ISDN AND THE SMALL USER: REGULATORY POLICY ISSUES

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1. Introduction

Universal, public ISDN[1] offers different promises and challenges to different groups. To local telephone companies, it is a means to assure a large share of the most rapidly growing component of telecommunications—enhanced information services — as well as to capture video distribution from cable television systems. To technologists who work at the forefront of emerging microelectronics technology, ISDN is a gateway to access information and to eliminate the barrier of geographic distance in information processing and remote control. To many large businesses, it promises to provide a public alternative to private telecommunications systems for serving their increasingly complex requirements for internal information services. To small businesses it may be regarded as a means for remaining competitive with large firms which can justify investment in their own private network. To most residential and small business customers of local telephone companies, ISDN is probably without meaning, although these users unknowingly may have a great deal at stake in whether it is deployed.

To political leaders and regulatory authorities, ISDN offers both an exciting promise and a worrisome headache. Local telephone companies want to implement ISDN ubiquitously, and they are monopolies who provide a service that is economically, socially, and politically of great importance; hence, the decision to implement ISDN in the public telephone system and subsequent decisions about who should bear its costs will be strongly influenced by regulators. These decisions will not be easy, for much is at stake in committing the nation to ISDN. One possibility is that ISDN is, or soon will become, the dominant technology for a national telecommunications system. If so, any nation which does not adopt it quickly will inflict significant cost disadvantages on a variety of domestic industries that make extensive use of information services. Moreover, its citizens may be deprived of access to new consumer services which are available elsewhere and which are highly valuable. Regulators who drag their feet may

Integrated Broadband Networks: The Public Policy Issues / Martin C.J. Elton (Editor)

cause their constituents to lose ground economically to people whose regulatory authorities are more visionary. At the other extreme, ISDN may be an excessively complex and costly technology for which there is little demand. If so, a commitment to it would force regulators to choose between undermining the financial viability of the local telephone companies which adopt it or dramatically raising prices for ordinary services which derive little or no benefit from ISDN capabilities.

The prospect for ISDN deployment by local telephone companies raises a variety of policy issues that regulators will have to confront in the 1990s. The focus of our analysis is the set of issues related to the "small user," by which we mean the vast majority of subscribers to the telecommunications network (both residences and small businesses) who now use it exclusively for ordinary telephone service and for limited or specialized information services, such as alarm monitoring or credit card approval, which can be provided using non-ISDN technology. The sophisticated residential or small business customer who uses a personal computer and a modem to gain access to enhanced information services could be expected to take advantage of ISDN capabilities, and so is not a member of our small user class. We assume that these users will prefer ISDN development, although the extent to which they will need or want ISDN is also open to question. We also assume, *arguendo*, that most residences and small businesses will not be in this category. Perhaps this assumption is too pessimistic; however, whether most small users will make use of ISDN or, if they do use it, derive any net benefit from it, is an issue that is very much in doubt.

Today, both interexchange and local exchange carriers (IECs and LECs) are poised to begin offering N-ISDN. Illinois Bell and AT&T already have tariffed products. All of the carriers are investing aggressively in new digital switching and signaling systems that will provide the backbone for supporting ISDN services. The LECs are also beginning to invest in fiber optic technology for the local loop. Fiber optic cable is a necessary precursor of B-ISDN.

These events raise the core policy question, should B-ISDN be made available ubiquitously throughout the public telephone network? This question cannot and need not be answered definitively, for it depends on the resolution of numerous technological and market uncertainties. The more immediate issues implied by this question are the identification of the most useful steps for reducing these uncertainties, and the priority and urgency that should be given to assuring that these steps are taken.

Our purpose is not to answer these questions but to increase the precision with which they are asked. Specifically, we seek to identify the nature of the possible risks and benefits to small users of implementation of N-ISDN, and then B-ISDN. In addition, we seek to identify how these risks and benefits depend on other regulatory policies affecting local telephone companies. We reach three conclusions:

1. the principal source of risks for small users has very little to do with the presence of rate-of-return regulation, and so will not be significantly

ameliorated by the adoption of price caps or other proposed alternatives for regulating monopoly utilities;

2. the single most important policy affecting the expected net benefits of ISDN deployment is the extent to which competitive alternatives are made available to small users; and

3. regulators should cautiously exploit the learning opportunities afforded by N-ISDN before committing prematurely to ill-defined B-ISDN technologies and standards. This decade is the appropriate time to engage in extensive technical and economic tests of ISDN. The ultimate value of the system that will emerge is likely to be greater if, simultaneously, regulatory constraints on the extent of local service competition in telecommunications are also removed.

2. Technical Preliminaries

ISDN is a confusing term with at least three distinct meanings in the policy debate.[2]

ISDN as Vision

At the most general level, ISDN is a visionary dream about the telecommunications network of the future, a network that is still decades away. It is also a long-term competitive strategy of local telephone companies. In this context, ISDN refers to a fully digital network that provides the complete array of imaginable voice, data, and information services in a single ubiquitous system to which everyone has access. The keyword in ISDN is "integrated," which reflects the idea that the public network will be able to provide efficient interconnection for all possible telecommunication services. The key word is *not* "digital," for extensive digitalization of the public network has already taken place. The baseline for comparison with ISDN is a public network with digital switches and digital transmission over trunks, but with analog connections to end users and more limited capabilities in the network.

ISDN as Standard

The second meaning of ISDN is embodied in the set of technical standards that will determine its capabilities and the equipment which is compatible with it. The technical standards will be determined first by the most demanding services that the network will be required to support, and second, by a requirement to retain compatibility with less demanding services and older customer equipment. If the former means two-way switched video and switched supercomputer communications to homes or small businesses, then local loop standards must permit digital communications at high speed over fiber optic cables. Most of today's local access facilities use analog transmission over copper wire.

As presently conceived, the technical standards for an integrated, ubiquitous network must serve at least three important performance goals:

1. to move enormous quantities of information quickly;

2. to have very high reliability (few errors and high availability); and

3. to possess sufficient flexibility to accommodate the idiosyncrasies of different types of traffic.

The purposes of the flexibility requirement are to facilitate changes in user demands, to economize on network capacity, and to ensure high reliability. Flexibility means that neither a telephone utility nor a residential or small business subscriber will face great difficulties or costs if the subscriber should decide to change from ordinary telephone service to some form of advanced service (for example, a microcomputer connected to a supercomputer or a computer-assisted design system). To achieve maximal flexibility requires software control of the network. Software control means that computer programs — perhaps in the form of chips or cards — determine the characteristics of service provided to a user, rather than hardware — the characteristics of the physical facilities used in the local loop.[3]

While achieving these goals, the network must retain the capability to provide simple services inexpensively. ISDN is not likely to be politically acceptable as a public switched network if it raises the cost of ordinary telephone service. A ubiquitous network must also be accessible to customers using a wide variety of advanced equipment, including customers with private networks. ISDN standards specify precisely what kinds of information channels the public network will accommodate and the technical specifications that equipment must meet to be compatible. Customers whose equipment is not compatible with the ISDN standard will be required to provide interface devices to connect their equipment to the public network.[4] Because these devices can be costly, the choice of an ISDN standard confers technical and economic advantages on certain equipment suppliers and users.

N-ISDN standards are still being developed although telephone companies and their customers have already begun to install digital equipment. Thus far, the standards development process has been evolutionary in that it has sought to maintain as much compatibility as is feasible with the existing stock of digital equipment in the network. Likewise, the transition from early narrowband standards to B-ISDN is also intended to be evolutionary, adding new technical capabilities as broadband technology and services emerge, without causing the immediate obsolescence of N-ISDN equipment. Because this evolutionary strategy must take into account a diverse array of producers, users, and equipment, the development of ISDN standards has been and will continue to be a gradual process. David and Steinmueller describe ISDN as "a standards 'movement,' a broad effort to achieve consensus among vendors and users of telecommunications equipment about how data networks should be implemented in the remainder of this century."[5]

Two local access standards were adopted in 1984 by the Consultative Committee for International Telephone and Telegraph (CCITT), the most important international body for developing industry standards. These two standards, Basic Rate Interface (BRI) and Primary Rate Interface (PRI), implement the simplest form of N-ISDN access to the public network.[6] Several technical details concerning the implementation of N-ISDN and numerous other standards for broadband access, service characteristics, and software control of the network, remain to be developed.

ISDN as Product

The third meaning of ISDN refers to the actual hardware, software, and service capabilities of the network. Neither the ultimate vision nor the implementation standards specify the actual components of the network and the uses to which they will be put. To the contrary, ISDN is to be sufficiently flexible that components and services not now imagined can be incorporated into the system easily. Any component that meets ISDN standards, or any service that can be implemented with such equipment, can be a part of ISDN.

