2026 ETHERNET ROADMAP

The Past, Present and Future of Ethernet

ethernet alliance

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BASE CAMP ETHERNET —SCALING THE AI ALPS

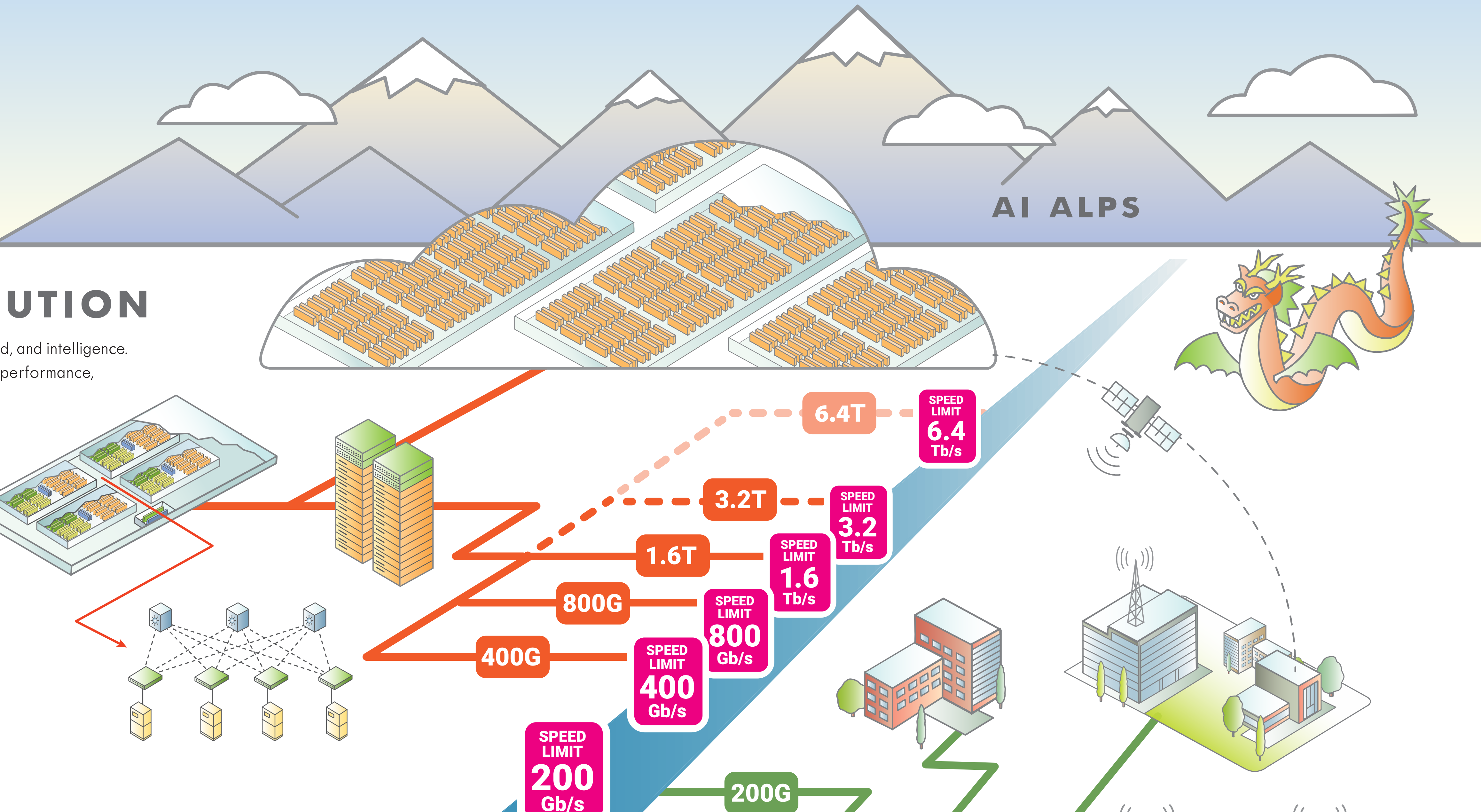
NETWORKS POWERING THE AI REVOLUTION

As AI reshapes the digital landscape, cloud and service provider networks are converging to deliver new levels of scale, speed, and intelligence. Ethernet continues to advance with innovations such as 1.6 Tb/s connectivity and Linear Pluggable Optics (LPO), enabling the performance, efficiency, and reach required to power AI-driven workloads across every domain.

CLOUD PROVIDERS

Cloud providers widely adopted 10G servers in 2010 to support hyperscale data centers. By the 2020s, surge in AI applications required faster connectivity, leading hyperscalers to transition from 25G/lane speeds to 50G, 100G, and beyond. These warehouse-scale data centers utilize a diverse mix of active and passive copper cables, multi-mode and single-mode fiber, and emerging technologies like LPO to support 100G, 200G, 400G, and 800G interconnects. The ongoing challenge is balancing bandwidth growth with power efficiency and cooling innovations to sustain rapid AI-driven scaling.

