White Paper

VIAVI Solutions

Path to 800G: Technical Challenges and Testing Strategies

400G to 800G: a jump, not a journey

Though 400 Gigabit Ethernet (400G) is still working its way into production networks, demand for even higher speeds has arrived. Data centers are already leading initial 800G deployments as data requirements from private enterprise networks prove unrelenting. Blame the rollout of next-generation applications and workforces that are more distributed than ever.

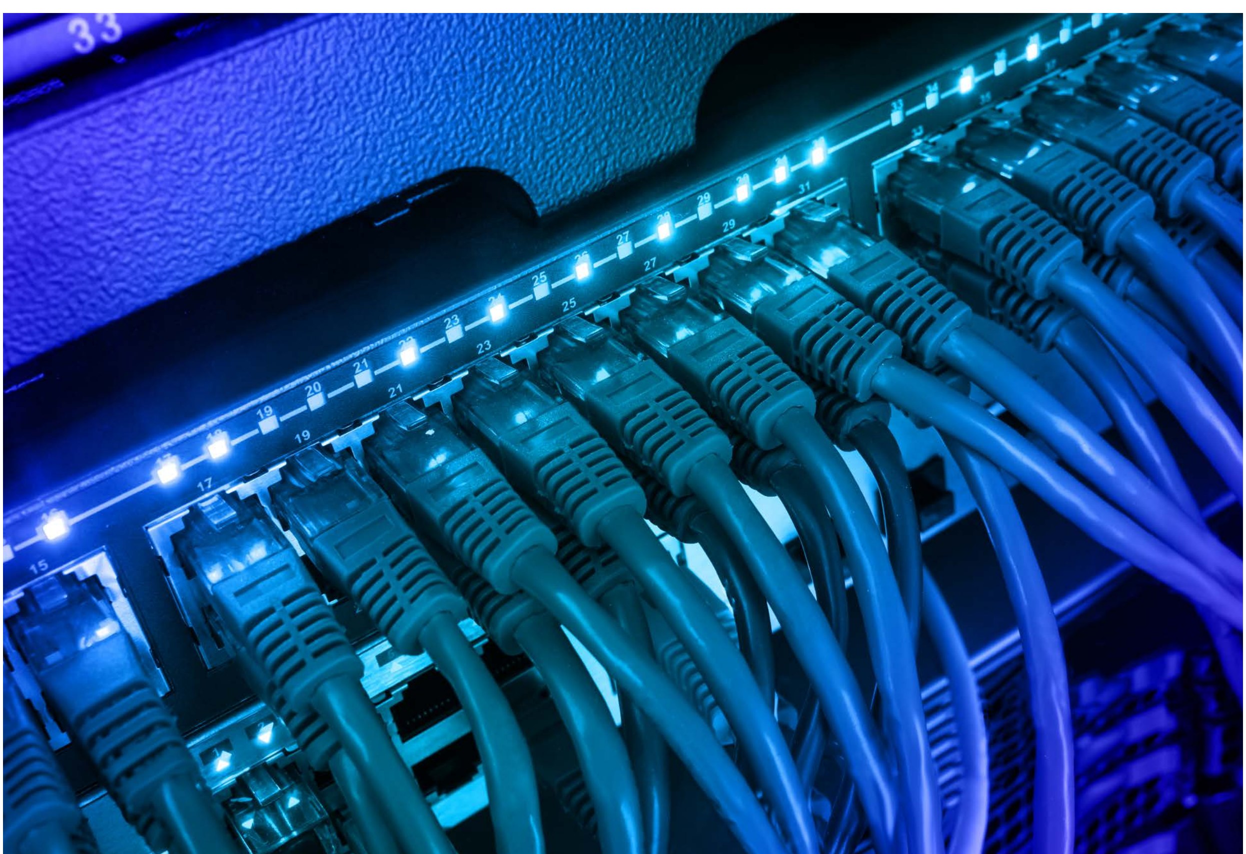
These trends are unconcerned with the orderly, planned procession of network transport generation evolutions. They are not waiting for consensus or standards. The only timeline that matters is how quickly operators and the network vendors that support them can get to market with the right infrastructure.

