Telecommunications Electronic Reviews (TER)

ter

telecommunications

electronic reviews

Volume 2, Issue 4, October, 1995

Telecommunications Electronic Reviews (TER) is a publication of the Library and Information Technology Association.

Contents

ter issues (/lita/publications/archive/ter)

A New Addition

We are pleased to offer an addition to TER: technology case studies. In this issue we highlight ISDN, a technology that has received a fair amount of press recently. You will find a review of one helpful book, a tale of one library's experience in implementing ISDN, and a useful list of ISDN resources.

We hope to continue to provide reviews of specific networking technologies that hold promise for local and wide area networking in libraries. If you have had experience implementing a particular technology in these categories and would like to share it with your colleagues, please contact me at TWilson@uh.edu (mailto:TWilson@uh.edu).

Thomas C. Wilson, Editor-in-Chief TER

REVIEW OF: Gerald L. Hopkins. The ISDN Literacy Book. Reading, MA: Addison-Wesley, 1995.

by Thomas Dowling

ISDN (Integrated Services Digital Network) is a technology that stands perpetually on the verge of becoming the Next Big Thing but is too often seen as the Last Big Disappointment. Perceptions and misperceptions shape the ISDN landscape, and its implementation has probably been delayed more by the hype coming from its most gung-ho supporters than from the actions of its detractors or the inertia of the current telephone system. In his introduction to this book, Robert Metcalfe--who declared 1982 "The Year of the LAN" and who therefore understands technology that moves much faster than organizational change--acknowledges the problems involved in early ISDN implementation (in some circles, the acronym stands for "It Still Does Nothing"). He introduces the author as an ISDN proponent who is quite able both to describe a global ISDN network uniting telephone and computer networks, and to identify other possible futures for a national and global networking structure.

As co-founder of the North American ISDN Users' Forum, Hopkins seems aware that he may come across as an ISDN apologist. While authors of such books are entitled and expected to be enthusiastic about the technology they describe, Hopkins is usually careful not to "root" for ISDN over other technologies. This lends a welcome air of objectivity to his support for ISDN.

The ISDN Literacy Book is written for the technically inclined professional with experience in telecommunications or networking. Fairly complicated topics are raised and discussed without bringing in too much introductory matter. In short, this is ISDN literacy for people whose current technical literacy already extends to related fields. Some sections of the book stray briefly into novice-oriented information (most readers, for example, will already understand the difference between analog and digital signals, and will certainly know the definition of a bit), but this is not a text for newcomers to telecommunications.

After an introductory chapter that defines and describes ISDN, Hopkins explores both the "Demand Pull" and "Supply Push" that are bringing ISDN to market. Of the two, the description of the supply push is more convincing; the demand for increased bandwidth and connectivity will be familiar to most readers, and a somewhat nebulous description of a society increasingly dependent on the free flow of information will seem a little stale. In describing the push toward connectivity in the telecommunications industry, though, Hopkins--a Bell Atlantic engineer--explains why the current telephone system is nearing the limits of its ability to expand in an evolutionary way, and why some revolutionary restructuring is required. The telephone industry is simply becoming unable to manage and afford a network that is mostly digital, except for the actual connections to the great majority of end-users.

A central group of chapters describes in technical detail how ISDN operates, what services it can provide, how it provides them, and the details of how people and machines telecommunicate in an ISDN environment. Chapters 5 and 6, "The ISDN Network-Services Model" and "ISDN Protocols" provide the greatest amount of the book's technical information. These are the chapters that describe what a basic ISDN connection actually consists of: two separate 64 Kbps digital channels working in conjunction with a third channel devoted to handling meta-information. Of particular interest to people working with computer networks is a description of how ISDN networks primarily used for circuit-switched applications coexist with packet-switching networks. These are also the chapters that spell out step by step how ISDN connections are actually made. Nine pages are devoted to a thorough description of what happens during a simple voice-only telephone call.

The next section of the book deserves high marks for sorting out the mechanisms which shape ISDN development, including the standards bodies involved and what each of them does. Since the ISDN standards process involves groups from ANSI, the Telephone Industry Association, the ITU, ISO, the IEEE, and the IETF, it is a substantial benefit to know which group is producing which standards. Appendix A is a more detailed list of relevant ITU standards, and Appendix C lists the IETF RFC documents related to ISDN.

It is hard to track down the number of installed telephones in the United States, but that number is comfortably above 100 million, and the great majority of those telephones currently have an analog connection to their carrier's local office. Technical problems aside, it is obvious that ISDN deployment is an enormous project management problem. Hopkins addresses this aspect of ISDN in three chapters, "Providing ISDN," "Implementing ISDN Applications," and "What Could Go Wrong?" Of particular interest is the discussion of public versus private funding options for large-scale ISDN implementation, and the description of challenges for innovation created by both government regulation and telephone businesses themselves. Hopkins leaves the reader with a picture of a telecommunications industry that has yet to decide how far it will embrace competition, and a telecommunications infrastructure whose inertia serves to inhibit change while also making that change increasingly necessary. Hopkins identifies doing nothing as the only likely alternative to implementing ISDN and concludes that "[t]his is so unacceptable in our postindustrial information age that ISDN seems _almost_ inevitable."

