Summary of Recent Optical Access Work in 802.3

--- 802.3ca, 802.3cp, and 802.3dk

Yuanqiu Luo
Futurewei Technologies

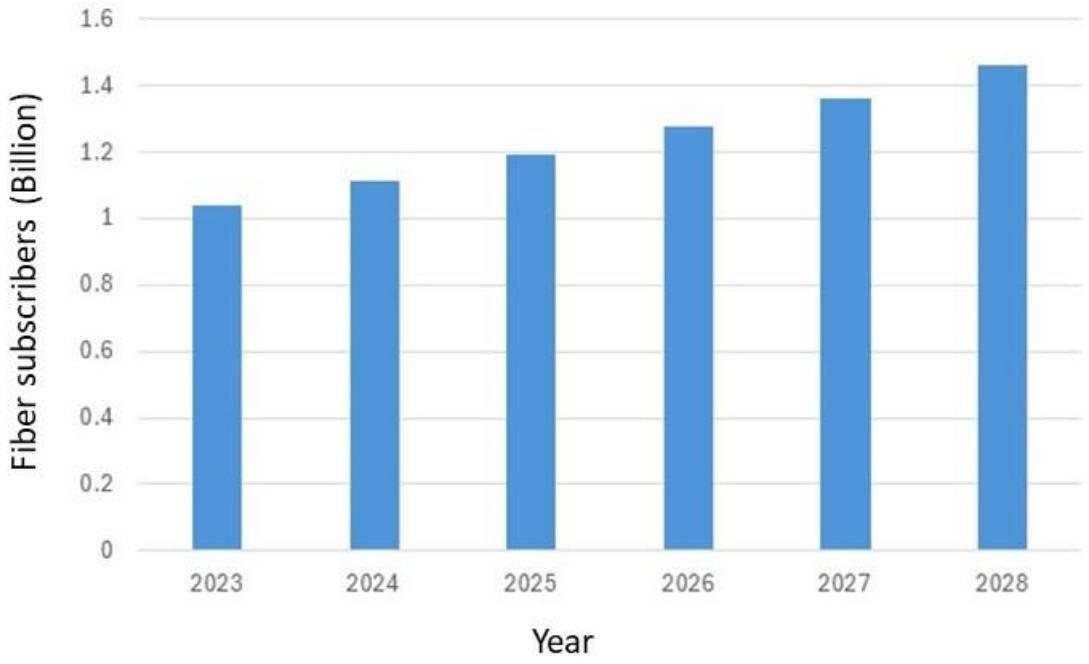
Chair, IEEE P802.3dk
Editor, IEEE P802.3cp

Ninth Joint IEEE 802 and ITU-T Study Group 15 Workshop
13 July 2024, Montreal, Canada

Introduction

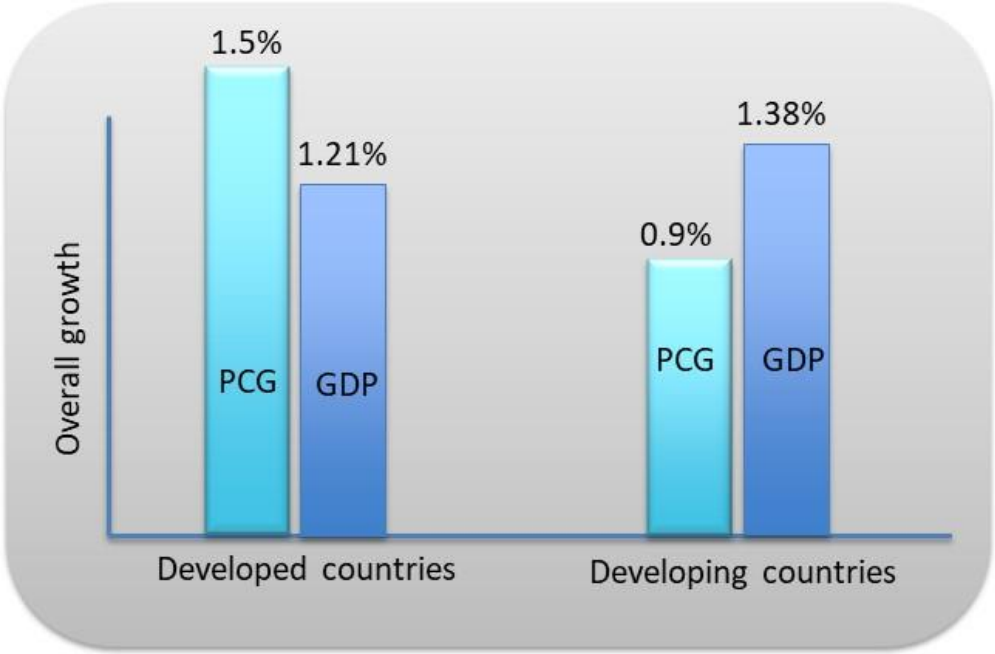
Optical Access Contributes to Economic Growth

