The Spaces of BASE-T

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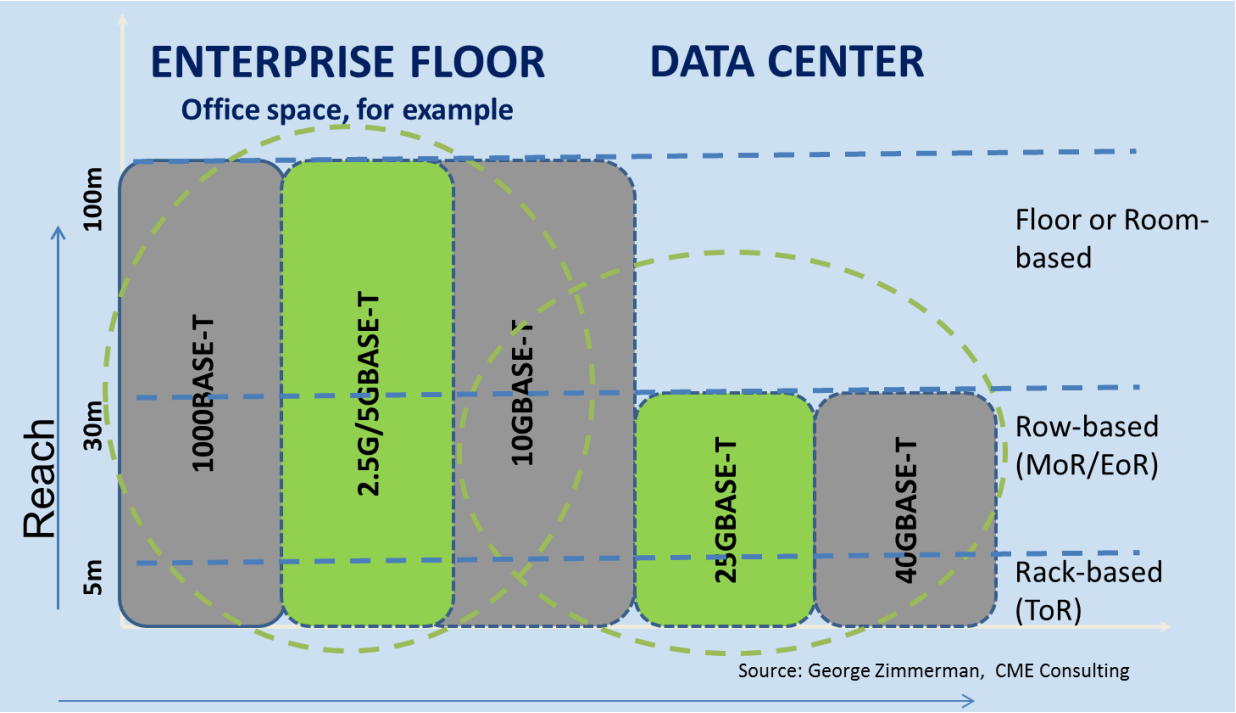
1. Introduction

Until recently, conventional wisdom has had it that twisted pair, or BASE-T Ethernet was the one-size fits all solution for in-building mass-market Ethernet data transfer. So ubiquitous is BASE-T that the specified connector for it, the familiar RJ-45 plug and jack, are popularly associated as 'the Ethernet connector'. From 10 to 100 to 1000BASE-T, general purpose wired Ethernet progressed regularly as the preferred port in data center, enterprise, home, and even industrial applications with a single PHY used in all segments. One hundred meter reach in category cabling was the norm under all use cases. Each next speed fit neatly into the use cases and applications of the last, and it was only a matter of time before cost and power moved to the point where port speed increased in all use cases. As a result, new speeds were introduced one at a time in a steady progression, ubiquitous across in-building networks.

However, recent standard efforts see multiple new speeds of BASE-T Ethernet offered into the market place more or less simultaneously. While 10GBASE-T is belatedly ramping in the market, it coexists with a continually growing 1000BASE-T, new offerings at 2.5 Gb/s and 5 Gb/s, and new standards developments for 25G and 40GBASE-T. These only include the variants that use structured 4-pair copper cabling. There are also the BASE-T1 (single-pair) 100 Mb/s and 1000 Mb/s BASE-T Ethernet variants which have more obvious differentiated applications (e.g. Automotive). Even among the 4-pair BASE-Ts, each has its own applications space and use model, which can roughly be divided into two major segments - Enterprise floor and Data center. Additionally, each major segment has several performance niches diversifying the BASE-T Ethernet PHY universe beyond its traditional one-size-fits-all approach. This whitepaper will examine the various segments and niches, and explain how they fill out the 'Spaces of BASE-T'.



