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System Requirements for 100GbE 4x25G Backplane Channels

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Outline

- Review Channel Analysis Results
- System Requirements
- FEC Options
- Marketing Requirements
- PHY Proposals

Channel Analysis

- Backplane BER and Reach Objective:
  - Define a 4-lane 100 Gb/s backplane PHY for operation over links consistent with copper traces on "improved FR-4" (as defined by IEEE P802.3ap or better materials to be defined by the Task Force) with lengths up to at least 1m.
  - Support a BER of better than or equal to 10^{-12} at the MAC/PLS service interface.
- Consider channel analysis[1] from 2 "improved FR-4" 1m channels submitted to the 100GCU Study Group:

Channel	Channel Data Type	Total Length (inches)	Materials (Line Card Backplane)	Line Code	Vpp (v)	IL at 6.25 GHz (dB)	IL at 12.5 GHz (dB)	Required FEC NCG[2] for 0 dB margin at 10^{-12} BER (dB)	Required FEC NCG for 3 dB margin at 10^{-12} BER (dB)
TE Whisper[3]	Simulated	42.8	Nelco 4000-6 Nelco 4000-6	PAM-4	1.0	-27	-49	**8**	**11**
TE Whisper[3]	Simulated	42.8	Megtron-6 Megtron-6	NRZ	1.0	-16	-26	**2**	**5**

[1]: http://www.ieee802.org/3/100GCU/public/may11/hatab_01_0511.pdf
[2]: NCG = Net Coding Gain
[3]: http://www.ieee802.org/3/100GCU/public/ChannelData/TEC_11_0428/shanbhag_03_0411.pdf

System Requirements

- 1m of “improved FR-4” can potentially cover a wide range of physical channels depending on actual implementation:
  - Nelco Channels:
    - IL ≈ -50 dB at 12.5 GHz
    - Multi-level coding scheme feasible (e.g. PAM-4)
    - Amplitude possibly larger than 1.0 Vpp (diff)
    - FEC with NCG of at least 7 dB to exceed 10^{-12} BER
  - Megtron Channels:
    - IL ≈ -30 dB at 12.5 GHz
    - NRZ coding feasible
    - Amplitude of 1.0 Vpp (diff)
    - FEC with NCG of about 2-5 dB for 10^{-12} BER
- The preferred coding and FEC schemes must be different for both sets of channels in order to meet system performance objectives.
  - Actual system robustness likely require extra margin for BER exceeding 10^{-12}, such as a goal of 10^{-15}.

PAM-4 vs. NRZ Coding

- In general, PAM-4 is expected to have higher SNR margins than NRZ when:

$$IL_{f_{NYQ-PAM\,4}} - IL_{f_{NYQ-NRZ}} > 20\log_{10}\left(\frac{3}{V_{PP}}\right)$$

$$for \quad V_{PP} = 1V_{PP}$$

$$IL_{f_{NYQ-PAM\,4}} - IL_{f_{NYQ-NRZ}} > 9.5dB$$

  - Consider channel analysis[1] from 4 "improved FR-4" channels submitted to the 100GCU Study Group:

Channel	Channel Data Type	Total Length (inches)	Materials (Line Card Backplane)	Vpp (V)	IL at 6.25 GHz (dB)	IL at 12.5 GHz (dB)	Delta IL (dB)	10^{-12} BER PAM-4 Margin (dB)	10^{-12} BER NRZ Margin (dB)
TE Whisper	Simulated	42.8	Nelco 4000-6 Nelco 4000-6	1.0	-27	-49	22	-8	**-11**
TE Whisper	Simulated	42.8	Megtron-6 Megtron-6	1.0	-16	-26	10	-1.6	**-1.9**
TE Whisper	Simulated	29.8	Nelco 4000-6 Nelco 4000-6	1.0	-19	-34	15	-3	**-4.5**
TE Whisper	Simulated	29.8	Megtron-6 Megtron-6	1.0	-11	-18	7	**1.4**	2.3

FEC Options Re-Visited

There are many types of FEC choices coupled with NCG, overheads, and latency (over-clocking is likely unavoidable) :

- KR Codes: Fire Code (2112, 2080) based on 64/65 coding
  - 2 - 2.5dB NCG; no extra redundancy, add process latency of ~220ns.
- RS codes*: e.g. RS(340, 320), RS(224,208), RS(255, 239), RS(255, 223) etc.
  - 3-7%; 3-6.5dB gain.
  - 10-13%; up to 8dB; RS(255, 223) adopted by 802.3av.
- Proprietary (ITU) codes: much higher latency
  - 7% hard-decision such as G.975 codes: ~8 - 8.5dB NCG.
  - 13-20% hard-decision: 10-10.5dB NCG.
  - 20% LDPC codes: NCG ~ 11dB; 2x or 3x latency over HD

*: Many RS code scheme proposed for this category by the study group.

Marketing Requirements from IC vendor Perspective

Too many directions to nail down by the group:

- Channel target: what will be realistic at what cost/power levels?
  - Do we have “one solution fits all” scenario? Some cost-sensitive system vendor not willing to move to new materials (tough vs. easy medium).
- Coding fight: NRZ PHY or not?
  - NRZ vs. others schemes such as PAM-4.
- Are we ready for FEC Options?
  - FEC or no FEC? What is the latency and over-clocking target?
  - FEC gain options?
- Multi-channel impacts:
  - What xtalk level we can handle with the “improved” channel?
- Do we still care about backwards compatibility?

Suggested PHY Proposals

Proposal 1:

- PAM-4 PHY: Support for “Nelco” channels up to 40” (1m):
  - IL ≈ -50 dB at 12.5 GHz
  - PAM-4 coding
  - FEC with NCG of at least 7 dB for 10^{-12} BER
  - Investigate Tx amplitude > 1Vpp
- NRZ PHY: Support for “Megtron” channels up to 40” (1m):
  - IL ≈ -30 dB at 12.5 GHz
  - NRZ Coding
  - Tx amplitude 1Vpp
  - FEC with NCG of at least 2 dB for 10^{-12} BER

Proposal 2:

- NRZ PHY: Support for “Nelco” channels up to 30” (0.75m) and “Megtron” channels up to 40” (1m) :
  - IL ≈ -35 dB at 12.5 GHz
  - NRZ Coding
  - Tx amplitude 1Vpp
  - FEC with NCG of at least 5 dB for 10^{-12} BER