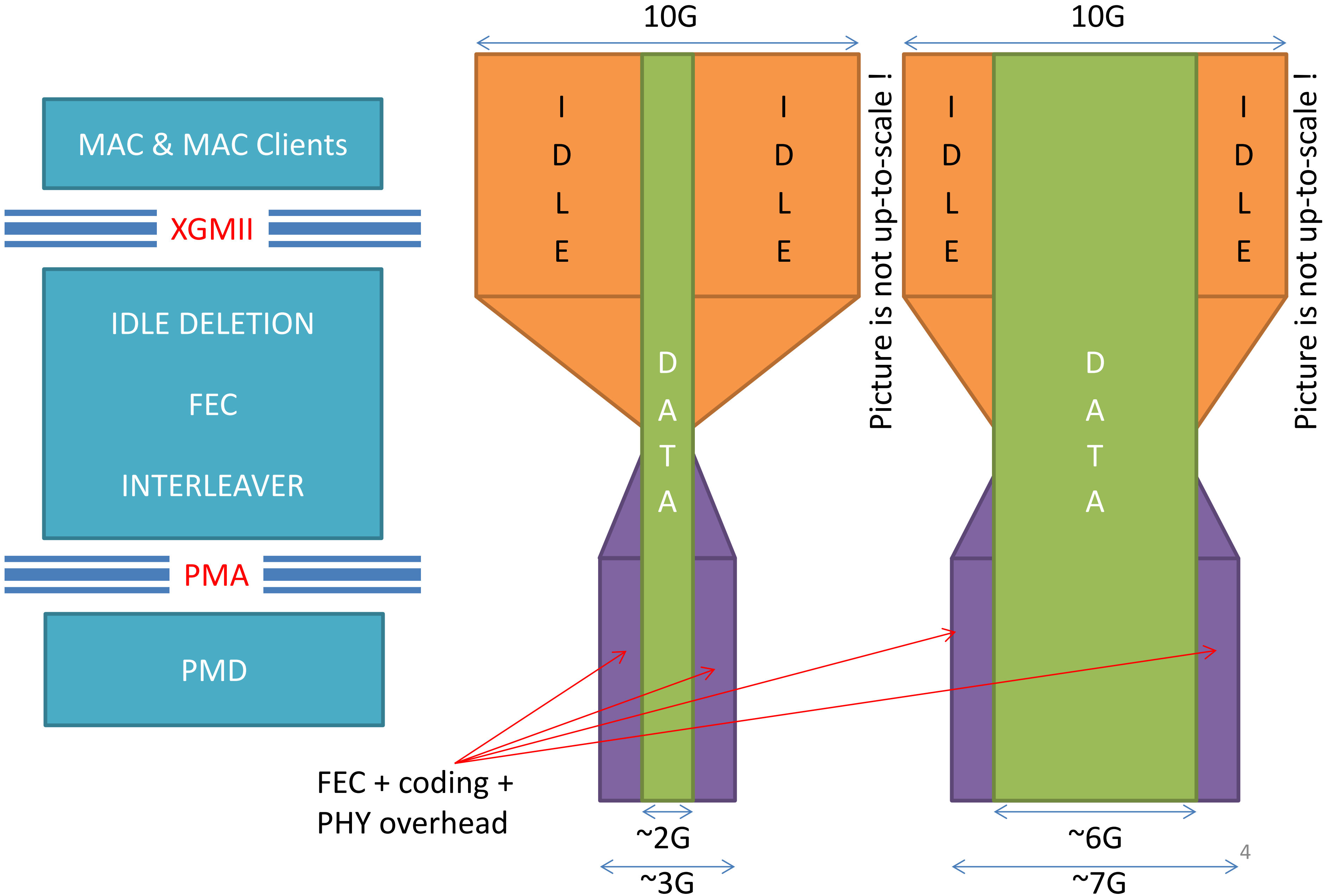
- This slide deck provides details about DRA function in EPoC, and illustrates detailed changes to 10G-EPON DRA function needed to support this function in EPoC, following on [2]
- It is suggested to include DRA in EPoC based on the outline presented in these slides

Note: For now only the basic functionality is covered, while more advanced features (like, e.g., code word shortening) will be treated in a separate presentation. Further revisions to description, overhead formulas, etc., will be needed over time.

Receive Direction in CLT/CNU

DRA IN EPOC - RX

DRA in EPoC (in picture)



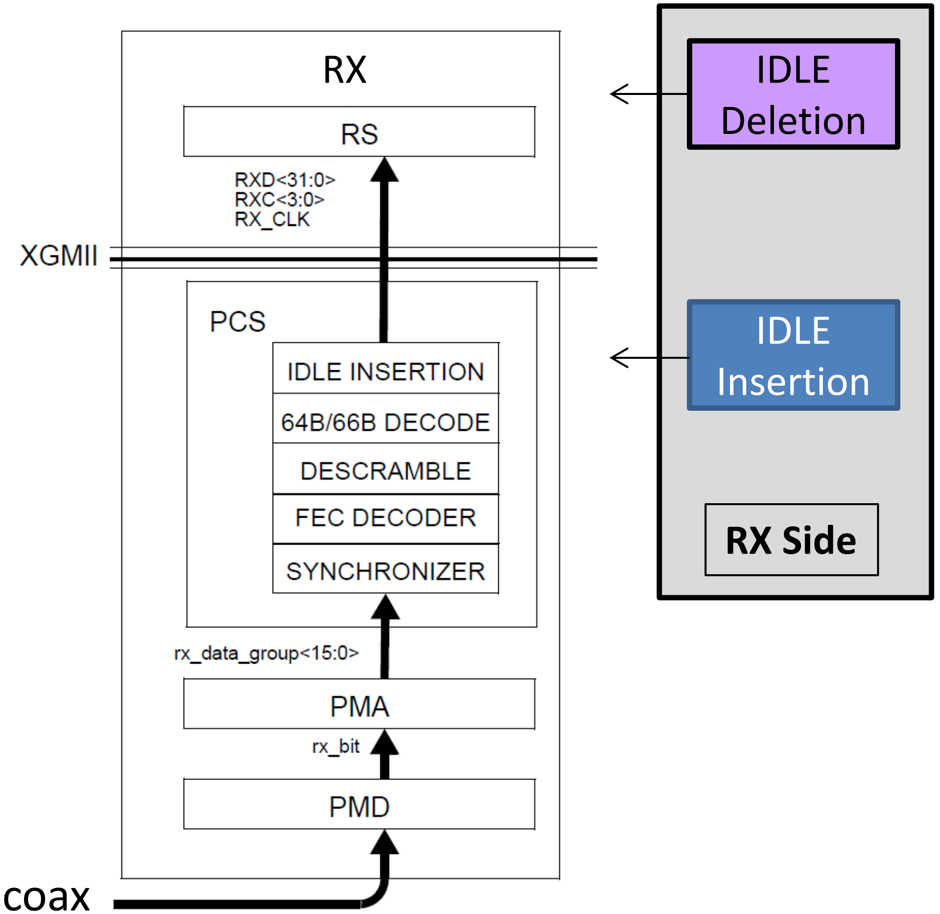
IDLE handling in Rx direction (CNU/CLT)

IDLE Deletion process

- Extra IDLEs are then removed above XGMII interface and complete Ethernet frames are then passed to respective MAC Clients.
- Data rate above MAC is equal to R_{eff}.

IDLE Insertion process:

- FEC encoded packets arrive at PCS at the PMD rate and are fed into the FEC decoder. After removal of FEC parity, data rate becomes R_{eff}.
- Gaps between frames are filled with IDLEs to match XGMII data rate (data rate of R_{MX}).



IDLE Deletion (baseline I)

IDLE Deletion process - objective

- Extra IDLEs are removed above XGMII interface and complete Ethernet frames are then passed to MAC Clients – this is part of normal Ethernet MAC operation
  - data rate above MAC is equal to R_{eff}

How is that achieved in 10G-EPON?

- The Reconciliation Sublayer (RS) processes incoming packets from the receiving PCS layer and selects the target MAC instance based on LLID contained in preamble
- IDLEs are discarded by MAC, and they never reach any MAC Client

How it could be done in EPoC?

- Implementation of this function from 10G-EPON can be directly reused in EPoC – see IEEE Std 802.3, 76.2.6.1.3 for more details [1]

<u>Baseline proposal I</u>: IDLE Deletion in EPoC in Rx direction to use 10G-EPON IDLE Deletion mechanism per IEEE Std 802.3, Clause 76. This applies to both CLT and CNU sides.

