Can the Carriers Deliver on SONET's Full Potential?

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The technology trials have been successful. Now SONET may be facing its biggest hurdle: the carriers' organization.

Synchronous Optical Network (SONET) has been evolving since the mid 1980s as the next-generation, North American, wide-area telecommunications carrier transmission standard. SONET was developed specifically for high-speed, highly reliable, serial digital transmission over optical fiber. The current asynchronous digital transmission systems (i.e., T1) were optimized for metallic carrier or analog microwave radio, and for the relatively static prednisolone network environment.

As transmission requirements expand beyond T1 and T3, SONET provides carrier mechanisms to flexibly provision, multiplex and manage these higher-capacity facilities. Almost all American carriers have conducted SONET trials and begun limited deployment within their internal backbone networks.

Despite these advances, however, SONET has not experienced the enthusiastic rollout predicted in its earlier days. This article provides a status report as of 1993 and predicts how SONET will evolve in the next several years.

What Is SONET?
SONET is a subset of CCITT standards, and it can interwork with a companion set of standards, developed by the European Telecommunications Standards Institute (ETSI), called Synchronous Digital Hierarchy (SDH). Beginning in 1985, a great deal of effort was expended to harmonize the differences between the North American SONET proposal, which grew out of the ANSI (American National Standards Institute) T1X1 subcommittee, and the SDH. By 1990, a significant amount of work had been completed by both ANSI and the CCITT standards bodies, resulting in specifications for a digital signal hierarchy, frame format and multiplexing technique.

Although SONET and SDH use slightly different terminologies, their basic structure is identical, as both are designed to interoperate at OC-3 (155 Mbp and higher transmission rates. Both partition a network into layers, consisting of inputs, outputs and transport networks.

All transport networks are made up of subnetwork nodes and links, with links connecting inputs and outputs via one-way, two-way and one-to-many paths. Each of these paths can in turn be decomposed into one or more subnetwork connections, with the same set of network element primitives. Lower-level layers provide services to upper-layer clients; hence, SONET SDH explicitly support a client/server paradigm in transport, supervision and operation. Figure 1 shows how end user services might be client for SONET network servers using this layering.

The standards groups are currently working on SONET synchronization and clock recovery. SONET's flexible transmission format might make it difficult for premises equipment to synchronize local clock with network clocks, as is done with current premise T1 multiplexers. It is still assumed that all SONET devices will take their timing from stratum 1 clocks but a variety of avenues are being investigated to determine how this will actually be accomplished in mixed vendor/carrier/customer networks.

While SONET and SDH are meant to be compatible at OC-3 (SONET) and STM-3 (SDH) and above, there is a good deal of contention among equipment providers, basically due to global market economics: Whichever is used the most has the potential for significant economies of scale in product engineering, manufacturing, marketing and support. This could produce a cost advantage for one camp over the other. In reality, however, SONET and SDH are quite compatible and more alike than different.

SONET Driven by Voice Services
SONET and SDH were driven by the voice services provided by common carriers and their traditional equipment suppliers. The basic unit of bandwidth is the 64-kbps voice channel and multiples thereof for non-voice services. SONET was developed in part to replace metallic pair gain systems and in part to more economically support drop-and-insert functionality at high bit rates. In these respects, it has excelled.
So far, however, the carriers have deployed SONET only in trial overlay networks. SONET's software hooks have been demonstrated to support traditional transmission functions, such as drop-and-insert multiplexing, grooming, consolidation, bridging, protection, network fault isolation and link restoration. Most carriers expect that SONET will gradually displace all other interoffice network transport formats and that it will dramatically simplify carrier support operations, increase network resource utilization and reduce transmission equipment expenses.

At the same time, SONET could enable the carriers to quickly offer uniquely customized network services, if they base their transport capacity provisioning process on Signaling System 7 technology. These transport services could be configured and priced for individual customers in a "spot market," in contrast to the current commodity market, with its broadly tarified service offerings.

On the one hand, the slow growth of voice services will drive the carriers to deploy SONET transport in order to achieve increased resource utilization and productivity. On the other hand, customer premises-based demand for non-voice services (such as multimedia network computing applications) could also drive carriers to deploy SONET-based transport toward these new sources of revenue.