The remainder of the book is largely filled with a wealth of resource lists; the final chapter is a well-annotated bibliography of jumping-off points for people seeking further information and updates. In addition to the appendices mentioned above that list standards affecting ISDN, a further appendix provides excerpts from the "Catalog of National ISDN Solutions for Selected NIUF Applications" from the North American ISDN Users' Forum; the reader is referred to an ftp site, ftp://info.bellcore.com/pub/ISDN/CATALOG/ (ftp://info.bellcore.com/pub/isdn/catalog/), for the complete text. [Readers should note that the book mistakenly gives the directory as "/pub/isdn/catalog".]

Back matter includes a bibliography, an index, and a helpful glossary of telecommunication terms. The glossary could well be expanded in scope, however. Descriptions of ISDN often seem to take on the appearance of a mystical incantation, for example:

The network terminating unit (NT1) provides various testing capabilities (like loopback) and also transforms the 2B+D signal into a different bitstream format. At the S/T interface, two pairs of wires...are used.

Jargon-rich sections like this can be explicated through context, but readers tracking down a term from the index will find themselves at sea. A more substantial glossary would help, as would one which provides entries for both an acronym and the phrase for which it substitutes. The current glossary usually provides one entry for either the phrase or the acronym, and the reader can be left trying to guess which one to look for.

In conclusion, this book succeeds in its objectives of giving technical readers a baseline understanding of the issues and technology surrounding ISDN, and provides thorough pointers to both print and electronic sources of more detailed information. It alerts the reader to the fact that there are non-technological factors involved in ISDN's deployment, but avoids partisanship. It will be a useful text for network administrators and trainers who are beginning to work with ISDN, along with professionals involved in network planning who may be looking at ISDN for future growth.

Thomas Dowling (TDowling@u.washington.edu (mailto:TDowling@u.washington.edu)) is Networked Information Librarian, Public Services at the University of Washington.

table of contents | ter issues (/lita/publications/archive/ter)

ISDN for the Library WAN: A Review of ISDN Technology through Practical Application

by Marshall Breeding

Part I. Case Study: Using ISDN to support a remote network for Vanderbilt University Library

Goals of the Project

The main objective of this project is to provide network services to a library facility located several miles off campus, beyond the reach of the campus-wide network. The remote site will eventually be the workplace for about six staff members, each with his or her own computer. The main applications that require support include access to our IBM mainframe-based NOTIS system, participation in a library-wide Pegasus Mail system, connections to OCLC Prism, shared and private data files on a network file server, and standard office automation applications, including word processing, spreadsheets, and databases.

We selected ISDN as the telecommunications method for the project. The network protocols involved include IPX and IP. The primary network environment used by the library is Novell NetWare, but we also make substantial use of TCP/IP-based applications. The desired result of the project is to provide a computing environment at the remote facility that appears to the users to be the same as that available to the on-campus libraries, in terms of both use and perceived performance.

The Vanderbilt Library Network Environment

The libraries at Vanderbilt University rely on Local Area Networks (LANs) for all aspects of automation. LANs support access to Acorn, the library's NOTIS-based automation system, OCLC, electronic mail, and office automation functions such as word processing, spreadsheets, and databases. The Jean & Alexander Heard Library (http://www.library.vanderbilt.edu (http://www.library.vanderbilt.edu/)) consists of eight divisions spread out among several buildings on campus. Each library building has its own internal LAN which connects to the other library LANs through the campus-wide Ethernet network. All the library LANs rely on relatively high-speed connections to the systems and servers on the network. The campus network consists of a mixture of broadband Ethernet, Ethernet over fiber optic cabling, as well as a FDDI backbone. The library uses Novell NetWare 3.11 as its primary network operating system and makes wide use of TCP/IP-based applications. All software applications, including Microsoft Windows, as well as all data files, are loaded from NetWare servers. Most library staff can print to departmental laser printers through the network. Some of the libraries have a NetWare server housed in their own building while others share high-capacity servers located in the communications facility in the General Library Building (GLB). Almost all workstations in the library are provided with a World Wide Web browser, an Internet Gopher client, and other Internet access utilities.

Computing support for the Library Annex

In addition to the library divisions and departments located on campus, the library maintains an off-site remote storage facility, called the Library Annex, located about four miles from the main campus. The primary function of the Annex is the storage and retrieval of library materials, a process which relies heavily on the circulation module of NOTIS and electronic mail to manage the operation. The library plans to relocate one of its technical processing departments at the Annex which will increase the total number of staff and will require additional network services.

Previous Connectivity Model

For some time the Library Annex has had some limited connectivity to the campus network. To support the operation of the remote storage facility, access to the NOTIS and to an electronic mail facility was essential. A dedicated 9.6 Kbps digital data circuit connected the main office of the Library Annex and the communications facility in the GLB. This circuit connected to a DEC terminal server to provide access to NOTIS and to a VAX computer. These terminal servers operate through DEC's Local Area Transport (LAT) protocol. The types of services available through LAT are limited to those that operate through terminal sessions. A single port on the DEC terminal servers can support multiple sessions, allowing Library Annex staff to connect to the CTRVAX and to NOTIS simultaneously, and to cycle among the active sessions. Through the use of a statistical multiplexor, we were able to support two computers at the Annex. Two terminal server ports connected to ports on the multiplexor at the central communications facility in the GLB. At the Annex, the corresponding ports of the multiplexor connected to serial ports of each of the two PCs.