Global broadband fiber subscribers surpassed 1 billion in 2023. It is expected to be >1.4 billion by 2028 with a CAGR of ~7%



Omdia, 2023

10% increase in broadband access was associated with 0.9%~1.5% increase in per capita economic growth, or 1.21%~1.38% GDP growth



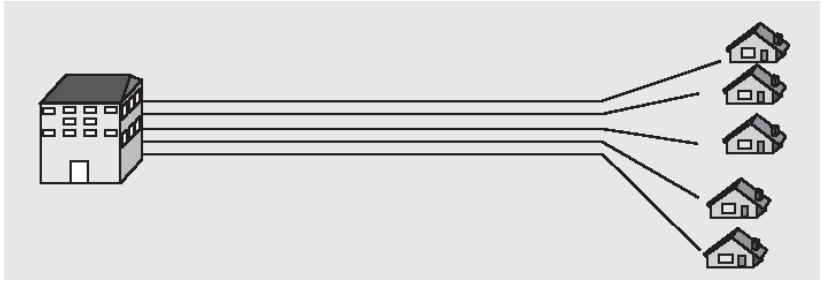
"World Development Report: Data for Better Lives", The World Bank, 2021
"Affordable High-Speed Internet is Spurring Economic Growth and Boosting Small Businesses", The White House Briefing Room, May 2024

Main Solutions for Optical Access

Point-to-multipoint (PtMP) optical access

- Passive optical networks (PONs)
- Passive outside plant
- TDM/TDMA for medium sharing
- High loss budget due to splitter loss
- Low port density at central office

