

100GBASE-KP4 Link Training Summary

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(Regarding Comment #38)

Purpose of this Presentation

- Provide a high-level summary of the KP4 training proposal
 - Complete presentation containing technical details is too long to review in comment resolution session
- Additional details and supporting material is available in `lusted_01_0912.pdf`

Consensus Call Held

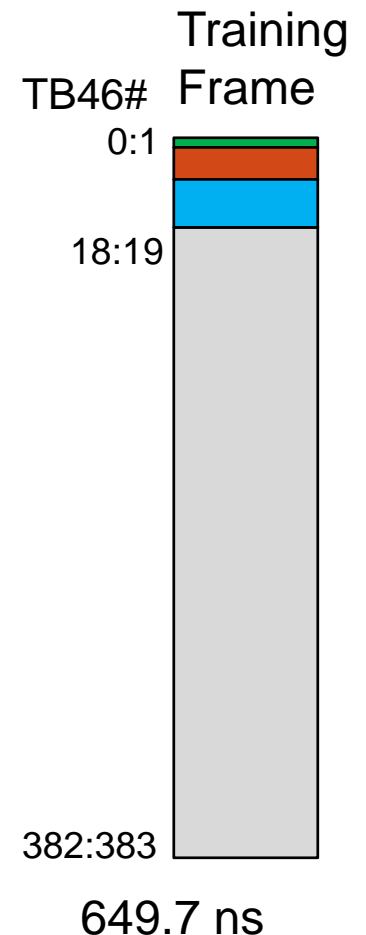
- 1 conference call was conducted to review the 100GBASE-KP4 training proposal.
 - See `lusted_01_0912_KP4_training_consensus_post-call.pdf` sent to reflector
- 28 individual participants: Lusted, Kent C; Ran, Adee; Matt Brown; 'Mike Dudek'; 'Albert Vareljian'; Rita Horner; Jeff Slavick; Healey, Adam B (Adam); Zhongfeng Wang; Piers Dawe; Elizabeth Kochuparambil ; Bart Zeydel; Scott Irwin; Hongtao Jiang
- Thanks for attending, sharing thoughts and reviewing ideas!

100GBASE-KP4 Link Training Assumptions

- Based on P802.3bj Draft 1.1 and P802.3bh Draft 3.1
- Maximize compatibility with existing training mechanism in Clause 72.6.10
- Leverage the tight integration and inter-dependence of the PMA and PMD functions, specific to Clause 94.
 - Similar to PCS/PMA dependency in 10GBASE-T link training (Clause 55)

100GBASE-KP4 Link Training Change Preface

- Pack the Frame Marker, Control Channel and Training Pattern into 46 UI training frame words (TFW)
 - Each TFW corresponds to two full 46-bit terminated blocks (TB46).
 - Simplifies design (i.e. no gearbox)
 - Enables early data alignment during training period
 - Enables regular data recovery and fast switching to data mode
- Use PAM2 for frame marker and control channel, use PAM4 signaling in the training pattern
- At end of training process, make it easy to lock to the correct offset in PMA frame
- Add parity check to both control channel fields to preserve DC balance



384 x 46 = 17764 bits in 1 training frame
192 x 46 = 8832 PAM4 symbols in 1 training frame
1 Training Frame = 384 Termination Blocks (TB46)
1 Training Frame = 192 Training Frame Words (TFW)

Frame Marker and Control Channel

- Restricted the Frame Marker, Coefficient Update, and Status Report fields to level -1 for a 0 and level +1 for a 1 to enable easy receiver lock to the training pattern over poor quality and non-equalized channels.
 - Make it full-swing, i.e. “NRZ” like
- Frames are delimited by the 46 PAM4 symbol pattern, 23 +1 symbols followed by 23 -1 symbols, +1s first, as expressed in 13.59375 Gbd symbols.
 - This pattern does not appear in the control channel or the training pattern
 - Serves as a unique indicator of the start of a training frame.

Control Channel Encoding

- Control channel uses 9 TFWs of DME signaling
- Pack 4 data cells of control channel into 1 TFW
 - Uses 40 of 46 PAM4 symbols in 1 TFW
- The data cell length is 10 100GBASE-KP4 PAM4 symbols. (~736ps)
 - Approximately the same duration at 10GBASE-KR cells

What about the Remaining 6 UI?