IDLE Insertion – Rx direction

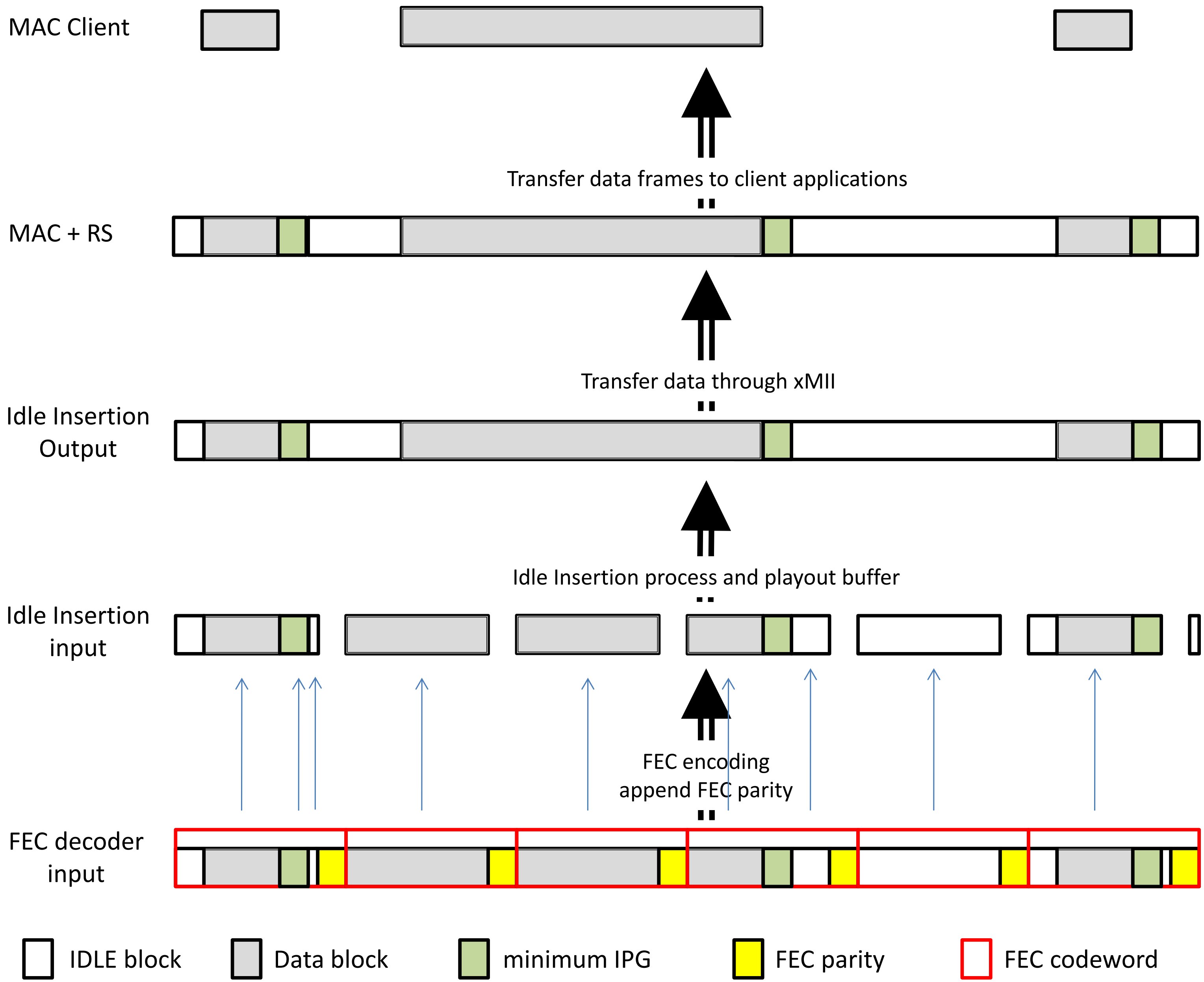
IDLE Insertion process – objective

- FEC encoded packets arrive at PCS at the PMD rate and are fed into the FEC decoder at the RX side.
- After removal of FEC parity, data rate becomes R_{eff}. Gaps between frames are filled with IDLEs to achieve data rate of R_{MX} and match XGMII data rate.

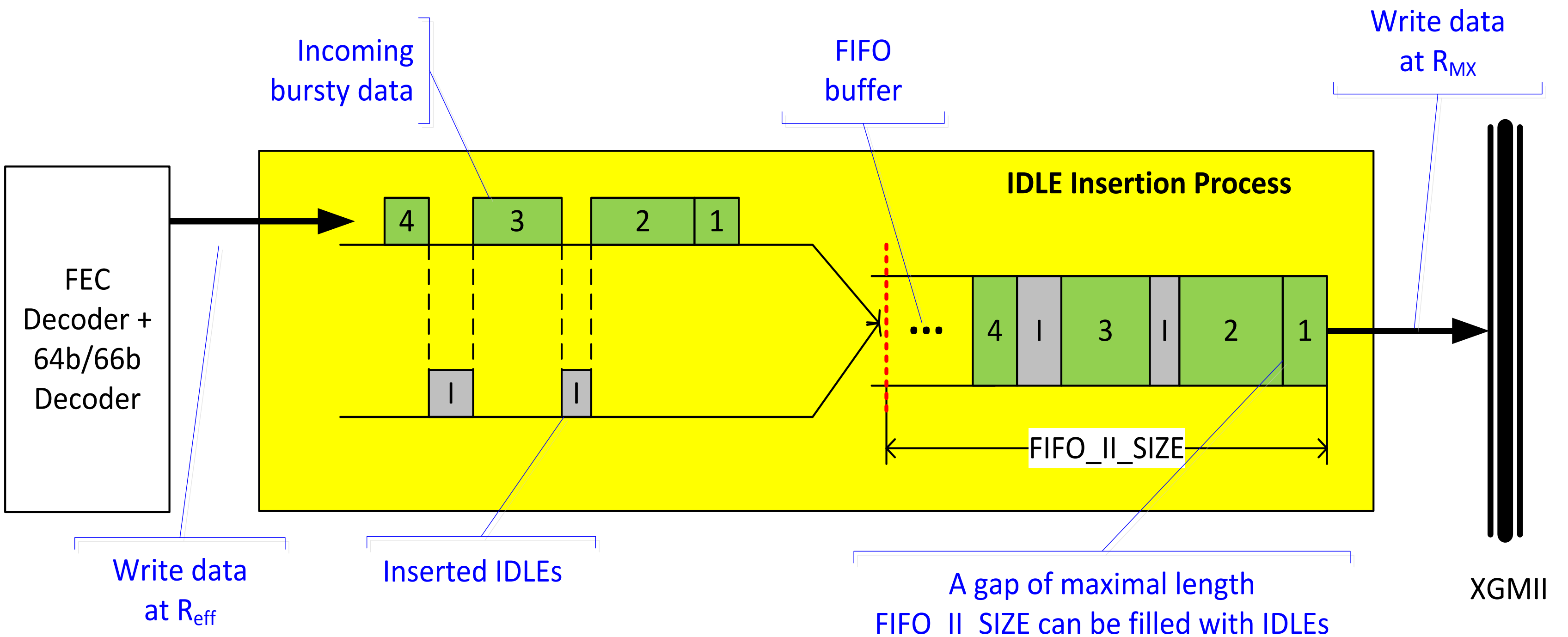
How is that achieved in 10G-EPON?

- Data leaving FEC decoder is bursty. FEC parity data was removed. Effective data rate is smaller than R_{MX}.
- Bursty data is then fed into the IDLE Insertion function, containing a play-out buffer. Data is inserted at R_{eff} and sent towards XGMII at R_{MX}.
- Difference between R_{eff} and R_{MX} is compensated by insertion of IDLE characters when play-out buffer becomes empty
- The next two slides demonstrate this process in a visual form

