Extending Link Training to Optics

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Overview

- **Benefit of link tuning for optics**
- **Background on Ethernet CR/KR link training**
- **Background on the OIF CMIS-LT link training**
- **Benefit and challenges of optical link training**
- **Optics-LT**
  - Selects best TX setting
  - Enable pre-coder
  - Enable FEC bypass
- **Preliminary Optics-LT flow diagram**
- **Summary.**

Benefit of the Optical Link Tuning

- **The benefit of link training and tunning was brought up during 802.3dB task force for 100G MMF links and we had to make the 100G-SR work without the benefit of optimizing for low/high modal dispersion**
  - 200G-SR may not even be feasible without link tuning
- **Config A is TDECQ compliant, but config B/C are not required to be TDECQ compliant**
  - Example configurations
    - Config A could be optimized for back-to-back, config B for mid-span, and config C for high CD
    - Config A is the TDECQ compliant setting, Config B optimized for far-end BER, Config C optimized for far-end BER
    - An 800G-LR4 config may include configuration for low CD, high CD, and one that shifts XPM penalty
- **200G-DR and 200G-FR links may have limited dispersion but still will benefit by having different optical power levels and/or optimized for best BER instead of just meeting TDECQ**
- **All of the optical links will benefit from the ability to turn pre-coder on/off**
- **A tuned optical link is more likely to operate with inner-FEC bypassed and meet the BER.**

Background on Ethernet AN/LT

- **Ethernet LT 1st developed for 10GBASE-KR require point-point link operation implementing LT based on CL72 (NRZ), CL136/162(PAM4), and and Autoneg based on CL73**
  - LT require the link to operate in loopback (point-point) and works well for two end-stations
  - Host A and host B both operate as initiators with independent management entities.

Original KR CL72 LT Frame

Octets		
4	Frame marker	
16	Coefficient update	Control channel
16	Status report	
512	Training pattern	

