

IEC-ITU-T Workshop

Standardization Roadmap for Cabled Multi-Core Fibre and Optical Network Sensing Technologies



Trends in Submarine Networks and Expectations for Multi-Core Fiber Deployment

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ASN External use

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Artificial Intelligence (AI) is the main driver for capacity:

- Demand still growing at a significant pace.
- 25 to 33% depending on the routes, **average 26%** (Source Telegeography),
- Doubling every 3 years

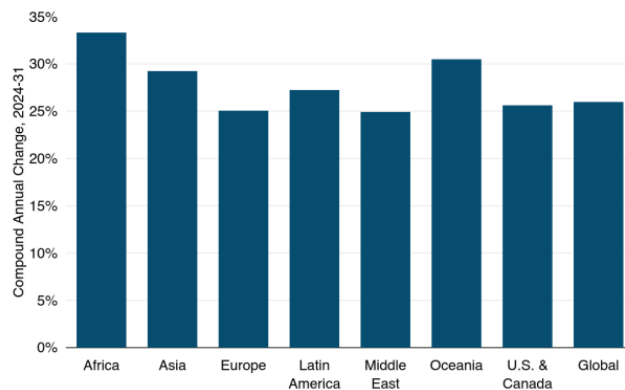
Be prepared for the impact of AI full scale usage

In Submarine systems : several 24 FP / 500 Tbps systems becoming life in 2025

Capacity demand: needs for Petabit cables

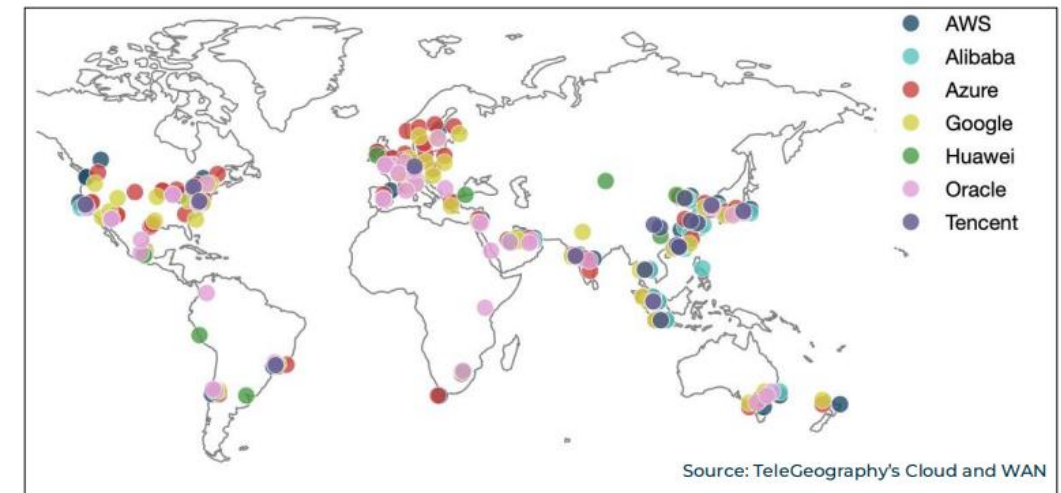
Strong demand growth globally

Used International Bandwidth Growth by Region



- Globally, used international bandwidth is expected to grow at a 26 percent CAGR from 2024-31.
 - This rate of growth implies a doubling roughly every 3 years.
- International links connected to Africa are expected to have the fastest growth, increasing at a 33% CAGR.