In principle, neither the ultimate vision of ISDN nor the implementation standards carry any necessary implications regarding the ownership of the backbone telecommunications network or the equipment that is connected to it. For example, local access could be provided by several parallel or overlapping networks which are interconnected to each other, to interchange carriers, and to a variety of service providers using various combinations of their own equipment and the switches and other intelligent equipment in their local access network. This version of ISDN simply requires that all of the network and terminal equipment be compatible. Alternatively, the structure of the industry could resemble AT&T before divestiture, with a single corporate entity owning all components of the network and all terminal equipment, and supplying all information services.

In practice, ISDN is not neutral with respect to the ultimate structure of the network because it begins with an assumption that is inherently centralizing. The advantages of ISDN depend on the presumption that all telecommunications services should be provided within the framework of a single set of technical standards. It may be that the optimal telecommunications system would be comprised of several networks, each of which is optimized for a particular class of uses. These networks might be connected through interface devices or gateways[7] and would have different technical standards and capabilities. The underlying premise of this vision is that most of the traffic on each network would not pass through an interconnection between networks, and that most users would place relatively little value on interconnectability.[8]

3. Economic Issues in ISDN Deployment

The core issue in the deployment of ISDN is the extent to which LECs should be permitted to make successive upgrades to the backbone telecommunications system so that the full range of information services can be provided to all telephone subscribers. Although telephone companies have made considerable investments in digital technology, and will continue to do so, the extent of ISDN deployment is still a live issue. Much of the research and development required to offer N-ISDN has already taken place in the development of digital central office switches; however, the network equipment that has been installed by local telephone companies to implement digital switching is not compatible with current N-ISDN standards and may need to be replaced or augmented to guarantee compatibility.[9] To date, no one has demonstrated a fully operational network which is consistent with the first generation CCITT standards for N-ISDN. Bell Communications Research has developed different ISDN test equipment for each of the five major equipment vendors whose digital switches are deployed in the public network. The equipment from different vendors is not fully compatible although it may become so if pending technical issues can be resolved at sufficiently low cost. Likewise, the terminal equipment that can be used with any one of these switches cannot be used with the others without an interconnection device.[10] B-ISDN deployment faces even larger problems and uncertainties. None of the network equipment now deployed in the public network for digital switching and transmission will support B-ISDN without modifications. Thus, much of the existing investment in ISDN may become obsolete quickly. From a policy planning standpoint, all of this means that most of the costs of implementing ISDN are still to be incurred.

By contrast, considerable investments have been made in specialized private networks which use advanced digital and fiber optic technology. During the first triennial review of the AT&T divestiture agreement, LECs and the Antitrust Division of the U.S. Department of Justice argued that during the1980s, more than half of the increment to capacity in local networks was accounted for by systems that are not part of the basic local telephone system and that are not owned by LECs.[11] Large corporate users have already built extensive private networks that incorporate advanced digital switching and transmission. Many of these private networks already support services more advanced than those planned for the initial N-ISDN system; for example, the use of voice compression technology that packs two voice circuits into the bandwidth equivalent of a single BRI channel. Moreover, private networks are generally not compatible with either the present public network or ISDN, and they interconnect to the public network via gateways (usually PBXs).

The past behavior of users of advanced digital networks does not necessarily suggest that the integrated approach of ISDN is inferior, for the local exchange network has not been evolving fast enough to afford these users a reasonable alternative to specialized, separate systems. Nevertheless, these separate investments reveal that for some users, at least, non-integrated systems are a viable means for providing advanced information services. Deployment of ISDN will face the problem of whether these users will want to switch to ISDN, or to invest in gateways that give them access to the ISDN network while retaining the use of other systems.[1]

A Conceptual Model of the Policy Choices Surrounding ISDN

The economics of the decision concerning the range of capabilities that ought to be incorporated into the local public network is complex, but the essential elements can be captured in a rather simple way. Suppose that telecommunications services are of two types, "plain" and "novel," and that each can be provided separately over dedicated networks or in combination over ISDN. In the former case, the separate networks can be interconnected through a gateway. The gross user value of each service is determined by the technical standards of the network that provides the service and whether the two services are interconnected (interconnection allows added uses). The costs of each service depend on the standards that are selected and whether the services are provided separately, but with an interconnecting gateway, or jointly in an integrated network. Let *V* stand for values, *C* for costs, *s* for standards, *p* and *n* for the two types of services, *i* for integration, and *g* for gateway. By assumption, technology can create two new sources of value: V_n (from novel services in a separate network) and V_i (from new services arising from integrating novel and plain services). The optimal technical configuration can be identified by comparing the solutions to the following three optimization problems.

Problem 1

$$\underset{s_p,\, s_n}{\text{Maximize}} \quad V_p(s_p) - C_p(s_p) + V_n(s_n) - C_n(s_n)$$

Problem 2

$$\underset{s_p,\, s_n}{\text{Maximize}} \quad V_p(s_p) - C_p(s_p) + V_n(s_n) - C_n(s_n) + V_i(s_p,s_n) - C_g(s_p,s_n)$$

Problem 3

$$\underset{s_i}{\text{Maximize}} \quad V_p(s_i) + V_n(s_i) + V_i(s_i) - C_i(s_i)$$

In all of these problems, it is assumed that two related problems have already been solved: how to price services in each case, and how to identify the cost-minimizing technology for any given set of standards. Because of uncertainties concerning costs and demand, and due to inherent incentive problems associated with utility regulation, these are unrealistic assumptions. Their implications will be explored after the basic conceptual model is presented. In each model the costs represent the combined costs of the public network, the costs to suppliers of information services, and the costs customers incur in acquiring the necessary equipment to make use of the services which are provided, including any switching costs that would be required if a change in standards made existing equipment incompatible with the "plain" network.

The solution to Problem 1 is the set of standards that would provide the best specialized, non-interconnected networks. In general, these standards would not be the same as the best standards for Problem 2. The reason is that the standards derived in Problem 1 will not necessarily maximize the net value of the two networks when the creation of new services by integration through a gateway is taken into account; hence a trade-off must be made between the separated uses (the maximand in Problem 1) and the net value of integration ($V_i - C_g$ in Problem 2). A key point about standardization is that it *always* involves some compromise among conflicting performance objectives. Thus, if the separate networks are designed with gateway interconnection in mind, users of the separate services might be required to suffer some loss of service value and/or increase in cost in order to capture the gains of interconnection.

Likewise, in contemplating a completely integrated network both separate services must be provided using the same technical configuration of the network. Total integration will yield benefits to the extent it reduces the costs of all services and/or enhances the value of integration; however, integration can reduce the values of the two separate services. In addition, integration can result in higher costs than the costs of the two separate networks (perhaps $C_i(s_i^3)$ exceeds $C_p(s_p^1) + C_n(s_n^1)$, where superscripts refer to the optimal standards for the corresponding problems). Similarly, an integrated network is superior to separate networks with a gateway only if the lost value in the separate services is offset by increased value and/or lower costs in integration. That is, V_p and V_n are likely to be somewhat lower in the solution to Problem 3 than they are in the solutions to Problems 1 and 2 because the standard will be a compromise between the two. But achieving integration through a single network may produce greater incremental value in V_i and/or lower total system costs; for example, $C_i(s_i^3)$ may be less than:

$$C_p(s_p^2) + C_n(s_n^2) + C_g(s_p^2, s_n^2).$$

The preceding formulation of the problem of choosing the best configuration for a national telecommunications system suggests several key questions for policy makers:

- What are the comparative costs of providing interconnection through gateways or through a single compatible network?

- To what extent does designing separate systems to facilitate their interconnection, or designing an integrated system, detract from the value of the services that might otherwise be provided separately?

- What values will emerge from interconnection and how do they differ between interconnection through gateways as compared to provision in an integrated network?

The first question addresses traditional issues concerning the nature of costs in telecommunications services, to what extent are there economies of scale and scope in telecommunications services? Economies of scale arise when an increase in aggregate use of the network causes a less than proportionate increase in total costs. Economies of scope arise when the combined costs of production of two or more goods produces lower costs than their separate production.[2] In principle, network integration could have economies or diseconomies of either type; in practice, as we argue in the next section, the primary practical issue is whether integration may have important diseconomies of scope that might offset economies of scale in transmission.

The second and third questions raise an issue on the demand side that parallels the issue of economies of scope on the cost side. The second question pertains to diseconomies of service integration that could be a form of "communications pollution" —a reduction in the value of one activity because it is supplied jointly with another. The third question refers to an opposite, beneficial effect, arising from the ability to derive additional value from combining service capabilities. Because no felicitous phrase for these kinds of effects has yet been proposed we will refer to these, too, as economies or diseconomies of scope; however, this is a departure from the conventional use of this concept which is normally restricted to effects on costs of production arising from integrated supply.

