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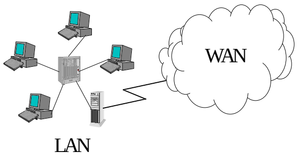


*Data Networking*

# The Secret Sauce of Convergence

## New Software Helps the Internet Find Its Voice

*"We have reached an amazing moment: fundamental advances in microprocessors, photonics, storage and wireless technologies, together with the digitization of just about everything from photography to radio and television, combined with the universal adoption of Web technology, are ushering in a **golden age of networking."***[1]

### Not So Fast!

Before we join hands to usher in this "golden age of networking" when all media (including telephone, data, television, radio, photography, fax, etc.) converge into a single integrated network, there are some technical issues to be resolved. Specifically, an overall architecture for the integration of voice and data networks must be created and new software products and control protocols must be developed and perfected.

Such new products are currently being engineered by Bellcore and Cisco for Sprint's new Integrated On-Demand Network (ION) in the traditional telephone market and for Canada's Videotron in the cable TV market. While other vendors are also developing advanced products to facilitate the convergence of voice and data, we focus mostly on the Bellcore/Cisco approach as they appear to be leading the race at this point. The objectives of this report are to explain how convergence will really happen and to help investors understand:

- how data networks and voice networks will integrate technically and how advanced telephony features (such as call waiting, caller ID, call forwarding, 800 numbers, etc.) will operate over data networks
- who has the advantage between data networking vendors (such as Cisco and Ascend) and voice vendors (such as Lucent and Nortel).
- why we believe convergence is inevitable and not just another passing tech fad
- why so much spending on convergence is happening now and why we believe the data networking architecture will ultimately win.

**We believe the new "converged" architecture described in this report will be operational in both public and private networks this time next year.** Most incumbent carriers have begun developing data networks to augment their well established voice infrastructures. We believe these incumbent service providers will link their new data networks to the telephone system utilizing an architecture similar to the one being developed by Bellcore and Cisco. Competitive carriers are, of course, focusing exclusively on building data infrastructures capable of carrying both voice and data traffic from the start. The architecture described in this report will allow these emerging carriers to provide advanced telephony services over their new data networks.

**Buy**

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[1] "Moore's Law – The Least of the Changes," *Business Communications Review*, August 1998.

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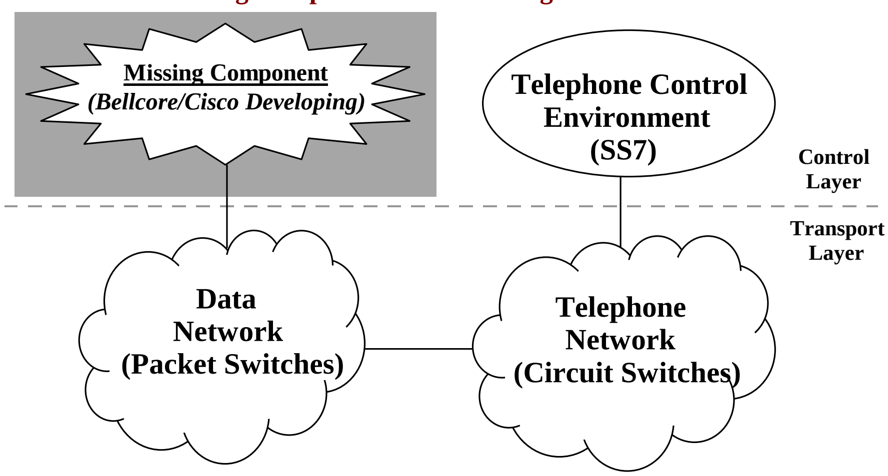
# Introduction

## The Missing Piece of Data Networks

Today's telephone networks consist of two primary components: a "transport" layer that physically transports our voices back and forth and a "control" or "signaling" layer that insures that advanced features (such as call forwarding, call waiting, 800 numbers, etc.) are applied to the calls as appropriate. By contrast, what exists today in data networks is generally only the "transport" infrastructure, and there is no separate "control" layer. This missing element is shown as the shaded area in Chart 1. The architecture under development by Bellcore and Cisco that is described in this report focuses primarily on creating a separate control infrastructure for the data side of Chart 1. This helps integrate the voice and data transport layers and establishes a mechanism for providing advanced services to data networks.

**Chart 1: The Missing Component for a Converged Voice/Data Environment**




Source: JPMS.

## Structure of This Report

The full picture of how all of the pieces of the new converged architecture fit together is shown in this report in Chart 10 on page 13. However, jumping right into the converged network may be a bit too complex for everyone. Therefore, for clarity, this report builds up to the total picture starting with the telephone portion of the overall architecture and then moves to the data side. So, the first few sections of this report simply represent a summary of the existing voice and data infrastructures. Investors who are up to speed on today's voice and data architectures can skip the first few sections and begin with the paragraph titled "New Architectural Design Features of Bellcore and Cisco," which begins on page 12.

## This Report Is Not Overly Technical

**This report is for everyone.** You do not need to have a technical background. There are lots of graphics and every technology term is explained in the report. The attempt is to describe the new technical concepts of voice-data convergence in nontechnical terms.

## Who Is Bellcore?

Since this report examines the new architecture being developed by Bellcore and Cisco, a short description of Bellcore is appropriate. Before the breakup of AT&T (T/$70.06/Market Performer), Bell Labs provided research and development services for all organizational units of AT&T. Bellcore was established in January 1984 as the research and development center for the newly divested Regional Bell Operating Companies (RBOCs), matching up with Bell Labs, which stayed with AT&T. Bell Labs is, of course, part of Lucent today. Working with the RBOCs and AT&T, Bellcore has been called "the company that engineered the U.S. telephone network."

After the Telecommunications Reform Act of 1996, it became clear that the RBOCs were going to begin competing with each other in a deregulated environment. Therefore, joint ownership of Bellcore by the RBOCs made little sense, and Bellcore was sold to Science Applications International Corporation (SAIC) in November 1997. SAIC is a private, employee-owned network integration and services company of 30,000 professionals headquartered in San Diego with revenues of approximately $4 billion. Bellcore is a wholly owned subsidiary boasting over $1 billion in revenues and 5,700 communications professionals. Bellcore's headquarters are in New Jersey. Initially, of course, almost all of Bellcore's engagements were for the RBOCs, but today over 50% of Bellcore's revenues come from non-Bell engagements, such as the Sprint (FON/$81.38/Long-Term Buy) and Videotron contracts that are discussed in this report.

The partnership of Bellcore and Cisco is strategically important for both parties. For Cisco, the Bellcore relationship significantly levels the playing field in voice expertise with their new competitors Lucent and Nortel. From Bellcore's perspective, the relationship pairs them with the leading data networking supplier.

# The Telephone Network

## The Transport Layer – Circuit Switches

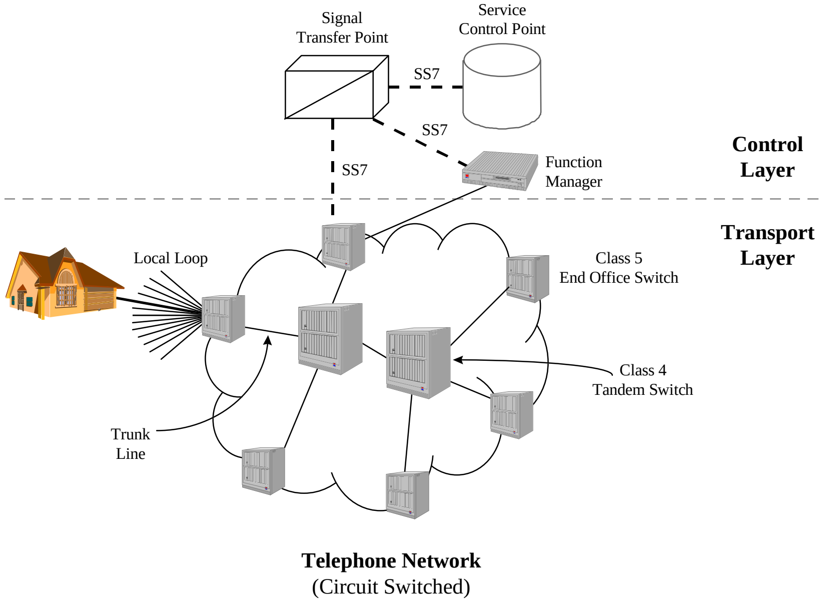
The new architecture from Bellcore and Cisco simply interfaces with the existing public switched telephone network (PSTN) and does not propose to alter it in any way. The transport layer of the telephone network consists principally of Class 5 circuit switches (called "end office" switches) and Class 4 circuit switches (called "tandem" or "trunk" switches). These devices are housed throughout the country in buildings called "central offices," and these switches (along with the trunk lines connecting the switches) physically transport our voices from sender to receiver – typically in digital form.

*For a comprehensive review of the industry's attempts to modernize, replace, or bypass the currently installed "local loop," refer to* Telecoms in the Age of the Internet[2]

Today's PSTN is pictured very conceptually in Chart 2 below. As a general rule of thumb, the trunk lines connecting switches within the core of the PSTN (i.e., within the cloud) are constructed from fiber optic cables, while the circuits connecting our homes to the nearest central office are made with copper wires. The connection from the PSTN to our homes is commonly referred to as the "last mile" or the "local loop." Because the 43 million tons of copper wire buried in the ground typically has not been refreshed in quite some time, the last mile of the telephone network has been called "the land time forgot."[3]

[2] Simon Flannery and David Barden, *Telecoms in the Age of the Internet*, J.P. Morgan Equities Research Report, November 24, 1998.
[3] *Data Communications*, February 1998.

**Chart 2: The Telephone Network**




Source: JPMS.

## The Control Layer – SS7 Signaling

In addition to the transport layer of the telephone network, Chart 2 also depicts the control (or "signaling") layer of the PSTN. The control activities are referred to as "out of band" signaling because the control functions typically do not take place over Class 4 and Class 5 circuit switches. In other words, control activities and voice transmission are not carried out over the same path. A quick description of the components of the control layer follows:

- **SS7 Protocol** – This is the communications protocol utilized throughout the telephone control environment. SS7 is used for call setup (i.e., determining the path the call will take and establishing the circuit) and for accessing databases to obtain special handling instructions for advanced telephony services. Additionally, SS7 communicates network status information such as "trunk line 123 is being taken out of service." SS7 is an industry standard, bi-directional, full duplex protocol operating at either 56 Kbps[4] or 64 Kbps. "Full duplex" means that communications take place in both directions simultaneously. Because SS7 is an industry-wide standard, calls can originate on one carrier's network and terminate on another's. SS7 signaling can be employed at any time during the call, not just at the beginning and end.

- **Service Control Points (SCPs)** – These are the databases that contain programs that provide advanced telephony features such as call waiting, call forwarding, caller ID, 800 numbers, etc. Control-point software can operate on computer platforms ranging from Pentium-class PCs to high-end UNIX systems, and each Service Control Point can support calls from multiple end-office switches (i.e., from hundreds of Class 5 switches supporting millions of consumers). Because Service Control Points are so critical to the operation of the public telephone system, SCPs are typically deployed in pairs to provide backup.

[4] Kbps = kilobites per second. This is a standard measure of network speed.

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- **Signal Transfer Points (STPs) –** These are the "packet switches of the SS7 network"[5] that route control messages to the correct destinations. Each Service Control Point platform is linked to at least two of these Signal Transfer Points so that alternate paths are always available in case any single component fails.

