LAST MILE – BRINGING IT HOME
Findings Report Backgrounder

Submitted by: Professional Options and Keating Consulting Service, Inc
To: Subcommittee on Private Sector Last Mile Solutions

1.1. Telecommunications is the Infrastructure Issue of the 2002.

Just as electricity, streets, and sewers are core infrastructures that serve residents, businesses, and government alike so too is telecommunications infrastructure a community-wide need. On a college or corporate campus, telecommunications wall-plugs are already as common as electric outlets. The challenge now is to extend this level of universal service to all small businesses, homes, and public buildings throughout local communities.

1.2. A Brief History of Telecommunications Regulation

A large legacy from past policy, dominated by telecommunications regulation, shapes the context for broadband policy. That legacy principally concerns regulation of wireline communications through common carriers, but it also includes regulation of cable, broadcasting, other wireless communications, and regulations applied to the Internet. The legacy's salient features are briefly reviewed in this appendix.

1.3. THE LEGACY FROM PAST POLICY

1.3.1. Common Carriers (Telephony)

Local and long distance telephone companies operate as common carriers, which historically have had close regulatory scrutiny by both federal and state agencies. The history of common carriage is fundamental to the baseline for broadband deployment, because it shaped what exists today in the telephone infrastructure as well as expectations in numerous industries and locales about the nature of investment and competition in communications and information infrastructure.

A telecommunications "common carrier" is the term used to describe a provider of telecommunications transmission service that offers its service to the public for a fee and, in contrast to, for example, a television station owner or a cable television operator for most of its channels, does not control the content of the information transmitted by its facilities or services. Rather, the carrier's customer controls the content and the destination of the transmission. Criminal or civil responsibility for the content rests (for the most part) with the sender, not the carrier. For most of the 20th century, federal and state regulation of common carriers has been considered necessary because telecommunications services in any geographic area have been provided by a single carrier.1 Similar thinking and tactics have been applied to providers of other kinds of infrastructure regarded as utilities, such as electric power or water, and historically to transportation, including rail, toll roads, ferries, and the like.

While policy goals are established through laws, regulatory agencies implement the laws through rulemaking. The Federal Communications Commission (FCC) regulates the interstate activities of such carriers,2 and state commissions regulate their intrastate activities.3 Rulemaking and other administrative proceedings follow a set of practices that involve issuing a notice of intent to act, solicitation of comments, and other formalities. These processes have given rise to a cadre of in-house and private-practice lawyers, economists, and lobbyists seeking to promote or discourage certain kinds of decisions by regulators. Depending on one's perspective, these processes may reflect an open, fair process for implementing regulations or a drag on the telecommunications marketplace.

Regulators were persuaded that local and long distance services were natural monopolies and, consequently, could be provided at the lowest cost through a single firm. Economic regulation, not competition, would constrain the prices and practices of the monopoly carriers. Under this regulatory regime, the Bell System provided local telephone service in virtually all urban areas and gradually extended its reach to many rural areas. Its long distance network interconnected Bell as well as subscribers of the remaining thousand-plus independent telephone companies (each a monopoly in its franchise territory), enabling any subscriber to call any other telephone subscriber. Over time, the Bell System became the envy of the world because of the breadth, price, and quality of its service offerings.

In the last third of the 20th century, however, technological advances cast increasing doubt on the premise that telephone service, or at least certain aspects of it, should be provided on a monopoly basis. In the 1960s and 1970s, the FCC gradually relaxed regulation of telephone terminal equipment (e.g., telephone handsets, private branch exchanges), known as customer premises equipment (CPE).4 These actions spawned the emergence of an intensely competitive market for handsets, fax machines, private branch exchanges (PBXs), and other terminal equipment.5 In the 1970s and 1980s, the FCC followed a similar pattern of phased regulatory relaxation in the long distance market. The most significant event in the introduction of long distance competition involved an antitrust case spawned by such competition and AT&T's response to it. In 1982, AT&T and the U.S. Department of Justice entered into a consent decree, known as the "Modified Final Judgment" (MFJ), that required AT&T to divest its local operating companies.6 By separating AT&T's monopoly segments from its more competitive long distance operations, the decree went a long way toward opening the latter to facilities-based competition, because it eliminated the incentive of the local telephone companies to discriminate against MCI and other would-be AT&T competitors through their monopoly control over the local network.

