

NBASE-T 2.5G/5G Ethernet Technology

Basis for the IEEE 802.3bz Standard

VERSION 2.0

Overview

For about ten years now, enterprise networks, and Ethernet networks in general, have been comfortably equipped for the vast majority of their throughput needs with 1000BASE-T Ethernet at the access layer, but time is running out for this workhorse technology. The most significant catalyst for change is in the Wi-Fi space. The rapid adoption of IEEE 802.11ac Wave 1 and Wave 2 standards and bring-your-own-device (BYOD) policies are shattering the 1Gbps throughput barrier of 1000BASE-T Ethernet. Add to that a growing number of data-intensive use cases for enterprise campuses—university research, medical imaging, CAD/CAM, and media editing—demanding more than 1Gbps—and it would appear that the enduring run of 1000BASE-T may be coming to at least a reckoning, if not an end.

Enterprise, industrial and many home networks seeking throughput beyond Gigabit Ethernet for client access are bumping up against a real problem: the nominal 1Gbps limitation of legacy Category 5e/6 cabling in most of the installed infrastructure worldwide today. Refitting buildings with the newer Cat6a cabling needed for 10GBASE-T is an option, but can be prohibitively disruptive and costly for some organizations. The IEEE 802.3bz standard was approved in the fall of 2016 and addresses this issue by enabling data rates of 2.5Gbps and 5Gbps over legacy Cat5e/6 cabling.

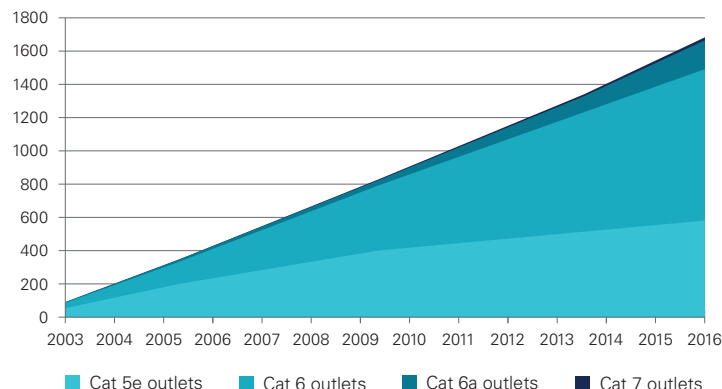
To address the pressing demand for speeds surpassing 1Gbps ahead of completion of the IEEE 802.3bz standard, the NBASE-T Alliance, a 45+ member consortium of industry leaders representing all aspects of the ecosystem, developed pre-standard specifications and products in parallel, and in tandem, with the IEEE process. Using NBASE-T specifications, users were able to deploy 2.5GBASE-T/5GBASE-T technology well before the standard was finalized. Individuals from NBASE-T member companies were key contributors at every stage of the IEEE process. As a result, the IEEE 802.3bz standard relies on a technology baseline compatible with the NBASE-T specification.

The Bottleneck

As is often the case, the effort to boost throughput and speed in a legacy ecosystem exposes a bottleneck. At the access level of enterprise networks, this bottleneck is Category 5e/6 twisted pair cabling between the Wi-Fi access point (AP) or client devices and the switch. In 2014 around 90 percent of the worldwide installed base of enterprise access links used Cat5e or 6 cabling. Prior to development of NBASE-T technology, this constrained data rates to a maximum of 1Gbps over 100 meters, presenting a barrier to the effective use of higher data rate 802.11ac Wave 2 APs.

