10G 4-Lanes Ethernet over Backplane proposal

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Partial list of 802.3ap presentation that were used

- "*System Vendor Requirements for 10Gb/s Backplane*" - mandich_01_0704_pdf, July/04 Plenary meeting
- "*Need for 4-Lane 10GEthernet Backplane Support*" - lynch_01_0504.pdf, May 2004 Interim meeting
- *"What We Learned from XAUI and How to Apply it to Ethernet in the Backplane"* - ghiasi_01_0104.pdf, January 2004 Interim meeting

Motivation

- *4 lanes copper support today:*
  - *XAUI supports up to 20" on the FR4*
  - *CX4 supports up to 15m Twinax cabling*
  - There is no standard for transmitting & receiving 10G Ethernet over 20" to 1 meter of enhanced FR4
- *"System vendors NEED an interoperable 4-Lane 10G standard for up to 1M of enhanced FR4" – May interim* P802.3ap meeting, *lynch_01_0504.pdf*
- "*Define a 4-lane 10Gb/s PHY for operation over the 802.3ap channel model*" - IEEE P802.3ap Objectives, updated during July 802.3 Plenary meeting

Guideline

- No MAC changes
  - Preserve the 802.3ae frame format
  - Preserve min and max frame size of current 802.3 Std
  - Support Existing media independent interface – (XGMII)
- No PCS changes to 802.3ae
- Adopt Clause 45 management registers
- Support autonegotiation – including legacy devices that were not designed to support Autoneg
- Simplest and well-known signaling approach that can do the job
- Support operation over at least 40” with 2 connectors copper links with BER of 10^{-12} or better

What we have learnt from XAUI deployment

- No more alternative far-end and near-end compliance points.
  - Single Transmitter compliance point should be selected. Near-end is clear favorite
- Eye opening criteria isn't the best way to ensure devices interoperability
  - Xmt template test seems to be preferable to ensure
- Lack of explicit Random Jitter specification didn't proof itself very well…
  - Random Jitter should be specified
- BER of 10^{-12} isn't sufficient for many end customer. 10^{-15} or even 10^{-17} is requested for many practical applications.
  - Recent technology progress should be enough to tighten this parameter to the above values
  - One Measurements technique has been demonstrated already to group during July Plenary meeting. Others are available as well.

How to start: PHY parameters

- 8b/10b coding scheme
- NRZ signaling
  - Has been proven as capable to drive 3.125 signals. Multiple IC vendors have demonstrated 40" + over legacy FR-4 backplanes and few connectors
  - Adopted by 802.3ak (CX4) for more challenging channel model (over 15dB attenuation at Nyquist rate)
- Predefined Pre-emphasis:
  - Successfully deals with ISI w/o additional power dissipation
  - Has limited effect on crosstalk parameters for NRZ signaling scheme
  - Well-known technique – widely used for high-speed SERDES today – also as optional feature in XAUI transceivers
- Equalization
  - It's always nice to have performance margin ☺
  - Can be left to the implementer – depends on the selected BER target

Transmitter parameters: focus on pre-emphasis – *Pro's and Con's*

- Pro's:
  - Easier receiver implementation without transmit power increasing
  - Compliance measurement is well-defined and easy (almost ☺)
  - Implementation is cheap and straightforward
- Con's
  - Emphasizes native high-frequency impairments – NEXT/FEXT, RJ
  - Has to be pre-defined – regardless actual communication link characteristics (assuming that no side information channel available)
- Bottom line:
  - When carefully adjusted to the channel parameters, provides powerful tool to increase operational distance with nominal SNR value for almost no charge.
  - The best effect is achieved when used in combination with receive-side based equalization

