The 2015 Ethernet Roadmap

Contributors:

John D'Ambrosia, Dell

Scott G. Kipp, Brocade

Executive Summary

Ethernet has always been about innovation, and, still today, the global ecosystem of Ethernet stakeholders leans forward into the visionary questions, *What more can Ethernet do, and what else can the world do with it?* However, never in Ethernet's 40 years plus have those questions touched upon so many nuances across markets, requirements and applications.

Now that Ethernet is in its 40s, the leading networking technology in the world is embracing a diversity of applications. In 2010, the Ethernet standardization community broke from its history of boosting the technology's highest speed strictly by a factor of 10. Today—with adoption fervent on a number of diverse fronts including automotive networks, power, industrial control, next-generation and residential access and server connectivity in hyperscale data centers—Ethernet is embracing the fact that there are now considerable and substantial markets that are growing in their own ways and paces that simply cannot be ignored.

The result is that the proven technology is amid a period of multi-faceted innovation, without betraying any of the core characteristics that have driven Ethernet's emergence over the last four decades. Ethernet is developing four new Ethernet speeds—2.5, 5, 25 and 400 Gigabit Ethernet (GbE)—to add to the existing six speeds—Megabit Ethernet (MbE), 100MbE, GbE, 10GbE, 40GbE and 100GbE). Over the next decade, several more speeds are being considered, including 50GbE, 200GbE and multiple speeds beyond 400GbE. Together, these speeds define the core of the 2015 Ethernet Roadmap.

This paper will explain the requirements and applications that are driving the great diversification in the Ethernet roadmap and illustrate the Ethernet Ecosystem. This paper gives the story behind the printed 2015 Ethernet Roadmap, which is available for free download at www.ethernetalliance.org/roadmap/.

The two sides of the 2015 Ethernet Roadmap are shown on the next page.