The simple conceptual model represented in the three problems does not take into account several additional complexities. One is the relationship between the solution to the design problem and the ownership structure of the industry. The first problem posits a separate private network plus a public network, neither of which is connected to the other. Separation of ownership means that the operators of each network would be making decisions that affected only their own costs and benefits. The second problem raises an important policy issue about the choice of the separate standards. Each network's configuration will affect the costs and benefits of the other network. There is no reason to believe that the operators of either separate network would take adequate account of the effect of their choices on the other system. Moreover, to the extent that the services offered by each were to be in some degree competitive, each network would have an incentive to disadvantage customers of the other who sought interconnection with it. Hence, Problem 2 raises the issue of how standards coordination and gateway investments would come about.

Another important issue that is not part of the three problems is the extent of investments that will be part of a network, compared to the part that will be made by service providers and customers. Each problem presumes that cost-minimization is the objective. This will not necessarily be the case if the standards for a network can be manipulated to provide market power to any of the three types of participants (network owner, service supplier, customer). For ISDN, an important example of this issue is the problem of deciding how much intelligence to build into the public network, versus how much should be left to users or service suppliers.

Another real-world problem is that all of the components of the three models are not known and some are subject to considerable uncertainty. The feasible range of capabilities for a telecommunications network is constantly changing in unpredictable ways, so that the issue of selecting the optimal number and design of networks, and their degree of interconnectedness and compatibility, is a continuing problem of adaptation to new information, and evolution from one set of configurations and standards to another. In this circumstance, any policy decision today will affect the benefits and costs of the policy options which will emerge in the future. Because today's policy decisions can foreclose valuable alternatives tomorrow, two additional policy strategies ought to be considered. One is built-in flexibility: to place some value on policy choices that do not foreclose future options. Standards choices, in particular, tend to risk foreclosing valuable options that may be unanticipated even a few years before they emerge.[3] In general, standards offer relatively high short-term benefits by contributing to compatibility, but they risk the creation of an insurmountable cost barrier when a superior technical configuration appears. In periods of rapid technological change, premature standardization is a serious risk that deserves detailed consideration. The second commendable policy strategy in periods of rapid change is to invest in more information to reduce uncertainties regarding policy decisions. Specifically, it makes sense to monitor the details of costs, demand, and service quality carefully when the underlying technical and economic facts are changing rapidly.

Application of the Conceptual Model

In one respect, telecommunications technology is evolving in ways that favor an integrated system. Digital transmission has several advantages over analog transmission and would be the preferred technology even for a network that provided only voice communications.[4] Furthermore, telecommunications utilities already use fiber optic transmission for high-capacity links in their networks. The policy issue is whether digitalization and ultimately, fiber optic transmission, should be extended all the way to the end user. This is often referred to as the "last mile"problem.

In reality, the term "last mile" is easily misinterpreted. In the near future, given current trends in fiber optic costs, it is more an issue of the last few hundred yards.[5] Even so, far more is at stake than the technical characteristics of end user connections. Expanded ISDN capabilities will require significant changes in the capabilities of the entire network.[6] Moreover, although the policy choice is not all-or-nothing conversion of end user connections, enhanced ISDN capabilities have an important all-or-nothing feature. Unless ISDN is to be made available only to Centrex customers, a large part of the public network will have to be substantially upgraded, even if only some areas or customers want to use the new services and enhanced features that will be made feasible by ISDN.

Ultimately, the choice between a single public B-ISDN and separated, specialized, incompatible networks turns on the extent of long-run economies of scale and scope in telecommunications and on the cost of gateways to connect incompatible systems. A single ISDN system is superior if: the total demand for all types of services does not exhaust scale economies; if the full range of information services does not require substantial extra expenditures to accommodate them on the same network; and if gateways for connecting separate networks are relatively costly. The first N-ISDN standards, because they do not support some services already provided over private networks, do not represent a commitment to a single ISDN system. Indeed, by resolving technical uncertainties about the capabilities of the public network, they will encourage third parties to develop new gateway technologies to enhance the value of the separated networks. But B-ISDN is more likely to represent a commitment to one network. The construction of a public B-ISDN system should reflect the judgment that economies of scale and scope favor the joint provision of all, or nearly all services through the same access and switching system. In this sense, a complete commitment to ISDN is inherently centralizing in that it implies some degree of natural monopoly in the telecommunications system.

For LECs to implement B-ISDN requires providing each user with a dedicated access line of very high capacity, most likely by running a fiber optic loop almost all the way to the end user.[7] Will most users have sufficient demand for broadband services to justify the fixed costs of a dedicated high-capacity drop? Most of the debate about the desirability of early commitment to B-ISDN has focused on whether most customers of the public network are likely to have sufficient demand for new B-ISDN services to make this investment worthwhile.[8] Of course, this is an important issue. We will not enter into this debate here but our silence should not be construed as dismissing the issue. Instead, because it has received less attention, we focus on whether full integration of the network is technologically attractive, especially to small users who might not want to take advantage of the new features and services.

As discussed above, the integration of all services into a single network requires compromises and trade-offs between services, thereby increasing the costs of some services. These product-specific diseconomies of scope are evident even in the first set of N-ISDN standards.[9] The N-ISDN standard for basic access specifies the type of connection that will be used by the typical small customer (either small business or residential household). This connection is comprised of three channels, and is known as the "2B+D" access line. The B, or bearer, channels will carry digitalized voice conversations and most data traffic. The B standard has a bandwidth of 64 kbps and was designed to be compatible with the digital equipment already installed in telecommunications networks.[10]

One manifestation of diseconomies of integration is in the transmission costs of implementing the B channel standard. The desire to maintain backward compatibility precluded exploiting the latest digital voice technology and achieving greater bandwidth economies.[11] The B channel has more transmission capacity than is necessary for most of its uses, and hence does not fully exploit the capabilities of the sunk investment in the local loop. Not only is this the simplest form of access but it biases future decisions in favor of B-ISDN by reducing the value of existing investments in the local loop. Furthermore, it creates compatibility problems for private networks which deploy more advanced technology. This, too, biases future choices in favor of B-ISDN by limiting the extent to which N-ISDN can be used to exploit integration benefits through gateways. With respect to data traffic, the problems of the 64 kbps B channel are more pronounced. It offers much more capacity than is needed to support the usual slate of switched data services, including credit card authorizations, alarm monitoring, and text-oriented remote terminal-to-host computer connections. On the other hand, 64 kbps is insufficient to support activities that make full use of the capabilities of most personal computers. The reason for this is a key feature of data-related activities: data traffic is typically much more diverse than voice traffic and hence no single data speed is optimal for all types of traffic. The 64 kbps standard is a compromise that provides too much capacity for voice and most switched data traffic, but not enough for computer-to-computer peer communications. The latter will require the adoption of another set of standards that will permit faster transmission.

A potentially important factor affecting the cost of voice and data integration is the different technical demands that voice and data place on the switching capabilities of the network. Voice communications require relatively little transmission of information, more or less continuously, while a circuit connection is active. Voice transmission is tolerant of errors (noise on the line) but intolerant of transmission delays. Switched data traffic typically involves short bursts of information interspersed with long periods of silence. It is intolerant of error but is not sensitive to short delays. The latter is due in part to the inherent "burstiness" of switched data traffic, and also a result of the typical uses of data transmission. Making a terminal operator wait a few seconds for a file transfer to finish is less of a problem than delaying a telephone call. The two types of transmissions place different demands on the telecommunications network. As a result, adding data transmission to the voice network changes the nature of the demands that are placed on switches.

For voice transmission, a switch must interpret instructions about the destination of the transmission and then establish and maintain a connection during the duration of the conversation. Because voice conversations last a long time (from a computer's perspective) and require relatively limited monitoring once the connection is established (because an occasional transmission error is easily tolerated), the primary work of the switch is to set up the end-to-end circuit, to terminate the connection at the end of the call, and perhaps to measure its duration for billing purposes.

Switched data traffic is often of shorter duration, or bursty enough so that it is inefficient to maintain a circuit connection for the duration of a call. Consequently, packet switching, where the network routes each burst or packet of information separately, is likely to be more economical, because it only ties up transmission resources when sending data. Furthermore, because data traffic is relatively intolerant of errors, it may require more transmission monitoring during the call. Finally, many of the new information services that will justify the demand for ISDN are likely to require some processing of data in the public network, and probably in the central office switch. Thus, public switches will serve as gateways between customers and service providers even if both are ISDN-compatible.

The enhanced features anticipated to be offered with N-ISDN will cause the original setup and termination tasks to be more complicated. Added complexity is likely to result in greater demands being placed on the central processor of a switch. If a switch is to be used for all purposes, it must have more elaborate capabilities for maintaining connections and continuity of information flow than is necessary for data services, and more complex central processing and more accurate data transmission than is necessary for voice communication.

