Intel and Ethernet

Driving Ethernet innovation for nearly 30 years

The Technology vision for Ethernet

Ethernet is an industry standard for a packet-based computer networking technology for local area networks (LANs) that has become the foundation for most wired communications technology. Over the last 30 years, it's become the network of choice for wiring homes and enterprises around the world. Today more than 85 percent of all installed network connections and more than 95 percent of all local area networks (LANs) are Ethernet-based[1]. Nearly all traffic on the Internet starts or ends on an Ethernet connection.

The term "ether" in "Ethernet" is said to have come from "luminiferous" the medium that 19th century physicists thought responsible for the propagation of light.

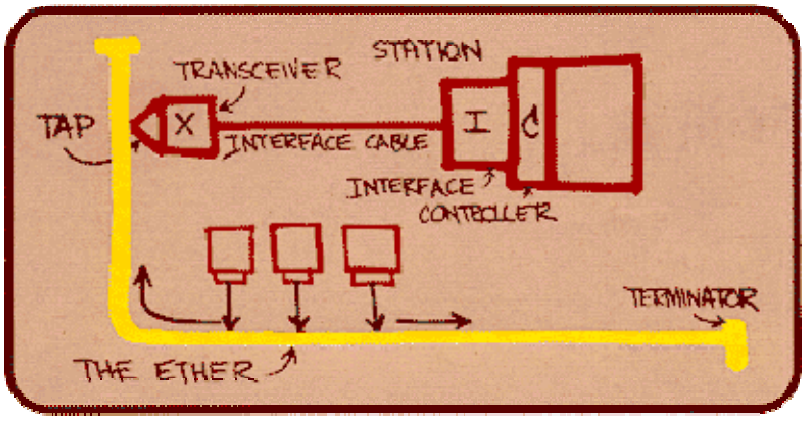
The relentless rapid growth in Internet Protocol (IP) traffic and its popularity for carrying sophisticated voice, data and media applications (particularly video) continue to drive the demand for greater network bandwidth. At present, Gigabit Ethernet (GbE), and increasingly 10 Gigabit Ethernet (10GbE), provide the core of data center computing and storage resources.

Today Intel provides a broad portfolio of Ethernet solutions ranging from cost-effective 10/100 Mbps and Gigabit connections for PCs to high performance 10 GbE adapters for servers. The relentless progress of Moore's Law will increasingly move systems toward greater bandwidth as processor performance drives the need for ever more capacity, both for those devices using the processors and the network links aggregating the bandwidth from multiple devices. What's down the road? Even greater Ethernet speeds, cost reductions and power efficiencies through future Intel innovations in process technology and architecture.

The term "Ethernet" commonly refers to products that comply with the IEEE 802.3 networking standard, but is also used to market other technologies compatible with the Ethernet frame format.

A standard is born: the origins of Ethernet

Ethernet was invented in 1973 when Robert Metcalfe, a researcher at Xerox, wrote a memo to his superiors about the possibilities of a networking solution he was developing. It wasn't until 1976 though that Metcalfe and David Boggs, Metcalfe's co-worker, published a paper titled, "Ethernet: Distributed Packet-Switching for Local Computer Networks." At the time, Metcalfe envisioned data moving at 1 Mbps. (For perspective, consider that in the same year Intel was releasing its 8080 processor running at 4.77 MHz.)



This diagram was hand drawn by Robert M. Metcalfe and photographed by Dave R. Boggs in 1976 to produce a 35mm slide used to present Ethernet to the National Computer Conference in June of that year. On the drawing are the original terms for describing Ethernet

Impatient to see Ethernet commercialized, Metcalfe left Xerox in 1978 to consult and promote Ethernet. Recognizing the importance of communications technology and standards in the fledging desktop computer market, Intel joined mini-computer maker DEC and Xerox to lead in developing the Ethernet standard. In 1980 the DIX (DEC, Intel, Xerox) "blue book" Ethernet specification was published. It was the basis for the development of IEEE 802.3, the Ethernet standard published in 1985.