VIAVI's latest work with customers has been defined by swifter-than-expected pursuit of 800G. Originating first in North America and Europe, 800G activity in Asia Pacific is now gaining steam as well.

This is a global movement. One that will look much more like a jump than a journey.

Key Takeaway

A global movement toward 800G has begun as operators and network vendors position to address new data demands.



A Market Emerges with Exacting Needs

Early adopters are already asking VIAVI to validate high-density devices and systems as the 800G ecosystem prepares to deliver even faster capabilities that can maximize the capacity of existing, space-limited physical locations. Specifically, an urgent need exists for vendor-neutral interoperability testing to support rapid 800G advancement and adoption.

The demand for 800G Ethernet testing is being driven by:

- Unprecedented levels of data center workloads from new applications such as Internet of Things (IoT), digital reality, artificial Intelligence (AI) and machine learning (ML), continued adoption of SaaS applications, as well as work-from-home traffic.
- Rapid access to provide the performance needed for CPU and memory resource disaggregation.
- The need to validate higher power-consuming applications and impact on the number of servers deployable in a data center.
- Operator rollouts in regions with high transport demands.

Already, VIAVI has helped validate 800G optical transceiver interoperability on test links that emulated hyperscale data center traffic. We have also validated 800G optical transceiver performance via real-world traffic emulation to support continued expansion of online applications and services in data centers. We are working with partners to advance vendor-neutral 800G testing solutions.

This ground-breaking work has demonstrated the viability of next generation high-speed Ethernet devices and readiness to support initial demands, and is ensuring deterministic, efficient networks and best possible customer experiences for the future.

The timeline for 800G testing is beginning to crystallize.

Key Takeaway

VIAVI is already validating 800G devices' readiness to meet initial market demand as testing timelines begin to crystallize.

800G Testing Timeline Taking Shape

Across the ecosystem, testing needs and use cases differ, but all are critical to the success of 800G.

As is typical with new technologies, 800G testing is rolling out in stages, migrating up the protocol stack as successes occur at lower layers. In this early stage, cost and efficiency benefits have emerged when using a single solution to test and qualify equipment and software. Testing needs are being defined by the discrete requirements of ecosystem stakeholders.

Transceiver and cable vendors are the early adopters, concentrating on the physical layer with an initial focus on error rates.

Semiconductor companies that design and manufacture switch chipsets are focusing on speeding development and manufacturing processes to bring complex new chips to market as quickly and cost-efficiently as possible. Continuous pre-silicon verification emulation testing followed by post-silicon validation testing is fast-tracking the design of complex chips with better, higher-quality results.

With chipsets becoming more widely available, network equipment manufacturers (NEMs) and hyperscalers are focusing first on bringing up a stable link, then on application performance and the impact of real IP and higher-layer protocol traffic on performance. This involves verifying vendor transceivers and chipsets, and performing QA application testing.

As this testing takes place, complexity and confusion stemming from fragmented standards development and timelines have brought the key challenges at this stage into focus. Stakeholders do not have the luxury of waiting for these challenges to be sorted. They must move ahead now.

Doing so with confidence means leaning on testing earlier and more comprehensively than any previous evolution required. Understanding what can go wrong and when is the first step toward plotting a strategy for early-stage success.

