10 Gigabit Ethernet Technical Brief

Introduction

Since the ratification of the IEEE 802.3ae 10 Gigabit Ethernet standard in June 2002, the penetration of 10 Gigabit Ethernet has rapidly increased. The June 2006 ratification of the IEEE 802.3an 10GBASE-T, 10 Gigabit Ethernet over UTP has further extended this trend. As more and more bandwidth-intensive and latency-sensitive applications are deployed in enterprises, data centers and service provider networks, 10 Gigabit Ethernet has gained market acceptance due to the plug-and-play simplicity of the Ethernet standard and its inexpensive wiring options. 10 Gigabit Ethernet is the natural migration path for forward-thinking enterprise, data center and service provider architects.

10 Gigabit Ethernet IEEE Standard Interfaces

In June of 2002 the IEEE 802.3ae committee ratified the 10 Gigabit Ethernet standard and along with the general specification, defined a number of fiber optic interfaces as shown in Figure 1.

These standard interfaces attempted to satisfy a number of different objectives including support for Multimode Fiber (MMF), Single-Mode Fiber (SMF) and SONET compatibility. Of the seven interfaces that were standardized in 2002, only 10GBASE-LR, 10GBASE-ER and to a lesser extent 10GBASE-SR have gained broad market acceptance. In order to meet market demands, 10 Gigabit Ethernet standardization efforts are evolving. There are several new 10 Gigabit Ethernet interfaces that have been proposed and are in various stages of development and standardization. Below is brief comment on each interface and its level of market acceptance.

- **10GBASE-SR**—The relatively short distances (30–80 meters on traditional MMF) that can be achieved with this interface limit its use to within a data center. A typical use for the 10GBASE-SR in a data center is to interconnect two Ethernet switches or to link an end-device (e.g. 10 Gigabit Ethernet server or storage device) to an Ethernet switch.
- **10GBASE-LR**—The 10GBASE-LR is by far one of the most popular 10 Gigabit Ethernet interfaces. The 10GBASE-LR is being used for most every 10 Gigabit Ethernet need and will likely continue to be one of the most popular interfaces of choice for the foreseeable future.
- **10GBASE-LX4**—The 10GBASE-LX4 uses 4 lasers in parallel as opposed to one single serial laser source. This technical characteristic has unfortunately limited the viability of the 10GBASE-LX4 because it is simply too costly and complex to produce 10GBASE-LX4 optics in volume. As a result, most optical vendors have chosen not to develop the 10GBASE-LX4 optics for the newer MSAs such as XFP and hence there is limited availability of this interface.
- **10GBASE-ER**—Almost all 10GBASE-ER 10 Gigabit Ethernet ports are used by Ethernet service providers for inter-POP connectivity. Due to its relatively high cost, this interface will only be used when there is a need to send a 10 Gigabit Ethernet signal greater than 10 km over dark fiber.
- **10GBASE-ZR**—To accommodate the growing demand for 10 Gigabit Ethernet use for longer distance than offered by 10GBASE-ER, based upon IEEE 802.3ae's specification or 40 km, 10GBASE-ZR was introduced to provide the longest reach 10 Gigabit Ethernet optics. 10GBASE-ZR has a range of up to 80 km over dark fiber using 1550nm laser wavelength, and is typically used for inter-POP connectivity where distance is more than 40 km.
- **WAN Interfaces (SW, LW, EW)**—The sole purpose of the WAN PHY was to achieve 10 Gigabit Ethernet and SONET OC-192/STM-64 compatibility. By virtue of this purpose, this interface will only be of interest to and is primarily used by service providers.
- **10GBASE-CX4 (IEEE 802.3ak)**—10GBASE-CX4 is the copper 10 Gigabit Ethernet standard but instead of running over twisted pair it is specified to run over a twinaxial cable (the same cable used for Infiniband) with 24 gauge wire. This cable is fairly rigid and considerably more costly than Category 5 or 6 UTP. The primary applications for 10GBASE-CX4 are as a standards-compliant stacking interface (e.g. stacking interface between two individual fixed-configuration switches) and potentially for an end-device (e.g. server or NAS) attachment to an Ethernet switch in a data center. The later application has a 15 meter distance limitation.
- **SFP+ Direct Attach**—SFP+ Direct Attach is known as the successor technology to 10GBASE-CX4. SFP+ Direct Attach, as implied in the name, uses SFP+ MSA and by using the inexpensive copper twinaxial cable with SFP+ connectors on both sides, provides 10 Gigabit Ethernet connectivity between devices with SFP+ interfaces. SFP+ Direct Attach has a 10 meter distance limitation, thus the target application is interconnection of top-of-rack switches with application servers and storage devices in a rack.