The extent to which diseconomies of integration in switches will become more important as B-ISDN is implemented remains unknown. The broadband channels in B-ISDN cannot be switched by any existing switch. Switches which can handle the data speeds achievable with fiber optics are still being designed.[12] Consequently, whether the implementation of B-ISDN will exacerbate the cost penalty associated with switching on an integrated network remains uncertain.

Another potential source of costs to small users arises from the necessity for LECs to develop advanced signaling systems to accommodate faster, more complex data transmission. Recall that ISDN has two objectives: to accommodate a wide range of services using high-speed digital transmission and to permit software control of access to network capabilities by users. Achieving these objectives requires more than hardware; it requires substantially more complex software for recognizing and interpreting the user's instructions about what is to be done with the data flow that is about to arrive. A signaling system is a convention for communicating how information flow is to be handled — where it is supposed to go, how it is supposed to get there, and what is going to be done to it along the way.

The software necessary to implement signaling systems that would make use of current N-ISDN standards and capabilities remains to be completed, so that its impact on the efficiency of the operation of the network for traditional communications services is unknown.[13] Advanced signaling systems will be installed even without N-ISDN to exploit the opportunities presented by digitalization of the public network. Digitalization can reduce the costs of advanced signaling systems which can perform more elaborate routing and thereby increase the utilization of transmission facilities. The potential diseconomy of scope for small users due to N-ISDN is that additional complexity will bring added errors in making and maintaining connections for all services, not just the ones requiring the more advanced signaling systems that ISDN will require. In the short term, new software is certain to contain coding errors and will thus impose transition costs. In addition, modification of the network hardware and software will be required to take advantage of the capabilities of proposed signaling systems. These enhancements will add capabilities that provide no benefits to users who want only conventional services. This source of diseconomies to small users from network integration will be permanent, rather than transitional.[14]

Another example of a potential diseconomy of integration for small users can be inferred from the development of the standards for N-ISDN line codes, which were adopted in the spring of 1988. The line code standards refer to the electronic characteristics of digital transmissions over the local loop. The specific line code scheme affects the performance characteristics of transmission, such as the distance over which the signal can be transmitted without retransmission equipment. The standards that were adopted in 1988 have not yet been implemented, but they are expected to be more expensive to implement than the experimental N-ISDN line codes which the LECs have been using.[15] The new standards are intended to overcome problems of interference and signal loss which were encountered in earlier experiments. These problems, in turn, arise primarily because of the additional transmission quality that is needed to provide N-ISDN data services over existing local loops. For small users who do not make use of these N-ISDN capabilities, the additional transmission costs will be another diseconomy.

Implementation of ISDN not only increases the sophistication of the local network, it also increases the technical demands that will be placed on maintenance personnel who will be called upon to keep it running. Checking out the source of problems in a voice-grade connection (analog or digital) is relatively simple compared to trouble shooting an ISDN network where far more things can go wrong. The difficulty increases geometrically with the range of capabilities offered over the network. As the network becomes more complex, more advanced testing equipment and procedures will have to be implemented, and more skilled technicians will have to be employed as line maintenance and installation personnel. The vision of ubiquity and software control, where any access line can be used for any purpose, implies that ordinary users will be required to bear the costs of more expensive maintenance.[16]

Another example of a diseconomy of integration for small users takes the form of services that may be cancelled (or continued only at unreasonably high costs) if ubiquitous ISDN is adopted. The most widely discussed example is the so-called "power problem" in fully fiber optic B-ISDN. The existing network carries enough electric power to operate simple customer terminal equipment, such as ordinary telephones. When a customer's electricity supply fails the telephone still works. The least-cost deployment of B-ISDN which involves the replacement of copper wire by fiber optic transmission would eliminate the power supply on the network, thereby leaving users to supply electricity, presumably from the current provided from an electric utility. Of course, the telephone network is powered by electricity, so that copper wire connections could be maintained to supply power to end users. To do so, however, vitiates some of the cost-advantages of optical fiber (reduced corrosion maintenance, duct space reduction, etc.). It also imposes unnecessary costs on users who will normally supply their own power, such as those who use ISDN capability to connect computers or other advanced electronics equipment to the network. Indeed, if copper wire connections are maintained for power, they may as well be used for the kinds of services small users now demand; and if this transpires, the case for LEC ownership of the B-ISDN fiber network becomes problematic, for the fiber and copper networks would be separated (with separate switches) in any case.

A less noted problem for small users is that ISDN is incompatible with the simultaneous use of extension telephones, at least in their present form. When voice communications are transmitted digitally, the input from two telephone instruments cannot be transmitted over the same connection without adding additional electronics to the user's internal wiring or connection to the local network. Hence, simultaneous operation of more than one telephone requires that each has a separate connection to the local network and that the customer use an advanced conference calling service. Grandma and Grandpa will not be able to talk simultaneously to the grand kids on Christmas without either paying for conference calling, or purchasing their own mini-PBX.[17]

ISDN will also require either abandonment of analog terminal equipment or new investment to maintain its usefulness. In general, small users who wish to maintain existing customer premises equipment will need to have an interconnect device to use the ISDN network. The device can be either of two types. The first is a hybrid local network, wherein each subscriber decides whether to be an ISDN or an ordinary subscriber, and the interconnection electronics is in a switch in the local network. The other option is a totally digital network which requires an interface device at or near the customer in order to permit the use of analog or other non-ISDN equipment. In the present analog network, the ordinary user simply connects to the telephone company's termination device without the use of additional conversion electronics. The hybrid network preserves this option, but at a higher cost than would be required if all communications on the network were standardized and switches did not have the capability to receive and send analog communications, and to connect analog and digital customers.

If all network terminations at the customer's point of use were ISDN compatible, a terminal converter would be required to translate the analog message from the telephone to a digital message compatible with the local telephone network. Present FCC rules would prohibit LECs from incorporating this interface into the LEC-owned local network. The FCC could relax the current termination requirement, but this would simply reallocate the first-order assignment of the cost burden from the user to the telephone company. Someone eventually would bear this cost — a cost that is a direct consequence of trying to develop a digital network in the presence of a massive stock of incompatible customer premises equipment.[18]

The last example of a potential diseconomy of integration for small users has to do with the security of information transmitted over the public network. The security problem has three dimensions. One is security against eavesdropping, or the unauthorized and undesirable reception by a third party of transmitted information. The second is information burglary, or using the network to access valuable stored information without approval. The third is data vandalism, whereby valuable information is damaged by the insertion of useless or harmful information.[19]

Only the first security problem arises in voice communication, and even here the network is not designed to provide much protection against intruders. Indeed, it is not even designed to avoid intermittent eavesdropping which arises from problems related to connection and transmission.

Data transmission security varies depending on the extent to which that security is valued. In some cases its value is very high, such as in networks for automatic teller machines and other means of electronic funds transfer. Advanced information services are likely to have demanding security requirements because they will entail the use of valuable software and/or data resources. The market value of information services derives from the capabilities made possible by their software and data. Security against unauthorized access will have a very high value to providers of advanced services.

The extent and cost of securing the telecommunications network depends on its technology and on the sophistication of its hardware and software. One advantage of B-ISDN is that it lowers the costs of information security. High-speed digital transmission more easily accommodates encryption technology, and fiber optic cables are more difficult to tap without detection. Ubiquity of ISDN with software control implies that added security will be a feature of every access line. Providing a measure of security for all uses, including voice communications in which it has low value, constitutes a source of diseconomies of integration for small users.

Related to the issue of security is the question of reliability. The value of enhanced information services will depend on the extent to which they can be reliably integrated into the day-to-day operations of the user. A corporation may be unwilling to commit all of its traffic to a single B-ISDN fiber access line for fear of experiencing a costly delay in business activities should that channel fail. Under current arrangements, each large building is connected to a central office over a number of different cables, so that a single sewer rat cannot chew through the entire communications umbilical in one meal. One manifestation of the value of diversity is the fact that most Fortune 500 corporations obtain long distance services from more than one IEC to avoid being too dependent on a single supplier.

To repeat a prior caution, the preceding examples of diseconomies of integration do not constitute a case for pursuing the strategy of separate networks for advanced services. They do not demonstrate that any form of ISDN has global diseconomies of scope. Other benefits of integration to customers who will not confine their use of the network to the kinds of simple services that are already available on the public network could offset these costs. Whether this will happen depends on the nature of the hardware and software that remains to be developed and on the value to customers of services that do not yet exist. It also depends on the magnitude of the penalties in costs and capabilities that would be imposed if B-ISDN technology were implemented on a separate public network — or even on a large number of separate private networks.