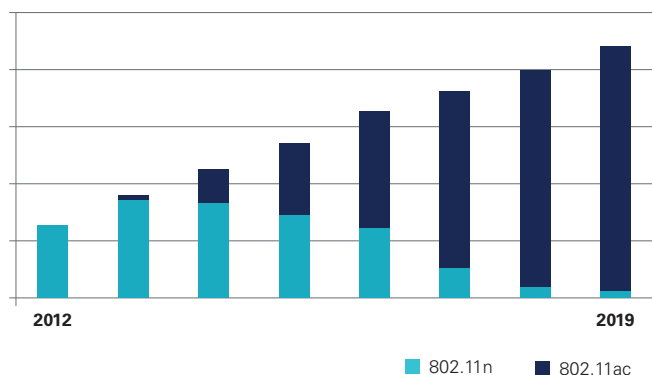
Replacing cabling with newer Cat6a (or better) cabling built to 10GBASE-T standards is one way to eliminate the bottleneck. However, while Cat6a is a viable option for greenfield deployments, it presents significant feasibility issues for legacy infrastructure. Not only is cable replacement disruptive to operations, but it is also cost prohibitive. With a cost outlay of \$200 to \$800US per new cable for hundreds of access points, the cost of retrofitting an established campus can easily run into the multiple \$100,000s. Given the huge (1.3B) installed base of Cat5e and Cat6, Cat6a will take a long time to become ubiquitous (Figure 1).

Figure 1: Installed Base of Ethernet Cabling by Category (millions of outlets) *Source: BSRIA*



The immediate pressure on the 1Gbps bottleneck is significant and growing. The rapid adoption of 2Gbps 802.11ac Wave 1, and close on its heels, 6.9Gbps Wave 2, brings the weight of a burgeoning, impatient wireless market to bear. In 2015, about 40 percent of enterprise AP units shipped supported 802.11ac. This number is projected to increase to 75 percent by 2017. In addition, 802.11ac Wave 2 is expected to grow rapidly and exceed Wave 1 by 2019 (Figure 2). Indeed, the proliferation of more powerful BYOD Wi-Fi devices—the latest smart phone, tablet or wearable technology—is a primary driver, though established medical, imaging, media, education and research-intensive enterprises that rely on communicating large amounts of data are also straining under the 1Gbps constraint. There are also clear applications in the expanding field of machine vision in areas like industrial control and transport automation.

Figure 2: Enterprise AP volume Split
Source: Dell’Oro Group Wireless LAN 5-year Forecast Jan 2015



The reach of 2.5G/5GBASE-T extends beyond the enterprise space and many networks driven by need for fast downloads, device synchronization and backup applications. NBASE-T interfaces can certainly be added to in-home network servers as their capabilities grow. There are already products announced in the gaming area. Broadband deployments with EPON and DOCSIS are starting to break the 1Gbps barrier, supporting the demand for increasingly data-intensive, media-rich content and flexible workplace culture. As with many technological advancements though, NBASE-T technology is most likely to gain purchase in the enterprise space first, where there is more pressing demand. Extension to service provider and other markets will certainly follow organically.

Bridge the standards gap through collaboration

In 2014, networking industry leaders recognized that a number of key factors were coinciding to create a growing gap in the market served by Ethernet technology. At the time, IEEE Ethernet standards were focused upward, to 25 Gigabit, 100 Gigabit and higher. Despite the fact that there was an obvious and growing need to tap into 1-10 Gigabit potential, the 2.5G/5GBASE-T realm was not being addressed by the standards body. Granted, a 10GBASE-T standard existed, but the associated cabling upgrade presented a barrier for established enterprises.

These industry leaders knew there was imminent need for an intermediate Ethernet speed, and that it was important to release a specification that could be put into practice immediately. In late 2014, a variety of companies in the enterprise infrastructure space came together to drive consensus around a new standard and deliver specifications that would enable immediate product development. Aquantia, Cisco Systems, Freescale (now NXP) and Xilinx formed the NBASE-T Alliance with the specific objective of filling the gap between the 1000BASE-T and 10GBASE-T Ethernet standards. The activities of the group centered around developing 2.5G/5GBASE-T specifications and products, and aiding in the development of an IEEE 802.3 standard. When the 802.3bz process commenced that fall, individuals from alliance member companies were key contributors, and continued to contribute at every stage. By late 2015, the alliance had grown to over 45 members, representing the entire spectrum of the networking ecosystem—access points, Ethernet switches, storage and computing, and supporting component technologies such as physical layer ICs (PHYs), processors, connectors, controllers, switches, FPGAs, Power-over-Ethernet (PoE) ICs, cables and test equipment. Member companies are either actively engaged in developing NBASE-T specs or products or working in related areas such as cabling or test equipment.