Transmitter parameters: focus on pre-emphasis - *Mathematically speaking…*

- If we'd like to leverage CX4 experience…
  - Pre-emphasis filter
    - pre-emphasis specified by α

$$y_n = \frac{1}{1+\alpha} x_n - \frac{\alpha}{1+\alpha} x_{n-1}$$

  - Maximal and minimal filter outputs

$$x_n = V_{peak}, x_{n-1} = V_{peak} \Rightarrow V_{Low} \equiv \frac{(1-\alpha)}{(1+\alpha)} V_{peak}$$

$$x_n = V_{peak}, x_{n-1} = -V_{peak} \Rightarrow V_{High} \equiv V_{peak}$$

  - Frequency response

$$H_B(z) = \frac{1}{1+\alpha} - \frac{\alpha}{1+\alpha} z^{-1}$$

$$|H_B(\theta)|^2 = \frac{1-2\alpha\cos\theta+\alpha^2}{(1+\alpha)^2} \Rightarrow |H_B(0)|^2 = \frac{(1-\alpha)^2}{(1+\alpha)^2} \qquad |H_B(\pi)|^2 = 1$$

  - Pre-emphasis

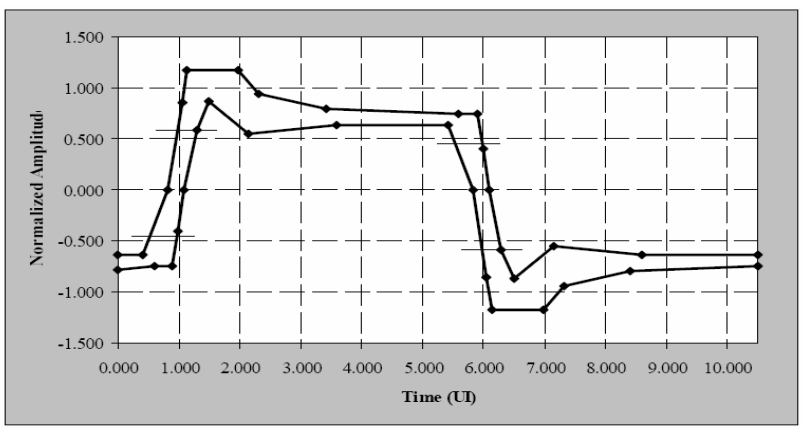
$$1 - V_{Low} / V_{High} = \frac{(1-\alpha)}{(1+\alpha)}$$

$$\text{Max} = 100\ \% \ (V_{Low} \text{ - - > } 0)$$

$$\text{Min} = 0\ \% \ (V_{Low} = V_{High})$$

Transmitter parameters: focus on pre-emphasis – *Discussion*

- From noise enhancement perspective for worst case condition (maximal length worst case insertion loss) it's best to have the highest pre-emphasis
- But when considering the full system application (crosstalk effects, thermal noise, etc) and when very short traces are a possibility splitting the load between the equalizer and pre-emphasis is advantageous
- Performance-wise, optimal value is determined as one that provides highest SNR value at the *slicer input.* Can be determined theoretically (with few reasonable assumptions) – with following full-system simulations
  - Jitter, crosstalk, AWGN and impairments affects are accounted automatically
  - Equalizer can be included or excluded from the simulation model
  - Once performed for worst-case channel, simulation should be redo for shortest (minimal ISI) channel model – to ensure there is enough margin left
  - Finally, detailed "template fitting" calculation procedure to be developed and proved in simulation. Especial attention to be put on the RL affect accommodation – most problematic one based on CX4 experience



Example of Xmt template proposal (taken from 802.3ak)