Demand Considerations

The hypothesis maintained in the preceding discussion is that large numbers of customers will continue to demand only the voice and simple data services that do not benefit from ISDN. This assumption may not be true. The long-run desirability of ISDN depends on whether new services will be developed which make use of the new capabilities of the network and whether customers will want to purchase them at a price sufficient to cover their costs. From the perspective of the small user, the existing network can provide a wide array of services without implementing even N-ISDN.[20] The vast majority of residential users make no use of them, for they do not own the terminal equipment that would make them accessible. For the most part, existing on-line information services are relatively expensive and do not attract many residential or small business customers. They tend to be designed for, and marketed to, large organizations such as corporations, universities, and government agencies. Small business users do employ some of these services, notably credit card authorizations, but are not yet a major source of demand for data services. Moreover, the kinds of services used by small businesses can easily be provided without implementing N-ISDN technology. In any event, virtually all of the traffic (99%) carried on the public telephone network is ordinary telephone calls. The implementation of B-ISDN would dramatically increase the range of capabilities available and reduce the costs of others that are available now; however, it is difficult to visualize exactly what small users would want that would be sufficiently valuable to override the diseconomies of integration described above given the overriding importance of ordinary voice communications.

In undertaking the exercise of conceptualizing demand-based rationales for B-ISDN, the common starting point is the dual system which is available today: ordinary telephone access (which can be used for some information services as well) and one-way video distribution through cable television. This baseline is more appropriate for residences than small businesses, for about half of residences subscribe to cable television, whereas few businesses receive it because it has not yet offered much in the way of useful business services. B-ISDN has to find a combination of price and capabilities that beats this baseline.

The principal advantage of B-ISDN is the capability to develop services which require very high data transmission rates and two-way point-to-point distribution. For most small users, the only plausible use for this capacity is transmitting high-quality motion color video: on-demand high-definition entertainment programs, two-way color video telephony, and interactive services such as home shopping involving motion video display of merchandise, and electronic purchase.[21] One can debate the likelihood that customers will want these capabilities, but resolution of the issue will require implementation.

The Role of Experimentation

One cannot resolve the issues of cost and demand without attempting to deploy ISDN; yet full deployment risks committing to the wrong technology or stacking the deck in favor of a ubiquitous monopoly in telecommunications. The obvious resolution of this dilemma is to conduct tests of existing N-ISDN standards that are specifically designed to determine whether voice and data integration makes economic sense.

To date, several ISDN tests have been undertaken but these have been narrow and technical in nature, and are not what we are proposing here. We propose more than a technical test of whether ISDN hardware and software works and how it performs. One point of the test would be to resolve questions about the details of economies of scale and scope. Permitting experimentation should mean more than simply letting LECs begin to deploy N-ISDN to resolve technical problems in meeting standards. Instead, it requires careful monitoring by regulators in an open, public process. Regulators will have to develop far more detailed means for measuring service-specific costs, demand, and performance characteristics of the network than they have used in the past. The results would have to be made available in an open forum that invites comparisons with other alternatives. Standard practice in many states is for the details of costs and use of the telephone networks to be treated as confidential information which can have only limited use by anyone other than regulators and telephone company personnel. Strict confidentiality is a controversial policy in all regulatory issues; it is especially undesirable if a comprehensive, objective assessment of ISDN is to be undertaken. Only by relaxing these restrictions will all states share in the information generated by each experiment and will objective analysis be assured.

The prospects for useful demand experiments are less bright than for collecting useful data about the costs and performance of the backbone network. New services will have fixed development costs, regardless of whether they are offered in few or many markets. An ISDN service experiment provides a limited opportunity for early recovery of these fixed costs. Nevertheless, an experiment can provide useful data on the extent to which users will want to make use of enhanced information capabilities, and may induce some service experiments. From the perspective of small users, switched two-way color video is the only service thus far proposed that will require B-ISDN. If N-ISDN does not usher in new services for residential and small business customers, the likelihood that B-ISDN will do so is remote. Hence, N-ISDN experiments can reduce much of the uncertainty about the effects of ISDN on small users.

Because local telephone companies have already made extensive investments in making local exchanges N-ISDN compatible, the incremental cost of collecting more information about costs, performance, and demand is not very high. Specifically, providing N-ISDN capability in some urban exchanges will require a modest investment to upgrade local loops and switches and a somewhat more than modest investment in interface devices and gateways that make existing terminal equipment compatible with the new system.[22] To proceed with experimental implementation of the first generation of N-ISDN standards will not be particularly costly and will provide useful information about possible future uses of ISDN. Regulators will have to come to grips with how the costs of implementation should be shared among LECs, users of new services, and the remaining customers of the LEC, an issue which we will not address here.

Downside Risks of Delayed Commitment

A period of experimentation amounts to a delay in the decision about full deployment of N-ISDN. Some have argued that delay will be unacceptably costly. Delay does involve risks, but it also provides benefits that more than offset these risks. The policy alternatives to limited experimentation are: to place serious restrictions on ISDN development by LECs; to commit to the comprehensive deployment of N-ISDN capabilities; or to leap to B-ISDN standards. The argument against complete denial is that experiments will be relatively inexpensive and may provide valuable information. The argument against a deeper commitment to extensive N-ISDN or even B-ISDN commitment is that because technical and economic uncertainty is high, a strategy which emphasizes retaining flexibility and gathering more data promises greater long-term benefit.

The argument for early commitment and deployment of ISDN is based on the risks of delay. In fact, delay could prove to be costly in two ways.

By failing to provide ISDN capability as fast as possible, large-scale users of information services will continue to construct private networks which utilize the most advanced capabilities. Once these costs are sunk, LECs may be unable to induce these users to return to the public network. This would limit their ability to capture scale economies and thereby to offer low enough unit costs of capacity so that new services can be developed at an attractive price to the consumer.

The importance of this problem depends on a comparison between the likely useful life of an investment in a private network and the amount of time that is likely to pass before the public network can be reconfigured so that B-ISDN (and the new services it will bring) can be made available. Because the details of B-ISDN deployment have yet to be developed and many of the network components that it will require have yet to be invented, widespread implementation of B-ISDN seems far off under the best of circumstances. This suggests that it is too early to commit to an integrated system. Moreover, given the compromises necessary to implement N-ISDN, it seems likely that it is too early to sacrifice further exploration on the part of private users in optimizing their own systems.

The second possible risk of delay is that others will commit to B-ISDN, and once this commitment is made, jump ahead in the technologies for implementing or using it. These others can be either other localities (from the perspective of a state regulator) or other nations. The essence of this argument is not that B-ISDN, as we might now conceive it, is the dominant technology of the future, but that even if it is not, the country or locality which deploys it first will have a significant first-mover advantage. In the presence of substantial technological uncertainty, early commitment to implementation is only justified if an early choice of technology, even a mistaken one, confers substantial, enduring advantages.

The history of the microelectronics and computer industries is not consistent with the view that first-mover advantages are of overwhelming importance. IBM was a relative latecomer in the computer industry, and the semiconductor industry has proven to be one in which firms rarely enjoy large, stable market shares for more than a few years.[23] None of the original providers of automatic teller machines are in the industry fifteen years later.[24] Moreover, large, high-technology firms in the U.S. are not without access to advanced telecommunications systems, largely because the U.S. has permitted a diverse array of private networks to be constructed.

The primary problem associated with delaying B-ISDN would appear to be that it might excessively concentrate some communications-intensive domestic industries because only large firms find private networks to be economically attractive.[25]

The case for further experimentation is based on an analysis of the underlying technical and economic uncertainties inherent in ISDN technology. However, our analysis has not yet taken into account how the fact that LECs are regulated might affect the attractiveness of these options. Both N-ISDN and especially B-ISDN entail a greater commitment to a line of technical development that moves the nation towards ubiquitous regulated monopoly for all telecommunications services — or virtually all — for the indefinite future. Consequently, ISDN is likely to require a greater scope for regulation than would the alternative of separate networks providing different methods for access to information services. A complete analysis requires an examination of the additional problems associated with a choice between more and less long-term regulation.

4. Utility Regulation and ISDN Deployment

Regulation necessarily converts the decision to adopt a new technology from a technical and economic issue to a political one. There are two reasons why this occurs. First, inherent in any monopoly is the potential for substantial excess profits as well as the opportunity to use technical choices to allocate advantages among users of the monopolist's services. This potential for allocating distributive gains gives rise to a political competition between the monopolist and its customers to divide the benefits of the technology.[26] Second, the very presence of regulation distorts the technical choices made by a regulated firm. The firm will not be led by the incentives it faces to make efficient technological choices, but instead will have an incentive to use technology as a strategic weapon against competitors, customers and regulators. Even if regulators could avoid distorting prices and the direction of evolution of the regulated firm owing to the first factor, they would still create distortions in the evolution of technology owing to the second.

Interpreted within the context of B-ISDN, these two considerations give rise to the following concerns.

First, B-ISDN might be efficient, at least in the sense that it would be economically attractive, if it could be adopted without the distorting influences of regulation. However, it might also cause a redistribution of the benefits of the telecommunications network so that some of its users would be made worse off by its adoption. If this occurs, residential and small business subscribers are likely to be the losers.

