P2P Ethernet for Optical Access

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Outline

- Basic requirements for optical access Ethernet
- Existing PMD review
- Potential ways to develop new P2P PMDs
- Market considerations

Requirements for Access Ethernet

- Operate over single strand of single mode fiber (G.652)
- Loss budgets similar to G.985 / G.986
  - Class S = 0~15dB, Class A: 5~20dB, Class B 10~25dB
- Silent start behavior (ONU only speaks when spoken to)
- Power saving behavior (potentially, link rate adaptation)
- OAM features, such as Port-ID
- Support for synchronization / ToD

Existing P2P Ethernet Access

- Part of P802.3ah EFM (2004)
- 100BASE-X (Cl 58, 66), 100 Mb/s, 10 km
  - 100BASE-LX10 - 2 fiber (1310 nm)
  - 100BASE-BX10 - 1 fiber (1550 nm DS, 1310 nm US)
  - Similar to ITU-T G.985
- 1000BASE-X (Cl 59, 66), 1 Gb/s, 10 km
  - 1000BASE-LX10 - 2 fiber (1310 nm), SMF / MMF(550 m)
  - 1000BASE-BX10 - 1 fiber (1490 nm DS, 1310 nm US)
  - Similar to ITU-T G.986

Ethernet optical rates 10G (not intended for access applications)

Project	Name	Lanes/Dir	Fiber count	Fiber type	Reach (km)	Pwr Budget (dB)	Ch IL (dB)	penalties (dB)	λ (nm)	Tx[3] (dBm)	Rx[4] (dBm)	Section	Clause
802.3ae – 2002	10GBASE-ER	1	2	SMF	40	15	10.9	4.1	1550	-4.7 to 4.0	-15.8	4	52
	10GBASE-EW												
	10GBASE-LR	1	2	SMF	10	9.4	6.2	3.2	1310	-8.2 to 0.5	-14.4	4	52
	10GBASE-LW												
	10GBASE-LX4 (see note 2)	4 wdm	2	SMF	10	7.5	6.2	2.0	1276 1300 1325 1349	-0.5 max /lane	note 2	4	53

Note 1	10GBASE-xW PMDs operate at 9.95 GBd, 10GBASE-xR PMDs operate at 10.3125 GBd
Note 2	10GBASE-LX4 does not specify a min Transmit average power nor a Receive power.
Note 3	Tx = Average launch power
Note 4	Rx = Minimum receive power

Short reach (DC) PHYs not shown

10G PHY Tx details

	Common Characteristics			Transmitter Characteristics											
	Signaling Rate		range	min	max	min	min	min	max	max	min	max	max	max	
PHY Name	Nom	accuracy	Center λ	side mode suppression	Avg Pwr	Avg Pwr	Tx Pwr (OMA-TDP)	OMA	TDP	Off pwr	ER	RIN	ORL	Reflectance	Ref
units	GBd	ppm	nm	dB	dBm	dBm	dBm	dBm	dB	dBm	dB	dB/Hz	dB	dB	Table
10GBASE-ER	10.3125	±100	1530 - 1565	30	4	–4.7	–2.1	–1.7	3.0	–30	3	–128	21	n/s	52-16
10GBASE-EW	9.95328	±20													
10GBASE-LR	10.3125	±100	1260 - 1355	30	0.5	–8.2	–6.2	–5.2	3.2	–30	3.5	–128	12	–12	52-12
10GBASE-LW	9.95328	±20													
10GBASE-LX4	3.125	±100	1269.0 – 1282.4 1293.5 – 1306.9 1318.0 – 1331.4 1342.5 – 1355.9	0	-0.5(1)	-1.25(1,2)	-	-6.25(1)	-	-30	3.5	-120	-	-	53-7
Note 1:	Per Lane														
Note 2:	OMA														

Short reach (DC) PHYs not shown

10G PHY Rx details

	Common Characteristics			Receive Characteristics									
	Signaling Rate		range	max	min	max	max	max	max	max	min	max	
PHY Name	Nom	accuracy	Center λ	Avg Pwr	Avg Pwr	Damage threashold	Sensitivity (OMA)	Reflectance	Stressed Sensitivity (OAM)	Vert. Eye closure penalty	Stressed eye jitter	Elec.l 3 dB upper cutoff freq	Ref
units	GBd	ppm	nm	dBm	dBm	dBm	mW (dB)	dB	mW (dB)	dB	UI pk-pk	GHz	Table
10GBASE-ER	10.3125	±100	1530 - 1565	–1.0	–15.8	4	0.039 (–14.1)	–26	0.074 (-11.3)	2.7	0.3	12.3	52-17
10GBASE-EW	9.95328	±20											
10GBASE-LR	10.3125	±100	1260 - 1355	0.5	–14.4	n/s	0.055 (–12.6)	–12	0.093 (–10.3)	2.2	0.3	12.3	52-13
10GBASE-LW	9.95328	±20											
10GBASE-LX4	3.125	±100	1269.0 – 1282.4 1293.5 – 1306.9 1318.0 – 1331.4 1342.5 – 1355.9	-.05(1)			35.0 (-14.45)(1)		45.7 (-13.4)(1)	1.1		0.375	53-8
Note 1:	Per Lane												
Note 2:	OMA												

