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Gigabit Ethernet

Abstract

In today's networks, Ethernet accounts for approximately 80% of all LAN connections, with numbers steadily increasing as Gigabit Ethernet delivers what customers need. Gigabit Ethernet offers higher performance, lower maintenance costs, lower cost of entry and increased scalability when compared to other high-speed technologies. This report presents an overview of Gigabit Ethernet, including Ethernet's current position in the industry, benefits of Gigabit Ethernet as a strategic evolution for networks, Gigabit Ethernet technology fundamentals, Gigabit Ethernet deployment scenarios and Gigabit Ethernet Performance Analysis.

1. Introduction

The Information Technology industry has seen tremendous growth and advancement in networking technologies in the last five years. Many organizations depend upon their local-area networks (LAN) and information technology infrastructure for growth, competitiveness and also for sharing of resources, information and applications. More and more users are being networked to provide connectivity to an increasing number of complex and mission-critical corporate applications. Among the many high-speed LAN technologies available (including Token Ring, ATM and FDDI), Fast Ethernet, or 100BASE-T, is the most popular one. [1]

However, the growing use of 100BASE-T connections to servers and desktops is creating a great need for an even higher-speed network technology at the backbone and server level. The most appropriate solution is Gigabit Ethernet. Gigabit Ethernet provides 1Gbps bandwidth for campus networks with the simplicity of Ethernet at lower cost than other technologies of comparable speed. It offers a natural upgrade path for current Ethernet installations, leveraging existing end stations, management tools and training. [2]

2. Benefits of Gigabit Ethernet

To support increasing bandwidth needs, Gigabit Ethernet incorporates enhancements that enable fast optical fiber connections at the physical layer of the network. It provides a tenfold increase in MAC (Media Access Control) layer data

rates to support video conferencing, complex imaging and other data-intensive applications. Gigabit Ethernet compatibility with Ethernet preserves investments in administrator expertise and support staff training, while taking advantage of user familiarity. There is no need to purchase additional protocol stacks or invest in new middleware. Just as 100Mbps Fast Ethernet provided a low-cost, incremental migration from 10Mbps Ethernet, Gigabit Ethernet will provide the next logical migration to 1000Mbps bandwidth. [3]

2.1 Easy Migration to Higher Performance Levels

One of the most important questions network administrators face is how to get higher bandwidth without disrupting the existing network. Gigabit Ethernet follows the same form, fit and function as its 10 Mbps and 100 Mbps Ethernet precursors, allowing a straightforward, incremental migration to higher-speed networking. All three Ethernet speeds use the same IEEE 802.3 frame format, full-duplex operation and flow control methods. In half-duplex mode, Gigabit Ethernet employs the same fundamental CSMA/CD access method to resolve contention for the shared media. And, Gigabit Ethernet uses the same management objects defined by the IEEE 802.3 group. Gigabit Ethernet is Ethernet, only faster. [4]

2.2 Decreased Overall Costs Over Time

Cost is an important factor in evaluating any new networking technology. The overall cost includes not only the purchase price of equipment, but also the cost of training, maintenance and troubleshooting. [3]

- Competition and economies of scale have driven the purchase price of Ethernet connections down significantly.
- Switched Gigabit Ethernet connections are lower in cost than 622 Mbps ATM interfaces (assuming identical physical media interfaces).
- Over time, advances in silicon, including 0.35-micron CMOS ASIC technology, will provide even greater performance gains and cost reduction opportunities that will result in a new, even more cost-effective generation of Ethernet technology.
- Because the installed base of users is already familiar with Ethernet technology, maintenance and troubleshooting tools, the support costs associated with Gigabit Ethernet will be far lower than other technologies.

- Deployment of Gigabit Ethernet will be faster than alternative technologies. Once upgraded with training and tools, network support staff will be able to confidently install, troubleshoot and support Gigabit Ethernet installations.

So Gigabit Ethernet will decrease the overall cost significantly over time. [4]

2.3 Supports for New Applications and Data Types

The emergence of intranet applications portends a migration to new data types, including video and voice. In the past it was thought that video might require a different networking technology. But today it is possible to mix data and video over Gigabit Ethernet through a combination of the following:

- Increased bandwidth provided by Gigabit Ethernet, enhanced by LAN switching.
- The emergence of new protocols, such as Resource Reservation Protocol (RSVP), that provides bandwidth reservation.
- The emergence of new standards such as 802.1Q and 802.1p that will provide virtual LAN (VLAN) and explicit priority information for packets in the network.
- The widespread use of advanced video compression such as MPEG-2.

