



ADDRESSING THE NEXT RATE CHALLENGES: 448GBPS SIGNALING FOR AI

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OIF 448Gbps Signaling for AI Workshop April 15-16, 2025

MISSION

What's our role in this grand scheme? Well, the Ethernet Alliance has a clear mission:

Promote the awareness, adoption, and advancement 01 of existing and emerging Ethernet technologies.

02 Educate Ethernet technology consumers using a unified, vendor-neutral voice.

03 Drive Ethernet's multi-vendor interoperability through validation, demonstration, certification, and events.

Expand the market by making Ethernet technologies 04 easier to adopt.





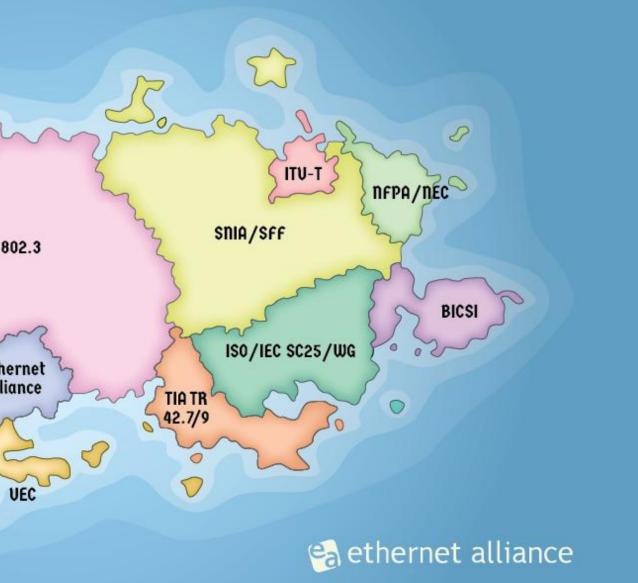
ETHERNET WORLD

We bring together the diverse nations of "Ethernet World" – uniting stakeholders, enabling cooperation, and guiding efforts to define problems and solutions.









ethernet alliance PUBLECE PRIVATE AMDA INTEROPERABILITY TESTING OFC, ECOC, PLUGFESTS

The Ethernet Alliance works with its members to:

- Ensure "It just works" (in the form of plugfests)
- Prove "It just works" (demos at OFC)
- Explain "It just works" through blogs, webinars, and more.



Interoperability Certification

The Ethernet Alliance Power over Ethernet (PoE) Certification Program débuted in 2017 to ensure seamless interoperability by taking the guesswork out of the PoE equation.

Define and Address Installation Challenges

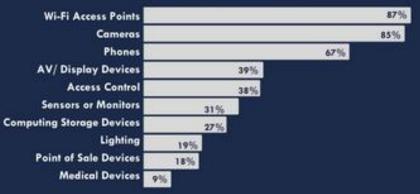
Simplify Integration

Ensures Reliable and Predictable Operation

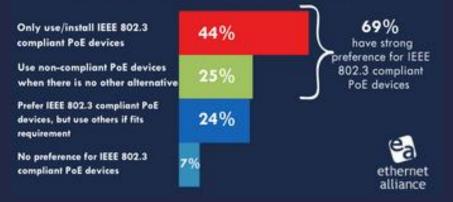
2024 Ethernet Alliance Power Over Ethernet (PoE) Survey Conducted by the Ethernet Alliance on the state of the PoE market 33% plan to instal



Top Devices Installed

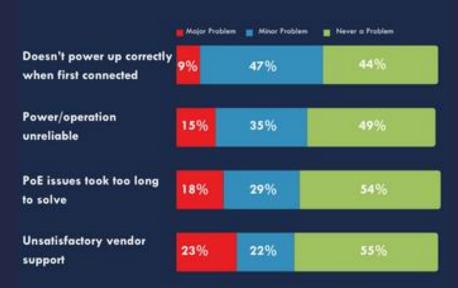


Strong Preference for IEEE 802.3





PoE Device Installation Challenges



Ethernet Alliance PoE Certification Program



The Value of PoE Certification



Learn more at ethernetalliance.org/poecert

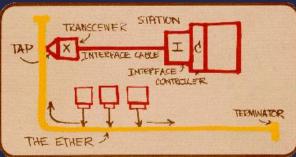
Technology and Partners

The Ethernet Alliance is "the" central voice for all things Ethernet.