Point-to-point (PtP) optical access



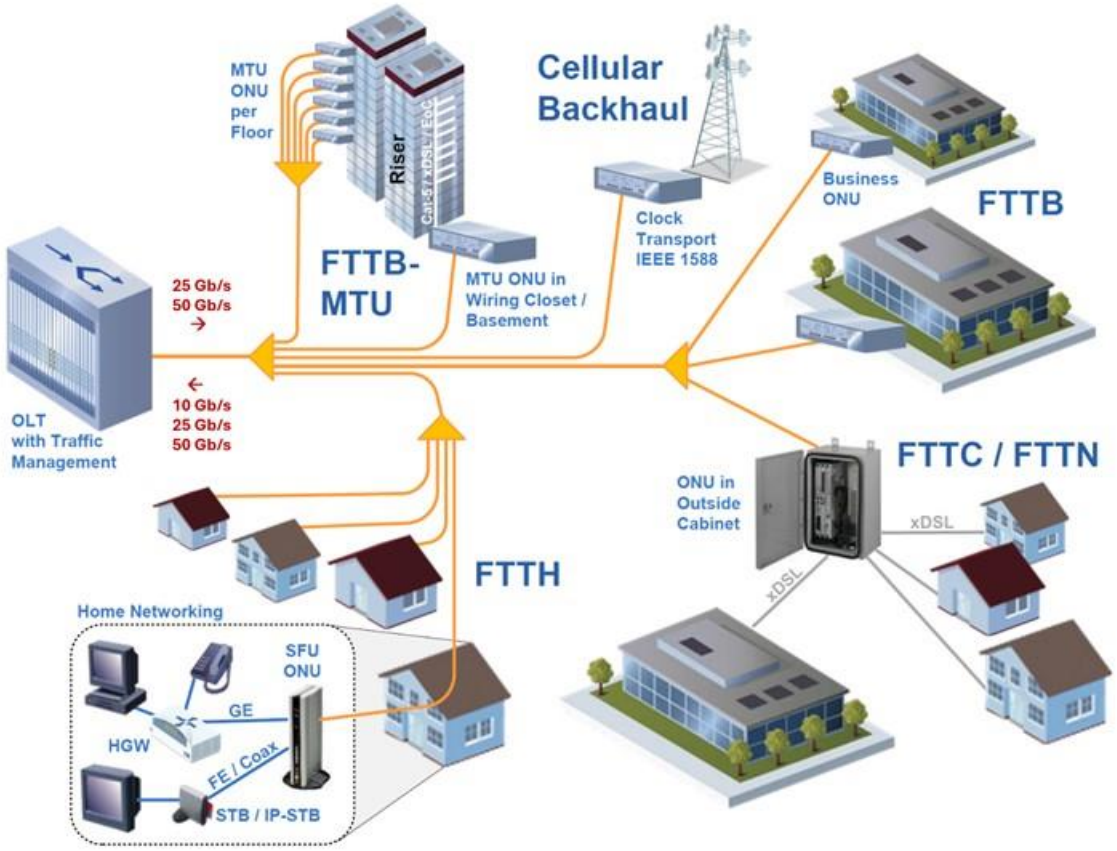
- Single fiber bidirectional (BiDi) access
- Passive outside plant
- Dedicated fiber for each user
- Low loss budget
- High port density at central office

Recent 802.3 Work on Optical Access

Task Force	Project Title	Solution Category	Access Rate	Distance	Approved Standards
P802.3ca	25 Gb/s and 50 Gb/s Ethernet Passive Optical Networks	PtMP PON	25 Gb/s 50 Gb/s	10 km 20 km	IEEE Std 802.3ca-2020
P802.3cp	Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs	PtP BiDi	10 Gb/s 25 Gb/s 50 Gb/s	10 km 20 km 40 km	IEEE Std 802.3cp-2021
P802.3dk	Greater than 50 Gb/s Bidirectional Optical Access PHYs	PtP BiDi	100 Gb/s 200 Gb/s	10 km 20 km 40 km	In progress

P802.3ca

P802.3ca: 25 Gb/s and 50 Gb/s Ethernet Passive Optical Networks



- First international standard specifying PON beyond 10 Gb/s
- It provides a wide range of technical options
  - DS rate (Gb/s): 25, 50
  - US rate (Gb/s): 10, 25, 50
  - Rate combination (DS/US): 25/10, 25/25, 50/10, 50/25, 50/50
  - Loss budget (dB): 24 (medium), 29 (high)
  - Distance (km): 10, 20
  - Split ratio: 1:16, 1:32
  - Wavelength plan: 2 DS wavelengths, 3 US wavelengths
  - Coexistence system: GPON, 10GE-PON
  - Channel bonding: Nx25

"NG-EPON Call for Interest", https://www.ieee802.org/3/cfi/0715_1/CFI_01_0715.pdf

IEEE Std 802.3ca-2020: Key Toolkit for High-Speed PON Design

- Specifications in IEEE Std 802.3ca-2020 have become the foundational toolkit for the development of high-speed PON (HS-PON)
  - Wavelength selection to support coexistence with legacy PON systems
  - Optical interface design to facilitate mass production of low-cost ONUs
  - Multiple wavelength channel bonding to provide Nx25 Gb/s rates
  - Strong FEC encoding to achieve higher gains
  - …