The decree removed one of AT&T's most substantial competitive advantages by requiring the Bell Operating Companies to provide equal access to other long distance companies.7 As competition in the long distance industry matured, additional technical impediments were eliminated (such as the introduction of 800-number portability across long distance carriers) and new entrants began to make inroads into AT&T's market share, the FCC gradually relaxed price regulation of AT&T on a service-by-service basis.8

The latter half of the 1980s and first half of the 1990s were marked by the continued erosion of AT&T's long distance dominance, as MCI, Sprint, and scores of other competitors gained significant inroads (although AT&T remains the largest provider). In light of these changes in the marketplace, the FCC gradually loosened its controls over different segments of AT&T's long distance business, culminating in a 1995 decision that eliminated the remaining FCC price controls of AT&T's basic residential services.9 Although AT&T remained subject to price regulation for more than a decade after it divested its Bell Operating Company subsidiaries, the prices of interstate services offered by new (and accordingly much smaller) providers of long distance, such as MCI, were not regulated.10 By the end of the 1990s, AT&T's share of the long-distance market had slipped below 50 percent

In the late 1980s, federal and state regulators also began to take the first steps toward opening local telecommunications markets to competition. Following several states such as New York and Illinois, the FCC adopted its Expanded Interconnection rules, which required incumbent telephone companies to interconnect their networks with new firms that wished to provide competing local transport services. These developments raise the possibility of shifts in state regulatory emphasis from retail rate regulation to wholesale enforcement.11

The enactment of the Telecommunications Act of 1996 marked the commencement of the most concerted effort by state and federal regulators to dismantle the monopoly control over local telecommunications markets exercised by the Bell Operating Companies and other incumbent telephone companies. The results have yet fallen short of the quick movement to "deregulation" that some had hoped for. Armed with new statutory authority, the FCC and state regulatory commissions moved aggressively to require local incumbents to open their markets. Incumbent telephone companies, called ILECs (incumbent local exchange carriers) continue to have overwhelming market shares, particularly among residential customers, thanks to their initial monopoly position and scale and scope economies that are difficult to overcome. To help overcome these incumbent advantages, the Telecommunications Act of 1996 mandated that incumbents offer competitors (CLECs) access to unbundled network elements at reasonable rates. Because ILECs continue to control well over 90 percent of local market revenues and customers, they remain subject to comprehensive price regulation at both the federal and state level. CLECs, lacking market power, generally are not.

In 1999, the FCC adopted rules for the gradual deregulation of the incumbent telephone companies' provision of local service used for interstate communications. Prices should be deregulated when there was evidence that the incumbent could not exercise market power.12 Meanwhile, there has been horizontal consolidation among telephone companies plus vertical integration of such companies (e.g., Qwest acquired USWest; NYNEX merged with Bell Atlantic, which merged with GTE to become Verizon; SBC acquired Pacific Telesis and Ameritech; MCI merged with WorldCom, which also merged with UUNet; and AT&T acquired TCI and other cable interests). Thus, although the 1996 act eliminated legal barriers to entry in those states where they persisted, economic and technical barriers are eroding more slowly. Nevertheless, competitors have made inroads among business customers in urban markets. Against this backdrop, issues posed by open access in broadband have prompted FCC initiatives.

1.3.2. Cable

The regulatory regime governing cable television systems is entirely different from the common carrier scheme. It has a much shorter history, and it reflects the fact that following its earliest days, when cable was used to provide television service in regions not reached by broadcast television, cable grew by providing an alternative to an existing entertainment and information service (broadcast television) and faced initial deployment challenges. Cable operators do not have to offer their transmission service to the public on a nondiscriminatory basis, unlike common carriers. Most important for understanding how regulation was approached, cable systems maintain considerable control over the content that is transmitted over their distribution facilities. Unlike common carriers, they have asserted First Amendment rights with regard to the content they carry, a status upheld by the courts. Cable operators generally are not required to offer access to their distribution system to enable other (unaffiliated) content providers to deliver their products to cable subscribers (major multiple system operators that vertically integrate content production and cable service are required to devote a portion of their system capacity to unaffiliated networks). Even without any mandate to do so, however, operators offer unaffiliated content channels for two reasons: (1) no single operator has enough high-quality content to fill all of its capacity, and (2) operators generally find that customer demand for these channels exists. Thus, almost every system carries CNN, which is an AOL Time Warner service, and ESPN, which is owned by Disney-ABC. In addition, cable operators, under certain circumstances, are required to offer access to providers of traditional video services under the so-called leased access provisions of Title VI of the Communications Act of 1934 (as amended). Also, there have been local content requirements through public, education, and government channel provisions of franchises. Nonetheless, the contrast between the relative freedom to control content and the obligations placed on common carriers--which gives rise to expectations of similar behavior in the future--is one genesis of today's "open access" debate,13 discussed below.