In their internal networks, the carriers will continue to benefit from SONET deployment. To successfully exploit SONET’s non-voice market opportunities, however, they will need to build marketing skills to identify and sell potential customers on SONET, and they will face additional challenges.

**ATM, Broadband ISDN and SONET**

ATM switching can be achieved on the customer premises with equipment offerings that would connect to SONET-based, private-line transmission facilities. ATM switching also could be implemented in the public network and offered as part of a service using carrier SONET transport. In either scenario, demand for SONET-based services can be expected to increase as ATM gains acceptance.

Customers and carriers face different economic imperatives when designing their respective networks. In premises, client/server networks, application-to-application delays are more costly than underutilized equipment. Hence the efficient utilization of premises transmission resources is not as important as the capital cost of the equipment.

In contrast, carriers must provide network-based transport services as cost effectively as possible, while equipment costs can be shared among multiple customers and multiple service offerings. Hence transmission utilization, and not capital equipment costs, becomes much more important to the carriers.

**SONET** is also meant to be the transmission basis for so-called Broadband Integrated Services Digital Network (BISDN) standards and associated equipment and services. Implicit in much of the BISDN activity is the notion that the network is the information repository of intelligence, and that peripherals attached to the network tend to lack intelligence.
Although the carriers want to add value—for example, by multiplexing and grooming in the networks rather than on the premises, which could both generate revenues and displace CPE—this desire runs counter to the prevailing trend of customers deploying sophisticated, intelligent premises equipment and networks to meet their most significant business needs.

This current lack of CPE for interfacing to SONET is reminiscent of what happened to narrowband ISDN. Customers have multiple needs, and having many vendors supply many products appears to be the most efficient way to meet those diverse needs. SONET network interfaces have been defined, and we can expect vendors to come forward with products in the next two to three years.

The higher-level BISDN standards, which are just now emerging from standards bodies to support Synchronous Transfer Mode (STM) and Asynchronous Transfer Mode (ATM) switching functions, include a variety of Asynchronous Adaptation Layer (AAL) standards. These permit ATM to interwork with different types of transmission standards—i.e., SONET, as well as LAN technologies such as Ethernet, token-ring, FDDI, and Fiber Channel Systems (FCS).

These standards are very much driven through the ATM Forum by customer premises equipment hardware and software vendors. Many of these vendors have evolved their products to encompass adapter cards in PCs and workstations that interface to conventional unshielded twisted pair telephone wiring, in turn connects to a hub or high-speed switch that can bridge and route packets.

The evolution of these products away from bus technologies and toward switch technologies will be based on the following:

1. An evolution of disk-drive channel interfaces, such as IBM System/370 Channel-to-IBM System/390 Enterprise System Controller (ESCON) and to Fiber Channel System, which will support many interfaces, such as Small Computer System Interface (SCSI) or High Performance Parallel Interface (HIPPI) for disk arrays for high-performance file servers.
3. 802 variants (such as Ethernet via 10BaseT, 100BaseT, token-ring at 4 Mbps and 16 Mbps and extensions).

This natural evolution will occupy these vendors and their customers for the rest of the decade. ATM will probably be a common switching layer for SONET WANs and premises LANs. Note, however, that all these premises examples are driven by non-voice applications.

Client/Server Architecture and "Downsizing"

Another factor that the carriers must take into account in their marketing and business plans is the movement away from host/terminal computing and toward client/server configurations. Client workstations and PCs carry out presentation-level services (such as windowing via different graphical user interfaces), while servers permit sharing of expensive resources (such as laser printers, database management systems and communications links).

This new software architecture, which often appears in the trade press under the rubric of "downsizing," is well on its way to becoming a de facto market standard, and it will have a major impact on how carriers provide services to customers and how carriers operate their own networks. Like most large organizations, the carriers have many large, unconnected data systems and are beginning to explore the migration of their software applications to client/server network computing.

More New Premises Tools

The advent of cost-effective compact disk read-only memory (CD-ROM) drives, supported by different operating system environments (MS-Windows, Macintosh, Unix, MS-Windows NT and Taligent), will lead to new applications that will require higher bit rates than current local area network standards can support. Traditional file transfer and decision-support functions for text information will grow to include pictures, graphics, images, spreadsheets and sound.