- Define the last 6 PAM4 symbols in each of TFW #2-11 as overhead cell
 - Transition position is 3 PAM4 symbols
- Set overhead cell to a DME logic '1' of 6 PAM4 symbols width
 - Preserve the DC balance on the line
 - 000111 or 111000, depending on previous cell value
 - Same DME coding rules as before

Coef Update Field

~~Table 72-4~~ Coefficient update field

Cell(s)	Name	Description
15:14	Reserved	Transmitted as 0, ignored on reception.
13	Preset	1 = Preset coefficients 0 = Normal operation
12	Initialize	1 = Initialize coefficients 0 = Normal operation
11:8	Reserved	Transmitted as 0, ignored on reception.
5:4	Coefficient (+1) update	<u>5</u> <u>4</u> 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold
3:2	Coefficient (0) update	<u>3</u> <u>2</u> 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold
1:0	Coefficient (-1) update	<u>1</u> <u>0</u> 1 1 = reserved 0 1 = increment 1 0 = decrement 0 0 = hold

11:7 Reserved
6 Parity Check

Cell ordering
not finalized

Status Report Field

- 20 cells
 - 5 TFWs
 - 10 TB46
- Add new features
- Keep coef status and move Receiver Ready
- Cell ordering not finalized

Cell(s)	Name	Description
19	Parity Check	Parity calculation for Status Report Field
18:14	EEE State	Current EEE state of local transmitter, if EEE is implemented.
13:12	Training Frame Countdown	Number of training frames remaining before link training process transitions to data mode
11:7	PMA Alignment Offset	Relative location of the next training frame within the PMA frame
6	Receiver ready	1 = The local receiver has determined that training is complete and is prepared to receive data. 0 = The local receiver is requesting that training continue.
5:4	coefficient (+1) status	<u>5</u> <u>4</u> 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated
3:2	coefficient (0) status	<u>3</u> <u>2</u> 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated
1:0	Coefficient (-1) status	<u>1</u> <u>0</u> 1 1 = maximum 1 0 = minimum 0 1 = updated 0 0 = not_updated

New Parity Check Fields

- This is an improvement over the original clause 72 rules
 - Guarantees DC balance of DME cells during training
 - Coef update and status report fields always starts with +1 PAM4 symbols
 - Increases protection against false acceptance of sensitive messages, e.g. preset, init, receiver ready
- Use cell 6 of the coef update field and cell 19 of status report field to encode a parity check for each respective field

