Proposal of a Physical Medium Attachment for GEPOF technical feasibility

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Agenda

- Motivation
- Objectives
- PHY control states machines
- Adaptive Tomlinson-Harashima Precoding

Motivation

- In [6] was presented a transmission structure proposal for GEPOF PHY able to fullfil with the special requirements of automotive applications like:
  - Clock frequency deviation: +/- 200 ppm (aging and temperature)
  - Max. wake time (from power off to Gigabit link ready): 100 ms
  - Clock frequency drift of 5ppm/ºC
  - Fast temperature drift of ~4ºC/s
  - Continuous tracking of non-static communication channel caused by vibrations and temperature

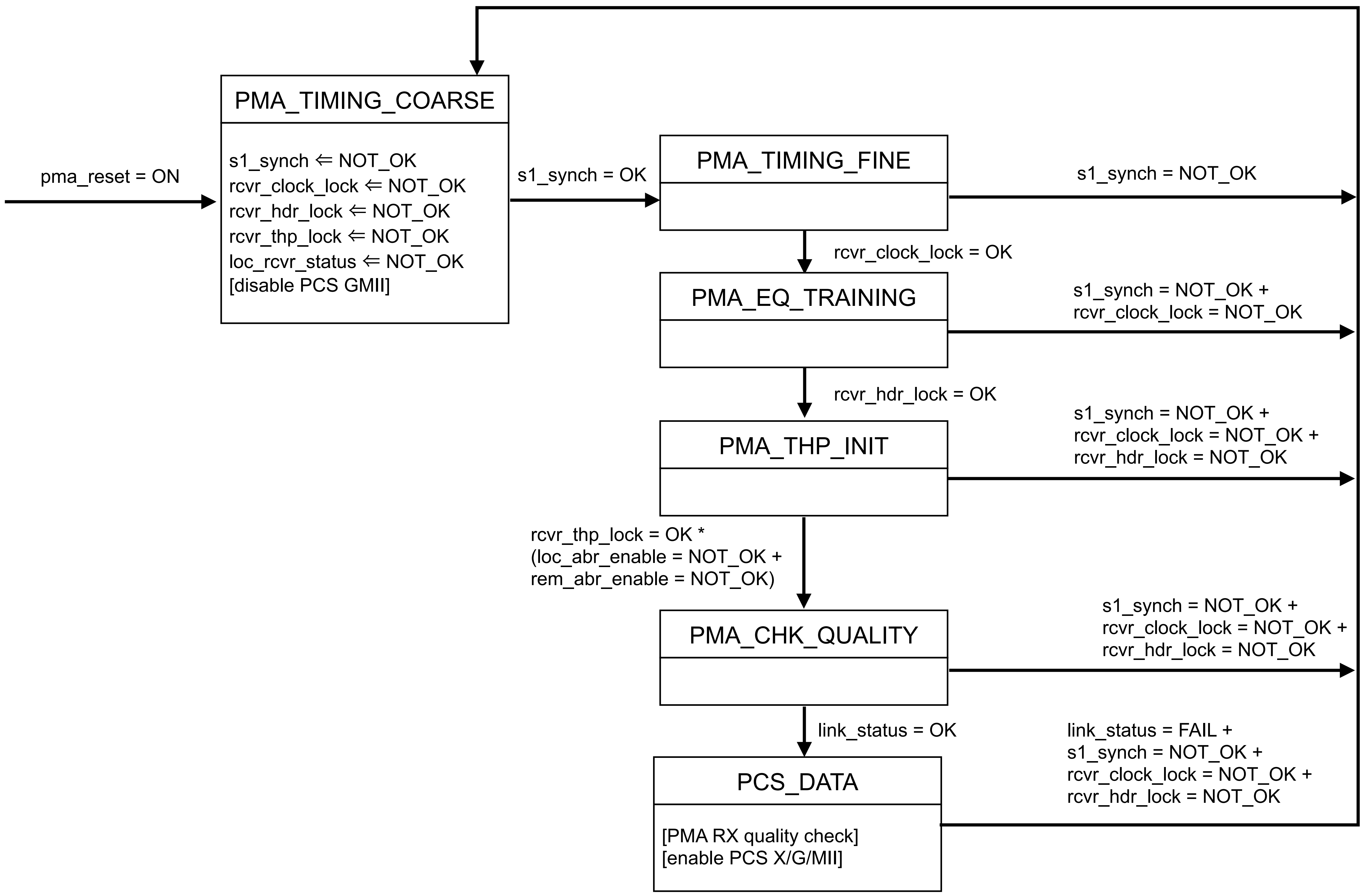
- A set of gaps for technical feasibility are identified:
  - Adaptive Tomlinson-Harashima Precoding ➤ negotiation and synchronization of precoding coefficients between link partners
  - Link establishment ➤ PHY control
  - Link monitor