Ethernet's rise to dominance

The speed of Metcalfe's original Ethernet turned out to be 2.94 Mbps. It soon increased to 10 Mbps. Successive generations keep increasing the speed each time by a factor of 10, leading to the rule of thumb "10 times the speed at 3 times the cost." Driven by Moore's Law and manufacturing economies of scale, the price of Ethernet in relation to performance continually falls.

Metcalfe is also famous for coining a theorem about the growing importance of networks known as "Metcalfe's Law." This theorem states that the value of a communications network is proportional to the square of the number of users. This theorem has proved remarkably true. Ever-growing numbers of users create attractive markets for applications. As these applications prove valuable, more and more users are added or sign on (in the case of the Internet) increasing the value of the network and encouraging the creation of more applications and usage models.

Infonetics Research projects that Ethernet revenue will continue to show strong growth through 2011. According to the firm worldwide Ethernet service revenue grew 33% from 2006 to 2007 to 12.5 USD billion and revenue for mid-band Ethernet services will increase 120% from 2007 to 2011. Infonetics Research's principal analyst Michael Howard says "customers expect and get a better per bit cost for Ethernet services."

Ethernet wasn't the only networking solution developed at the time, but it is the one that eventually won out. A big factor in Ethernet's favor was its establishment as an open industry standard. Having a standard that's developed and supported by a group of companies (an ecosystem) instead of a single company gives assurance to customers that there's competition and a healthy supply of products. Intel's efforts to standardize the technology touched off a massive cycle of high growth that was further fueled by dropping prices. Networking costs dropped because vendors and integrators could concentrate on one uniform, interoperable technology. Interoperability enabled businesses to deploy larger and larger networks using any manufacturer's products. All this led to the wide-scale deployment of the networks that drive the Internet and applications we use today.

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Another factor that helped propel Ethernet's acceptance was its early introduction to the market. Ethernet started as a simple concept that both clearly worked and had the potential for continuing improvements. This enabled manufacturers of Ethernet products to get to market quickly and deliver a consistent string of product advancements. Intel helped lead the way, shipping the world's first high-volume 10 Mbps Ethernet controller in 1982.

Several key attributes of Ethernet help explain why it continues to this day to be a pervasive technology for IP networking.

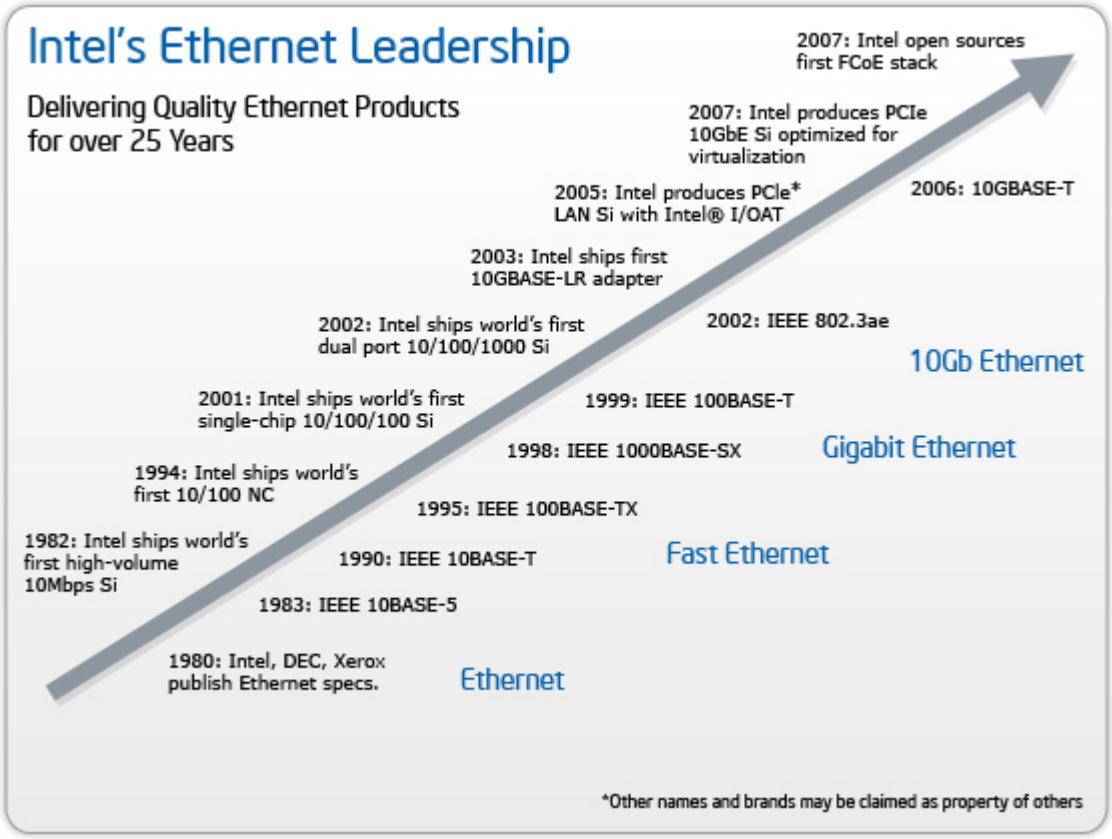
- Scalable performance
- Scalable reach in meeting a variety of networking applications from short range LANs (~100 meters) to MANs (40+ kilometers)
- Low cost
- Flexibility and interoperability
- Ease of use and administration

