Technology Exploration Forum

Next Gen 100Gb/s Ethernet Optics

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Outline

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- Existing 100Gb/s Ethernet Optics
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- New Data Center Application
- Recent Optics Link Examples
- **100Gb/s Optics Applications**
- Next Gen 100Gb/s Ethernet Optics
- Next Gen 100Gb/s 2km SMF Reach
- Next Gen 100Gb/s ~500m SMF Reach
- 100Gb/s Non-Ethernet SMF Optics
- Desired Ethernet Industry Activities
- **Summary: Next Gen 100Gb/s Optics**

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Existing 10Gb/s & 40Gb/s Optics

	10GE-SR IEEE 802.3ae	**OC-192 SR-1** ITU G.693	**10GE-LR** IEEE 802.3ae	**40GE-SR4** IEEE 802.3ba	**40GE-FR** IEEE 802.3bg	**P1I1-3D1** ITU-T G.959.1	**40GE-LR4** IEEE 802.3ba
rate Gb/s	10	10	10	40	40	40	40
reach km	**0.3**	**2**	**10**	**0.1**	**2**	**10**	**10**
fiber	duplex MMF	duplex SMF	duplex SMF	parallel MMF	duplex SMF	duplex SMF	duplex SMF
λ nm	850	1310	1310	850	1550	1310	1310
penalties dB	4.7	1	3.2	6.4	2	1	2.6
loss budget dB	**2.6**	**4**	**6.2**	**1.9**	**4**	**6**	**6.7**
link budget dB	7.3	5	9.4	8.3	6	7	9.3

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Existing 100Gb/s Ethernet Optics

	100GE-SR10 IEEE 802.3ba	**100GE-LR4** IEEE 802.3ba
rate Gb/s	100	100
reach km	**0.1**	**10**
fiber	parallel MMF	duplex SMF
λ nm	850	1310
penalties dB	6.4	2.2
loss budget dB	**1.9**	**6.3**
link budget dB	8.3	8.5

- 100GE-SR10
  - 100m parallel MMF 24MTP
  - 10x10G
- CPPI
  - un-retimed module I/O
  - 10x10G
- 100GE-LR4
  - 10km duplex SMF
  - 4x25G
- CAUI
  - re-timed module I/O
  - 10x10G
- *(100GE-ER4 SMF 40km)*

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100Gb/s Link Reach Distribution

- 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: summary of responses from data center operators, many part of NANOG, to proposal to reduce 100Gb/s SMF 10km reach objective to 3km or 4km
- **>50% require 10km 100Gb/s:**
  - 4km to 5km
  - 5km to 10km
  - <4km with 10km budget to support extra link losses
- <50% require 3km or 4km 100Gb/s:
  - 500m to 1km
  - 1km to 2km
  - 2km to 4km

Source: 802.3ba email archive, Chris Cole, 7/01/08, 12:35 PM

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New Data Center Application

- Majority of data center 10Gb/s interfaces are 10GE-SR
- 10GE-SR VCSEL technology has significantly lower cost & power than 10GE-LR DFB laser technology
- 10GE-SR 300m reach covered 99% of data center links when adopted in 2002, and still covers majority of links today
- Since 2002, because of appearance of Internet Data Centers, there is a new reach application:

  IDC >300m link with ~10GE-SR bit/sec cost

- 100GE-SR10 and 100GE-SR4 use parallel VCSEL PIC and MTP technology, so are practical for <100m links but not for >300m
- No 100Gb/s duplex optics technology exists with ~10GE-SR bit/sec cost & power for any link reach

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Carrier 40Gb/s Link Budget Examples

40Gb/s client link budget deployed in network	ATT	China Telecom	Deutsche Telekom	NTT	Sprint	Verizon
6dB used (4dB loss budget)	Yes	Yes	Yes	Yes	Yes	Yes
7dB preferable	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, Next Gen Optical PMD CFI Discussion, 11/8/10, Dallas, TX
- Carrier 100Gb/s link needs are similar to 40Gb/s link needs
- **Application budget needs are well met by 100GE-LR4**
- Need ~10GE-LR bit/sec cost for 100G links