Cable television is subject to limited federal regulation. Under Title VI of the Communications Act of 1934 (as amended), the "basic tier" of services, encompassing mostly local television signals, is subject to rate regulation. Local authorities could regulate the price of the basic tier, pursuant to formulas prescribed by the FCC, unless "effective competition" existed, as defined by the Cable Act of 1992 (such price regulation expired in 1999). Cable television operators also are limited in their ability to expand horizontally and vertically with content providers. Devising, implementing, and enforcing regulations for the cable industry under the 1992 act was difficult and time-consuming. A major complication was that cable service, like broadband, is multifaceted and varies in capability from one service area to the next. In the end, it is not clear that the regulation accomplished much in the long run, with the exception of the rules that made cable network programming available to overbuild competitors and satellite services at "reasonable" prices, which spurred competition in video delivery.

Cable systems are also subject to local regulation--through the franchise agreements that they execute with municipal, county, or, in a few cases, state authorities. These agreements typically run one or more decades and are a source of revenue for the municipalities that issue them.

As franchise agreements have come up for renewal, the new capabilities of cable systems to deliver advanced video and data services have dominated the negotiations. As discussed in Chapter 4 in the report, a key development beginning in the 1990s was the progressive upgrading of cable plant to incorporate fiber (hybrid fiber coax), which increased system quality and capacity and more recently facilitated use of cable infrastructure for Internet access. However, cable operators are not under a legal obligation to upgrade their plant to be able to offer broadband, cable modem services. Further, if operators complete such an upgrade, they currently are not (as a class) required to make access to that transmission service available to unaffiliated providers of broadband services. Open access requirements (discussed in Chapter 5) have figured heavily in several franchise negotiations. Other elements arising in contemporary franchise negotiations include establishment of minimum data bandwidth and rights-of-way (such as joint trenching rules where there are multiple entrants). New considerations analogous to the traditional public, educational, and government (PEG) requirements include extensions to nonvideo services and making fiber available to local governments (and possibly for other customers).

1.3.3. Internet

Fear of regulation has always haunted the Internet, although it is considered "unregulated." Popular misunderstanding has even motivated the FCC to issue a fact sheet (last revised in January 1998) to dispel myths about charges and taxes it was alleged to have imposed or to be considering imposing on the Internet or its use.14 Since the late 1990s, FCC commissioners and staff have written and spoken publicly about the benefits of the commission's hands-off approach to the Internet.15 But the growth in public interest in the Internet and the businesses behind it continues to raise questions about prospects for government intervention, including regulation, whether direct or indirect.

The historic interaction of regulation with the Internet was ad hoc, even unintended. Anecdotal evidence suggests that the Internet was not recognized as a phenomenon or concern by most regulators until the 1990s, when it became commercial, and those circumstances or actions that can be identified do not seem to have been framed with the Internet in mind.16 For example, a key enabler, in retrospect, was a series of FCC decisions that gave customers the right to attach approved devices directly to the network, which has allowed both ISPs and users to attach modems to their phone lines--a necessary precondition for dial-up access.17 Some observers also point to common carriage regulation as an important Internet enabler. Entry by ISPs has been facilitated by common carrier rules which mandate nondiscriminatory access and reasonable rates apply to both the dial-up lines used by individual customers and the telephone network dedicated lines used by many ISPs to connect points of presence to the Internet.

Another enabler came in the 1980 second Computer Inquiry, when the FCC ruled that firms that use basic telecommunications services to provide an enhanced service of some kind (such as information delivery) are not engaged in the provision of a "basic" common carrier, telecommunications service (such as local telephone service). Rather, they are providing an "enhanced" service and, accordingly, are not subject to the direct jurisdiction of the FCC or state regulatory commissions. That decision served to nurture commercial value-added networks, bulletin boards, database services, and other data communications services in the 1970s and 1980s. These proved, in retrospect, to be training grounds for the more open Internet, as well as ISPs, in the 1990s.

