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Technology Note: Internetworking Products

While using data networks has become a part of everyday life for students, few understand what the companies who make the "guts" of large computer networks (Cisco, Juniper, Nortel, Sycamore, others) actually produce. Not only is the technology confusing, but it is constantly evolving. In this note, you'll get a base-level knowledge of the technology—enough to engage in meaningful business discussions about companies in the internetworking industry. We'll first describe the initial situation that gave rise to a market for internetworking products. Then, we'll look at some of the key characteristics that distinguish these products, including "intelligence," transmission media, and languages/protocols. Finally, we'll describe some of the forces that shape markets for internetworking products.

What Need Do Internetworking Products Fulfill?

Although IBM and Digital Equipment started building computer networks much earlier, the networking industry's coming of age coincided with the PC revolution in the early '80s. By providing electronic connections between a set of computers and peripherals, local area networks (LANs) allow a community of PC users to send email and to share resources, such as files, printers, modems, and other peripherals. (Larger networks will sometimes include long-distance connections, and may be referred to as WANs, or wide area networks. A brief summary of LAN technologies is included in *Exhibit 1*)

Although sending email and sharing files is commonplace today, it was not always so. Companies that wished to share information from one network to another faced enormous challenges. For example, in 1982 Stanford University had 5,000 different computers on campus and 20 incompatible email systems. This made it almost impossible for different departments to share information. (It was this awkward situation that provided the original inspiration for the founders of Cisco.)

 As dependence on computers and LANs grew, so did demand for a way to share information from network to network, irrespective of manufacturer. Internetworking

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products were created to fulfill this need. Today they are in high demand as corporations race to build their own information superhighways and become the leading "e-businesses" in their industry.

What Do I Need To Know About These Gadgets?

 If you simply visualize large metal or plastic boxes with lots of wires going into and out of them, you're off to a good start. Generally speaking, internetworking products are primarily differentiated in terms of speed and reliability. Also, because a significant level of expertise is required to design a network or customize and configure an internetworking product, quality service is also a critical differentiator.

A prerequisite to understanding the markets for internetworking products in greater detail is understanding the three dimensions along which they are readily categorized.

"Intelligence": the level of sophistication they use to decide where and when to transmit packets of information.

Transmission media: the types of wires and/or wireless frequencies over which they are designed to operate.

Protocols (languages): the communication standards they are designed to understand and/or translate.

Let's take a closer look at each.

Intelligence

While the speed at which an internetworking product can receive and retransmit bundles of data is important, the performance of an (inter)network as a whole also depends on the "intelligence" of its internetworking products. "Smart" internetworking products do things like monitor network traffic and figure out which of several available routes is fastest before sending a message. Less intelligent internetworking products simply "pass things along."

The four main categories of internetworking products are described below in order of increasing "intelligence":

1. Repeaters were created to lengthen the range of electrical signals, which weaken over distances. By placing repeaters in strategic places on a network, the quality of data is assured. Basically, a repeater takes the electrical signal, amplifies it, and passes it on. Repeaters have also been helpful in optical networks, since light signals suffer from the same dispersion problems over distance as electrical signals.

2. Bridges originally were designed as simple devices that connected two Local Area Networks (LANs). Much like repeaters in their earliest form, they simply amplified a signal and passed it on. Later, bridges that had some translation capabilities were produced. These allow two LANs which do not use the same protocols to communicate with one another.

3. Switches were created to send signals from one network to many different networks by opening and closing the corresponding circuit. Simply put, a switch was a bridge with many connections.

4. Routers were designed to be extremely intelligent switches. Instead of sending data from point A to point B across one connection as a switch or bridge would, a router was designed to send the data across the fastest path available. In its memory, the router had a myriad of different paths each data packet could take from point A to point B. When the router was asked to send a packet to a specific address, it would analyze the network and ship the packet via the fastest route.

As the technology has evolved, the neat and tidy distinctions between the four product categories have blurred. Bridges are now capable of monitoring networks to find the fastest path, and switches have become more powerful than the original routers. What was once a sophisticated router is now a simple switch. It is important, therefore, to rely more heavily on a product's description than on the name assigned to it by the equipment company's marketing department.

Transmission Media

Data can travel from point A to point B over four different media, described below. Speed, or bandwidth, is the most critical attribute of each transmission medium. Bandwidth is defined as the quantity of data that can be transmitted in a given time period, generally quoted as bits per second.