2. Enterprise Floor Ethernet:

Serving access to the enterprise floor is the traditional stronghold of BASE-T Ethernet. With support for a flexible installed base of structured category 5e, 6, and 6a cabling at 100-meter reach, BASE-T Ethernet is still the workhorse for delivering data to the enterprise floor, and each BASE-T Ethernet technology fills its own space.

BASE-T serves an enterprise environment consisting primarily of installed cabling plants where cabling was installed in the late 1990s to early 2000s, and therefore designed for the applications of that era. Category 5e cabling was designed and installed to support Fast Ethernet and Gigabit Ethernet (100BASE-T and 1000BASE-T) specified to 100 MHz frequency and without specifications for higher frequencies or interference between cables. Category 6 cabling was designed to provide headroom for Gigabit Ethernet, extending performance to higher frequencies but still not specifying interference between cables. In the 2000's as the cabling needs of 10GBASE-T technology became apparent, Category 6a cabling was introduced with performance to even higher frequencies and specifications to limit interference between cables.

100/1000BASE-T: Still the default connection

For many reasons - application needs at individual nodes, cost, power, limited I/O capabilities of single user endpoints, and support for category 5e cabling, which remains the lowest common denominator of LAN wiring common today - 100/1000BASE-T is still the universal connection on the enterprise floor for PCs, printers, and wireless access points. All other enterprise BASE-T Ethernet PHYs emulate it and provide improvements. Each has 100-meter reach, but each increases speed with increasing demands on the cabling, serving applications that demand higher speeds.

10GBASE-T: The high-end of performance

10GBASE-T came along next chronologically. It was intended to follow 1000BASE-T in the normal succession of speeds in the one-size-fits-all paradigm that used to rule BASE-T Ethernet. Today 10GBASE-T is available for the highest speed needs on the enterprise floor. Like 1000BASE-T, it supports 100-meter reach using newer category 6a cabling to guarantee the distance, and also runs for shorter distances on category 6 cabling. 10GBASE-T serves those enterprise floor applications that need its speed and will continue to grow. However, in the enterprise environment there is a lot of room for solutions between 1 Gb/s and 10 Gb/s, and the mature installed base of cabling is a valuable asset with a long lifetime.

2.5G and 5GBASE-T: Emerging to migrate networks to higher speed

2.5G and 5GBASE-T enter the picture to fill the void between 1 Gb/s and 10Gb/s in the application space. With two new PHYs users can make optimal use of the configuration of their installed cabling which may stretch to 100-meter reach. However, when used with older cabling types than category 6a there may be variable interference between links according to the particular installation's capability. The IEEE P802.3bz objectives call these 'use cases', referring mainly to the ratio of cable length and interference and, in the case of category 5e, high frequency performance of the cable plant. These scenarios for 2.5G and 5GBASE-T will be influenced by cabling topologies, quality, and installation practices.

Both speeds will support 100-meter reach on installed category 5e and category 6 cabling, although the use cases for the lower speed will be broader than those of the higher speed. Of course, both 2.5G and 5GBASE-T are expected to work at 100 meters without restriction on category 6a cabling. As a result, these new PHYs offer a bridge to higher speed for existing 100-meter BASE-T networks, and intermediate speed operation on newer networks. Initially these new speeds will serve multi user

nodes such as wireless access points demanding aggregated speed but it is expected that the speed jump from 1 Gb/s to 2.5 Gb/s will begin the long delayed speed migration of single-user end stations up from 1000BASE-T on the enterprise floor.

3. Data Center Server Access

Concurrently the market sees increasing networking speed demands in the data center. Recent trends have seen data center architectures become optimized around switching local either to a row of server racks (e.g., middle- or end-of-row) or to a rack of servers (e.g., top-of-rack). This has resulted in shorter distances between servers and access switches. Server configurations and performance have continued to diversify resulting in highly varied needs for speed.