Existing and Planned Cloud Data Centers



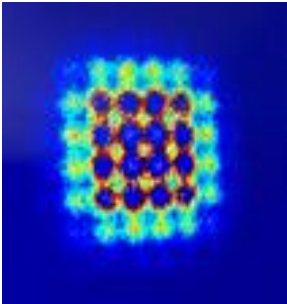
Introduction: increasing Capacity

Shannon's Law for capacity as a function of the bandwidth and SNR

$$C \sim P \times B \times M \times \log_2(1 + \text{SNR})$$

- C – Communication Capacity
- P – Spatial paths per fiber (cores, modes)
- B – Frequency Bandwidth
- M – Number of WDM Channels
- SNR – Signal to Noise Ratio

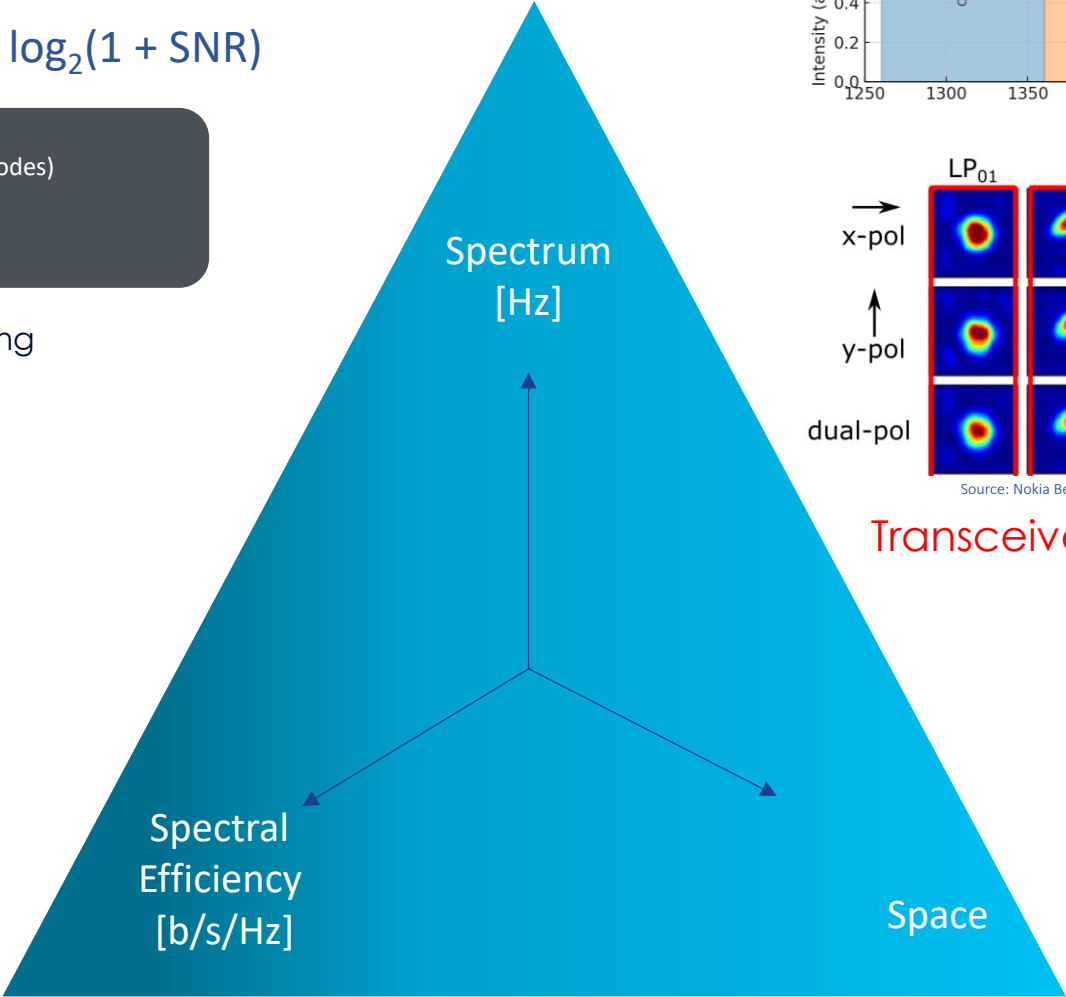