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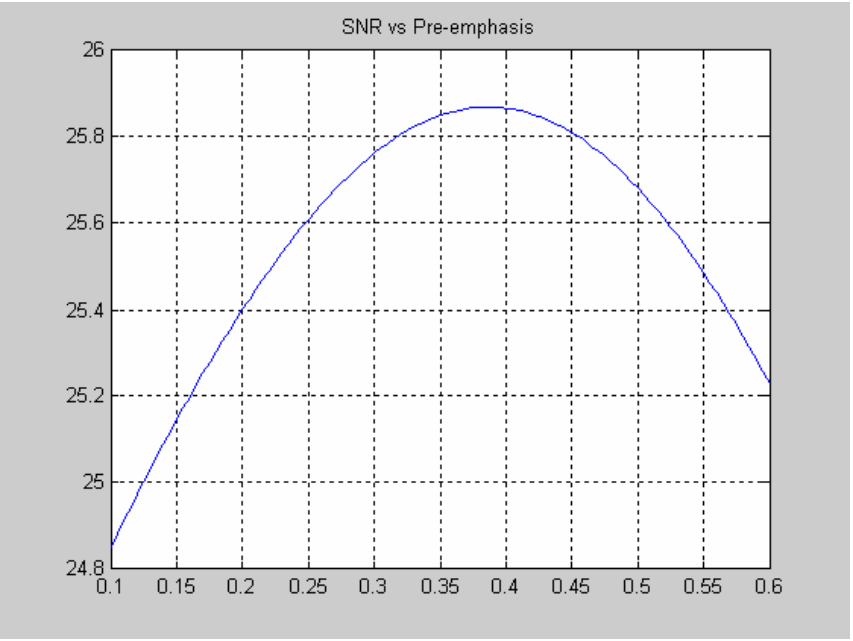
Transmitter parameters: focus on Jitter and RL spec

- Xmt Return Loss should be specified explicitly – as it was done in 802.3ak
- Jitter generation parameters: while exact value must be derived based on the channel parameters and simulation results, one aspect is clear: leaving RJ parameter restricted by TJ value only (when DJ~0) causes lot of interoperability issues. Here is CX4 solution:
  - All three components – RJ, DJ and TJ are bounded:
    - DJ ≤ 0.17UI
    - RJ ≤ 0.27UI
    - TJ ≤ 0.35UI - less the max(RJ) + max(DJ)!

How to start: Channel model

- 10G serial link requests are dominated
- Once we reached a broad consensus on modeling approach parameters, “low speed” portion of the model should be investigated more intensively
- Question to group: Should we defined additional channel model for 10G parallel and 1G serial PHYs only?
  - Will allow to support legacy backplanes/connectors
  - Will allow to target BER lower then 10^{-12} not in conjunction with 10G serial link challenges
  - Will easier backward compatibility with XAUI and 1000BASE-X