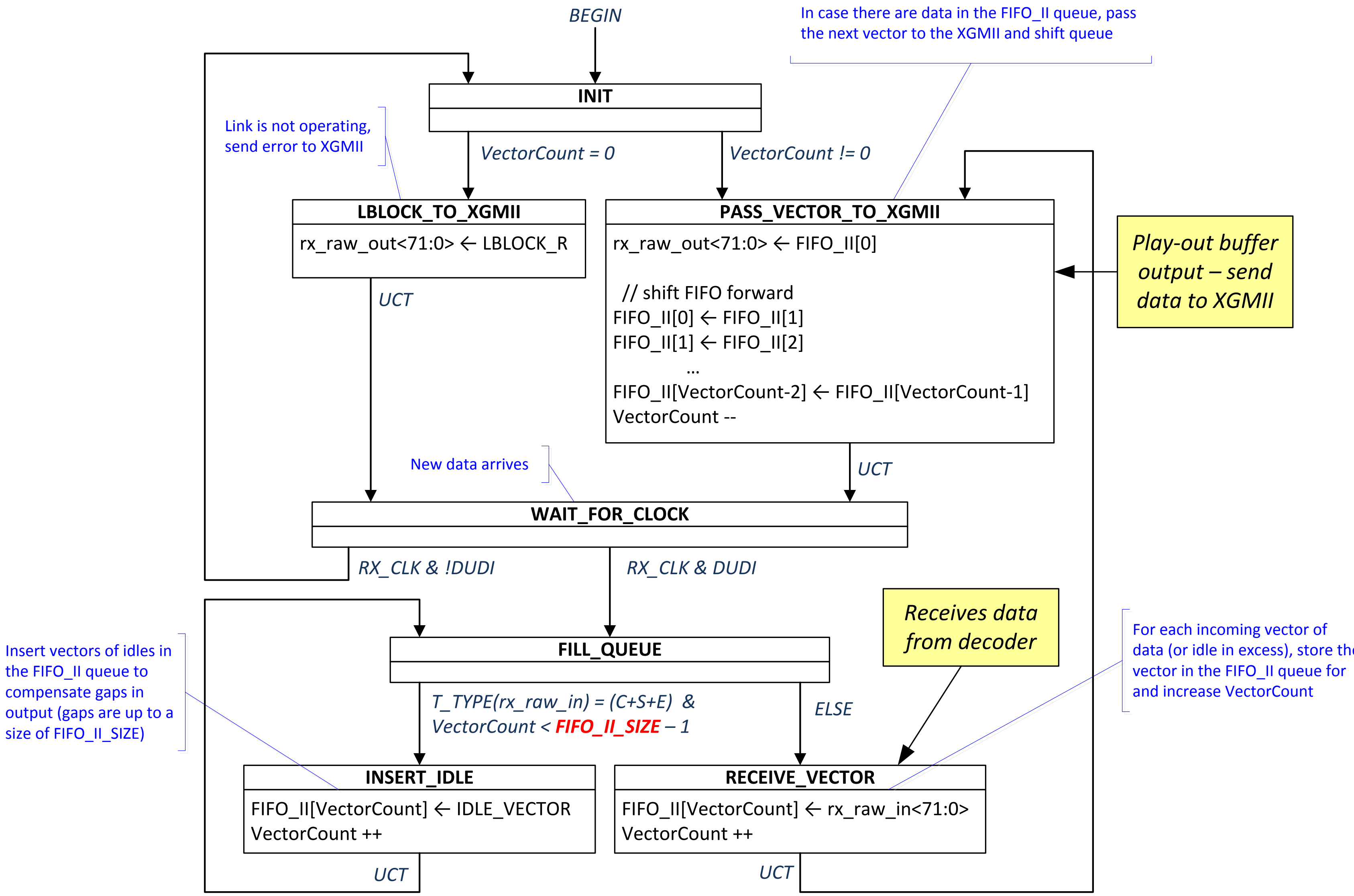
IDLE Insertion (in picture)



IDLE Insertion (operation example)



IDLE Insertion (SD)



IEEE Std 802.3, Figure 76-23

IDLE Insertion (baseline II)

How it could be done in EPoC?

- Implementation of this function from 10G-EPON can be directly reused in EPoC – see IEEE Std 802.3 [1], 76.3.3.7 and Figure 76-23
- The size of the IDLE Insertion buffer (parameter *FIFO_II_SIZE*) will need to be defined, based on supported PHY rates and adopted FEC for DS and US
  - FIFO_II_SIZE needs to accommodate FEC and DRA for the largest possible gap that can be observed under normal operating conditions
  - Corresponds to the maximum-size frame at lowest coax rate and the associated FEC parity

<u>Baseline proposal II</u>: IDLE Insertion in the Rx direction reuses 10G-EPON design as defined in IEEE Std 802.3, Clause 76. The value for the FIFO_II_SIZE is TBD at this time, pending selection of FEC code and minimum coax data rate. This applies to both CLT and CNU.

Straw Poll #1 and #2

#1: IDLE Deletion in EPoC RS in Rx direction to use 10G-EPON IDLE Deletion mechanism per IEEE Std 802.3, Clause 76. This applies to both CLT and CNU sides.

Ad-hoc call: Yes: 9 / No: 0 / Undecided: 0

TF meeting: Yes: / No: / Undecided:

#2: IDLE Insertion in EPoC PCS in the Rx direction reuses 10G-EPON design as defined in IEEE Std 802.3, Clause 76. The value for FIFO_II_SIZE is TBD at this time, pending selection of FEC code and coax data rate. This applies to both CLT and CNU.

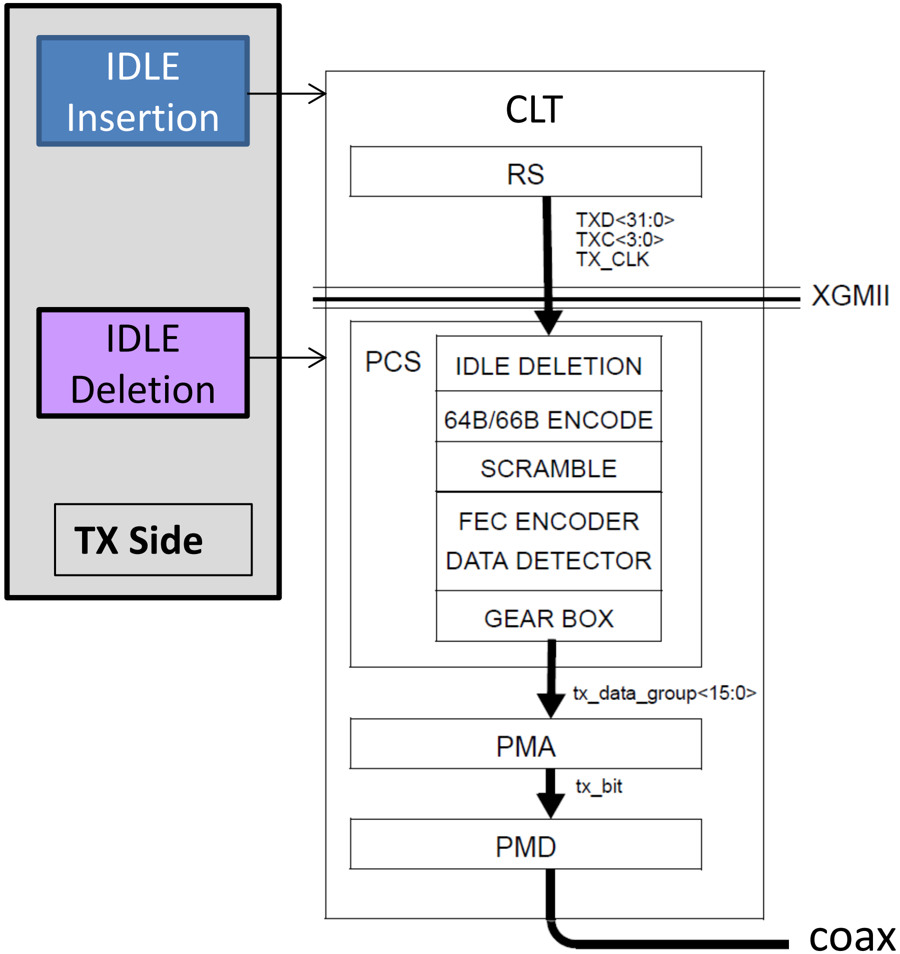
Ad-hoc call: Yes: 9 / No: 0 / Undecided: 0

TF meeting: Yes: / No: / Undecided:

Transmit Direction in CLT/CNU

DRA IN EPOC - TX

Handling in the TX direction (CLT/CNU)



IDLE Insertion process

- Packets are properly inserted (by the Multipoint Transmission Control) and filled with IDLEs by the MAC layer. MPMC keeps data rate at R_{eff}.
- In this way, a fixed rate of 10G is guaranteed by MAC for the XGMII interface (R_{MX}). Extra IDLEs inserted by MAC create space for FEC parity bits and all PHY overhead in PMD

IDLE Deletion process

- Extra IDLEs are then removed by the IDLE Deletion process inside the PCS (upper PHY stack) to match with PMD rate and include FEC parity bits.
- At the output of IDLE Deletion process, data rate is equal to R_{eff}.