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HERNET WORKING GROUP











ROADMAP



BACK TO THE FUTURE OF ETHERNET EST. 1973

CLOUD PROVIDERS

Clevel previders widely adapted 10G servers in 2010 to support hyperscale data centers. By the 2005, the growing demand for AI and Machine Learning applications required laste connectivity, leading hyperscalars to transition from 25G, fane speeds to 50G, 100G, and beyond. These warehouse-scale data centers utilize a diverse mix of active and possive coop obles, multi-mode and single-mode fiber, and emerging technologies like Eneor Phygoble Optics (JPO) to support 100G, 200G, 400G, and 800G interconnects. The challenge remains boloncing bandwidth growth with power efficiency and cooling innovations to sustain rapid scaling.

Over the past decade, the gap between Telco and Claud provider networking needs has narrowed, particularly with th global expansion of 5G services. Historically, teloos drave technology advancements to match and user and equipment demands, while cloud and hypersocia providers prioritized higher density, faster speeds, and energy efficient interco Taday, the two sectors are more aligned than ever, fastering preater collaboration to develop and deploy scalable. high performance retworking solutions that neet both enterprise and consumer earlief needs.

SERVICE PROVIDERS & ENTERPRISE

ders have long been at the forwhant of high speed Ethernet innovation, driving advancements in router connections, LPON, optical transport (OTN) client optics, and wired and wireless backhout. The global railour of 50 networks has intensified denand for fronthaul and backhoul solutions, accelerating Etherset's evolution toward Nigher speeds and longer distances.

Ethernet speeds forward, with 1.6 Tals on the horizon to neer prowing data demands. Synchronous Ethernet (SyncE) has become a

consistors of SG retwork synchronization, and its adoption is expected to expand significantly in the coming years as Telcos deploy sevil generation services.

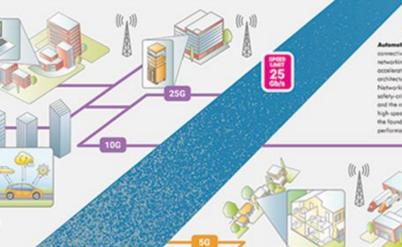
Enterprise and compuse networks represent a newsive morket for Ethernet, with over a billion point shipping annually. The najority of these point are BASE-T or the access layer, while multi-mode (RWM) and single-mode (Ser (SAM) support higher speed corrections deeper in the network, Evolving Wi-R access points and Enterprise-class client With consumer video consumption surging, bandwidth requirements show no signs of slowing. Service provider retworks continue to push are skilling from 10008ASE. T to 2.5G, SG, and 100 BASE. T, while optical ports are repidly edvancing from 10G/40G to 25G, 100G, and 200G.



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ensuring greater capacity, efficiency, and future scalability



AUTOMOTIVE, WI-FI, ENTERPRISE & 5G

domative industry is enbracing Ethernet as the backbone of next gen vehicle connectivity. Single-Poir Ethermet (SPE) enobles cost effective, scoluble in vehicle networking supporting ADAS, autonomous vehicles, and infortainment while accelerating the convergence of legocy NN technologies. A najor shift to zonal orchitectures is reducing vehicle weight and complexity, while Time-Sensitive Natworking (TSN) anaures dataministic, real-time communication for solary critical applications. With software-defined vehicles (SDN), on the rise and the rapid growth of the automotive Etherset earlies, deeped is surging for high speed, low-latency setworking. These advancements position Othernet as the foundation for intelligent, connected transportation, delivering the performance, reliability, and scalability needed for the future of mobility

 $(((_{1})))$

A: Wi-FL7 (X2) Tool rols out, Ethernet rengins the bookbone ensuring Nich-speed, low latency connectivity for next-pay wireless networks. With multi-link operation (MLO), 320 MPIz channels, and 40%-GAM, WI-FI 7 delivers forter speeds and improved efficiency, but reliable wheel heribbad is essential to coloris its full activitial. Ethernet's raise in powering dense enterprise, industrial, and home networks continues to expond, supporting higher-speed occess points (ANJ, lower latency, and seamless integration with 5G and fiber retworks. The synargy between WI-Fi and Etherner's critical for enabling scalable. high-performance hubrid networks for the future.