More recently, through Section 271 of the Telecommunications Act of 1996, the former Regional Bell Operating Companies are prohibited from offering interLATA services--which include both long distance telephony and Internet transmission services--in states in which they provide local telephone service, until they have satisfied certain market-opening requirements. As a result, while these companies may operate dial-up and broadband ISPs, customers must obtain connectivity to the rest of the Internet through a regional or national ISP operated by another company. Also, although virtually all Internet communications cross state lines, in 1997 the FCC affirmed18 an earlier ruling that the transmission between an end user's premises and an enhanced service provider's location in the same calling area would be treated as a local call, rather than as an interstate call, regardless of whether that transmission carries data, an e-mail message, or even (at least under certain circumstances) a voice call over the Internet.19

Finally, differences in inter-network traffic flows have fed debate over so-called reciprocal compensation, a subject of FCC inquiry in 2000-2001.20

The Telecommunications Act of 1966 had another consequence that has been important for the deployment of broadband Internet access. Because the act required the ILECs to unbundle their circuits to CLECs, a class of CLECs came into existence that offered data rather than voice over these circuits, by means of DSL technology. This investment in DSL by competitive providers seems to have spurred investment in DSL by ILECs, and thus to have driven the overall rate of DSL deployment. At the present time, the market downturn has put many of these competitive DSL providers in peril, but this should not cause one to dismiss the contribution of competition in this case.

When incumbent telecommunications providers offer DSL, this service comes under the purview of the historical legacy of telecommunications regulation. When an incumbent telecommunications provider sells an enhanced service (which is not regulated) over a "basic" service, the incumbent provider must provide the basic service to others. DSL is seen as a basic service. Thus, at the present time, the ILECs must unbundle their data services at two levels. They unbundle their physical loops so competitive DSL providers can implement DSL, and they unbundle their DSL service so competitive ISPs can sell Internet access over the incumbent's DSL service.

The history presented here, which illustrates indirect regulatory support for the Internet that has been largely inadvertent (at least until the late 1990s), unfolded without consideration of broadband. It focuses on the presence or absence of regulatory intervention into pricing and market entry. Broadband expands the potential space for intervention in at least two ways: First, it involves different kinds of industries and technologies providing Internet access under different regulatory regimes (e.g., some have expressed concern about the implications for ISP support of cable-based Internet access in contrast to common carriers). Second, distinguishing between information services and telecommunications carriers blurs when facilities owners integrate carrier and information service functions, as is being seen in at least cable- and satellite-based broadband offerings.

1.4. PRESENT: THE 1996 ACT

Much of the current policy framework relates to the Telecommunications Act of 1996, which was framed as a reform effort. Since its enactment and the unfolding of derivative activities, there is increasing awareness of what it does and does not accomplish. This piece of legislation, a major modification to the Communications Act of 1934, was shaped during the early to mid-1990s. The language of the act indicates that its primary goals are to promote competition and reduce regulation as a means of increasing growth in telecommunications services and reducing prices.21 It was enacted shortly after the 1995 commercialization of the Internet backbone and introduction of the browsers that helped to popularize the World Wide Web and before such technologies were widely used. Even though many of the key actors understood that sweeping change was on the horizon, full appreciation of the key role of the Internet did not exist, in society or in Washington.

The Telecommunications Act of 1996 adjusted the relative roles of federal and state regulators, increasing that of the states. Whereas the Communications Act of 1934 preserved state authority over intrastate rates and services, the 1996 Act specified state roles in interconnection, incumbent telephone company long distance market entry, and promotion of advanced services. It sent mixed signals on federal preemption of state regulators, and it reinforced a kind of cooperative federalism.22

Most directly relevant to broadband, the Telecommunications Act of 1996 calls for the FCC and states to encourage deployment of advanced technologies for telecommunications to all Americans on a reasonable and timely basis. But what satisfies "advanced," "all," "reasonable," and "timely"? The act, in support of service to "all" Americans, calls for access to advanced telecommunications and information services in rural and high-cost areas to be "reasonably comparable" to that in urban areas in terms of price and quality. This formulation is interesting because it joins unregulated information services with regulated telecommunications services; what that implies for policy approaches and their targets is unclear. Specific provisions of the act related to broadband are summarized in Box 5.1, Chapter 5.

1.5. Notes

1 These monopolies were created initially by AT&T's aggressive acquisition of independent telephone companies in the early 20th century. The regime emerged in the wake of the 1913 agreement between the Bell Telephone system and the U.S. Department of Justice, known as the Kingsbury Commitment. In return for certain concessions, Bell Telephone was permitted to retain the local telephone companies it had acquired since the turn of the century and to maintain its monopoly control over long distance.