Probabilistic Constellation Shaping



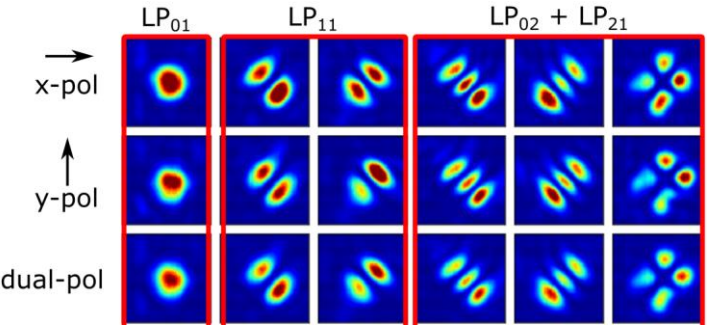
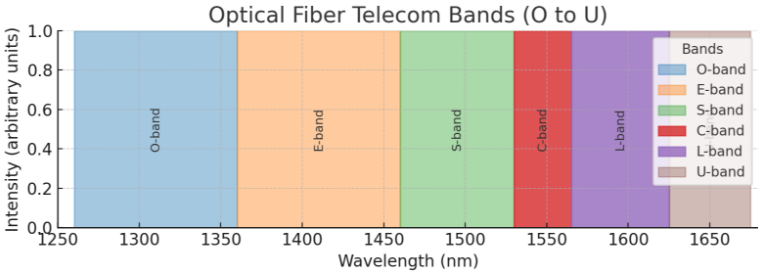
Shannon Limit



Source: Nokia Bell Labs

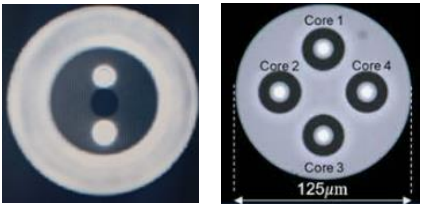


Amplifiers power efficiency



Source: Nokia Bell Labs

Transceiver complexity

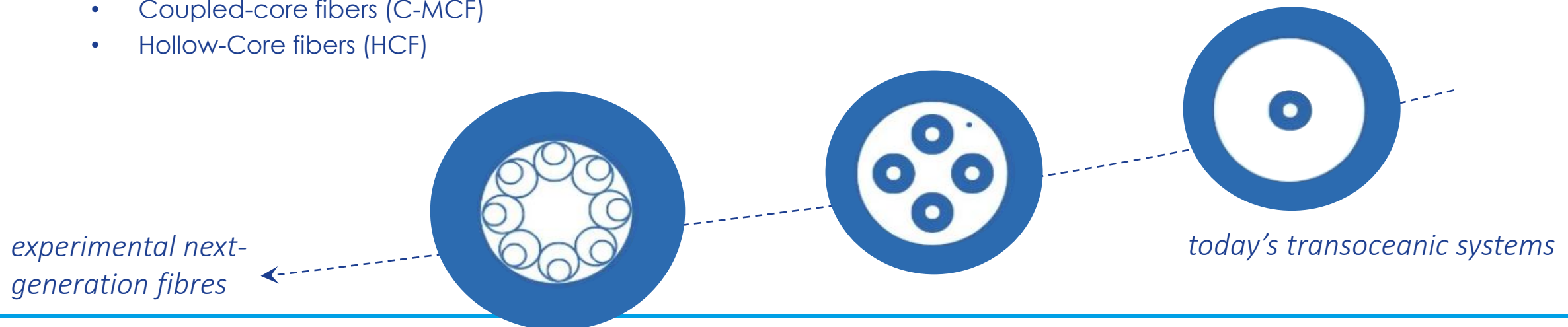


Multi-core fibers

Customer and Industry expectations

A full set of expectations is expressed by **customers** but also **industry players**