1. Twisted pair wire is simply copper telephone wire, the medium for almost all residential phone lines. (Two copper wires, separately insulated, are twisted together. This acts to reduce interference between pairs.) Twisted-pair wiring comes in different grades and thickness; the thicker the copper wire, the higher the quality. Relative to the other media, the disadvantages of copper wire include interference and attenuation (the signal loses strength over long distances). The advantage, of course, is that it is already in place. Installing new wiring in residences is an extremely expensive proposition.

Because the original telephone network infrastructure was designed to handle only analog audio signals, digital data transmissions over twisted-pair connections must be converted to analog signals and back by modems. As a result of this signal conversion process, bandwidth is limited, most often to 56K bps. A newer technology, Digital Subscriber Line (DSL), brings higher bandwidths (up to ~100x

improvement) over twisted-pair connections by eliminating the need for any digital-to-analog conversion. Upgrading the switches in the telephone networks to handle DSL is a major investment for telephone companies.

2. Coaxial cable, which is used to bring cable TV into homes, can be used in data networks with bandwidths about 20x the speed of modems. As with twisted-pair wiring, it has a very large installed base. Compared to fiber optic cable, it is inexpensive to install.

3. Fiber optic cable, or optical fiber, is the most expensive transport medium but also the fastest and most reliable. Companies such as Level 3, Qwest, and Williams have spent billions laying fiber optic cable made by Lucent, Corning, Pirelli, and other firms. Most fiber optic cable has been installed in densely populated areas and in long-distance links at the core of major networks. In rural areas, it is still too expensive. In most of today's networks that employ fiber, data is converted from electrical signals into light pulses and back into electrical signals within each switch. This optical-electrical conversion process is a bottleneck. New technologies are under development that will enable all-optical switching and remove this bottleneck.

4. Wireless technologies send data through the atmosphere rather than along a wire. Transmissions can be made in several portions of the electromagnetic spectrum, which is commonly segmented by frequency. Different wireless technologies utilize different segments of the spectrum, such as radio frequency (RF), infrared (IR), and microwave. The frequency used changes the extent to which signals are   (a) constrained to travel in a straight line, (b) able to penetrate through buildings, (c) subject to interference from other signals, and (d) able to travel long distances. Because the spectrum is very crowded and is a public resource, it is regulated by the government. Several wireless innovations have managed to squeeze increasing amounts of data into substantially reduced spectrum. Wireless connections are utilized in networks in a wide variety of configurations. High bandwidth communications are possible.

Protocols

Many engineers, working for different companies, designed computer networks to address a multiplicity of specific needs. As a result, a variety of communication protocols are in place. To enable interoperability, internetworking products must take on the role of translator in addition to the role of postal carrier.

Early in the development of the networking industry, the International Organization for Standards (ISO) tried to implement standard communication protocols for the industry. Although this attempt was not fully successful, it did leave an important legacy—a framework that categorizes all elements of the necessary protocols in a seven-layer hierarchy. This framework, known as the Open Systems Interconnection (OSI) Model, is shown below. It is important to understand that in order to

interoperate, two computers must either use the same protocol or have an intervening translation capability at each of the seven layers of this hierarchy.

Layer 7	Application
Layer 6	Presentation
Layer 5	Session
Layer 4	Transport
Layer 3	Network
Layer 2	Data Link
Layer 1	Physical

The highest layers of the hierarchy deal with elements that an average PC user might understand, while the lowest layers deal with elements that perhaps only a computer designer or an electrical engineer would understand. For example, at the higher layers of the framework, there are protocols for file handling and email message handling. Middle layers include protocols for addressing and packaging bundles of information. Lowest layers include protocols for compressing 1s and 0s, and methods for error-checking bit streams.

There are many protocols that specify rules for one or more of the seven OSI layers. From a business perspective, it is important to recognize when two standards conflict with one another. A conflict exists when different protocols are used at the same OSI layer.

Internetworking products make data communication possible despite these conflicts. Two frequently mentioned standards, TCP/IP and ATM, are in conflict because while TCP/IP allows for data packets of variable size (some can be quite large), ATM requires all packets of information to be of the same (small) size. Therefore, connecting an ATM network and a TCP/IP network would require an internetworking product with that specific translation capability.

Thanks in part to the confusing "alphabet soup" of acronyms that accompanies protocols, it is very difficult to stay on top of what works with what, and when there is a conflict. Therefore, simply remember to investigate conflicts, using the OSI framework as a guide, when a question about product interoperability arises.

What Forces Affect Markets For Internetworking Products?