Over the past decade, the gap between Telco and Cloud provider networking needs has narrowed, particularly with the global expansion of 5G and AI services. Historically, Telcos drove technology advancements to match end-user and equipment demands, while cloud and hyperscale providers prioritized higher density, faster speeds, and energy-efficient interconnects. Today, these sectors are more aligned than ever, fostering greater collaboration to develop and deploy scalable, high-performance networking solutions that meet both enterprise and consumer market needs.

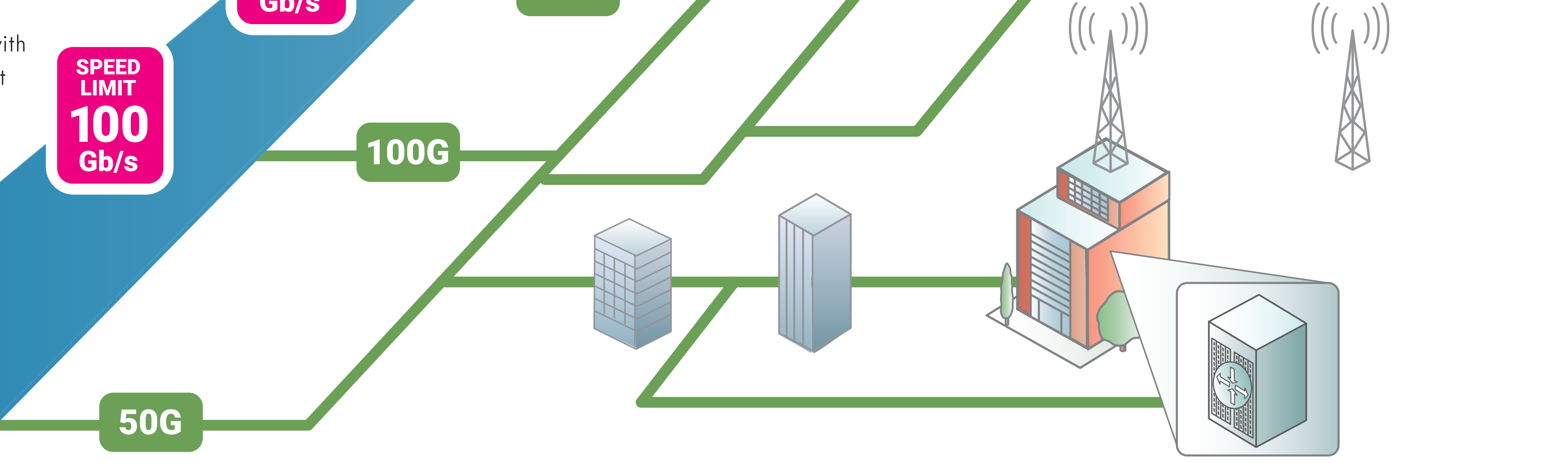


SERVICE PROVIDERS & ENTERPRISE

Service providers have long been at the forefront of high-speed Ethernet innovation, driving advancements in router connections, EPON, optical transport (OTN) client optics, and wired and wireless backhaul. The global rollout of 5G networks—and the growing adoption of AI-powered services—have intensified demand for scalable fronthaul and backhaul solutions, accelerating Ethernet's evolution toward higher speeds and longer distances.

With consumer video and AI-driven applications surging, bandwidth requirements show no signs of slowing. Service provider networks continue to push Ethernet speeds forward, with 1.6 Tb/s on the horizon to meet growing data demands. Synchronous Ethernet (SyncE) has become a cornerstone of 5G network synchronization, and its adoption is expected to expand significantly as Telcos deploy next-generation, AI-enhanced services.

Enterprise and campus networks represent a massive market for Ethernet, with over a billion ports shipping annually. The majority of these ports are BASE-T at the access layer, while multi-mode (MMF) and single-mode fiber (SMF) support higher-speed connections deeper in the network. Evolving Wi-Fi access points, AI-driven analytics, and Enterprise-class client devices are accelerating the transition to higher-speed Ethernet. BASE-T ports are shifting from 1000BASE-T to 2.5G, 5G, and 10G BASE-T, while optical ports are rapidly advancing from 10G/40G to 25G, 100G, and 200G, ensuring greater capacity, efficiency, and future scalability.



INTEROPERABILITY AND CERTIFICATION

The Ethernet Alliance is committed to building industry and end user confidence in Ethernet standards through its multi-vendor interoperability demonstrations and plugfests. Our PoE Certification Program takes this mission to the next level!

Our industry-defined PoE Certification Test Plan is based on the IEEE 802.3 (Ethernet) PoE standards, and products passing this test will be granted the Ethernet Alliance PoE Certification Logo. The trademarked logo provides instant recognition for products based on these standards, and increases multi-vendor interoperability between products bearing it. The logos indicate the power class and product type providing clear guidance on which devices will work with each other.

