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Initial thought about Modulation format & FEC for “Long-reach” 400GbE

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1. Motivation & Scope

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Motivation

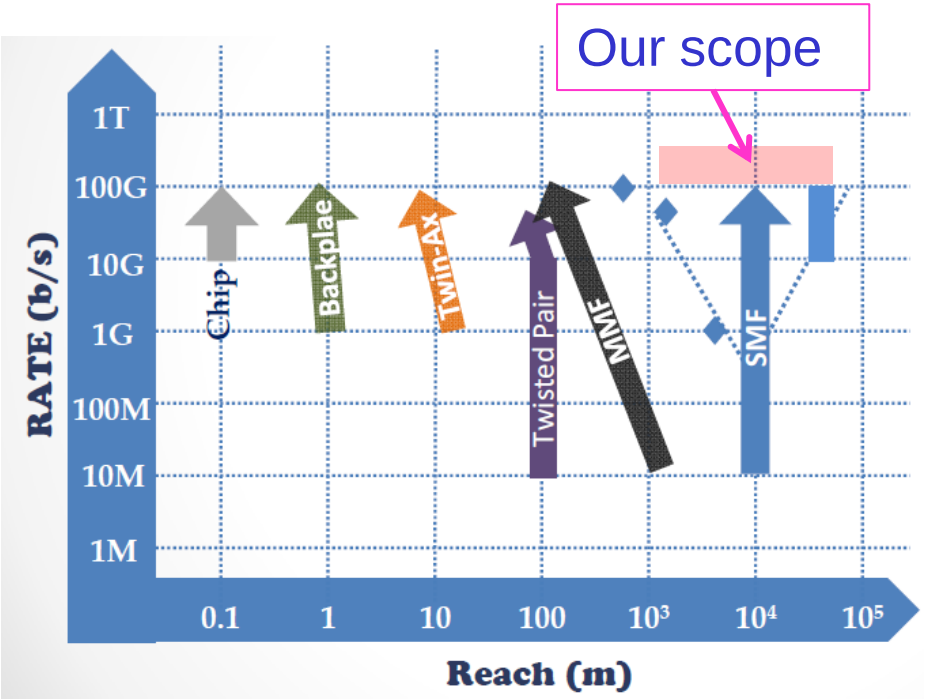
Increase of data rate over SMF 10-40km would be required, similar to other PHYs.

So, we think simultaneous discussion about over 100G transceiver for LR & ER is needed.

Scope

Towards a discussion about 400GbE LR & ER transceiver, we will show our thought regarding the followings;

- Number of lanes
- Symbol rate (Modulation speed)
- Modulation format & FEC



http://www.ieee802.org/3/400GSG/public/13_05/dambrosia_400_02_0513.pdf

2. Requirement for realization of 400GbE LR & ER

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To realize 400GbE LR & ER, the following items are required;

1) Number of lanes : ≤ 8

- Able to realize compact size & high port density
- Able to improve cost, power consumption & yield
- Reduced complicated deskew , etc

2) Modulation speed : 25G ~ 34G

- Compatible to electrical IF (i.e. 25Gbit/s per lane)
- Reduced Gearbox (in case of 25G)
- Reduced too high cost optical / electrical components, etc

What are candidates to realize 400GbE LR & ER satisfied with the above requirements?

3. Realizable candidates of 400GbE LR & ER

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We will compare modulation schemes regarding performance(ROSNR).

(Lanes) x (Bit rate per serial)	Modulation scheme		ROSNR [dB] @1E-3	Comments
	Symbol rate (w/o FEC OH)	Format		
16λ x 25G	25Gbaud	NRZ	17.2 *1	- Too many wavelength
8λ x 50G	25Gbaud	PAM4	22.0 *1	- Similar components from 100GbE can be used
4λ x 100G	25Gbaud	DP-QPSK	15.3 *2	- Similar components from OTN can be used
	25Gbaud	DMT	22.0 *3	- Similar components from 100GbE can be used
	33.4Gbaud	PAM8	26.9 *1	- Need “Gearbox”
	50Gbaud	PAM4	25.0 *1	- Need high bandwidth optical / electrical components
2λ x 200G	25Gbaud	DP-16QAM	22.9 *2	- High spectral efficiency
1λ x 400G	25Gbaud	DP-64QAM	31.9 *2	- Need narrow linewidth LDs