IDLE Insertion – TX Direction

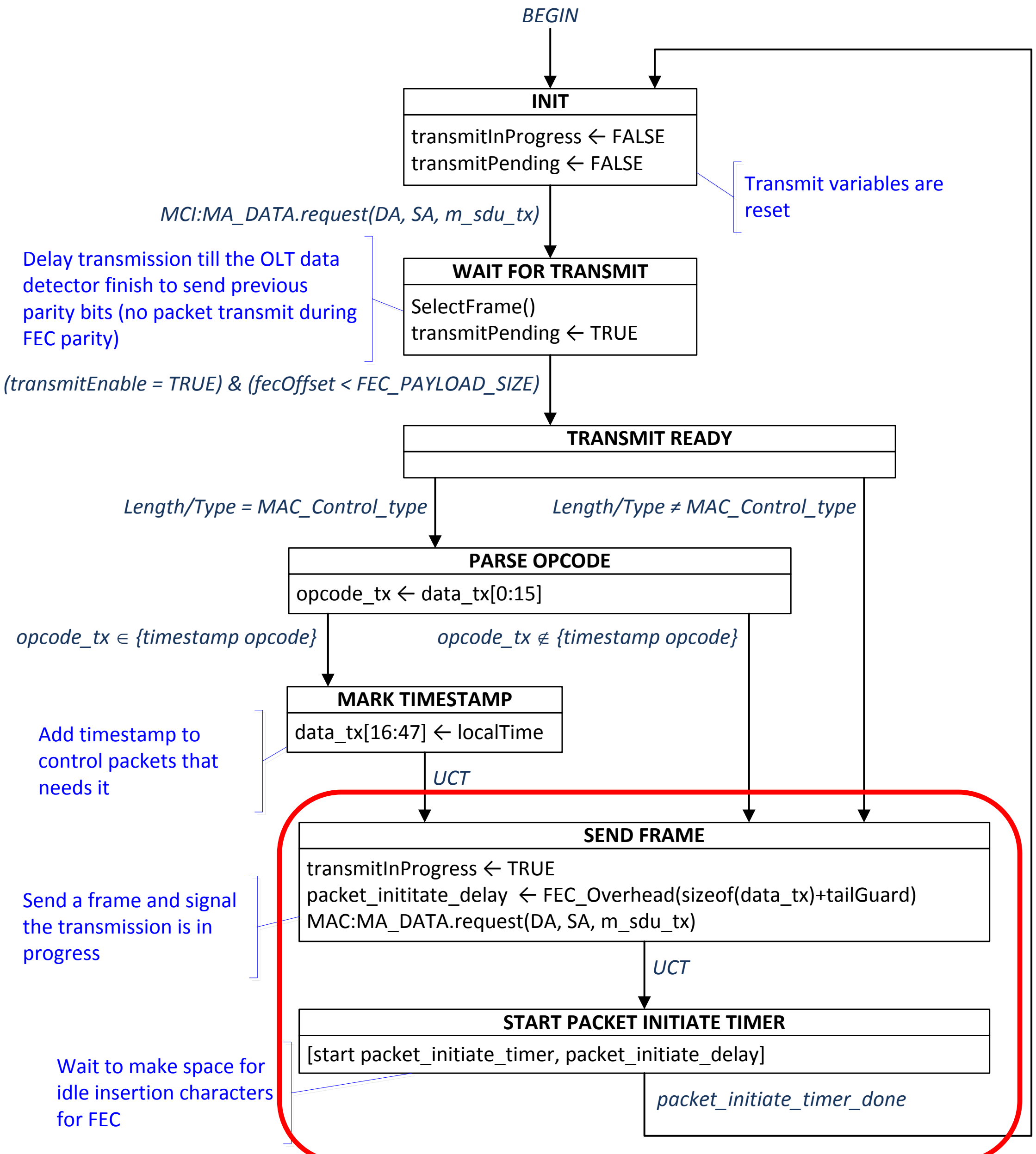
IDLE Insertion process - objective

- Extra IDLEs are inserted above XGMII interface (by MPMC), in order to leave sufficient space for insertion of FEC parity in PCS and other PMD overhead

How is that achieved in 10G-EPON?

- IDLE insertion in implemented for the TX direction by spacing packets at Multi-Point Control , so that MAC can inserts IDLEs (see IEEE Std 802.3 [1], 77.2.2)
- Every time a packet is sent, a function called FEC_Overhead is executed to compute any additional waiting time that needs to be considered for FEC parity insertion
  - The additional time is added on a per code word base, after the packet that complete the payload content of the code word
  - The packet and the FEC code word payload does not need to align, i.e. a packet can be carried by one or more FEC code words
  - See the next three slides for details

EPON IDLE Insertion – OLT side

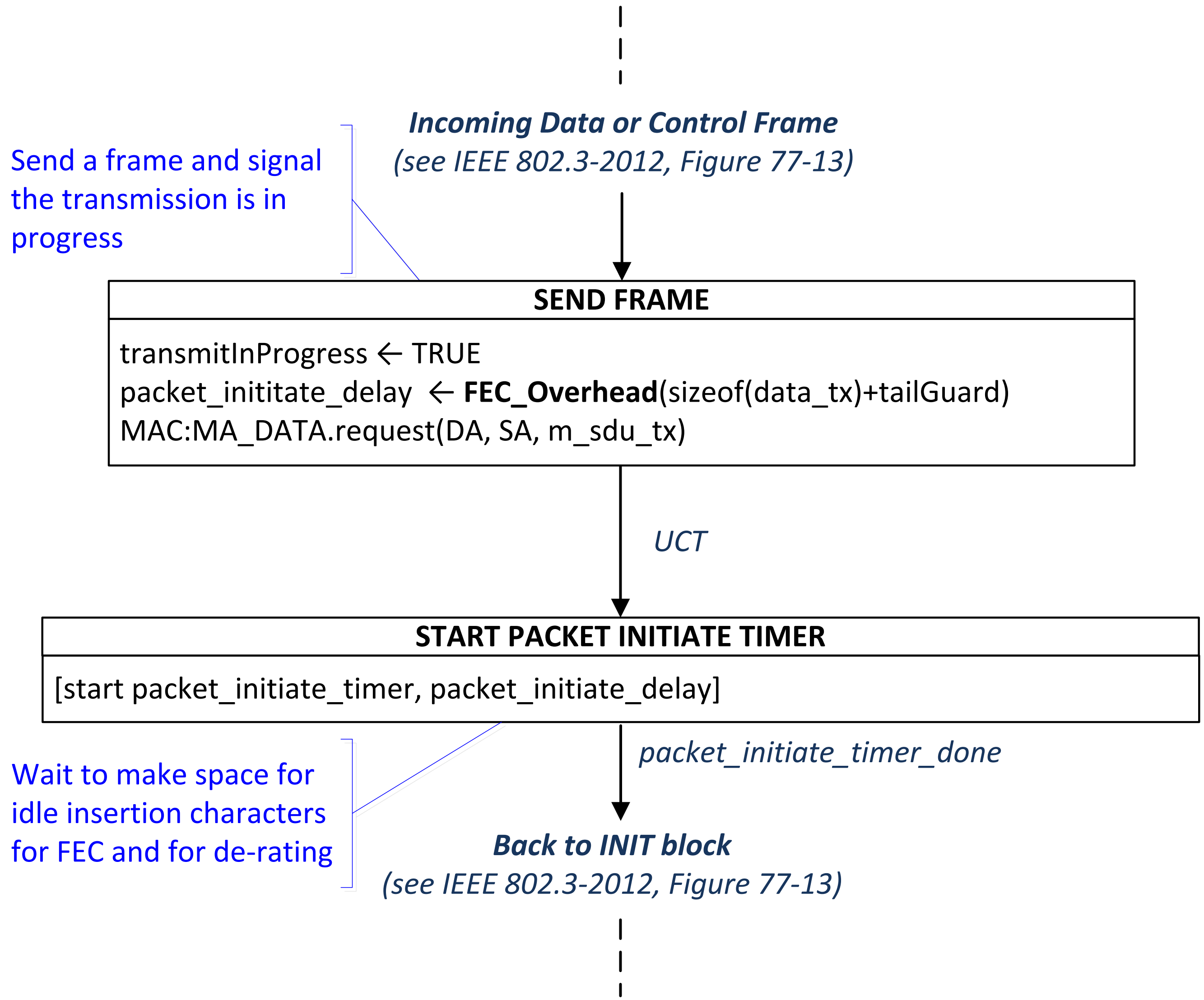


Key remarks:

- 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)