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AMS-IX IDC 100Gb/s Link Example

link element	loss (dB)
100GbE router port	0.5
fiber: 100m to 500m (2km max)	0.2 (0.8)
patch panel	0.5
patch cord: <100m	0.05
patch panel	0.5
cross-connect	3.0
patch cord: <100m	0.05
100GbE router port	0.5
loss budget (dB)	**5.3 (5.9)**

- Source: Henk Steenman
- **Application budget needs are well met by 100GE-LR4**
- Needs ~10GE-LR bit/sec cost for 100G links
- Typical ~4dB loss enables use of lower loss budget interfaces

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Facebook IDC 10Gb/s Link Example

link element	loss (dB)
10GbE server port	0.5
patch cord: <100m	0.05
patch panel	0.5
fiber: 100m to 600m (1000m max)	0.3 (0.4)
patch panel	0.5
patch cord: <100m	0.05
10GbE switch port	0.5
loss budget (dB)	**2.4 (2.5)**

- Source: Donn Lee
- Majority of 10Gb/s link needs are well met by 10GE-SR 300m
- Needs 10Gb/s ~600m links with ~10GE-SR bit/sec cost
- **Also needs some 100Gb/s ~600m links with ~10GE-SR bit/sec cost**

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Google IDC* 100Gb/s Link Example

Data Center Size (sq ft)	Data Center Size (sq m)	Square Data Center Longest Cable Length (m)	Rectangular Data Center Longest Cable Length (m)
10,000	918	68	72
400,000	36,731	391	414

- Source: "LDC Operator Perspective" in 10x10 MSA White Paper final_2, May'11 (Google only LDC Operator listed as co-author)
  - Large Data Center (LDC) application requirements:
    - 414m max duplex SMF cable length
    - 40% 10GE-LR bit/sec cost (~10GE-SR bit/sec cost)
    - multiple optics suppliers
- Source: ECOC 2010 Market Focus Google presentation
  - Google preferred link budget for this application: 3.8dB
- **100Gb/s link need is ~500m with ~10GE-SR bit/sec cost**

* Ex. of many other names for IDC: Barn Scale Computer (BCS)

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100Gb/s Optics Applications

Application	100m	~500m	2km	10km
~loss budget	2dB	2 to 3dB	4dB	6dB
~link budget = loss + penalties	8dB	2.5 to 3.5dB	6dB	8.5dB
bit/sec cost & power target	~10GE-SR	~10GE-SR	~10GE-LR	~10GE-LR
volume laser technology	VCSEL PIC	none (solution TBD)	DFB PIC	DFB PIC
fiber	parallel MMF	duplex SMF	duplex SMF	duplex SMF
Ethernet Standard	100GE-SR10	**none (need???)**	**none (need???)**	100GE-LR4

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Next Gen 100Gb/s Ethernet Optics

- IEEE 802.3 Next Gen 100Gb/s Ethernet Optics CFI
  - Planned for July'11 802.3 Plenary Meeting in SF
  - If approved, 1st Study Group meeting in Sept'11
  - **Next Gen 100Gb/s CFI justification: increase 100Gb/s Ethernet optics density to support higher bandwidth and reduce cost & power**
  - CFI Lead: Dan Dove, CFI Co-champion: Kapil Shrikhande
- CFI Cu track: CAUI-4, CPPI-4
  - 4x25G PCB trace chip to module I/O
  - Enables low cost & power 4x25G optical modules
  - Key study areas: 1) host reach, 2) technical approaches; un-retimed vs. retimed, EDC, FEC
  - Cu Champion: Ryan Latchman

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Next Gen 100Gb/s Ethernet Optics

- CFI MMF track: 100GE-SR4
  - 4x25G OM3 & OM4 12 MTP parallel MMF
  - Key study areas: 1) reach vs. power, 2) EDC, FEC
  - MMF Champion: Jonathan King
- CFI SMF track: 100GE-nR4
  - **4x25G short reach duplex SMF**
  - Key study areas: 1) effect on reach of un-retimed 25G interface, 2) feasibility of new optics technologies if there is 3) market need for lower reach and loss budget SMF link, 4) EDC, FEC
  - Caution: market volume and technology may not justify a new 100Gb/s duplex SMF Ethernet standard
  - SMF Champion: Pete Anslow