Wavelength plan

Direction	HS-PON Wavelength	Reference in P802.3ca
Downstream	1342 nm	DW1
Upstream	1270 nm 1300 nm	UW0 UW1

Loss budget

HS-PON Class	Loss budget	Reference in P802.3ca
N1	29 dB	PR30

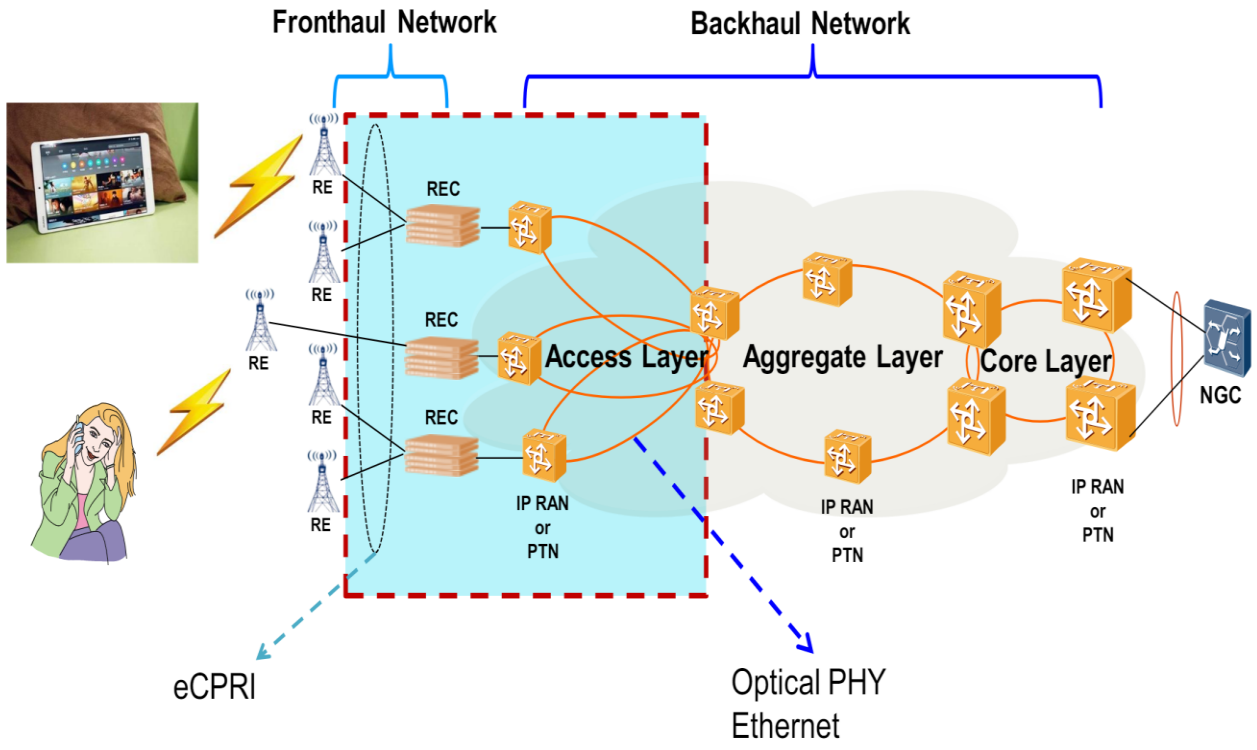
FEC code

Direction	HS-PON FEC code	Reference in P802.3ca
DS	LDPC (17280, 14592)	LDPC (17664, 14592)

US	LDPC (17280, 14592)
	LDPC (15872, 14592)
	LDPC (HM1, HM2)
		LDPC (17664, 14592)

P802.3cp

P802.3cp: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs



- P802.3ah (2004) defined lower rate PtP BiDi PHYs
  - 100BASE-BX10, 100 Mb/s, 10 km, 1550 nm DS, 1310 nm US
  - 1000BASE-BX10, 1 Gb/s, 10 km, 1490 nm DS, 1310 nm US
- A study shows that ~30% of the independent operator market uses PtP optical access solutions. They are mainly for FTTH and FTTBusiness
- 5G boosts using PtP BiDi for wireless fronthaul and backhaul