Intel and the continuing evolution of Ethernet

Since the inception of Ethernet, Intel has continued to help drive Ethernet technology by providing technological advances and active leadership in standards committees and industry associations. The company has planned a key role in developing faster standards, delivering architectural innovations, and fostering networking product growth into new market segments. Intel was a founding member of the Fast Ethernet Alliance (100 Mbps) in 1993, the Gigabit Ethernet Alliance (1000 Mbps) in 1996, the 10 Gigabit Ethernet Alliance in 2000, and the broader Ethernet Alliance in 2006.

As the leading supplier of Ethernet components worldwide, Intel continues to invest heavily in Ethernet research and development to help increase speeds and proliferate Ethernet into new applications. Some Intel achievements include:

- The world's first 10/100 Mbps network interface card (NIC) in 1994.
- The first single-chip 10/100 Mbps controller in 1997.
- The first single-chip 10/100/1000 Mbps controller in 2001.
- In 2002, Intel shipped the first XPAK Multimode Optical Transceiver delivering 10-Gigabit Ethernet and 10-Gigabit Fibre Channel transport for storage systems at half the cost, a third less power consumption and a third of the size of earlier solutions. The world's first 10 Gigabit Ethernet NIC in 2003.
- In 2006, Intel introduced the first low-profile quad-port Ethernet network interface card (NIC). By incorporating four Gigabit Ethernet connections in a low-profile PCI Express slot, it improved server throughput and rack density at the same time.
- In 2007, Intel released first "initiator" source code to enable Linux implementations of Fibre Channel over Ethernet (FCoE). By allowing fiber channel SAN traffic to run over Gigabit Ethernet networks, FCoE enables consolidation of storage area network (SAN) and LAN traffic, simplifying network infrastructure in datacenters.



Intel's interest in Ethernet

With Intel's long history of driving Ethernet technology and contributing to the evolution of the standard, Intel has a lot invested in Ethernet. This investment is only natural. Ethernet is essential for and ubiquitous in connecting PCs and servers, so it makes good business sense for Intel to be in the Ethernet business and leverage this communications platform to add further performance and value to PCs and servers. In fact, as the company has increased the performance and capacity of its processors through multi-core technology, it's become increasingly important to enable faster Ethernet performance so users can enjoy greater benefit from these processor performance increases. Through the years Intel has been a leading innovator and manufacturer of Ethernet network interface cards (NICs) and LAN on Motherboard (LOM) controllers for PCs and servers, as well as responsible for many manageability and reliability innovations for Ethernet connections. Recently, though the hardware-based capabilities of Intel® vPro™ Technology, a business client platform technology, Intel has provided remote PC management over Ethernet and even improved virus protection through detection and network isolation of clients under attack.