Objectives

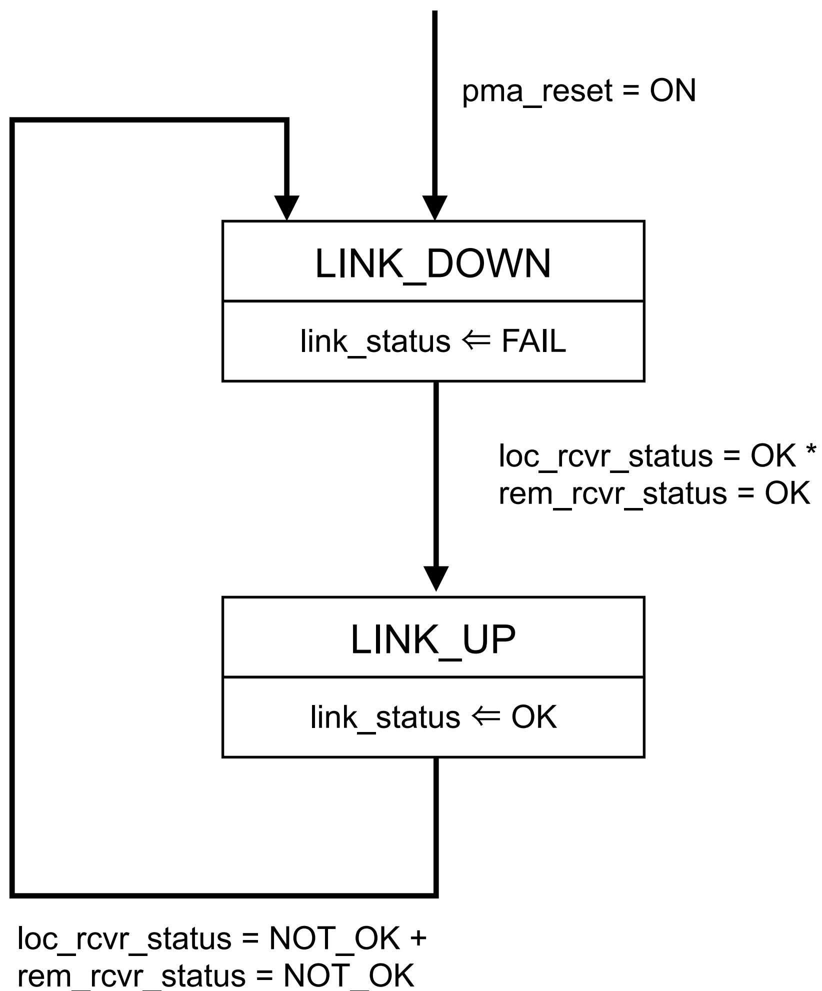
- The main objective of this presentation is to propose a PMA able to fit with the requirements described in [1], [2] and [6] and compatible with both, the transmission structure proposed in [6] and the PCS proposed in [7], for the technical feasibility assessment
- The PMA proposal shall address next key topics:
  - Adaptive THP during link establishment as well as continuous operation
  - PHY control and link establishment
  - Link monitor
- For synchronization and capabilities advertisement between link partners it will be assumed that information contained in header (i.e. PHD) described in [7] is interchanged between devices in a robust manner. Robustness is guaranteed by the transmission structure defined in [6]