These technologies and protocols combine to make Gigabit Ethernet an extremely attractive solution for the delivery of video and multimedia traffic. [4]

2.4 Flexible Internetworking and Network Design

Network administrators today face a myriad of internetworking choices and network design options. They are combining routed and switched networks, and building intranets of increasing scale. Ethernet networks are shared (using repeaters) and switched based on bandwidth and cost requirements. The choice of a high-speed network, however, should not restrict the choice of internetworking or network topology. All of today's internetworking technologies, as well as emerging technologies such as IP-specific switching and layer 3 switching, are fully compatible with Gigabit Ethernet, just as they are with Ethernet and Fast Ethernet. Gigabit Ethernet is available in a shared, repeated hub (with the accompanying low cost per port) as well as on LAN switches and routers. [4]

3. How Gigabit Ethernet Works:

Gigabit Ethernet uses the same IEEE 802.3 Ethernet frame format and same frame size, and a compatible full or half duplex carrier sense multiple access/collision detection (CSMA/CD) schemes scaled to gigabit speeds. [5]

3.1 Ethernet Frame Format

It is simple to connect existing lower-speed Ethernet devices to Gigabit Ethernet devices using LAN switches or routers to adapt one physical line speed to the other. Gigabit Ethernet uses the same variable-length (64 to 1514 byte packets) IEEE 802.3 frame format found in Ethernet and Fast Ethernet (Table 1). [1]

Bytes 7	1	6	6	2	46 – 1500	4
Preamble	SFD	Destination Address	Source Address	Length of Data field	Protocol Header, Data and Pad	FCS

SFD = Start Frame Delimiter

FCS = Frame Check Sequence (for cyclic redundancy check)

Table 1. IEEE 802.3 Frame

Because the frame format and size are the same for all Ethernet technologies, no other network changes are necessary. This evolutionary upgrade path allows Gigabit Ethernet to be seamlessly integrated into existing Ethernet and Fast Ethernet networks. In contrast, other high-speed technologies use fundamentally different frame formats. High-speed ATM, for example, implements a fixed-length data cell. When connecting Ethernet and Fast Ethernet to ATM, the switch or router must translate each ATM cell to an Ethernet frame, and vice versa. [1]

3.2 Full and Half-Duplex Operation

Like its predecessor, Gigabit Ethernet operates in either half-duplex or full-duplex mode. Gigabit Ethernet also employs standard Ethernet flow control methods to avoid congestion and overloading. [5]

3.2.1 Enhanced CSMA/CD

Gigabit Ethernet adopts the same fundamental CSMA/CD access method to resolve contention for the shared media. As a result, the maximum network diameter used to connect nodes is limited by the CSMA/CD protocol. IEEE 802.3 (10BaseT) defined the original CSMA/CD mechanism that is illustrated in Figure 2. [4]