Owing to the activities of the alliance and other industry elements, IEEE 802.3bz progressed forward very rapidly. In the months between October 2014 and May 2015, the process moved quickly from the initial Call for Interest, through the study group phase, into work by the task force to draft a specification. In May 2015, the 802.3bz Task Force adopted a technical baseline aligned with the NBASE-T specification. Consensus formed quickly at every stage and the IEEE 802.3bz standard was approved at record speed in September 2016.

From the outset, achieving a standard that enables multi-vendor interoperability for 2.5GBASE-T and 5GBASE-T Ethernet has been fundamental to all NBASE-T Alliance efforts. Backing by over 45 industry members made the NBASE-T Alliance a valuable asset in the definition and development of technical consensus and baselines for IEEE 802.3bz, and pre-standard development and deployment for those organizations that needed it.

NBASE-T Alliance and the standards

The NBASE-T Alliance provides 2.5 and 5 Gigabit Ethernet PHY specifications and products in alignment with the IEEE 802.3bz standard. Key attributes of NBASE-T technology are:

- Supports full duplex 2.5G/5G data rates over Cat5e/6 or better cables (rates normally supported in a multi-speed device such as a 100M/1G/2.5G/5G/10G PHY)
- Scalable in terms of power and cost across the broad range of products
- Represents a superset of 802.3bz features, with the addition of “downshift” capability in the event of performance issues on non-compliant cabling installations
- Compatible with PoE, PoE+, UPoE and Energy Efficient Ethernet at all data rates
- Extends Ethernet auto-negotiation to add in the new 2.5G/5G data rates.

The established 10GBASE-T standard is the technical basis for both NBASE-T and 802.3bz. While many features of the three are identical, some features differ in compatible ways.

The NBASE-T PHY PCS/PMA, PHY/MAC Interface and the Link Segment are identical and compatible with 802.3bz, while auto-negotiation is slightly different. In order to provide compatible auto-negotiation, NBASE-T systems can support two auto-negotiation modes: NBASE-T auto-negotiation, as well as IEEE 802.3bz compatible auto-negotiation described below.

PHY PCS/PMA

NBASE-T Physical Coding Sublayer (PCS) specifications are based on the IEEE 10GBASE-T PCS and Physical Medium Attachment (PMA) standards. A few accommodations are necessary, though, to support the new 2.5Gbps and 5Gbps data rates:

- The clock is scaled by 1/2 and 1/4 in order to accommodate 5Gbps and 2.5Gbps data rates, respectively
- The Low Density Parity Check (LDPC) for NBASE-T is fully coded in order to protect all bits and improve performance for 2.5G/5Gbps rates

- The NBASE-T specification provides LDPC error correction capability rather than the simple CRC-8 error detection used by 10GBASE-T
- NBASE-T LDPC also does not employ DSQ128 coding, and instead transmits LDPC bits using the full constellation available from the PAM-16 modulation

The technical baselines for the PCS layer in IEEE 802.3bz are identical to those of the NBASE-T specification, so seamless compliance is ensured.