How to start: *Example of theoretical pre-emphasis calculation*

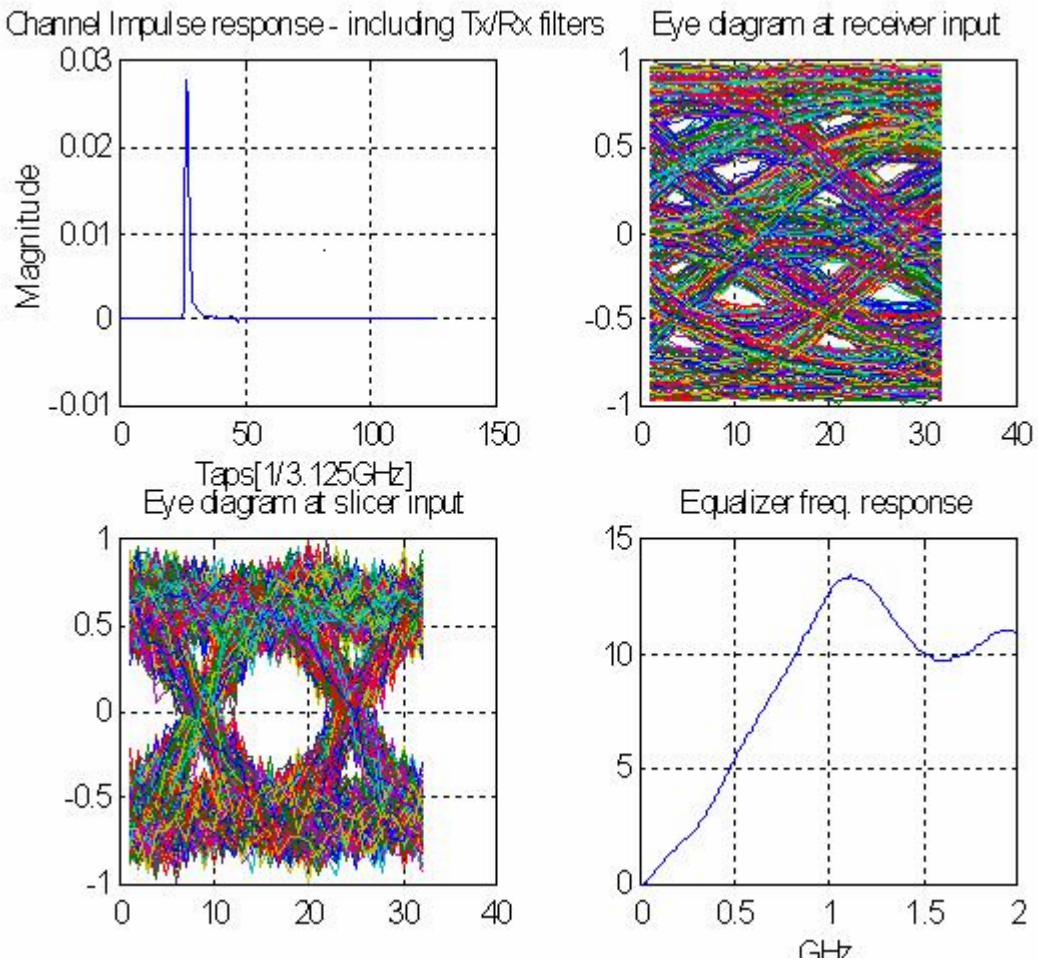


- 802.3ae XAUI channel model extended to 40” was used
- No Crosstalk noise
- No Receive side equalization

Optimal α = 0.385

Optimal Pre-emphasis =~ 44%

How to start: *example of full-system simulation results*



- - 802.3ae XAUI channel model extended to 40” has been used
- - Tx and Rx assumed to have 1.8G limited bandwidth
- - Not worst-case jitter
- - Complexity considerations have not been taken into account

Suggested Transmitter Electrical Characteristics

Parameter	Value	Justification
Signaling speed, per lane	3.125G±100ppm, GBd	Same as XAUI & CX4
Differential p2p output V, Min & Max	800mV – 1200mV	Same as CX4
Differential p2p output Voltage difference, max	150mV	Same as XAUI & CX4
Differential impedance	100Ohms	Same as XAUI & CX4
Differential output RL	-10dB @100-625MHz -10+10log(f/625) @ >625MHz	Same as CX4
Common Mode Voltage, Min & Max	-0.4 – 1.9V	Same as CX4 (XAUI?)
Rise/Fall time, Min & Max	60 - 130ps	Same as XAUI & CX4
Differential Output Template	TBD Note: Has to be adjusted to channel's model parameters	Adopted by CX4
Output jitter (p2p, max) TJ = RJ + DJ RJ DJ	Note: Has to be adjusted to channel's model parameters 0.35 UI 0.27 UI 0.17 UI	TJ & DJ values are same values as required by XAUI and CX4 Additional restriction for RJ adopted by CX4 – see slide #10 for explanations

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Suggested Receiver Electrical Characteristics

Parameter	Value	Justification
Bit Error Ratio, max	Equal or less then 10^{-12} Question: Should we seriously consider lower BER request? 10^{-15} ? 10^{-17} ?	Same as XAUI and CX4.
Signaling Speed, per lane	3.125G ± 100ppm, GBd	Same as XAUI & CX4
Receiver Coupling	AC Note: unless 10G serial requirements will contradict	Same as XAUI & CX4
Differential p2p input levels, max	1200mV	Same as CX4;
Return Loss	-10dB @100-625MHz -10+10log(f/625) @ >625MHz	Same as CX4
Differential impedance	100Ohms	Same as XAUI & CX4

Next steps

- Decide on the target BER
- Decide if we're going to support channel model in addition to the one defined for 10G serial mode
- Conduct full-system simulation model
- Decide on the Tx/Rx compliance points – TP2/TP3 pair like CX4? TP1/TP4?
- Autonegotiation
- Clause 45 Register Map update – if required to support 4-lanes 10G mode

Back-up: example of simulation model