As of 2008, a major focus for Intel and the rest of the Ethernet ecosystem is convergence over Ethernet for the data center. This means instead of IT customers having to configure separate networks for data access over Ethernet, storage over Fibre Channel and cluster traffic over InfiniBand*, Intel and the industry are working to create one converged fabric using Ethernet that will reduce the cost and power requirements of supporting today's multiple switches, adapter cards and cables. On the server level, this could simplify the number of connections from today's multiple I/O servers with two to three adapter cards to single I/O servers. By decreasing the number of NICs, this will help reduce the size, cost, and power consumption of servers.

Intel's role in the Ethernet Alliance

For years, various alliances were created to champion a specific speed increase in the Ethernet standard. These alliances would work on the specification and shepherd it through the IEEE's standards process. The alliances would then promote the revised standard and provide opportunities for interoperability testing. Recognizing in 2005 that a more general industry association was needed that would continuously promote ongoing improvements in the standard for years to come, Intel helped create the Ethernet Alliance. This organization seeks to promote industry awareness, acceptance, and advancement of technology and products based on both existing and emerging IEEE 802 Ethernet standards and their management.

As a founding member of the Ethernet Alliance (EA), Intel is an active member of the organization with employees serving on the EA board of directors, volunteering as committee chairs, and contributing to whitepapers, technology demonstrations, and industry panels at conferences. The organization provides a forum for various members of the ecosystem to discuss ideas for new Ethernet-based technologies and standards, which helps facilitate and speed up the standards development process. The Ethernet Alliance also acts as a vendor-neutral voice to the market on new Ethernet technologies, providing information, education and demonstrations on benefits and applications.

Ethernet developments

The following partial list of IEEE 802.3 Working Group activities demonstrates Ethernet's ability to evolve and meet new needs and demands.

- IEEE Std 802.3an-2006 - 10GBASE-T 10 Gigabit Ethernet over Twisted Pair Cabling (supports lower cost 10 Gigabit interconnects by enabling high-density 10 GbE switches).
- IEEE Std 802.3ap-2007 - Backplane Ethernet (defines Ethernet connections at 1 Gb/s and 10 Gb/s over backplanes for blade servers and other modular communication equipment).
- IEEE P802.3at - DTE Power Enhancements Task Force (increases the amount of current delivered by Power over Ethernet).
- IEEE P802.3av - IEEE Task Force for 10Gbit/s backwards compatible with 802.3ah Ethernet passive optical network (extends the speed of EPON networks to 10 Gb/s).
- IEEE P802.3az - Energy Efficient Ethernet Task Force (develops specification for reducing the energy consumption of networking equipment and communicating state and control information for enabling/disabling energy efficient modes of operation).

- IEEE P802.3ba - 40 Gb/s and 100 Gb/s Ethernet Task Force (works to standardize both 40 Gb/s and 100 Gb/s speeds as part of the IEEE 802.3ba specification).

Intel's leadership in current Ethernet standards development

Intel has made significant contributions to recent and ongoing Ethernet enhancements, actively driving Ethernet enhancements in IEEE 802 working groups and other industry associations. Here are some highlights of Intel's activities.

10GBASE-T

Based on the IEEE Std 802.3an-2006, 10GBASE-T supports 10 Gbps operations on 100m of twisted-pair copper cabling and has only become feasible through new developments in signal processing and coding technologies. This standard is likely to revolutionize the data center and provide a means to move 10 Gbps performance at a lower cost per gigabit to high volume applications. Intel has been integral in driving development of 10GBASE-T technology, participating in the standards process, promoting it through the Ethernet Alliance, and incorporating it in Intel products.

10GBASE-T offers two important advantages to network managers and IT professionals planning data centers and enterprise networks. First, it supports legacy copper UTP cabling and new installations of copper cabling, maintaining the existing structured cabling paradigm and support for RJ-45 connections and patch panels. Second, 10GBASE-T will over time enable lower cost 10 GbE interconnects by enabling high-density 10 GbE switches. Because of greater density and relatively low component cost, 10GBASE-T will enable network equipment manufacturers to dramatically lower the cost of 10 GbE interconnects.