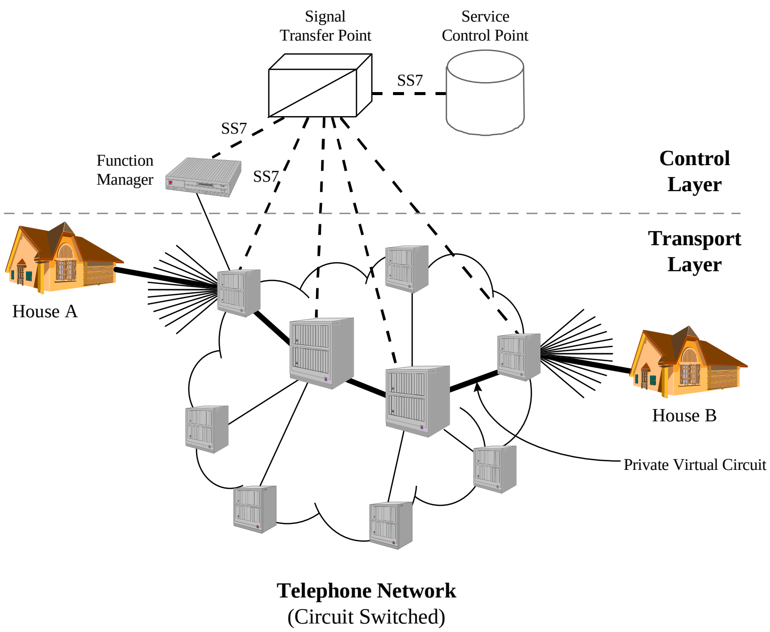
- **Function Managers –** These devices (also called service nodes) are intelligent peripherals that provide services such as computerized voice and voice mail.

## How It Works

Chart 3 depicts how the signaling layer and transport layer operate together to provide advanced telephone services. In this example, person A picks up a telephone handset and dials person B's number. This connects the sender to the edge office switch in a central office that in turn interrogates the database at the Service Control Point to see if there are any special instructions for this call. The message "how should I handle this call" from the Class 5 switch in the central office is routed to the proper database at the Service Control Point through the Signal Transfer Point. The SS7 control environment first checks to see if person B's local line is busy. If it is, then the SS7 control environment interrogates the database to determine if additional handling instructions are on file. If the line is busy and no additional instructions have been given, then a recorded busy signal is played to the caller from the caller's local central office without a physical circuit ever having been established.

If person B's line is available, then the SS7 signaling system establishes the circuit from person A to person B through the network switches as shown. If there is no response from person B after a predetermined number of rings, the Function Manager may be activated by SS7 signaling to play a message to person A stating, "There is no answer yet. If you would like to leave a message for this person [for a fee that goes to the telecommunications service provider] just press the number 1 on your telephone." These sorts of advanced telephony features are designed to provide the maximum level of service to the caller and the maximum fees to the service provider.

**Chart 3: Establishing a Private Virtual Circuit**




Source: JPMS.

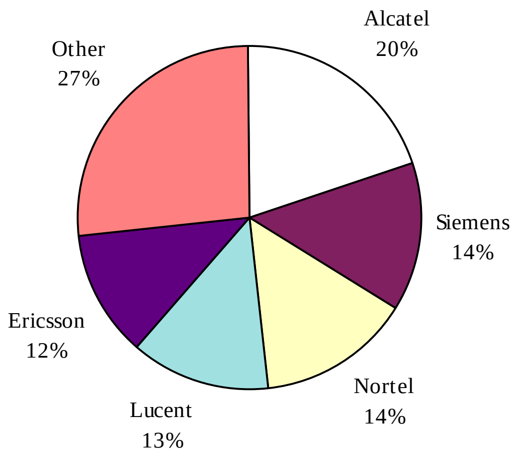
[5] http://www.webproforum.com/bell-atlantic2/topic04.html.

## What Is Circuit Switching?

The telephone architecture described above is called "circuit switching." This approach dedicates physical resources (i.e., bandwidth and switch ports) to create a connection (i.e., a circuit) between sender and receiver that is fixed for the duration of the call. This circuit is "private" because no other people in the network are able to use any of the bandwidth allocated to this call. The circuit is "virtual" because although there is not a single physical wire running from the sender to the receiver, there seems to be. One of the main reasons we believe circuit switching will ultimately lose to data architectures is that the bandwidth allocated to the telephone circuit is always 100% dedicated – even during pauses in conversation when no one is talking.

Chart 4 shows the current worldwide market shares of telephone circuits.

**Chart 4: Market Shares of Telephone Circuits**



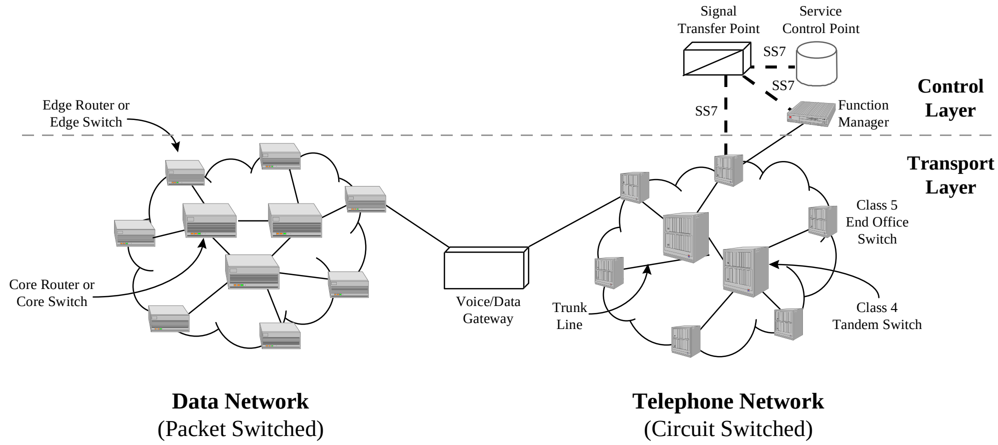

Source: IDC.

# Data Networks

## Overview

Chart 5 below begins to fill in the data networking portion of a converged voice and data network by showing how the transport portions of both interface. Everything in Chart 5 exists as commercially available products today and nothing in the picture is experimental.

**Chart 5: Data Networks Connected to the Telephone Network**




Source: JPMS.

## Voice/Data Gateways

The conversion of voice traffic into data packets takes place in gateways and is a three-step process: 1) digitize voice calls if necessary, 2) compress the contents (standard 64 Kbps voice circuits can be successfully compressed down to 8 Kbps in many data networks), and 3) packetize the signals. Today's gateways are based on digital signal processing (DSP), which is a key technology in the integration of voice and data. In fact, digital signal processing is so central to voice/data convergence it has been called "the lubricant of convergence."[6]

Voice/data gateways are available today from a variety of vendors, including Cisco, Ascend, 3Com, Lucent, Nortel, Ericsson, Motorola (MOT/$57.06/Buy), Siemens, Vocaltech, Dialogic, Vienna Systems, Netspeak, Micom, and RADvision. As you would expect, Cisco's gateway is built on a router while most of the others operate on standard computing platforms – typically Pentium-class PCs running Windows NT or Sun's Solaris UNIX system.[7] While today's gateways usually support hundreds of connections, within three to five years the port density is expected to increase to hundreds of thousands of simultaneous connections.[8] During this time, the gateway platforms are expected to mature into larger and more reliable "carrier class" devices. In the next section we will explain how Cisco and Bellcore are adding "control" functions to the gateways in addition to the "transport" functions described above.

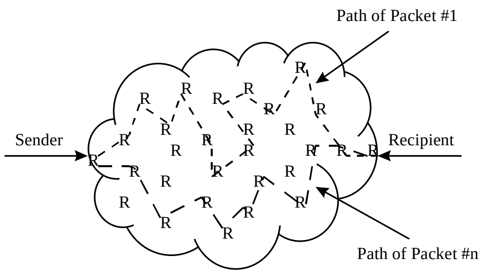
[6] Chris Lamb, director of business development, 3Com Corporation.
[7] BCR's Voice 2000, *Business Communications Review*, October 1998.
[8] STARTRAX 98, *Systems for VoIP*, Ryan Hankin Kent, Inc., November 1998.

## Switching vs. Routing

While there is no “standard” data network, the primary components of today’s wide area data networks are routers and switches. In discussions about convergence of voice and data networks, it is assumed that the data portion of the integrated network consists of routers or ATM switches. Chart 6 presents a quick review of routing and switching.

### Chart 6: Routing and Switching

**Traditional Routed Network (Internet)**



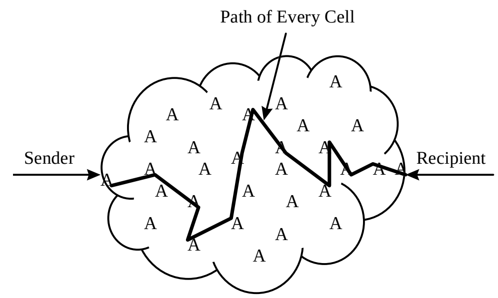

**R** = Router

**Characteristics** = Slow, but flexible. Each packet can take a different path through the network and each router performs a table look-up computation for each packet it encounters. This is called **connectionless** communications. If a section of the network goes down, routers simply route the traffic around the problem area.

**Packet** = An entire file of data is broken down into chunks of data called packets that can be transmitted individually and reassembled at the destination to recreate the original file. There is no set size or format for packets, which are also called “frames.”

**In a typical Internet session**, each packet is processed by 15-20 routers (typically referred to as 15-20 “router hops”).

**ATM Switched Network**




**A** = ATM Switch

**Characteristics** = Fast, but less flexible. Every cell takes the same path, and if the connection is broken anywhere along the way the entire path must be reestablished. This is called **connection-oriented** communications.

**Cell** = Standard-sized chunk of data with standard header information. Because cells are standardized, ATM switches can read the address of the cell’s destination and switch the cell with almost no delay, which is called switching “at wire speed.”

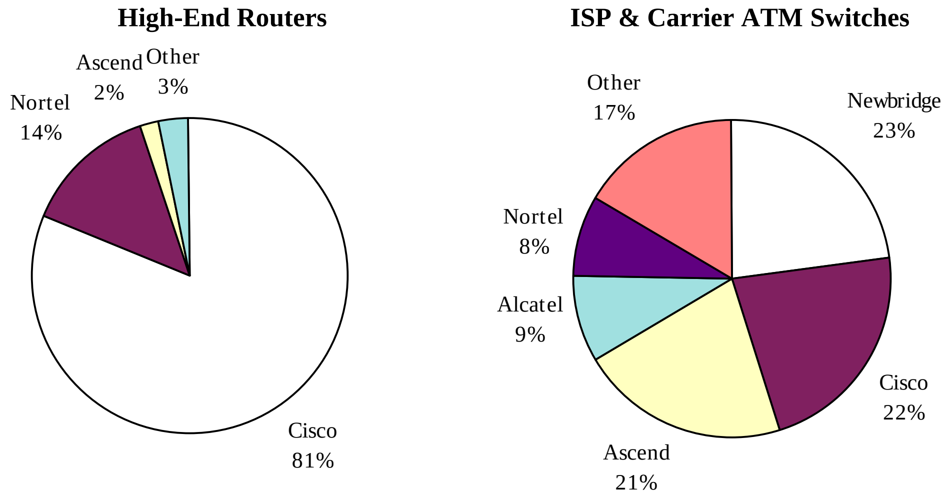
Source: JPMS.

*For a comprehensive discussion of IP routing, ATM and frame relay switching and other data networking devices, refer to the following JP Morgan Equity Research reports:*

**Data Networks: Still a Paradox**, *January 27, 1998*
**The Networking Paradox**, *February 27, 1997*

The worldwide market shares of routers and ATM switches sold into the carrier market are shown in Chart 7 below.

