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The Once and Future Ethernet

By Daniel Svensson 05.01.2001 0

The year 2001 will likely be known as the year when Ethernet led the network convergence. This proven transmission technology is uniquely poised to span LANs as well as MANs and WANs. This year, the first real 10 Gigabit Ethernet products will emerge, enabling the combination of LANs, MANs, and WANs by providing Ethernet that is fast enough for all types of networks. With convergence, however, comes special challenges for futureEthernet designers.

Over the past two decades, Ethernet has grown into the most widely used technology for LANs. Gigabit Ethernet, on the other hand, has found its way into MANs and WANs but has met resistance in the legacy marketplace. The new Ethernet standard, 10 Gigabit Ethernet, will not only be 10 times faster than its predecessor, but is designed to promote the convergence of networking technologies. Therefore, Ethernet is an obvious choice for network architects since it combines simplicity, cost-effectiveness, flexibility, and scaleability. With 10 Gigabit Ethernet, these advantages can be
applied to all kinds of networks.

A brief history

Ethernet was invented by Robert Metcalfe in the mid-1970s. In the early 1980s, the Institute of Electrical and Electronics Engineers (IEEE) standardized the invention under the name IEEE 802.3 carrier sense multiple access with collision detection (CSMA/CD). The 802.3 work group has since created the successors Fast Ethernet (802.3u) and Gigabit Ethernet (802.3z). Currently, the work group is in the process of standardizing
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IEEE 802.3ae, the proper name for 10 Gigabit Ethernet. The finalized standard is set for a March 2002 release.

The first applications for 10 Gigabit Ethernet will most likely be campus and enterprise backbones and equipment interconnects, though ISPs are also showing great interest in early deployment. Requirements for each of these applications are quite different. In the PHY, the applications have
different distance and media characteristic requirements to support.

There are also higher-layer requirements to consider such as switching and routing, quality of service (QoS), and management support. These higher-layer requirements, however, are not described in the IEEE 802.3ae standard since Ethernet is limited to defining the PHY and the media
access control (MAC) layer.

In 2002, 10 Gigabit Ethernet will mostly likely migrate to other applications, such as the Internet backbone. This market will move slower than the previously mentioned markets, because it primarily consists of slow-moving telco giants with legacy equipment. Backbone deployments set significant requirements for flexibility on the standard. Among the standard's basic requirements is the distance criteria, which covers distances
from 100 meters to 40 kilometers.

To extend usability, the standard for 10 Gigabit Ethernet will include the option to send Ethernet over SONET/SDH, thus reusing a large portion of today's core networks. This enables ISPs to gradually approach the final goal of a converged Ethernet network. It is important to point out that Ethernet over SONET/SDH is only an alternative route for legacy networks, and, in most cases, pure Ethernet will be a superior solution.

Beyond the LAN

In the LAN environment, 10 Gigabit Ethernet will be used in enterprise networks, especially data centers/server farms and ISPs. It will initially be used for interconnection between highly aggregated data center switches and between data center floors or buildings. Typical applications include switches with one or more 10 Gigabit Ethernet ports and multiple Gigabit Ethernet ports. This follows the evolution of earlier Ethernet versions where each new Ethernet standard had been positioned in the market as a high-speed uplink alternative.

These Ethernet applications will likely emerge in 2001 and 2002, followed by multi-port 10 Gigabit Ethernet systems in 2003. At that time, 10 Gigabit Ethernet will also be used as uplinks to the MAN and WAN and a few years later, 10 Gigabit Ethernet NIC cards will emerge, opening up server-switch interconnects to use 10 Gigabit Ethernet links just as they had used Gigabit Ethernet.