The first generation of the program (Gen 1) certifies Type 1 and Type 2 products that use 2-Pair wiring (PoE 1). The second generation of the program (Gen 2) certifies Type 3 and Type 4 products using 2-Pair and 4-Pair wiring (PoE 2). See table below for details:

PoE Types and Classes	PoE 1 2-Pair PoE – Type 1 / Type 2				PoE 1 2-Pair PoE – Type 2	PoE 2 4-Pair PoE			
Class	0	1	2	3	4	5	6	7	8
PSE Power (W)	15.4	4	7	15.4	30	45	60	75	90
PD Power (W)	13	3.84	6.49	13	25.5	40	51	62	71.3
		PoE 2 4-Pair PoE – Type 3						PoE 2 4-Pair PoE Type 4	

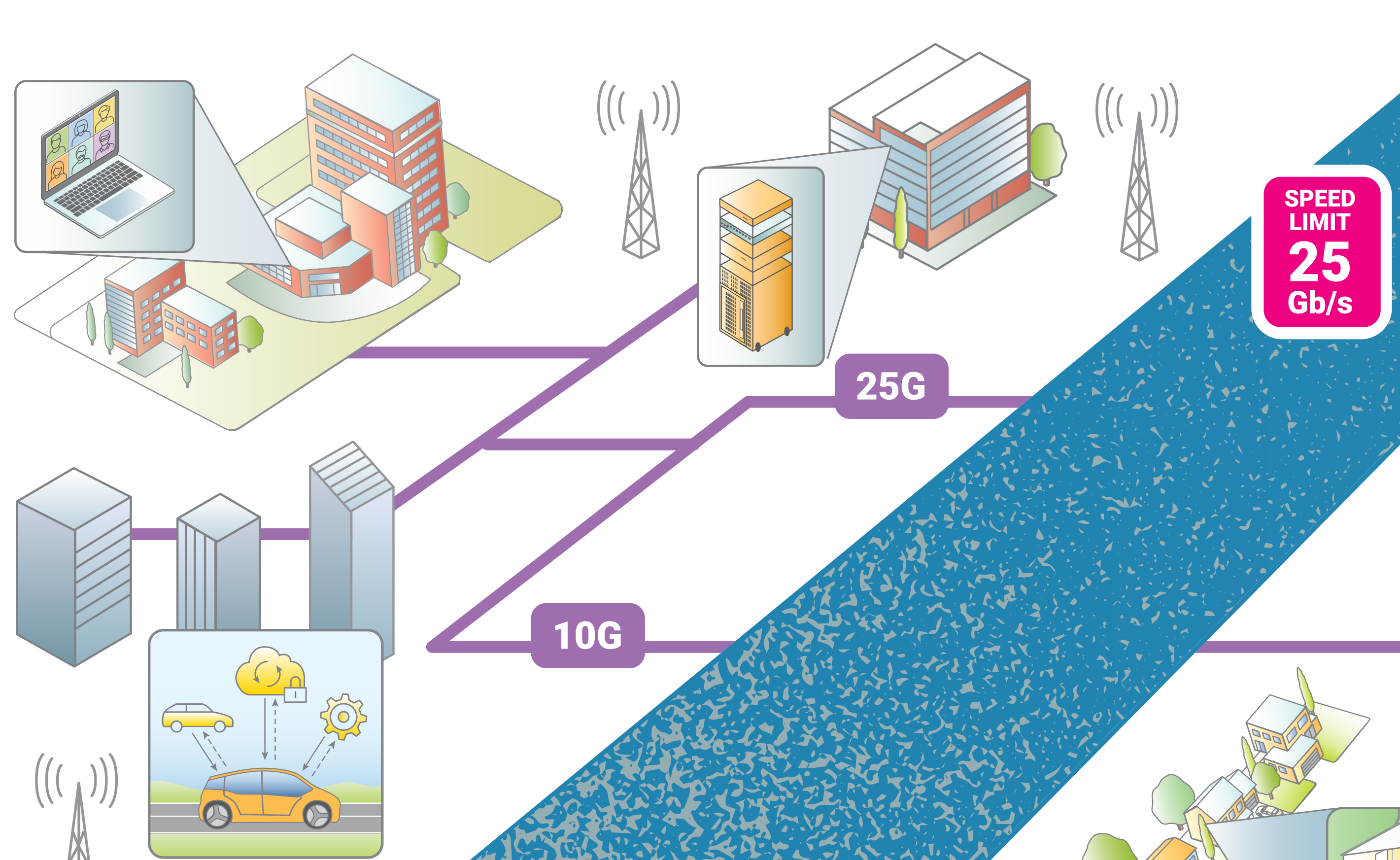
EA Certified™   EA Certified 2.0™

https://ethernetalliance.org/poecert/

AUTOMOTIVE, WI-FI, ENTERPRISE & 5G

The **Automotive** industry is embracing Ethernet as the backbone of next-generation vehicle connectivity. Single-Pair Ethernet (SPE) enables cost-effective, scalable in-vehicle networking, supporting ADAS, autonomous vehicles, and infotainment while accelerating the convergence of legacy IVN technologies. A major shift to zonal architectures is reducing vehicle weight and complexity, while Time-Sensitive Networking (TSN) ensures deterministic, real-time communication for safety-critical applications. With software-defined vehicles (SDVs) on the rise and the rapid growth of the automotive Ethernet market, demand is surging for high-speed, low-latency networking. These advancements position Ethernet as the foundation for intelligent, connected transportation, delivering the performance, reliability, and scalability needed for the future of mobility.

