Link Training for AUI Based on OB Signaling

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Overview

- Prior work related to AUI link training/tuning
- Principle of Ethernet in-band link training
- The benefit of tuning 802.3ck AUI
- The challenge of using in-band LT on multi-segmented link
- Management based OB link training “CMIS-LT”
- Principle of CMIS-LT
- CMIS-LT operation and application use cases
- Summary.

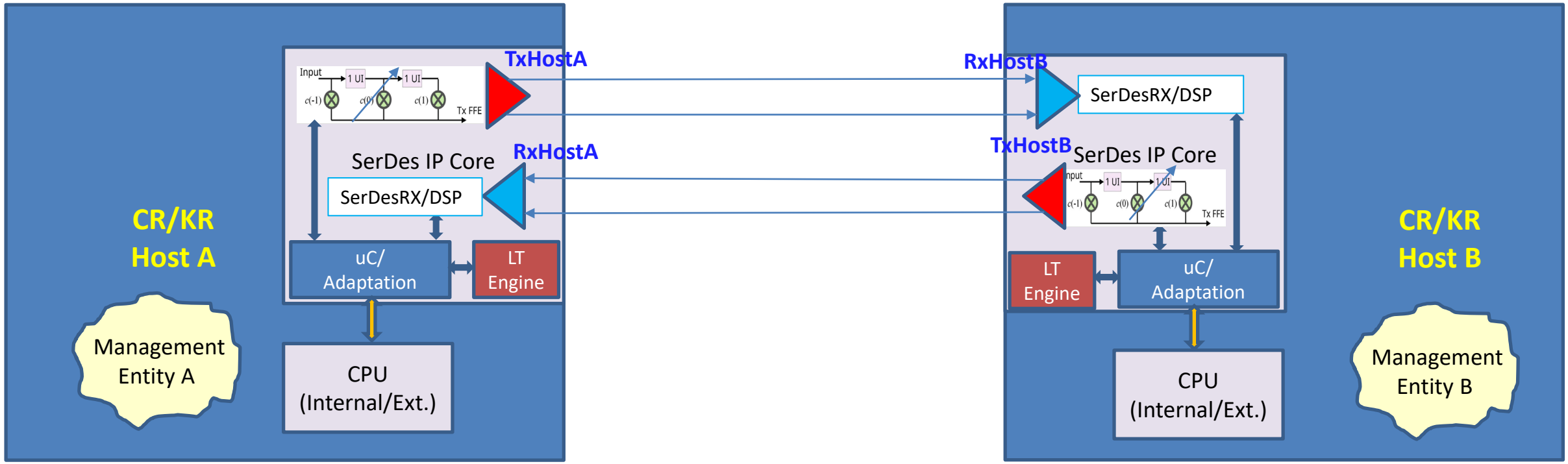
This contributions is view of the authors on OB Link Training and one should not assume how OIF will define CMIS-LT.

Background

- **In 802.3ck in-band link training was considered**
  - ran_3ck_01_0918 suggested continuous adaptation should be considered, and beside in-band link training management register approach should also be considered
  - slavick_3ck_02_0918 investigated various transmitter and receiver architecture with some requiring in-band transmit tuning
  - ran_3ck_adhoc_01_052720 adjust transmit output using CMIS and later creating AUI-S and AUI-L
  - gopalakrishnan_3ck_01a_1118 investigated TX heavy FFE vs RX FFE with conclusion that heavy RX FFE is more robust
  - ghiasi_3ck_01_0721 show the penalty associated with sub-optimum module TX FFE with just two settings AUI-S/AUI-L
  - Another key concern raised was that any in-band LT would eliminate non-CMOS CDR option
- **Based on extensive 802.3ck investigation where even at 100G there is a benefit tuning the TX FFE the author started a project in the OIF management track called "CMIS-LT" to optionally train/tune AUI links with out-of-band "OB" signaling**
  - CMIS-LT is protocol agnostic and can train/tune multi-segmented links use the host management.