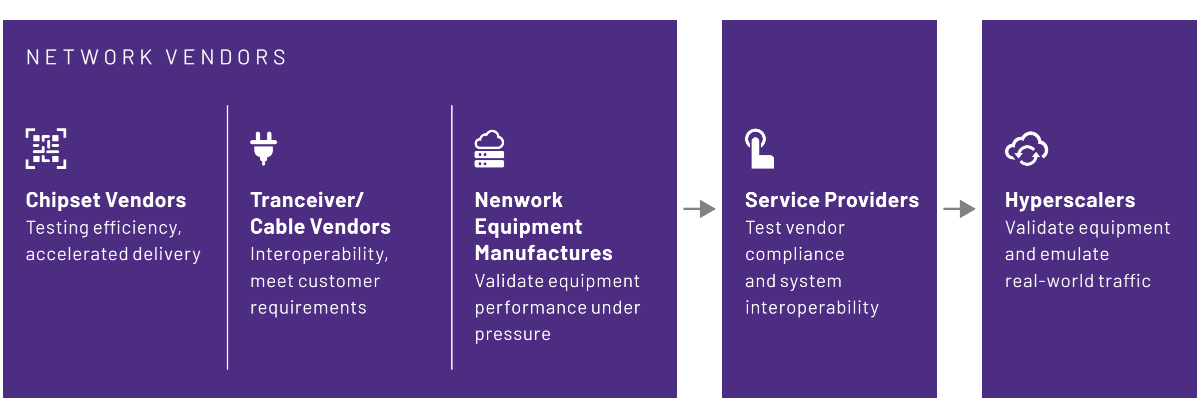


Figure 1. Ecosystem Testing Needs

800G Technical Challenges Drive New Testing Requirements

Although 800G is being defined based on 400G technology, there are significant new technical challenges at all layers. These challenges impact the entire ecosystem, from chipset and transceiver/cable vendors to NEMs and hyperscalers.

There will be a range of issues in the future around protocol testing, software and scale. VIAVI has already made advancements in these areas while also identifying priority "day one" challenges that must be solved immediately. These challenges are having a substantial impact on the kind of testing that must be conducted and capabilities required to support it. They span interoperability, physical layer performance and efforts required to bring systems up.

There are myriad challenges facing 800G early adopters:

1. Evolving standards impact the ecosystem

Standards for 800G PCS and adaptation of 400G FEC for 800G continue to evolve, bringing small changes but also some major leaps. While 800G implementations using 100G lanes rely on PAM4 signal encoding from prior generations, these rollouts will need to account for a doubling of PAM4 speeds, from 50Gb/s to 100Gb/s. Future strategies anticipate getting to 800G via four 200G lanes rather than eight 100G lanes. This would be a major change that would ultimately introduce additional technical challenges.

Several issues were identified during the migration from NRZ to PAM4 modulation. Some of these lower-level issues, for example if Gray coding was disabled, could be identified by examining per-lane PCS stats. Similar issues will need to be investigated again following the move to higher order modulation for 200G lanes.

Especially in these newly defined areas, real-world interoperability needs to be validated between vendor devices.