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Next Gen 100Gb/s 2km SMF Reach

- **Market shows no need for separate 2km only reach**
- Data centers use 10GE-LR with 10km budget
- Central offices use OC-192 SR-1 with 2km budget
- Volume of the two interfaces is about the same
- Early SR-1 single rate 300-pin modules have been replaced by pluggable dual rate modules meeting both specifications (free lunch for Carriers!)
- Despite large link budget delta, lower cost of 2km reach is not enough to justify SR-1 single rate pluggable modules
- 40GE-FR is not a counter example. 2km link reach was adopted to support inter-operability with large installed base of 1550nm OC-768 VSR 300-pin MSA modules

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Next Gen 100Gb/s 2km SMF Reach

- **Technology shows no need for separate 2km only reach**
- The link budget delta between 1310nm DFB laser based 2km vs. 10km 100Gb/s applications is 2.5dB
- 2.5dB reduction in 100GE-LR4 link budget leads to modest cost & power reduction
- 2km reach applications are <50% of 10km reach applications, so near term volume does not justify a separate development
- Split in volume and increase in OpEx cost of supporting two different SMF interface types wipes out any cost savings of 2km only reach interface
- **2km and 10km reach apps. are best met by 100GE-LR4**
- Required industry focus is transition from discrete 25G EML based Gen1 to PIC 25G DFB laser based Gen2, to reduce cost & power to get on ~10GE-LR bit/sec cost curve

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Next Gen 100Gb/s ~500m SMF Reach

- **100Gb/s ~500m reach application is the right focus** for the IEEE 802.3 Next Gen 100Gb/s Study Group (if approved) SMF track because of new IDC link needs
- Study feasibility of new optics technologies to meet ~10GE-SR (VCSEL equivalent) bit/sec cost & power
- Study market potential and volume
- Study the exact IDC link max reach requirement using 802.3 HSSG studies as starting baseline, and rigorous reach distribution data (ex.: Alan Flatman's superb studies)
- No justification may be found for new duplex SMF 802.3 standard, either because of insufficient market volume or immature optics technology alternatives

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100Gb/s Non-Ethernet SMF Optics

	"2km" 10x10G MSA r1.2
rate Gb/s	100
reach km	**"2"**
fiber	duplex SMF
λ nm	1550
penalties dB	2.5
loss budget dB	**2.6**
link budget dB	5.1

- 10x10G MSA "2km" spec is not per industry practice. Loss budget is consistent with ~500m reach application
- 10x10G MSA "2km" spec driving LDC Operator requirement has 414m max reach and 3.8dB link budget, which is consistent with ~500m reach application
- 10x10G MSA "2km" spec penalties are unnecessarily high because of 1550nm λ
- 10x10G 1550nm "10km" spec will not be per industry practice because 1550nm λ possible penalties are not interoperable
- **10x10G MSA specs have created confusion among end users**

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Desired Ethernet Industry Activities

- Promote real Ethernet optics standards
  - 100GE-SR10
  - 100GE-LR4 (& ER4)
- Debunk misleading marketing labels:
  - 10x10G "2km"
  - 10x10G "100GE-LR10"
- **Defend IEEE 802.3 process & standards against attacks**
- Educate end users about rigorous optics link engineering
  - Loss budget and reach
  - Link budget and penalties
- Build consensus towards future Ethernet optics standards
  - 100GE-SR4
  - 100GE-nR4 (if need confirmed in IEEE 802.3)

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Summary: Next Gen 100Gb/s Optics

Application	100m	~500m	2km & 10km
~loss budget	2dB	2 to 3dB	6dB
~link budget = loss + penalties	8dB	2.5 to 3.5dB	8.5dB
bit/sec cost & power target	~10GE-SR	~10GE-SR	~10GE-LR
volume laser technology	VCSEL PIC	none solution TBD	DFB PIC
fiber	parallel MMF	duplex SMF	duplex SMF
Ethernet Standard	**100GE-SR10 →100GE-SR4**	**need TBD in IEEE 802.3**	**100GE-LR4**

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Thank You

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