Expanded Network Requirements

While this configuration proved adequate for some time, the computing needs of the Annex eventually required a more sophisticated arrangement. Because of an organizational change, the library had plans to move additional staff and functions to the Annex. The department relocated to the Library Annex will not only participate in the operation of the remote storage facility, but will also conduct technical services operations.

Our primary goal for the Library Annex was to provide a computer environment like that of the other library divisions and departments on campus. The Annex would have its own local area network with all the services generally supported on the library network: access to NOTIS, Pegasus Mail, OCLC Prism, Internet services, as well as general office automation support. The Annex would have its own NetWare server since the slower wide-area network link would not be adequate for access to the main library server in the GLB.

The use of NOTIS requires a continuous session between the individual computers at the Annex and the IBM mainframe. The library has a pair of IRMALAN/EP gateways that convert the mainframe's native SNA communications to Novell's IPX/SPX protocol. Client workstations run DCA's IRMALAN for Windows which are configured to communicate with the IRMALAN gateways and perform 3270 terminal emulation. Through the use of block mode transmission, an IBM 3270 terminal session consumes very little bandwidth.

With Pegasus Mail, messages are delivered from one user's mail directory to another if both the sender and recipient use the same NetWare server. Pegasus can also deliver from one NetWare server to another. As long as there is a server for the remote network, the mail system should operate with acceptable performance. External mail would be delivered through a Mercury SMTP gateway running on the Annex's NetWare server, following the same model as all other NetWare servers in the Library.

Selection of ISDN as a Telecommunications Method

One primary consideration involved the selection of an appropriate telecommunications link between the Library Annex and the rest of the Library network. Other technologies were considered, but the Library chose Basic Rate ISDN. Not only is ISDN relatively inexpensive, but it would offer more than enough bandwidth for the type of communications that are required between the Annex and the rest of the campus network. Basic Rate ISDN offers two 64 Kbps B channels which can be combined to offer up to 128 Kbps of effective communications rate. As long as we provided a local file server for software and data storage, we believed that this communications rate would support 6-8 users on the remote network.

Other branches of the University were also exploring ISDN. This project would serve as a pilot project in a wider investigation of ISDN-based technologies. Since the University Telecommunications department was interested in exploring this technology for other wide-area networking projects, they would be available for technical support.

Implementation

The initial stage of the implementation involved the creation of a LAN at the Library Annex. This was fairly easily accomplished. Each of the PC's was equipped with 10BaseT Ethernet card and connected to a 3Com Ethernet hub (http://www.3com.com/0files/products/dsheets/lbfms2ds.html (http://www.3com.com/0files/products/dsheets/lbfms2ds.html)). A file server was set up at the Annex, equipped with a 20-user license of Novell NetWare 3.11, and configured in a similar way to each of the other library servers. At this point, Library staff could log into the network at the Annex and use software applications from the server. External services such Acorn and Pegasus Mail were not yet possible.

The project involved the installation of two ISDN lines. ISDN, as a general purpose digital link, does not follow a point-to-point configuration as would other leased-line circuits. While the primary purpose of this pair of ISDN lines will be to communicate with each other, each can potentially send and receive calls from any other telephone number. For this project, we requested one line to be installed at the Annex and the other in the computer networking facility in the GLB. This facility connects to the campus network through a fiber-optic link, and provides a secure location for all the multiport repeaters, NetWare servers, CD-ROM servers, and other networking equipment.

While the installation of the ISDN line itself was straightforward, many difficulties arose with the equipment necessary to use this line. The difficulties in obtaining communications equipment that would operate over an ISDN link and handle the complexity of our network caused the project to be more difficult than anticipated.

Our initial plan was to use a pair of access routers, one housed in the GLB communications facility and the other at the Annex. The primary requirements for this equipment involved the support of ISDN as a communications link, and the ability to handle IP and IPX protocols. There were a number of ISDN access routers on the market at the time, designed primarily for TCP/IP networks and Internet access. Few offered support for IPX.

Ascend's Pipeline 50

Our initial equipment consisted of a pair of Ascend Pipeline 50 ISDN access routers (http://www.ascend.com/prodinfo/pipeline/P50/P50ISDN.html (http://www.ascend.com/prodinfo/pipeline/P50/P50ISDN.html)). These routers were specifically designed for connecting remote LANs such as ours through an ISDN connection. The Pipeline 50 routers offered the ability to route IP packets, but could only bridge IPX packets. This router made excellent use of the ISDN circuit through its ability to combine the two 64 Kbps B-channels to create an effective 128 Kbps of bandwidth. Ascend developed what it calls multipoint point-to-point protocol that allows the B-channels to be combined. Through bandwidth on demand, zero, one, or two channels would be active as needed. The Pipeline 50 included a built-in NT1 allowing it to be connected directly to the jack installed by the telephone company and saving us the expense of purchasing an external NT1. The disadvantage of this approach is that it precludes the use of other ISDN devices on the line, but we had no such plans anyway.