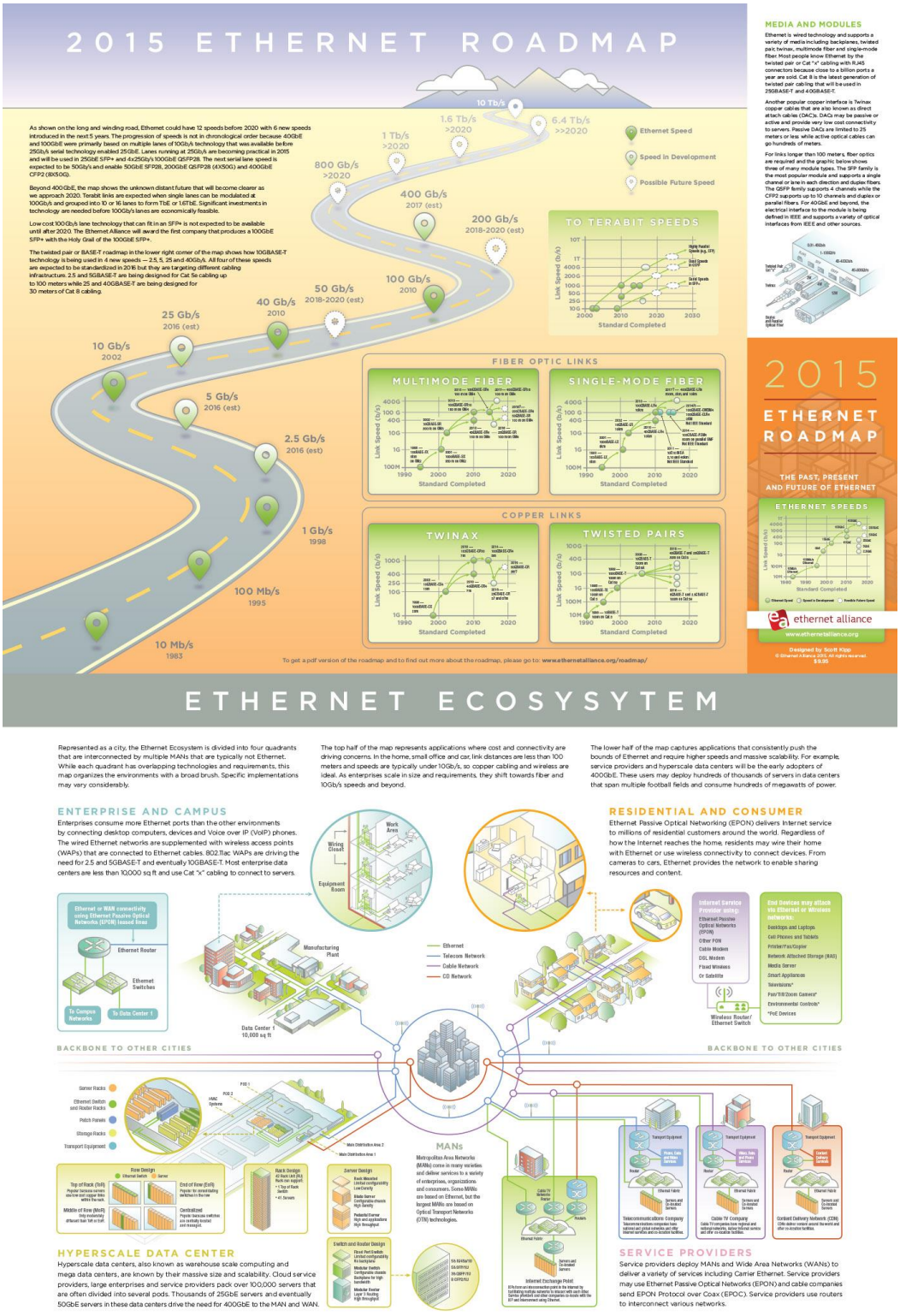

Figure 1: The 2015 Ethernet Roadmap – A higher-resolution version is available online at www.ethernetalliance.org/roadmap/

Embracing Today's Varied Requirements

Since its initial approval at 10 Megabits per second (Mb/s) in 1983, IEEE 802.3™ "Standard for Ethernet" has been updated regularly to address evolving market demand by delivering increased capacities and features. In 1995, the Ethernet Ecosystem standardized 100MbE. Then, GbE came in 1998; 10GbE, in 2002, and 100GbE, in 2010. It was an orderly and dependable progression for which Ethernet became globally known: 10 times the speed, at three times the cost.

For many years, Ethernet built it, and, indeed, they came—from industry sectors that the technology's pioneers never envisioned Ethernet serving. Subscriber access, cellular backhaul, power infrastructure, smart meters, personal medical devices, the Internet of Things (IoT), connected cars … all of them came to rely on Ethernet, a technology initially conceived to support connectivity among computers, printers, servers and other devices inside a local area network (LAN).

But, in 2010, the pattern was broken. This time, 40GbE (a leap of only four times from the previous highest standardized speed) was standardized, in addition to 100GbE, in IEEE 802.3ba™, paving the way for new generations of both high-rate server connectivity and core switching with the first standard ever to simultaneously define two new Ethernet speeds.

In the five years since, development and deployment at points all along the Ethernet value chain have exploded. Today, Ethernet is undergoing no less than a standardization binge; 25GbE, 2.5GbE and 5GbE, as well as 400GbE, are all on their way from the IEEE 802.3 working group. IEEE has never standardized this many speeds at one time. And before the end of the decade, we expect two more speeds—50GbE and 200GbE, as well. This would amount to the standardization of six Ethernet speeds in five years—the same amount that the previous 40 years provided.