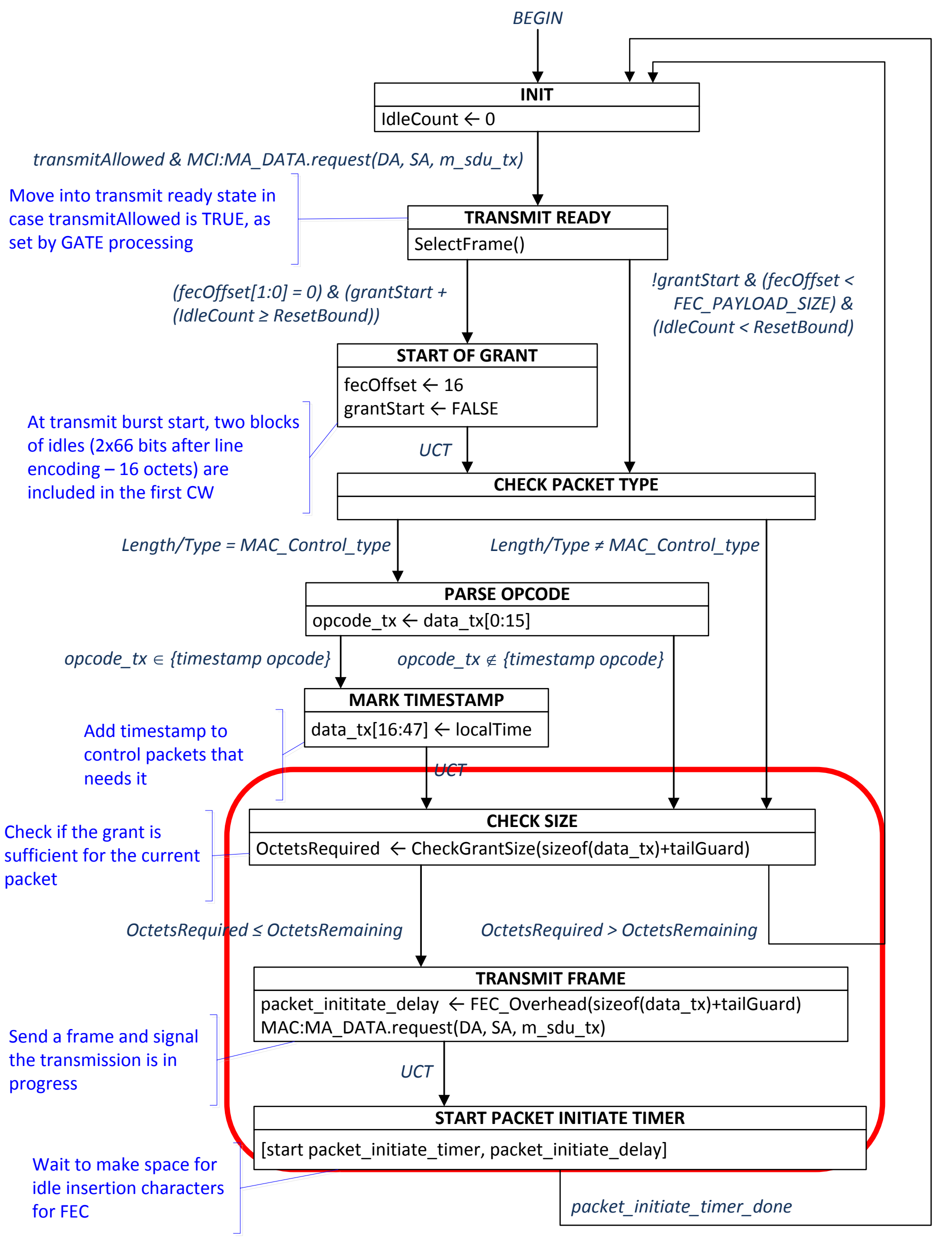
IEEE Std 802.3, Clause 77, Figure 77-13

EPON IDLE Insertion – OLT side



IEEE Std 802.3, Clause 77, Figure 77-13 - Details

EPON IDLE Insertion – ONU side

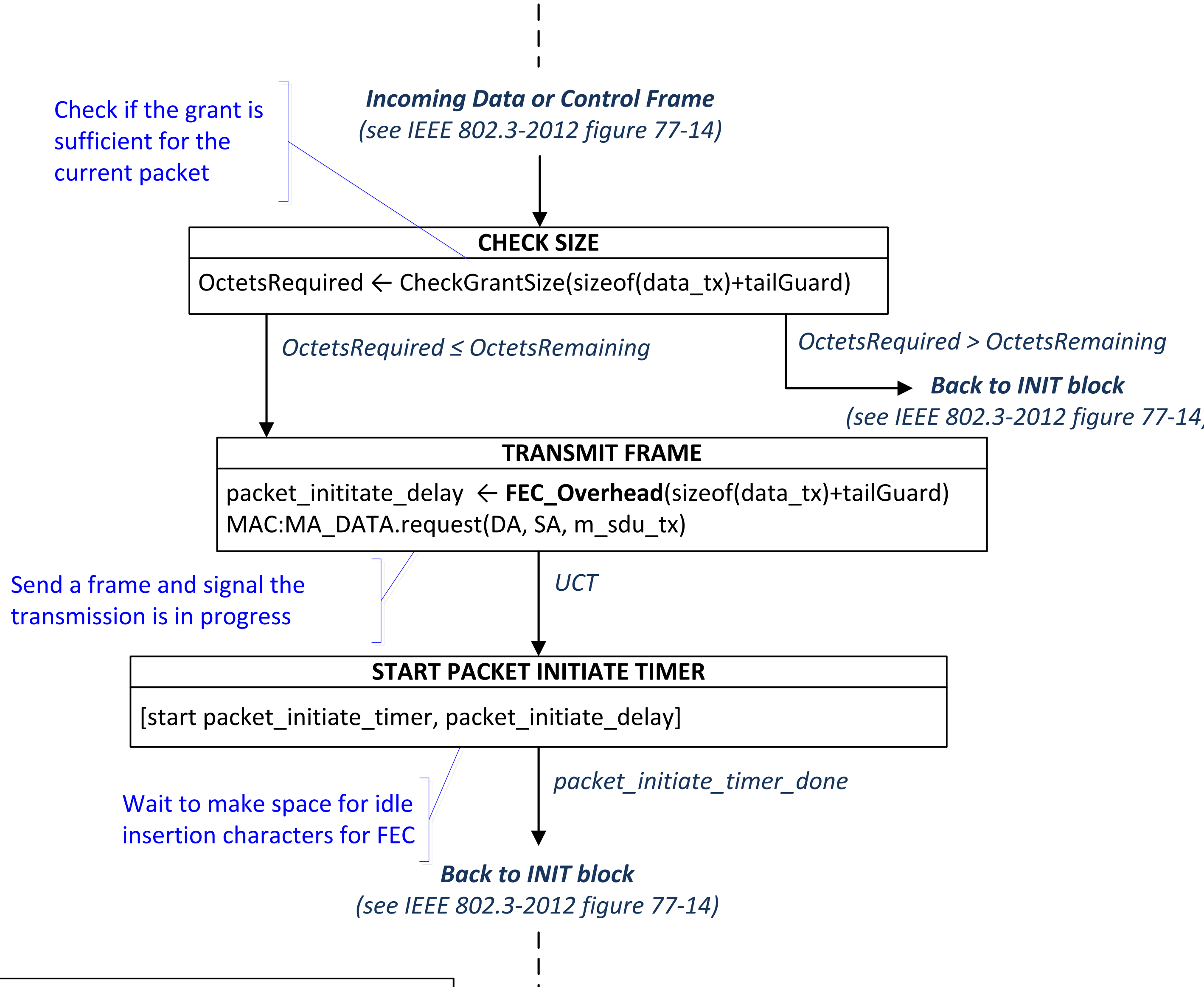


Key remarks:

- 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)