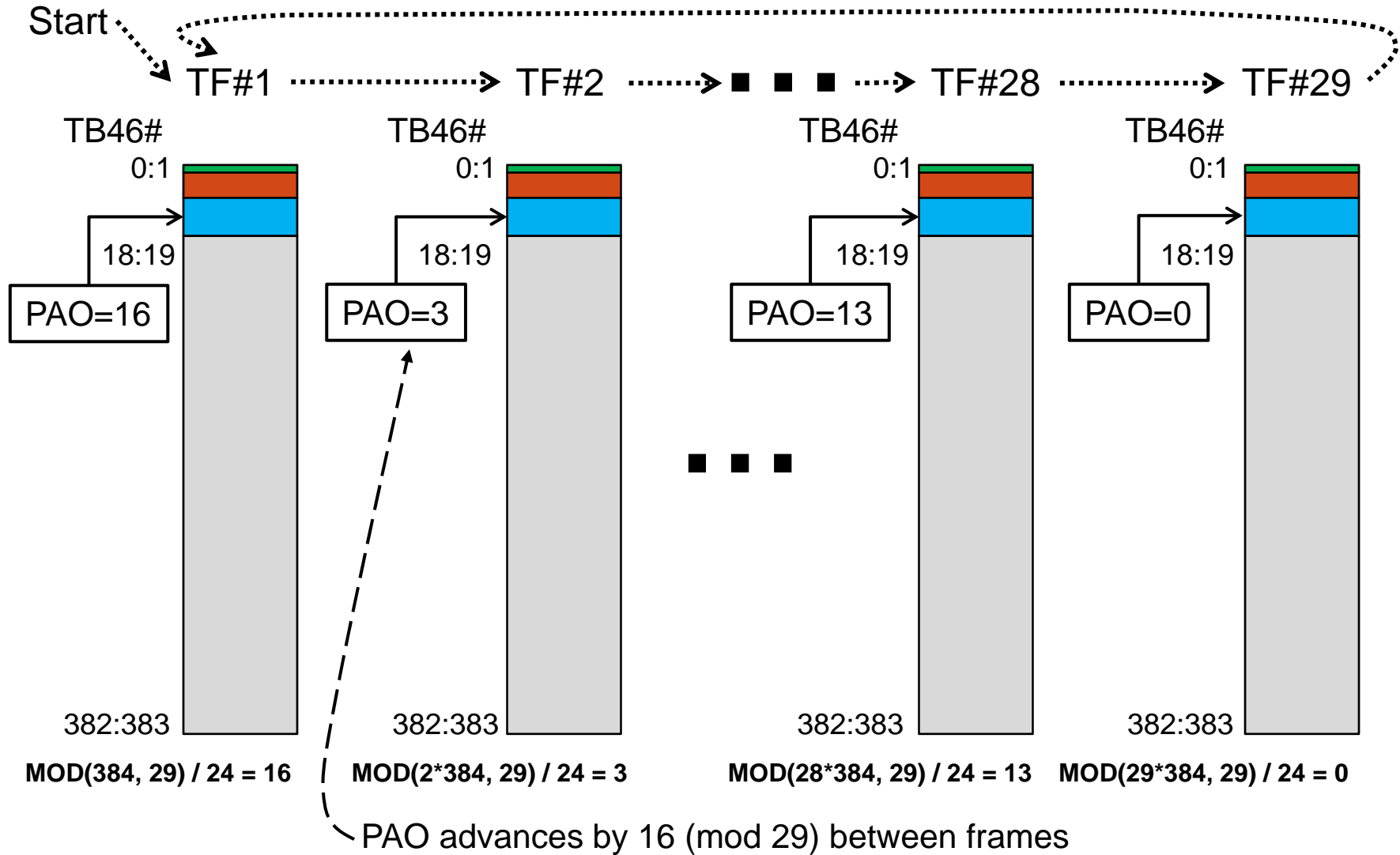
New Status Report Cells

- **EEE State (Cells 18:14)**
 - Current EEE state of local transmitter, if EEE is implemented
 - Otherwise, reserved and set to 0.
 - See brown_01_0912.pdf for more details
- **Training frame countdown counter (Cells 13:12)**
 - Used to signal the transition from training to data mode.
 - Start at 3, decrement toward 0 during the last 3 frames sent (2 -> 1 -> 0)
 - 3 indicates 3 or more frames remaining
 - When a frame is sent with this value = 0, after the last TFW of training pattern is sent, transmission immediately switches to the PMA frame

New Status Report Cells (2)

- PMA Alignment Offset -- PAO (Cells 11:6)
 - To shift instantly to data mode after the last training frame ends, RX needs to know the relative offset of the first data block (TB46) from the 40-bit overhead within the PMA frame
 - PAO encodes the relative location of the TB46 after the end of the training frame (mod 696) as a 5-bit integer
 - The start of the next training frame is $24 * \text{PAO}$