PHY Control State Machines

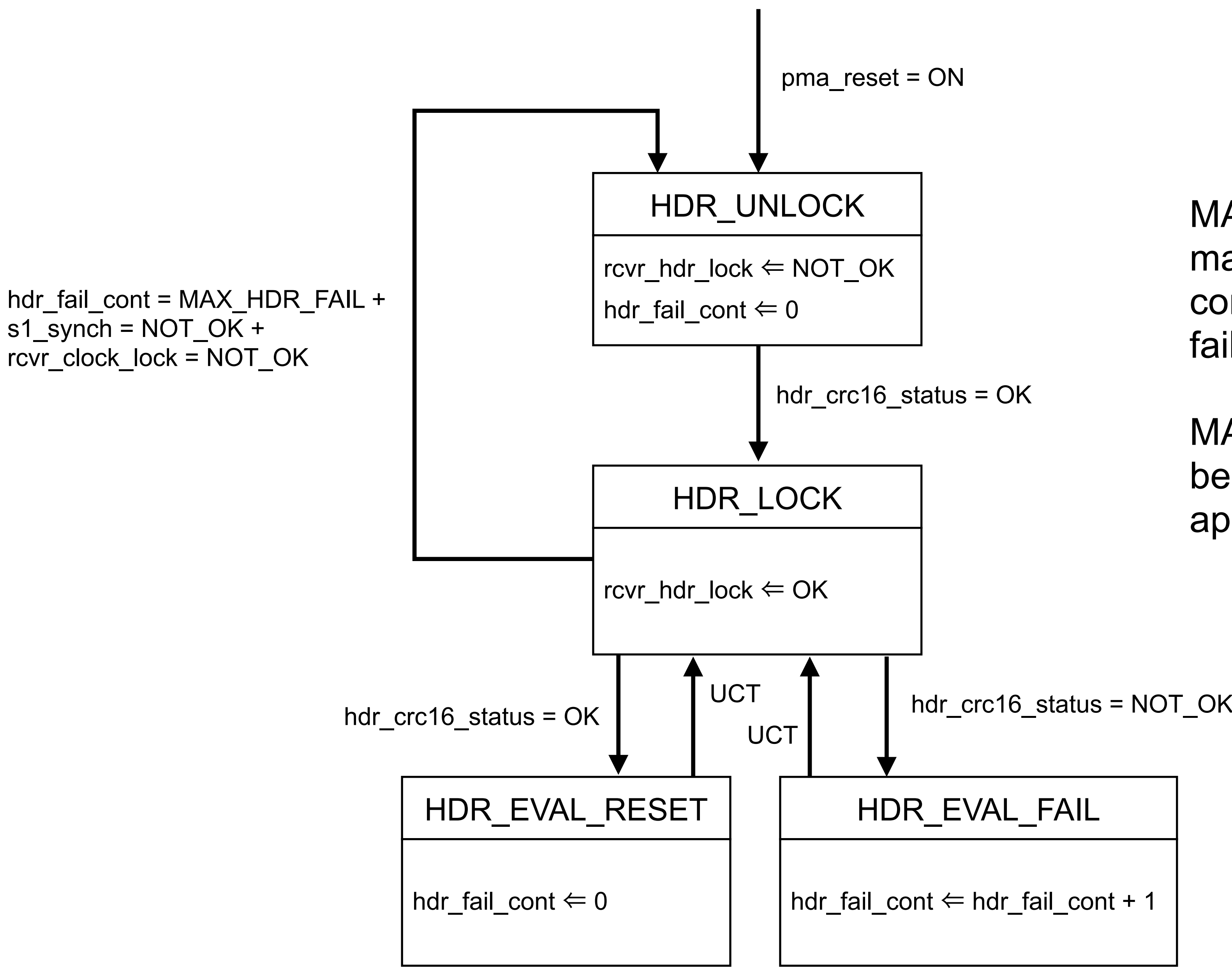
PHY Control: Link establishment



PHY Control: Link monitor



PHY Control: Physical header monitor



MAX_HDR_FAIL: maximum acceptable contiguous header CRC failures

MAX_HDR_FAIL should be 1 for critical safety applications

PHY Control: variables

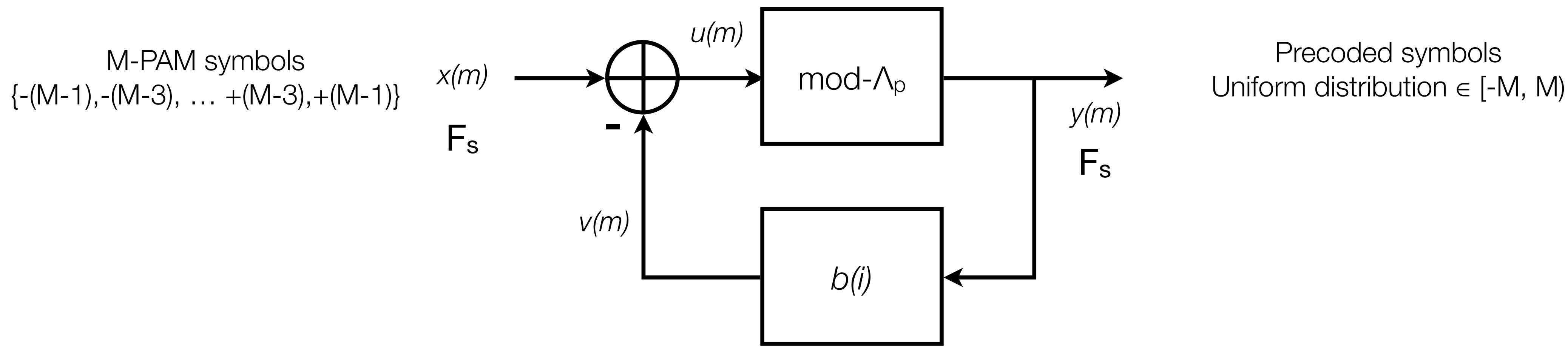
- **s1_synch:** variable set by the PMA Clock Recovery function to indicate the transmission structure and symbol synchronization have been achieved, so that the PHY is able to recognize the start of the transmit block.
  - OK: synchronization based on S1 pilot signal has been achieved.
  - NOT_OK: synchronization has not been achieved.
- **rcvr_clock_lock:** variable set by the PMA Clock Recovery function to indicate that the clock has been properly recovered from the receive signal.
  - OK: clock is stable and optimum phase is provided for sampling receive signal.
  - NOT_OK: clock has not been recovered from receive signal and/or it is not stable.
- **loc_rcvr_status:** variable set by the PMA Receive function to indicate the correct or incorrect operation of the receive link for the local PHY.
  - OK: the receive link for the local PHY is operating reliably.
  - NOT_OK: operation of the receive link for the local PHY is unreliable.

PHY Control: variables

- **rem_rcvr_status:** variable set by the PCS Receive function to indicate whether correct operation of the receive link for the remote PHY is detected or not (received in PHD.RX.STATUS, see [7])
  - OK: the receive link for the remote PHY is operating reliably.
  - NOT_OK: operation of the receive link for the remote PHY is unreliable.
- **link_status:** variable that is set by the PMA Link Monitor and passed to the PCS via the PMA_LINK.indication primitive
  - OK or FAIL.
- **rcvr_hdr_lock:** variable set by the PMA Receive function to indicate whether correct reception of PHD is detected
  - OK: PHD reception is reliable.
  - NOT_OK: PHD reception is unreliable.