**Chart 7: Market Share Data for Routers and ATM Switches**



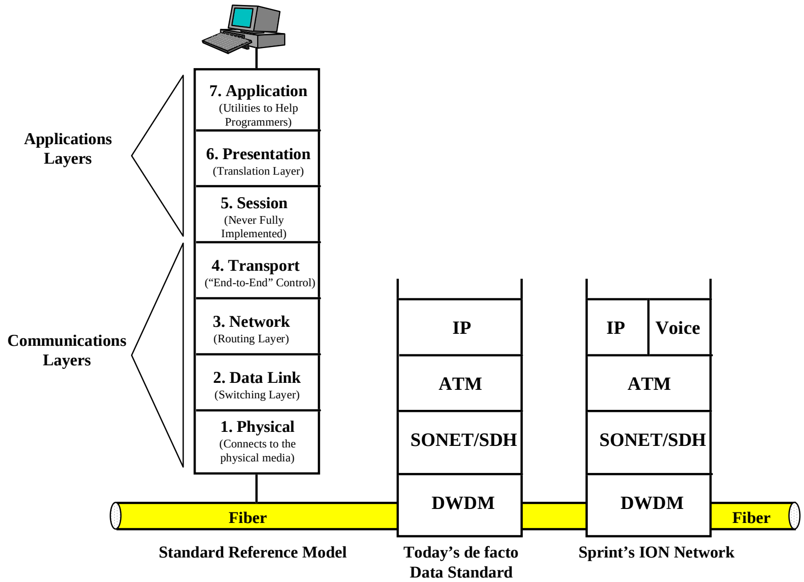

Source: JPMS, The Dell'Oro Group, and Dataquest.

## The Fight Between Routing and ATM Switching Is Over – Both Win

For the past several years a lively debate has been raging about which of the two most popular data protocols would win – the Internet Protocol (IP) or ATM. Clearly, IP has exploded as an industry standard with the growth of the Internet, and many people have consequently written off ATM as a casualty of the Internet. However, our recent visits with telecommunications service providers in Asia, Europe, and the United States show that ATM is also being installed almost everywhere by incumbent service providers because of its "multiservice" capabilities. That means that ATM has the ability to simultaneously transport multiple types of traffic (such as voice and IP data).

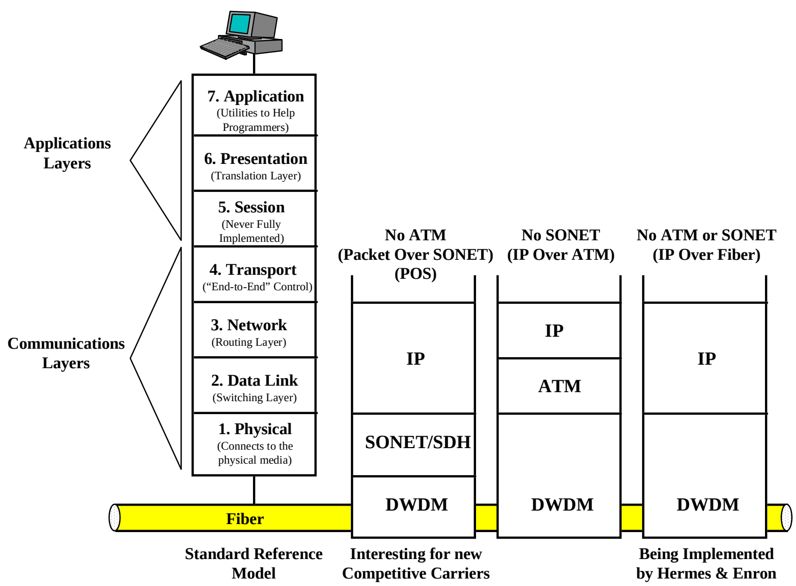
Additionally, although not important today, ATM can guarantee service levels that may in the future allow carriers to offer services with different levels of quality and charge customers accordingly. So, both IP and ATM are selling like hot cakes, and a de facto standard data architecture has evolved over the past year that includes both technologies. Chart 8 portrays this current de facto standard data architecture and Chart 9 shows some newer, more experimental structures. An important observation is that **IP and dense wave division multiplexing (DWDM) are components in every architectural structure being either implemented or seriously considered by service providers.**

## Chart 8: Common Data Architecture




Source: JPMS.

## Chart 9: Potential New Data Architectures




Source: JPMS.

## Why Pure Data Networks Do Not Need "Signaling" Layers as Voice Networks Do

The "brains" of the public switched telephone network are built into the SS7 signaling environment. That is where questions such as "Where are you going?", "What route am I going to send you on?" and "What services are you eligible for?" are answered. By contrast, these questions are answered in the routers (and routing portions of switches) in data networks, so no separate signaling environment has been required to date. Convergence changes that.

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## New Architectural Design Principles of Bellcore & Cisco

We now begin discussing new products being developed by Bellcore and Cisco. Their architecture for the integration of voice and data adheres to the following set of design principles.

1. **Isolate control functions from transport functions**. The network design being developed by Bellcore and Cisco consists of two separate layers, each providing different functions. First, a "transport" layer establishes the physical connection between senders and receivers and forwards traffic from one to the other. Second, a "control" layer determines how the call (i.e., any kind of communications session) is to be handled and provides advanced telephony and data features as appropriate. This separate control layer is called "out of band signaling" because the control (or signaling) functions generally do not take place over the same physical path as the actual voice and data transmissions. This separation of control and transport functions has already been implemented in today's telephone network, and in the converged environment of the future it will allow advanced telephony services to be provided even when the data transport infrastructure is changed and upgraded. Because data networks are so immature compared to voice networks, it is virtually certain that there will be numerous upgrades to the data portion of integrated networks in the future. The converged architecture must, of course, easily accommodate changes in the data transport layer.

2. **Provide interoperability with the existing public telephone network**. We believe that the evolution of today's "circuit switched" telephone network into the "packet switched" data network of the future will happen gradually over (at least) a decade. During that time, the new and old networks must interoperate so that everyone can communicate. Bellcore and Cisco's design insures that all telephones can communicate with the new converged networks.

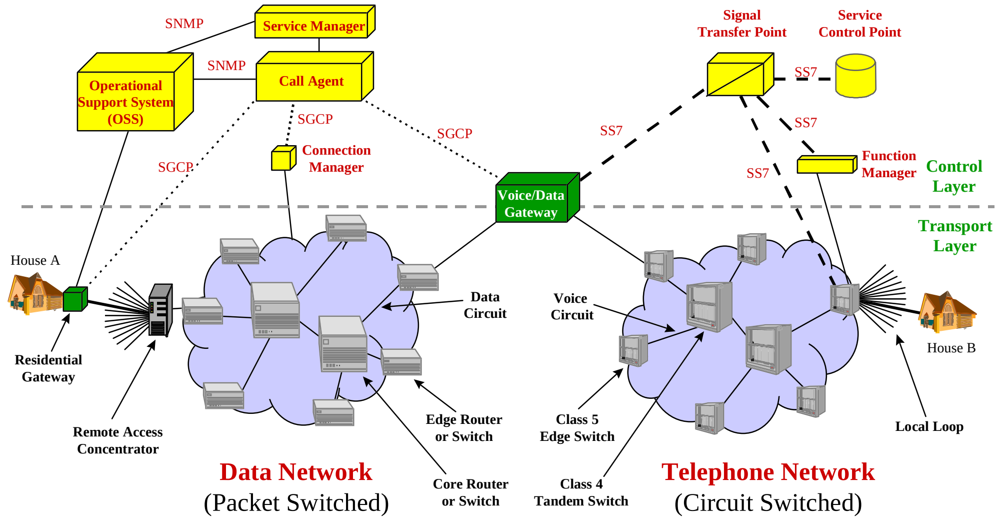
3. **Support multiple data technologies**. In a data networking environment, where "nothing is constant except change," it is important to have an overall architecture that caters to changing technology. The new design fulfills that requirement and initially supports two core data transport technologies (ATM and IP) and will accommodate nearly any access technology, such as DSL, cable, wireless, and fiber.

4. **Comply with standards**. Bellcore and Cisco's design utilizes standard signaling protocols (such as SS7 and SGCP, which are described later in this report) and standard programming interfaces. The former helps insure interoperability between networks and the latter enables network operators to alter a customer's service profile more easily.

### The Complete Picture

Chart 10 attempts to put all the pieces together to show a conceptual overview of the new architecture being developed by Bellcore and Cisco. The components of this architecture that have not yet been discussed in this report are the Call Agent, Service Manager, Connection Manager, Residential Gateway, a new control protocol called SGCP, Operational Support System (OSS) , additional functions of the Voice/Data Gateway, and a standard data network management protocol called SNMP. These are described below.

**Chart 10: Complete Picture of Convergence**




Source: JPMS and Bellcore.

- **Call Agent** – This product, which is new from Bellcore, is the heart of its new control architecture. The Call Agent serves as the link between the SS7 signaling environment and the physical transport layer of data networks (via the Voice/Data Gateway). It is the traffic cop that insures calls are handled properly (i.e., get to the right destination and receive advanced services appropriately) in the data side. In a fully converged voice/data network, the Call Agent is notified via signaling from the residential gateway that a call is originating. The Call Agent then determines which, if any, advanced features (such as call forwarding, call screening, 800 numbers etc.) are applicable to the call. For most of these new services, Call Agent will have its own locally stored information (similar to the capabilities at Service Control Points in the SS7 environment). In some cases it will be necessary for the Call Agent to interface with the SS7/SCP databases on the telephone side, but most of the advanced call logic will be stored locally. Call Agent then works with the Connection Manager (see below) to ensure that the call, with the appropriate advanced services, is routed to the proper destination. Call Agent software is being developed to operate in a UNIX environment and will initially run on HP (HWP/$65.44/Market Performer) and Sun (SUNW/$77.38/Buy) platforms.

- **Service Manager** – Also new from Bellcore, Service Manager is a Java-based product that allows network operators to easily alter a customer's service profile (i.e., the services the customer has subscribed to and will pay for). Service Manager can be thought of as a flexible "front end" for Call Agent.

- **Connection Manager** – This component supports the Call Agent by isolating Call Agent from the underlying ATM or IP network. In fact, the Call Agent does not even know what protocol the data network is using. This permits the technology in the data network to be changed over time without having to modify the Call Agent. The Connection Manager receives a command from the Call Agent to establish the circuit and Connection Manager then sets up the physical path. In an ATM network the circuit is established by using the routing algorithm built into the ATM protocol (called PNNI signaling) while in an IP network the path is established by simply sending the IP address of the voice/data gateway to the residential gateway and letting normal IP routing take over from there.

- **Residential Gateway** – In the announcement of Sprint's ION network, it was advertised that the residential gateway would be available from Radio Shack for approximately $200. Press coverage has focused on the ability of the residential gateway to measure (and bill for) network utilization by the number of packets transmitted rather than by the

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length of the call in minutes. It is, of course, an unproven theory that customers will save money if they pay by the packet rather than by the minute, and it is also unknown how much money customers will be willing to pay for the gateway. Nonetheless, a residential gateway is a fundamental component of the new architecture because it is the connection point between the home and the Call Agent. This residential device receives control messages from Call Agent such as "ring the telephone." For Videotron's network, Cisco is developing the residential gateway.

- **SGCP (Simple Gateway Control Protocol)** – This protocol is an emerging standard that defines how voice, data, and video traffic will be transported over data networks. Just as SS7 was described as the protocol used in the control environment of the telephone network, SGCP is being utilized by Bellcore and Cisco as the control protocol for the data side. When the voice/data gateway determines that an incoming call is intended for House A (shown on the left side of Chart 10), the voice/data gateway sends an SGCP signal to the Call Agent saying "ring House A." Call Agent in turn uses SGCP to tell the residential gateway to ring the telephone in House A. SGCP has been designed by Bellcore and Cisco as an improvement for data networks on a more commonly known protocol called H.323, which is described in Appendix III along with other protocols that may evolve into the standard.