Cabling surveys put the majority of links in data centers well below 50 meters. Studies performed during the study group leading to the IEEE P802.3bq 25G/40GBASE-T concluded that a 30-meter maximum distance would well cover the end of row application.

1000BASE-T: Workhorse and management networks

In the data center 1000BASE-T is still a workhorse, but often more for managing devices in the control plane than for data plane server and storage-access networking. Lower performance legacy devices may use 1000BASE-T. Massive arrays of micro servers (resulting in high port growth) may be individually connected at speeds of 1 Gb/s. However hyperscale cloud data centers have long since shifted to 10 Gb/s, and even enterprise and smaller business server links are now migrating to 10 Gb/s with the emergence of 10GBASE-T

10GBASE-T: Emerging in enterprise and smaller data centers

The shift of cloud data centers to 10 Gb/s preceded the commercial deployment of 10GBASE-T. As recently as 2011 many declared BASE-T as finished in the data center for all but management and low speed applications. Today however, 10GBASE-T is shipping in servers and access switches, and is emerging on the enterprise and smaller data center space as a cost effective solution for those still migrating to 10 Gb/s speeds. 10GBASE-T's use of category 6 and 6a cabling bridges nicely from the emerging enterprise floor applications and provides an entry point to 10 Gb/s networking. Most 10GBASE-T PHYs save significant power operating at the reduced

distances found in data centers, such as 30 meters, making them even more attractive as data center reaches decrease. As the broader market of smaller data centers moves to 10 Gb/s BASE-T fills that space with 10GBASE-T.

25GBASE-T and 40GBASE-T: Re-emerging for higher speed server access

For the next generation of server interconnect, BASE-T appears optimized in both time and reach. The IEEE P802.3bq Task Force is making excellent progress on a standard for 25G and 40GBASE-T PHYs as the cloud data center begins to move to 25 Gb/s server access.

25GBASE-T is expected to develop on a fast track because of the work already done to define 40GBASE-T, and because of its lower complexity, to come out at a competitive cost/power point. 25GBASE-T will be developed concurrently with the 25Gb/s single lane twin ax standards effort (IEEE P802.3by) to complement applications of 25 Gb/s Ethernet by additionally enabling flexible end of row and top of rack server interconnections. 40GBASE-T is expected to serve a higher performance part of the server market in similar data center architectures, and is expected to have a more delayed and specialized growth ramp than 25GBASE-T. Much of its application is dependent on the directions 40Gb/s Ethernet takes in the access network. 40GBASE-T technology may yet additionally produce a quick specification for a 50 Gb/s BASE-T Ethernet, potentially on the same cabling infrastructure.

The cabling infrastructure for higher speed BASE-T Ethernet has consolidated. Both 25GBASE-T and 40GBASE-T PHYs are expected to use 'link segments' with a 30 meter distance for structured end-of-row applications but with a 5 meter 'direct attach' specification for within-rack applications. The cabling industry has responded in advance, developing category 8 cabling and components (and ISO Class I/Class II channels) characterized to 2 GHz for these applications beyond 10 Gb/s. The result is that the data center infrastructure has completed its migration to an application space differentiated from that on the enterprise floor enabling data center designers to plan for at least a quad speed (1G, 10G, 25G, and 40 Gb/s) infrastructure and possible support of 50 Gb/s in the future.

4. Conclusion

The diversity in the BASE-T world represents a healthy segmentation of the market into two primary applications each with its own needs. The previous conventional wisdom of 10x exponential speed steps has given way to incremental speed steps to serve each market segment. This better fits the demands of end stations, maturing legacy infrastructure, and bandwidth needs of access networking. On the enterprise floor where 100m reach is a necessity, the use of 1000BASE-T continues to grow but is now augmented by 2.5G, 5G and 10GBASE-T on cabling categories from 5e up to 6a. Meanwhile, many data centers are converging on a rack or row based architecture up to 30 meters using newer cabling categories from 6a to 8. This topology supports BASE-T speeds from 10 Gb/s to 25 Gb/s and 40Gb/s in development now and a possible 50G not far behind. BASE-T technologies will continue to adapt and evolve to fill diverse spaces as Ethernets continues to add new markets.

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