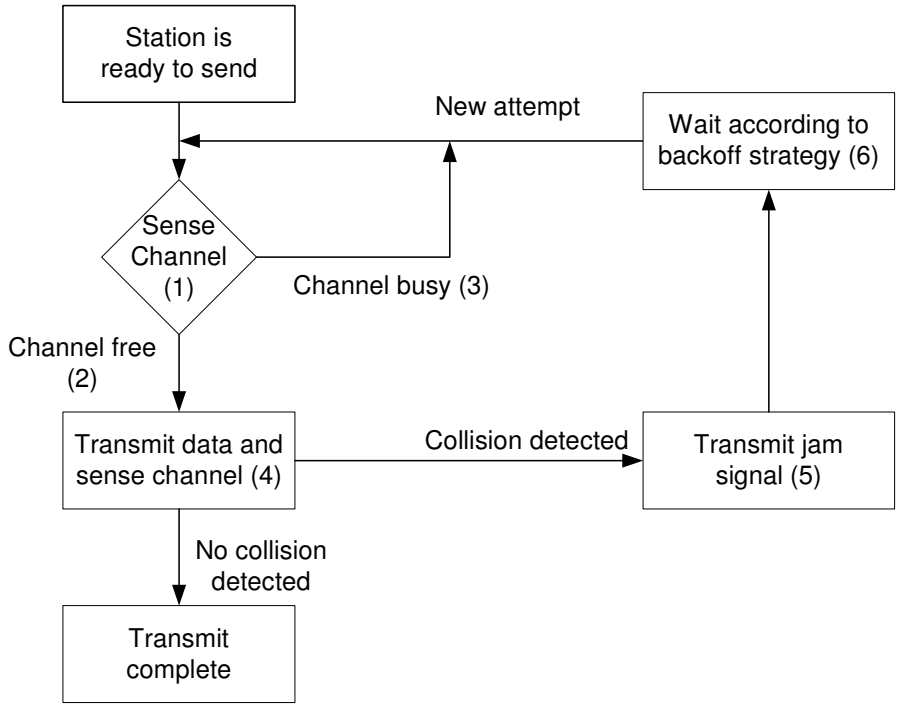

Figure 2. CSMA/CD Flow Chart

The Gigabit Ethernet CSMA/CD method has been enhanced in order to maintain a 200-meter collision diameter at gigabit speeds. Without this enhancement, minimum-sized Ethernet packets could complete transmission before the transmitting station senses a collision, thereby violating the CSMA/CD method. [4]

To resolve this issue, both the minimum CSMA/CD carrier time and the Ethernet slot time have been extended from their present value of 64 bytes to a new value of 512 bytes. (Note that the minimum packet length of 64 bytes has not been affected.) Packets smaller than 512 bytes have an extra carrier extension. Packets longer than 512 bytes are not extended. These changes, which can impact small packet performance, have been offset by incorporating a new feature called packet bursting, into the CSMA/CD algorithm. Packet bursting will allow servers, switches and other devices to send bursts of small packets in order to fully utilize available bandwidth. [5]

Devices that operate in full-duplex mode (switches and buffered distributors) are not subject to the carrier extension, slot time extension or packet bursting changes. Full-duplex devices will continue to use the regular Ethernet 96-bit interframe gap (IFG) and 64-byte minimum packet size. [7]

3.2.2 Full-duplex Operation

Full-duplex networks are very efficient since data can be sent and received simultaneously. However, full-duplex transmission can be used for point-to-point connections only. Since full-duplex connections cannot be shared, collisions are eliminated. This setup eliminates most of the need for the CSMA/CD access control mechanism because there is no need to determine whether the connection is already being used. [5]

When Gigabit Ethernet operates in full duplex mode, it uses buffers to store incoming and outgoing data frames until the MAC layer has time to pass them higher up the legacy protocol stacks. During heavy traffic transmissions, the buffers may fill up with data transfer than the MAC can process them. When this occurs, the MAC layer prevents the upper layers from sending until the buffer has room to store more frames; otherwise, frames would be lost due to insufficient space.
In the event that the receive buffers approach their maximum capacity, a high water mark interrupts the MAC control of the receiving node and sends a signal to the sending node instructing it to halt packet transmission for a specified period of time until the buffer can catch up. The sending node stops packet transmission until the time interval is past or until it receives a new packet from the receiving node with a time interval of zero. It then resumes packet transmission. The high water mark ensures that enough buffer capacity remains to give the MAC time to inform the other devices to shut down the flow of data before the buffer capacity overflows. Similarly, there is a low water mark to notify the MAC control when there is enough open capacity in the buffer to restart the flow of incoming data. [6]

Full-duplex transmission can be deployed between ports on two switches, a workstation and a switch port, or between two workstations. Full-duplex connections cannot be used for shared-port connections, such as a repeater or hub port that connects multiple workstations. Gigabit Ethernet is most effective when running in the full-duplex, point-to-point mode where full bandwidth is dedicated between the two end-nodes. Full-duplex operation is ideal for backbones and high-speed server or router links. [7]

3.2.3 Half-duplex Operation

For half-duplex operation, Gigabit Ethernet will use the enhanced CSMA/CD access method. With CSMA/CD, the same channel can only transmit or receive at one time. A collision results when a frame sent from one end of the network collides

with another frame. Timing becomes critical if and when a collision occurs. If a collision occurs during the transmitting of a frame, the MAC will stop transmitting and retransmit the frame when the transmission medium is clear. If the collision occurs after a packet has been sent, then the packet is lost since the MAC has already discarded the frame and started to prepare for the next frame for transmission. In all cases, the rest of the network must wait for the collision to dissipate before any other devices can transmit. [5]

