Technical & Economic Feasibility of 40km SMF 100GE Transceivers

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Outline

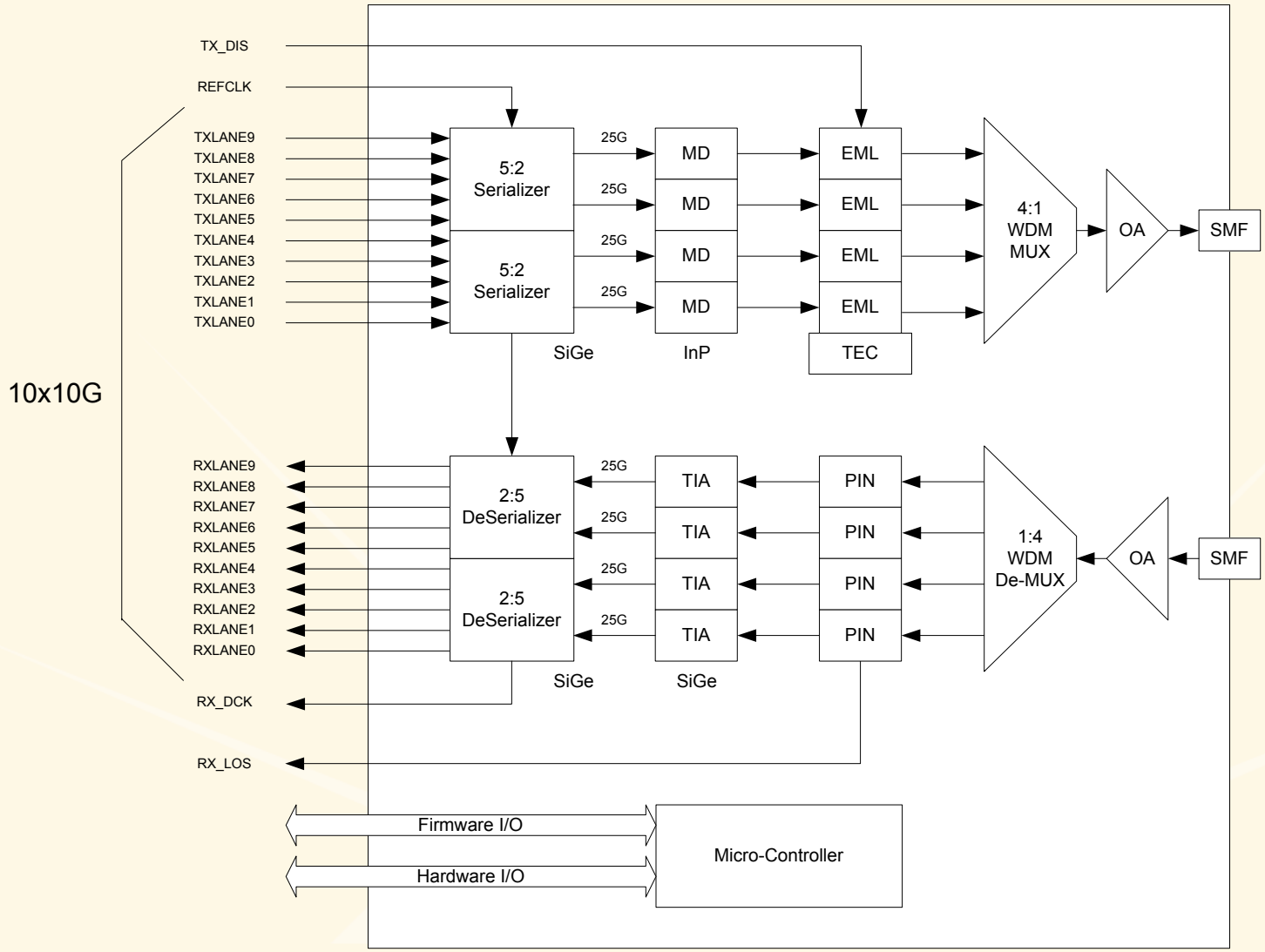
- Applicable HSSG Fiber Optic Ad Hoc SMF Alternative
- Gen1 40km 4x25G 1310nm Optically Amplified (OA) Transceiver Architecture
- 40km Transceiver Technical Feasibility Check List
- 4λ 1310nm LAN WDM Baseline
- 4λ 1310nm LAN WDM 25G Optical Link Budgets
- OA Receiver Sensitivity Analysis
- OA Receiver Sensitivity Measurements
- 40km Transceiver Power
- 40km Transceiver Economic Feasibility
- Gen2 40km 4x25G 1310nm Optically Amplified (OA) Transceiver Architecture
- Discussion