PMA Alignment Offset Example



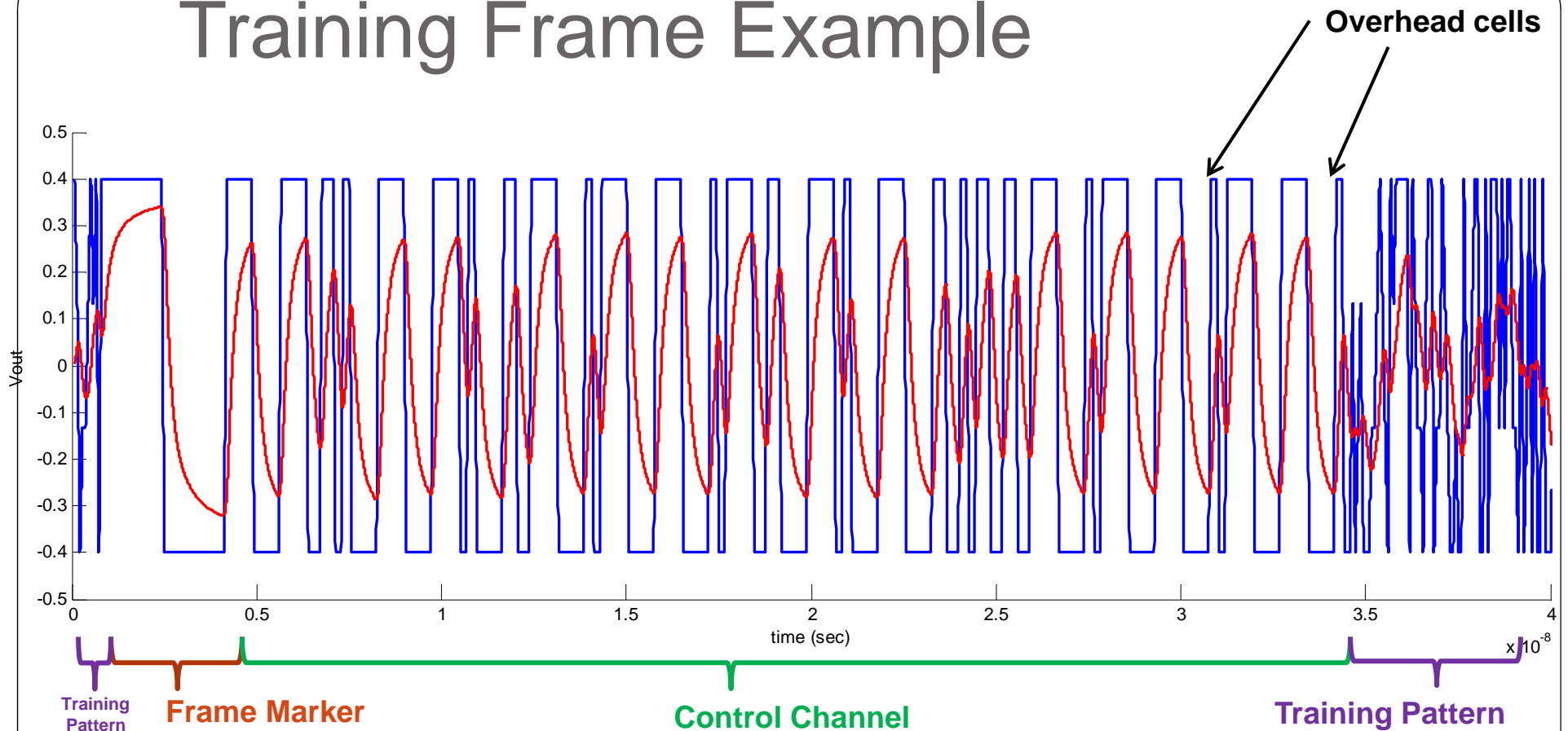
Training Pattern Motivation

- Use the PMA transmit and receive functional specifications as currently defined in P802.3bj Draft 1.1 to enable the transmitter and receiver to exercise termination block, gray coding, and $1/(1+D) \bmod 4$ precoding stages.
 - Overhead framer does not have to be exercised, but alignment is tracked through PMA Alignment Offset (PAO) cell
- Generate multi-level PAM4 signaling for receiver calibration
- Choose a pattern that is PMA termination block friendly

Training Pattern Details

- PRBS13 is used for training pattern generation, followed by its inverse
 - Use four unique states to create a distinct DC balanced sequence for each lane
 - Helps with lane order identification later on.
 - 8191 bits are generated from the LFSR (a full PRBS13 cycle)
 - Additional 8189 bits are generated and sent inverted (a full PRBS13 cycle minus 2 bits)
 - Last 2 bits of the inverse PRBS13 are discarded, so PRBS uses $16380/45=364$ TB46
- Pack each 45 bits of PRBS13 into TB46
- Training frame (frame marker, control channel and training pattern) contains 384 TB46

Training Frame Example



- Blue = no channel
- Red = after IL = ~30dB @ 7GHz channel (without TXFFE equalization)
- Training pattern shown is incomplete. Figure is zoomed to frame marker and control channel

Channel used "TEC_Whisper42p8in_Nelco6_THRU_C8C9" from

http://www.ieee802.org/3/100GCU/public/ChannelData/TEC_11_0428/shanbhag_03_0411.pdf

Full Termination Block Update

- With the proposed change to full termination in brown_3bj_03_0912, the training frame remains basically the same:
 - Modify where appropriate for the changed architecture
 - PAO: The start of the next training frame is now equal to $12 * PAO$
 - now measured in TB92 instead of TB46
 - Update frame for 1 termination block = 1 TFW
 - The 2 TB46 become 1 termination block (i.e. TB92)
 - Keep the PRBS seeds for now
 - Investigate better seeds for next draft

Conclusion

- 100GBASE-KP4 Training frame in this presentation has the following qualities:
 - Reuses most of the existing 10GBASE-KR PMD training mechanism
 - Encompasses the PMA and PMD architecture unique to 100GBASE-KP4
 - Provides PAM2 for ease of alignment and PAM4 signaling for receiver calibration
 - Supplies DC-balanced, lane-specific seeded training pattern
 - Offers parity check for coef update and status report fields
 - Enables fast and efficient transition to data mode
 - Facilitates EEE signaling, if required