100GE Optics Proposal

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Outline

- Client Optics Applications Overview
  - 1000m Structured Data Center Optics Details
  - 2km Carrier Central Office Optics Details
  - 10km General Data Center Optics Details
- Baseline 100GE Optics Proposal
  - Proposal Overview
  - Structured Optics Details
- FEC Extended 100GE Optics Proposal
  - Proposal Overview
  - Baseline ⇔ FEC AN Functionality
  - Baseline ⇔ FEC Manual Alternative
- Summary

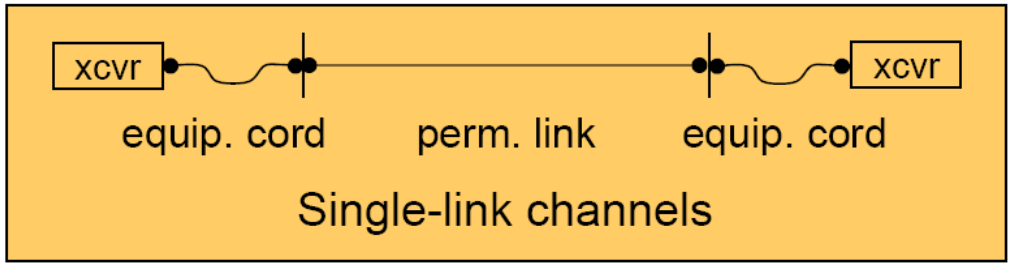
Client Optics Applications Overview

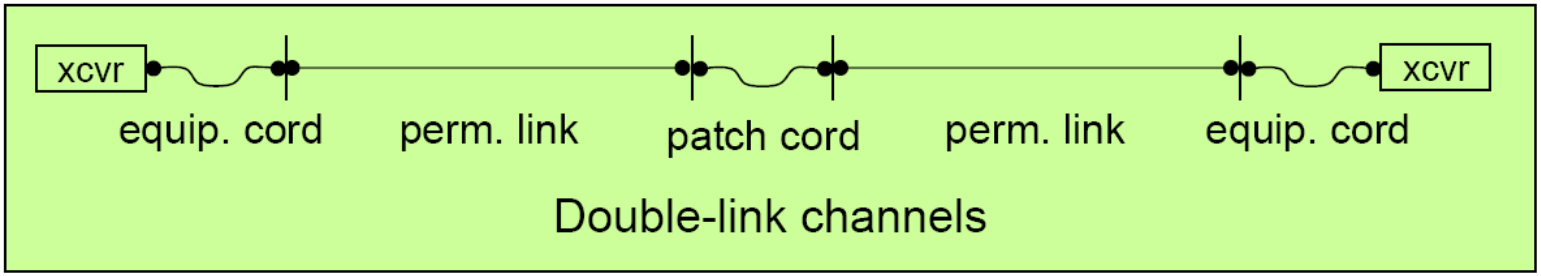
Client optics application & media type	High density data center parallel MMF	Structured data center duplex SMF *	Carrier central office duplex SMF *	General data center duplex SMF *	Metro inter-data center duplex SMF
nominal reach	100m	1000m	2km	10km	20, 30, 40km
min. loss budget	2dB	2dB	4dB	6dB	11 to 21dB
bits/sec cost vs. volume curve	10G VCSEL	10G VCSEL	10G DFB Laser	10G DFB Laser	10G EML
10G standard	duplex MMF 10GE-SR	none	OC-192 SR-1 = G.693 10G	10GE-LR	10GE-ER G.959.1 10G
40G standard	40GE-SR4	none	40GE-FR G.693 40G	40GE-LR4 G.695 10G	proposed 40GE-ER4
100G standard	100GE-SR10	none	none	100GE-LR4 G.959.1 25G	100GE-ER4 G.959.1 25G

* Discussed in more detail on following pages

1000m Structured Optics

- What is a 1000m structured data center optical link?
- 1000m or shorter duplex SMF link with two or four connectors; similar to a structured duplex or parallel MMF link
- Does NOT support more than four connectors
- Does NOT support optical loss elements like passive cross-connect
- Example structured links from “Fiber Cabling Trends in Data Centers”, Paul Kolesar (CommScope), 802.3 NG 100G SG, Chicago, Il, 09/11.





1000m Structured Optics, cont.