Reach (Technical) Feasibility of 100GE Alternatives

SMF	10km 1310nm	40km 1310nm	10km 1550nm	40km 1550nm
10x10G DML	yes + CL	yes + CL + OA	yes	maybe + OA
10x10G ML	yes + CL	yes + CL + OA	yes	yes + OA
5x20G / 4x25G DML	yes	maybe + OA	maybe	maybe + DC
5x20G / 4x25G ML	yes	yes + OA	yes	yes + DC
2x50G DQPSK I/Q ML	yes + CL	yes + CL + OA + DC	yes + CL + DC	yes + CL + OA + DC
1x100G TDM ML	yes + CL + OA	yes + CL + OA + DC	yes + CL + OA + DC	yes + CL + OA + DC

CL = Cooling (or semi-cooling,) OA = Optical Amplification, DC = Dispersion Compensation
Green shading designates alternatives under detailed study by Fiber Optic Ad Hoc contributors.
Red oval designates alternative in this presentation.

Gen1 40km 4x25G 1310nm Transceiver Architecture



40km 4x25G OA Transceiver Technical Feasibility

Item	Status	Comments
Optical Link Budget	√	40km cooled EML & OA link budget shown. Additional OA RX data in this presentation.
Dual 5:2 SiGe SerDes	√	40G SiGe SerDes commercially available. 20G operation shown.
Quad InP Mod Driver	√	40G InP MDs commercially available. 20G and 25G operation shown.
Quad EML TOSA w/ WDM Mux & OA	√	40G EMLs & SOAs commercially available. 20G and 25G operation shown. WDM Mux optics commercially available.
Quad PIN/TIA ROSA w/ OA & WDM DeMux	√	40G PIN/TIAs & SOAs commercially available. WDM DeMux optics commercially available. Additional 20G & 25G data in this presentation.
Connector / I/O Signal Integrity	√	10G I/O Connectors commercially available. 10G signal integrity shown.
Mechanical / Thermal	√	Viable mechanical form factor shown. 20W and higher power dissipation shown. Additional OA power data in this presentation.

4λ 1310nm LAN WDM Baseline

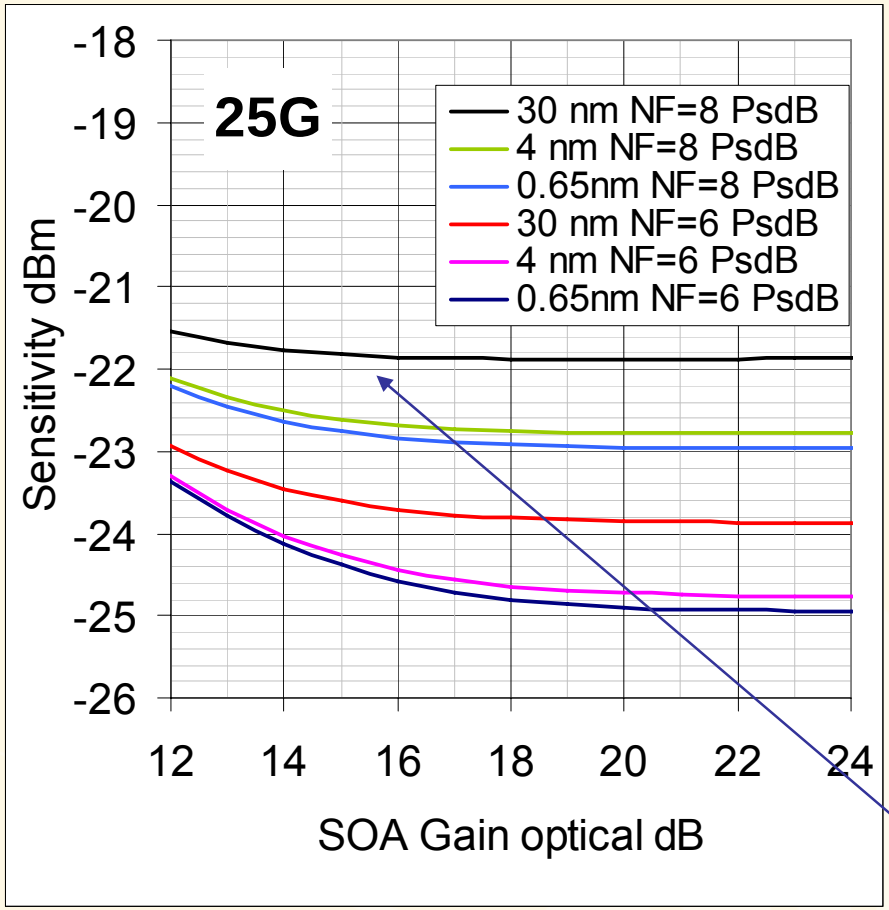
- 4λ 1310nm LAN WDM Characteristics (for all 100GE reaches)
  - 1312nm band center
    - Minimum Loss (in the O-band)
    - Minimum Chromatic Dispersion
  - 400GHz to 800GHz DWDM spacing (possibly on ITU G.694.1 grid)
    - Corresponds to 2nm to 4nm λ spacing
    - Resulting <12nm band is compatible with standard monolithic laser array processes (unlike CWDM 60nm 4λ band, or LX-4 75nm 4λ band)
    - Does not impose stringent frequency stability requirements (unlike DWDM systems with <200GHz spacing)
    - Avoids non-linear effects of DWDM systems with <200GHz spacing
  - Requires cooling or semi-cooling
- 4λ 1310nm LAN WDM 100GE Transceiver Benefits
  - Reasonable Mux and DeMux filter requirements
  - Monolithic laser arrays lead to lowest long term transmitter cost
  - Monolithic laser array, Mux/DeMux and OA are potential PIC components
  - Shared development among reaches
  - Shared measurement and testing of reaches
  - Interoperability between reaches
  - Economies of scale