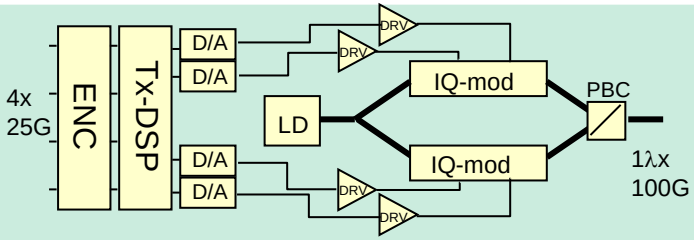
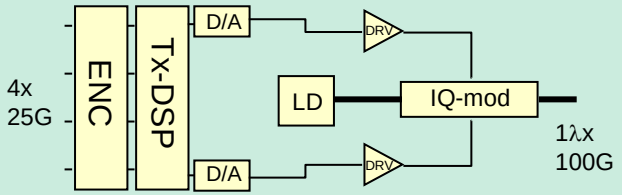
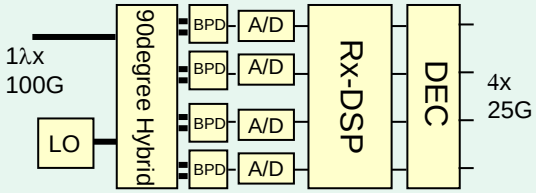
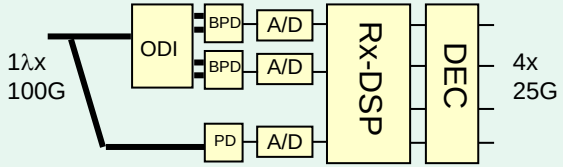
Considered with number of lanes, symbol rate & performance,
4λ x 100G with 25Gbaud can be one of possible candidates.

www.ieee802.org/3/400GSG/public/13_05/song_400_01_0513.pdf
* 1: Estimated value with Required OSNR of 10G NRZ
* 2: Estimated value referred to “http://www.chinacommunications.cn/EN/Y2010/V7/I3/24”
* 3: Referred to “*http://www.ieee802.org/3/bm/public/may13/tanaka_01_0513_optx.pdf*”

DP : Dual Polarization

4. Introduction of our studying solution

We will introduce “Direct-detection Single Polarization 16QAM” satisfied with “4 λ” & “25Gbaud” as other solution, comparing with Digital Coherent DP-QPSK.

	Digital Coherent Dual Polarization QPSK	Digital Direct-detection Single Polarization 16QAM
Tx side Configuration (per λ)		
Rx side Configuration (per λ)		
Feature	- Mitigate impairments with DSPs - Adopted same technique as 100G OTN transceiver - Good sensitivity - Over 1000 km transmission is realizable (Optimal for Metro & Core)	- Mitigate impairments with DSPs - Reused same components as DP-QPSK transceiver except ODI - Reduced DSP amount due to single polarization - Reduced components due to single polarization & direct-detection

DSP : Digital signal processing
D/A : Digital to Analogue converter
A/D : Analogue to Digital converter
DRV : Electrical Driver
LD : Laser diode
IQ-mod : IQ modulator
LO : Local Oscillator
BPD : Balanced photo diode
PD : Photo diode
ODI : Optical delay interferometer
ENC : Encoder
DEC : Decoder
PBC : Polarization beam combiner
Electrical signal line
Optical signal line

5. Modulation format & FEC

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Reported cases and our solution regarding modulation format & FEC are shown as follows;

	NRZ	PAM-4	PAM-4	DMT	PAM-8	1-pol 16QAM (Our study)
Bit rate per lane[bit/s]	25G (16 lane)	50G (8 lane)	100G (4 lane)	100G	100G (4 lane)	100G (4 lanes)
Target BER (FEC threshold)	< 1E-12	2.2E-5	2.2E-5	1E-3	2.7E-2	< 1E-4 (Under study)
FEC type	No FEC	RS(544,514, t=15,m=10) CG ~ 6.5dB	RS(544,514, t=15,m=10) CG ~ 6.5dB	BCH(TBR) CG ~ ?	? CG ~ 12dB	Under study CG ~
FEC overhead	-	< 3%	< 3%	12.5%	40%	-
FEC latency	-	< 100ns	< 100ns	< 100ns	400 ns	-
Symbol rate w FEC [Baud]	25.8G	25.8G	51.6G	29.0G?	43.6G	(25.8+α) G

http://www.ieee802.org/3/bm/public/nov12/welch_01_1112_optx.pdf
http://www.ieee802.org/3/bm/public/nov12/ghiasi_01a_1112_optx.pdf
http://www.ieee802.org/3/bm/public/may13/tanaka_01_0513_optx.pdf
http://www.ieee802.org/3/400GSG/public/adhoc/logic/jun26_13/wangz_01_0613_logic.pdf

In order to realize 400GbE LR & ER with “4 λ” & “25Gbaud”, stronger FEC than RS(544,514,t=15,m=10) is required.

6. Summary

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✓Need to discuss about 400GbE LR & ER transceiver

✓Candidate of 400GbE LR, ER optical architecture?
-> 4 λ x100G (25Gbaud) may be reasonable
regarding number of lanes, modulation speed and performance

✓Single polarization Direct-detection 16QAM is
one of candidates for 400GbE LR & ER realized with 4 λ x100G (25Gbaud)
* Details of this will be shown in future meetings

✓Stronger FEC is required

Thank you