Short reach (DC) PHYs not shown

Ethernet optical rates 40/100G (not intended for access applications)

40/100 Gb/s Ethernet													
Project	Name	Lanes /Dir	Fiber count	Fiber type	Reach (km)	Pwr Budget (dB)	Ch IL (dB)	penalties (dB)	λ (nm)	Tx (dBm)	Rx (dBm)	Section	Clause
802.3ba-2010	40GBASE-LR4	4 wdm	2	SMF	10	9.3	6.7	2.6	1271 1291 1311 1331	-7 to 2.3 /lane	-13.7	6	87
	100GBASE-LR4	4 wdm	2	SMF	10	8.5	6.3	2.2	1295.56 1300.05 1304.58 1309.14	-4.3 to 4.5 /lane	-10.6	6	88
	100GBASE-ER4	4 wdm	2	SMF	40	21.5	18	3.5	1295.56 1300.05 1304.58 1309.14	-2.9 to 2.9 /lane	-20.9	6	88
802.3bm-2015	40GBASE-ER4	4 wdm	2	SMF	40	21.1	18.5	2.6	1271 1291 1311 1331	-2.7 to 4.5 /lane	-21.2	6	87

Short reach (DC) PHYs not shown

40/100G PHY Tx details

	Common Characteristics			Transmitter Characteristics																
	Signaling Rate		range	min	max	min	min	min	max	max	avg	min	max	max	min	max	max	max	
PHY Name	Nom	accuracy	Center Wavelength	side mode suppression	Total Avg Pwr (all lanes)	Avg Pwr (per lane)	Avg Pwr (per lane)	OMA (per lane)	OMA (per lane)	delta OMA Pwr (any 2 lanes)	delta OMA pwr (any 2 lanes)	Tx Pwr OMA-TDP (per lane)	TDP (per lane)	Off pwr (per lane)	ER	RIN	ORL	Reflectance	Ref
units	GBd	ppm	nm	dB	dBm	dBm	dBm	dBm	dBm	dB	dBm	dBm	dB	dBm	dB	dB/Hz	dB	dB	Table
40GBASE-LR4	10.3125	±100	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	30	8.3	2.3	–7	3.5	–4	7	—	–4.8	2.6	–30	3.5	–128	20	–12	87-7
40GBASE-ER4					10.5	4.5	–2.7	5	0.3	5	—	–0.5	2.6	–30	5.5				
100GBASE-LR4	25.78125	±100	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19	30	10.5	4.5	–4.3	4.5	–1.3	5	—	–2.3	2.2	-30	4	-130	20	-12	88-7
100GBASE-ER4					8.9	2.9	–2.9		0.1	—	3.6	—	2.5		8				

Short reach (DC) PHYs not shown

40/100G PHY Rx details

	Common Characteristics			Receive Characteristics												
	Signaling Rate		range	max	max	min	max	max	max	max	max	max	min	min	min	
PHY Name	Nom	accuracy	Center Wavelength	Damage threashold	Avg Pwr	Avg Pwr	OMA	Delta OMA Pwr	Reflectance	Sensitivity OMA	Elec. 3 dB upper cutoff freq	Stressed Sensitivity OAM	Vert. Eye closure penalty	Stressed eye J2 jitter	Stressed eye J9 jitter	Ref
units	GBd	ppm	nm	dBm	dBm	dBm	dBm	dB	dB	mW (dB)	GHz	mW (dB)	dB	UI pk-pk	UI pk-pk	Table
40GBASE-LR4	10.3125	±100	1264.5 to 1277.5 1284.5 to 1297.5	3.3	2.3	–13.7	3.5	7.5	-26	–11.5	12	–9.6	1.9	0.3	0.47	87-8
40GBASE-ER4			1304.5 to 1317.5 1324.5 to 1337.5	3.8	–4.5	–21.2	–4	7	-26	–19		–16.8	2.2			
100GBASE-LR4	25.78125	±100	1294.53 to 1296.59 1299.02 to 1301.09	5.5	-10.6	4.5	5.5	—	-26	-8.6	31	-6.8	1.8	0.3	0.47	88-8
100GBASE-ER4			1303.54 to 1305.63 1308.09 to 1310.19		-20.9		—	4.5		-21.4		-17.9	3.5			