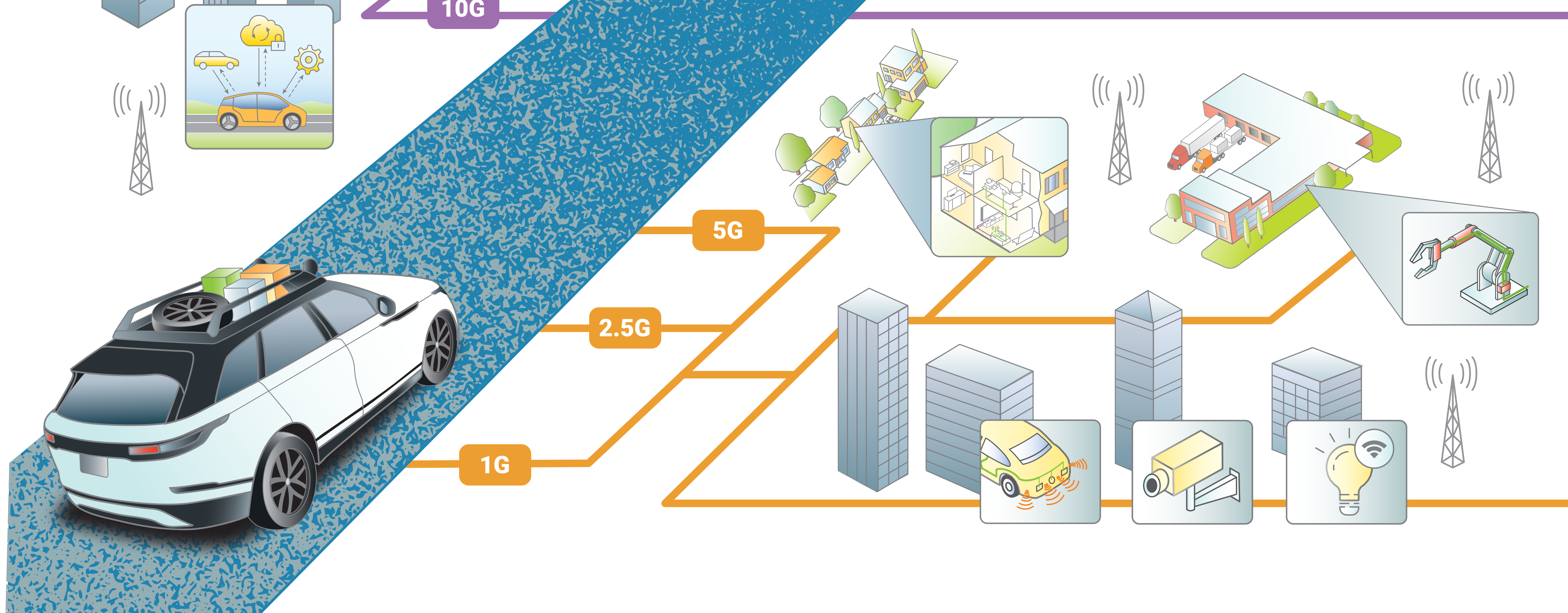
As **Wi-Fi 7** (802.11be) rolls out, and with Wi-Fi 8 (802.11bn) on the way, Ethernet remains the backbone ensuring high-speed, low-latency connectivity for next-gen wireless networks. With multi-link operation (MLO), 320 MHz channels, and 4096-QAM, Wi-Fi 7 delivers faster speeds and improved efficiency, but reliable wired backhaul is essential to unlock its full potential. Ethernet's role in powering dense enterprise, industrial, and home networks continues to expand, supporting higher-speed and higher-power access points (APs), lower latency, and seamless integration with 5G and fiber networks. Increasing numbers of APs are using 2.5G/5G/10GBASE-T links for higher throughput, and the increased power available with 802.3bt PoE to support additional functions such as built-in GNSS/GPS, band steering and application hosting. The synergy between Wi-Fi and Ethernet is critical for enabling scalable, high-performance hybrid networks for the future



AUTOMATION, 5G, AUTOMOTIVE & ENTERPRISE

The convergence of Ethernet, Wi-Fi, 5G, and automation is transforming industrial and building networks. The flexibility of **Wi-Fi 7** and **5G** combined with Ethernet's delivery of power and data enables real-time, deterministic communication, crucial for Industrial IoT (IIoT) and smart automation. This synergy enhances network efficiency, scalability, and automation, paving the way for Industry 4.0 innovations.

Industrial and building automation applications are rapidly shifting from legacy fieldbus networks to Ethernet, accelerating the adoption of Interconnection, Information Transparency, Technical Assistance, and Decentralized Decisions—the core themes of Industry 4.0. Ethernet unlocks decades of IT networking advancements while delivering ruggedized physical layers including the growing family of the single pair BASE-T1 PHYs, designed for harsh operational environments. Additionally, Time-Sensitive Networking (TSN) is revolutionizing real-time automation by providing the services (e.g., time distribution, controlled latency) needed for modern industrial applications



ARTIFICIAL INTELLIGENCE/MACHINE LEARNING (AI/ML)

Artificial Intelligence and Machine Learning (ML) are driving the roadmap extending Ethernet speeds to 3.2T and beyond.