2 Under Title II of the Communications Act of 1934, as amended.

3 Because AT&T and the independent local telephone companies were permitted to operate as government-protected monopolies, the prices and other terms and conditions of their service offerings were subject to close scrutiny by federal and state regulators to prevent the telephone companies from exercising their market power. If a call originates in one state and terminates in another state or foreign country, that service is subject to the FCC's jurisdiction. If a call originates and terminates within the same city or within the same state, that service is subject to the state commission's jurisdiction.

4 Prior to the FCC's action, telephone equipment was part of the service that the local telephone company provided to its customers. Indeed, customers were prohibited by the companies' tariffs from attaching other equipment to the network.

5 In deregulating CPE, the FCC also preempted state commissions from continued regulation of that equipment. The FCC's jurisdiction under the Communications Act of 1934, as amended, in the 1970s was limited to interstate services. The commission recognized, however, that, as a practical matter, it could not deregulate "interstate" CPE, since such equipment is used to place and receive both interstate and intrastate communications. Hence, it barred state agencies from continuing to regulate the provision of CPE in order to prevent such policies from frustrating the FCC's national deregulation policy. See North Carolina Utils. Comm. v. FCC I.

6 See United States v. American Tel. & Tel. Co., 552 F. Supp. 131 (D.D.C. 1982), aff'd, 460 U.S. 1001 (1983).

7 The operating companies were required to modify their networks to enable a subscriber to these other providers also to use the "1+" prefix to obtain access. Prior to the implementation of this "equal access" requirement, subscribers of long distance companies other than AT&T were required to dial a seven-digit local number, then dial a multidigit personal identification number, and then dial the long distance number they were calling.

8 For example, when 800-number portability made it possible for an 800-number customer to switch long-distance carriers and retain its 800 number (e.g., 1-800-FLOWERS), the FCC removed its price regulation of AT&T's 800 service offerings.

9 Because the FCC's jurisdiction is limited to interstate services, it does not regulate the rates that local telephone companies charge for local and intrastate services (such as calls from Los Angeles to San Francisco). Local telephone companies, however, provide origination and termination service to interstate long distance companies. That is, the local telephone companies carry an interstate call from the originating end user to the interstate carrier's switch, where it is placed on the long distance carrier's network. Local telephone companies also carry calls from the long distance company's switch to the called party's premises. This origination and termination service is known as interstate access service and is subject to the FCC's jurisdiction.

10 The FCC's theory was that since the new entrants did not possess market power, there was no need to regulate their rates. If consumers were dissatisfied with an MCI offering, they could always take service from AT&T, whose rates were regulated.

11 Bob Rowe. 2000. "Implementing a Cooperative Federalist Approach to Telecom Policy." Speech presented at Federalist Society, Washington, D.C., September 27.

12 What criteria should be applied remains a controversial subject. The incumbents have chafed at delays to their entry into long distance. Competitors to the ILECs have maintained that the criteria used by the FCC do not provide an accurate picture of the availability of alternative providers of local telecommunications services, and that the FCC blueprint would permit the incumbents to preserve their monopoly control over local markets by granting them substantial pricing flexibility when they continue to wield market power.

13 Proponents of open access have argued, among other things, that when a cable system furnishes access to an Internet service provider, it is engaged in the provision of a common carrier service and, consequently, should be required with the same access obligations that characterize common carriage provided by telephone companies.

14 Federal Communications Commission. 1998. "The FCC, Internet Service Providers, and Access Charges." Available online at <http://www.fcc.gov/Bureaus/Common_Carrier/Factsheets/ispfact.html>.

15 See, for example, Jason Oxman. 1999. "The FCC and the Unregulation of the Internet." Office of Plans and Policy, Federal Communications Commission, Washington, D.C., July. Available online at <www.fcc.gov/bureaus/opp/working_papers/oppwp31.pdf>.

16 The early development of the Internet was motivated in part by a desire to find relief from the high costs of dedicated leased line services available from the regulated telecommunications industry of the 1960s, which constrained early applications of data communications for government and the research community. The prevailing telecommunications environment fed the interest and efforts of the researchers supported by the Defense Advanced Research Projects Agency, who both developed the early technology and were the first to benefit from the economies provided through packet-switching.

