10 Gigabit Ethernet Technology Overview
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From its origin more than 25 years ago, Ethernet has evolved to meet the increasing demands of packet-switched networks. Due to its proven low implementation cost, its known reliability, and relative simplicity of installation and maintenance, its popularity has grown to the point that today nearly all traffic on the Internet originates or ends with an Ethernet connection. Further, as the demand for ever-faster network speeds has grown, Ethernet has been adapted to handle these higher speeds and the concomitant surges in volume demand that accompany them.

The One Gigabit Ethernet standard is already being deployed in large numbers in both corporate and public data networks, and has begun to move Ethernet from the realm of the local area network out to encompass the metro area network.

Meanwhile, an even faster 10 Gigabit Ethernet standard is nearing completion. This latest standard is being driven not only by the increase in normal data traffic but also by the proliferation of new, bandwidth-intensive applications. The draft standard for 10 Gigabit Ethernet is significantly different in some respects from earlier Ethernet standards, primarily in that it will only function over optical fiber, and only operate in full-duplex mode, meaning that collision detection protocols are unnecessary. Ethernet can now step up to 10 gigabits per second, however, it remains Ethernet, including the packet format, and the current capabilities are easily transferable to the new draft standard.

In addition, 10 Gigabit Ethernet does not obsolete current investments in network infrastructure. The task force heading the standards effort has taken steps to ensure that 10 Gigabit Ethernet is interoperable with other networking technologies such as SONET. The standard enables Ethernet packets to travel across SONET links with very little inefficiency.

Ethernet’s expansion for use in metro area networks can now be expanded yet again onto wide area networks, both in concert with SONET and also end-to-end Ethernet. With the current balance of network traffic today heavily favoring packet-switched data over voice, it is expected that the new 10 Gigabit Ethernet standard will help to create a convergence between networks designed primarily for voice, and the new data centric networks.

The 10 Gigabit Ethernet Standard

Under the International Standards Organization’s Open Systems Interconnection (OSI) model, Ethernet is fundamentally a Layer 2 protocol. 10 Gigabit Ethernet uses the IEEE 802.3 Ethernet Media Access Control (MAC) protocol, the IEEE 802.3 Ethernet frame format, and the minimum and maximum IEEE 802.3 frame size.

Just as 1000BASE-X and 1000BASE-T (Gigabit Ethernet) remained true to the Ethernet model, 10 Gigabit Ethernet continues the natural evolution of Ethernet in speed and distance. Since it is a full-duplex only and fiber-only technology, it does not need the carrier-sensing multiple-access with collision detection (CSMA/CD) protocol that defines slower, half-duplex Ethernet technologies. In every other respect, 10 Gigabit Ethernet remains true to the original Ethernet model.

An Ethernet PHYsical layer device (PHY), which corresponds to Layer 1 of the OSI model, connects the media (optical or copper) to the MAC layer, which corresponds to OSI Layer 2. Ethernet architecture further divides the PHY (Layer 1) into a Physical Media Dependent (PMD) and a Physical Coding Sublayer (PCS). Optical transceivers, for example, are PMDs. The PCS is made up of coding (e.g., 64/66b) and a serializer or multiplexing functions.

The 802.3ae specification defines two PHY types: the LAN PHY and the WAN PHY (discussed below). The WAN PHY has an extended feature set added onto the functions of a LAN PHY. These PHYs are solely distinguished by the PCS. There will also be a number of PMD types.
10 Gigabit Ethernet in the Marketplace

The accelerating growth of worldwide network traffic is forcing service providers, enterprise network managers and architects to look to ever higher-speed network technologies in order to solve the bandwidth demand crunch. Today, these administrators typically use Ethernet as their backbone technology. Although networks face many different issues, 10 Gigabit Ethernet meets several key criteria for efficient and effective high-speed networks:

• Easy, straightforward migration to higher performance levels without disruption,

• Lower cost of ownership vs. current alternative technologies – including both acquisition and support costs

• Familiar management tools and common skills base

• Ability to support new applications and data types

• Flexibility in network design

• Multiple vendor sourcing and proven interoperability

Managers of enterprise and service provider networks have to make many choices when they design networks. They have multiple media, technologies, and interfaces to choose from to build campus and metro connections: Ethernet (100, 1000, and 10,000 Mbps), OC-12 (622 Mbps) and OC-48 (2.488 Gbps), SONET or equivalent SDH network, packet over SONET/SDH (POS), and the newly authorized IEEE 802 Task Force (802.17) titled Resilient Packet Ring.