The technology of choice

In the MAN/WAN, 10 Gigabit Ethernet will combine networks by making Ethernet the network technology of choice. Where dark fiber is installed, Ethernet will be an easy and low-cost alternative to

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In the MAN/WAN, 10 Gigabit Ethernet will combine networks by making Ethernet the network technology of choice. Where dark fiber is installed, Ethernet will be an easy and low-cost alternative to reach 10-Gbps data rates for 40 km or farther. 10 Gigabit Ethernet will also be a natural alternative in dense wavelength division multiplexing (DWDM) networks or in remote networks by building an Ethernet WAN. Although a pure Ethernet network is preferable, the deployment of 10 Gigabit Ethernet can be accelerated by running Ethernet over the OC-192c SONET network.

Most 10 Gigabit Ethernet applications require some kind of port aggregation. Minimizing complexity and increasing value requires a system with highly integrated semiconductors. A highly integrated system could include one switching chip with integrated MACs, which is then connected to physical interfaces, a low-cost CPU, buffer memory, and address look-up memory. The switching chip performs switching on layer 2 MAC addresses and layer 3 switching (routing) on IP or any other layer 3 addresses. Routing has become increasingly important in enterprise networks, not to mention the Internet backbone where routing by default is required.

The switching chip should also prioritize and classify data to provide QoS. The need for QoS and bandwidth management becomes increasingly important, considering the current demand for streaming voice and video. It is important that this type of traffic be intellectually prioritized, and that any QoS functions are implemented at wire-speed. So-called network processors are often proposed as the solution to QoS problems, but although most of the network processors claim QoS features, they don't have the aggregated throughput of a switch fabric and they often have limited processing power.

Figure 1 shows a simple, yet powerful system with one 10 Gigabit Ethernet port and 12 Gigabit Ethernet ports. This could be used as a "pizza box" solution with minimal cost due to the small component count. The diagram suggests single-port PHY devices, although multi-port devices already exist in the market.

There are a few considerations to make in order to design a suitable 10 Gigabit Ethernet system. Design issues a system developer must examine include the board-level media interface, the media type, the physical media dependent (PMD), and the implications of SONET compatibility.

Media interfaces

In next-generation PHY products, a greater amount of the electrical (or logic) PHY device will be combined with the optical portion to form a PHY module. Such a configuration will decrease the complexity of the systems, since the system designer must deal with one less board connection and interface in the design. Between the MAC layer and the PHY, two interfaces will be included in the 802.3ae standard: 10 Gb media independent interface (XGMII) and 10 Gb attachment unit interface (XAUI).

XGMII is a 37-b wide interface (in one direction) designed as an extrapolation of the gigabit media independent interface (GMII) for Gigabit Ethernet. XAUI, meanwhile, is a four-lane differential signal interface. XGMII is a simpler interface to build in silicon and is considered to be quite straightforward in comparison with XAUI. However, since XAUI is a differential interface, it gives room for more tolerant board layouts. While XGMII is limited to run just 3 inches, XAUI is specified to run up to 20 inches on a PCB. XAUI can also be used over backplanes, a feature that becomes increasingly important in today's scaleable applications.

The choice of which MAC-PHY interface to use will depend on the application. In early port aggregation applications with a few 10 Gigabit Ethernet ports, XGMII will prove to be the simplest, but when the number of ports increase, a narrower interface will be required to prevent an overly complicated board layout. XAUI will most likely serve as the interface of choice when designing 10 Gigabit Ethernet

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Distance and media types

PMD was one of the toughest nuts to crack in the process of defining the standard. In order to support a wide variety of distances, there must be several different PMDs in the standard. The 10 Gigabit Ethernet standard is defined around a few distance criteria. The distances and the preferred media choice are displayed in **Table 1**.

TABLE 1: The Distances of Supported PMDs

PMD	Fiber Supported
850-nm serial	65-m new multi-mode fiber (MMF)
1310-nm WWDM	300-m installed MMF or 10-km
single-mode fiber (SMF) 1310-nm serial	10-km SMF
1550-nm serial	40-km SMF

With the shortest distance supported, the 850-nm serial PMD will be used in server rooms and shorter building interconnect. However, it will require new fiber. This PMD is estimated to be the most cost effective, whereas the 1310-nm DWDM PMD is suitable for the installed base where it can run over the same distance and fiber as the Gigabit Ethernet PMD 1000Base-SX does. The 1310-nm DWDM PMD will be used in building interconnects that presently use Gigabit Ethernet.