Short reach (DC) PHYs not shown

802.3 P2P optical work in progress

- P802.3bs 200 Gb/s and 400 Gb/s
  - Draft 3.5
- P802.3cc 25 Gb/s Ethernet over Single-Mode Fiber
  - Draft 3.3
- P802.3cd 50 Gb/s, 100 Gb/s, and 200 Gb/s Ethernet
  - Draft 3.0
- 802.3 Beyond 10 km Optical PHYs Study Group
- 802.3 Ballot process
  - Three ballot phases;
    - Task Force (Draft 1.x),
    - Working Group (Draft 2.x) and
    - Sponsor Ballot (Draft 3.x)
  - Typically 3-4 draft versions per ballot.

802.3 P2P optical work in progress of interest

Project	Draft	Name	Rate (Gb/s)	Lanes/Dir	Fiber count/type	Reach (km)	Pwr Budget (dB)	Ch IL (dB)	penalties (dB)	Wavelength (nm)	Tx/lane (dBm)	Rx/lane (dBm)	Signaling rate (GBd)	Signaling accuracy (ppm)	Modulation	Clause
		units	Gb/s			km	dB	dB	dB	nm	dBm	dBm	GBd	ppm		
P802.3bs	D3.5	200GBASE-LR4	200	4 wdm	2 SMF	10	10.2 (1) 10.3 (2)	4	3.9 (1) 4 (2)	1295.56 1300.05 1304.58 1309.14	5.3 to -3.4	5.3 to -9.7	26.5625	±100	PAM4	122
		400GBASE-LR8	400	8 wdm		10	10.1 (1) 10.2 (2)	6.3	3.8 (1) 3.9 (2)	1273.54 1277.89 1282.26 1286.66	5.3 to -2.8	5.3 to -9.1				
P802.3cc	D3.3	25GBASE-LR	25	1		10	9.7	6.3	3.4	1310	2 to -7	2 to -13.3	25.78125	±100	NRZ	114
		25GBASE-ER				40	2.7	18	20.7		6 to -3	-4 to -21				
P802.3cd	D3.0	50GBASE-LR	100	1		10	10.3	6.3	4	1311	4.2 to -4.5	4.2 to -10.8	53.125	±100	PAM4	140

Use with caution, numbers can still change

Potential solutions

- The biggest issue regarding the PHY is the change to single fiber working (full duplex)
- Primarily, this is a wavelength question
  - Existing PHYs use the same wavelengths on both sides
  - This makes both sides identical, which is good for P2P (there isn't a low volume OLT and high volume ONU)
- We need to find two wavelengths, hopefully that already exist in the marketplace

Possible approach for 10Gb/s

- Start with 10GBase style optics
  - 10GBase-LR works at 1260-1355nm
  - 10GBase-ER works at 1530-1565nm
- P2P could use ER downstream, and LR upstream

Possible approach for 20Gb/s

- Start with 40GBase-_R4 style optics
  - 40GBase-LR4/ER4 use CWDM grid optics: 1271, 1291, 1311, 1331nm
- P2P could use 1291, 1331nm downstream, 1271, 1311nm upstream

Example from the marketplace

Optical Transceivers

10Gb/s Bidirectional 10km SFP+ Optical Transceiver

FTLX2071D3xx

(https://www.finisar.com/sites/default/files/styles/colorbox/public/product-images/FTLX2071D3xx%20SFP%2B%20Bi-Di.jpg?itok=eb850gQj)

Form Factor: SFP+

Finisar's FTLX2071D327/FTLX2071D333 10Gb/s Enhanced Small Form Factor Pluggable SFP+ transceivers are designed for use in 10-Gigabit Ethernet links up to 10km over a single-strand Single Mode fiber. This capability doubles the capacity of installed legacy single mode fiber links. They are compliant with SFF-8431 and IEEE 802.3ae 10GBASE-LR/LW, and 10G Fibre Channel 1200-SM-LL-L. Digital diagnostics functions are available via a 2-wire serial interface, as specified in SFF-8472.

The FTLX2071D327/FTLX2071D333 is a "limiting module", i.e., it employs a limiting receiver. Host board designers using an EDC PHY IC should follow the IC manufacturer's recommended settings for interoperating the host-board EDC PHY with a limiting receiver SFP+ module. The optical transceiver is compliant per Directive 2011/65/EU. See Finisar Application Note AN-2038 for more details.