IEEE Std 802.3, Clause 77, Figure 77-14

EPON IDLE Insertion – ONU side



IEEE Std 802.3, Clause 77, Figure 77-14 - Details

10G-EPON *FEC_Overhead* function

***fecOffset* advances by 1 every 8 bit times <u>on PHY</u>**

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

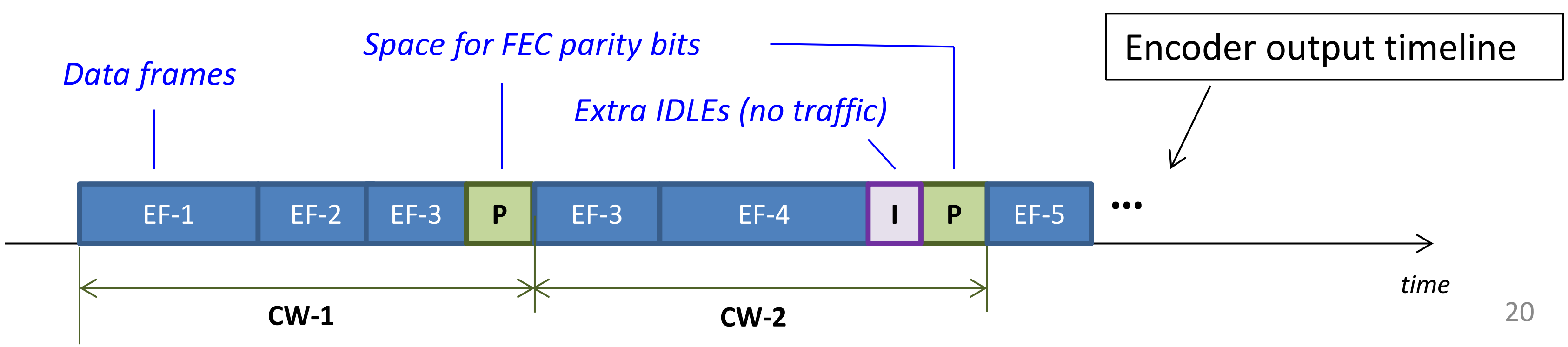
12 bytes for IPG

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

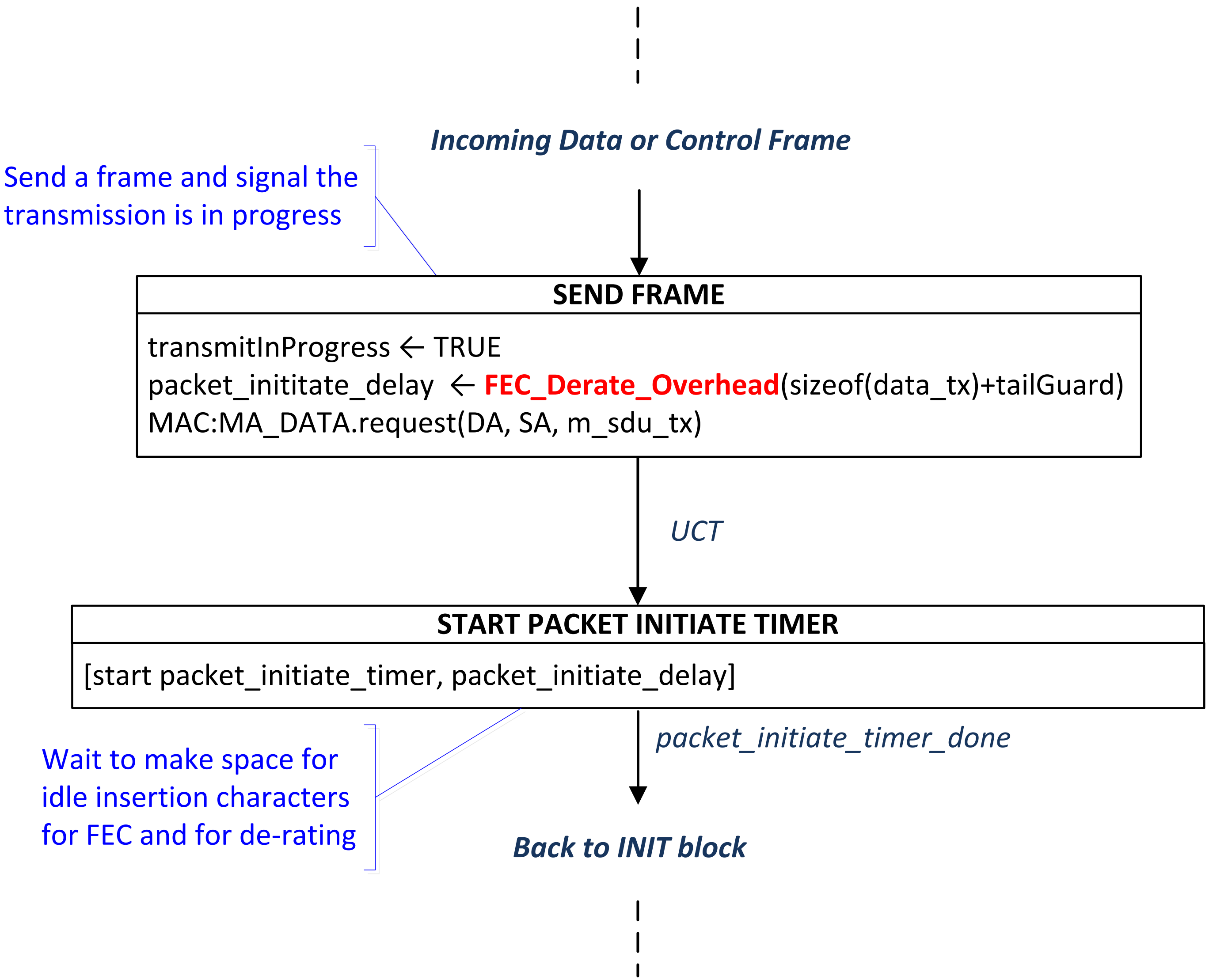
FEC parity bits Size

FEC information bits Size

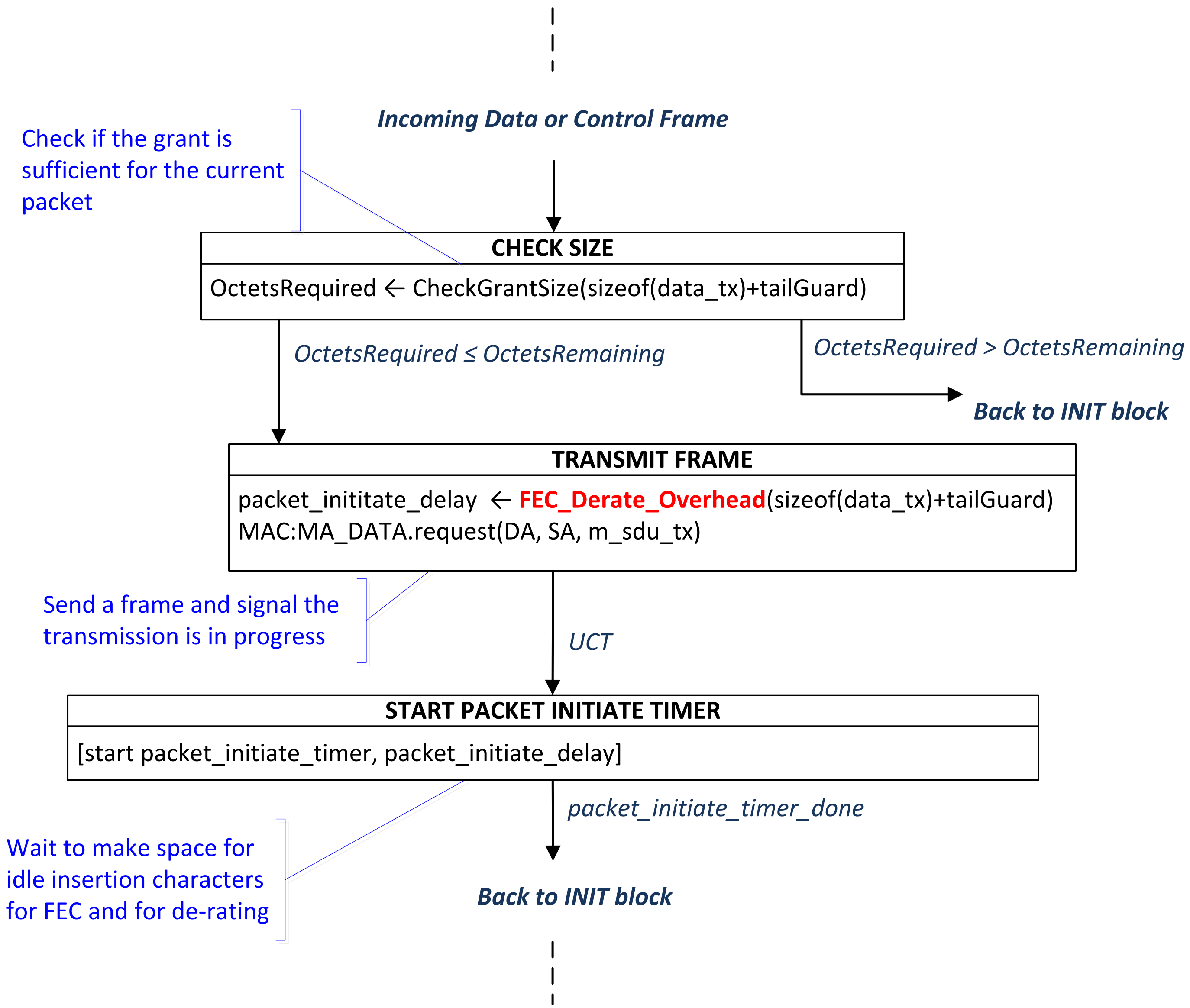
The function returns the length of the data to transmit and cumulates information bits (tracked by the variable *fecOffset*) - when the cumulated data exceeds the FEC_PAYLOAD_SIZE, a FEC_PARITY_SIZE interval is also included to space for parity



EPoC IDLE Insertion – CLT side



EPoC IDLE Insertion – CNU side



EPoC *FEC_Overhead* Function

How it could be done in EPoC?

- The ***FEC_Overhead*** function is updated to ***FEC_Derate_Overhead*** to include also the de-rating component, which needs to be applied to data, IPG and parity insertions

Example

12 bytes for IPG *XGMII Rate* *Coax Rate* *FEC information bits Size*

FEC_Derate_Overhead(length) = 12 + ceiling[(R_MX/R_PHY – 1) *

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

Packet Length, including IPG and preamble

FEC parity bits Size

fecOffset advances by 1 every 8 bit times on coax PHY

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

EPoC IDLE Insertion (baseline III)

Baseline proposal III: IDLE Insertion in EPoC RS in the Tx direction re-uses 10G-EPON design as defined in IEEE Std 802.3, Clause 77 with new FEC parameters for EPoC. The functionality is extended to include de-rating by means of a new function *FEC_Derate_Overhead(·)* that replaces the *FEC_Overhead(·)* function.

- The exact modifications to the overhead formula and related parameters are TBD.

Note: The name of the new function is just an example and can be finalized at a later stage.