In half-duplex mode, Gigabit Ethernet's performance is degraded. This is because Gigabit Ethernet uses CSMA/CD protocol that is sensitive to frame length. The standard slot time for Gigabit Ethernet is not long enough to run a 200-meter cable when passing 64-byte frames at gigabit speed. In order to accommodate the timing problems experienced with CSMA/CD when scaling half-duplex Ethernet to gigabit speed, slot time has been extended to guarantee at least a 512-byte slot time using the technique called carrier extension. The frame size is not changed; only the timing is extended. [6]

Half-duplex operation is intended for shared multi-station LANs, where two or more end nodes share a single port. Most switches enable users to select half-duplex or full-duplex operation on a port-by-port basis, allowing users to migrate from shared links to point-by-point, full-duplex links when they are ready. [5]

4. Gigabit Ethernet Products

Since Gigabit Ethernet is Ethernet, the types of Gigabit Ethernet products will be quite straightforward: switches, uplink/downlink modules, NICs, Gigabit Ethernet router interfaces, and buffered distributors. There will be pure multiport Gigabit Ethernet switches with high performance backplanes, as well as devices that have both Gigabit Ethernet and Fast Ethernet ports in the same box. Gigabit Ethernet uplinks will appear as modular upgrades for fixed-configuration Fast Ethernet devices or modular, chassis-based hubs to provide a high-speed connection to the network. Vendors of high-performance routers can be expected over time to deliver Gigabit Ethernet interfaces as well. [6]

Some Gigabit Ethernet vendors have developed buffered distributor. The buffered distributor is a full-duplex, multiport, hub-like device that interconnects two or more 802.3 links operating at 1Gbps or faster. Like an 802.3 repeater, it is a non-address-filtering device. The buffered distributor forwards all incoming packets

to all connected links except the originating link, providing a shared bandwidth domain comparable to an 802.3 collision domain. (Buffered distributors have been called "CSMA/CD in a box.") Unlike an 802.3 repeater, the buffered distributor is permitted to buffer one or more incoming frames on each link before forwarding them. There has also been technical discussion of half-duplex Gigabit Ethernet repeaters. [4]

As a shared bandwidth device, the buffered distributor should be distinguished from both routers and switches. While routers with Gigabit Ethernet interfaces may have backplanes that support bandwidths greater or less than gigabit rates, the ports attached to a Gigabit Ethernet buffered distributor s backplane share one gigabit of bandwidth. In contrast, the backplanes of high-performance, multiport Gigabit Ethernet switches will support multigigabit bandwidths. [4]

5. Gigabit Ethernet Deployment

Gigabit Ethernet deployment scenarios will most likely mirror the model of Fast Ethernet. The transformation will be driven by several factors: [3]

- The established popularity of Ethernet and the compatibility offered by Gigabit Ethernet solutions
- The experience and momentum already garnered in bringing Fast Ethernet to market
- The commitment and expertise of the vendors involved

5.1 Switch-to-Switch Connection

Gigabit Ethernet will be switched and routed at the network backbone with switch-to-switch connections as shown in Figure 3. The first installations will use optical fiber for long connections between buildings and copper links for shorter connections. [3]

5.2 Switch-to-Server Deployment

Switch-to-server deployments will be implemented to boost access to critical server resources as shown in Figure 4. Many 100Mbps switches contain module slots that will accommodate Gigabit Ethernet so they will be able to uplink to server connections at 1000Mbps. [3]