The lack of IPX routing was our largest concern for the Pipeline 50 routers since the majority of our network services rely on this protocol. For large networks such as ours, routing packets is much more efficient than bridging. While ISDN is fairly fast compared to modems and other wide-area networking technologies, it is a much slower passageway than that used within LANs. Every effort must be made to eliminate any unnecessary packets sent across the ISDN link. One of the characteristics of IPX networks involves a high degree of overhead through Service Advertising Protocol, or SAPs. SAPs, while making sure that all services on the network are known to all network users, can overwhelm slower links on a large and complex network. Ascend's short term plans included the implementation of IPX spoofing and eventual plans to support true IPX routing. Spoofing involves programming the router to mimic some of the functions of IPX SAPs without having to pass all the SAPs across the ISDN link. With routing, SAPs and all other network traffic can be selectively passed across the ISDN link.

The Pipeline 50 access routers include a single Ethernet connection, a RJ-45 jack for the BRI ISDN line, and a serial port for connecting a terminal for the initial configuration. To configure the Pipeline 50, you connect a terminal or a PC running terminal emulation software to the serial port. A menu-based configuration utility allows you to set all the parameters and options. The router can be connected to the Ethernet network with either a 10BaseT or a coaxial BNC connector. A RJ-45 cable connects directly to the ISDN jack provided by the telephone company since the unit includes a built-in NT1. An external power adapter must also be connected to the unit.

Our implementation of Ascend's Pipeline 50 routers was completely unsuccessful. After installing the equipment and carefully following the configuration procedures, the routers would not operate for more than a few seconds at a time before they would reset themselves. While the routers could successfully place and receive calls with each other, the B channels were in a constant state of activation and deactivation. When a single computer was connected to the Pipeline 50 in the GLB, the line would operate normally, and this PC could log into the network at the Annex. But as soon as the Pipeline 50 at the GLB side was connected to the full network, it would immediately fail. We concluded that this router could not handle some aspect of the complexity of our network. Even with assistance by engineers from both Ascend and from our University

Telecommunications office, we were unable to make the equipment operate properly in our environment after several weeks of effort. We had the Ascend routers on an evaluation plan, so we were free to return them.

On Technology's ISDyNE IPX Router 66

Our next step involved the replacement of the Ascend routers with a pair of access routers from On Technology, called the ISDyNe IPX Router 66 (http://www.on.com/on/hardware/isdynero.html/tig1432 (http://www.on.com/on/hardware/isdynero.html/tig1432)). These routers claimed basically the same features as those from Ascend, but specialized in Novell networks, supporting true IPX routing. Through SAP filtering, we could control some of the factors that caused the Ascend equipment not to work in our environment. On Technology fully guaranteed that the routers would work and we could return them for a full refund if we were not satisfied with any aspect of their operation.

The implementation of the ISDyNe routers was fairly straight- forward. While the Ascend routers needed to be configured through a terminal connected to a console port, the ISDyNe routers were configured through the network itself via Telnet. ISDyNe supplies a Telnet client that connects to the router's Ethernet address even before it has been programmed with an IP address. The ISDyNE Router 66 also includes a built-in NT1, allowing it to be connected directly to the ISDN jack. Once connected to the ISDyNe routers, a command-line interface is used for entering commands to set the configuration parameters. The commands available for programming the ISDyNe are basically the same as configuring network utilities under Unix. While the documentation is extremely sparse, those familiar with Unix should be able to figure out the commands and syntax.

While the ISDyNe offered some improvements in function for us over the Pipeline 50, we initially had some of the same difficulties. The diagnostic utilities of this router did enable us to diagnose better and bypass some problems to make the unit function at least in a limited way. When initially connected to our network, the ISDyNe routers exhibited almost exactly the same symptoms as the previous equipment. The router would constantly reset itself and the B channels were in a constant cycle of activation and deactivation. The operation of the ISDyNE Router 66 involves at least two internal tables, one that describes SAPs and another that describes network addresses broadcast on the network through Router Information Protocol (RIP). The size of both of these tables is limited to 255 entries. We were able to manage the SAP table through the establishment of a SAP filter and to indicate the specific SAPs that needed to be passed across the ISDN link. The internal SAP table consists only of the entries specified. The number of entries that can be stored is limited to 64 characters. This allowed us to store only about three out of the 10 entries necessary to make our primary IPX services available to the remote network at the library Annex. We could specify the full set of entries, but only a subset could be stored in nonvolatile memory. Each time the router was reset, we would have to reenter much of the table. Even with SAP filtering enabled, we continued to have problems with the router constantly resetting itself and the channels of the ISDN link.