Network topological design and operation has been transformed by the advent of intelligent Gigabit Ethernet multi-layer switches. In LANs, core network technology is rapidly shifting to Gigabit Ethernet and there is a growing trend towards Gigabit Ethernet networks that can operate over metropolitan area distances.

The next step for enterprise and service provider networks is the combination of multi-gigabit bandwidth with intelligent services, leading to scaled, intelligent, multi-gigabit networks with backbone and server connections ranging up to 10 Gbps. In response to market trends, Gigabit Ethernet is currently being deployed over tens of kilometers in private networks. With 10 Gigabit Ethernet, the industry has developed a way to not only increase the speed of Ethernet to 10 Gbps but also to extend its operating distance and interconnectivity. In the future, network managers will be able to use 10 Gigabit Ethernet as a cornerstone for network architectures that encompass LANs, MANs and WANs using Ethernet as the end-to-end, Layer 2 transport method.

**Ethernet bandwidth** can then be scaled from 10 Mbps to 10 Gbps – a ratio of 1 to 1000 — without compromising intelligent network services such as Layer 3 routing and layer 4 to layer 7 intelligence, including quality of service (QoS), class of service (CoS), caching, server load balancing, security, and policy based networking capabilities. Because of the uniform nature of Ethernet across all environments when IEEE 802.3ae is deployed, these services can be delivered at line rates over the network and supported over all network physical infrastructures in the LAN, MAN, and WAN. At that point, convergence of voice and data networks, both running over Ethernet, becomes a very real option. And, as TCP/IP incorporates enhanced services and features, such as packetized voice and video, the underlying Ethernet can also carry these services without modification.

As we have seen with previous versions of Ethernet, the cost for 10 Gbps communications has the potential to drop significantly with the development of new technologies. In contrast to 10 Gbps telecommunications lasers, the 10 Gigabit Ethernet short links — less than 40km over single-mode (SM) fiber — will be capable of using lower cost, uncooled optics and, in some cases, vertical cavity surface emitting lasers (VCSEL), which have the potential to lower PMD costs. In addition, the industry is supported by an aggressive merchant chip market that provides highly integrated silicon solutions. Finally, the Ethernet market tends to spawn highly competitive start-ups with each new generation of technology to compete with established Ethernet vendors.
Interoperability Demos

One of the keys to Ethernet’s success is the widespread interoperability between vendors. In keeping with its mission to provide resources to establish and demonstrate multi-vendor interoperability of 10 Gigabit Ethernet products, the 10 GEA hosted the world’s largest 10 Gigabit Ethernet Interoperability Network in May, 2002. The live, multi-vendor network was on display at the NetWorld+Interop trade show in Las Vegas, Nevada. The network will also be on display at SuperComm, June 4-7, 2002 in Atlanta Georgia.

Comprised of products from 23 vendors, the network included a comprehensive range of products: systems, test equipment, components and cabling. The end-to-end 10GbE network was over 200 kilometers long and showcased five of the seven PMD port types specified in the IEEE 802.3ae draft: 10GBASE-LR, 10GBASE-ER, 10GBASE-SR 10GBASE-LW and 10GBASE-LX4. The network boasted 10 network hops, 18 10 GbE links, and represented all aspects of the technology; WAN, MAN and LAN.

As part of the demonstration 12 companies showed chip-to-chip communication over the IEEE 802.3ae XAUI interface. The collection of products and technologies illustrate years of industry collaboration and signal to the market that 10 Gigabit Ethernet is ready to be deployed and implemented into networks around the world.

Applications for 10 Gigabit Ethernet

10 Gigabit Ethernet in the Metro

Vendors and users generally agree that Ethernet is inexpensive, well understood, widely deployed and backwards compatible from Gigabit switched down to 10 Megabit shared. Today a packet can leave a server on a short-haul optic Gigabit Ethernet port, move cross-country via a DWDM (dense wave division multiplexing) network, and find its way down to a PC attached to a “thin coax” BNC (Bayonet Neill Concelman) connector, all without any re-framing or protocol conversion. Ethernet is literally everywhere, and 10 Gigabit Ethernet maintains this seamless migration in functionality.

Gigabit Ethernet is already being deployed as a backbone technology for dark fiber metropolitan networks.