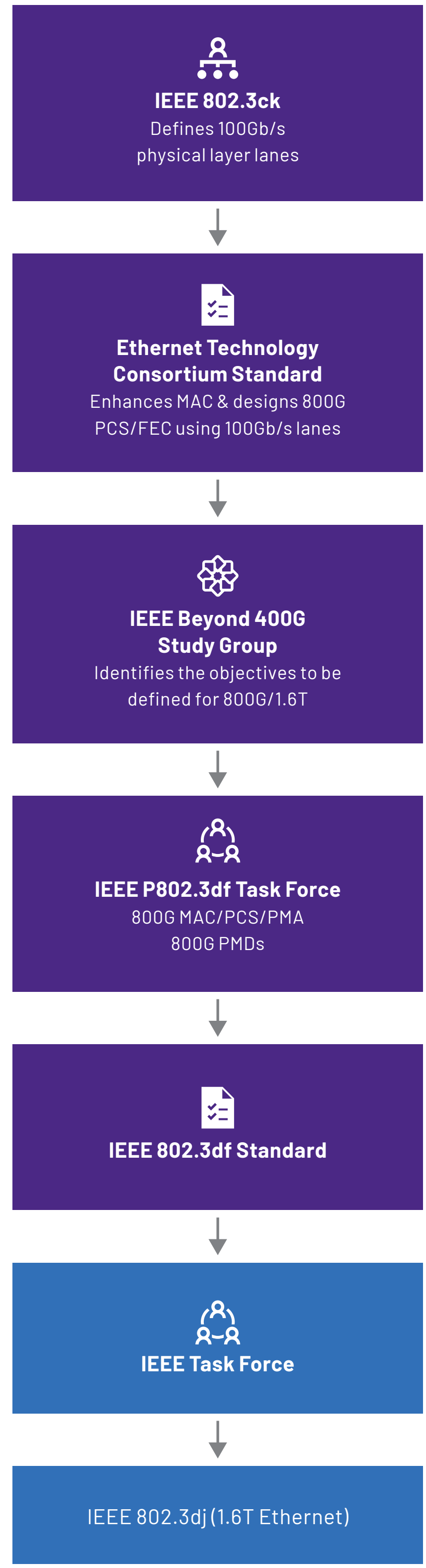


Figure 2. Evolution of 800G Ethernet Standards and Beyond

2. Early devices will not support complete standards

Early devices may not support the requirement for both Auto-Negotiation (AN) and Link Training (LT) for electrical signal transmission. Depending on the ASICs used, some may support only LT and others, both AN and LT. Further, ASICs that only support LT may not be compatible with ASICs that support both AN and LT, so in these cases, both AN and LT will need to be disabled and the link may need to be tuned manually.

The AN/LT compatibility issue is critical to address as LT allows receivers to adjust the link partner's transmit settings. This capability makes it easier to link up over various cables with multiple devices while reducing the need to manually tune transmit settings. In the absence of AN/LT, the potential arises for situations where links cannot be achieved, or link flaps occur.

When link flaps happen frequently, throughput can be affected dramatically. With mature optical technologies, link flaps are rare, and usually caused by a bad cable, configuration error or a defective transceiver. With new technologies such as 800G, link flaps can also be caused by heat issues, design issues with the transceiver modules or problems with the switches themselves.

ADVANCING 800G DEPLOYMENTS

> "Testing has been a critical aspect of the Ethernet ecosystem throughout the technology's emergence as the foundation of network communications globally, and testing's role in accelerating adoption of the next Ethernet speeds will continue to be critical."

- **Peter Jones**, Ethernet Alliance Chairman

3. Debugging optics are expensive and in short supply

High speed optics are in limited supply and may cost tens of thousands of dollars each, making them costly to test. Additionally, several potential optics issues can emerge in 800G given high levels of power generated and heat produced. If not cooled efficiently, erratic performance may result.

Signal communications in both directions between the optics and the line need to be tested. Also, interoperability needs to be validated on the optical channel and the electrical host interface. Test systems need to transmit signals to the optics that are accepted by them, and the optics need to send acceptable signals back to the test system. Optics also need to provide debugging access to accelerate determination of the root cause of issues to minimize finger-pointing when problems occur.

4. Twice as fast means amplified challenges

Speed comes at a cost. The massive jump from 400G to 800G brings a sizeable speed increase and higher frequencies (i.e., >50GHz spectral content). Doubling the spectrum also doubles the sampling speed and the symbol rate. As a result, minor issues that may not have caused an impact in the past can be detrimental to electrical performance at 800G. It is the equivalent to using a 500X microscope versus one at only 80X power.

Maintaining high fidelity at these high rates requires enhanced ASIC design, such as the need for exotic materials and circuit board fabrication processes with tighter tolerances.

Challenges introduced by high speeds span PCB design issues and traces. Excessive heat is also a concern due to faster optics and more powerful ASICs. Even pin spacing can become an issue. Further, any impedance discontinuity between connectors and modules can result in electrical reflections with negative consequences on fidelity and performance.

Stress testing optics, ASICs and trace lanes emerges as an important practice to avoid power fluctuations and PCB re-spins that would require redesign and remanufacturing. Also, making it standard practice to involve engineering teams every time something new is connected can ensure proper interoperation. Finally, optimizing across parameters for which there is full control, such as transmitter and receiver characteristics, can also clear a path to success.

5. Need to accurately verify physical layer health

PAM4 links have errors by nature, so Forward Error Correction (FEC) is mandatory. But errors in excess of the 15 symbols allowed result in uncorrectable error codewords that cause Frame Check Sequence (FCS) errors and packet loss.