As explained in the preceding section, B-ISDN is likely to have product-specific diseconomies of scope that will prove costly to small users. Moreover, users of sophisticated information services have sufficient demand for telecommunications that they have reasonable alternatives available to them should the public network become excessively expensive or should the quality of its services become unacceptably low. Large users need only remain connected to the public network for the purpose of remaining accessible to users of plain telephone service. This can be done through a gateway to the public network that is not used for all other services.[27] This combination of events would prevent local telephone companies from charging users of sophisticated services much more than the costs of these services; if they tried to do so, the large users would switch to another network. This in turn might force the LECs to charge ordinary telephone subscribers more than the cost of plain vanilla service on the B-ISDN system. Indeed, if the technology really has these properties, such a pricing response would be economically efficient.[28] Yet it might also be politically unacceptable because of its distributional consequences. The end result could be: B-ISDN is not constructed; or competitive networks are not permitted or are otherwise restricted in use and capabilities so that LECs can succeed in charging large users enough to offset losses on ordinary telephone service.[29] The latter may be the best choice among those which are acceptable to small users. But investors in existing alternative networks and their customers are likely to fight against any proposal to shut them down or limit their uses so that the LECs can increase the prices of the very services that these alternative networks provide. Moreover, to make such a decision, regulators must have sufficient information to conclude that a ubiquitous monopoly is the optimal economic structure for the industry.

The second policy concern is that LECs will want to adopt B-ISDN even if it is economically inefficient. This possibility is widely discussed, but its full scope is not generally appreciated. Most of the discussion has focused on the incentives facing firms which are subject to rate-of-return regulation, which calculates the allowed profit of a firm as an estimate of the firm's cost of financial capital multiplied by the current book value of its investments. If the prices resulting from rate-of-return regulation constrain a firm's profits, the firm has two undesirable incentives: to engage in excessive substitution of capital for other inputs (because it only earns profits on capital investments); and to cross-subsidize markets that it would otherwise lose (because the loss of sales would reduce its need for capital investments).[30] These twin issues give rise to the concern that LECs will provide competitive enhanced services at prices that do not recover their costs, and recoup the loss in higher prices to users who have no alternative forms of access and who have highly inelastic demand for ordinary telephone service.[31]

Some of the characteristics of ISDN which were summarized in the preceding section are consistent with the overcapitalization hypothesis. Specifically, ISDN entails increased capital costs per subscriber (e.g., investment in switches and software), against a prospect of insufficient service demand to recover them. Rate-of-return regulation encourages LECs to take such risks. Should the new technology prove to have too little demand to justify the incremental cost of developing and deploying it, firms would have the prospect of recovering at least some of these costs from ordinary ratepayers. Small users stand to bear some fraction of the risk, even those who will never use the enhanced services and who, therefore, stand no chance to benefit.

The traditional solutions to the overcapitalization and cross-subsidization problems are separation of monopoly and competitive services, and alternatives to rate-of-return regulation for setting prices.[32] Separation, whether structural or via accounting practices, is a means for assuring that one category of services does not subsidize the other.[33] The most commonly recommended alternative method for setting prices is price caps, whereby the combined effect of all price changes must not exceed some specified price index. Under a permanent price cap, where the price index does not depend on future costs or demand, a utility has no incentive to adopt a long-run pricing strategy in which one of its products is priced below its marginal cost of production.

Price cap regulation and accounting and/or structural separations are potentially useful tools for improving the performance of regulated firms. They are especially useful during a relatively protracted period of transition from regulated monopoly to competition. But they only partially ameliorate, and do not solve, the problem of inefficient investment and service provision by regulated firms. There are three reasons why this is so.[34]

First, the rapidly changing technology in telecommunications is likely to make any given set of regulatory rules obsolete within a short time. A price cap formula is certain to require periodic adjustment in order to take into account new services or to prevent the firm from either going bankrupt or capturing ever-increasing monopoly profits. No method for making these adjustments has yet been discovered which does not distort the investment incentives of the regulated firm. Likewise, the boundary between competitive and monopoly services is not only likely to shift over time, but will depend in part on the R&D decisions and technology choices of the firm. The character of the separate subsidiaries is likely to change, and to respond to a regulated firm's R&D strategies, thereby serving to distort the rate and direction of technical change.

Second, neither price caps nor separations deal with the strategic use of prices as a means of retarding entry or encouraging cooperative behavior among competitors. The attractive properties of price caps and separations apply to situations in which the structure of the market and the behavior of the firms in it have already been determined. Even with separation and price caps, firms can use prices to facilitate collusion or to discourage entry. Moreover, when the price cap does constrain a firm's profits, price cap regulation can actually increase the incentive of a firm to engage in such behavior.

Third, neither price caps nor separations alter a regulated firm's incentive to use its monopoly in one part of the network to provide leverage in competitive arenas through means other than pricing. Non-price strategies against competitors were the most important component of the government's antitrust case against AT&T. These included: discriminatory provision of access which raised the costs and lowered the quality of rivals' services; misrepresentation of the requirements and problems associated with accommodating competitors; and the use of R&D and technology choice as a means to foreclose entry.[35]

The vision of B-ISDN shared by LECs and their regulators could have features that are consistent with a strategy of uneconomic entry-foreclosing investments. These are:

- Precommitment to excess capacity in advance of warranted demand.

- Precommitment to a technology which moves the cost structure of the industry towards higher fixed costs and lower variable costs of service, which in turn precommits the regulated firm to lower prices should competition emerge.

- Adoption of a more complex, and hence less transparent technology, which enhances the advantages of the owner of the backbone network.

- Precommitment to a massive R&D program which promises to be a source of rapid and unpredictable change in the operating characteristics of the network, thereby serving to increase the risks of competitors who must adapt to technological changes imposed by the LEC.

As long as B-ISDN is not too costly, it will have these strategic values for LECs, even if integration is inefficient or demand is insufficient to justify the full array of B-ISDN capabilities.

The most direct consequence of unwarranted strategic investment in B-ISDN is not its damaging effect on small users; it is that costs and prices will be unnecessarily high for the enhanced services. The principal threats to residences and small business are: first, some of the product-specific diseconomies of scope discussed above; and second, the long-run possibility that, should ISDN investments prove uneconomic because too few new services are demanded, small users will be called upon to bail out the LECs.

Thus far, advocates of ISDN have offered two additional types of policies to protect against uneconomic, strategic uses of B-ISDN. One is the threat of antitrust action should the LECs misbehave, the other, Open Network Architecture (ONA), or a requirement that the technical characteristics of the public network be transparent to competitors, thereby facilitating competition against LEC services.[36] Perhaps these are effective safeguards but the issue remains uncertain. Strategic deployment of technology, urged on by regulators cheering on the sidelines, will be very difficult to sustain as an antitrust complaint, especially during a period when costs are unknown, demand is unknown, and service characteristics are changing rapidly. Even in the best of circumstances one would expect the telecommunications services industry, like microelectronics, computers, and computer services, to have a relatively high casualty rate among entering firms. Proving a damaging anticompetitive act will be difficult. Meanwhile, ONA remains a policy objective rather than a concrete set of requirements and standards regarding the public network. It may be practically impossible to implement even with the best of intentions because of the complexity of the software that will be required by B-ISDN and the rapid evolution of the telecommunications network as more and more ISDN standards are adopted.

The most effective safeguard for all types of LEC subscribers is a reasonable alternative means of access. Competitive access and private network alternatives have succeeded in constraining the prices that LECs charge to large users — indeed, they may well have caused some LEC prices to be too low. Likewise, the best safeguard for small users would be some alternative form of access.

For the vast majority of small users there are no practical access alternatives today to the LEC. Regulatory policy has worked to constrain those alternatives that are available and that have any hope of emerging as a serious source of competition. A detailed discussion of access alternatives for small users is beyond the scope of this paper but a few examples will illustrate how their development is precluded by regulatory policy.

One possibility is cellular radio which is now used solely for mobile telephone services. The FCC has created two cellular companies in each metropolitan area and given at least one of the two licenses to the local carrier. While two carriers are better than one, competition is better served by three or four. Moreover, allocation of the licenses to LECs mitigates against the use of the technology as a competitive form of access. Given the allocation of regulatory responsibility in the 1934 Communications Act, it is not clear how the FCC could use radio technology to compete with ordinary telephone service, nor is it clear whether, if this were permitted, the costs would be low enough to provide an effective cap on LEC telephone prices. Nonetheless, the FCC has not pursued a policy that would encourage this form of competition, even though some advocates of cellular radio believe that it could become a viable access alternative.