This approach can also be used for single-mode fiber up to 10 km; the 1310-nm serial PMD is intended for single-mode fiber up to 10 km, typically MAN interconnects in campus networks and where that distance is not enough. The 1550-nm serial PMD will extend the range to 40 km, but is also estimated to carry the highest cost of the chosen PMDs.

In an effort to define a flexible standard, 10 Gigabit Ethernet seems to have ended up with a jumble of PMDs. Fortunately, there is already ongoing work for a swappable PHY module, similar to the gigabit interface converter (GBIC) for Gigabit Ethernet. The module, including the PHY logic and the optical transmitter and receiver, will simplify the changing of media type.

SONET/SDH compatibility

During the emergence of the 10 Gigabit Ethernet standard, there has been much discussion on what the SONET/SDH-compatible PHY implies. There are those that will even say that Ethernet is now just a SONET-extender. This is a totally incorrect statement, as we shall soon see.

In addition to the pure Ethernet PHY, the 10 Gigabit Ethernet stand-ard will also feature a SONET/SDH-compatible PHY that allows Ethernet frames to be sent over a SONET/SDH link. Such a network will appear as Ethernet from the edges, but will have the capability to use the SONET/SDH infrastructure. This PHY is often called a WAN-PHY – a misnomer since the PHY doesn't limit itself to the WAN, just as the LAN-PHY does not limit itself to the LAN. **Figure 2** shows a SONET network connecting two Ethernet LANs using the 10 Gigabit Ethernet WAN-PHY. The two LANs in the figure are connected by a SONET

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equipment (LTE) of the SONET ring.

The WAN-PHY is designed for speeds at OC-192c rate, i.e. 9.58 Gbps. This means that the 10 Gigabit Ether-net MAC has to decrease the data rate from 10 to 9.58 Gbps when a WAN-PHY is connected. A SONET-compatible 10 Gigabit Ethernet PHY includes a WAN interface sublayer (WIS) that converts the Ethernet frames into SONET/SDH-compatible frames.

The conversion is achieved by stuffing the Ethernet frames into the SONET payload envelope. Path, line, and section overhead figures are then calculated and added to the WAN.

In the 10 Gigabit Ethernet standard, the content of the SONET headers is minimized, and most parts of the headers are static. The SONET headers do, however, include enough information enabling a SONET/SDH management station to monitor the traffic over a WAN-PHY.

Application scenarios

While early servers incorporating 10 Gigabit Ethernet connectivity required NIC cards, these links typically needed to be aggregated to a 10 Gigabit Ethernet port. **Figure 3** shows how such a solution is accomplished. Just as in the move to Fast Ethernet, there appears to be a gradual shift towards incorporating these 10 Gigabit Ethernet ports directly on the server's PCB.

The media type of choice within the server room would be one of the short-reach PMDs, either 850-nm serial (although the supply of these may be limited) or 1350-nm wide wavelength division multiplexers, (WWDM). If the server connects distant rooms, a 1350-nm WWDM is the most reasonable alternative. Consider the system with one 10 Gigabit Ethernet port and 12 Gigabit Ethernet ports illustrated in the system in **Figure 1** . That design, perhaps using XGMII as the media interface, is a viable option for this scenario.

10 Gigabit Ethernet products should be entering the market this year, although the standard itself will not be finalized until March 2002. In order to span diverse network types, the 10 Gigabit Ethernet standard has to be flexible. Designers must choose among various media types and wrestle with several on-board design considerations, such as which media independent interface to use. Systems like the ones described in this article will drive
the emergence of this standard, and open it up for other applications enabling the converged network.

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