Ethernet for AI

The interconnect architecture within AI-driven data centers is rapidly evolving, incorporating advanced copper and fiber solutions to meet AI's soaring bandwidth demands while also reducing environmental impacts. Ethernet's progression towards higher speed interfaces, the widening variety of interconnect options, and advancements in power efficiency are ensuring that Ethernet can meet the needs of AI/ML workloads.

Ethernet has become the de facto standard for scale-out AI networking and is rapidly becoming the technology of choice for scale-up as well. It offers high bandwidth, low latency, and energy efficiency, all of which are needed to interconnect XPU clusters of up to, and beyond hundreds of thousands of XPUs in AI training and inference clusters.

Various international industry consortia are adopting Ethernet to support scale-out and scale-up networks for AI/ML. Of note are the Ultra Ethernet Consortium (UEC) Specification 1.0 defining a new network stack for AI, and the Ultra Accelerator Link (UALink) 1.0 Specification, which adopts the Ethernet PHY. Also, the Open Compute Project has launched the Ethernet Scale-Up Networking (ESUN) and Scale-Up Ethernet Transport SUE-T projects. ESUN is developing specifications for L2/L3 framing, header efficiency, lossless networking, and error recovery, while SUE-T is focusing on transport solutions. These and other advancements reinforce Ethernet as the foundation for end-to-end AI networking.

LATEST INTERFACES AND NOMENCLATURE

	Backplane	Twinax Cable	15-40m(OT) Single Twisted Pair	>100m (OT) Single Twisted Pair	100m (IT) Twisted Pair (2/4 Pair)	MMF	500m SMF	2km SMF	10km SMF	20km SMF	30 km SMF	40km SMF	80km SMF	Electrical Interface	Pluggable Module
10BASE–	T1S		T1S	T1L	T										
100BASE–			T1	T1L	T										
1000BASE–			T1		T										SFP
2.5GBASE–	KX		T1		T										SFP
5GBASE–	KR		T1		T										SFP
10GBASE–			T1		T	SR			LR BR10-D/U	BR20-D/U		ER BR40-D/U			SFP
25GBASE–	KR1 KR	CR1 CR/CR-S	T1		T (30m)	SR			LR EPON BR10-D/U	EPON BR20-D/U		ER BR40-D/U		25GAUI	SFP
40GBASE–	KR4	CR4			T (30m)	SR4/eSR4	PSM4	FR	LR4			ER4		XLAUI XLPPI	QSFP
50GBASE–	KR2 KR	CR2 CR				SR		FR	LR EPON BR10-D/U	EPON BR20-D/U		ER BR40-D/U		LAUI-2/50GAUI-2 50GAUI-1	SFP/QSFP
100GBASE–	KR4 KR2 KR1	CR10 CR4 CR2 CR1				SR10 SR4 SR2 VR1/SR1	PSM4 DR	CWDM4 FR1	LR4/4WDM-10 LR1	4WDM-20 LR1-20	ER1-30	ER4/4WDM-40 ER1-40	ZR	CAUI-10/CPPI CAUI-4/100GAUI-4 100GAUI-2 100GAUI-1-S/L	SFP/SFP-DD QSFP/QSFP-DD OSFP
						VR1/SR1	DR	FR1						EEI-100G-RTLR-1-S/L	
100G–							DR1-LPO							LEI-100G-PAM4-1	
200GBASE–	KR4 KR2 KR1	CR4 CR2 CR1				SR4 VR2/SR2	DR4 DR1	FR4 DR1-2	LR4			ER4		200GAUI-4 200GAUI-2-S/L 200GAUI-1	QSFP/QSFP-DD SFP-DD
						VR2/SR2								EEI-200G-RTLR-2-S/L	
200G–							DR2-LPO							LEI-200G-PAM4-2	
400GBASE–	KR4 KR2	CR4 CR2				SR16 SR8/SR4.2 VR4/SR4	DR4 DR2	FR8 FR4 DR4-2 DR2-2	LR8 LR4-6/LR4-10		ER4-30	ER8	400ZR	400GAUI-16 400GAUI-8 400GAUI-4-S/L 400GAUI-2	QSFP/QSFP-DD OSFP
						VR4/SR4	DR4	DR4-2 FR4						EEI-400G-RTLR-4-S/L	
400G–							DR4-LPO FR4-LPO							LEI-400G-PAM4-4	
800GBASE–	ETC-KR8/KR8 KR4	ETC-CR8/CR8 CR4				VR8/SR8 VR4.2/SR4.2	FR4-500 DR8 DR4	FR4 DR8-2 DR4-2	LR4 LR1	ER1-20		ER1	800ZR-A 800ZR-B 800ZR-C	800GAUI-8-S/L 800GAUI-4	QSFP-DD OSFP/OSFP-XD
						VR8/SR8	DR8	DR8-2						EEI-800G-RTLR-8-S/L	
800G–							DR8-LPO							LEI-800G-PAM4-8	
1.6TBASE–	KR8	CR8				VR8.2/ SR8.2	DR8	DR8-2						1.6TAUI-16-S/L 1.6TAUI-8	QSFP-DD OSFP/OSFP-XD

Gray Text = IEEE Standard Red Text = In Task Force Green Text = In Study Group Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces

Orange Text = LPO MSA specification in early stages of standardization, not compliant with IEEE electrical interfaces

Dark Blue Text = OIF specifications, a new electrical interface, an alternative to IEEE 802.3 AUI for 500m and 2km PMDs, providing interoperability over fiber.