In order for these new information modes to be useful to end users, the delays or latencies associated with moving this type of information from one PC or workstation to another will often need to be under five seconds, and hence the need for at least 100-Mb/s transmission rates to desktops. At present, ATM appears to be the only viable switching technology that can support these diverse applications and evolve to support new rates and functions, but it will require a decade or more.

In summary, voice applications will not drive the anticipated growth in demand for network-base transmission services. Instead, the combination of non-voice applications (graphics, image, video, etc) and the need for transparent internetworking of LANs at remote locations (each of which could be running different protocol stacks) will demand new levels of service from the carrier networks. In addition, one-month intervals to provision and install transmission facilities will become increasingly unacceptable for customers who want to move quickly to new platforms or experiment with new technologies.

Where will these customers get the timely and cost-effective services they require? Will the carrier be able not only to benefit from SONET with internetwork productivity gains but also to convert SONET potential into viable customer services and corresponding support systems?

Premises-Based Transmission Standards Will Compete with SONET as Access Technologies

The key issue here is that SONET will not be used by premises-equipment vendors to handle local a
networking: SONET will only be supported by gateways or communication servers on the premises that interface to carrier networks via conventional services (such as dialup, voice grade private line and fractional T1) as well as SONET.

SONET's dependence on optoelectronic components makes SONET premises equipment simply too expensive. At more than $300 per port, the cost of SONET CPE would be too great, especially when compared with the under $200 per port price of alternatives, such as 10BaseT Ethernet, and their evolution to higher bit rates.

Manufacturing economies of scale suggest that network services based on electronic techniques—such as Fiber Channel Systems and IBM's extended channel networking—will more likely be developed as future network interfaces. These premises network access technologies could enjoy large economies of scale and may well have costs far below that for direct SONET access.

Carriers Are Committed to SONET

Despite the apparent trends toward intelligent premises equipment, the momentum behind ATM, FCS and other high-speed premises networking, and the lack of SONET premises equipment, 1992 was a watershed year for SONET with U.S. carriers. Interviews with the major U.S. local and interexchange carriers indicate that SONET is indeed the next-generation transmission standard, and that 1993 will see the beginning of major SONET equipment procurements.

The limited U.S. deployment of SONET transmission in local and interexchange carrier interoffice networks is primarily due to the huge embedded base of asynchronous transmission equipment. By the end of this decade, however, the carriers expect the bulk of U.S. toll transmission to be handled by SONET, with virtually complete conversion to SONET for interoffice transmission by 2010.

A number of transition plans have been proposed for migrating from the current asynchronous transmission plant to SONET. Some involve self-healing rings that permit more reliable SONET-based services to be deployed, while others are based on digital access and cross-connect systems (DACSs) that permit grooming and consolidation of both synchronous and asynchronous traffic and allow for a cost-effective transition process.

In conjunction with ATM, SONET is poised to take over the North American common carrier transmission equipment market place. Its strong voice-transport service capabilities, coupled with its ability to support the emerging new network services from the premises-based non-voice applications, based on client/server computing and multimedia applications, augurs a rosy future for SONET.

Integrated circuitry is being developed by semiconductor manufacturers to support both SONET and ATM. In addition, all the major telecommunications equipment vendors that traditionally supply common carriers have developed proprietary SONET and ATM chip sets. These are important steps toward making SONET cost effective for both carrier-internal and premises-network-access applications.

The carriers appear to be optimizing their networks for the slow growth of voice traffic, in large part because the capabilities of their internal computer systems have been optimized for voice service rather than for the emerging non-voice services. Unfortunately, the transition from current asynchronous to synchronous transmission plant—and the reorganization of support systems and personnel—may make SONET less, not more, cost effective, especially in the short run.

SONET Network Management Will Require Major Carrier Changes

The SONET network management standards groups have been very active, and in many ways they have surpassed SONET's information transport standards efforts. Network management encompasses all the aspects of transport, plus issues related to installation, administration and fault handling.

In the last three years, the standards bodies have determined what SONET management capabilities will be required. They are currently discussing how to include both the OSI and SNMP management models.