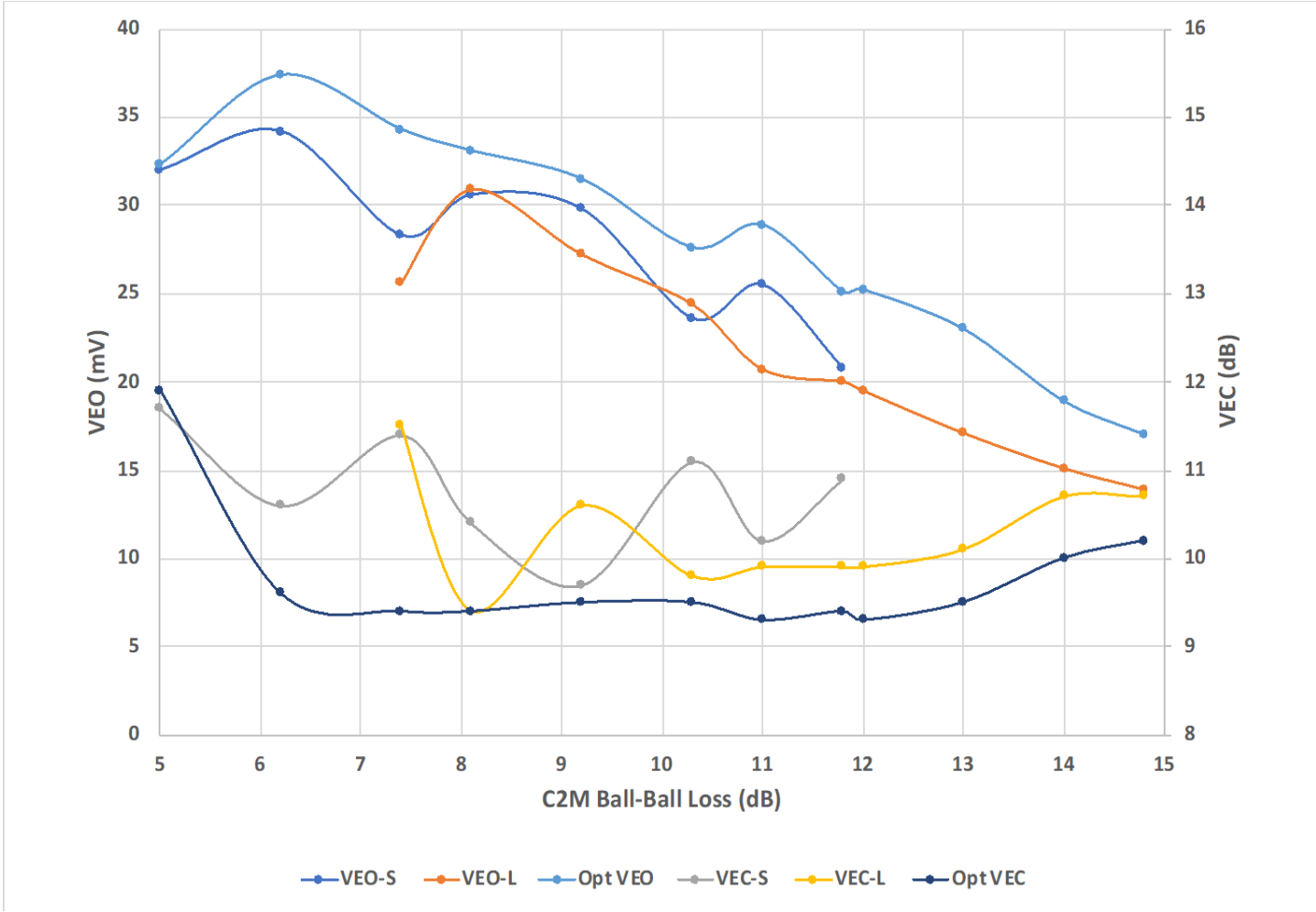
Ethernet Link Training (LT)

- **Link training is in band and only happens during startup period**
  - Receiver DSP drives and tunes the far end TX FFE for optimum SNR
  - Two management entities are driving optimization without visibility to actual TX FIR taps!