Auto-negotiation

Auto-negotiation allows devices based on different Ethernet standards to co-exist in a network. This mitigates the risk of network disruption arising from incompatible technologies. IEEE 802.3 standards preceding 802.3bz do not support auto-negotiation for 2.5Gbps and 5Gbps. NBASE-T solutions perform auto-negotiation by extending the current 10GBASE-T scheme as described in Clause 55, with one difference. NBASE-T auto-negotiation introduces an Organizationally Unique Identifier (OUI) Tagged Message, as defined in 802.3-2012 annex 28C.6, to advertise NBASE-T PHY capabilities, NBASE-T 5G mode, and NBASE-T 2.5G mode. An NBASE-T PHY sends Base, Next and Extended pages. The message page contains the OUI assigned by IEEE to the NBASE-T Alliance, 0xFA073E. Following the OUI page is an unformatted message page containing the NBASE-T capabilities. The OUI Tagged Message and unformatted message page are encapsulated within one Extended Message Page and one Extended Unformatted Page as described in 802.3-2012 Annex 28C. NBASE-T systems support the IEEE 802.3bz standard auto-negotiation feature via firmware upgrade.

PHY/MAC Interface

IEEE 802.3 defines the 10 Gigabit Media Independent Interface (XGMII) between PHY and MAC as a logical interface, not a physical interface. The IEEE 802.3bz standard is similar, but leaves physical implementations of the PHY-MAC interface to the industry to define. Vendor-defined de-facto MII exist, the most common of which are specified in Cisco Systems specifications, Serial Gigabit MII and Quad Serial Gigabit MII, SGMII, QSGMII, USGMII and USXGMII respectively. These interfaces allow multiple data rates and multiple ports over a single Serializer/Deserializer (SerDes). The NBASE-T Alliance has released specifications for a PHY/MAC interface based on these specifications, with the goal of accelerating system deployment. They provide for minimal reconfiguration of the SerDes Phase

Locked Loop (PLL), hence faster convergence, when data rates change over the network interface. Because SGMII and QSGMII do not support 2.5Gbps or 5Gbps data rates, Cisco Systems has defined the Universal Serial XGMII (USXGMII) for use in NBASE-T product development. USXGMII supports 100M, 1G, 2.5G, 5G and 10Gps data rates on a single SerDes operating at 10.3125 Gbps. For cost optimization, USXGMII can alternatively operate at 5Gbps, while supporting 100M, 1G, 2.5 and 5G traffic.

Link Segment

The Link Segment specified by IEEE 802.3bz defines cable and RJ45 connector termination requirements between two endpoints. The specification encompasses link bandwidth, insertion loss, return loss, and cross-talk, both between the four twisted pairs of the link segment, and between adjacent cables (i.e. alien crosstalk). The NBASE-T Alliance initiated development of 2.5/5Gigabit Link Segment specifications, contributed these specifications to the IEEE 802.3bz Task Force, and this important work was incorporated in the IEEE 802.3bz standard. NBASE-T member companies were key contributors to TIA TR42.7 and ISO/IEC SC25 WG3 technical reports, which describe how 2.5GBASE-T and 5GBASE-T may be used on installed Category 5e and Category 6 cabling. Because NBASE-T specifies the same PCS/PMA as 802.3bz, NBASE-T PHYs are fully compatible with the 802.3bz link segment.

Filling an immediate need

In an ideal world, product development occurs after standards are in place. When this cannot be the case, the best possible solution to bridge a pre-standard gap is one put forth by industry leaders that have the influence, incentive and interdependence to ensure that interim solutions will be compliant with, or at least software-upgradeable to, the standard when ratified. In the case of 2.5GBASE-T and 5GBASE-T, there was a gap. Industry leaders stepped up to foster early consensus and interoperability across the ecosystem, laying important groundwork to accelerate the standards process and ensure compliance of products developed pre-standard.

Given the palpable demand for data rates between 1000BASE-T and 10GBASE-T Ethernet over legacy infrastructure, 2.5 and 5 Gigabit Ethernet is a critical addition to the suite of current networking standards, with immediate applications. The NBASE-T Alliance played a key role in recognizing this need, laid credible, vetted groundwork for the smooth adoption of a viable standard and provided pre-standard specifications and products that are compliant, or require no more than a software/firmware update to be compliant, with the standard. As a result of these efforts, enterprises finding themselves constrained by Gigabit Ethernet have confidently and cost-effectively accessed data rates by two- to five-fold over their existing cabling infrastructure.

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