- **Operational Support Systems (OSSs**) – OSSs are available today from Bellcore, Lucent, Nortel, and other voice equipment vendors and perform functions such as billing, customer care (i.e., managing the services provided), accounting, and network management. These can be extremely complex systems, and quite often the reason it takes so long for a service provider to alter its network is the complexity of modifying the OSS. No one wants to develop a new OSS, and we believe Cisco levels the competitive playing field with Lucent and Nortel by leveraging Bellcore's OSS. In the new architecture, it is envisioned that customers will review their telephone bills via a web page, note any discrepancies, and pay automatically by notification of the OSS from the web-based billing page. Customers can also sign up for additional services or modify their service selections through the OSS, which is connected directly to Call Agent. Bellcore's OSS is client-server based with Windows NT clients (Java clients are being added). The server is HP's UNIX platform with Oracle databases.

- **Voice/Data Gateway** – In the previous section, the existing "transport" functions of the voice/data gateway in converting voice circuits to data packets (and vice versa) was described. In the new architecture being developed by Bellcore and Cisco, an additional "control" function is being added. As seen in Chart 10, the voice/data gateway now must be able to terminate the SS7 telephone control protocol and initiate the corresponding SGCP message (and vice versa). We have therefore repositioned the voice/data gateway showing it partially in the transport layer and partially in the control layer. Cisco is also developing the voice/data gateway for Videotron's network.

- **SNMP –** SNMP is a nine-year-old standard data network management protocol (it stands for Simple Network Management Protocol) from the IETF.[9] SNMP is very common in today's data networks and is used to communicate management and administrative functions.

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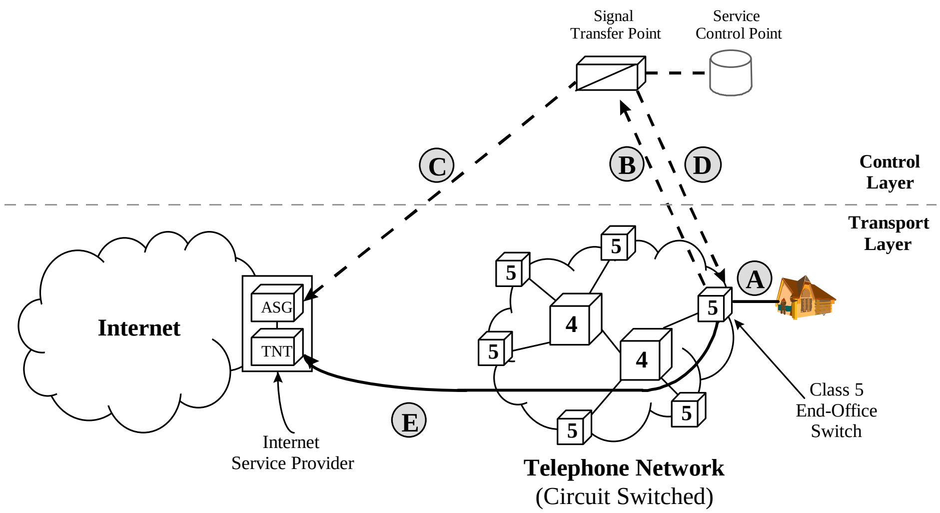
[9] The IETF (Internet Engineering Task Force) is the organization that establishes standards for the Internet.

## Ascend Communications

Although this report concentrates on the architecture and products being developed by Bellcore and Cisco, we do not want to leave the reader with the impression that those are the only companies working to converge voice and data networks. Ascend has announced its "MultiVoice" strategy for integrating voice traffic over almost any type of data transport (i.e., IP, ATM, and frame relay) and has already shipped products that implement the latest phase of that strategy to Level 3 Communications. Chart 11 depicts Ascend's current architecture, which is designed to provide a service called "Internet Call Diversion." Internet Call Diversion is a way of keeping Internet data sessions off of the Public Switched Telephone Network (PSTN), since Internet traffic is swamping the PSTN.

**Chart 11: Ascend's Internet Call Diversion Architecture**




Source: Ascend Communications and JPMS.

The two components of Chart 11 that have not previously been discussed in this report are:

- **ASG (Ascend SS7 Gateway)** – This is the product Ascend acquired from Stratus. It consists of an SS7 protocol stack (which is software) and Service Control Point software (for advanced telephony functions) operating on the Stratus fault-tolerant computing platform.

- **Remote Access Concentrator** – Depicted above as a "TNT," these devices are deployed mostly by Internet service providers (ISPs) to terminate Internet access requests (principally from analog modems) and concentrate these individual calls (from people like you and me) onto much larger circuits directed into the Internet. Competitive advantage in the remote access concentrator market comes from engineering high port density into the hardware (i.e., how many modems can the vendor cram into a standard seven foot high rack?) and from developing advanced functionality in the management software. Ascend is the market-share leader in remote access concentrators, and its high-end product is called the Max TNT.

Here's how Internet Call Diversion works. First, a residential customer dials an Internet service provider to initiate an Internet session. This is shown as *link A* in Chart 11. Next, the Class 5 edge office switch in the customer's central office diverts the call to the SS7 control environment to ask how to handle the call (it is clear to the Class 5 switch that special handling is required). The message "How do I handle this call?" is depicted in Chart 11 as *link B*. The Service Control Point software in the SS7 control environment then determines that the call is an Internet session and simultaneously 1) notifies the ASG (Ascend SS7 Gateway -

which is located near the remote access concentrator within an ISP's facility) that an Internet call is coming and 2i) instructs the original Class 5 switch to direct the call to its outbound port, which is connected directly via a trunk line to the ISP's Remote Access Concentrator. In Chart 11, these transmissions are shown as *links C and D*, respectively. In the final step, the Internet session is established over the trunk line, which "cuts through" the telephone network and does not utilize any of the Class 4 Tandem switches in the PSTN or any Class 5 Edge Office switches other than the original one at the point of entry for the call (depicted as *link E* is Chart 11). Now the person can stay on the Internet as long as desired without clogging up resources in the public telephone network.

The final stage of Ascend's MultiVoice strategy (to be announced early next year) should provide the blueprint for its overall data control environment. This software will perform functions similar to those of the Bellcore/Cisco control environment described in this report.

## WHO WILL WIN – VOICE OR DATA VENDORS?

### For Data Networking Vendors It's Acquire or Be Acquired

The previously separate investment sectors of data networking and telecommunications equipment are rapidly coming together into a single, integrated sector with an aggregate market capitalization of over $350 billion. We believe that the combined market will be dominated by four or five giant equipment vendors, each offering a full set of products and services, while mid-cap and small-cap companies will probably either be acquired or crushed by the competition. There are two primary reasons why we believe only giant equipment vendors will survive in the new environment:

1. **Fewer Strategic Vendors for Each Carrier**: Service providers want to reduce the number of strategic communications equipment vendors they deal with. This means that the breadth of a vendor's technology portfolio is becoming as important as the quality of any single product. The era of buying only "best of breed" products and integrating them internally is drawing to an end. Carriers are moving to a model in which they would rather buy good routers, switches, and access concentrators from a single vendor (who is committed to future upgrades) than buying today's best routers from one vendor, today's fastest switches from another, and today's densest access concentrators from yet a third. We believe that mid- and small-cap communications vendors must aggressively broaden their product portfolio if they wish to remain independent.
2. **Global Support Demanded**: Since carriers are competing in a global market, they are selecting vendors that can provide equipment and service around the world. That is a difficult task for small- and mid-cap vendors.

While we believe the new $350+ billion communications sector will be dominated by four or five giants, there will always be room for hot new start-ups with creative approaches and the ability to stand on their own for some time. In today's market, Uniphase and Broadcom are examples of such hot new start-ups.

## Who Is Best Positioned?

Neither the data networking vendors nor the telecommunications equipment vendors are perfectly positioned for the coming war. Each side has advantages, as shown in Table 1. As with most innovations in technology, winning this war will be more about excellent execution than early positioning advantages.

**Table 1: Competitive Analysis – Data vs. Voice Vendors**

| Sector | Advantages |
|---|---|
| **Data Networking Vendors**<br>Cisco<br>Ascend<br>3Com<br>Newbridge | **1. Superior Knowledge of Data:** Voice and data are converging into a data architecture. This is an advantage for data networking vendors as they already know how to build, scale, manage, and support data networks.<br><br>**2. Faster Internal Clocks:** Data networking vendors move faster and are traditionally more responsive to customer's demands for changes because new data networking products are typically delivered every year. |
| **Telecommunications Equipment Vendors**<br>Lucent<br>Nortel<br>Alacatel<br>Tellabs | **1. Huge Customer Bases:** The large installed base of carrier customers represents a significant advantage for telecommunications equipment vendors as distribution channels are well established and carriers are already comfortable doing business with them.<br><br>**2. Superior Knowledge of the SS7 Control Environment:** Voice networking vendors have developed robust telephony control environments over the years, and we think these will continue to play major roles in the converged networks of the future. Cisco and Ascend are working to level the playing field in this area – Cisco via the Bellcore alliance and Ascend through its Stratus acquisition. |

Source: JPMS.

## INVESTING IN CONVERGENCE

Appendix I is a current comparable table for the communications sector. Appendix II contains one-page investment summaries for CSCO, ASND, COMS, LU, NN, and NT. All of these vendors are currently developing products that integrate voice and data, and some of their activities are summarized below.

**BUY**

- **CSCO** – As described in this report, we believe Cisco and its partner Bellcore are **leading the race** to figure out how to integrate voice and data. Additionally, Cisco plans to have all key products NEBS[10] compliant by early next year.

**BUY**

- **ASND –** Ascend has announced a portion of its overall strategy to integrate voice and data and will disclose its complete architecture in January 1999. The current phase of the company's MultiVoice strategy is described in this report. A key element of Ascend's strategy was its **acquisition of Stratus,** which provided Ascend with a fully debugged SS7 protocol stack, a broad portfolio of Service Control Point software (800 numbers, call waiting, etc.), and a fault-tolerant computing platform upon which the software operates. Ascend is calling its new control structure for the data side of a converged network SS8

**BUY**

- **COMS** – 3Com is totally committed to convergence and 100% of its new products will be both voice and data capable. This includes Palm Pilot, network interface cards (NICs), and modems along with its data switches and remote access concentrators. Future alliances and acquisitions will be driven by the concept that convergence is a "fundamental milestone, not just a fad."[11] 3Com is making significant progress in **LAN telephony** (integrating voice and data in local corporate environments). The next version of the company's SuperStack switch (available in the first quarter of calendar year 1999) will be both a data switch and a voice switch (called a PBX). This new "**data PBX**" is the result of 3Com's collaboration with Siemens. Additionally, during the first half of next year, 3Com is expected to release its **Ethernet IP Telephone,** further integrating voice and data over local area networks. The company is working with Siemens and Microsoft to develop "gatekeeper" software that maps telephone numbers into IP addresses and to develop directory management, billing, and other administrative software. In the wide area, 3Com's Total Control Remote Access Concentrator now provides voice over IP services, and the company is positioning its Total Control concentrator to divert the flood of Internet traffic that is trying to swamp the public telephone network. This is similar to Ascend's Internet Call Diversion strategy.

**BUY**
***Lucent is covered by***
*Gregory S. Geiling*
*(1-212) 648-3320*
*Brantley W. Thompson*
*(1-212) 648-7883*

- **LU –** Lucent has three main advantages as the market moves toward convergence: 1) a large installed base of equipment with all of the leading communications carriers, 2) a strong understanding of the SS7 software that controls the public switched telephone network, and 3) a very large servicing organization that allows Lucent to provide "turnkey" solutions to its customers. As the vendor that **fundamentally built today's public telephone network,** Lucent has an intricate understanding of the complex software that operates today's voice networks. However, the company currently lacks competitive ATM switching and IP routing solutions and, as these technologies are the main focus of current data deployments, it is imperative that Lucent strengthen its position in these key product areas. So far, Lucent's strategy has been to make relatively small data acquisitions (Livingston for remote access, Agile for LAN-ATM interfaces, Yago for ATM access, Prominet for LAN switching, etc.) while relying on its own internal research and development capabilities for the main data networking products

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[10] NEBS (Network Equipment Building System) is a set of performance standards for communications equipment operating in public networks.
[11] Eric Benhamou, chairman and CEO, 3Com Corporation.

such as core ATM switches and IP routers. Since it has been over two years since Lucent became independent from AT&T, which may account for acquisitions using pooling rather that purchase accounting, the industry is waiting to learn whether Lucent will change its current strategy and make a major, blockbuster acquisition.