The router also keeps an internal table of network addresses broadcast on the network from other servers and routers through the Router Information Protocol (RIP). The number of devices on our network that advertise themselves through RIP is extensive. Unfortunately, the ISDyNe router's internal RIP table can handle only 255 entries. As soon as this table overflows, the router fails and resets itself. Although the router includes filtering to avoid overflows of the SAP table, no such RIP filtering is available. It does include the ability to selectively route information based on the number of intervening routers, or "hops" on the network. By tinkering with the hop count, we were able to bring the number of entries in the RIP table to just below 255 and make the router operate. This was not an altogether successful strategy in that the services that needed to be accessed would frequently become unknown to the remote network due to the dynamic nature of how hop counts are maintained on a network. The router would operate for only a few hours at a time, and would need to be reset from one to three times per day. Each time the router was reset, we would have to reenter the names of several library servers into the SAP table. We considered this to be a very unacceptable level of functionality and made plans for a more reliable approach.

On Technology is a relatively small company, and the ISDyNe Router 66 was its first hardware product. Only limited technical support is available for this product. The primary means of technical support is through electronic mail. Non-technical sales staff offer some support via telephone. Only after considerable persistence was I able to talk to the primary technical engineer for this product. Once the our problem was isolated to limitations in the router's software capabilities, no immediate resolution was possible. If we wanted to enhance the software to handle RIP filtering, we would have to pay $100 per hour for custom programming. We did not consider this to be an acceptable solution since the complexity of our network is not that unusual and that none of the limitations of the router were documented.

Cisco 2503 routers

Finding the low-end access routers lacked the power and sophistication necessary to handle our network, we turned to more full-featured network routers. After a review of many other competitors, we eventually selected the Cisco 2503 router (http://cio.cisco.com/warp/public/563/4.html (http://cio.cisco.com/warp/public/563/4.html)). This router offers support for a wide variety of data link types and network protocols and is designed to accommodate complex networks. Cisco is one of the leading manufactures of network routers and has an excellent reputation for high-quality products and technical support.

Our plan for the Cisco routers involved two wide area networking applications. Not only would they connect the LAN at the Library Annex with the campus network, one would also be used to provide access to OCLC's Prism service. We purchased a Cisco 2503 router, equipped with Cisco's modular Internetwork Operating System (IOS) Version 10.2 enterprise network software, to be installed in the GLB communications facility. One characteristic of Cisco's routers is that their software is purchased separately from the hardware. Different versions of the software offer different features and are priced accordingly. One of the requirements for the router used to support access to OCLC's Prism service is that it perform X.25 to TCP/IP translation. Many routers can encapsulate X.25 traffic in IP packets, but true translation is required for this application. Cisco's most complete version of IOS, called its Enterprise software set, was required for this function.

The Cisco 2503 has one AUI Ethernet connector, a BRI ISDN port, and two serial ports. A console port is provided for the initial configuration of the router. Once the router has been connected to the Ethernet network and configured with an IP address, you can connect to it from any other computer on the network through Telnet.

The telephone company provides a RJ-45 connector as the termination of the Basic Rate ISDN line. In ISDN terminology, this is the U reference point. The U reference point is a two-wire interface that sends and receives on the same pair. The PRI port of the Cisco 2503 is a TA device. To connect other devices to the U interface requires an NT1 device. While the Ascend and ISDyNe access routers have the NT1 built in, the Cisco requires an external NT1. Although this adds an additional $150 in cost for each NT1, it does allow the possibility for sharing the ISDN line with other devices. It is common, for example, to use an ISDN line for both telephone and network communications. The NT1 device has a single U interface which connects to the ISDN wall jack through a straight-through RJ-45 cable. Most NT1s have multiple S or T ports which connect to multiple ISDN devices. Another straight-through RJ-45 cable connects the S interface on the NT1 with the BRI connection on the Cisco router.

We purchased a Cisco 2503I as the router to be used at the Library Annex. This is basically the same router as the 2503, but is a specially configured package for ISDN applications. The 2503I includes only a BRI connection and AUI Ethernet port. Although it has two serial ports physically installed, they are disabled. This router also comes with a version of Cisco's software customized for connecting a remote LAN through an ISDN line and supports only IP and IPX protocols.

Another complication we encountered with the implementation of the Cisco routers involved the ISDN lines themselves. Both of the ISDN lines had been in operation for several months, having been used successfully with the ISDyNe routers, with their intern al NT1s. When we installed external NT1s, we could not get the line at the Annex to activate. At first, we suspected that the NT1 was defective, but even after we exchanged the NT1s at the GLB and Annex, the Annex side would still not operate. Since the ISDN line was working with the previous equipment, we did not suspect the line itself. We measured the voltage on the U interface and discovered that it was significantly below the 40 volts expected. We obtained an NT1 from another vendor, and the line finally worked. Although there is a telephone switch located in the building next to the Library Annex, it did not support ISDN at the time our line was installed. Our line was serviced from another switch, considerably more distant. It appears that the signal strength of the line was below specifications, at a level that would work with only some NT1s. Since the switch at the station next to the Annex now supports ISDN, we plan to have the circuit rerouted.

The configuration of the Cisco router involves several steps. The router has a console port, to which you connect a terminal or the serial port of a PC running terminal emulation software. The baud rate data bits, and parity of the terminal must match the default settings of the router's console port. When the router is initially powered on, it prompts for some basic parameters. It asks if each of the ports are in use, and if they are, for some initial configuration parameters. Once you have completed the preliminary configuration, the router can be restarted. If all goes well, you should be able to Telnet to the router over the Ethernet network to complete the configuration and to test and monitor the router's operation.