10GBASE-T (IEEE 802.3an)

10GBASE-T is a copper 10 Gigabit Ethernet standard that runs over twisted pair cabling (e.g. UTP). One can think of it as the 10 Gigabit Ethernet equivalent of the 1000BASE-T standard.

The IEEE formed a 10GBASE-T working group in November 2003 and ratified a final standard in July 2006.

The principal drivers behind 10GBASE-T are low cost and utilization of widely deployed and well understood twisted pair cabling. The primary application for 10GBASE-T will be for end-device (e.g server or NAS) attachment to an Ethernet switch in a data center.

The key advantages for 10GBASE-T are as follows:

- No change to the Ethernet frame format or the minimum and maximum frame sizes
- A full duplex only standard supporting star-wired LANs with point-to-point links and structured cabling topologies
- Support for auto-negotiation
- Support for coexistence with 802.3af "Power over Ethernet" (PoE)
- Support for the following link distances:
  - Category 5e UTP – up to 55m
  - Category 6 UTP – up to 55m
  - Category 6a UTP – up to 100m

10GBASE-LRM (IEEE 802.3aq: Long Reach on FDDI-grade Multimode Fiber)

A study group was formed in November, 2003 by the IEEE to investigate the standardization of a 10 Gigabit Ethernet optical interface that will support a 300 meter distance on "FDDI grade" multimode fiber (62.5mm, 160/500 or 200/500 Mhz*km MMF). This interface is needed because 10GBASELX4 is too costly and complex to produce in volume. IEEE 802.3aq was ratified in September 2006.

The objectives for this standard are as follows:

- Leverage existing 10 Gigabit Ethernet technology (10GBASE-R PCS)
- Support the fiber media selected from IEC 60793-2-10: 2003
- At least achieve 220 meters on installed 500 MHz*km multimode fiber and achieve a distance of 300 meters on multimode fiber
- Pricing less than or equal to the price of 10GBASE-LR. This standard will require the use of a 1310nm laser, hence the price comparison to 10GBASE-LR
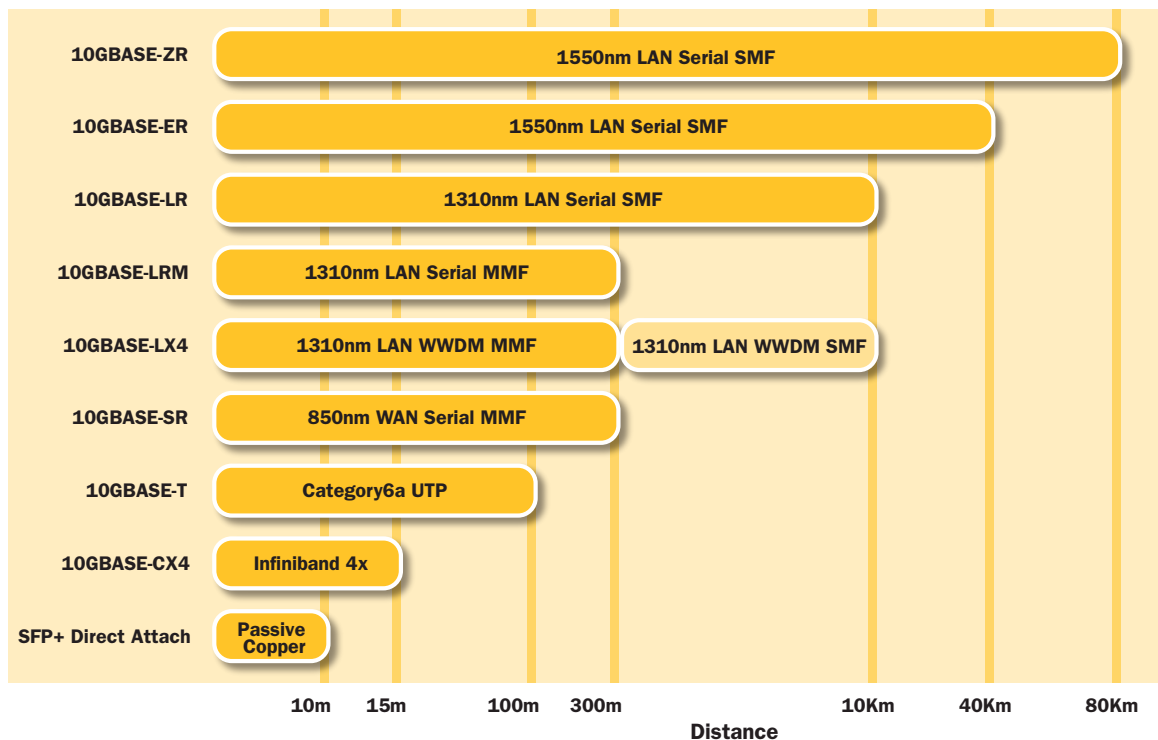