IDLE Deletion – TX Direction

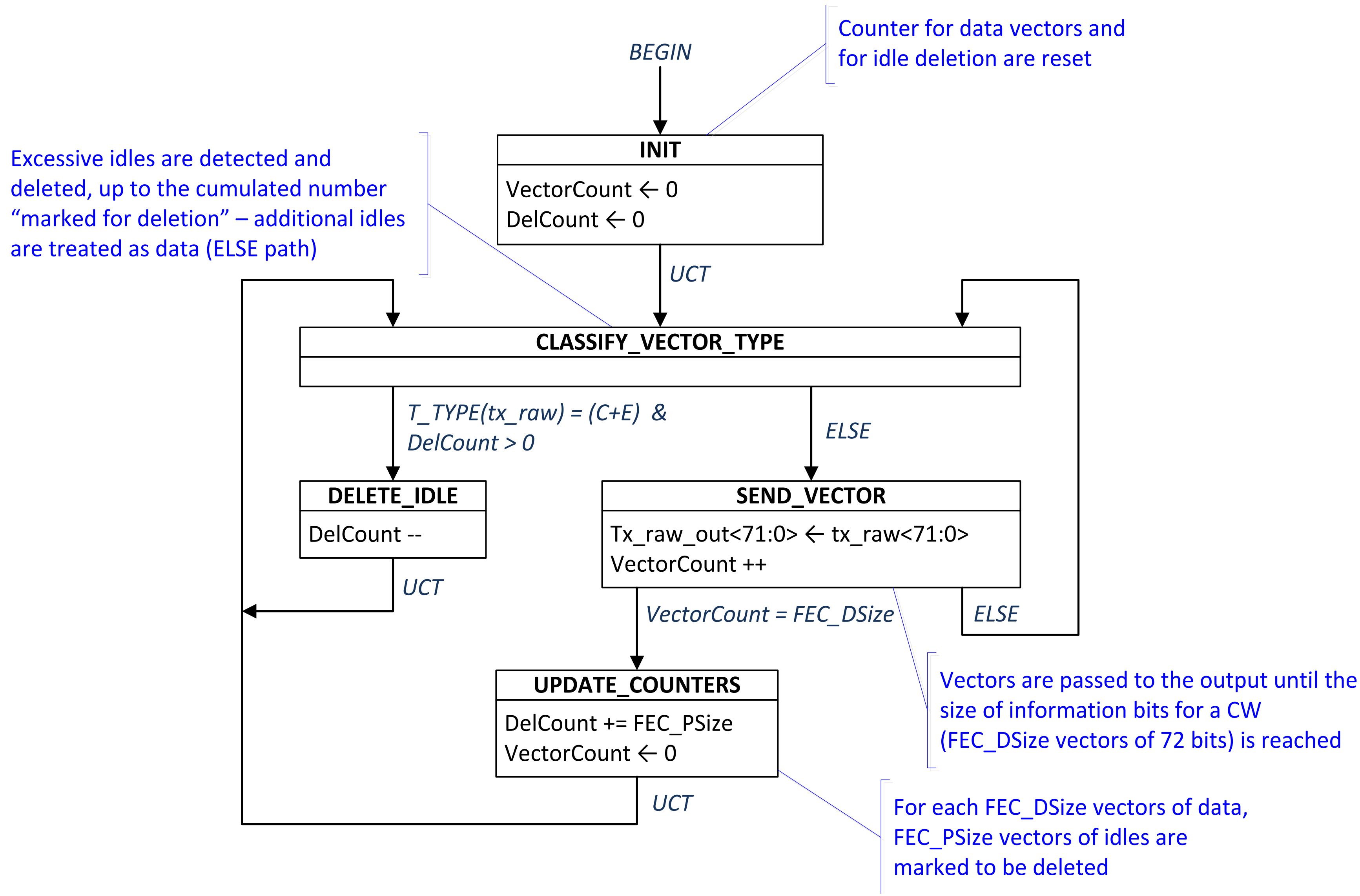
IDLE Deletion process - objective

- Extra IDLEs are removed below XGMII interface before PHY processing occurs
  - Effective data rate at PHY after deletion is equal to R_{eff}

How is that achieved in 10G-EPON?

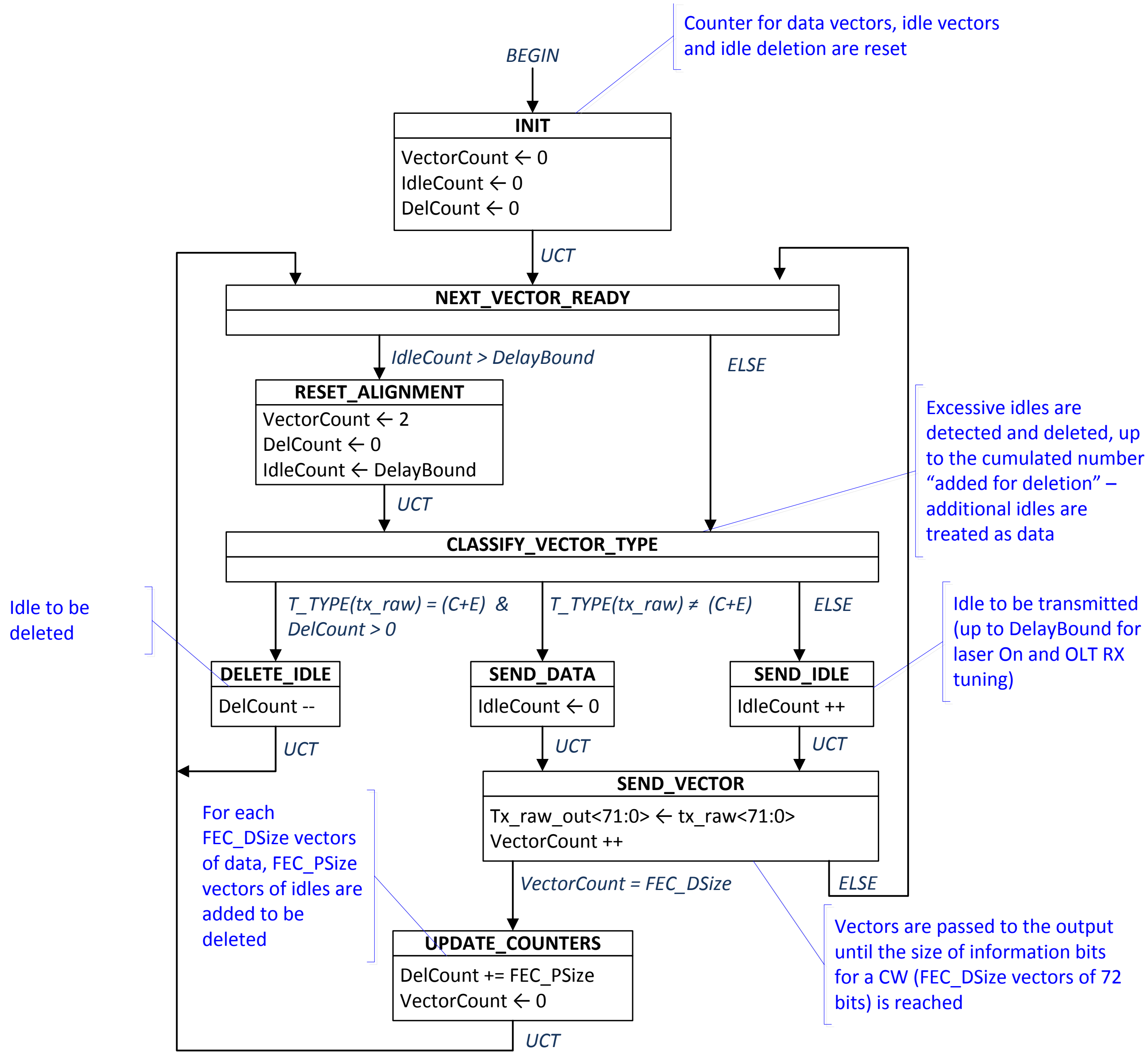
- IDLE deletion in implemented in the PCS for TX direction (see IEEE Std 802.3 [1], 76.3.2.1)
- The number of vectors transiting the XGMII interface are counted and the function deletes FEC_PSize IDLEs at each FEC code word payload FEC_DSize of data:
  - At initialization vector counter and IDLE deletion counter are reset to zero
  - Each time a vector of data transits, the vector counter is incremented
  - When the vector counter reaches the size of the code word payload, the IDLE deletion counter is incremented by the size of the code word parity
  - Each time vector of IDLEs transits, deletion occurs in case the IDLE deletion counter is larger than zero (e.g. still some IDLE to be deleted)
- See next slide for the corresponding state diagram

10G-EPON IDLE Deletion – OLT side



IEEE Std 802.3, Figure 76-9

10G-EPON IDLE Deletion – ONU side



In US, enough IDLEs to cover *DelayBound* time are transmitted

This DelayBound value represents the delay sufficient to initiate the laser and to stabilize the receiver at the OLT