Except for the initial prompts presented the first time the router is powered on, the Cisco routers are configured through a command line interface. Cisco routers are extremely sophisticated and a large set of commands are available for controlling their operation. Extensive documentation is available. A CD-ROM version is provided without cost, and paper documentation is available at a nominal cost. The configuration parameters can be written to the router's internal nonvolatile memory so that they will be used each time the router is reset. The Cisco router has both global and port-specific configuration parameters. The global features include the network hostname of the router, the default IP gateway on the network, the domain name of the network, any other host names that need to be defined, and the routing protocol to be used.

Several parameters are required for the configuration of the BRI interface on the router. Since the various models of telephone switches handle ISDN communications somewhat differently, you must specify what type of switch is involved, in our case a Northern Telecom DMS-100. For this type of switch you must also specify the two SPIDs assigned to the BRI circuit.

The main purpose of the router is to transmit data over an ISDN telephone circuit to and from a remote network. The router needs to know how to place and receive calls. While low-end access routers generally can be programmed to communicate with only one other router, the Cisco routers can communicate with multiple remote LANs, though only one at a time. For each remote network, you configure a dialer statement that associates a remote network address with a telephone number to be dialed when data needs to be transmitted to that network.

Most ISDN routers, including the Cisco 2503, include a feature called "dial on demand." With this feature, the router dials and activates the line only when data actually needs to be transmitted. After a specified interval of inactivity the call is terminated and the line is inactivated. Another feature, called "bandwidth on demand" allows multiple channels to be activated and deactivated as needed. Dial on demand is especially attractive when there are costs associated with using the ISDN lines. If the number dialed is long-distance or if all call calls incur charges, then dial on demand is an essential feature. But if the call is local and there are no connect-time charges, then the dial on demand parameters can be set accordingly. With ISDN, the time required to set up or tear down a call is very small.

One characteristic of the Cisco router is that each port, or interface, of the router has its own network address. The Ethernet interface requires an IP address for the interface and the address of the IP network to which it connects. The IPX network must also be specified, but IPX network addresses are determined automatically. The Cisco router requires that each interface on the device be configured for a separate network or subnetwork. In our case, the main campus network is a class B IP network with the address 129.59.0.0. Our remote LAN at the Library Annex is a Class C IP network with the address 199.78.112.0. In order to satisfy the requirement that all the interfaces connect to logically distinct networks, we had to assign a different class C address to the network that consists of the two ISDN lines. Devoting two class C IP addresses to a single remote network of 5 nodes represents an extremely inefficient use of IP address space. We plan to collapse the two class C networks into one through subnetting. Our initial efforts to subdivide the remote network at the Library Annex through a subnetwork mask were unsuccessful. We plan to continue our efforts to implement subnetting and make more efficient use of the IP address space.

The Cisco router includes a number of features for optimizing the routing of IPX protocol. One option involves the spoofing of IPX SAPs to create a static list of services available on the remote network. You can also create an access list to define a SAP filter that selectively defines services to be dynamically advertised to the remote network. The dial on demand routing features allows you to create access lists of the type of packets to be transmitted to the remote network. Access lists allow you define which types of packets are interesting enough to activate the line for transmission. The configuration of the Cisco router was a relatively complex task that required some assistance from Cisco's technical support center. A team of engineers was available to help with the process. Specialists in dial on demand protocols, IP routing, and Novell networks all participated in the process of diagnosing our problems and deriving a working configuration for the routers. Once the routers were configured, the network connection to the Library Annex has been extremely reliably. While we had to deal with failures of the ISDyNe routers several time per day, the Cisco routers have operated continuously without a single problem.

Assessment of the Technology

We consider the results of the implementation of the remote network at the Library Annex to be quite successful. We were able to offer all the network services to the Annex as we do for all the other networks, and the perceived performance is excellent. As a telecommunications method, we remain satisfied with ISDN as far as the costs for the level of bandwidth offered. The two ISDN lines, with their potential 128 Kbps effective communications rate costs us only slightly more then our previous 9.6 Kbps digital leased line. The installation fee was comparable with that of alternative line types, the lead time for installation was reasonable, and South Central Bell, our regional telephone company, has delivered very good support and service.

Before undertaking a project that involves ISDN, you must be well- versed in the details of the technology--more than with other telecommunications methods. In order to implement an ISDN-based network, you must be aware of many aspects of the telephone system such as the type of digital switching system used and the distance involved between the switch and your premises. Having to provide NT1 devices, either externally or internally within the devices also complicates the use of ISDN. This complication applies only to the Unites States, since the NT1 is provided by the telephone company in all other parts of the world.

The process of selecting, installing, and configuring the ISDN equipment proved to be extremely difficult. Part of our problems reflect the state of the technology, and part was just bad luck. Our experience with ISDN access routers was extremely disappointing. While best suited for fairly simple networks where support for only a single protocol is required, we found that access routers lack the control and features offered by full-fledged network routers. If your network is large and complex, if you need to deal with multiple protocols, or have other complicating factors, you may need to invest in more sophisticated equipment. While the Cisco router was slightly more expensive than the alternatives and much more complex to configure, its ability to handle multiple functions and protocols made it the best choice for our environment.