Analysis of FEC statistics is emerging as the single-most valuable tool for assessing physical layer health. It provides a more granular view of performance and predicts FCS errors. As a result, link health issues, such as a saturated receiver, can be detected in advance and without waiting days or weeks for the actual FCS error to occur.

FEC statistics establish a robust electrical connection baseline before FEC error injection can be conducted in a controlled manner.

Spotlight On Key 800G Use Cases

Actual work in the field and lab are where predictions and theoretics give way to real world learnings. There are already several noteworthy use cases and activities shaping understanding of 800G's capabilities and unique challenges, and the role testing is playing to advance technology and dependent markets alike:

Transceiver/Cable Vendors

Use case: Assure 800G interoperability in environments where standards are not yet set or still open for interpretation.

Test strategies: Get a solid 800G link up and validate the line rate traffic transmission using the IEEE 802.3ck QSFP-DD application. Develop and bring the 800G link operational to emulate the traffic of hyperscale data centers. Assess simple, pre-FEC and post-FEC error rates and ensure they are within specs. Identify healthy and unhealthy links. Stress test by injecting errors into the traffic stream. Confirm Layer 2 framing, forward error correction, and symbol rate. Create an environment to continuously test and validate performance.

Hyperscalers

Use case: Implementation, and network and application performance between and within data centers.

Test strategies: Verify that the network stays up and application performance is high quality. Verify all layers and qualify vendor equipment. Make use of test KPIs and embedded expertise to test directly. Assess thermal and power situation. Continuously test and validate network and application performance.

Chipset Makers

Use case: Pre-silicon validation and post-silicon verification best practices.

Test strategies: Pre-silicon, provide EDA emulation and software-based traffic emulation. Automate and speed testing workflows via libraries of test scenarios. Emulate silicon at Layer 1 to catch bugs in real-time prior to manufacturing and reduce redesign and remanufacturing cycles. Conduct post-silicon testing to validate the manufactured chipsets.

Network Equipment Manufacturers

Use case: Assure link and application performance under live network conditions.

Test strategies: Bring stable link up and validate application performance. Test to ensure devices will perform under stress. Assess and monitor for thermal and power issues. Exercise equipment under real-life conditions. Continuously test and validate network and application performance. Flexibility to cover testing needs of specific use cases in depth and to evolve with changing needs.