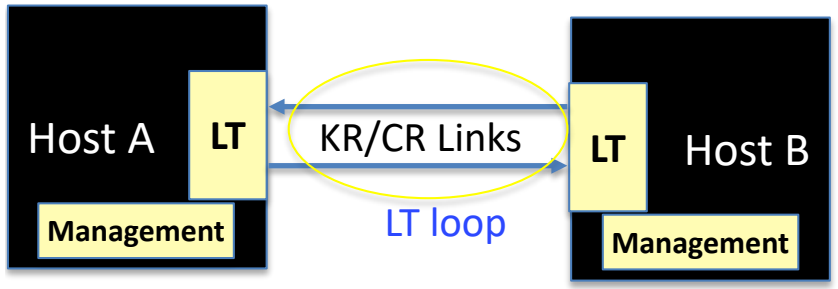
Figure 72–2—Training frame structure

Expanded CL136 LT Frame Supporting PAM4

Transmission order is left-to-right then top-to-bottom

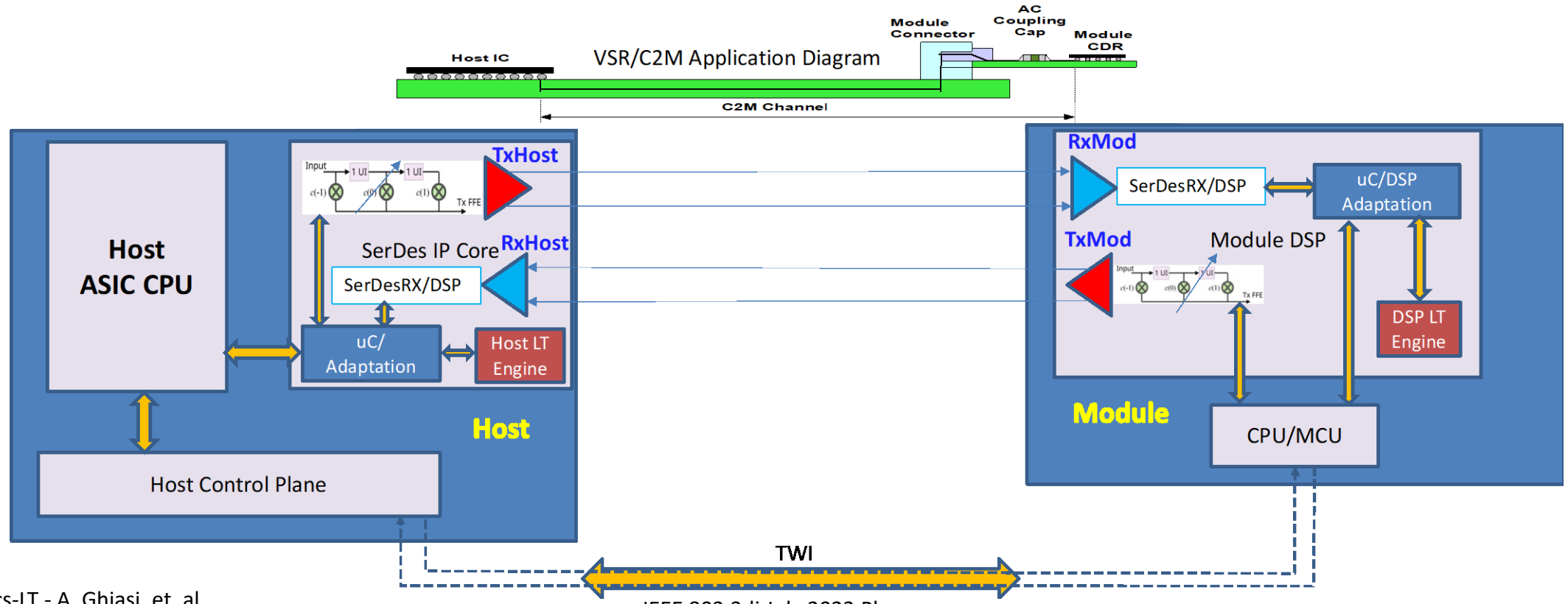
16 3's followed by 16 0's				Frame marker (32 UI)
Cell 15	Cell 14	···		Control field (128 UI)
			Cell 0	
Cell 15				Status field (128 UI)
			Cell 0	
				Training pattern and zero pad (16 384 UI) PRBS13
			00	

Figure 136–3—Training frame structure



Background on CMIS-LT

- **CMIS-LT is a sophisticated OB link training with the command send on the TWI**
  - CMIS-LT link optimization include the classic Ethernet CL72 like Increment/Decrement/hold or direct R/W some or all the taps given the availability of OB link to send the the commands
  - CMIS-LT is a project in the OIF management that will define a CMIS supplement
  - Optical LT has similarity to CMIS-LT by having a side-band channel (BCH padding bits)
  - For further background on the CMIS-LT see ghiasi_3dj_01_230116 .



Extending Link Tuning to Optics

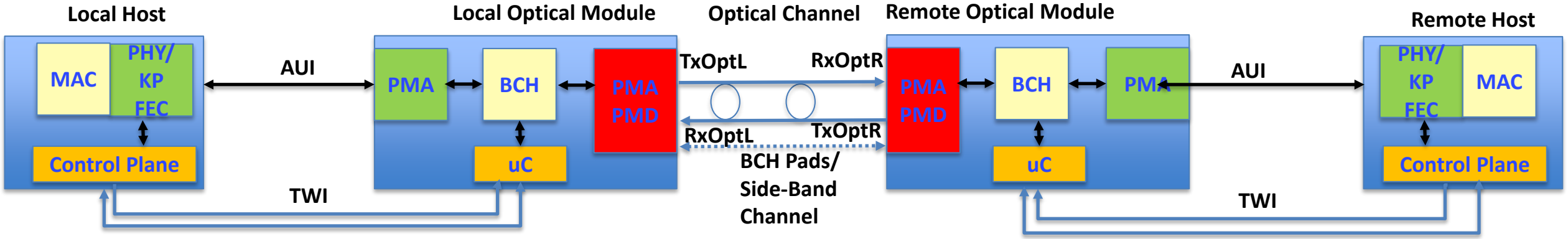
- **patra_3dj_01b_2303 Hamming encoder (128,120) provides 3x128 bits pads**
  - ramesh_3dj_01a_2303 investigates reliability of padding bits for side-band signaling and messages
  - rechtman_3dj_01a_2305 proposes simplified pad insertion by inserting 3 CW(128 bits) every 3264 inner FEC CWs
- **Side-band channel that is transmitted along with Hamming data can be utilized for**
  - Remote management
  - Reading remote module SNR/BER
  - Select among few (A, B, C) well behaved transmitter settings
    - A, B, and C settings is based on manufacturer, class of optics, and/or reach
    - *Not recommending autonomous link training for optics due to non-linearities, different classes of optics require different optimization, transmitter gets out of compliance zone, and the risk of data/side-band channels going down*
  - Request 1+D pre-coder on/off
  - Inner Hamming FEC bypass where the link operates with just KP4 FEC.