Intel is working with the Ethernet Alliance to provide interoperability testing and public demonstrations of 10GBASE-T products and their advantages. Intel's first-generation standards-based 10GBASE-T adapter, the 10 Gigabit AT Server Adapter, is a dual-speed adapter that supports both 1 GbE and 10 GbE throughput for data migration operations and connection to legacy switches.

Ethernet enhancements for data centers - Data Center Bridging (DCB)

The demands on Ethernet networking in the data center continue to grow as the role of Ethernet expands to become the unified data center networking fabric for the convergence of network, storage, and high performance clustering traffic. With data centers becoming more complex, managing multiple different interconnect technologies is getting more expensive, hence Ethernet has become the attractive choice for convergence. To enhance Ethernet capabilities for convergence in data center, Intel has been actively working with IEEE 802 and InterNational Committee for Information Technology Standards* (INCITS) Technical committee T11, to develop emerging standards for data center networking, including the IEEE 802.1 Data Center Bridging and T11 FC-BB-5 for Fibre Channel over Ethernet. DCB is a collection of specifications that include: Congestion Notification (IEEE P802.1Qau) and Priority based Flow Control (IEEE P802.1Qbb) for providing lossless characteristics; Enhanced Transmission selection (IEEE P802.1Qaz), a framework for assigning bandwidth for different traffic classes; and a discovery and capability exchange protocol (DCBCXP) for conveying capabilities and configuration between DCB neighbors. Intel is one of the early drivers of Ethernet convergence technologies and has been contributing to the standardization of converged Ethernet enhancements since 2004. Intel is also working with the Ethernet Alliance to provide vendor-neutral advocacy and education for the marketplace on the new DCB and network storage technologies coming out of standards bodies, as well as to promote interoperability testing of multi-vendor equipments supporting these new standards.

Fibre Channel over Ethernet (FCoE)

The broad industry move to run networking, storage and clustering traffic over a single mainstream Ethernet pipe in tomorrow's data centers requires a way to incorporate existing Fibre Channel technology (a high performance network technology primarily used for storage networking and standardized in the INCITS T11 Technical Committee). The solution is FCoE technology, a mapping of Fibre Channel frames over selected full duplex IEEE 802.3 networks that allows Fibre Channel to leverage 10 GbE networks while preserving the

Fibre Channel protocol. This is important for protecting and extending the investment that customers have made in Fibre Channel storage networks. Intel has been very active in helping drive consensus on the FCoE standard in T11 and the Fibre Channel Industry Association, as well as taking the lead in adding that capability in the operating systems through the founding and ownership of openFCoE.org, an open source community for writing the FCoE stack for Linux. This work will pay big dividends by reducing the cost and power requirements of supporting today's multiple switches, adapter cards and cable. With FCoE, IP network and SAN data traffic can essentially be consolidated in a single Ethernet fabric. What's more, with the ability to combine Fibre Channel with 10 GbE, companies will be able to consolidate I/O and reduce: the number of network interface cards or adapters required to connect to disparate storage and IP networks; the number of cables; and, the power and cooling costs of these devices.

Energy Efficient Ethernet (EEE)

Recent studies by industry[3] and government[4] have highlighted the issues of escalating energy consumption by data centers and the proliferation of PCs in businesses and homes. One small but significant - by sheer number of connection devices - contributor is Ethernet. Through the IEEE P802.3az Energy Efficient Ethernet Task Force, Intel has been working with other industry leaders on developing a standard for EEE. The IEEE's Energy Efficient Ethernet Task Force is working on this draft standard designed to make network communications greener. Fundamental to this draft standard is an Intel-proposed Low-Power Idle (LPI) state that will reduce power consumption of Ethernet interfaces in servers, desktops and other end devices as well as network switches during periods of low link utilization.