AI ALPS

AUTOMATION, 5G, **AUTOMOTIVE & ENTERPRISE**

The convergence of Dhernet, SG, and outomation is transforming industrial and building retworks (SG's wireless flexibility combined with Diherren's reliability endbles real-time, deterministic communication, crucial for industrial fait (ItaT) and snart automation. This synergy enhances renvork efficiency, scalability, and outomotion, powing the way for industry 4.0 innovations.

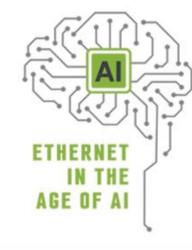
Industrial and building outamation applications are repidly shifting from legac faildbus retworks to Ethernet, occalerating the adoption of interconnection, Information Transportancy, Technical Assistance, and Decentralized Decisions---the ore thenes of Industry 4.0. Ethernet unlocks decodes of IT netwo advancements while delivering ruggedized physical layers like IOBASE-TIL. designed for hand operational environments, Additionally, Time Sensitive Networking (15N) is revolutionizing real time outpraction, bringing Bitement back to its roots with 10,100 MB.'s speeds and shared media, now enhanced for modern

LATEST INTERFACES AND NOMENCLATURE

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ARTIFICIAL INTELLIGENCE/MACHINE LEARNING (AI/ML)



beyond 400G Ethernet speeds to support the training and inference of large language models (SIMU, All and Machine earning (MC) are driving the roadhap extending Etherner speeds to 1.61 and beyond. The architecture within Al-driven data centers is evolving, leveraging a blend of copper and fiber solutions to meet Al's scoring bondwidth demands. Ethernen's progression howards higher speed interfaces, the widening variety of interconnect options, and advancements in power efficiency are ensuring that Internet con meet the needs of ALML

To address these demands, the Ultra Ethernet Consortium (UEC) is moducing the Uhra Ethemet standard, an gen, intercoerable, high-performance chitecture tailored for Al. Supported by industry leaders across switch, retworking semiconductor. and system providers, as well as hyperscalers, Uhra Ethernet is designed to scale out Al Infrastructures efficiently.

2025 ETHERNET ROADMAP OIF 448Gbps Signaling for AI Workshop April 15-16, 2025



INTERCONNECT TECHNOLOGIES

yn Vosn Vosn Vosnas Vosnas Vina PLUGGABLE MODULES

Linear Pluggable Optics (LPO) and Linear Receive Optics (LRO) The current high speed optical earliest is dowinated by referred patients, but there is regarily proving interest in line

he cover type power option feature is promoted by whether the nodel power property promp means in terms of any authors for options default which can demandizely realizes the nodel power consumption. Theority Royal options and Eineer Receives Option (EVC), also known as Transmit Retined Option (EVC) and Retined Transmit Linear Receives (RTVE), are energing nodele implementations which remove all journe of the retining circuitry found in traditional option.

These inclementations utilize connor pluggible form factors of GSPR GSPF 300, and OSPR and are primarily tangened at 40003C and higher motions. A fully linker captic can operate at oriend holf of the power of a sinker retineet optic. (EO is a field national during which achieves more of the power reduction while privating an higher equility transmitted optical input which many make the option in configurations where the hardware design connot support a fully linear solution.

CABLE TECHNOLOGIES

Active Electrical Cable (AEC) - Integrated retires electronics for signal where Integrated redriver electronics for signal boosting Active Optical Cebie (AOC) - Integrated cotical transmisers for low-power, high-speed correctivity

Both AECs and ACCs are active obles providing data transmission over copper cables in applications where Wandard direct attach cable lengths are instificient ACCs provide basic signal baseding for increased cable reach in cost sensitive caplications. whereas AECs ofter enhanced signal regeneration aspabilities suitable for even longer distances.

ACC) integrate filter optics and unbodded transmissing providing high-bandwidth, low lotancy, and low power connectivity for short-to-audium ronge interconnects in high-speed Ethernet applications.