**Long-Term Buy**

- **NN –** Newbridge Networks is not developing specific products to help integrate voice and data; rather the company is focusing on establishing a versatile IP-based networking architecture. The purpose is to allow carriers to provide managed IP services that are capable of transporting both voice and IP data.

**Long-Term Buy**

***Nortel is covered by***
*Gregory S. Geiling*
*(1-212) 648-3320*
*Brantley W. Thompson*
*(1-212) 648-7883*

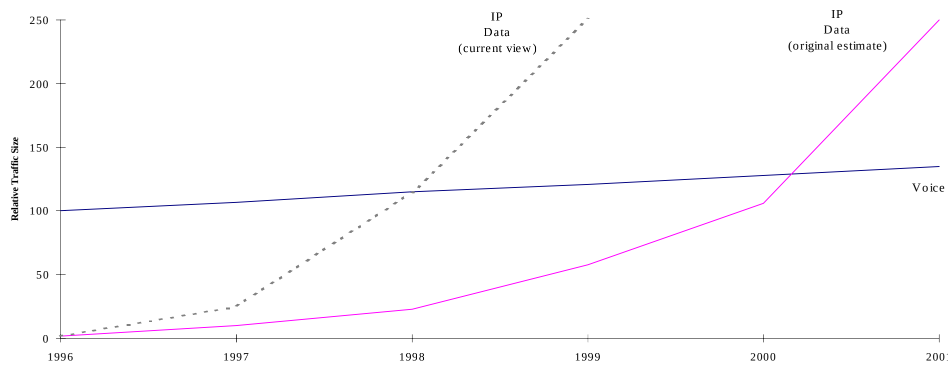
- **NT –** Northern Telecom is well positioned as the industry moves toward convergence, in our view. Nortel has a very strong understanding of the public telephone network and boasts entrenched relationships with major carriers. These relationships are especially strong with interexchange carriers (IXCs). We think Nortel has been very successful in developing relationships with the "new breed" of carriers, such as MCI WorldCom (WCOM/$64.38/Buy), Level 3, Qwest (QWST/$43.38/Market Performer), Williams, and others. Of all the traditional telecommunications equipment vendors, we believe Nortel has done the best job so far of marketing ATM switches. Many of Nortel's ATM switches were developed internally, while one product line is the result of the company's past relationship with Fore Systems. Nortel is now in the process of developing an understanding of the IP environment with its recent acquisition of Bay Networks and its alliance with (and investment in) Avici, which is a "next generation" IP router start-up.

## WHY IS CONVERGENCE HAPPENING NOW?

We believe the two primary factors causing investments in converged networks to accelerate are 1) the even-faster-than-anticipated explosive growth of data traffic and 2) the early beginnings of competition for incumbent service providers.

Until recently, the consensus view was that the volume of data traffic would not overtake voice traffic until around the turn of the century. However, we now have evidence that, in fact, the volume of data has already caught up with voice, and we believe 1998 will be remembered as the year in which data exceeded voice traffic for the first time. Bellcore agrees with this assessment, indicating that a close examination of actual network utilization reveals that much of what we think of today as "voice" traffic is actually data pretending to be voice. A good example of this is fax data traveling over the public telephone network, which would typically be classified as voice traffic. A revised view of data growth is pictured in Chart 12.

**Chart 12: Data Traffic Overtakes Voice in 1998**




Source: JPMS, The Yankee Group, and Telstra.

Recent conversations with Internet backbone suppliers in Europe and Asia as well as in the United States indicate that **Internet traffic is accelerating**. It is clear that telecommunications service providers are responding to this demand by accelerating their spending on data networking equipment and on technologies that foster the convergence of voice and data. This appears to be moving much faster than originally envisioned and estimates of the size of the voice-over-data market are increasing. As an example, the market research firm IDC predicts that the voice-over-data market will approach $25 billion by 2002.

In addition to the explosive growth of data, another factor pressuring incumbent carriers to begin investing in data networks is the emergence of aggressive and well financed competitive service providers that are focusing exclusively on data. Competition in the long distance markets is real today. In the local markets, we believe competitive local exchange carriers (CLECs) do not currently represent major threats to the massive residential customer base of incumbent local exchange carriers (ILECs). However, aggressive new CLECs are now "skimming the cream" at the largest and most profitable accounts of the Regional Bell Operating Companies (RBOCs) – namely large corporate customers. It is estimated that these corporate customers represent about 30% of the business of incumbent local service providers.[12] While the baby Bells may not have broken out into a full case of the competitive sweats just yet, we do sense the presence of a few beads of perspiration on their foreheads. Like it or not, competition is coming and all carriers must now prepare.

[12] Simon Flannery & David Barden, *Telecoms in the Age of the Internet*, J.P. Morgan Equities Research Report, November 24, 1998.

# Why the Data Architecture Wins

## Voice Circuits

The “circuit switching” architecture of the telephone network dedicates network capacity to create a connection (a circuit) between sender and receiver that is fixed for the duration of the call. Importantly, in circuit switched environments the physical network resources are 100% dedicated to the call even during pauses in conversation when no one is talking.

## What’s the Problem?

Although the circuit switching architecture has worked well for decades while telephone calls were relatively short and bandwidth requirements were small and fixed, it is not well suited for the much longer sessions and huge demand for network capacity that have been unleashed through the explosive growth of the Internet and corporate intranets. One big problem is that circuit switching does not permit sharing of network resources during the dead time common in Internet sessions while the person is thinking, reading, napping, or doing anything else without logging off of the web site. During that dead time, network resources are still tied up – dedicated to a session that is not utilizing them. This is a formula for very high Capex and very low return on that capital investment for communications carriers, and it only promises to get progressively worse as data traffic begins to dwarf voice communications.

The second big problem with the architecture of voice circuits for Internet traffic is that the telephone network does not permit the selection of data transfer rates that are appropriate for the application. In the telephone system all transmissions are fixed at the very slow speed of 64 Kbps while data transmissions can require multiple megabits of throughput.

## Packet Switching Wins

**We believe voice and data are converging onto a data architecture** for two reasons:

1. Data networks utilize an architecture called packet switching that breaks large blocks of data into smaller chunks called “packets” or “frames” and sends these individual chunks of data through the network without predetermining the path the packet will take and without utilizing physical resources in excess of what the packet requires. In ATM networks, where the path has been predetermined, the ATM cells (think of them simply as small, standardized chunks of data) share the network’s bandwidth with other calls and are interspersed with cells from numerous other sessions. This sharing of resources provides much higher return on invested capital for telecommunications service providers.

2. Additionally, data networks currently operate at speeds over 100,000 times faster than voice networks, and this disparity is increasing.

## Benefits of Convergence

In our opinion, convergence will have short-term, mid-term and long-term benefits. These are summarized below.

### Short-Term Benefits – Save Money Now

Given the current regulatory environment, it is much less expensive to place telephone calls over the Internet (or corporate intranets) than it is using the public telephone network. The regulatory double-talk that creates this situation is discussed in the next paragraph. The effect is that by using the Internet for telephone calls and fax transmissions it is possible to avoid fees that currently account for 30-40% of domestic long distance telephone charges and (much more dramatically) for 80-90% of international costs. As long as this tariff arbitrage opportunity lasts, we believe there will be pressure to reduce the usage of the public telephone network in favor of the Internet.

Here is the way the regulatory environment works. Long distance carriers (AT&T, MCI WorldCom, Sprint, etc.) pay access fees to local exchange carriers (Bell Atlantic [BEL/$54.69/Buy], SBC, etc.) and to international PTTs (British Telecom [BTY/$143.19/Market Performer], NTT [$36.88/Buy], etc.) for the use of their local facilities. These charges are based on minutes of usage and can be significant (as described above). In international markets, these access fees have been negotiated separately by each country and can vary significantly country to country. Since Internet Service Providers (ISPs) are currently classified as “Enhanced Service Providers” rather than “Long Distance Providers,” they are able to avoid paying the access tolls. However, in our view **this tariff arbitrage opportunity will almost certainly not last forever**. Although the Clinton administration has requested that the FCC hold off on regulating Internet telephony, the FCC has stated that fees on Internet telephone services are possible (we think probable) in the future.

### Mid-Term Benefits – Obtain Enhanced Services

When the Bellcore/Cisco architecture is implemented, a full suite of advanced intelligent network (AIN) services are expected to be available over the Internet. These services will include 1-800, 1-900, call screening, call waiting, call forwarding, mobile roaming, credit card calling, voice mail, 5-digit calling, caller ID, number portability, directory assistance, ∗66, etc. The availability of these advanced services at favorable fees could certainly drive voice-over-IP usage as well.

### Longer-Term Benefits – Reduce Infrastructure Costs

One of the fundamental financial underpinnings of the migration to converged networks is that telecommunications service providers can reduce their Capex and increase their return on invested capital by commingling voice, data, and video transmissions and transporting them all over a data architecture. Since data networks allow sharing of unused capacity while traditional telephone networks do not, data architectures are inherently more Capex efficient. However, we believe it will take several years to realize this Capex efficiency because carriers must learn how to operate converged networks. Ultimately (in decades) the cost savings to carriers could be substantial as they eliminate circuit switched networks entirely and rely completely on packet switched architectures. However, don’t hold your breath waiting for that one.

## Convergence Happens

### Overview

The market perception seems to be that by using the Internet for voice transmissions we can *"dial up friends anywhere in the world and talk for hours without ringing up long-distance charges."*[13] A perspective closer to reality (from the same source) is *"voice over IP has too many hang-ups for end-to-end deployment, but answers the call in a few key areas."* The main point of this section is **that fax over the Internet is a viable service today but that it is premature to consider broad deployment of voice over the Internet** because the technology must mature (although we think it clearly will be a viable service in the future).

### Fax Over the Internet

We believe one of the **leading edges of convergence will be the transmission of fax documents over the Internet.** Fax appears to be an excellent application for the Internet because the cost savings can be both significant and easy to measure. Dataquest estimates that Internet fax usage will grow from 44 million pages (at $0.22/page) in 1997 to 382 million pages (at approximately $0.18/page) this year. While that growth may appear to be robust, with a total domestic fax market of 65 billion pages in 1997 it can be seen that the Internet portion of the fax business is tiny. Although fax represents about one-third of the telephone bills for Fortune 500 corporations[14] and approximately one-half of all corporate fax usage is for intracorporate faxes, many corporations do not know how much they spend on fax and are therefore not immediately interested in solving a problem they are not aware they have. However, the financial payback for heavy international fax users who convert to Internet fax occurs after only about one month.[15] We believe fax service bureaus represent a near-term growth opportunity for Internet fax because these customers spend a lot on fax and understand their costs.

Internet fax services are currently being offered or piloted by PSINet, UUNet, GTE (GTE/$64.38/Buy), AT&T, and NetCom (NTC/$16.50/Market Performer). The primary Internet fax equipment vendors utilized by these service providers are Open Port and NetCentric.

Fax traffic can be initiated in two ways – either from fax machines or from PCs using LAN-based fax servers – with the great majority of usage coming from the former. Fax machines from many manufacturers are now Internet enabled, including Panasonic, Konica, Mita, Ricoh, Lanier, Sharp, and Pitney Bowes. Additionally, a variety of IP add-on devices are on the market for existing fax machines.