Another possibility is shared tenant service. Large users bypass LECs for access to long distance carriers for various kinds of advanced data transmission systems and for intra-organizational local calling by purchasing their own switches (usually a PBX) and arranging for some of their own interconnection lines. Small users could avail themselves of the same opportunity by banding together to form what amounts to their own local telephone company. But in most states this is prohibited by state regulators. Normally shared tenant service is only permitted within the same building; it cannot cross a property line. Whereas there is uncertainty and controversy about the extent to which these prohibitions effectively prevent more extensive use of shared service, nonetheless regulatory rules prevent a market test.[37]

Another example is provided by cable television. Many cities have required cable television systems to provide capacity for some two-way transmissions; however, cable companies have not aggressively pursued ways to make use of this capability. One reason is that states cannot regulate ordinary cable television services, owing to the

Cable Communications Policy Act of 1984; however, they can regulate services that compete with the offerings of LECs. Consequently, cable television companies face the costs of regulation should they attempt to offer such things as alarm monitoring services, let alone ordinary telephone access. Again, the extent to which cable television could offer economically and technically attractive services in competition with LECs is uncertain and controversial, but the debate about the issue has been deprived of practical significance by the omnipresent threat of state regulatory intervention.

The lack of access alternatives for small users has not yet caused them great economic harm. Historically, their vulnerability has not been fully exploited. The long standing regulatory bargain is for government to grant protected monopoly franchises in return for low access prices. This has often produced results that differ from the ones that would be predicted solely by analyzing the incentives of the regulated firm. For example, small users in rural areas receive large subsidies, rather than face exploitive prices.[38] But in this instance history is not a reliable predictor of the future. The emergence of competitive alternatives for large users has reduced substantially the subsidies that can be extracted from them, and consequently single-line access prices have begun to rise, especially for businesses.[39] The lesson in recent developments is that alternative access for small users may be the only possible protection against bearing undue costs from ISDN development.

5. Conclusions

Our reading of the available information about ISDN leaves us with substantial uncertainties about its benefits, costs and distributive effects. We have emphasized the potential problems with premature commitment to an LEC-based integrated digital network not only because the technology has substantial economic risks; there is a non-negligible chance that the deployment of each successive ISDN standard will impose costs on users who seek only relatively simple services. There is also the chance that LECs will want to push ISDN faster and farther than makes economic sense.

In the presence of uncertainties and risks, a strategy designed to gather information while maintaining flexibility regarding future choices is recommended. While we believe that useful information is likely to be obtained from implementing some N-ISDN standards and experimenting with the new services they provide, we also believe that, simultaneously, regulators should encourage technologies that provide alternative means of access for small users. One example would be to remove restrictions against shared tenant services so that neighborhoods and retail sales areas can more easily form their own cooperative access provisions. A second example would be to allocate sufficient spectrum space to create a third cellular telephone service in each metropolitan area; to remove the requirement that cellular licensees who are not LECs use the technology only for mobile service; and to ease restrictions on other forms of radio communications so that they can be used for radio telephone service. Still another would be to permit cable systems to offer the kinds of information services that small users now use — such as alarm monitoring — without subjecting them to extensive state regulation.

Meanwhile, it is time to permit a full-scale experiment in which some local exchanges are made fully N-ISDN capable. The idea would not be to test standards and equipment but to collect economic information that would be relevant for further regulatory decisions. Arrangements will have to be made to assure that small users in the test areas are not inconvenienced by the conversion; however, the expenses involved are not so great that some arrangement among regulators, LECs, and service providers cannot be worked out.

ISDN experiments should be focused on areas where market conditions are most favorable for the successful introduction of new services in order to encourage service providers to participate. Questions concerning the value of building ubiquitous networks can be raised when more information is available as to whether the most likely users of ISDN capabilities will take advantage of them. For the experiment to provide the best information about demand, pricing policy will have to foreswear the long-standing practice of trying to extract excess profits from enhanced services in order to subsidize basic access. The point of the experiment is to collect information, not subsidies for rural telephone users. Likewise, this type of experiment requires setting aside the fear that partial implementation of ISDN will create an informational underclass among those who do not gain access to it. In our view, this concern will be riper after we have some basis for believing that ordinary telephone subscribers actually have something to gain from implementing ISDN in the local public network.

The purpose of the experiment is to collect information and to reduce the risks regulators will face in making decisions about the proper scope and characteristics of the LEC network. To serve this purpose the experiment must be carefully monitored. Traditionally, regulatory authorities have paid scant attention to the details of costs of service in the network and so have not developed accounting methods that would enable them to estimate the incremental cost of a specific service or technical characteristic of the network. An ISDN experiment will be far less valuable to regulators if they do not insist on careful, accurate monitoring of the capital and operating costs of the experiment, and its performance characteristics.

There is a risk that such an experiment might delay deployment of ISDN. Given the presence of extensive private networks and other capabilities already available to large users, this risk does not appear to be particularly great. Early commitment to B-ISDN does not appear to promise much in the way of benefits because implementation is still far in the future, yet it runs the risk of chilling continued innovation in local and metropolitan networks and premature commitment to technical standards that may prove to be undesirable.

As our colleagues Paul David and Edward Steinmueller have asserted, the ISDN bandwagon is here, and we are prepared to step on (not to jump) — as long as the band plays a long, slow waltz.

Notes

We gratefully acknowledge the useful comments and suggestions provided by Tim Bresnahan, Henry Geller, Charles Jackson, and Eli Noam, none of whom necessarily agrees with the arguments presented herein.

1. ISDN is shorthand for Integrated Services Digital Network. We use the term when making general reference to all forms of this technology, B-ISDN when specifically referencing broadband ISDN capabilities, and N-ISDN when discussing narrowband standards such as those which began to be implemented in the late 1980s as a first step towards a more ambitious system.

2. See William Lehr, ISDN —*An Economist's Primer on a New Telecommunications Technology*, Stanford Center for Economic Policy Research, 1989, for a more detailed discussion of the technical assertions regarding ISDN made herein. In subsequent footnotes, this report will be referred to as Lehr's *ISDN Primer*.

3. The key software systems which are required for network management are called Operations Support Systems (OSS). These represent a central feature of future network plans. Such systems do not yet exist so the ultimate cost for OSS software is unknown. For a discussion of the important role to be played by advanced network software, see Richard Snelling, "Southern Bell: On the Road to ISDN," *Telecommunications*, May 1, 1988; or, Jacob Appel, et. al.,"Pacific Bell's Network and Systems Concept for the 90s," *IEEE Selected Areas of Communications*, July, 1988.

4. An example of an interface device is a modem, used for interconnecting a personal computer to the telephone network.

5. Paul A. David and W. Edward Steinmueller, "The ISDN Bandwagon Is Coming — Who Will Be There To Climb Aboard?", Stanford Center for Economic Policy Research, 1988.

6. The digital switches and terminal equipment currently in use for ISDN access generally do not meet these standards, as discussed below.

7. The term is used here in its economic sense; a gateway is "some means...for effectuating...technical connections between distinct production subsystems...in order for them to be used in conjunction, within a larger production system." Paul A. David and Julie Ann Bunn, "The Economics of Gateway Technologies and Network Evolution," *Information Economics and Policy*, 1989. Vol. 3, p. 170. A simple interface device such as a modem is not a gateway because it does not create a new production technology. A gateway makes a distinct contribution to production. One example is a PBX, which connects a local network to the public network but also performs its own functions.

8. For a discussion of the relative benefits of one versus several networks, see Roger G. Noll, "Regulation and Computer Services," in Michael L. Dertouzos and Joel Moses, *The Computer Age*, Cambridge: MIT Press, 1980.

9. For example, most of the older digital transmission facilities use in-band signaling which is incompatible with the clear channel requirements for ISDN. Furthermore, none of the ISDN trials has used the most recently approved line coding scheme. See Lehr's ISDN Primer for more details.

10. See Robert M. Lefkowits, "Myth America: Dispelling Popular Misconceptions About What ISDN Can Do," *Communications Week*, July 25, 1988, p. 17.

11. See Peter Huber, *The Geodesic Network*, Washington: U.S. Department of Justice, 1987, Chapter 2.

12. For a detailed discussion of the development of specialized local networks, see David and Steinmueller, op. cit.

13. For a complete technical development of these concepts, see John Panzar and Robert Willig, "Economies of Scope," *American Economic Review*, Vol. 71, No. 2, May, 1981.

14. A famous example is the highly inefficient QWERTY layout of the typewriter keyboard. See Paul A. David, "Clio and the Economics of QWERTY," *American Economic Review*, Vol. 75, No. 2, May, 1985.

15. Digital voice transmission is better than analog for the following reasons, among others: digital signals travel farther with less distortion; digital signals are easier to switch than analog signals and do not need to be demultiplexed for switching between trunks; and digital retransmission equipment is less complicated and cheaper than comparable analog equipment.

16. Coaxial cable television connections may be adequate for offering B-ISDN over the last few hundred feet. Local area network technologies can presently support 10 Mbps at distances up to 300 feet over twisted pairs.