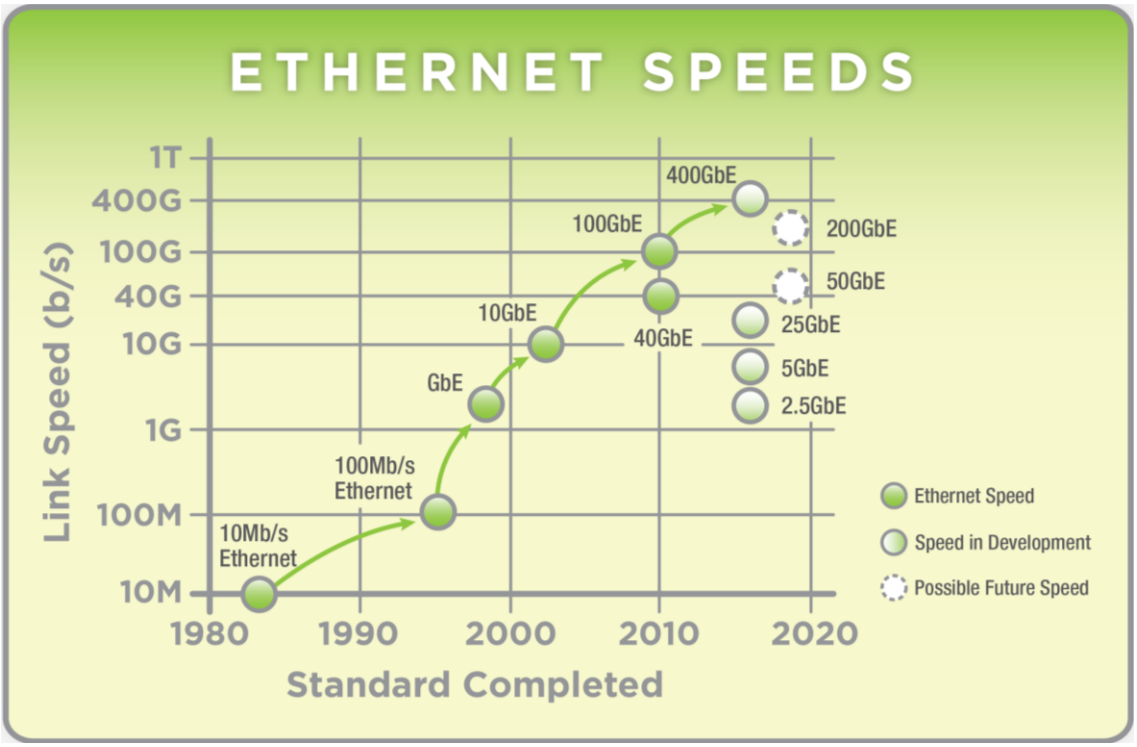

Figure 2: The Speeds of Ethernet

It is a different mindset of innovation. The Ethernet community is no longer locked in to the notion of introducing new speeds in factors of 10; rather, the cast of Ethernet users has become so varied that no longer can such a diverse Ethernet Ecosystem be expected to leap to any single, next given speed. Yes, Ethernet is continuing to advance at its highest rate in order to stay ahead of exponentially growing, global bandwidth requirements. But the fact is that true innovation is occurring within varied application spaces at lower speeds. Many servers today are still using GbE; many Ethernet users around the world are not going to care about Terabit Ethernet (TbE) speeds for the foreseeable future, or even 400GbE for that matter. Ethernet has always been and will always be about connectivity and how far this technology can go, but the Ethernet community embraces that the need for speed is relative to the given niche application.

And, by the way, “niche” is no longer nichey. These niche applications, for which so many different standardized speeds are being developed, sometimes represent *hundreds of millions* of ports for Ethernet. The billion-port-a-year Ethernet market has become large enough to enable huge-volume niche applications that are customized in a practical and profitable manner.

Staying Ahead of Tomorrow's Needs

Today, the varied developers of IEEE 802.3—with projects based on specific use cases with clear objectives and solution spaces—is at work to deliver standards that meet the needs of well-defined users and applications. These new developments continue to expand the Ethernet ecosystem. Examples include:

- **400GbE**—The Bandwidth Assessment Ad Hoc spent two years assessing the Ethernet market's emerging application needs and concluded that 400GbE would strike the correct balance among varied considerations including cost, power, density and bandwidth demand. The IEEE 802.3 working group subsequently launched development of 400GbE in March 2013. More information is at http://www.ieee802.org/3/ad_hoc/bwa/BWA_Report.pdf.

- **25GbE**—Hyperscale data centers' demand for high bandwidth at low cost for server-to-switch interconnects led to the start of development of 25GbE in July 2014. The high-end components that figure to enable 25GbE for the cloud have already been developed because standardized 100GbE is achieved by four lanes of 25Gb/s technology. In addition to optimizing existing industry investments, standardization of 25GbE also is a logical step within context of the need to aggregate those connections into 100GbE uplinks. More information is available at http://www.ieee802.org/3/by/index.html.

- **2.5GbE and 5GbE**—In this case, the market driver is wireless access. To support the latest "Wi-Fi®" technology—IEEE 802.11ac™—without requiring that users change their cabling infrastructure, 2.5GbE and 5GbE are being developed for the network edge and wired connections to wireless access points. More is available at http://www.ieee802.org/3/NGEBASET/index.html.

- **25GBASE-T and 40GBASE-T**—The development of 25GBASE-T and 40GBASE-T is being driven by the need for high-speed connectivity to servers at very low cost. These two new standards will use CAT 8 cabling for greenfield installations. CAT 8 is being developed specifically for these new speeds and will be even lower cost than the direct-attach SFP+ cables used in 25GbE. More information is available at http://www.ieee802.org/3/bq/index.html.