Why Optical TX Link Training is Challenging

- **Traditional in-band or out-band link training where the receiver adjust the partner TX FFE taps values unlikely to work for optical transmitters given:**
  - Autonomous TX FFE tuning may drive optical TX OMA into non-compliance region
  - Different optical devices require different adjustments
    - VCSEL/DML – asymmetrical turn-on/off
    - MZM – cosine compression
    - Electro-absorbers EA – non-linear transfer response
  - All of the above devices have a degree of temperature dependences that require adjusting DC operating point for optimum TECQ and TDECQ
    - The change in operating temperature may require going back and adjusting TX FFE for optimum TECQ and TDECQ
- **This proposal instead recommends to allow module to optionally support up to 3 well behaved optical TX settings (A, B, & C) and pre-coder on/off**
  - Optical TX settings are arbitrary and set by manufacturers based on device type, implementation, and reach
  - DR optics non-dispersion limited may only have one TX optical setting but with pre-coder on/off
  - LR/LR4 TX optical settings maybe optimized for B2C, mid-range, and 10 km and pre-coder on/off.

Optical Transmitter Tuning/Selection

- **Inner BCH padding bits allow local-remote optical module communication and management**



Local Host Register	Value
TX Config A (Default)	On
Sel TX Config B	Off
Sel TX Config C	Off
Tx Pre-coder	Off/On
Request LT	Yes/No
Request BCH Bypass	Yes/No
Prior BCH Bypass failed local host	No/Yes
Prior BCH Bypass failed remote host	No/Yes

Local Module Register	Value
TX Config A (default TDECQ compliant)	On
TX Config B (TDECQ may not be compliant)*	Off
TX Config C Tx Config B (TDECQ may not be compliant)*	Off
BCH Bypass	Off
Tx Pre-coder	Off
Remote LT status*	In process, completed, failed
Remote Mod LT capable*	Yes/No
Local LT status*	In process, completed, failed
Local Mod LT capable*	Yes/No

* TX config B and C TDECQ may not be compliant Manufacture may optimize these settings for best BER

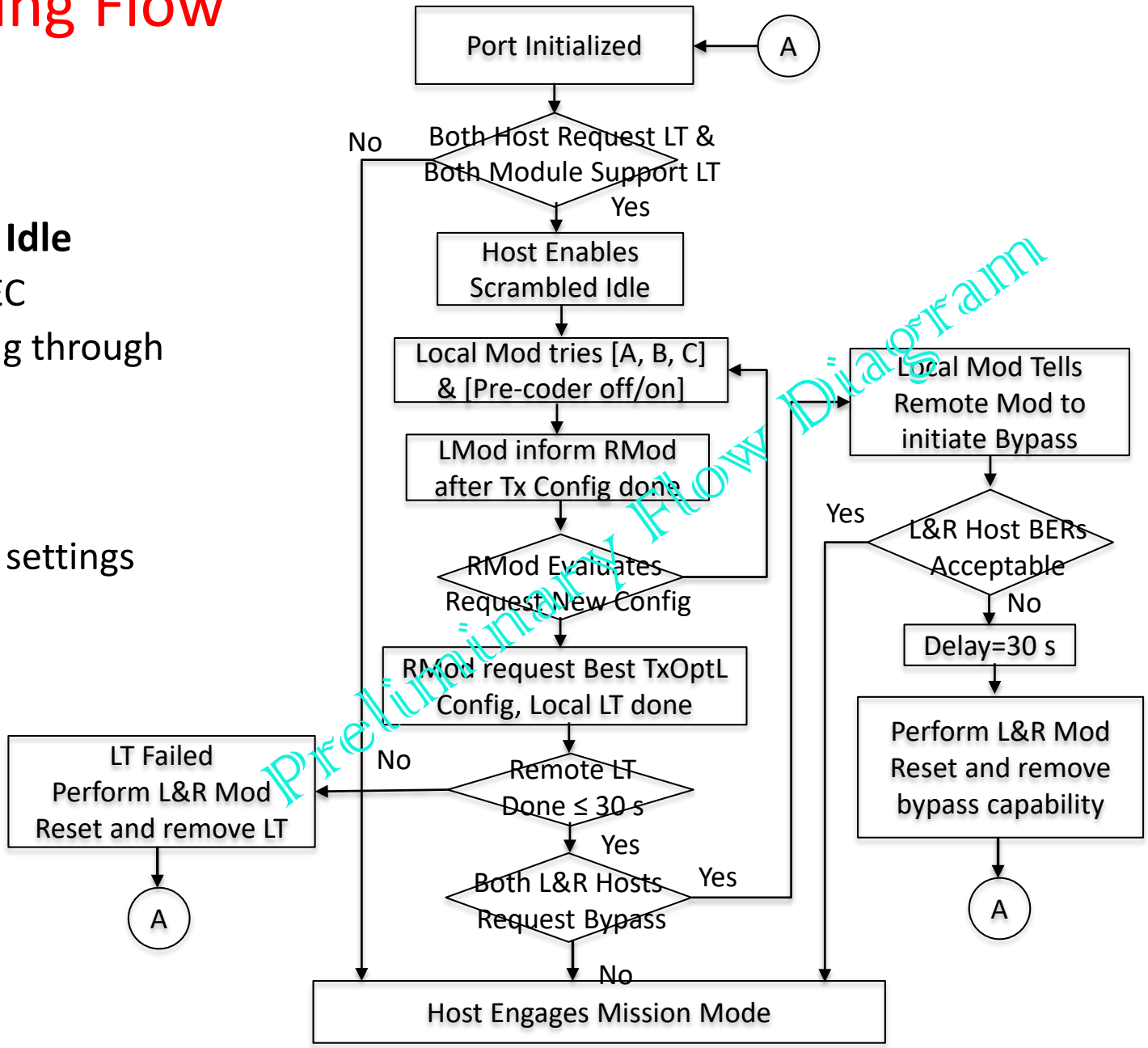
** These module registers are accessible by remote module and host.