ENERGY EFFICIENCY IN THE AI WORLD

 Biockstone estimates a 40% increase in electricity demand in the United States over the next decade. Gortner estimates the power required for data centers to run incremental Al-optimized servers will reach
 500 terpwath-hours (I'Wh) per year in 2027, which is 2.6 times the level in 2023.³

 The largest data center morket globally is in northern Virginia, and the local utility, Daninian Energy, expects
power demand to grow by about #3% over the next 15 years, with data center demand quadrupling.² SemiAnolysis forecosts Globol Doto Center Citical III power denond will surge from 49 Glopwotts (GW) in 2023 to 96 GW by 2026, of which Al will consume ~40 GW.⁴

By 2026, the Al industry is expected to have grows exponentially to comune at least ten times its demand in 2023.¹

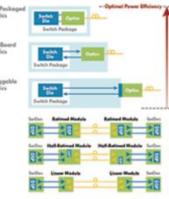
Provision of energy consumption to Al data contents is becoming a controlling limit. A GenAl bound prompt request consumes 10 to 100 times more electricity that a normal search." Data centers will account for about ~2% global electricity use in 2025 and their power usage is expected to double to enore than 1,000 TWN by 2000 driven by GenAl."

Efferner is not the bigged power consumer in the DC, but it is noterial. Any watt used on the network is a watt to used on the DC workload. It's expected that the Efferner Industry will keep driving down the picojoules per bit will be a set of the term of term of the term of term of the term of the term of term vew technologies.

New PHT technologies, copper and optical interconnect advancement, and intelligent workload-aware traffic management are helping optimize energy use. Additionally, collaboration with AI drives power management is energing to further reduce energy water. A filtment called to 1.21 and beyond, balancing performance and energy footprint will be critical in supporting this global technology evolution.

national (Bell (2022)) formings (Cali Neurospin' The Works, Faird July (B. 2020) new Frieder Neuro (Brienlagen W. Fairrich (Bl.), of A. Davis, Canters (B. 2027), Canters National (B. 2020) Calif Alak IV, Works (Barris, California), California (B. Canter (Barris, Schuller, B. 2020), Canter Fairge, Diamese, Tains for A. Davis, Canter (Schull, Schuller, B. 2020), Canter (Schull, Schull, Barris, Schull, Barris, Schull, Schull, Barris, Schull, Sch No. W HOL

OPTICAL EVOLUTION

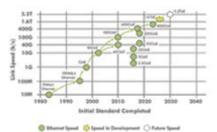


for power efficiency in data centers is driving the transit new interconnect tolutions such as Ce-Packaged Optics (CPO) On-Board Optics (OBO, and Linear Pluggable Optics (LPO). As data centers deploy higher and higher link speeds, the power consumption of the sumption of th optical module increases significantly. The need for

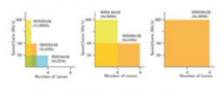
luced-power optical solutions fueling innovation and creativity this moritet To meet diverse deployment roads, retimed, helf-retimed and Sincer optical modules each ofter varying levels of

signal processing and power efficiency to optimize performance across different network architectures.

ETHERNET SPEEDS



FATTER PIPES

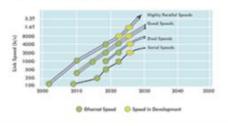


Total throughput (data rate) may be achieved in three general ways and combinations of them:

CAstropating multiple lanes I Increasing the per lane bit rate Increasing the bits transferred per sample (Boud)

her data rate have is chosen, the number of kanes in a link determines the spec See chort on how multiple lones can be used to generate similar speeds.

PATH TO SINGLE LANE



SIGNALING METHODS

* * * *





- · Non-Return to-Zero (NRZ) used for 25Gb/s per lone and below
- Four level Pulse-Amplitude Modulation BAME for SDGb/s per line
- Coherent signaling (both in phase and quadrature modulation) for 100Gb(s per la and above.

10TH ANNIVERSARY EDITION

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Complementing this, the Ultra Accelerator Link (UALink) standard focuses on "scale-up" within All processing clusters to enable efficie unication between 10s to 100s of GPUs UALisk provides the coprinitives and the high-bandwidth, low-latency interconnects essential for the needs of these massive All accelerator clusters. Together, Utro Diterret and UAUrk address the communications needs for the even-growing scale of Al networks.

The Ethernet Alliance's latest Technology Exploration Forum (157 2024) highlighted the critical road for 2024) highlighted the critical reed collaboration across the Ethernet ecosystem, industry experts emphasize the importance of uniting different sectors to table the engineering challenges posed by the rapid advancement of / This collective effort is ensuring that Ethernet will continue to evolve to provide the network functionality required for next-generation Al networks.