- **Limited technical risks**
 - Preference for mature technology
- **Cost per bit should continue its reduction**
 - Higher capacity for a single marine lay operation is automatically reducing cost per bit
 - Disruptive technologies do not mean cost reduction → Costs in our industry are highly driven by volume
- **Limited impacts on operations**
 - Lay and Recovery operations compatible with current fleet, tools and procedures (repairs and splicing)
- **Full compatibility with existing and future transmission gear**
 - Some fiber technology would require a significant redesign of transmission equipment, including submerged repeaters:
 - Coupled-core fibers (C-MCF)
 - Hollow-Core fibers (HCF)



Single-Core Fibres – The legacy and the workhorse

SDM Principle: Capacity increase will be generated by additional bandwidth across the submarine cable

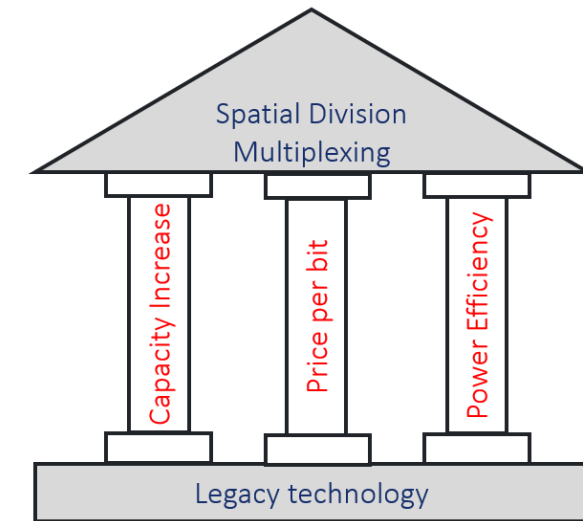
Using SMF, this can be achieved by different means:

- **More fibers inside the cable:**

- ❑ Most mature & widely adopted
- ❑ Stable gain flatness, power efficiency & optimized cost/bit
- ❑ Recent systems 12 – 16 FP keeping conventional cable size¹
- ❑ 200 μm outer-diameter fibers to enable higher FP numbers: 24 FP²
- ❑ Directly aligned with SDM principles

¹Submarine Networks, “ASN Introduces an Innovative Spatial Division Multiplexing Design, SDM1 by ASN,” Industry News, July 2019.

²M. Droques, “24FP cable based on 200 μm fibres: A new Technical Success,” Suboptics 2023

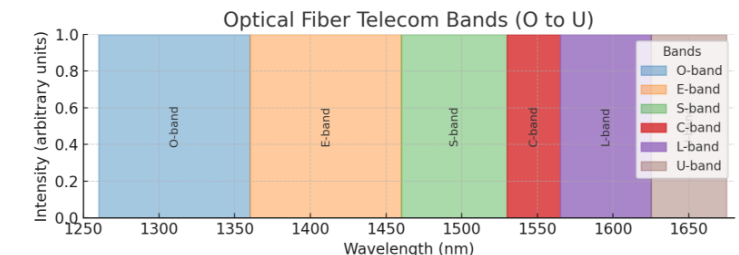


- **More bandwidth inside each fiber:** C+L transmission solution

- ❑ ~2 x usable spectrum – higher capacity per FP³
- ❑ Significant development to bring terrestrial amplifier technology into the submerged plant
- ❑ Power efficiency, Temperature sensitivity, challenging gain flatness implementation
- ❑ No room for more⁴...

³TE SubCom, “70.4 Tb/s transmission record using C+L over 7,600 km,” Ocean News, 2017.