Adaptive Tomlinson-Harashima Precoding

Tomlinson-Harashima Precoding: definition



- M = 2^k, being k the number of bits that define the M-PAM constellation generated by FEC encoder
- The coefficients of the feedback filter *b(i)* are dynamically adapted by using the PHD
- *b(i) = 0* ∀*i* at reset
- **State of feedback filter *b(i)* must be reseted (input signal memory equal to 0) before each Payload data block (after either S1, S2, or PHS states are transmitted). See [6]**

$$v(m) = \sum_{i=1}^{N_b} b(i) y(m-i)$$

$$u(m) = x(m) - v(m)$$

$$y(m) = \mathrm{mod}\left(\left(u(m) + M\right), 2M\right) - M$$

$$\mathrm{mod}(y,x) = y - x\left\lfloor \frac{y}{x} \right\rfloor$$

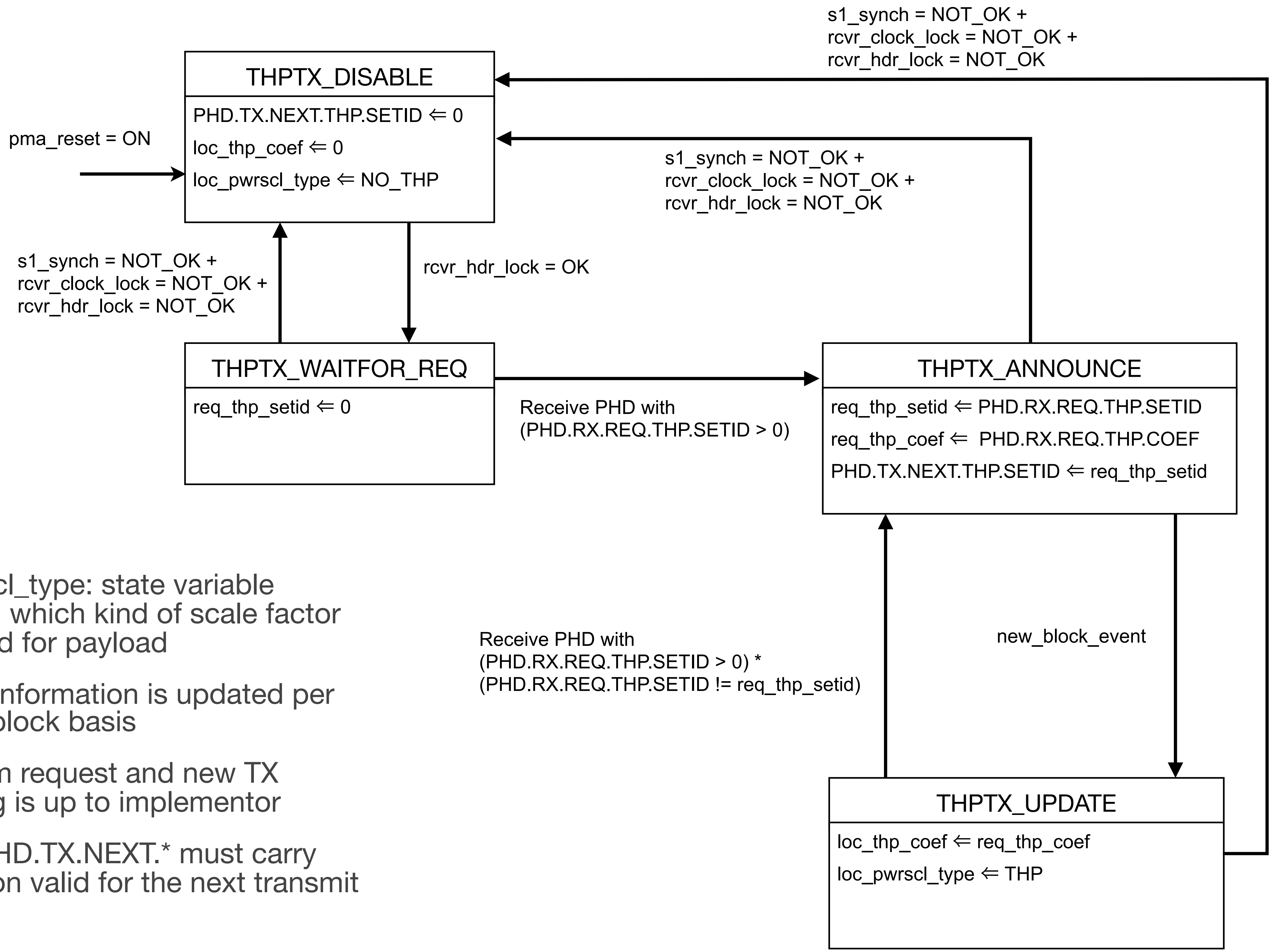
Introduction to adaptive THP

- Feedback filter is implemented at TX to eliminate the channel post-cursor
- Feedforward filter is implemented at RX to compensate both the pre-cursor and cursor of channel and to provide white noise for the symbols detection
- For correct operation of THP, it is required synchronization (i.e. matching) between the set of coefficients employed at the transmitter and those calculated at the receiver
- The receiver, by implementation of the adaptive filtering algorithm (e.g. RLS, LMS), estimates simultaneously:
  - Feed-Forward Filter (FFF) to be used at the receiver
  - Feed-Back Filter (FBF) to be used for precoding at the transmitter
- No partial adaptation of feedforward filter with fixed THP feedback is going to be considered, to avoid performance penalties and because the transmission structure proposed in [6] allows simultaneous FBF and FFF adaptation

General architecture of adaptive THP

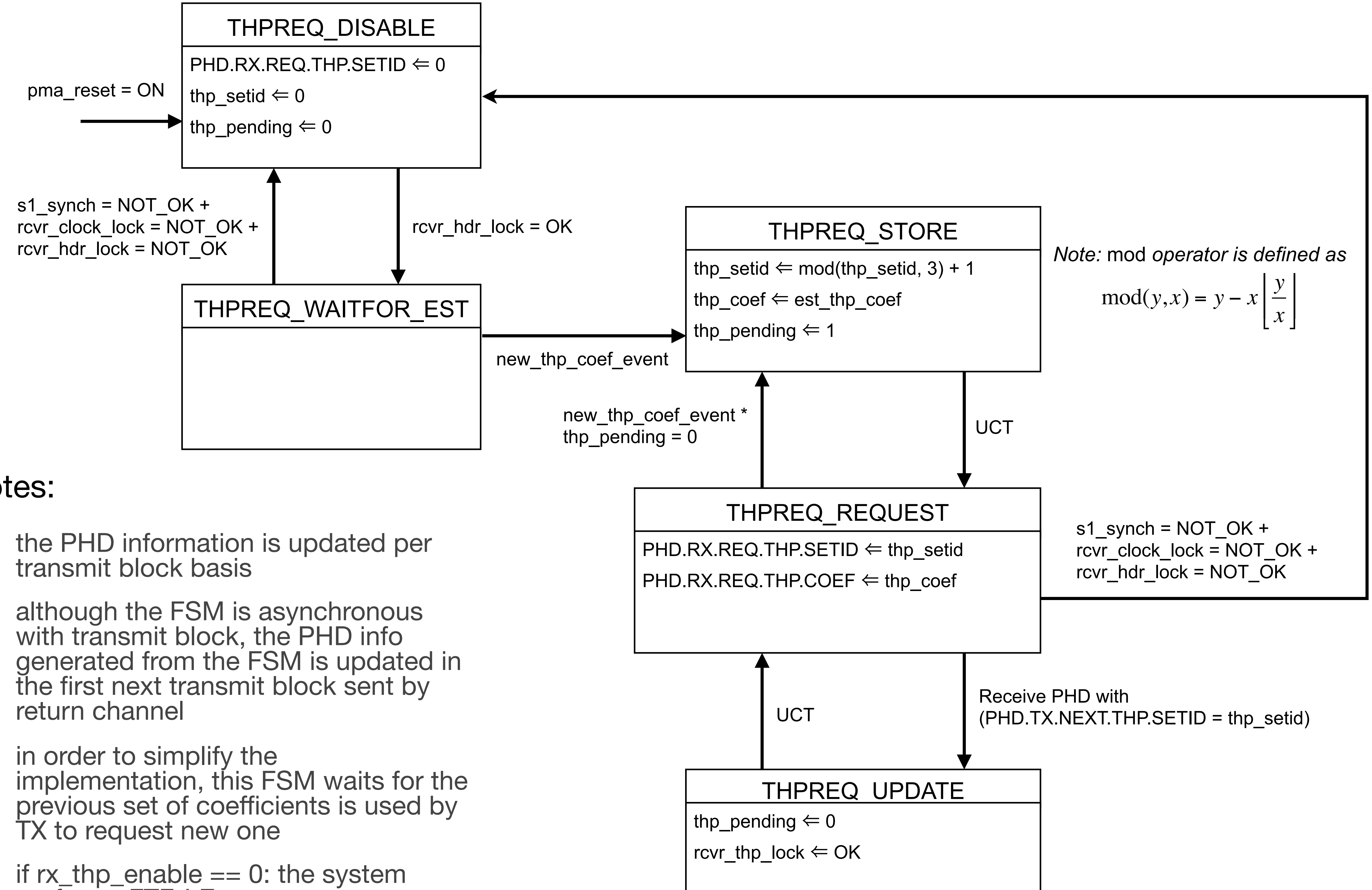
- The receiver, by implementing the adaptive filtering data-aided algorithm by using S2 pilots, estimates simultaneously:
  - Feed-Forward Filter (FFF) to be used at the receiver
  - Feed-Back Filter (FBF) to be used for precoding at the transmitter
- FFFand FBF are matched, hence transmitter and receiver must use the filters belonging to one estimation.
- The receiver makes a request to the transmitter for using a set of coefficients at FBF; this set is identified by a PHD.RX.REQ.THP.SETID > 0.
- The receiver saves the FBF and FFF corresponding to this SETID, to be used:
  - For PHS, performing VA MLSE
  - For Payload, performing FFF, when the transmitter has announced in the previous transmit block the THP will be enabled with PHD.TX.NEXT.THP.SETID > 0
- The receiver waits for the transmitter uses the requested set of FBF coefficients in THP to make a new request