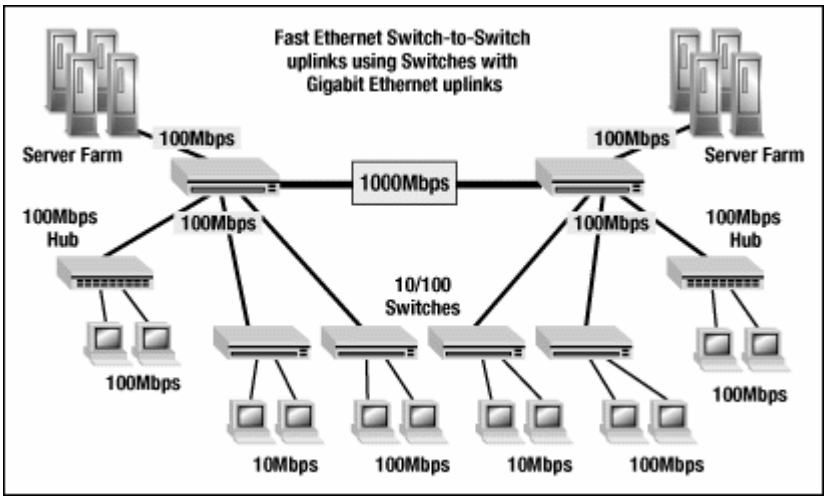

Figure 3. Switch-to-Switch Connection

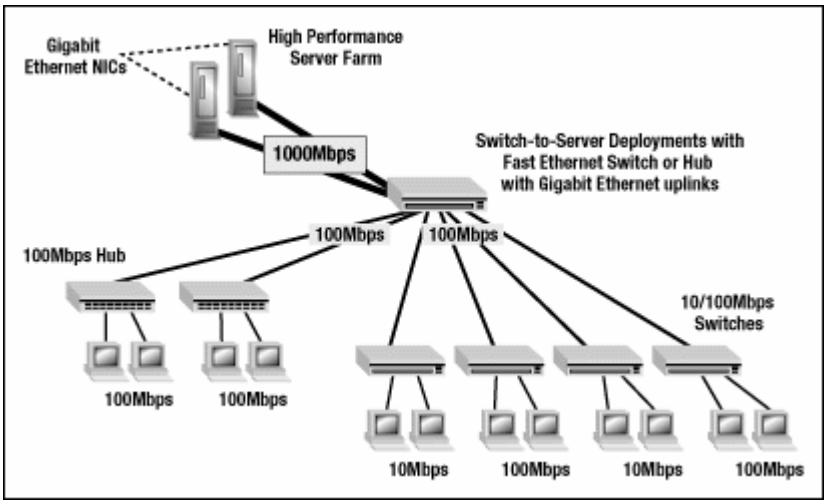

Figure 4. Switch-to-Server Deployment

5.3 Workgroup and Desktop Level Deployment

As desktop costs come down and user network demands increase, Gigabit Ethernet will move to the workgroup and desktop level as shown in Figure 5. Gigabit Ethernet switches will enter the backbone as older switches are replaced and Gigabit Ethernet will take over the switch fabric. This evolution will be driven by the increasing installation of 100Mbps PCs as the standard desktop, and the migration of power users to switched 100Mbps, and switch-to-switch uplink connections will advance to 1000Mbps. At this time, customers will see gigabit links that are compliant with the installed base of UTP Category 5 cabling. [3]

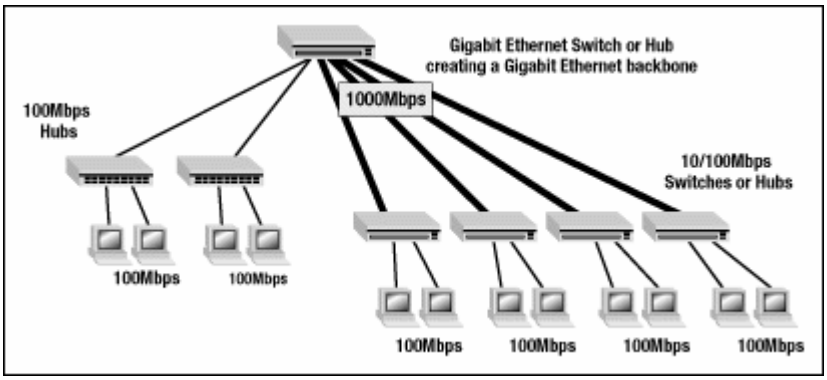

Figure 5. Workgroup and Desktop Level Deployment

6. Performance Analysis

Gigabit Ethernet performs at gigabit wire speeds. A theoretical simulation prepared by Intel Corporation shows that Gigabit Ethernet will exceed the performance of Fast Ethernet as packet size increases by an order of magnitude (Figure 6). [4]