- 10GE-SR 300m reach no longer covers 99% of data center links, as it did when specified in 802.3ae in 2002
- Large Internet Data Centers (IDCs) have created a requirement for optics with >300m reach and 10GE-SR bit/sec cost vs. volume curve
- First identified by Donn Lee, “Saturating 100G and 1T Pipes,” IEEE 802.3 Higher Speed Study Group, March 2007, p.10:

  The ‘typical’ datacenter is an old paradigm for intra-datacenter reach

  - 400m-1km needed (2km SR?)

- SMF LR optics, using DFB lasers, meet the reach requirement but exceed the 10GE-SR bit/sec cost vs. volume curve
- MMF SR optics, using parallel VCSEL Arrays and MTP connectors, meet the cost requirement but are only practical for ~100m reaches
- Large difference between 1000m structured and 10km general optics link budgets (~6dB) offers opportunities for new TX technologies

2km Carrier Central Office Optics

40G 2km telecom optics link budget	ATT	China Telecom	Deutsche Telekom	NTT	Sprint	Verizon
6dB deployed (4dB loss budget)	Yes	Yes	Yes	Yes	Yes	Yes
7dB preferable (5dB loss budget)	Yes	Yes	Yes	Yes	Yes	Yes
4dB sufficient for all links	No	No	No	No	No	No

- Source: “100Gb/s SMF Client Reach Specs” presentation during Next Gen Optical PMD CFI Discussion, 11/8/10, Dallas, TX
- All IEEE and ITU-T 10G and 40G 2km optics deployed during the past decade have minimum 4dB loss budget and link budget penalties supporting minimum 2km SMF reach.

10km General Data Center Optics

- All IEEE 10G and 40G general optics deployed during the past decade have minimum 6dB loss budget and link budget penalties supporting minimum 10km SMF reach.
- 802.3 HSSG extensively studied data center link reach over 16 month period, with main effort by HSSG Reach Ad Hoc
- Example HSSG study result (in 802.3ba email archives) summarizing responses from data center operators to proposal by optics suppliers to reduce 100G SMF reach objective from 10km to 3km or 4km
- >50% require 10km reach objective
  - 4km to 5km
  - 5km to 10km
  - <4km reach with 10km loss budget to support loss elements
- <50% require 3km or 4km reach objective
  - 500m to 1km
  - 1km to 2km
  - 2km to 4km
- There has been no new data since HSSG study to change the picture

Baseline 100GE Optics Proposal

Baseline 25.75 Gb/s line rate application	High density data center parallel MMF	Structured data center duplex SMF	General data center duplex SMF	Metro inter-data center duplex SMF
max. reach	70m	1000m	10km	40km
min. loss budget	2dB	2dB	6dB	21dB
standard	100GE-SR4	100GE-nR4	100GE-LR4	100GE-ER4

Baseline 100GE Optics Overview

- 802.3ba compliant ports with 25.75 Gb/s line rate
- Baseline support required to enable interoperability with 100GE-LR4 and 100GE-ER4 optics already deployed and/or to be deployed in the next several years.
- Baseline support required to enable development of 100GE-SR4 and 100GE-nR4 modules for use in 802.3ba only compliant ports to enable interoperability with other 100GE-SR4 and 100GE-nR4 optics
- 100GE-SR4 discussed in other Nov'11 NG 100G SG presentations
- 100GE-nR4 discussed in more detail on following page
- 100GE-LR4
  - Gen1 uses discrete 25G EML TOSAs (10G EML bit/sec cost vs. volume curve starting in 2009)
  - Next Gen uses quad 25G DFB PIC TOSAs (10GE-LR bit/sec cost vs. volume curve starting in 2012)
- 100GE-ER4 unchanged

Baseline 100GE Structured Optics Details

- 1000m structured data center duplex SMF application
- 100GE-nR4 is a generic designation with full name TBD, if adopted
- Minimum 100GE-nR4 link budget = ~2.5dB
- 100GE-LR4 link budget = ~8.3dB
- Example 100GE-nR4 specification:
  - 100GE-LR4 TX OMA (min) reduced by ~6dB
  - 100GE-LR4 RX SRS (OMA max)
  - 100GE-LR4 wavelengths (interoperable <1000m reach)
- TX technologies that can take advantage of reduced output power:
  - 25G DFB Laser PICs
  - 25G Si Modulator + CW Laser PICs
  - 25G InP Modulators + CW Laser PICs
  - 25G Long Wave VCSELs