Warning! The Ethernet landscape is evolving rapidly – technologies listed here are subject to change.

ENERGY EFFICIENCY IN THE AI WORLD

- Blackstone estimates a **40% increase in electricity demand** in the United States over the next decade.[1]
- Gartner estimates the power required for data centers to run incremental AI-optimized servers will reach 500 terawatt-hours (TWh) per year in 2027, which is **2.6 times the level in 2023.**[2]
- The largest data center market globally is in northern Virginia, and the local utility, Dominion Energy, expects **power demand to grow by about 85% over the next 15 years,** with data center demand quadrupling.[3]
- SemiAnalysis forecasts Global Data Center Critical IT power demand will surge from 49 Gigawatts (GW) in 2023 to 96 GW by 2026, of which **AI will consume ~40 GW.**[4]
- Goldman Sachs forecasts **global power demand** from data centers **will increase 50% by 2027** and by as much as **165% by end of the decade** (vs 2023).[5]

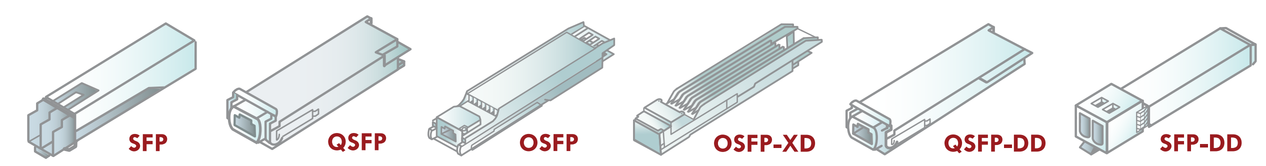
Provision of energy to, and removing heat from, AI data centers is becoming a controlling limit. Data centers will account for about ~2% global electricity use in 2025 and their power usage is expected to double to more than 1,000 TWh by 2030 driven by GenAI.[3]

Ethernet is not the biggest power consumer in the data center, but it is material. Any watt used on the network is a watt not used on the main workload. It's expected that the Ethernet Industry will keep driving down the picojoules per bit with new technologies.

New PHY technologies, copper and optical interconnect advancements, and intelligent workload-aware traffic management are helping optimize energy use. Additionally, collaboration with AI-driven power management is emerging to further reduce energy waste. As Ethernet scales to 1.6T and beyond, balancing performance and energy footprint will be critical in supporting this global technology evolution.

1 "Blackstone (BX) Q2 2024 Earnings Call Transcript." The Motley Fool. July 18, 2024.
2 "Gartner Predicts Power Shortages Will Restrict 40% of AI Data Centers By 2027." Gartner. Nov 12, 2024.
3 "As GenAI Asks for More Power, Data Centers Seek More Reliable, Cleaner Energy Solutions." Deloitte. Nov 19, 2024.
4 "AI Data Center Energy Dilemma - Race for AI Data Center Space." SemiAnalysis. Mar 13, 2024.
5 "AI To Drive 165% Increase In Data Center Power Demand by 2030." Goldman Sachs. Feb 2025.

INTERCONNECT TECHNOLOGIES



PLUGGABLE MODULES

Linear Pluggable Optics (LPO) and Linear Receive Optics (LRO)

The current high-speed optical market is dominated by retimed optics, but there is rapidly growing interest in linear-based solutions for optical modules which dramatically reduce the module power consumption. Linear Pluggable Optics (LPO) and Linear Receive Optics (LRO) are emerging techniques which remove all/some of the retiming circuitry found in traditional optics.

These implementations utilize common pluggable form factors of QSFP, QSFP-DD, and OSFP and are primarily targeted at 400GbE and higher markets. A fully linear optical module can operate at around half of the power of a similar retimed device. LRO is a half-retimed solution which achieves some of the power reduction while providing a higher quality transmitted optical signal.