⁴Ronit Sohanpal et al., “Measurement and Analysis of the Power Consumption of Hybrid-Amplified SCL-band Links,” ECOC 2025, paper W.03.05.6



Multi-Core Fibres – The path to high level Spatial Division Multiplexing

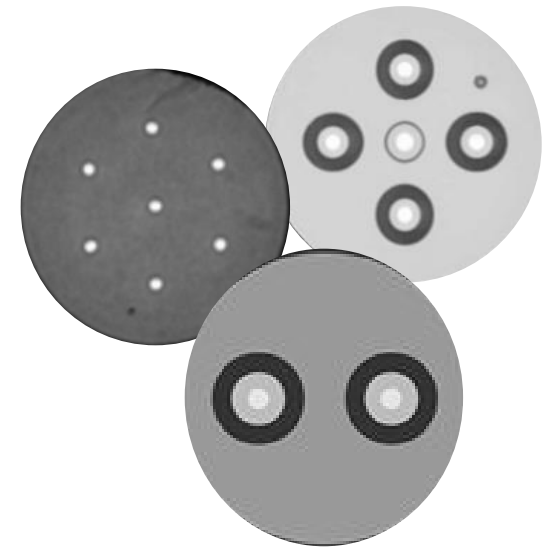
Motivation: single-core fibre capacity is approaching a cable size limitations.

Key aspects for transoceanic transmission:

- ❑ **Low attenuation**
- ❑ **Cladding diameter**: Maintained at 125 μm to ensure full compatibility with existing optical fiber infrastructure.
- ❑ **Core count**: Typically weakly coupled-core 2–4 cores for scalable mass production, with experimental demonstrations up to coupled-core 19 cores¹⁻³.
- ❑ **Inter-core crosstalk management**: Minimization or compensation ?
- ❑ **Fan-In Fan-Out devices or integrated bidirectional MC-EDFA⁴ ?**

➔ Potential drawbacks

- ❑ Innovative technology
- ❑ New components to be integrated in the wet plant
- ❑ Industrial tools to be adapted (splicing machine)
- ❑ Complex gain flatness implementation between cores



¹Sumitomo - 2C Z-PLUS Fiber ULL: "Two-core ultra-low-loss fiber with an attenuation of 0.158 dB/km at 1550 nm and an effective area of 112 μm^2 , within a standard 125 μm cladding."

²G. Rademacher *et al.* "Randomly Coupled 19-Core Multi-Core Fiber with Standard Cladding Diameter," in Optical Fiber Communication Conference (OFC) 2023, Technical Digest Series (Optica Publishing Group, 2023), paper Th4A.4

³Lightera - AllWave FLEX 4X MCF: "A 4-core rollable ribbon fiber designed for terrestrial and data center interconnects, leveraging spatial division multiplexing (SDM) to multiply capacity."