Part II. ISDN: A selected annotated bibliography

ISDN on the World Wide Web

Dan Kegel's ISDN Page (http://alumni.caltech.edu:80/~dank/isdn/ (http://alumni.caltech.edu/~dank/isdn/)). This web site offers one of the most complete guides to Internet resources related to ISDN. It includes pointers to other known resources on the Internet and provides very comprehensive lists of vendors and products on all aspects of ISDN technology. Pointers to the RFC's related to various aspects of ISDN and other proposals are provided. This site is very well organized and contains significant detailed information. This site is mirrored by web servers in England, Poland, Germany and other parts of the United States. Many of the other ISDN sites on the Internet borrow heavily from Kegel's.

ISDN Informationbase (http://igwe.vub.ac.be/~svendk/isdn_homepage.html (http://igwe.vub.ac.be/~svendk/isdn_homepage.html)). Created and maintained by Sven De Kerpel (a student at Brussels Free University), this Web site contains both original content and pointers to other Internet resources. The ISDN Information base provides lists of Internet resources, print materials, vendors of ISDN hardware and software, ISDN telecommunication operators, Internet access providers that offer ISDN-based services, and a glossary of ISDN terminology. Many of the lists on this site are noticeably incomplete, including only a sampling of the currently available resources, services, and vendors.

ISDN Online. Part of TechWeb, sponsored by CMP Publications, publisher of Network Computing magazine. This Web page includes a collection of articles previously published in Network Computing about ISDN, lists of vendors and products related to ISDN, and pointers to mailing lists and newsgroups on ISDN. Network Computing has consistently provided in-depth coverage of ISDN, and the inclusion of the full text of these articles makes the ISDN Online site an valuable resource.

Texas ISDN User's Group (http://www.crimson.com/isdn/ (http://www.crimson.com/isdn/)). An extremely comprehensive web site for ISDN information. It includes an introductory article, a pointer to the ISDN FAQ, and lists of ISDN hardware and software vendors, Internet access providers that offer ISDN-based services, and much more related information. Parts of the information on this site is derived, with credit, from Dan Kegel's ISDN Page.

ISDN: A User's Guide to Services, Applications, & Resources in California. Available in both print and electronic media: as a softbound book published by Pacific Bell (PB 2027-2) in November 1994 and as a Web resource (http://www.pacbell.com/isdn/book/toc.html (http://www.pacbell.com/isdn/book/toc.html)). This work provides a very clear and non-technical introduction to ISDN services. It includes case studies of ISDN implementations and describes the types of ISDN service available in California. An appendix lists many of the vendors that supply ISDN hardware. A generous number of graphics are provided.

SUCCEED's ISDN Information Page (http://fiddle.ee.vt.edu/succeed/isdn.html (http://fiddle.ee.vt.edu/succeed/isdn.html)). SUCCEED, a committee of the National Science Foundation, includes this ISDN reference page as part of their overall investigation of communications technologies. This Web site includes links to the most popular Internet resources related to ISDN technologies. Not comprehensive, but a good starting point.

news://comp.dcom.isdn (news:comp.dcom.isdn). This Usenet newsgroup serves as a major forum for discussion of ISDN technology and equipment. The discussion is generally on a moderately high technical level, but includes many basic questions and answers about ISDN access products and services. A FAQ is associated with the list that includes a significant amount of information (ftp://rtfm.mit.edu/pub/usenet/news.answers/isdn-faq/ (ftp://rtfm.mit.edu/pub/usenet/news.answers/isdn-faq/)).

gopher://noc.macc.wisc.edu:70/0R0-43101-/isdn/papers/glossary.isdn.terms-kluge (gopher://noc.macc.wisc.edu/0r0-43101-/isdn/papers/glossary.isdn.terms-kluge). A listing of ISDN other data communications acronyms created in 1991 by Goetz Kluge that includes several hundred acronyms and their expanded forms, but provides no definitions.

Regional Bell Operating Companies ISDN Services. The following Web pages describe the ISDN services of each of the RBOCs:

- Ameritech: http://www.ameritech.com/solutions/business/asg-ds-asds-isdn.html (http://www.ameritech.com/solutions/business/asg-ds-asds-isdn.html)
- Bell Atlantic: http://www.ba.com/isdn.html (http://www.ba.com/isdn.html)
- Bell South: http://www.atglab.bls.com:80/products-services/isdn.html (http://www.atglab.bls.com:80/products-services/isdn.html)
- Bellcore: http://www.bellcore.com/ISDN/ISDN.html (http://www.bellcore.com/ISDN/ISDN.html)
- Pacific Bell: http://www.pacbell.com/isdn/ (http://www.pacbell.com/isdn/)
- Southwestern Bell: http://www.sbc.com/swbell/shortsub/digiline.html (http://www.sbc.com/swbell/shortsub/digiline.html)
- US West: http://www.uswest.com/ISDN.HTM (http://www.uswest.com/ISDN.HTM)

ISDN in recent Trade Publications

Aber, Robyn. "ISDN and Dial-up Connectivity: Switched Data Solutions for Remote and Personal Office Internetworking." Enterprise Networking Journal (July 1995): 9-16.