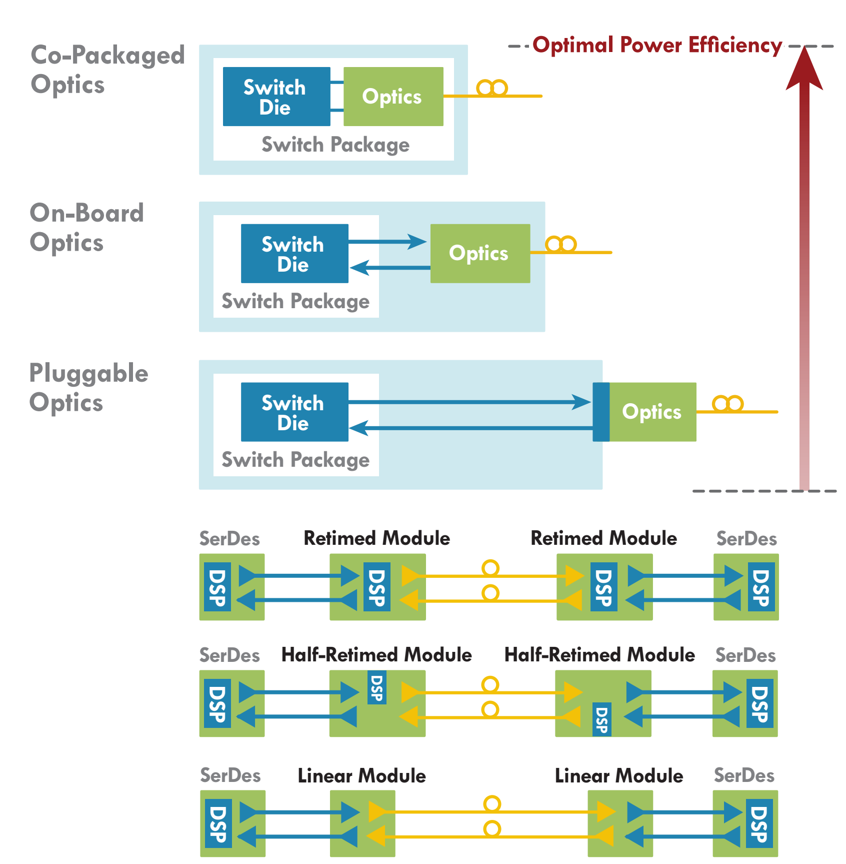
CABLE TECHNOLOGIES

Active Electrical Cable (AEC) – Integrated retimer electronics for signal enhancement
Active Copper Cable (ACC) – Integrated redriver electronics for signal boosting
Active Optical Cable (AOC) – Integrated optical transceivers for low-power, high-speed connectivity

Both AECs and ACCs are active cables providing data transmission over copper cables in applications where standard direct attach cable lengths are insufficient. ACCs provide basic signal boosting for increased cable reach in cost-sensitive applications, whereas AECs offer enhanced signal regeneration capabilities suitable for even longer distances.

AOCs integrate fiber optics and embedded transceivers, providing high-bandwidth, low-latency, and low-power connectivity for short- to mediu m-range interconnects in high-speed Ethernet applications.

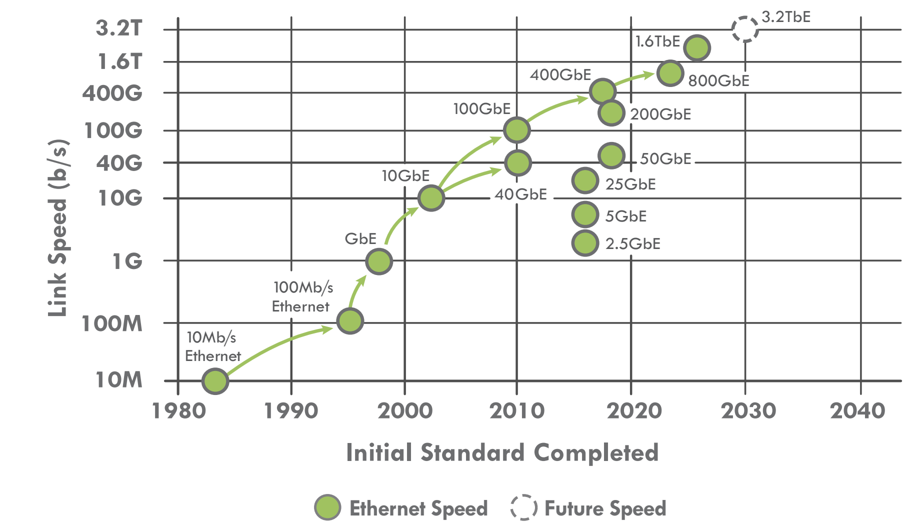
OPTICAL EVOLUTION



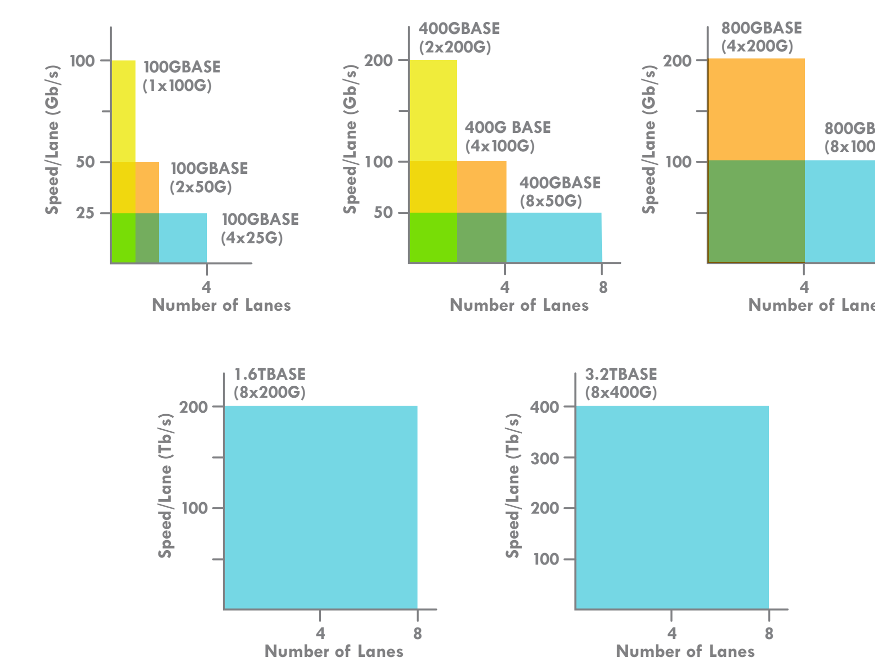
The ever-increasing demand for power efficiency in data centers is driving the transition to new levels of system and optics integration, such as **Co-Packaged Optics (CPO)**, **Co-Packaged Copper (CPC)**, and **LPO/LRO**. As data centers deploy higher and higher link speeds, the power consumption of SERDES links and the optical modules increase significantly. The need for reduced-power optical solutions is fueling innovation and creativity in this market.