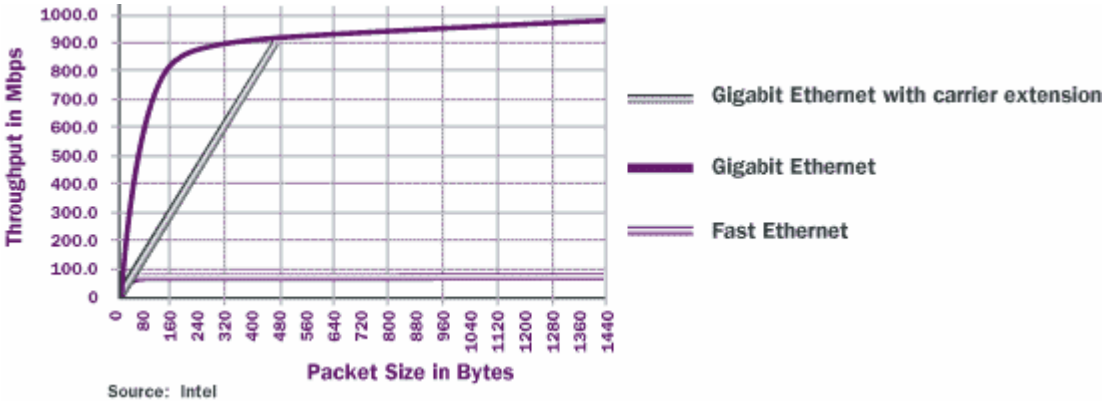

Figure 6. Gigabit Ethernet Performance Simulation

As packet bursting is implemented, Gigabit Ethernet will become even more efficient at handling small packets. Experiments performed by AMD show that in a half-duplex topology with collisions, a Gigabit Ethernet network achieved throughput of over 720 Mbps with a 100 percent offered load (Figure 7). [4]

Because most initial implementations of Gigabit Ethernet will be switched, full-duplex topologies without collisions, users should expect to easily surpass this 70 percent throughput rate, and possibly even approach the theoretical maximum of 2Gbps of full-duplex throughput.

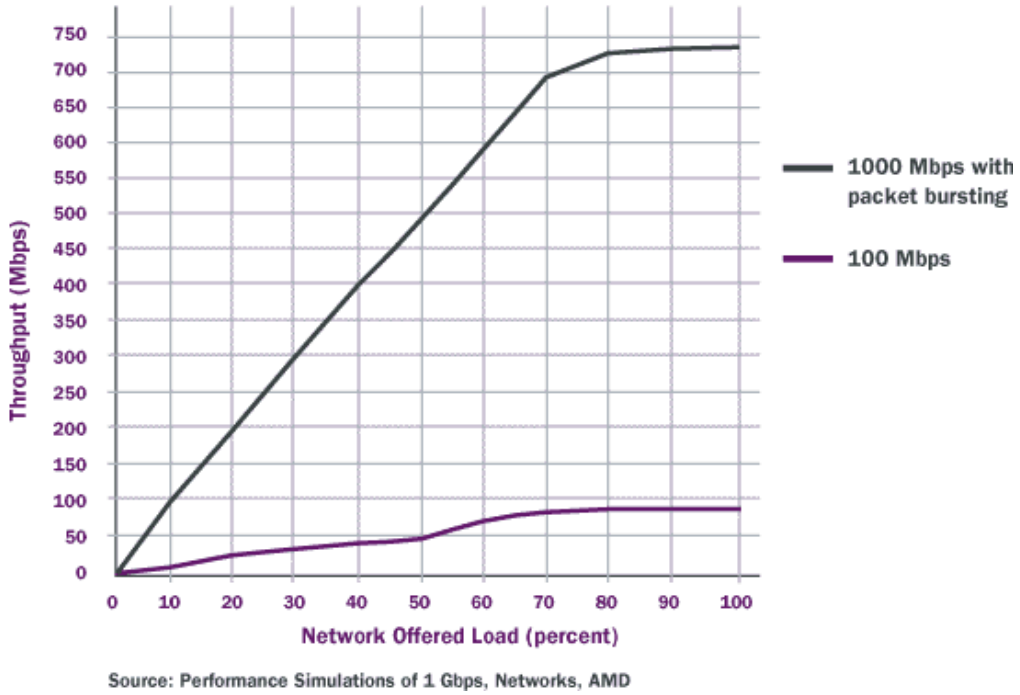

Figure 7. Network Throughput vs. Offered Load

7. Conclusion

Gigabit Ethernet is the ideal backbone-interconnect technology for use between 10/100BASE-T switches, as a connection to high-performance servers and as an upgrade path for future high-end desktop computers requiring more bandwidth than 100BASE-T can offer. Gigabit Ethernet will eventually operate over a variety of cabling types. It seems to be the optimum choice of networking technology based on cost-performance criteria.

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