THP TX FSM



- Notes:
    - loc_pwrscl_type: state variable indicating which kind of scale factor to be used for payload
    - the PHD information is updated per transmit block basis
    - delay from request and new TX precoding is up to implementor
    - always PHD.TX.NEXT.* must carry information valid for the next transmit block

THP REQ FSM



- Notes:
  - the PHD information is updated per transmit block basis
  - although the FSM is asynchronous with transmit block, the PHD info generated from the FSM is updated in the first next transmit block sent by return channel
  - in order to simplify the implementation, this FSM waits for the previous set of coefficients is used by TX to request new one
  - if rx_thp_enable == 0: the system performs FTF-LE

Adaptive THP: variables

- **new_block_event:** variable set by the PCS transmit function to indicate the encoding of a new transmit block starts
  - 1: indicates the event of a new transmit block starts. The value 1 extends during one transmit symbol period, and it is synchronous with the first ZERO symbol of a transmitted block.
  - 0: indicates no new block starts.
- **loc_pwrscl_type:** variable set by the PMA Phy Control function that indicates the type of power scaling performed in data payload sub-blocks
  - NO_THP: the power scale is set according to no THP is enabled in TX; feedback coefficients are zeroes
  - THP: the power scale is according to THP
- **loc_thp_coef:** variable set by the PMA PHY Control function that contains the local coefficients used by the PMA transmit for TH precoding of data payload sub-blocks. loc_thp_coef is a set of 9 real numbers representing the feedback coefficients b(i)
  - Coefficients are real numbers that take values in the interval [-2, 2).
- **req_thp_coef:** variable set by the PCS receive function that contains the coefficients requested by the link partner to be used for THP precoding of the data payload sub-blocks. req_thp_coef is a set of 9 real numbers that are received in PHD.RX.REQ.THP.COEF field (see [7]).
  - Values: coefficients are real numbers that take values in the interval [-2, 2).