Difference Between 100G-AUI-S/L vs Fully Optimized TX FFE

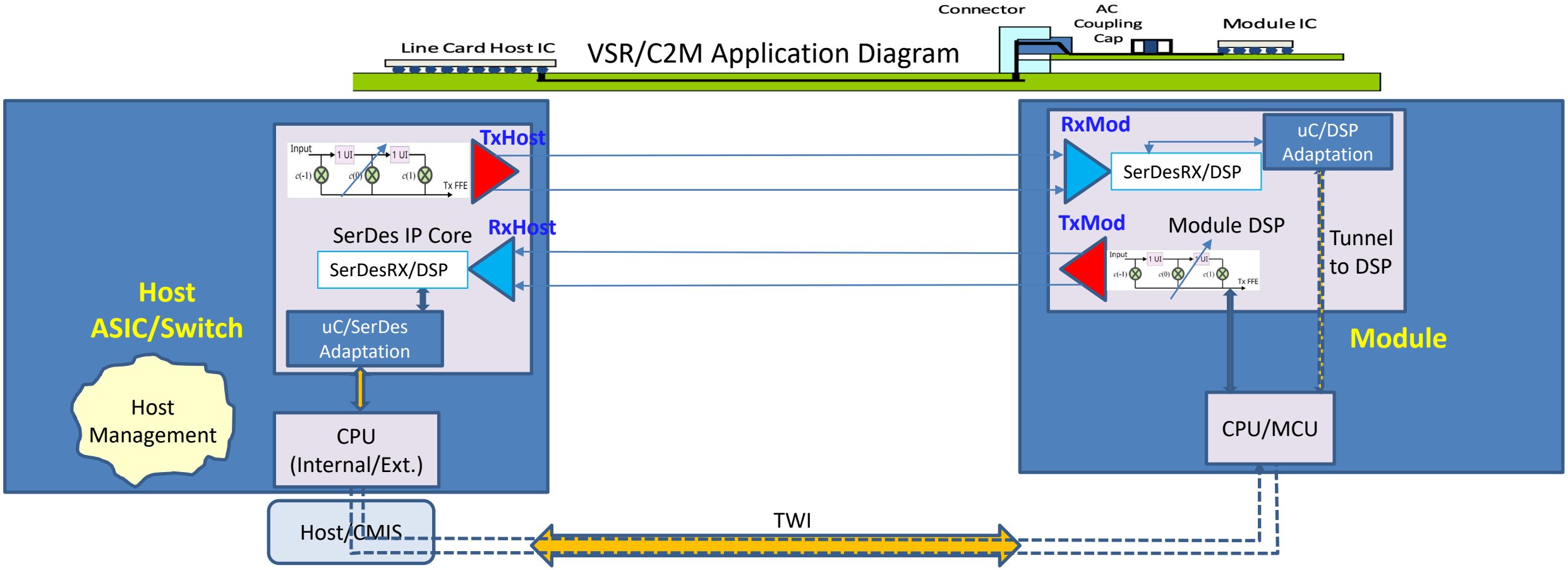
- **Penalty from optimum over AUI-S range**
  - Up to 6 mV (34%) in VEO penalty
  - Up to 1.6 dB in VEC penalty
- **Penalty from optimum over AUI-L range**
  - Up to 8.2 (40%) mV in VEO penalty
  - Up to 1.1 dB in VEC penalty
- **Realistic modules/system likely will have more than 1.6 dB VEC penalty considering modules are tested on MCB + synthetic loss vs real host channel.**



See https://www.ieee802.org/3/ck/public/21_07/ghiasi_3ck_01_0721.pdf

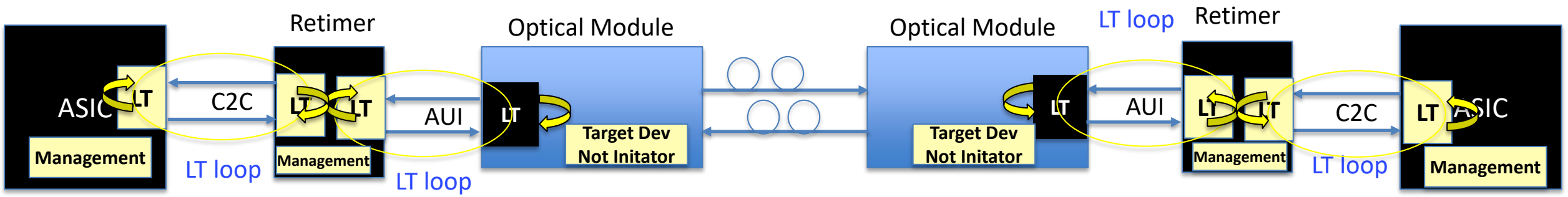
Overview of VSR/C2M Today

- **Host SerDes TX FIR is tuned at manufacturing, no LT**
  - Host management select AUI-S or AUI-L for TxMod setting.