Defining Successful Test Strategies

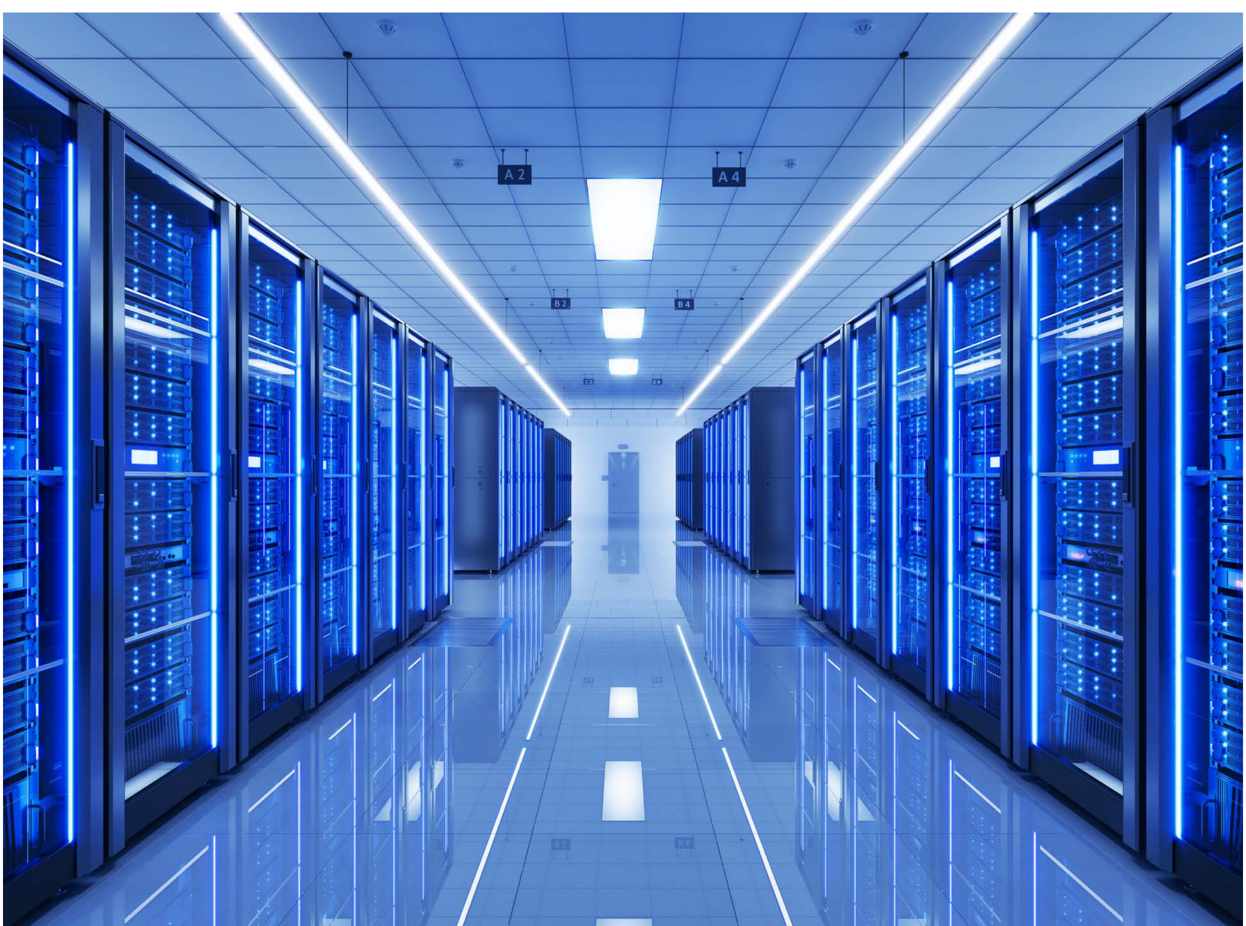
800G is moving rapidly toward accelerated deployments to meet the demands for higher speed connectivity. IoT, AI and 5G applications hinge on the industry's ability to more efficiently validate and deploy 800G.
It is the only way to quickly meet the increasing demand for more network capacity.

While use cases and test strategies differ across the 800G ecosystem, test solutions must flexibly evolve with standards and overcome complexity that should be expected to persist for the considerable future. Industry leaders must not only test and ensure the quality of the layers of the protocol stack of interest but also verify the performance of the lower layers.

With standards still being determined, components scarce due to supply chain issues, and new complexity introduced, proper testing is the single-best tool chipset vendors, hyperscalers and NEMS have to light the path ahead.

Key Takeaway

Early test solutions are meeting an important need but must flexibly evolve with standards and overcome early complexity up and down the network stack.



Safely Accelerating the Journey to 800G

VIAVI is working at the bleeding edge of current high-speed Ethernet technology development to help our customers design, develop and deploy 800G technology. Across innovation, technology partnerships and real-world work, we are giving early adopters the confidence to accelerate design and development of the world's first 800G-capable next-gen devices.

VIAVI provides 800G validation solutions for the entire ecosystem, offering multiple options to support implementation of 800G solutions. This includes helping to qualify equipment, allowing hyperscalers or NEMs to determine which supplier will best fit changing needs. For partners, VIAVI provides a neutral test solution to validate vendors.

VIAVI's integrated, hybrid (Layers 1-7) approach significantly reduces the cost of ownership compared to test solutions that specialize on specific layers. TestCenter platform provides end-to-end testing, actionable analytics, and a flexible environment to test the upper layers while the lower layers tests remain static.

For more information about VIAVI high-speed Ethernet testing solutions, visit www.viavisolutions.com/en-us/solutions/high-speed-ethernet-testing

Key Takeaway

Early 800G adopters must have the confidence to accelerate design and development of the world's next-gen high-speed devices. VIAVI stands ready to support them.