17 The certification scheme in 47 C.F.R. Part 68, adopted in the 1970s, enables firms to obtain FCC approval for devices that are attached to the network, permitting third parties to develop innovative communications equipment while ensuring that attachment of this equipment does not threaten the integrity of the network.

18 Access Reform Order, FCC 97-158, adopted on May 7, 1997.

19 Precisely which voice transmissions might be subject to access charges is a delicate area. For example, the Federal Communications Commission indicated in a 1998 report to Congress that a handset call to an ISP that terminated at a handset in another state may be classified as a basic telecommunication service and hence be subject to access charges.

20 The concern is that different kinds of providers may terminate traffic out of proportion to that which they hand off--especially the relative burdens of dial-up Internet traffic. At present, more may be terminated on CLEC than ILEC networks, implying (at least to the ILECs) significant reciprocal compensation payments by ILECs to CLECs, but the nature of potential funds flows depends on actual dial-up use in the future, a

subject of disagreement ("In 'Recip Comp' Debate, CLECs, Telcos Rely on Varying Projects for Dial-up Internet Traffic," Telecommunications Reports, January 8, 2001, pp. 9-10).

21 The preamble calls it "An Act to promote competition and reduce regulation in order to secure lower prices and higher quality services for American telecommunications consumers and encourage the rapid growth of new telecommunications technologies." Telecommunications Act of 1996, P.L. 104-104, 110 Stat. 56 (1996), Preamble.

22 Rowe, "Implementing a Cooperative Federalist Approach to Telecom Policy," 2000.

2. Economics of Infrastructure Investment

Like any other business, revenue, at least in the long term, must be sufficient for a broadband service provider to be profitable (or at least to break even, in the case of a public sector enterprise). As the previous discussion suggests, different technologies have different cost structures that shape their attractiveness in different market segments. At the same time, uncertainty about demand for broadband, consumer willingness to pay, and the interaction of these factors with different business models shapes investment in broadband deployment.

2.1. Understanding Costs

Broadband deployment costs fall into two broad categories: fixed (or per-passing costs), which are roughly independent of the number of subscribers, and variable (or per-subscriber) costs. Fixed costs include those of upgrading or installing wireline infrastructure within the neighborhood and installing or upgrading central office or head-end equipment. For wireless, the costs of acquiring wireless spectrum licenses are another per-passing cost. The most significant variable costs are the per-subscriber capital costs, including line cards, customer-premises equipment, and the costs of upgrading or installing connections to individual premises. Other variable costs include installation at the customer premises (which drives shifts to customer-installed solutions) and customer support and maintenance. Providing upstream connectivity involves both fixed costs, such as installation of regional or national transport links, and variable costs associated with provisioning regional and national connectivity to support the traffic load imposed by customers.

These costs are greatly shaped by density and dispersion. Where new wireline infrastructure is installed, more remote or sparsely populated areas will have significantly higher per-passing costs, reflecting per-mile constructions costs, that make investment riskier, and the lower per-passing costs of satellite or other wireless systems will be more attractive. Each particular circumstance will involve its own set of cost trade-offs, however. For instance, because installing remote terminal equipment imposes substantial costs, home-run fiber to the premises could turn out to be cheaper than a fiber-to-the-cabinet strategy in some rural cases.

2.2. Take-Rate Tyranny

Perhaps the most important implication of per-passing costs is the "take-rate tyranny" that dominates investment decisions. Because costs are dominated by the dollars-per-mile cost of installation, investment in wireline infrastructure has a cost structure in which most of the cost is determined by the number of houses passed, and a minority of the costs is determined by the number of subscribers. (Because they lend themselves to a strategy in which the cell size can be scaled to the take-rate, wireless systems can have an advantage, though the cost of spectrum must also be factored in.)

A very simplified cost model indicates the general shape of the financial dilemma facing those who invest in broadband infrastructure. If there are two providers instead of one--assuming no differentiation between the products, no first-mover advantage, and that costs are per-passing--the costs for each are unchanged but the revenues are halved. As a very rough example, if a provider makes an incremental investment in the distribution infrastructure that has a cost of $200 per passing and must recover this investment in 3 years, this is approximately $5 per month per passing. If the provider has the whole market and 50 percent of the homes are subscribers, this would imply that $10 per month of the per-subscriber payment would have to be allocated for return on this investment. If, however, there were two providers and each held half of the total 50 percent market share, then each provider would have to collect $20 per month from each subscriber as a return on this investment, in a market where the typical consumer payment is just $40 per month. More generally, when the market is split among multiple providers, some cost and revenue models for residential broadband become unprofitable. This also amplifies the advantages held by a provider that can make incremental upgrades to existing wireline infrastructure (the advantage depends on the cost of any required upgrades) over a de novo facilities-based competitor.