4λ 1310nm LAN WDM 25G Optical Link Budgets

25G per λ budget LAN WDM grid	2km	5km	10km	40km
TP2 max output power (dBm)	0	0	4	4
TP2 min output power (dBm)	-4	-4	0	0
TP3 min input sensitivity (dBm)	-8	-9	-8	-22
TP2 to TP3 max penalty (dB)	1 w/ ±4ps/nm max CD	1 w/ ±9ps/nm max CD	1 w/ ±18ps/nm max CD	2 w/ ±70ps/nm max CD
TP2 to TP3 max path loss (dB)	3 1dB fiber + 2dB other	4 2dB fiber + 2dB other	7 4dB fiber + 3dB other	20 17dB fiber + 3dB other

2km or 5km reach may have cost advantages over 10km reach.

25G OA Receiver Sensitivity Analysis



Analysis parameters

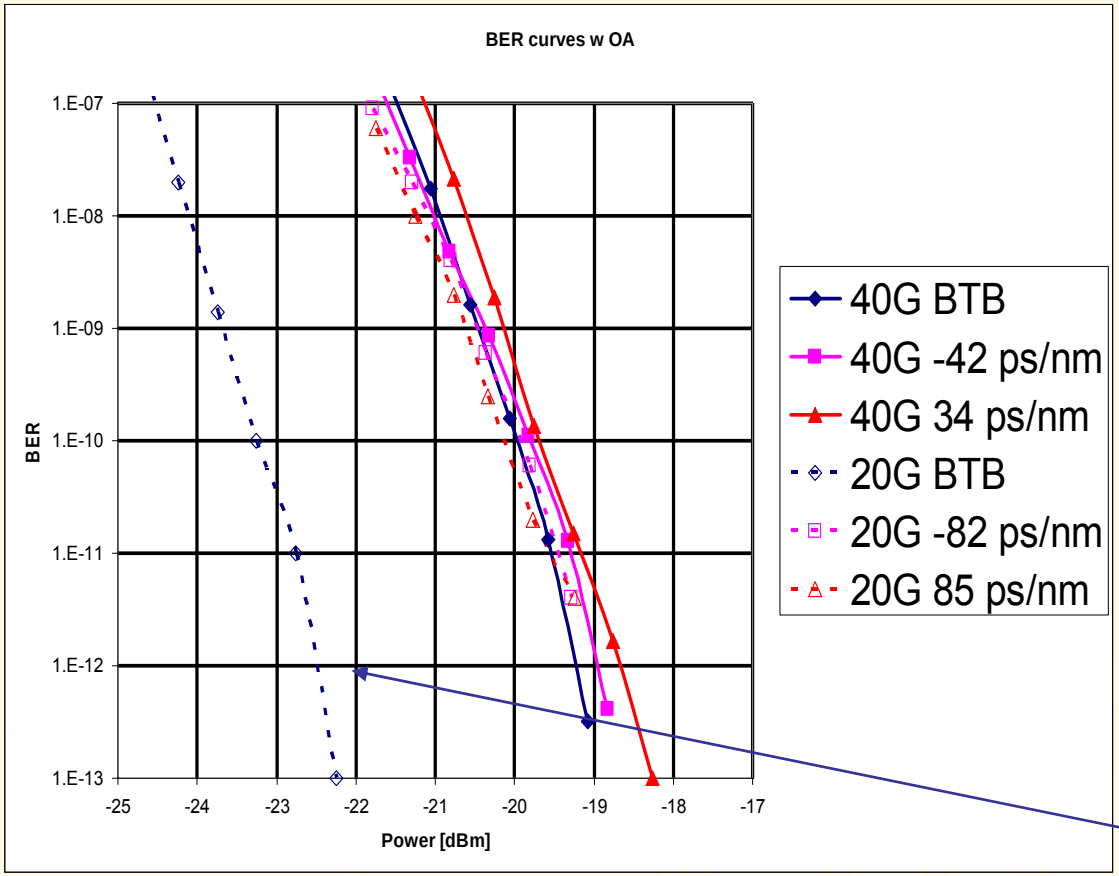
- Optical Filter bandwidth: 0.65nm, 4nm, 30nm
- Electrical Filter bandwidth: 17.5GHz
- Optical Amplifier Noise Figure: 6dB, 8dB
- Extinction Ratio: 8dB
- Un-amplified Receiver Sensitivity: -14dBm
- Photo-diode Responsivity: 0.6
- Receiver input noise: 13 pA/√Hz