### Telephone Over the Internet

A variety of voice over IP (VoIP) services are either currently being offered or are in trials throughout the United States with the cheapest rates being offered today by IDT Corporation (Net2Phone Direct service) at $0.05/minute and ICG Communications at $0.059/minute. Other service providers offering VoIP services include AT&T, Qwest, Level 3, MCI WorldCom, Delta Three, and AlphaNet. We believe that while voice over the Internet represents a potentially large future market opportunity for data networking equipment suppliers such as Cisco, Ascend, and Newbridge Networks, it is too early in the cycle for significant market penetration in the near term. Although a recent survey by Forester Research indicates that within two years over 50% of major corporations will be using IP telephony (up from 5% today), **during 1999 we expect hype to be high but revenues to be low from voice over the Internet services.**

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[13] VoIP in the Enterprise, *Network Computing*, October 1, 1998.
[14] Gallup poll sponsored by Pitney Bowes.
[15] *Fax Machines Embrace the Internet*, Dataquest, October 6, 1998.

## Two Technical Issues – Reliability and Call Quality

### Reliability of Voice vs. Data Networks

The public switched telephone network (PSTN) has been standardized and commoditized during the past several decades. One result of this has been the attainment of incredibly high levels of reliability in today's telephone networks. The overall PSTN operates at 99.999% reliability (referred to as "five 9's"), which implies that voice networks will be down less than five minutes a year. Almost unbelievably, parts of the PSTN operate with "six nines" (99.9999%) reliability, which means less than 30 seconds downtime a year. **Data networks are much less mature than voice networks,** which leads to two sure and two probable consequences:

- data networks are (for sure) significantly less reliable than voice networks
- data networking companies (for sure) have significantly higher gross margins than voice equipment vendors because data products are much newer and have not been commoditized over several decades
- data networking vendors (we believe) offer many years of noncyclical growth opportunities for investors as converged networks mature to become as stable and reliable as the PSTN
- service providers in a converged environment will (most likely) be upgrading their relatively immature data networking infrastructures every year to 18 months as contrasted with the four-to-five-year product cycles characteristic of today's voice switches.

### Quality of Internet Voice Transmissions

While high quality voice calls can be achieved over dedicated IP data networks relatively easily (go to any communications trade show and you will see and hear demonstrations), obtaining voice transmissions of acceptable quality over one very specific IP network (namely the Internet) is quite a different story. Some of the primary challenges poised by the Internet result from the fact that the Internet transports very unpredictable data flows (called "bursty" traffic patterns) and that it has no mechanism for ensuring that a customer obtains a specific level of quality in this unpredictable environment. For voice transmissions, a key problem is the time delay the network creates as a voice packet travels from sender to receiver. In networking terms, this delay is called "latency." Studies by Cisco have demonstrated that the quality of voice transmissions is unacceptably low if the latency gets to around 300 msec (miliseconds) or longer. In the Internet, if everything works perfectly, the best latency we can typically hope to achieve is about 260 msec. With large bursts of traffic erupting randomly throughout the Internet, things generally do not work perfectly, and voice calls can easily get garbled. Fax is much less sensitive than voice to Internet delays, and that is why fax over the Internet is likely to be a successful service before voice.

## APPENDIX I: COMMUNICATIONS EQUIPMENT COMPARABLES

| Ticker | Company | JPMS Rating | Price 12/11/98 | Mkt Cap ($MM) | LTM Rev ($MM) | Price to LTM Rev. | EPS CY98(E) | EPS CY99(E) | P/E CY98(E) | P/E CY99(E) | LTGR | P/E to LTGR CY98(E) | P/E to LTGR CY99(E) | Gross Margin | Operating Margin | Stock Price % Chg 1 Year | Stock Price % Chg 1 Qtr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data Networking Equipment** | | | | | | | | | | | | | | | | |
| CSCO | Cisco Systems | BUY | $83.50 | $137,942 | $9,178 | 15.0 | $1.31 | $1.62 | 63.6 | 51.5 | 27% | 235.4% | 190.6% | 65.5% | 29.7% | 126% | 26% |
| ASND | Ascend Communications | BUY | $60.19 | $12,436 | $1,195 | 10.4 | $1.19 | $1.70 | 50.6 | 35.3 | 35% | 144.4% | 101.0% | 64.2% | 26.4% | 143% | 48% |
| CIEN | CIENA Corporation | BUY | $15.63 | $1,609 | $508 | 3.2 | $0.40 | $0.49 | 39.1 | 31.9 | 30% | 130.2% | 106.3% | 31.2% | (3.7%) | (70%) | (49%) |
| COMS | 3Com Corporation | BUY | $43.81 | $16,054 | $5,228 | 3.1 | $0.75 | $1.76 | 58.7 | 24.9 | 25% | 234.6% | 99.7% | 44.8% | 8.4% | 31% | 62% |
| CS | Cabletron Systems | MP | $8.31 | $1,417 | $1,380 | 1.0 | $0.19 | $0.63 | 43.8 | 13.2 | 20% | 218.8% | 66.0% | 47.4% | 4.9% | (66%) | 9% |
| NN | Newbridge Networks | LTB | $28.50 | $5,038 | $1,147 | 4.4 | $0.65 | $1.05 | 44.0 | 27.2 | 25% | 175.9% | 108.9% | 58.6% | 15.1% | (36%) | 32% |
| ADTN | Adtran Inc. | | $21.25 | $829 | $281 | 2.9 | $1.12 | $1.37 | 19.0 | 15.5 | 31% | 60.5% | 49.5% | 50.9% | 22.6% | (42%) | (13%) |
| AWRE | Aware, Inc. | | $21.50 | $444 | $10 | 46.3 | ($0.12) | $0.13 | NM | 160.4 | 49% | N/M | 327.4% | 91.0% | (15.0%) | 107% | 231% |
| BRCM | Broadcom Corporation | | $108.00 | $4,724 | $150 | 31.4 | $0.69 | $0.91 | 155.6 | 118.5 | 48% | 322.1% | 245.3% | 59.6% | (2.8%) | N/M | 80% |
| FORE | Fore Systems | | $17.63 | $1,947 | $539 | 3.6 | $0.45 | $0.63 | 39.5 | 28.0 | 31% | 125.8% | 89.1% | 55.7% | 8.0% | 3% | (9%) |
| MADGF | Madge Networks | | $4.69 | $211 | $280 | 0.8 | $0.21 | $0.29 | 22.3 | 16.4 | 21% | 107.8% | 79.0% | 47.5% | (7.6%) | (13%) | 55% |
| NSPK | NetSpeak Corp. | | $9.25 | $116 | $8 | 14.7 | ($1.08) | ($1.07) | NM | NM | 78% | N/M | N/M | 82.6% | (105.1%) | (57%) | 9% |
| NETA | Network Associates, Inc. | | $53.38 | $7,172 | $825 | 8.7 | $1.53 | $2.13 | 34.8 | 25.1 | 34% | 101.3% | 72.9% | 82.2% | 31.7% | 79% | 40% |
| NWK | Network Equipment Tech. | | $11.13 | $237 | $298 | 0.8 | $0.59 | $0.84 | 18.9 | 13.2 | 19% | 98.0% | 68.6% | 52.8% | 6.6% | (26%) | (7%) |
| PAIR | PairGain Technologies | | $7.66 | $542 | $297 | 1.8 | $0.64 | $0.65 | 12.0 | 11.7 | 29% | 40.8% | 39.9% | 49.5% | 26.3% | (65%) | (29%) |
| PRMS | Premisys Communications | | $11.00 | $278 | $108 | 2.6 | $0.64 | $0.81 | 17.1 | 13.6 | 28% | 62.1% | 49.4% | 65.2% | 22.3% | (57%) | 17% |
| SHVA | Shiva Corporation | | $5.78 | $175 | $146 | 1.2 | $0.06 | $0.29 | 105.1 | 19.9 | 21% | 493.5% | 93.6% | 61.9% | (6.1%) | (36%) | 4% |
| SYNX | Synch Research | | $0.84 | $15 | $26 | 0.6 | ($0.58) | ($0.26) | NM | NM | 23% | N/M | N/M | 36.7% | (71.9%) | (77%) | (52%) |
| UNPH | Uniphase Corporation | | $57.38 | $2,191 | $192 | 11.4 | $0.97 | $1.49 | 59.0 | 38.5 | 41% | 145.0% | 94.6% | 46.4% | 15.1% | 54% | 19% |
| WSTL | Westell Technologies | | $4.88 | $178 | $91 | 2.0 | ($0.79) | ($0.56) | NM | NM | 38% | N/M | N/M | 31.8% | (35.8%) | (70%) | (17%) |
| XYLN | Xylan Corporation | | $18.88 | $820 | $314 | 2.6 | $0.83 | $1.06 | 22.7 | 17.9 | 34% | 66.0% | 52.0% | 56.1% | 11.9% | (9%) | (3%) |
| | **Data Networking Equip. *Wtd Avgs*, Avgs, & Totals** | | | **$194,376** | **$22,201** | **8.0** | | | ***61.5*** | ***47.0*** | **33%** | ***218.8%*** | ***166.4%*** | **56.3%** | **(0.9%)** | **(4.0%)** | **21.6%** |
| | **Voice Equipment** | | | | | | | | | | | | | | | | |
| LU | Lucent Technologies | BUY | $98.94 | $129,990 | $29,042 | 4.5 | $1.80 | $2.30 | 55.0 | 43.0 | 25% | 219.9% | 172.1% | 43.4% | 9.9% | 150% | 20% |
| NT | Northern Telecom | LTB | $45.94 | $24,249 | $15,975 | 1.5 | $1.85 | $2.35 | 24.8 | 19.5 | 22% | 112.9% | 88.9% | 40.8% | 9.4% | 2% | (6%) |
| RLT | Reltec Corp. | BUY | $23.81 | $1,342 | $1,019 | 1.3 | $0.57 | $1.10 | 41.8 | 21.6 | 40% | 104.4% | 54.1% | 25.0% | 8.1% | N/M | (8%) |
| ADCT | ADC Telecommunications | | $28.25 | $3,807 | $1,319 | 2.9 | $1.13 | $1.36 | 25.1 | 20.8 | 25% | 99.1% | 82.1% | 45.7% | 16.2% | (22%) | 11% |
| AFCI | Advanced Fibre Comm. | | $8.00 | $605 | $323 | 1.9 | $0.32 | $0.38 | 24.8 | 20.9 | 36% | 69.5% | 58.6% | 45.5% | 20.0% | (66%) | (13%) |
| ALA | Alcatel Alsthom | MP | $23.81 | $18,806 | $30,880 | 0.6 | $1.14 | $1.34 | 20.9 | 17.7 | 20% | 104.4% | 88.6% | 17.0% | 3.0% | (2%) | (21%) |
| ECILF | ECI Telecommunications | | $37.69 | $2,858 | $737 | 3.9 | $2.14 | $2.48 | 17.6 | 15.2 | 20% | 86.6% | 74.7% | 53.0% | 20.8% | 51% | 25% |
| ERICY | Ericsson Telephone Co. | LTB | $22.81 | $44,461 | $22,190 | 2.0 | $0.87 | $1.05 | 26.2 | 21.7 | 20% | 132.5% | 109.8% | 42.0% | 10.9% | 11% | 5% |
| SMAWY | Siemens AG | BUY | $62.00 | $36,307 | $66,811 | 0.5 | $2.79 | N/M | 22.2 | N/M | 15% | 153.3% | N/M | N/M | 2.3% | 5% | (8%) |
| TLAB | Tellabs, Inc. | | $59.69 | $11,594 | $1,493 | 7.8 | $1.90 | $2.39 | 31.4 | 25.0 | 31% | 102.1% | 81.4% | 62.5% | 30.2% | 18% | 3% |
| | **Voice Equip. *Wtd Avgs*, Avgs, & Totals** | | | **$274,021** | **$169,788** | **2.7** | | | ***39.0*** | ***28.5*** | **25%** | ***170.5%*** | ***119.2%*** | **41.7%** | **13.1%** | **16%** | **1%** |
| **SP50** | **S&P 500** | | **$1,166.46** | | | | **$45.00** | **$46.00** | **25.9** | **25.4** | | | | | | 24% | 3% |

Note: J.P. Morgan Securities estimates for ALA, ASND, CIEN, COMS, CS, CSCO, ERICY, LU, NN, NT, RLT, & SMAWY. First Call and Factset for remaining. JPMS Ratings: BUY, LTB = Long-Term Buy, MP = Market Performer, MU = Market Underperformer; LTGR = Long-Term (EPS) Growth Rate; LTM = Last Twelve Months; YTD = Year-to-Date; N/M = not meaningful.