Overall, demand for internetworking products can be very sensitive to the condition of the macroeconomy, just like any market for capital equipment. However, the performance of specific companies in the industry, most of which have very narrow product lines, is tied more closely to forces affecting demand for a specific category of internetworking product. Even a relatively mature company like Cisco, despite an impressive product breadth, is threatened by a variety of younger companies focused on optical internetworking products.

One key factor is the development level of various wired and wireless communication infrastructures. Installing new wiring in existing buildings, or installing wires over long distances, is very expensive and takes time. Though the infrastructure itself changes slowly, new technologies that squeeze more data into existing infrastructure make it harder to predict how, when, and where various communications infrastructures will be improved. This difficulty is compounded by new wireless technologies that squeeze more data into the same space in the electromagnetic spectrum (and governments which continue to allot more of the spectrum to wireless data networks).

The always-evolving popularity of various communication standards also dramatically affects the demand for the various types of internetworking products. Competitive factors that shape the evolution of standard-setting organizations are very hard to predict.

An additional force shaping markets for internetworking products is the convergence of networks that carry voice, video, and data for computing. In early stages of development, networks for each type of signal met unique demands. Voice required speed, continuity, and distance, well handled by copper networks with connections that could be fixed and dedicated for the duration of a telephone call. Video required high analog bandwidth but shorter distances, and was handled by wireless. Computer data required speed and reliability, but, unlike voice, allowed for asynchronous connections, resulting in very flexible networks with more dynamic switching capabilities. Improvements in technology and in available bandwidth are making it possible for single networks to handle all three types of signals. This is having a very interesting impact on once-distinct markets for internetworking products, as it will bring data network giants such as Cisco into direct competition with telephone equipment companies such as Lucent and Nortel.

Finally, some experts have speculated that demand for "smart" internetworking products will decline as bandwidth availability increases. Once fiber optic and wireless technologies have improved to the point where bandwidth is essentially free, there will be no reason to expend resources building complicated internetworking devices that analyze networks and search for the most efficient path (i.e., routers). So, along all three product dimensions—"intelligence," transmission media, and

protocols—demand for internetworking products is subject to some very complex factors.

Examples Of Networking Companies

Among the more successful networking companies are the following:

Cisco (revenues of $25 billion, variety of data and data/voice/video convergence products)

Lucent (revenues of $35 billion, very similar to Nortel; an AT&T spin-off)

Nortel (revenues of $30 billion, similar product line to Cisco, but grew up as a voice networking company, not a data networking company)

Sycamore (revenues of $0.5 billion, optical networking equipment)

ONI (revenues of $0.1 billion, optical networking equipment)

Juniper (revenues of $0.7 billion, backbone routers for service provider networks)

Redback (revenues of $0.3 billion, variety of broadband networking products for service provider networks)

Other Helpful Websites

Whatis.com

Technology investor

www.breezecom.com

www.giganet-wireless.com

Exhibit 1

LAN Technologies

1. Ethernet LAN technology, first introduced by Xerox in the 1970s, is the most widely used technology for LANs. As other technologies are more capable, Ethernet's primacy may be due only to first-mover advantage. Ethernet originally was capable of sending data at only 10 mbps (very slow). However, as applications became more bandwidth greedy, they demanded faster transmission speeds. Fast Ethernet was invented to send data at 10 times the speed of Ethernet, or 100 mbps. Gigabit Ethernet can send data at speeds of up to 1,000 mbps (or 1 gbps).

The Ethernet LAN sends packets of data as they are generated. If the data packet collides with something that is already on the network, the sending system waits a random amount of time and then re-sends the packet.

2. Token Ring technology is another popular LAN technology. Token Ring operates at speeds of 4 mbps or 16 mbps. IBM developed Token Ring LANs at the same time that Xerox was developing Ethernet technology. Token passing networks are not random, like Ethernet networks. A computer cannot send any packets of data onto the network until an empty token is available. A token can be thought of as a container for data that circulates around the network in various predetermined patterns. This approach eliminates the data collisions that are common on Ethernet networks. Token Ring is generally a good design only for smaller networks. The average Token Ring network has about 100 computers connected to it.

3. Fiber Distributed Data Interface (FDDI) is another Token Ring technology but one that operates at 100 mbps instead of 4 or 16. Also, FDDI is capable of operating over fiber optic wire and is designed to support LANs over large geographical areas. FDDI networks provide very fast, reliable service to bandwidth-hungry networks. Whereas data in a typical Token Ring network can only travel in one direction, data in an FDDI network can travel across the network in two directions when necessary. Because FDDI relies on fiber networks, it can be very expensive to implement.