"Bidirectional 50Gb/s optical access PHYs call for interest", https://www.ieee802.org/3/cfi/0718_2/CFI_02_0718.pdf

IEEE Std 802.3cp-2021: Three Rates, Three Distances

	10 Gb/s	25 Gb/s	50 Gb/s	Max Channel Loss
10 km	10GBASE-BR10 (Ref. 10GBASE-LR)	25GBASE-BR10 (Ref. 25GBASE-LR)	50GBASE-BR10 (Ref. 50GBASE-LR)	6.3 dB
20 km	10GBASE-BR20	25GBASE-BR20	50GBASE-BR20	15 dB
40 km	10GBASE-BR40 (Ref. 10GBASE-ER)	25GBASE-BR40 (Ref. 25GBASE-ER)	50GBASE-BR40 (Ref. 50GBASE-ER)	18 dB

- 5G wireless deployment motivated network operators to implement PtP BiDi for fronthaul and backhaul
  - Typical rates are 10, 25 and 50 Gb/s
  - Desired distances include 10, 20, and 40 km
  - Predictable delay through PtP BiDi links improves time synchronization accuracy
- Previous projects successfully defined 10, 25, and 50 Gb/s signaling for optical PMDs
  - These links can be leveraged to specify 10, 25 and 50 Gb/s PtP BiDi PHYs
- Since 2019, many 802.3cp links have been deployed for 5G fronthaul and backhaul transmission
  - Most of them follow specs of 50GBASE-BR10 and 50GBASE-BR40