To meet diverse deployment needs, **retimed, half-retimed, and linear optical modules** each offer varying levels of signal processing and power efficiency to optimize performance across different network architectures.

ETHERNET SPEEDS



FATTER PIPES

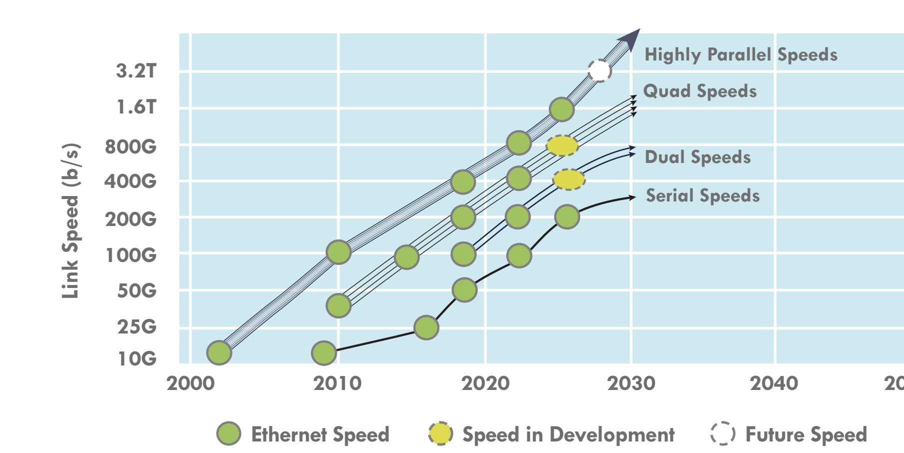


Total throughput (data rate) may be achieved in three general ways:

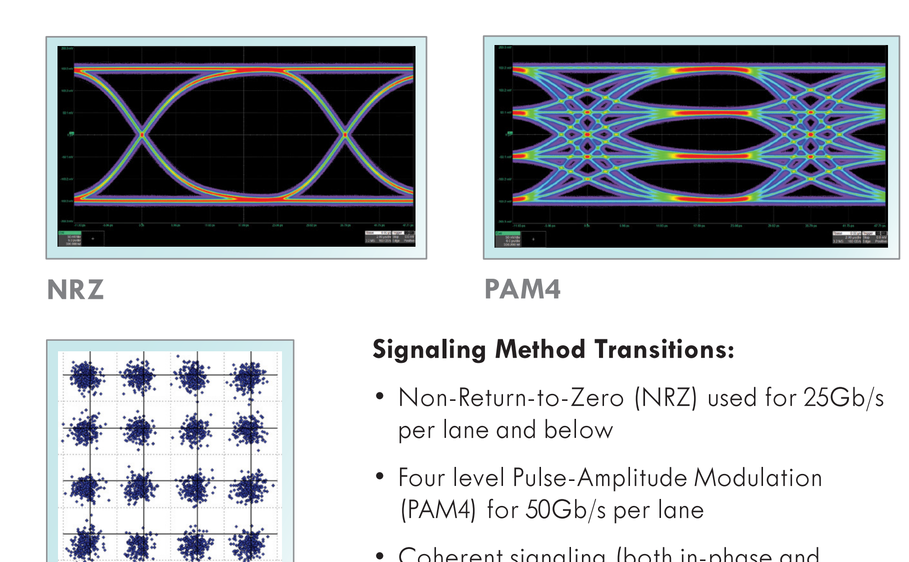
1 **Aggregating multiple lanes** 2 **Increasing the per lane bit rate**
3 **Increasing the bits transferred per sample (Baud)**

This chart shows how multiple lanes can be used to generate similar speeds. The per lane speed times the number of lanes determines the total link speed.

PATH TO SINGLE LANE



SIGNALING METHODS



NRZ

PAM4

Coherent

Signaling Method Transitions:

- Non-Return-to-Zero (NRZ) used for 25Gb/s per lane and below
- Four level Pulse-Amplitude Modulation (PAM4) for 50Gb/s per lane
- Coherent signaling (both in-phase and quadrature modulation) for 100Gb/s per lane and above.