Conclusion

- -22dBm Receiver Sensitivity is achievable with SOA technology.

Jonathan King, "OA Investigation," Finisar Corp.

40G & 20G OA Receiver Sensitivity Measurements



Measurement Set-up

- Data: 40G/20G PRBS 2^31-1
- TX: 40G 1554nm EML/TEC
- Path: DCF → SMF-28 → VOA → ISO
- RX: OA (13dB Gain, 8dB NF) → ISO (0.8db Loss) → OF (0.65nm BW, 2.4dB Loss) → 40G PIN/TIA
- 20G Receiver Stressed Sensitivity is degraded due to 40G CDR sub-optimal sampling phase.

Conclusion

- -22dBm Receiver Sensitivity is achievable with SOA technology.

Yuri Vandyshev, Tedros Tsegaye, “OA Investigation,” Finisar Corp.

40km 4x25G OA Transceiver Power

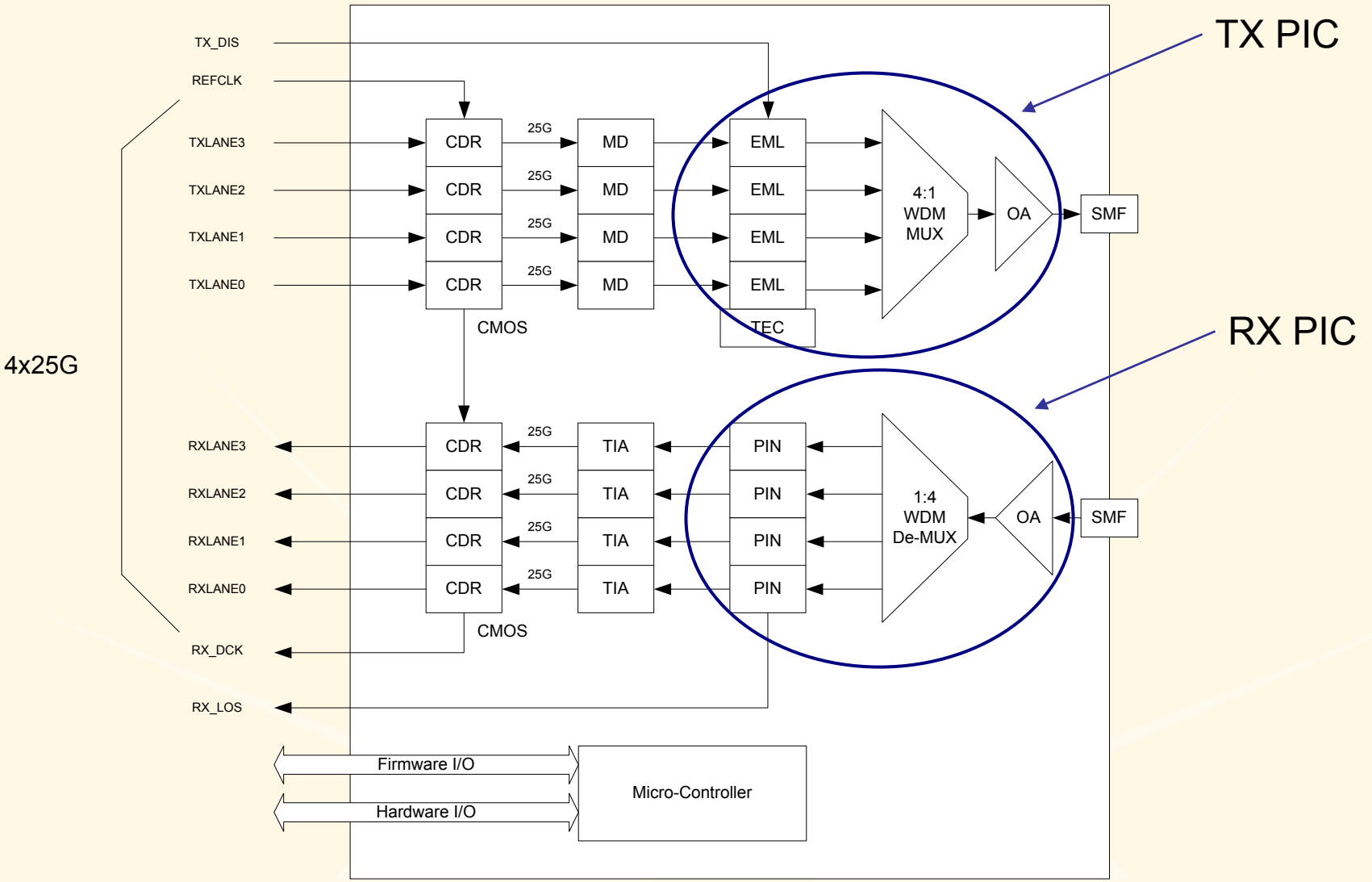
10GE-ER XENPAK Component	Power Watts	10km 4x25G Transceiver Component	Power Watts
XAUI (SiGe)	2.2	Dual 5:2 SerDes (SiGe)	6.5
Mod Driver (InP)	0.5	Quad MD (InP)	2.0
EML/TEC TOSA	1.5	Quad EML/TEC w/ WDM Mux & OA/TEC TOSA	7.0
PIN/TIA ROSA	0.3	Quad PIN/TIA w/ OA/TEC & WDM DeMux ROSA	3.7
other ICs	0.3	other ICs	0.7
Maximum operating power	**~5**	**Maximum operating power**	**~20**

40km 4x25G OA Transceiver Economic Feasibility

10GE-ER XENPAK Component	Relative BOM Cost	40km 4x25G Transceiver Component	Relative BOM Cost
XAUI (SiGe)	1x	Dual 5:2 SerDes (SiGe)	3x
Mod Driver (InP)	1x	Quad MD (InP)	3x