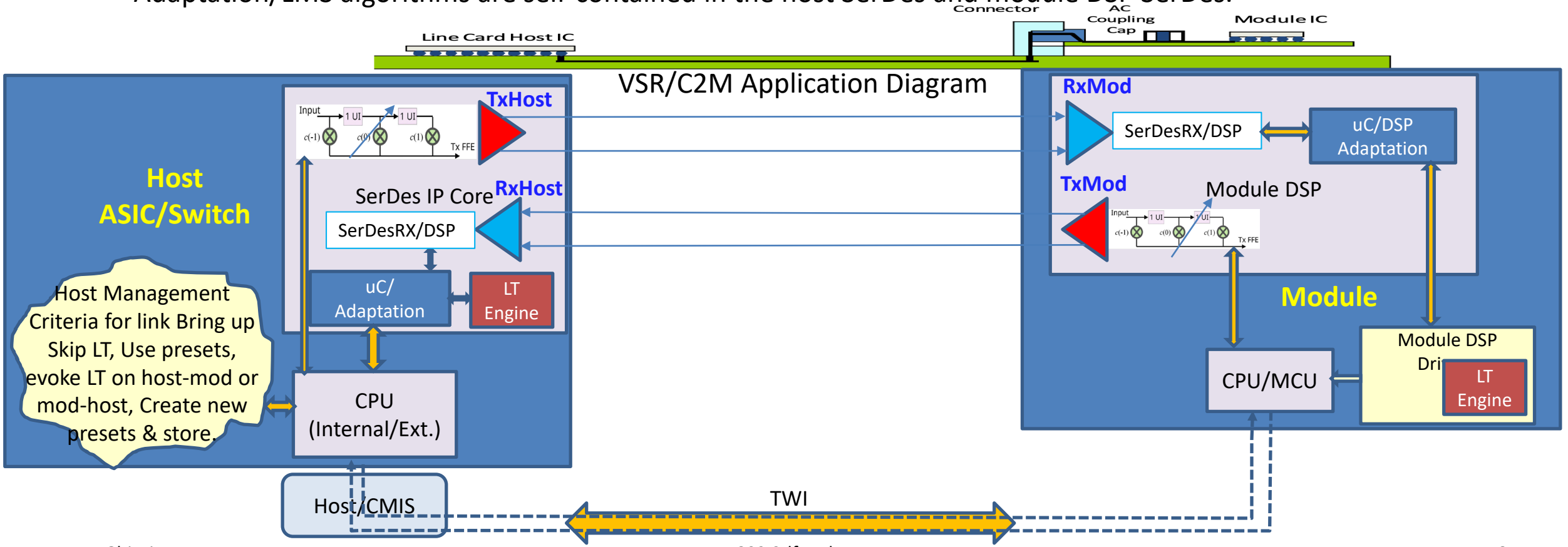
Complexity of adding Ethernet Link Training (LT) to Optical Modules

- **An optical link consist of 2-4 segments where each segment must be trained**
  - LT on the backplane or CR links operate as point-point
  - 4 segmented link with 8 LT engine need to work seamlessly as shown in diagram below just to to bring up an optical link
    - LT frames from one link segment can't be allowed to propagate to another segment as it will confuse the down stream state machine
  - A module CDR implementing in-band Ethernet LT would require full Mux/De-mux with AN/PCS logic ruling out serial CDR implementations and non-CMOS implementations
  - Ethernet LT maybe too complex for some optical modules!