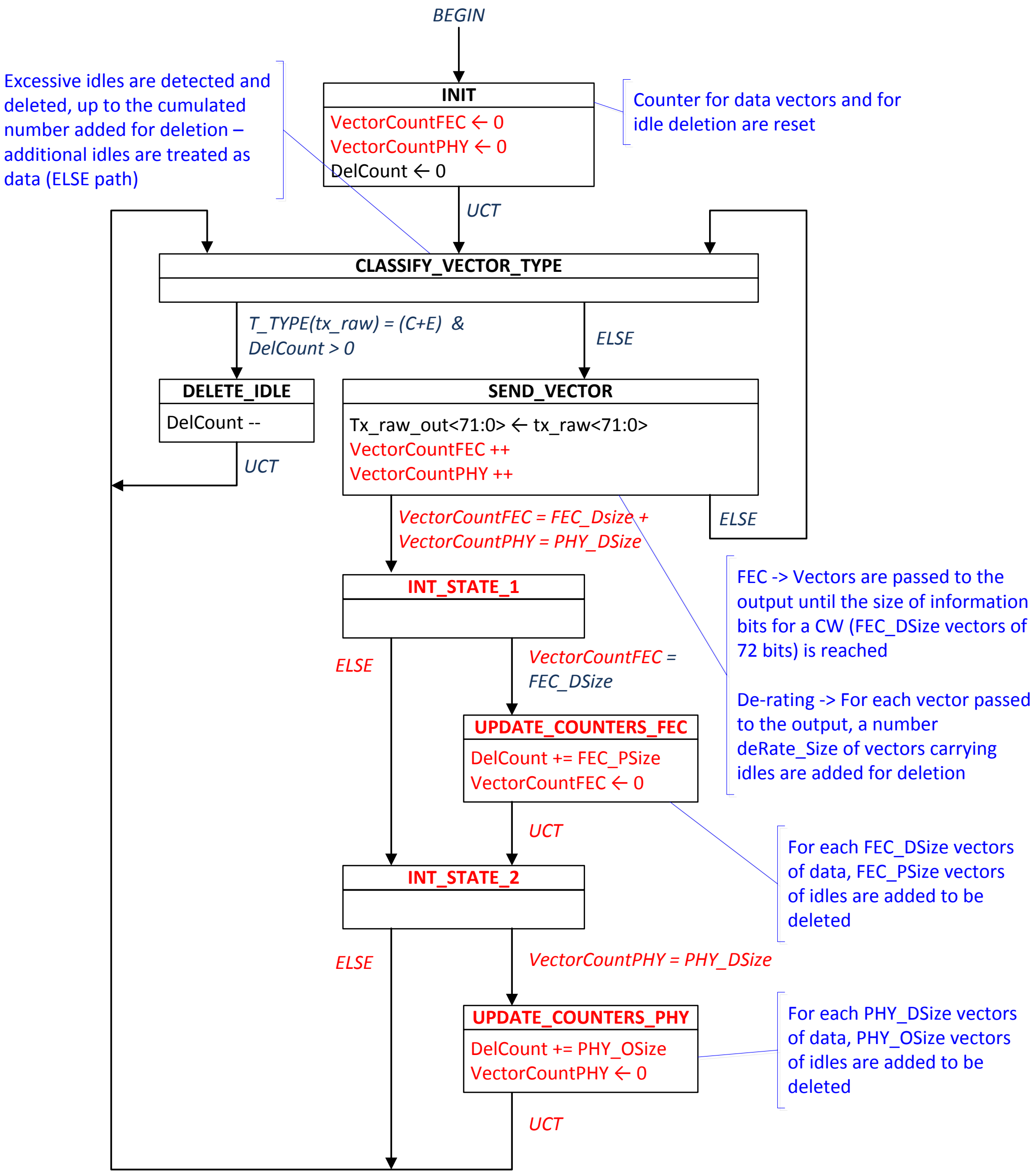
IEEE Std 802.3, Figure 76-10

EPoC IDLE Deletion – TX Side

How it could be done in EPoC?

- For FEC parity the same functionality could be re-used, with updated FEC parameters for CW payload and CW parity sizes (TBD, depending on FEC decisions)
- For additional IDLE deletion due to de-rating, the same principle can be applied by simply introducing a new independent counter:
  - In fact, for each vector of encoded data, a number of IDLEs proportional to the ratio between R_{MX} and R_{eff} needs to be deleted – they were inserted above XGMII to allows enough time for the PHY transmission at rate R_{eff}
  - Two new parameters PHY_DSize e PHY_OSize are introduced (values TBD):
    - Each time a vector of encoded data transits, the new vector counter for de-rating is incremented (this is done independently of the FEC vector counter)
    - When the de-rating vector counter reaches the size PHY_DSize, the IDLE deletion counter is incremented by the size PHY_OSize
  - Each time vector of IDLEs transits, deletion occurs in case the IDLE deletion counter is larger than zero (e.g. still some IDLE to be deleted)
- See next slide for the corresponding state diagram

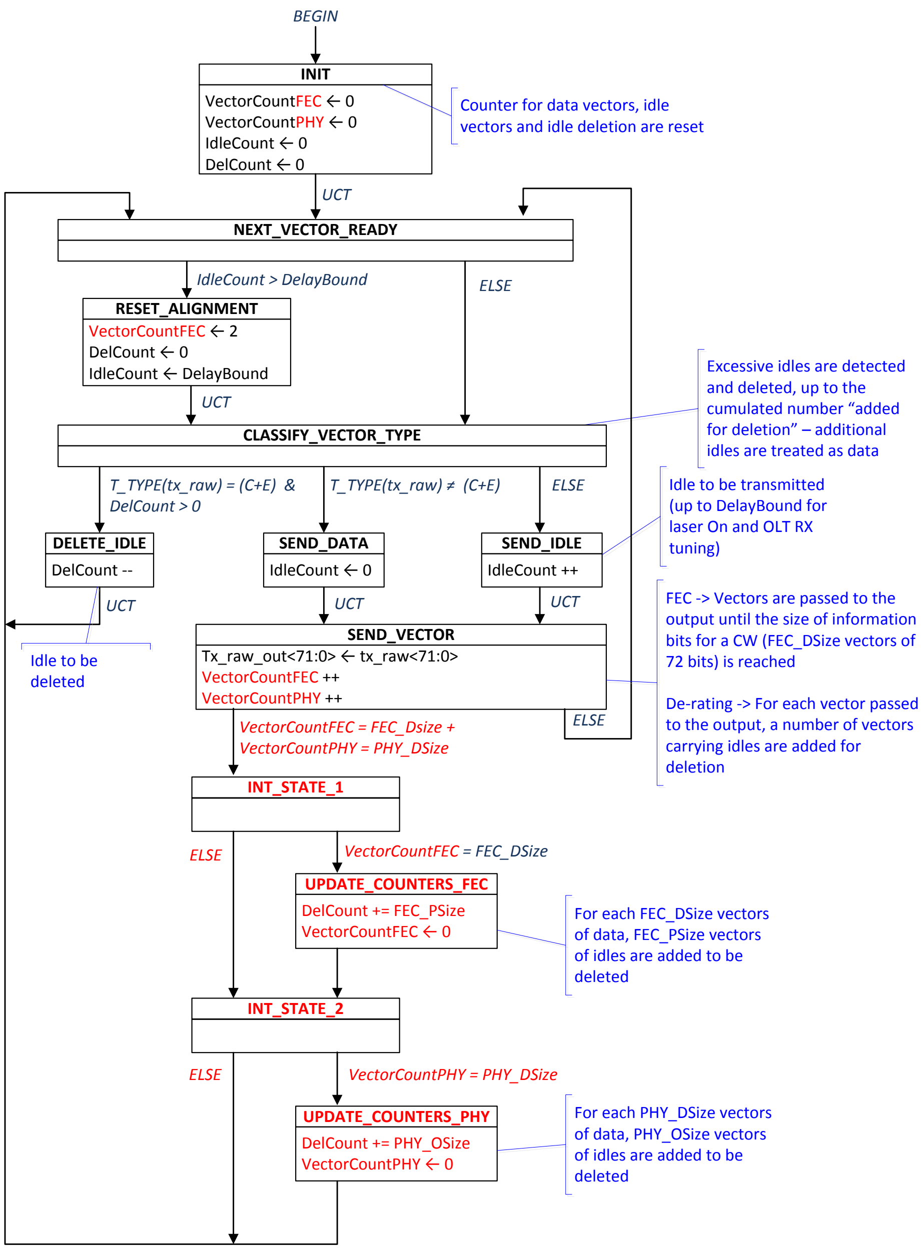
EPoC IDLE Deletion – CLT side



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 IDLE Deletion – CNU side



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

- 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 IDLE Deletion (baseline IV)

Baseline proposal IV: IDLE Deletion in the EPoC PCS in TX direction re-uses 10G-EPON design as defined in IEEE Std 802.3, Clause 76 with new FEC parameters for EPoC. The function is extended to the EPoC case via additional variables for de-rating compensation, as shown in previous slides 29 and 30.

Straw Poll #3

#3: IDLE Insertion in EPoC RS in the Tx direction re-uses 10G-EPON design as defined in IEEE Std 802.3, Clause 77 with new FEC parameters for EPoC. The functionality is extended to include de-rating by means of a new function *FEC_Derate_Overhead(·)* that replaces the *FEC_Overhead(·)* function.

- The exact modifications to the overhead formula and related parameters are TBD.

Ad-hoc call: Yes: 7 / No: 0 / Undecided:1

TF meeting: Yes: / No: / Undecided:

Straw Poll #4

#4: IDLE Deletion in the EPoC PCS in TX direction re-uses 10G-EPON design as defined in IEEE Std 802.3, Clause 76 with new FEC parameters for EPoC. The function is extended to the EPoC case via additional variables for de-rating compensation, as shown in slides 29 and 30.

Ad-hoc call: Yes: 6 / No: 0 / Undecided: 2

TF meeting: Yes: / No: / Undecided:

References

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

[2] **hajduczenia_05_0313**: “Data Rate Adaptation” – Marek Hajduczenia (ZTE), Andrea Garavaglia (Qualcomm)