EML + TEC TOSA	1x	Quad EML/TEC w/ WDM Mux & OA/TEC TOSA	6x
PIN/TIA ROSA	1x	Quad PIN/TIA w/ OA/TEC & WDM DeMux ROSA	10x
FR4 PCBA, XENPAK parts & PT20 connector	1x	Nelco PCBA, new form factor parts & connector	2x
Single channel testing	1x	Four channel testing	3x
Weighted average	**1x**	**Weighted average at similar volumes and points in time**	**7x**

Amortization of development and test equipment costs not included.

Gen2 40km 4x25G 1310nm Transceiver Architecture



Discussion

- 100GE 40km reach is Technically Feasible through the use of OA techniques.
- Other techniques such as high speed DMLs and high speed APDs may also become Technically Feasible for the 40km reach.
- 100GE 40km reach is Economically Feasible, if 4λ 1310nm LAN WDM, architecture, and components are common with other reaches.
- Proposed 40km Transceiver Architecture will offer significant cost reduction opportunities in the future, through use of 4x25G PICs and mainstream 4x25G data bus ICs.
- 4λ 1310nm LAN WDM offers lowest cost for every 100GE reach.
- Since 40km reach is likely to be included in PAR A, a 2km or 5km reach may be a better alternative then the 10km reach. (The discussion whether to change the 10km reach objective can be deferred to the 100GE Working Group.)