Out-of-Band LT Through CMIS "CMIS-LT"

- **CMIS-LT is protocol agnostics and doesn't require any dedicated hardware**
  - Two independent LT engines optimize TxHost-RxMod and TxMod->RxHost links using single management entity in the host that engages the LT engines
  - RxMod and RxHost requests are relayed to the partner transmitter through TWI
  - Adaptation/LMS algorithms are self-contained in the host SerDes and module DSP SerDes.



Potential High-Level DSP/SerDes-CMIS Operation

- **Module advertises TxMod FFE length**
- **Host informs module of TxHost FFE length**
- **Ability to read normalized TxHost and TxMod FIR**
- **Ability for RxMod (RxHost) to set the TxHost (TxMod)**
  - Or host restore prior settings/pre-sets
  - Jump to specific set of taps
  - After LT engagement SerDes receiver sent coefficient updates or jump via TWI and CMIS
  - If needed RxMod or RxHost will perform FFE taps coefficient update from the link partner
    - Select tap and step size followed no change, Increment, or Decrement
- **When RxMod (RxHost) have met the set criteria or reached best setting**
  - RxMod(RxHost) stop and report back to host
  - Host will engage mission mode operation.

Training RxHost Host SerDes and RxMod Module SerDes (Leverages General LT Flow of CL 136.8.11)

- **RxHost SerDes local adaptation and LT engine are in direct communication with host CMIS controller**
  - Based on SI parameters SNR/BER host determines if TxMod-RxHost need training
  - Host invokes RxHost link training
  - RxHost SerDes passes its request to the module
  - Module adjust TxMod FFE
  - Module informs host TxMod FFE updated
  - RxHost SerDes determines to repeat or inform the host link training is complete.

- **RxMod module DSP request for adjustment to TxHost are initiated with module Interrupt and then host will poll the module**
  - Based on SI parameters SNR/BER host determines if TxHost-RxMod need training
  - Host invokes RxMod link training
  - RxMod DSP passes its request to module CMIS
  - Module CMIS interrupt the host
  - Host reads module DSP requests
  - Host adjust TxHost FFE
  - Host informs module TxHost FFE updated
  - RxMod DSP determines to repeat or inform the host link training is complete.

CMIS-LT Application Use Cases and Operation

- **CMIS-LT is optional and if specific module-port combinations operate with sufficient margin/FOM the port gets enabled for immediate mission mode**
  - Margin/FOM are customer/application driven
- **CMIS-LT can be used at manufacturing to optimize TxHost or TxMod**
  - Assist in creation of module default AUI-S and AUI-L
  - New user presets created for TxHost and TxMod and stored on the host
- **TxHost and TxMod default port settings can be further optimized at deployment**
  - Per module supplier module skew plugged into a specific port
  - A specific module when plugged into a specific port
  - A more optimized user presets created for TxHost and TxMod and stored on the host
- **Optimized host transmit FFE (TxHost) settings and module receive optimized TX FFE (TxMod) are both stored on the host**
  - Stored FFE setting can be applied after reset/power down
- **Host system and module optimized port settings at time t=0 may need further adjustment at 224G due to aging, temperature, or humidity**
  - RxMod DSP or RxHost SerDes may signal the host and if supported the host may either perform non mission or mission mode tweak to TxMod or TxHost.

Summary

- **In 802.3ck in-band LT was not considered due to complexity of multi-segmented link and forcing the module CDR to CMOS implementation only**
  - At 100G the margin are rather tight and data show there is more than measurable benefit to tune the CK AUI transmitters
  - One of the big source of discrepancy in CK AUI is tuning the TP1a/TP4 with HCB/MCB and the behavior of the module when plugged in to the host
  - At 224G TP1a/TP4 correlation to system performance would only be worse
- **OB link training/tuning of AUIs through CMIS is optional but very flexible**
  - Utilized only if needed and does not require any dedicated hardware
  - Create user presets, enable tuning at startup, or perform some tweak during mission mode
- **OB link training pro and cons**
  - Pro – Protocol agnostic, does not require dedicated HW, OB link is always up, single management entity has visibility to both TX and RX links partners
  - Cons – Speed of TWI currently limited to 1 MHz and software
- **IEEE 802.3df task force should establish liaison with OIF management on CMIS-LT.**