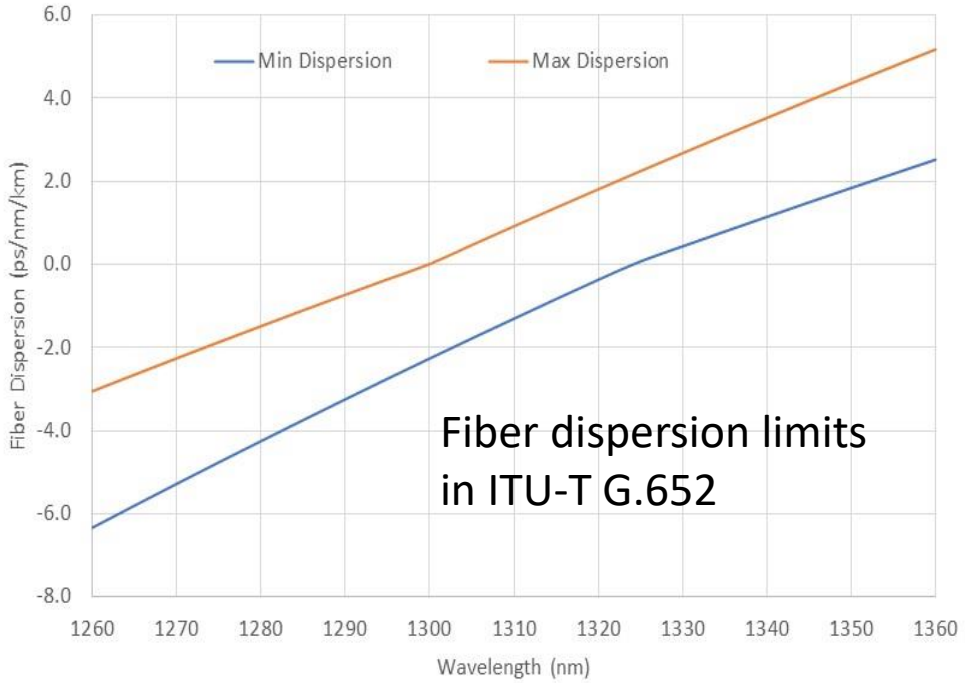
IEEE 802 ITU

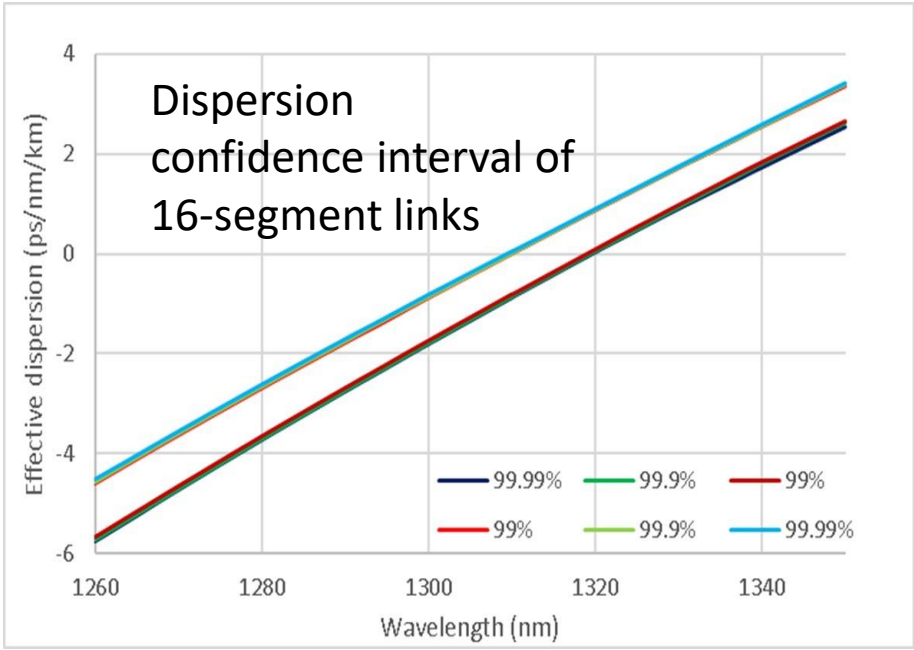
P802.3dk

P802.3dk: Greater than 50 Gb/s Bidirectional Optical Access PHYs

- P802.3dk is an extension of P802.3cp on bidirectional optics for access networks, and aims to standardize speeds higher than 50 Gb/s
  - 100 Gb/s PHYs to reach 10, 20, and 40 km
  - 200 Gb/s PHYs to reach 10, 20, and 40 km
- Task force initial meeting was in January 2023
- Draft has been progressed to D0.4
  - Baselines were selected for 100GBASE-BR10 and BR40
  - Specs of 100GBASE-BR20 and 200GBASE-BRx are under study
- Key issue discussed in the past months:
  - Can we push the limit of G.652 fiber for 100 Gb/s and 40 km using IM-DD?
  - Or is there a dispersion model which gives tighter limits and enough confidence for longer fiber links?

G.652 Fiber and Statistical Link Design





- Fiber dispersion limits in G.652 are described by a Sellmeier equation
- Zero dispersion wavelength (ZDW) varies from 1300 to 1324 nm
- Dispersion Slope (S0) varies from 0.073 to 0.092

- Fiber links are composed of multiple segments
- Each segment has a different random dispersion, and concatenating the segments produces an averaging effect
- Statistical techniques have been shown to give tighter limits on the chromatic dispersion

Conclusions

- PtMP PON and PtP BiDi are leading solutions of broadband access
- After successfully standardizing 10GE-PON and 1GE PtP, IEEE 802.3 WG is actively working on high-speed optical access standards
  - P802.3ca provides a toolkit for PON system design beyond 10 Gb/s
  - P802.3cp offers 9 types of PtP BiDi PHYs to support various 5G xhauls
  - P802.3dk explores the possibility of transmitting 100 Gb/s IM-DD to reach 40 km in access
    - Joint work with SG15 on fiber dispersion and statistical link design provides key answers


IEEE
802


ITU