As a result of the take-rate impact on per-subscriber costs, the provider with the highest penetration rate may have a substantial cost advantage over its competitors if per-passing costs are significant. According to rough figures supplied to the committee,16 the present per-passing costs to install fiber-to-the-curb are as follows: $150 per passing if only voice is offered, an additional $150 per passing if data service is provided as well, plus $300 per passing to provide video. Fiber cable installation adds another $350 to $400 per passing if done aerially and $700 to $800 per home passed if buried. Given these figures, consider two providers serving a local market, each offering voice, data, and video. Suppose each passes all homes, that 50 percent of homes subscribe in aggregate, and that one provider, the incumbent, serves 60 percent of all broadband homes, while a more recent entrant serves 40 percent of broadband homes. Both providers use aerial installations that cost $400 per passing. Then per-subscriber costs for the incumbent would be $1,000/0.30 = $3,333 (plus subscriber-specific installation costs), while for the entrant per-subscriber costs would be $1000/0.20 = $5,000 (plus subscriber-specific installation costs). The entrant's costs would be 50 percent greater than the incumbent's. This type of relationship means that competition that truly drove prices to costs would eliminate all but one firm unless markets were evenly divided among competitors or competitors offered differentiated services that appealed to different subsets of subscribers. The risks for entrants inherent in this type of relationship are obvious, especially if subscriptions are at all sticky (e.g., where customer loyalty or switching costs are significant). Unless competitors can find ways to substantially differentiate their services, entry may well be risky and vigorous competition difficult to sustain.

2.3. Paying for Broadband

The economic challenge of building and upgrading broadband infrastructure has proved daunting. Cast simply in terms of consumer willingness to pay and ability to attract investment in terms of that demand, it may be difficult to sustain high growth in penetration, upgrades, and new facilities construction. But broadband involves more players than simply the consumer and the infrastructure owner, and there are various ways in which the costs could be allocated among the various players. Other industries that share costs include telephony, in which different types of customers (e.g., residential versus business) pay different prices; commercial broadcast radio and television, in which consumers are sold as audiences to advertisers; and newspaper publishing, in which the subscription price is only a fraction of the cost of production and distribution. Such arrangements have been instrumental in building other communications infrastructures. Complex arrangements among multiple parties are possible, as is seen in broadcasting, where both costs and revenue can be shared between broadcast networks and local affiliates. The critical role of content suggests that issues related to copyright protection of digital content will be intertwined with broadband for some time to come.

Because broadband is a service capable of supporting each of these types of services and many new ones as well, there are potentially many different options for cost sharing. Figure 4.5 depicts a cluster of other players that surround the consumer and broadband infrastructure builder. Notably, broadband subscribers generally are interested in a wide range of content and applications that are not provided directly by the broadband provider itself--today this is largely the universe of content and services available through the Web. These services have been supported through a combination of e-commerce, transaction and subscription charges, and advertising (both direct, in the form of banner ads and the like, and indirect, as when a Web site is used as to draw the user into other media channels). One opportunity--and challenge--is to find ways of better aligning the economic interests of content or applications providers and infrastructure owners in order to share the costs of the access link with the end users. Another is to explore how government incentives or contributions from employers interested in various flavors of telecommuting or employee education could contribute to the overall investment required. New approaches to financing broadband include homebuilders that include fiber connections in the price of the home (and can then promote the homes as broadband-ready) and municipalities that provide mechanisms for amortizing the investment over a relatively long time period.

2.4. Focus on the Consumer

The factors discussed in the previous section notwithstanding, the consumer is the pivot around which all of the economic issues swing. Without consumer demand and a (somewhat) predictable willingness to pay (or evidence that advertising will be a large source of revenue), there is no market. Evidence from early deployment demonstrates demand. The national average penetration (somewhat more than 8 percent as of summer 2001) reflects and masks an uneven pace of deployment. In localities where the service has been available for a reasonable time, cable industry reports on markets that have had cable modem service available for several years suggest considerable demand.17

Although the committee is not aware of definitive studies of consumer willingness to pay for broadband (and the notion proposed in the past, that consumer willingness to pay for entertainment and/or communications is a fixed percentage of income, is generally discounted by economists today), the general shape of the market for communications, entertainment content, and information technology is beginning to emerge. Over 50 percent of homes in America have some sort of PC, with prices that averaged near $2,000 in recent years, and which are now dropping below $1,000 for lower-end machines, illustrating that many consumers are willing to make a significant investment in computing hardware and software. In rough terms, a typical $1,200 home computer replaced after 4 years costs around $25 per month.