10 Gigabit Ethernet interfaces, optical transceivers and single mode fiber, service providers will be able to build links reaching 40km or more.

With 10 Gigabit backbones installed, companies will have the capability to begin providing Gigabit Ethernet service to workstations and, eventually, to the desktop in order to support applications such as streaming video, medical imaging, centralized applications, and high-end graphics. 10 Gigabit Ethernet will also provide lower network latency due to the speed of the link and over-provisioning bandwidth to compensate for the bursty nature of data in enterprise applications.
Additionally, 10 Gigabit Ethernet will provide infrastructure for both network-attached storage (NAS) and storage area networks (SAN). Prior to the introduction of 10 Gigabit Ethernet, some industry observers maintained that Ethernet lacked sufficient horsepower to get the job done. Ethernet, they said, just doesn’t have what it takes to move “dump truck loads worth of data.” 10 Gigabit Ethernet, can now offer equivalent or superior data carrying capacity at similar latencies to many other storage networking technologies including 1 or 2 Gigabit Fiber Channel, Ultra160 or 320 SCSI, ATM OC-3, OC-12 & OC-192, and HIPPI (High Performance Parallel Interface). While Gigabit Ethernet storage servers, tape libraries and compute servers are already available, users should look for early availability of 10 Gigabit Ethernet end-point devices in the second half of 2001.

There are numerous applications for Gigabit Ethernet in storage networks today, which will seamlessly extend to 10 Gigabit Ethernet as it becomes available. These include:

- Business continuance/disaster recovery
- Remote backup
- Storage on demand
- Streaming media

10 Gigabit Ethernet will enable Internet service providers (ISP) and network service providers (NSPs) to create very highspeed links at a very low cost, between co-located, carrier-class switches and routers and optical equipment that is directly attached to the SONET/SDH cloud. 10 Gigabit Ethernet with the WAN PHY will also allow the construction of WANs that connect geographically dispersed LANs between campuses or POPs (points of presence) over existing SONET/SDH/TDM networks. 10 Gigabit Ethernet links between a service provider’s switch and a DWDM (dense wave division multiplexing) device or LTE (line termination equipment) might in fact be very short — less than 300 meters.

10GbE Chip Interfaces

Among the many technical innovations of the 10 Gigabit Ethernet Task Force is an interface called the XAUI (10 Gigabit Attachment Unit Interface). It is a MAC-PHY interface, serving as an alternative to the XGMII (10 Gigabit Media Independent Interface). XAUI is a low pin-count differential interfaces that enables lower design costs for system vendors.

The XAUI is designed as an interface extender for XGMII, the 10 Gigabit Media Independent Interface. The XGMII is a 74 signal wide interface (32-bit data paths for each of transmit and receive) that may be used to attach the Ethernet MAC to its PHY. The XAUI may be used in place of, or to extend, the XGMII in chip-to-chip applications typical of most Ethernet MAC to PHY interconnects.

Conclusion

As the Internet transforms longstanding business models and global economies, Ethernet has withstood the test of time to become the most widely adopted networking technology in the world. Much of the world’s data transfer begins and ends with an Ethernet connection. Today, we are in the midst of an Ethernet renaissance spurred on by surging E-Business and the demand for low cost IP services that have opened the door to questioning traditional networking dogma. Service providers are looking for higher capacity solutions that simplify and reduce the total cost of network connectivity, thus permitting profitable service differentiation, while maintaining very high levels of reliability.

Enter 10 Gigabit Ethernet. Ethernet is no longer designed only for the LAN. 10 Gigabit Ethernet is the natural evolution of the well-established IEEE 802.3 standard in speed and distance. It extends Ethernet’s proven value set and economics to metropolitan and wide area networks by providing:

- Potentially lowest total cost of ownership (infrastructure/operational/human capital)
- Straightforward migration to higher performance levels
- Proven multi-vendor and installed base interoperability (Plug and Play)
- Familiar network management feature set
An Ethernet-optimized infrastructure build out is taking place. The metro area is currently the focus of intense network development to deliver optical Ethernet services. 10 Gigabit Ethernet is on the roadmaps of most switch, router and metro optical system vendors to enable:

- Cost effective Gigabit-level connections between customer access gear and service provider POPs (points of presence) in native Ethernet format
- Simple, very high speed, low-cost access to the metro optical infrastructure
- Metro-based campus interconnection over dark fiber targeting distances of 10/40km and greater
- End to end optical networks with common management systems

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