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# Thoughts on PHY Control State Diagram for 100BASE-T1L

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# Introduction

- The 802.3dg task force has already had a number of presentations on training, based on the approaches used in clauses 97, 149 and 165
  - Including descriptions of training frames consistent with the adopted proposals for 8b6T encoding using 8N/(8N+1) block codes and an RS-FEC
    - Low latency mode using a 16B/17B (N=2) block code
    - Burst error protection mode using a 64B/65B (N=8) block code and RS FEC
  - And there has been discussion and general agreement on using PAM2 during training and switching to PAM3 for idle and data
- This presentation brings up some issues and details that should be considered for the PHY Control State Diagram
- In this presentation I will use the terms Leader and Follower as recommended by Annex K of the 802.3 2022 IEEE Standard

# Purpose of Training

- The purpose of training in 100BASE-T1L is to achieve the following
  - Sequence the bring-up of the Leader and Follower PHYs using PAM2 signaling
    - PAM2 has the advantage of robustness during start-up and blind acquisition as it is easier to open the eye
  - Exchange the PHY capabilities between the local and remote PHYs
  - Align the 8N/(8N+1) and RS-FEC frames
  - Stage the transition from PAM2 to PAM3 signaling
    - Allow a short period to allow for any adjustment to the adaptive filter coefficients when the signaling transitions from PAM2 to PAM3
  - Synchronize the transition to idle/data

# PHY Start-up for Long Reach Echo Cancelling PHYs

- There are some differences for long reach echo cancelling PHYs like 100BASE-T1L compared to short reach PHYs that are worth highlighting
  - 100BASE-T1L operates over 500m of reach at 100 Mb/s compared to less than 40m for the more recent 1G and Multi-G single pair Ethernet PHYs
  - At 500m the insertion loss at Nyquist (40 MHz) is almost 37 dB and is much greater than for the short reach BASE-T1 PHYs
    - This results in a much greater ratio of the local echo signal power to the received signal power
    - It is expected that when the Follower starts transmitting, there may be a period of time when the transmit timing is not reliable
    - This may require some additional safeguards around the behaviour of the PHYs while the echo cancellers are adapting
  - This was addressed in the 10BASE-T1L standard, and this issue should also be considered for 100BASE-T1L

# Transition Between States

- In IEEE PHY standards the sequencing of the Leader and Follower is controlled by a state diagram that defines the conditions to transition from one state to the next
- The transition between the various states is controlled by timers or by signaling between the Leader and Follower
  - The advantage of signaling between the Leader and Follower PHYs is that you have a deterministic means to change state that can be dependent on receiver information
  - However, it has the disadvantage you must have reliable signaling between the Leader and Follower which may take a significant time to achieve and thus delay the transition
- In the early stages of bring-up using a timer may be simpler

# Start of Follower Transmission

- In Clause 97, 149 and 165 the Leader signals to the Follower when it can start transmitting
  - This means the Follower must bring up its receiver fully so that it can correctly receive the '*en_slave_tx*' signal
  - This almost certainly will be a longer time than is required for the Leader to train its echo canceller and thus the '*en_slave_tx*' signal is redundant

# Reliable Follower Transmit Timing

- In many PHY standards it is implied that once the Follower starts transmitting that its timing is good
  - At 500m the insertion loss and consequently the ratio of the local echo signal power to the received signal power is much greater than for the short reach BASE-T1 PHYs
    - It is expected that when the Follower starts transmitting, there may be a period of time when the transmit timing is not reliable
- And normally, there is no limit on how long the Follower can remain silent
- In the 10BASE-T1L standard the first issue was addressed but not the second
  - The 10BASE-T1L standard allows the clock to unlock for a short period after the Follower starts to transmit
  - But it does not impose a limit on how long the Follower can remain silent
- Both of these issues need to be resolved for 100BASE-T1L

# Follower Frame Synchronization

- In clauses 97 and 149 the Follower is required to align to the frame structure of the Leader before it transmits anything
  - This means that the Follower must fully bring up its receiver and receive complex data before it can transmit anything
- This is highly prescriptive
- This may require a longer time to bring up the link

# Link Status Synchronization

- In some early PHY standards, such as 100BASE-TX there is very poor synchronization between the time that the link partners assert *link_status* = OK
  - With 100BASE-TX it is so poor that not only may one side start transmitting data before the other side is ready, but it may also result in the link never coming up
  - Some switches enforce a (long) wait time after link-up before sending data to avoid this problem
- The link status synchronization is better in later standards
  - For example, in clause 40 *loc_rcvr_status* is signaled to the link partner
  - In clause 97 *loc_phy_ready* is signaled to the link partner by a control code and then the link only comes up once *loc_phy_ready* and *rem_phy_ready* are both asserted
    - However, there are additional variable timers that offset link establishment
- In XGMII based PHYs Local / Remote Fault signalling is used to ensure link status synchronization
  - Local / Remote Fault signalling is not available in the clause 22 MII
  - Local / Remote Fault signalling is dependent on the RS which is external to the PHY
- We would like to ensure good link status synchronization for 100BASE-T1L
  - In Industrial Ethernet applications Link Status is commonly signaled on a H/W pin

# Conclusion

- We have agreement on many aspect of training
- We have good templates and examples from previous PHY standards as to how to proceed
- Some attention needs  to be given to at least the following issues
  - Start of Follower transmission
  - Reliable Follower transmit timing
  - Frame synchronization
  - Link status synchronization

# Questions ?