FEC Extended 100GE Optics

- Why FEC? Because it's the closest thing to free lunch in optics
- It's only free once, so lets gorge ourselves
- What FEC rate makes sense for optics?
- One that fully exploits the available technology to maximize coding gain while maintaining low latency
  - 28 Gb/s VCELs are in development to support 32x Fibre Channel
  - 28 Gb/s EMLs and DFB Lasers (discrete and PIC) are developed or in development to support 32x Fibre Channel and OTN OTU-4
  - 28 Gb/s electrical I/O is developed or in development
- 27.95 Gb/s FEC fully exploits available technology
  - same rate as OTU-4
  - enables re-use of components and test equipment
  - increases loss budget by ~2dB
  - reserves ~1dB for sensitivity and penalty degradation offset
  - low latency (tens of nanoseconds)
  - can be compatible with 100GE-KR4 FEC

FEC Extended 100GE Optics Proposal

FEC extended 27.95 Gb/s line rate application	High density data center parallel MMF	Carrier central office duplex SMF	Metro inter-data center duplex SMF	Metro inter-data center duplex SMF
max. reach	100m	2km	20km	40km
min. loss budget	4dB	4dB	11dB	21dB
standard	100GE-SR4f	100GE-nR4f	100GE-LR4f	100GE-ER4f

FEC Extended 100GE Optics Overview

- NG 100GE compliant ports with 27.95 Gb/s line rate
- 100GE baseline optics extended to higher rate operation
- 100GE-SR4f reach extended by ~40% (see other Nov'11 NG 100G SG presentations)
- 100GE-nR4f loss budget increased to 4dB enables support of carrier central office Ethernet applications
- 100GE-LR4f
  - 2dB loss budget increase from FEC
  - 3dB TX quad DFB laser PIC power increase enabled by relaxed eye safety measurement standards
  - sub-set of all metro inter-data center links supported with optics on 10GE-LR cost vs. volume curve
- 100GE-ER4f application unchanged
  - 2dB applied to RX SRS spec relaxation to improve yield

Baseline ⇔ FEC AN Functionality

- Baseline-only (single-rate) and FEC (dual-rate) modules are differentiated by conventional markings like handle color coding
- Baseline-only module in baseline-only port operates in baseline mode
- Baseline-only module in FEC port operates in baseline mode
- FEC module in baseline-only port operates in baseline mode
- FEC module in FEC port operates in baseline mode if far end has baseline-only module or port
- FEC module in FEC port operates in FEC mode if far end has both FEC module and FEC port
- AN protocol always starts in baseline mode
  - FEC port supports high BER operation in baseline mode
  - FEC port recognizes far end FEC port, both in baseline mode
  - FEC dual-rate operation is supported by either reference-less or host selectable reference rate module

Baseline ⇔ FEC Manual Alternative

- Baseline-only (single-rate) and FEC-only (single-rate) modules are differentiated by conventional markings like handle color coding
- Baseline-only module in baseline-only port operates in baseline mode
- Baseline-only port in FEC port operates in baseline mode
- FEC-only module in FEC port operates in FEC mode
- FEC-only module in baseline-only port doesn’t work
- FEC-only module in FEC port doesn’t work with far end baseline-only module and/or port
- Places burden on the end user to differentiate and match PMD types
- Less desirable than AN

100GE Optics Proposal Summary

- Develop new 100GE-SR4 standard for ~100m parallel MMF apps
- Develop new 100GE-nR4 standard for ~1000m duplex SMF apps
  - Reduce 100GE-LR4 TX OMA (min) by ~6dB to enable new technology to get on 10GE-SR cost vs. volume curve
- Support 100GE-LR4 for 10km apps
  - Transition to quad 25G DFB Laser PIC technology to get on 10GE-LR cost vs. volume curve
- Support 100GE-ER4 for 40km apps
- Develop a 27.95 Gb/s line rate FEC extended standard corresponding to every 100GE baseline standard with loss budget increased by ~2dB
- Develop new 100GE-SR4f standard with 40% longer reach than –SR4
- Develop new 100GE-nR4f standard for 2km carrier central office apps
- Develop new 100GE-LR4f standard for 20km metro apps
- Develop new 100GE-ER4f standard for 40km lower cost metro apps
- Develop AN protocol to seamlessly support baseline and FEC optics