Basic Optical TX Tuning/Selection Process

- **Process of optical TX tuning and inner FEC bypass**
- **Links comes up in default mode with BCH inner code on and pre-coder off**
- **If local & remote host both don't request LT or if one of the module doesn't support LT then go directly into mission mode otherwise host initiate LT**
  - L/R Host enable scrambled idle FEC data
  - Host initiate LT
    - LMod or RMod request partner module to switch between [Tx config A, Tx config B or C]&[Pre-coder Off, On] while the RxOpt evaluates the best setting
    - After evaluation is complete LMod or RMod will request the config with best BER
    - If remote LT isn't complete in 30 seconds after completion of local LT then LT fails and host gets informed, host may try again or remove the capability
  - LT completed
  - If BCH bypass is not requested or the ratio of corrected errors by the BCH decoder is too high to provide an expectation of adequate performance with BCH bypassed initiate mission mode with inner FEC not bypassed
  - If BCH bypass is requested
    - Host config L/R modules for BCH bypass
    - If L/R host don't link up in 30 seconds then L host will reset L module and R host resets R module, and hosts remove BCH bypass ability
  - Bypass completed
  - Host config the link to mission mode.

Preliminary Optical TX Tuning Flow Diagram

- **The test pattern is host sourced scrambled Idle**
  - Scrambled idle passes through the BCH FEC
  - RxOpt[L,R] evaluates the signal by stepping through the configs
- **LT functions consist of:**
  - Picking best optical TX
  - Pre-coder on/off for each of the above TX settings
  - Inner FEC bypass
- **Acronyms**
  - L – Local
  - R – Remote
  - Mod – Module
  - LMod- Local module
  - RMod- Remote module



Summary

- **Side-band channel BCH inner FEC provides a management/control channel between local-remote optical modules**
  - The side band channel padded bits are protected by BCH and are repeated for further robustness
- **Optical LT extend concept of point-point OB/Side-band and will leverage CMIS-LT OB LT for the AUI links**
- **The proposal**
  - Recommend defining 3 TX optical config (A, B, & C) and ability to turn on/off pre-coder to optimize and tune optical links for best BER
    - TX config A will be TDECQ compliant, but TX config B and C may not be TDECQ compliant instead may be optimized for best end-end BER
    - Number of configurations can be increased beyond 3 if required but due to potential loss of light/lock each configuration will add 3-5 seconds
  - Proposal also defines a method to bypass the BCH if both modules support the bypass function and both hosts are requesting to bypass
- **P802.3dj task force should continue defining BCH side-band COM link/data structure considering the benefit of optical link tuning and FEC bypass.**