# APPENDIX II: COMPANY ONE-PAGERS

## Cisco Systems (CSCO – NASDQ – BUY)

**Core Portfolio Holding –** Cisco is by far the top company in the data networking industry, boasting the leading management team, a number one or number two market share position in more than 10 different product sectors, and the broadest line of local and wide area networking systems that allow the company to be an "end-to-end" provider. Cisco's diversity eliminates the risk of a technology bet for its customers and its investors.

**Key Variables to Watch –** With 55-60% of its revenues coming from the corporate sectors, Cisco is **vulnerable to a significant slowdown in corporate technology spending**. Look for Cisco to defend and expand its local area networking business aggressively and attack the developing market for integrating voice and data networks, attempting to beat traditional voice equipment suppliers like Lucent and Nortel to the punch. Cisco is aggressively spending in the voice/data convergence area and should see incremental revenue growth from its efforts late this year and into 1999.

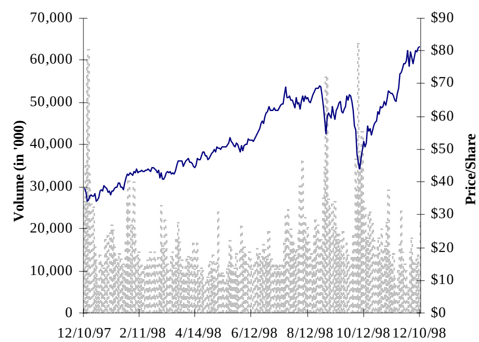
### Earnings Estimates

| | |
|---|---|
| **Recommendation** | **BUY** |
| **Long Term EPS Growth:** | **27.0%** |
| **12-Month Target Price:** | **$77** |
| **Average Daily Volume:** | **17,950,000 Shares** |

| JPMSI | Oct. | Jan. | Apr. | Jul. | FY |
|---|---|---|---|---|---|
| 7/98A | $0.26 | $0.29 | $0.30 | $0.32 | $1.17 |
| **7/99E** | $0.34 | **$0.36** | **$0.37** | **$0.39** | **$1.46** |
| **7/00E** | **$0.42** | **$0.44** | **$0.45** | **$0.48** | **$1.79** |
| **Street** | | | | | |
| **7/99E** | $0.34 | **$0.36** | **$0.37** | **$0.39** | **$1.46** |
| **7/00E** | **$0.41** | **$0.44** | **$0.46** | **$0.49** | **$1.79** |

Source: JPMS estimates and First Call.
Note: Fiscal year ends in July.

### CSCO Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- Strong management team that reacts very rapidly to changing market conditions. Cisco is extremely nimble.
- Largest installed base in the industry. Cisco is well established in the corporate and carrier sectors.
- Broad distribution capabilities. Cisco can withstand weakness in individual markets.
- Solid product portfolio for both the carrier and corporate markets.
- Not making technology bets. Cisco is focused on customers and covers all reasonable technology alternatives.
- Growing alliances with Bellcore, Intel (INTC/$116.44/Market Performer), and Microsoft (MSFT/$134/Buy). We think these will continue to develop in 1999.
- Broad positioning. Cisco has established a major presence across regions, customers, and products.
- Credibility with investors. Cisco provides balanced and reliable guidance.

**Weaknesses**

- Exposed to weakness in corporate tech spending.
- Relatively weak market position in remote access concentrators (number three behind ASND and COMS).
- Relative weakness in wide area frame relay and ATM switching (need upgrades to StrataCom products – expected in early 1999).
- Weakness in network management, which is currently being addressed through new product offerings.
- High-margin structure could be vulnerable as Lucent, Nortel, Alcatel, et al., enter the sector.
- Lack of a major presence in the small office/home office market. New ad program underway to address this space

## Ascend Communications (ASND – NASDQ – BUY)

**The Leader in Wide Area Switching –** ASND has rebounded in 1998, led by its solid portfolio of frame relay and ATM switching products, which have been very well received by carrier, ISP, and CLEC customers. In our view, Ascend has the greatest momentum in ATM WAN switching, winning such contracts as Bell Atlantic, Williams Communications, GTE, and MCI WorldCom. We believe that Ascend is one of the best positioned companies to take advantage of the trend to converge voice and data networks as new network builds are increasingly using ATM switching in the core.

**Key Variables to Watch –** Ascend reported strong quarterly revenues and earnings in the third quarter of 1998, but it confused the investor community with some accounting issues relating to a CLEC financing program and with weaker-than-expected core switching sales. We are not concerned about the financing program that Ascend is establishing for CLECs because we expect Ascend to work with third parties to help with CLEC funding in 1999. We also look for a strong fourth quarter in 1998 for core switching as Ascend continues to dominate the market for frame relay and ATM core switching. Ultimately, we feel that Ascend will need either to acquire or be acquired in the coming year as carriers across the globe look to consolidate equipment vendors.

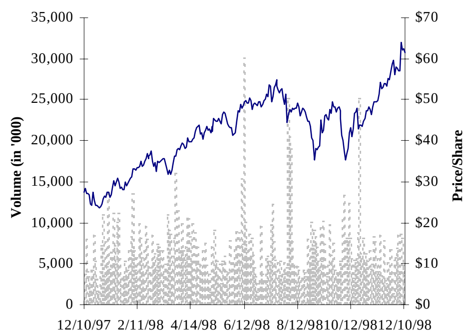
### Earnings Estimates

| | |
|---|---|
| **Long Term EPS Growth:** | **35.0%** |
| **12-Month Target Price:** | **$75** |
| **Average Daily Volume:** | **6,100,000 Shares** |

| JPMSI | Mar. | Jun. | Sep. | Dec. | FY |
|---|---|---|---|---|---|
| **12/97A** | $0.31 | $0.31 | $0.20 | $0.24 | $1.07 |
| **12/98E** | $0.26 | $0.29 | $0.32 | **$0.32** | **$1.19** |
| **12/99E** | **$0.37** | **$0.41** | **$0.44** | **$0.48** | **$1.70** |
| **Street** | | | | | |
| **12/98E** | $0.26 | $0.29 | $0.32 | **$0.32** | **$1.18** |
| **12/99E** | **$0.36** | **$0.40** | **$0.43** | **$0.48** | **$1.68** |

Source: JPMS estimates and First Call.

### ASND Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- Number one market share in remote access concentrators, ATM WAN switches, and frame relay switches.
- Industry's most widely accepted WAN switching solution with the introduction of its GX550 ATM switch.
- Building SS7 capabilities with its acquisition of Stratus.
- Strong carrier, ISP, and CLEC relationships.
- Growth to come in broadband access (from Sahara).
- Strengthening fundamentals still with reduced expectations.

**Weaknesses**

- Lack of order visibility during the quarter. Nonlinearity of quarterly revenue flow results in the "hockey stick" effect. We think this trend is improving.
- Lack of management depth (bench strength). Management tends to be technically oriented.
- Poor record of providing reliable guidance in 1997 still results in investor hesitation with the stock.
- Need to maintain technical lead, broaden product offerings, and continue to win major contracts to stay ahead of bigger players like Cisco and Lucent.

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## 3Com Corporation (COMS – NASDAQ – BUY)

**Compelling Valuation as Turnaround Continues –** 3Com has met or beat analyst expectations in each of its last two quarters and is heading into its seasonally strongest period. We think recent improvements in visibility and levels of channel inventory indicate that its biggest problems are now over and that the company can finally reap the benefits of a strong new product cycle. We believe that 3Com's business fundamentals have bottomed and that recent improvements in gross and operating margins will continue over the coming year. Despite some recent strength, COMS' valuation is still compelling relative to its peers. We continue to recommend COMS for patient investors willing to reap the rewards of a slow, steady turnaround over the next several quarters.

**Key Variables to Watch –** Actual demand (channel sell-through) for the next several quarters will be critical. Improvements in operating margins are expected, but real growth won't happen without top-line strength. Watch for sales growth from 56K modems, which has been picking up over the last couple of months. The fall quarter is typically a strong quarter for adapter cards and modems. Also watch for strength in the company's local area networking business. We think 3Com's new CoreBuilder 9000 switch (released last quarter) is off to a good start. And don't forget about the PalmPilot... its selling like hotcakes.

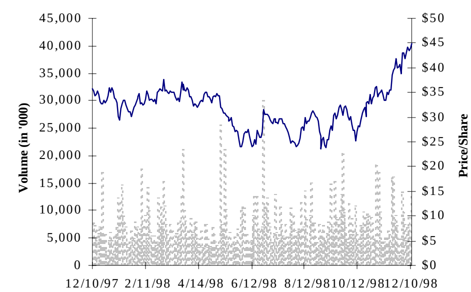
### Earnings Estimates

| | |
|---|---|
| **Recommendation** | **BUY** |
| **Long Term EPS Growth:** | **25.0%** |
| **12-Month Target Price:** | **$50** |
| **Average Daily Volume:** | **7,450,000 Shares** |

| JPMSI | Aug. | Nov. | Feb. | May | FY |
|---|---|---|---|---|---|
| 5/98A | $0.47 | $0.01 | $0.02 | $0.18 | $0.68 |
| **5/99E** | $0.24 | **$0.31** | **$0.36** | **$0.44** | **$1.35** |
| **5/00E** | **$0.45** | **$0.51** | **$0.52** | **$0.57** | **$2.05** |
| **Street** | | | | | |
| **5/99E** | $0.24 | **$0.31** | **$0.35** | **$0.42** | **$1.33** |
| **5/00E** | **$0.43** | **$0.47** | **$0.49** | **$0.53** | **$1.94** |

Source: JPMS estimates and First Call.
Note: Fiscal year ends in May.

### COMS Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- Strong management team with lots of bench strength and the ability to react quickly.
- Top brand name and industry leadership in the channel.
- Large installed customer base and new product cycle should drive growth (CoreBuilder 9000).
- Number two share in the remote access concentrator market; number one vendor in the small office/home office market; early leader in Gigabit Ethernet market.
- Improving visibility and lowered channel inventory have reduced risk.
- 56 Kbps modem standard is now complete (V.90) and sales growth is increasing.
- Well positioned to lead next generation access markets such as xDSL and cable modems.

**Weaknesses**

- Risk of volatile financial results for next few quarters as 3Com settles into its new inventory model.
- Exposed to price wars from Intel (INTC/$116.44/Market Performer) in adapter cards. We discount our target price to account for this risk, which we think will always be present.
- Positioning on "edge" of network (adapter cards and modems) not as deep with customers as positioning in "core" products.
- Not broadly positioned in carrier market. 3Com offers only remote and broadband access products.
- Product transitions under way from hubs to switches and from 10 Mbps Ethernet adapter cards to 10/100 Mbps adapter cards (the transitions are maturing, however, reducing the overall risk for 3Com).