Figure 1: Fiber Optic Interfaces

10 Gigabit Ethernet Pluggable Optics

Pluggable optics are very common for Gigabit Ethernet with the ubiquitous Small Form factor Pluggable (SFP) or "mini-GBIC". 10 Gigabit Ethernet is the same and there are several separate Multi Source Agreements (MSAs) that have been specified to enable 10 Gigabit Ethernet pluggable optics. Following is a brief rundown of all 5 MSAs.

XENPAK (www.xenpak.org)—XENPAK was the most mature and widely deployed of the various 10 Gigabit Ethernet MSAs in early days of 10 Gigabit Ethernet since it was the only MSA that could support all 10 Gigabit Ethernet standard interfaces. The XENPAK MSA was the most popular MSA for Ethernet switches.

X2 (www.x2msa.org)—X2 is a smaller version of XENPAK that is targeted at the same market as XENPAK.

XFP (www.xfpmsa.org)—XFP can best be described as a small form factor pluggable for 10 Gigabit Ethernet. It is to a XENPAK what an SFP is to a GBIC. XFP is the least mature of the various MSAs and is designed for "next generation optical transceivers". Its main advantage over the other MSAs is its size (allows for higher 10 Gigabit Ethernet port densities) and lower power consumption, and XFP is one of the most commonly used 10 Gigabit Ethernet MSA.

SFP+—SFP+ is the newest pluggable optics technology. It is targeted at the high density 10 Gigabit Ethernet implementations, especially data center networks. With its smallest form factor and lowest power consumption amongst all other MSAs, SFP+ enables much higher port density for Ethernet switches and 10 Gigabit Ethernet Adapters. SFP+ can support both optical transceivers and SFP+ passive copper cables to provide flexible and cost-effective 10 Gigabit Ethernet solutions particularly for shorter distance.

Note: A 10 Gigabit Ethernet MSA is simply an agreement on the physical, thermal and mechanical characteristics of a pluggable transceiver and does not in any way impact the internal 10 Gigabit Ethernet optical or copper interface (e.g. 10GBASE-LR vs. 10GBASE-CX4) inside the pluggable. In other words, a single point-to-point link can have different MSA pluggable (e.g. XENPAK vs. XPAK) formats on either end and will work just fine as long as the 10GbE optical or copper interface (e.g. 10GBASE-SR) inside the pluggable is identical.

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