Adaptive THP: variables

- **req_thp_setid:** variable set by the PCS receive function that contains the set identifier associated to the THP coefficients requested by the link partner and that is received in PHD.RX.REQ.THP.SETID field
  - 0: request for changing the THP coefficients is not performed.
  - 1 .. 3: set identifier.
- **rcvr_thp_lock:** variable set by the PMA Phy Control function to indicate whether the Tomlinson-Harashima precoding is initialized, therefore the PMA Receive function is receiving payload data sub-blocks TH precoded with the coefficients that were requested by the PMA Phy Control.
  - OK: THP is initialized; data payload is received TH precoded.
  - NOT_OK: THP is not initialized.
- **thp_setid:** variable used by PMA Phy Control to store the last THP set-id requested to the link partner.
  - 0: reset value.
  - 1 .. 3: set identifier.
- **thp_pending:** variable used by the PMA Phy Control function to store the pending status of a THP configuration request.
  - 0: reset or request is not pending. THP request was attended by the link partner, which applied the requested THP coefficients for data payload precoding.
  - 1: a THP configuration request is pending.

Adaptive THP: variables

- **thp_coef:** variable used by PMA Phy Control to store the last THP coefficients requested to the link partner. thp_coef is a set of 9 real numbers representing the feedback coefficients b(i)
  - Values: coefficients are real numbers that take values in the interval [-2, 2).
- **est_thp_coef:** variable set by the PMA Receive function that contains the coefficients estimated to compensate inter-symbol interference by means of Tonlinson-Harashima Precoding. est_thp_coef is a set of 9 real numbers representing the feedback coefficients b(i)
  - Values: coefficients are real numbers that take values in the interval [-2, 2).
- **new_thp_coef_event:** variable set by the PMA Receive function to indicate the estimation of THP coefficients has finished and a new set is ready.
  - 1: indicates the event of a new set of THP coefficients is ready from estimation. The value 1 extends during one receive symbol period and it may be asynchronous with the received block start.
  - 0: indicates no new set of THP coefficients is ready.

Conclusions

- A Physical Medium Dependent has been proposed able to fit with the requirements described in [1], [2] and [6] and compatible with both, the transmission structure proposed in [6] and the PCS proposed in [7], for the technical feasibility assessment
- The PMA proposal has been included solutions for:
  - Adaptive Tomlinson-Harashima Precoding
  - Link establishment
  - PHY control
  - Link monitor
- The PMA proposal, together the PCS proposed in [7] and the transmission structure proposed in [6], demonstrate the technical feasibility for implementation of a PHY for GEPOF based on high spectral efficient coded modulations and TH precoding, to meet with the requirements defined in [1], [2] and [6] for both automotive and consumer applications

References

- [1] *Rubén Pérez-Aranda, "Shannon's capacity analysis of GEPOF for technical feasibility assessment", GEPOF SG, Interim Meeting, May 2014*
- [2] *Rubén Pérez-Aranda, "Link budget requirements for Gigabit over POF", GEPOF SG, Interim Meeting, May 2014*
- [3] *Rubén Pérez-Aranda, "Optical receiver characteristics for GEPOF technical feasibility", GEPOF SG, Interim Meeting, May 2014*
- [4] *Rubén Pérez-Aranda, "Optical transmitter characteristics for GEPOF technical feasibility", GEPOF SG, Interim Meeting, May 2014*
- [5] *Rubén Pérez-Aranda, "High spectrally efficient coded modulation schemes for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*
- [6] *Rubén Pérez-Aranda, "Proposal of a transmission structure for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*
- [7] *Rubén Pérez-Aranda, "Proposal of a Physical Coding Sublayer for GEPOF technical feasibility", GEPOF SG, Plenary Meeting, July 2014*

Questions?