There is a diversity of justification behind each of these efforts, but a common theme undergirds all of them: the global requirement for a market-driven standard, fostering innovation and enabling multi-vendor interoperability across whatever application area the world's growing cast of Ethernet users seeks to enable.

To Terabit Ethernet

The purpose of a roadmap is to show people where they can go. They want to go to places they've never been. The 2015 Ethernet Roadmap shows how the industry is progressing towards Terabit Ethernet (TbE). TbE is in the future and expected after 2020. Significant investment is needed to get to Terabit speeds.

To explain the future, understanding the past is helpful. Ethernet speeds have been a mixture of serial and parallel lanes. To get to 100GbE, the industry used multiple lanes of 10Gb/s and 25Gb/s technology. First-generation 100GbE electrical interfaces used 10 lanes of 10Gb/s in the CFP form factor, and the second generation uses four lanes of 25Gb/s in the CFP2 and QSFP28. Affordable 25Gb/s technology was barely available in 2010 when the first 100GbE standard was written, but 25Gb/s technology is widely available in 2015. The industry agreed to develop individual lanes of 25Gb/s technology in the SFP+ form factor.

The 400GbE Task Force is using 16 lanes of 25Gb/s technology in the CDFP form factor, but the industry also wants to use eight lanes of 50Gb/s to create higher-density 400GbE in the CFP2 form factor. 50Gb/s lanes will enable 50GbE in the SFP+ form factor and 200GbE in the QSFP28 form factor. The speeds based on 50Gb/s lanes should be available by 2020.

Figure 3 shows the trend of these increasing lane speeds. The bottom line shows how individual lanes are being increased from 10Gb/s to 25Gb/s to 50Gb/s and eventually 100Gb/s in the SFP+ form factor in the 2020s. The middle line shows how our lanes are placed in a QSFP and supporting 40GbE, 100GbE, 200GbE and eventually 400GbE. The top green line shows how applications with the highest bandwidth demand go highly parallel with eight, 10 or 16 lanes to reach Terabit speeds. The first Terabit speeds could be 1Tb/s (10 lanes of 100Gb/s) or 1.6Tb/s (16 lanes of 100Gb/s). The 100Gb/s lane technology is, thus, the building block for TbE.