LPI both lowers power consumption of the Ethernet link and enables systems to reduce power consumption between transmission periods without inhibiting high-speed communications. LPI interfaces will be able to interoperate with legacy Ethernet interfaces. The solution also provides a method to optionally negotiate the wake or resume time from low-power idle, allowing systems to safely enter deeper sleep states to save additional system power. With Energy Efficient Ethernet, energy consumption will be more directly proportional to bandwidth utilization, unlike today's Ethernet devices which consume similar power regardless of the utilization rate or traffic load. EEE will be supported on a variety of speeds and physical media including UTP cables and server backplanes.

Specifications like Energy Efficient Ethernet will be increasingly important as IT operations become a bigger and bigger factor in the cost of operations and their energy efficiency becomes seen as a way to help meet corporate carbon-footprint requirements. How efficiently businesses run their network could even be a factor in maintaining a lower cost structure than competitors.

Higher speed Ethernet (40GbE/100GbE)

Networks continue to grow and bandwidth needs continue to increase with the popularity of Internet usage, electronic commerce, IPTV, VoIP, wireless communications, Video on Demand, and online collaboration, etc. At the same time, innovative and emerging server technologies including multi-core processing, virtualization, networked storage, and I/O convergence are contributing to a growing bandwidth requirement in the enterprise computing environment. At some critical Internet aggregation points as many as eight lanes of 10 GbE are aggregated to handle the bandwidth demand. Developments like this have made it obvious that Ethernet at a rate of 10 gigabits per second is no longer sufficient to cope with bandwidth demands at many aggregation junctions.

Intel has been contributing to the IEEE P802.3ba 40 Gb/s and 100 Gb/s Ethernet Task Force to solve the needs and requirements for the next revision of Ethernet technology. In the past, Ethernet speeds have always increased by a factor of 10. But this time, two needs arose that suggested a dual speed upgrade was required. Intel was one of the three primary drivers for getting 40 GbE included in the next revision of the Ethernet standard. Establishing 40 GbE along with 100 GbE was important because it will be less expensive than 100GbE and it's complementary to the speed migration path for PCI Express* (a computer expansion card interface standard introduced in 2004), making it more appropriate for use in cost-sensitive computing applications. It also works well with blade servers, an emerging form factor. Blade servers are designed so that each server blade has four lanes over the backplane each capable of 10 Gb/s. This means the many chassis currently in the market are capable of driving 40 GbE per blade. 100 GbE will be important to properly address the cost/performance requirements of many network aggregation applications, such as a switch to switch and telecommunications backbone links.

"There will be always room for invention as Ethernet expands its scope and adds new capabilities." *–Bob Grow, principal architect, Intel Global Public Policy group and former chairman of the IEEE 802.3 Working Group*

What lies ahead

Ethernet is sure to continue gaining momentum in data center applications as network convergence, server consolidation through virtualization, IPTV and other multimedia applications multiply, multi-core processors increase, and more high performance computing applications come online. The rapidly declining price of 10 Gigabit Ethernet ports, advancement in tunneling Fibre Channel traffic over Ethernet fabric, advances in Ethernet enhancements for data centers, and the drive for energy efficiency will all contribute to the growing convergence over Ethernet.

All these developments will add up to even greater urgency for continued innovation and industry cooperation in evolving Ethernet to meet the demands of tomorrow. At the center of this effort will be Intel. Working with industry partners, standards groups and industry alliances, Intel will continue to drive Ethernet technology and product growth to meet the demands of tomorrow with faster standards, new technologies, and architectural innovations that will push Ethernet speeds up and costs down.

Learn more

[1] Frazier, H.; Pesavento, G., "Ethernet Takes on the First Mile," IT Professional, Volume 3, Issue 4, Jul/Aug 2001, pages:17 - 22.

[2] "Infonetics Research projects Ethernet service revenue to continue upward climb," Network World, July 15, 2008.

[3] See Koomey, Jonathan G. Ph.D., "Estimating Total Power Consumption by Servers in the U.S. and the World", February 2007.

[4] See U.S. Environmental Protection Agency, "Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431", August 2007.