## Newbridge Network (NN – NYSE – Long-Term Buy)

**Focusing on Numbers – Refocusing Long-Term Strategy –** Newbridge Networks is not known for its excellent financial guidance, but we think the recent hiring of new president and COO Alan Lutz is instilling a sense of accountability at Newbridge that has never existed before. We do expect cost controls and financial guidance to improve going forward, but linearity could be tough to improve as the legacy TDM business (35% of sales) is very unpredictable. While we believe that Newbridge is in a good position as a top vendor in the hot ATM WAN switching space, its long-term strategy is now in question. Newbridge's relationship with Siemens is eroding, bringing with it questions of upgrade paths for customers currently deploying Newbridge ATM switches. We believe that Newbridge must develop a higher capacity switch of its own by mid-1999 or risk losing its strong installed base of world-class carrier customers.

**Key Variables to Watch –** Near term, we believe that Newbridge must meet or exceed analyst expectations to regain investor confidence that has been shattered by multiple pre-announced earnings releases over the last two years. Look for Alan Lutz to keep costs under control and focus employees' attentions on meeting financial objectives. The other key variable is the Siemens relationship. Historically crucial to Newbridge's success, the relationship is eroding as Siemens' expected high-powered ATM switch is delayed again and looks to be more related to a voice switch than a data switch. We believe that it is crucial for Newbridge to develop a next generation switch as an upgrade cycle for its customers or risk missing a critical window in the push to converge voice and data networks.

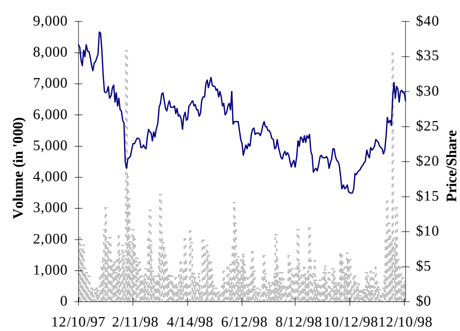
### Earnings Estimates

| | |
|---|---|
| **Recommendation** | **Long-Term Buy** |
| **Long Term EPS Growth:** | **25.0%** |
| **12-Month Target Price:** | **N/A** |
| **Average Daily Volume:** | **820,000 Shares** |

| JPMSI | Jul. | Oct. | Jan. | Apr. | FY |
|---|---|---|---|---|---|
| 4/98A | $0.26 | $0.23 | $0.07 | $0.13 | $0.69 |
| **4/99E** | $0.14 | $0.18 | **$0.20** | **$0.24** | **$0.76** |
| **4/00E** | **$0.25** | **$0.27** | **$0.28** | **$0.30** | **$1.10** |
| **Street** | | | | | |
| **4/99E** | $0.14 | $0.18 | **$0.22** | **$0.26** | **$0.82** |
| **4/00E** | **$0.27** | **$0.29** | **$0.32** | **$0.35** | **$1.26** |

Source: JPMS estimates and First Call.
Note: Fiscal year ends in April.

### NN Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- Broad base of telco customers. Newbridge has excellent relationships with large carriers.
- Number two share in wide area ATM, along with excellent ATM products.
- Alliance with Siemens encompassing product design, development, and marketing (but eroding) and a developing relationship with Ericsson.
- Strength in international markets.
- Affiliate program with exciting new start-ups, such as Cambrian, for wave division multiplexing.

**Weaknesses**

- Major product migration from time division multiplexers (35% of sales) to frame relay and ATM.
- A lack of visibility in TDM has resulted in an inability to provide reliable financial guidance.
- Single-technology focus. Newbridge is making big bets on ATM. We do not consider this a problem for the next twelve months.
- We think a deteriorated relationship with Siemens is creating uncertainty regarding next generation switch for Newbridge customers.

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## Lucent Technologies (LU – NYSE – BUY)

**Core Portfolio Holding –** We view Lucent shares as the single best play on the global growth we expect the telecom equipment markets to experience over the next few years. Lucent continues to benefit from its large exposure to the healthy North American market (and lack of exposure to the volatile emerging markets and Asia) as well as the trend among service providers to do increasing levels of business with equipment players that offer end-to-end product solutions. Internationally, Lucent should continue to benefit from its ability to leverage its high-margin North American business to help fund aggressive pricing on international contracts.

**Key Variables to Watch –** In the data networking arena, the spending shift by major carriers from voice-centric to data-centric equipment is occurring at an extremely rapid pace. We expect Lucent's strategy to gain a market leading position in data to intensify over coming months. Specifically, we would anticipate a number of new product introductions as well as continued acquisitions. Additionally, we continue to believe that Lucent's ability to further penetrate the international markets will be a critical component of its long-term success, and we will monitor this closely in 1999.

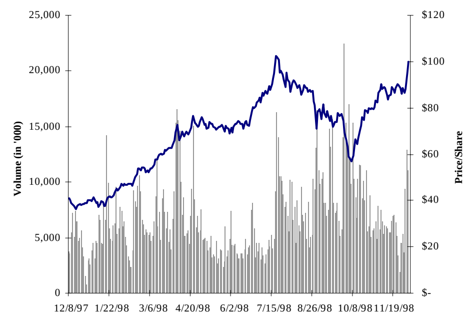
### Earnings Estimates

| | |
|---|---|
| **Long Term EPS Growth:** | **25.0%** |
| **12-Month Target Price:** | **$125** |
| **Average Daily Volume:** | **6,815,975 Shares** |

| JPMSI | Dec. | Mar. | Jun. | Sept. | FY |
|---|---|---|---|---|---|
| 9/98A | $0.86 | $0.14 | $0.32 | $0.41 | $1.72 |
| **9/99E** | **$0.97** | **$0.19** | **$0.40** | **$0.55** | **$2.10** |
| **9/00E** | | | | | **$2.50** |
| **Street** | | | | | |
| **9/99E** | **$0.97** | **$0.21** | **$0.40** | **$0.51** | **$2.09** |
| **9/00E** | **$1.16** | **$0.29** | **$0.47** | **$0.61** | **$2.51** |

Source: JPMS estimates and First Call.
Note: Fiscal year ends in September.

### LU Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- End-to-end solution provider able to bundle products and leverage higher margin products to fund expansion into new markets.
- Large installed base with several major carrier in North America.
- Leading position in many high-growth broadband technologies.
- Source of earnings leverage from execution on restructuring initiatives.
- Large exposure to North American market and limited exposure to volatile emerging market and Asia.
- Strong track record for achieving revenue and earnings growth in excess of both the industry and majority of its peers.
- Strong management team focused on long-term strategic direction.

**Weaknesses**

- Lacks a major presence in several major data networking markets.
- Weak international presence in major markets.
- Threat of new competitors such as Cisco and Ascend.
- Strong shift in carrier spending toward data-centric equipment.

## Northern Telecom (NT – NYSE – Long-Term Buy)

**Bay Integration a Source of Concern –** We believe that in the long run the acquisition of Bay Networks will benefit Nortel because it allows the company to gain a solid position in the enterprise data market much more quickly than it would have been able to develop through internal efforts. Additionally, we believe that the enterprise market will play an important long-term strategic role for Nortel as corporations increasingly look to outsource the operation of their local area networks to communications service providers. In the near term, however, we are concerned about the integration of Bay Networks and the fact that Bay Networks has a history of volatile financial results.

**Key Variables to Watch –** Integration of Bay Networks acquisition. While Nortel has decided to allow Bay to continue to operate largely as an independent subsidiary, we will be keeping a close eye on employee (specifically engineering) turnover over the coming months. We will also look toward fourth quarter revenue growth to give us comfort (or not) in Nortel's ability to achieve mid-teen top-line growth from ongoing operations in 1999.

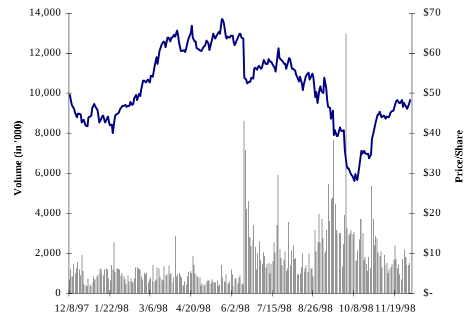
### Earnings Estimates

| | |
|---|---|
| **Long Term EPS Growth:** | **22.0%** |
| **12-Month Target Price:** | **$50** |
| **Average Daily Volume:** | **1,642,658 Shares** |

| JPMSI | Mar. | Jun. | Sept. | Dec. | FY |
|---|---|---|---|---|---|
| 12/97A | $0.21 | $0.30 | $0.29 | $0.74 | $1.84 |
| **12/98E** | $0.27 | $0.41 | $0.42 | **$0.70** | **$1.85** |
| **12/99E** | **$0.39** | **$0.49** | **$0.52** | **$0.85** | **$2.25** |
| **Street** | | | | | |
| **12/98E** | $0.27 | $0.41 | $0.42 | **$0.71** | **$1.84** |
| **12/99E** | **$0.36** | **$0.49** | **$0.47** | **$0.86** | **$2.19** |

Source: JPMS estimates and First Call.

### NT Last 12 Months Stock/Volume




Source: Factset and JPMS.

### Investment Thesis

**Strengths**

- Capable of offering end-to-end network solutions for wireless, voice, and data networks.
- Bay Networks provides Nortel with a strong position in the enterprise data market.
- Large installed base in the North American marketplace.
- Strong presence in high-growth broadband market.
- Leading provider of wireless networks with substantial position in the Latin American market.

**Weaknesses**

- Lack of substantial presence in the carrier data networking market.
- We believe the addition of Bay Networks further exposes Nortel to weakness in corporate tech spending.
- Weak international presence in major markets.
- Threat of new competitors such as Cisco and Ascend.

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## Appendix III: New Protocols – Many Aspire to the Throne

This appendix summarizes the new protocols currently in competition to become the standard for voice/data integration.

### The Current King – H.323

H.323 is a standard protocol that defines how voice, data, and video traffic will be transported over a data-based LAN and as such, it provides a foundation for converging voice and data in communications networks. H.323 was first approved by the International Telecommunications Union (ITU) in 1996 and was originally designed as a standard for videoconferencing over LANs. It was needed to compensate for the unpredictable nature of LAN traffic and to establish standards for compression and decompression of audio and video data streams. H.323 is independent from any specific hardware platform or operating system. Version 2 of the standard was approved by the ITU in January of this year and adds some security functions (although security remains a deficiency in H.323), speeds call set-up, and enables routing and billing functions. However, H.323 does not guarantee "quality of service," which remains an issue with IP-based data networks.

H.323 is based on two protocols developed by the Internet Engineering Task Force (IETF), called Real Time Protocol (RTP) and Real Time Control Protocol (RTCP), that are used for managing audio and video signals and for developing real-time applications. Even with this Internet heritage, H.323 is not exclusively an IP-only standard. It applies to IPX (from Novel) and AppleTalk (from guess who [AAPL/$33.75/Buy]) as well. A data-conferencing standard (called T.120) is a subset of H.323, and several types of "nodes" or functions are defined within H.323. These include 1) gatekeepers acting as routers in selecting routes, translating addresses and setting up calls, 2) gateways for bridging data packets to telephone networks, and 3) end-user terminals for interfacing all of this technology with real people.

### Aspiring to the Crown – SGCP, IPDC, and MGCP

Bellcore and Cisco developed Simple Gateway Control Protocol (SGCP) as an improvement on H.323, intended to be more appropriate and more scaleable for data transmissions. Subsequently, Level 3 developed another protocol defining how voice and multimedia traffic are to be handled over the Internet. Level 3's design is called Internet Protocol Device Control (IPDC). With urging from the Internet Engineering Task Force (IETF), Bellcore and Level 3 have recently announced the merger of their individual specifications into a new protocol called Media Gateway Control Protocol (MGCP). We assume MGCP will ultimately emerge as the IETF's standard for controlling voice traffic over the Internet. A summary of all of these competing multimedia protocols follows:

- H.323 – original standard approved by the telephony standards body (ITU)
- SGCP – developed by Bellcore and Cisco to improve on H.323
- IPDC – developed by Level 3 to improve on H.323
- MGCP – a merger of SGCP and IPDC sponsored by the Internet's standards body (IETF).