17. To offer N-ISDN services will require remedying the problem associated with digital facilities that do not support clear channel 64 kbps circuits. To do so will require the replacement of existing multiplexers (equipment that takes a signal and allows it to be packaged with similar signals for bulk transmission across the network). Because B-ISDN standards have not been adopted, we cannot specify how existing fiber in the network will have to be changed. Multimode fiber may have to be replaced, for most analysts expect single-mode fiber to dominate in the future.

18. By offering N-ISDN over existing copper wire, the LECs will increase the effective bandwidth in the existing plant and extend such capacity-based scale economies as currently exist in local access, but they will not fundamentally alter the cost characteristics of the local network. If, however, the LECs install fiber optic local loops, they will almost assuredly create a monopoly in transmission. Once the cable is installed it will be a sunk cost. Fiber optic technology has a high fixed cost and a very low marginal cost of capacity. Even the most optimistic forecasts for B-ISDN service demand do not foresee exhausting the scale economies in a fiber optic local loop. Indeed, for LECs to make their investment cost-effective they will need to capture all of the traffic currently carried by cable television operators and to experience significant additional demand for new (presently non-existent) services. See Lehr's ISDN Primer for a summary of available data on costs.

19. Using non-ISDN standards, LECs could offer black and white video telephony over copper loops. Fiber is needed to offer full color, high quality service. Thus, the cost of going from no video telephony to monochrome video telephony is much less than the cost of going from monochrome to color. See Lehr's *ISDN Primer* for more details.

20. An integrative technology produces *product-specific diseconomies* of scope when one or more service is more expensive than if offered separately. But this does not necessarily make the technology undesirable, for other services may experience offsetting economies of scale and scope due to the new technology.

21. The BRI D channel will have a bandwidth of 16 kbps, and will be used (primarily) for communicating the control signals which are used to set up, monitor and route calls through the network. It will also be possible to use the D channel for packet data traffic, but it is unclear whether this will be permitted by the LECs and/or regulators.

22. The regularity of human voice signals permits dramatic transmission economies through speech coding. Equipment which compresses voice channels to 32 kbps is widely in use; and equipment exists to achieve 4 kbps voice communications. See Lehr's ISDN Primer for more details.

23. See Kenneth Phillips, "ISDN's Built-in Problems," *Telecommunications*, October 1, 1987, for a critique of the N-ISDN integration program. Phillips argues that N-ISDN does not adequately integrate packet and circuit switching, but instead depends on two essentially separate, parallel networks. Most analysts expect initial deployment of broadband capabilities to be based on yet another parallel network, which will only gradually replace N-ISDN.

24. See Lehr's ISDN Primer for further discussion of signaling systems.

25. We are not implying that there should be a requirement that such diseconomies be avoided through the design of the network. Our argument is that the least-cost system involves something other than totally separated signaling systems for different kinds of network uses. If this is true, to require separation is to commit to unnecessary costs for implementing B-ISDN.

26. See M. Shepperd and W. Szeden, "What's it going to be—TCM or ECH?", *Telephony*, June 13, 1988, for a discussion of the debate over the N-ISDN line code. See Lehr's *ISDN Primer* for additional details.

27. To implement software control of the network will require computer programs that have not yet been designed, but that are likely to require some of the latest programming techniques which are being developed in artificial intelligence.

28. See Lefkowits, op. cit., and Lehr's *ISDN Primer*. Normally a customer will be able to use the two B channels for the conference call; however, in some cases two BRI access lines may be required.

29. The hybrid network appears to be the more likely choice, at least for a while. The current class of N-ISDN-capable switches will not require that all users convert to digital access. If some customers do not make the required investment in ISDN compatible terminal equipment (i.e., scrapping their old telephones and buying new ones), the LEC will have to continue to bear the added costs of maintaining a hybrid analog/digital network. This is likely to slow development and raise the costs of switches which are B-ISDN capable.

30. See R. Solomon and L. Anania, "The Vulnerability of the Computerized Society," *Telecommunications*, April 1, 1987, for a discussion of the vandalism that can occur when users are given access to signaling control, a feature of N-ISDN. The network will not know the source of instructions. In broadband networks, this becomes even more of a problem because things

happen so quickly that network recovery and protection software — which does not yet exist — may be unable to counter an attack quickly enough. This is an active issue in current debates about broadband standards.

31. See Lehr's *ISDN Primer* for numerous examples of alternative non-ISDN technologies which could be used to offer many of the services promised by N-ISDN. The point of identifying these alternative technologies is to indicate that the supposed pent-up demand for N-ISDN services could be served today if it were strong enough. Because these services apparently are not economically viable now, the costs of implementing them represent an upper limit on the prices which could be charged for similar ISDN services.

32. Neither one-way, point-to-point television nor one-way video with a very simple back connection requires even N-ISDN capability.

33. See Lehr's *ISDN Primer* for an estimate and explanation of the likely costs.

34. For detailed histories of these industries, see Richard R. Nelson, *Government and Technological Progress*, New York: Pergamon Press, 1982.

35. Sarah Julia Lane, Entry and Industry Evolution in the ATM Manufacturers' Market, Ph.D. Dissertation, Stanford University, December 1988.

36. This concern may prove to be unimportant because of the rapidly decreasing cost and increasing modularity of communications equipment and computers. Consequently, the advantages of large firms in using advanced information systems are declining. Whether these advantages will become economically unimportant, however, is an issue that cannot be resolved yet.

37. For a summary, see Roger G. Noll, "Economic Perspectives on the Politics of Regulation," in Richard Schmalensee and Robert Willig, *Handbook of Industrial Organization*, Vol. II, New York: North Holland, 1989.

38. When interexchange carriers adopt software defined networks, all IEC customers who use bypass facilities will be able to reach each other without using LECs. The only purpose of the gateway would be to reach customers who do not bypass local access. On the other hand, this may not be practical for two reasons: bypassers may not have a financial incentive to avoid local networks for telephone calls; or regulators may not permit complete bypass within local service areas.

39. The logic of optimal utility pricing when the relative costs of service shift against small users, or when an increased fraction of total costs becomes a fixed cost rather than a usage-sensitive cost, is to raise prices for residences and small businesses because their elasticity of demand is so low. For a complete development of this argument, see Alfred E. Kahn and William B. Shew, "Current Issues in Telecommunications Regulation: Pricing," Vol. 4, No. 2, Spring, 1987, pp. 191-256. Not surprisingly, not all regulators are willing to accept the distributional consequences of this argument; one has termed it "The Marie Antoinette School of Ratemaking: 'Let them make toll calls.'"

40. An example of a restrictive policy can be found in the arrangements for marketing satellite home receivers for television signals. These services are marketed exclusively by cable television franchises for customers who live in a cabled area, thereby guaranteeing the cable

franchise no loss in revenue should its customers decide to switch from the public cable network to a private reception system. In effect, this denies consumers the opportunity to benefit from the competition that satellite reception might otherwise provide.

41. As a technical matter, a firm would engage in the latter only if, for technical or regulatory reasons, it could not engage in unlimited substitution of capital for other inputs. See William A. Brock, "Pricing, Predation, and Entry Barriers in Regulated Industries," in David S. Evans, *Breaking Up Bell*, New York: North-Holland, 1983.

42. This is not an idle concern. Single-line business access in large cities has become substantially more expensive since divestiture and may now be above any reasonable measure of costs. Meanwhile, some LEC services facing competition — notably Centrex — have been the center of controversy because they may be underpriced. See Roger G. Noll and Susan R. Smart, "The Political Economics of State Responses to Divestiture and Federal Deregulation in Telecommunications," in Barry Cole, ed., *After the Break-up*, 1991.

43. See Robert M. Pepper, "Through the Looking Glass: Integrated Broadband Networks, Regulatory Policy and Institutional Change," OPP Working Paper #24, Federal Communications Commission, 1988, p. 56ff.

44. Separation addresses still another important issue, how to prevent a monopoly in facilities from spilling over into a monopoly in the content of communications, with undesirable first amendment implications. This important issue lies beyond the scope of our paper.

45. For a more extensive discussion, see Roger G. Noll, "Telecommunications Regulation in the 1990s," in Paula Newburg, ed., *New Directions in Telecommunications Policy*, Vol. 1, Durham: Duke University Press, 1989.

46. For details about the issues involved in this historic antitrust case, see Roger G. Noll and Bruce M. Owen, "The Anticompetitive Uses of Regulation: United States vs. AT&T," in John Kwoka, Jr. and Lawrence White, (editors), *The Antitrust Revolution*, New York: Scott Forseman, 1988.

47. See, for example, Pepper, op. cit., p. 59-62.

48. For more details about shared tenant service, see Huber, op.cit.

49. Pricing history also suggests that LECs cannot expect to make substantial profits on ordinary telephone service. The disturbing consequence of this is that LECs have been encouraged — implicitly at least — to look towards new services as their only realistic source of growth in profits.

50. For details, see Noll and Smart, supra, note 41.