Newman, Jeff. "Buyer's Guide: How to Choose and Implement ISDN Services and Products." Network Computing 6(3) (March 1, 1995): 152-165. This Buyer's Guide section in Network Computing begins with a summary of the basic concepts of ISDN, its advantages, the types of services available, and the various products involved, such as NT1 adapters, ISDN terminal adapters, interface adapters, and bridges/routers.

It gives advice on specific desirable features for ISDN hardware and software. Following this text , a table spanning 8 pages summarizes the ISDN products available with information about their functions, features, and pricing.

Nolle, Tom. "ISDN: Seize the Power" Internetwork (April 1995): 25-28, 46. In this very basic treatment of ISDN implementation, Nolle briefly summarizes the history of ISDN, discusses some basic concepts, and gives advice on ordering ISDN lines and equipment, and on installing and configuring equipment.

Rash, Wayne. Jr. "3Com's Big Impact on ISDN." Communications Week No. 560. (June 5, 1995): 12. This article reviews 3Com's new Impact ISDN adapter. This device connects to a personal computer through a serial cable and functions as a Basic Rate ISDN communications device, including both the NT1 and TA. It includes an analog jack that can be used for a conventional telephone or modem. The article gives the 3Com Impact a very high rating.

Rendelman, John. "FCC Backs off Plan to Charge for Individual ISDN Circuits." Communications Week No. 560. (June 5, 1995): 5. One of the most significant developments related to ISDN pricing involves a recent FCC ruling requiring that user charges for ISDN lines be based on the number of channels available instead of the line as a whole. These user charges if applied according to the new FCC interpretation could more than triple ISDN rates for some users. The FCC has now reversed itself, allowing the more liberal interpretation of the subscriber line charges. The ruling is tentative, with a final decision expected by Fall 1995.

Rendelman, John. "Putting ISDN on the Map." Communications Week No. 559 (May 29, 1995): 43-46. ISDN, while gaining ground, is not yet available in all parts of the country. This article describes the current state of ISDN availability in the United States. A map illustrates the level of ISDN availability and deployment within the area of each of the Regional Bell Operating Companies. Sidebars discuss the recent FCC tariff rulings and the use of ISDN for multimedia applications.

Robertson, Bruce and Jeff Newman. "ISDN Does it all!" Network Computing 6(5) (May 1, 1995) 62-80. Discusses some of interpretability issues involving ISDN, such as BONDING, Multilink PPP, and WinISDN. Reviews several hardware products related to accessing ISDN, including ISDN Systems Corp. SecureLInk, Accessworks QuickAccess Remote, Ascend's Pipeline 50HX, DigiBoard's PCMIMAC, and ISDN*tek's CyberSpace Internet Card. Sidebars discuss the IBM WaveRunner PC Card and ISDN Access to the Internet. A full page graphic illustrates the availability of ISDN services throughout the United States.

Salamone, Salvatore. "ISDN and Analog Access in One Package." Byte 20(7) (July 1995)181-182. This article describes the genre of devices that operate as both analog modems and ISDN interface. Such devices connect a computer to an ISDN line and can communicate with either ISDN-based services or those that use traditional analog phone lines.

Snell, Monica. "A Beginner's Guide to ISDN." LAN Times (April 24 1995. 80-84. This article discusses some of the issues involved in implementing an ISDN line. Some of the topics covered include the general state of ISDN deployment in the US, availability of ISDN services by the various Regional Bell Operating Companies, costs of ISDN lines in different parts of the country, and some of the issues involved with obtaining ISDN equipment. A sidebar discusses a recent FCC ruling that has significant cost implications for ISDN services. Consumer line charges were originally interpreted to apply to each ISDN Line, but recently the FCC ruled that the charge applies to each channel. Enforcement of this ruling could effectively cancel out the cost benefits of ISDN implementation.

Tropiono, Lenny and Diana McNutt. "How to Implement ISDN." Byte 29(4) (April 1995): 67-74. Many practical aspects of ISDN are covered in this very informative article. Beginning with the basic concepts of the technology, the authors quickly move on to the practical logistics of implementing ISDN, including pricing, availability, and the equipment involved. A sidebar lists 12 questions to ask when ordering an ISDN from your regional provider. Another sidebar contrasts ISDN with alternatives such as leased line services, concluding that ISDN may not offer the best solution for applications that involve very high bandwidth.

ISDN Technical Reference

ISDN Basics. Hewlett-Packard (Manual Part Number 18356-98201. February 1989). A technical introduction to ISDN technology. Includes descriptions of the basic concepts, puts ISDN into the perspective of the OSI network model, describes the different types of ISDN equipment and their corresponding reference points in the ISDN schematic, and provides details on the data frames as they exist in both Basic Rate and Primary Rate ISDN. Although this manual bears a relatively old publication date, the information it contains continues to be accurate and relevant.

Marshall Breeding (Breeding@library.vanderbilt.edu (mailto:Breeding@library.vanderbilt.edu)) is Library Networks and Microcomputer Analyst for the Vanderbilt University Library.

table of contents | ter issues (/lita/publications/archive/ter)

About TER