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Key Features
Applications
Downloads
Specifications

Distance:	10 km
Data Rate (max):	10.5 Gb/s
Protocol:	10x Fibre Channel Compliant, 10 Gigabit Ethernet Compliant, Wireless CPRI Compliant
Low End Case Temperature (°C):	-40
High End Case Temperature (°C):	85
Diagnostics:	Digital
Transmitter:	DFB Laser
Receiver:	PIN
Voltage Supply:	3.3
Connector:	LC
Wavelength:	BiDi 1271/1331nm

Possible approach for 25G

- Start with 25GBase-ER style optics
  - 25GBase-ER works at 1295-1310nm
- Other wavelength could be borrowed from 802.3ca
  - One of the upstream choices is 1260-1280nm
- P2P could use 1295-1310nm downstream, 1260-1280nm upstream

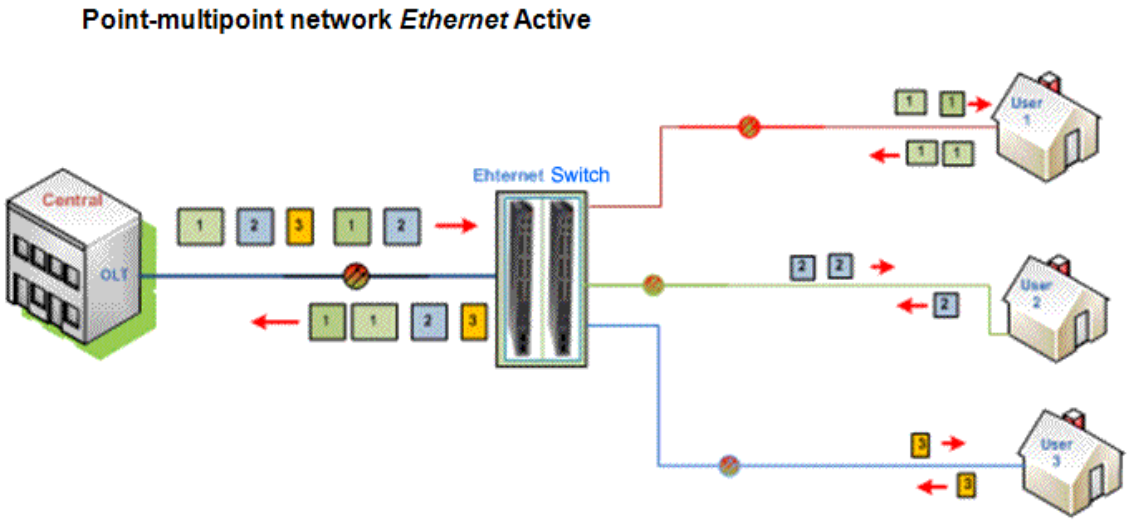
Possible approach for 25 or 50Gb/s

- Start with 100GBase-_R4 style optics
  - 100GBase-LR4/ER4 use 1295, 1300, 1305, 1310nm
- P2P could use 1300, 1310nm downstream, 1295, 1305nm upstream

Market considerations

- There are three main applications for P2P access Ethernet
  - FTTBusiness
  - FTTHome
  - Wireless fronthaul (and backhaul)

Use of P2P for FTTH



Source: ICP-ANACOM

FTTH market share by technology

- Worldwide FTTH market is $8B
  - That figure expected to remain steady over the next decade
  - Currently dominated by GPON and EPON
    - "Peak G-PON" happened in 2016
  - Expected to slowly shift to XGS-PON and 10GEPON
    - Crossover time ~2020
- P2P (aka Active Ethernet) responsible for a steady ~$300M of FTTH revenue
  - Basically, 5% of the worldwide market

Independent Operator technology usage

- Independent telcos tend to use Active Ethernet
- A recent study showed that
  - 480 providers used G-PON
  - 193 providers use active Ethernet
  - ~30% of the independent operator market

FTTWireless

- CPRI and eCPRI look to be major applications of P2P PMDs
  - CPRI is very inefficient, easily justifying 10G or higher
  - eCPRI is thankfully more efficient, but 5G uses so much more, we still need 25G up to 100G links in the fronthaul
- Volume estimation
  - 3B people / (100 people / RU) / 10 year rollout = 3M ports / year
- Per-port willingness to pay significantly higher than FTTH
  - Total revenue could surpass the existing market

Conclusions

- P2P optical access appears to be a viable use case for Ethernet technology
  - Certainly technically feasible, leveraging existing PHYs
  - Market opportunity is of reasonable size
    - Some companies are already making such things
- Why do this work in 802.3?
  - This is the rightful home of this technology
  - The special requirements (silent start) can reach a wider audience

Questions? Comments?

- Is there interest in starting a study group to consider single fiber PHYs for optical access?