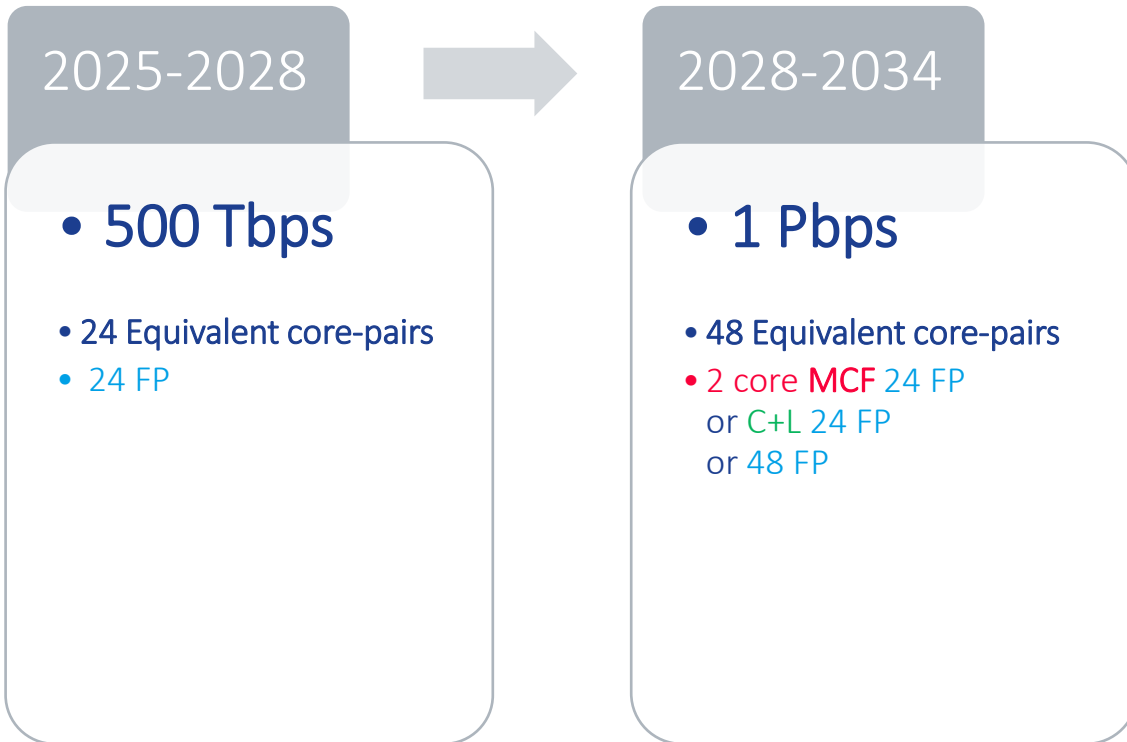
⁴Hitoshi Takeshita *et al.*, "FIFO-less Bidirectional Core-Pumped 4-core MC-EDFA Featuring with Multicore Isolator / Pump Combiner Hybrids," ECOC 2025, paper Tu.01.01.3