Figure 2 shows the traditional hierarchical partitioning of common carrier network management and premises-based subnetwork controllers: Operations Support Systems (OSSs) managed by common carriers interface with Subnetwork Controllers (SNCs) that, in turn, manage network elements (NEs). The computer systems used to manage the network are themselves interconnected by a network whose sole purpose is to pass coordinate information transfer between these elements.
The rules or protocols for interfacing these different modules require significant processor time per message, which in turn suggests that online operation will be difficult at best; highly reliable, fault-tolerant operation appears to be a distant dream based on this bottom-up approach to network management.

This has been the status quo for most carriers' network operations support and management to date. Although this approach has been adequate in the past, SONET offers the carriers (and their competitors) the potential for higher-quality, more streamlined and more flexible network management.

In the last three to five years, the carriers have recognized that SONET will be cost effective only if it is coupled with organizational changes that take advantage of SONET's intrinsic network operations, administration and maintenance (O&M) capabilities. These software "hooks" were designed into SONET at the outset, but their potential has yet to be realized by the carriers.

Putting these capabilities to work will require dramatic changes to be made in the carriers' business procedures for provisioning and management, and it will also necessitate the replacement of their traditional hierarchical management systems. These difficult steps are important, because the ability of the carriers to manage SONET networks will control the rate of SONET deployment and the rate of SONET-based services introduction.

Reengineering the Carriers' Business Processes
SONET has the potential to support much more streamlined provisioning and management, and to deliver services many end users suggest would be highly desirable. For example, video—or even multimedia—conferences between multiple locations could be set up on the fly, much as dial-up voice telephone conference calls are made.

The common carriers' current operations practices and procedures don't build momentum toward anything like the just-in-time inventory management of SONET virtual paths, but that is precisely what customers will demand in the future. Common carriers will need to "stockpile" SONET transmission facilities so that customers can get access to these resources when they need it, rather than on a schedule determined by the carrier's readiness to install and provision it for the customer. In many ways, the SONET network carriers need to operate like a factory: Raw material (transmission capacity) needs to be prefabricated into SONET links or segments and then assembled and tested, on demand, to meet a specific customer's need.

Customers want to access SONET network services in the easiest possible manner, having minimal impact on their own business operations. They will still want their administrative staff to handle order entry and order processing, while their network management staff handles network operations issues and their data processing group handles quality assurance and billing/payment.

Common carriers have mirror-image functions that currently meet these needs. The problem is that each of these organizations has its own, separate set of data systems and procedures. Transferring and converting information from one department to another adds time to the order interval and personnel to the payroll.

Because these organizations, systems and procedures are so thoroughly entrenched, the carriers will have a hard time changing them. Nevertheless, all the carriers recognize this is exactly what must be done if SONET is to achieve its full potential.

The multiple systems currently in use should be replaced by a single data model or image of the network transmission facilities that can be accessed by different business groups for their own unique needs. The presentation of information to each group can be quite different, but the internal data must be consistent. The data structures for this common data model appear to lend themselves to concurrent operations on scalable or massively parallel computer systems.

It would be impossible for the carriers to simply scrap their existing provisioning and network management procedures and systems. Fortunately, these database management servers could be implemented initially in small trials and pilots, then scaled up over the next decade based on a long-term transition plan. This is what most carriers plan to do in order to meet the SONET deployment schedules they envision.

Conclusion
SONET networks have already been successfully deployed in trial demonstration networks. We can expect problems involving clocking and synchronization to be resolved in the next two years. The lack of SONET CPE and network interfaces will undoubtedly impede SONET's progress to the premises, although this will not affect its viability as a carrier transmission standard.

The most difficult hurdle facing SONET at this time has to do with the carriers' embedded systems and procedures. Carriers and customers alike are evolving toward client/server network computing architectures; both have similar needs for more integrated and streamlined order entry and order processing, operations support and access to SONET's high-speed transmission facilities.

For the carriers especially, this translates into the requirement for a single consistent data model at the network element level that can be audited remotely and verified against the actual physical hardware and software configuration. If the carriers can successfully implement such an integrated management system, SONET networks will deliver their promised benefits: higher availability, higher reliability, higher business margins—and much more responsive, cost-effective network operations.