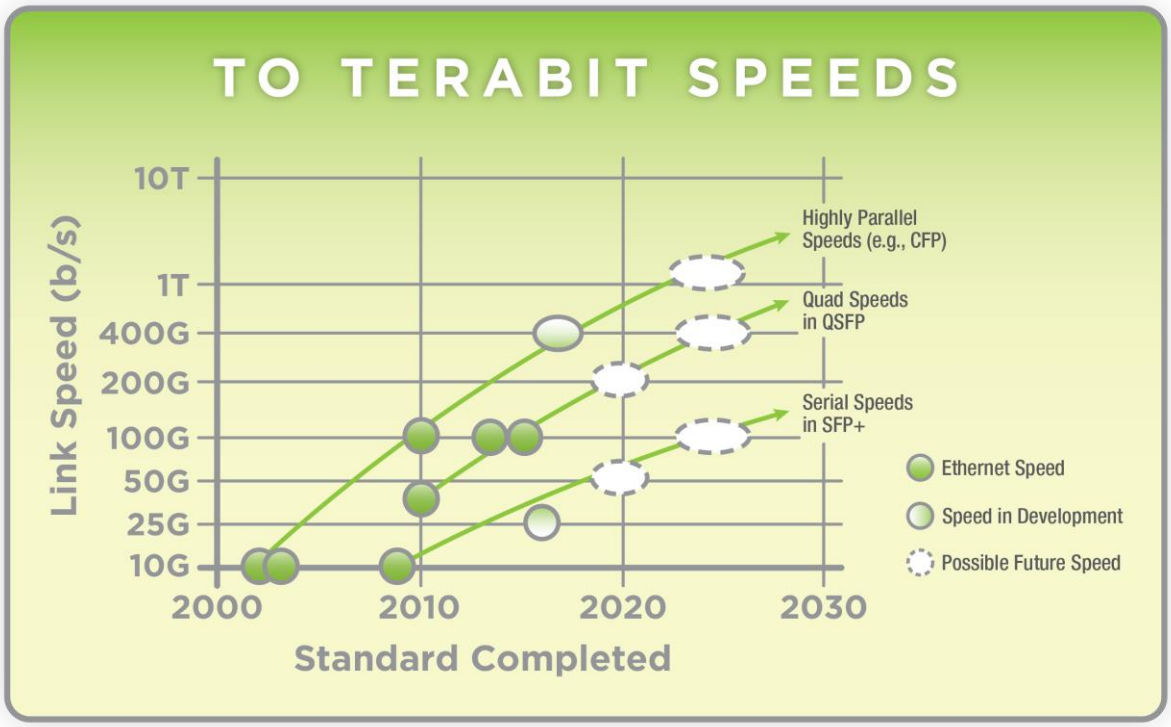

Figure 3: The Path to Terabit Speeds

To spur the industry development forward, the Ethernet Alliance has created two 100GbE challenges. The first challenge is "The Holy Cup of 100GbE Lambda" and requires the winner to demonstrate an optical 100Gb/s lane technology in the QSFP+ form factor. The second is "The Holy Grail of 100GbE SFP+" and requires 100Gb/s electrical and optical signaling. More information on these 100GbE challenges is at http://www.ethernetalliance.org/wp-content/uploads/2013/04/Ethernet-Alliance-100GbE-Challenges-09-16-14.pdf.

The 2015 Ethernet Roadmap is admittedly highly speculative for other speeds beyond 400GbE. When individual lanes reach 200Gb/s, then the likely speeds will be 200GbE, 800GbE and 6.4TbE in a future, 16-lane form factor. Likewise, 400Gb/s lanes would enable 400GbE SFP+, 1.6Tb/s QSFP+ and 12.8TbE. Technologies beyond 100Gb/s lanes are very costly right now, and the industry will have to invest hundreds of millions of dollars before these technologies reach the cost points of Ethernet. These technologies will become clearer over time.

The Ethernet Ecosystem

The front side of the 2015 Ethernet Roadmap is focused on speed and shows the speeds of individual links in optical and copper. The back of the map details the Ethernet Ecosystem. The Ethernet Ecosystem is broken into four quadrants:

- Residential and Consumer
- Enterprises and Campuses
- Hyperscale Data Centers
- Service Providers

The Ethernet Ecosystem is shown as a city and shows the variety of ways that Ethernet is used. From in the home to connecting hyperscale data centers to the Internet Exchange Points, Ethernet is the foundational networking technology. The graphic also shows how metropolitan and wide area networks (MANs and WANs) interconnect the city to itself and other cities.

The back of the map also shows typical network architectures and the equipment that is used to build the network. In the hyperscale data center quadrant, the map shows how the large data center is carved into pods that are interconnected through main distribution areas. The pods are built from rows and rows of racks, and each rack contains a variety of servers, storage and networking equipment in different configurations. Together, these components create the Ethernet Ecosystem that delivers the growing variety of applications.

Stay the Course with Ethernet

A conversation about Ethernet innovation no longer can be just about rates but also must be expanded today to address applications *and* technologies globally. Such complexity is represented in the 2015 Ethernet Roadmap.

The 2015 Ethernet Roadmap illustrates how a dozen Ethernet speeds should be shipping by 2020. The roadmap shows different roadmaps for different media types because copper cabling is significantly different than optical fiber. Likewise, multimode fiber is different than single-mode fiber, and the roadmap differences are readily apparent. Finally, the roadmap speculates on future speeds beyond 2020 as we reach the TbE era.

The backside of the map shows how Ethernet is used in a variety of applications in one holistic view. From cars and homes to buildings and data centers, the Ethernet Ecosystem is growing and maturing to provide the lowest-cost connectivity of any networking technology. Ethernet ships over a billion ports per year, and, because of the diversity of applications, no other networking technology ships at this scale.

Ethernet is the dominant networking technology in the world, and the 2015 Ethernet Roadmap helps explain how it will continue to flourish in a variety of new applications and speeds. Count on Ethernet to innovate and lead networking technology to new heights.

The Ethernet Alliance continues to support the broad expansion of Ethernet. Ethernet Alliance activities span from incubation of new Ethernet technologies to interoperability testing to demonstrations to education. Our members include system and component vendors, industry experts and university and government professionals, all working together to take Ethernet standards to the marketplace. Any company with an interest in developing or promoting Ethernet is welcome to apply for membership, and there are ample ways to engage whether you are a large or small company and whether you want to contribute to Ethernet Alliance or to just observe. To learn more, please visit http://www.ethernetalliance.org/about-us/how-to-join/.