Possible trend-line

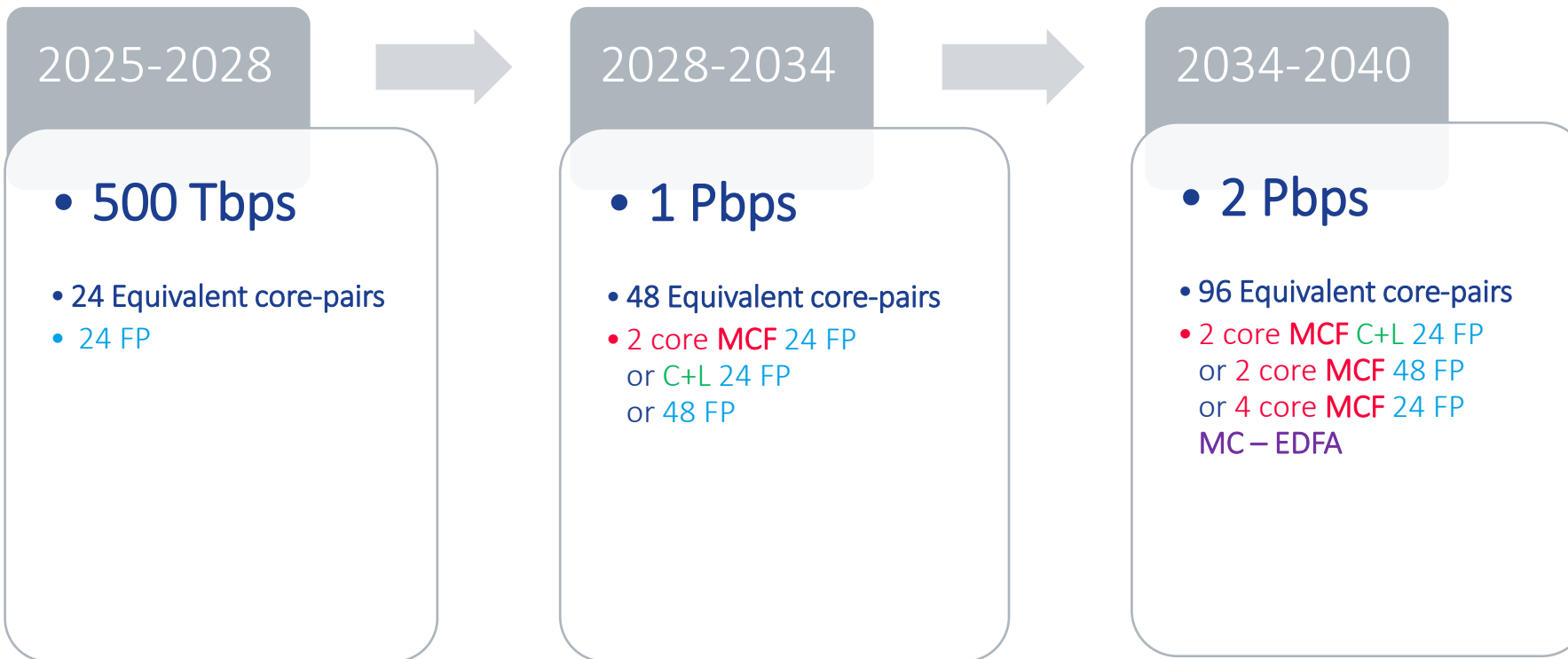
2025-2028

- **500 Tbps**
- 24 Equivalent core-pairs
- 24 FP

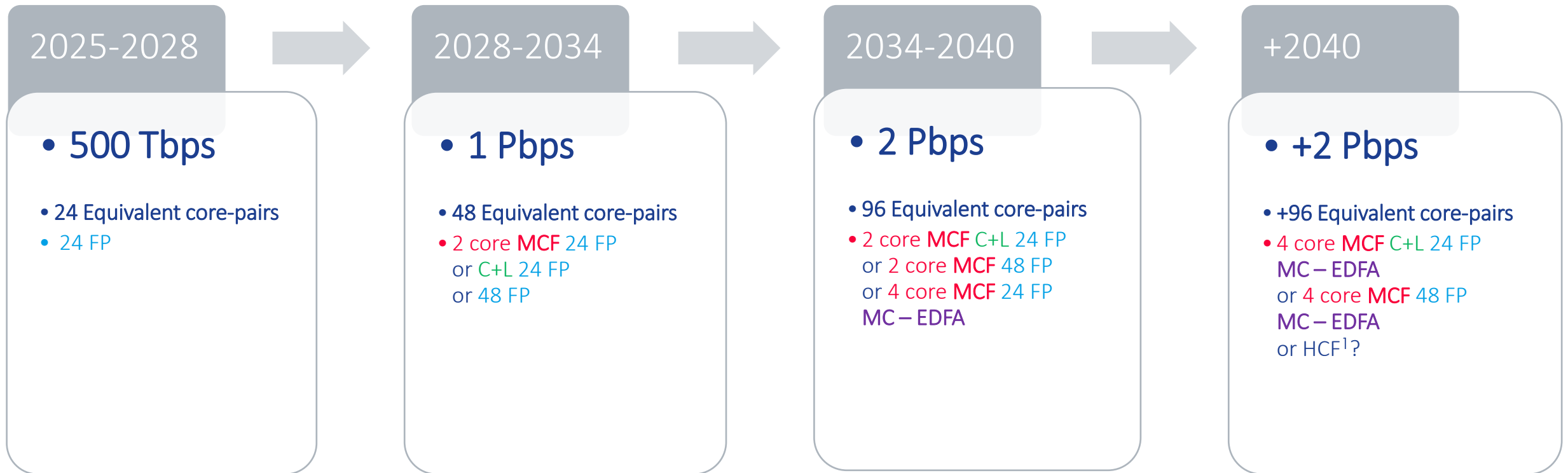
Possible trend-line



Possible trend-line



Possible trend-line



¹ Yingying Wang, “40 km, 0.052 dB/km and 83 km, 0.076 dB/km in Interstitial-Tube-assisted Hollow-Core Fibre,” ECOC 2025, PDP Th.03.01.1

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