A majority of the homes that have PCs are going online and connecting to the Internet, and it is a reasonable projection that only a very small fraction of machines will remain offline in the coming years. Using the primary residence phone line, and purchasing a somewhat more limited dial-up Internet service, the price approaches the $10 per month (providers have also experimented with service and PCs that are provided free, so long as the consumer will allow advertisements to be displayed during network sessions, although recent reports from this market segment put in question the long-term viability of this approach). The entry price today for broadband is not dramatically different from that for high-end dial-up service. A separate phone line costs as much as $20 per month, and unlimited-usage dial-up Internet service generally runs $20 or more per month. Of course, the market offers a range of price and performance points from which the consumer can pick. At the high-end, high-speed DSL can cost up to several hundred dollars per month, and business-oriented cable services are offered at a premium over the basic service.

The total consumer expenditure for such a computer plus basic broadband service is potentially as much as $90 per month, of which the Internet provider can expect to extract less than half. From this revenue base a business must be constructed. If 100 million homes were to purchase broadband service at $50 per month, this would result in total annual revenues to broadband Internet providers of more than $50 billion, which is similar in magnitude to current consumer expenditures on long-distance services.

One question that the market has not yet explored is whether the consumer would make a significant capital investment, similar to the $1,000 to $2,000 that a computer costs today, as part of obtaining Internet service. For example, if there were a home-run system with fiber running to the residence (making it a relatively future-proof investment), but the consumer had to activate that fiber by purchasing the end-point equipment, would this be an attractive option if the equipment costs were comparable? Would residents be willing to finance the capital costs of installing that fiber in the first place? While there is no hard evidence, wealthier consumers, who have demonstrated a willingness to make purchases such as multiple upscale multimedia PCs and expensive consumer electronics, might well be willing to make such investments, and some residential developers have opted to include fiber.

2.5. The Pace of Investment

The rapid evolution of some aspects of the Internet can lead observers into thinking that if something does not happen within 18 months, it will not happen. But the phenomena associated with deployment cycles measured in months have generally been in the non-capital-intensive software arena. The cost of entirely new broadband infrastructure--rewiring to provide fiber-to-the-home to all of the roughly 100 million U.S. households--

would be some $100 billion, reflecting in considerable part construction costs that are not amenable to dramatic cost reductions. Even for cable and DSL, for which delivering broadband is a matter of upgrading existing infrastructure, simple economics gates the pace of deployment. For both new builds and incremental improvements, an accelerated pace of deployment and installation would bring with it an increased per-household cost. Some broadband deployment will be accomplished as part of the conventional replacement and upgrade cycles associated with telephone and cable systems. In some cases, this process will have dramatic effects--two examples are HFC replacement of all-coaxial cable plants and aerial replacement of copper with fiber as part of a complete rehabilitation of old telephone plant--but in many others cases, the improvements will be incremental. To accelerate beyond this pace means increasing and training an ever-larger workforce devoted to this task. As more new people are employed for this purpose, people with increasingly higher wages in their current jobs will have to be attracted away from those jobs. Similar considerations apply to the materials and manufacturing resources needed to make the equipment that is needed.

The investment rate also depends critically on the perspective and time horizon of the would-be investor. For an owner of existing facilities--the incumbent local exchange carriers and cable multiple system operators--realistic investment is incremental, builds on the installed base, and must provide return on a relatively short timescale. The tendency to make incremental upgrades to existing telephone and cable plants reflects the view that a replacement of the infrastructure (such as with fiber) would necessitate installation costs that can be avoided by opting to upgrade. The perception is that users would not be willing to pay enough for the added functionality that might be achieved with an all-fiber replacement to offset the extra costs of all-new installation. Changes in either costs or perceived willingness to pay could, of course, shift the investment strategy.

Once the provider has a broadband-capable system, it will only have incentives to spend enough on upgrades to continue to attract subscribers and retain existing customers by providing a sufficiently valuable service. Where facilities-based competition exists, these efforts to attract and retain customers will help drive service-performance upgrades. From this perspective, the level of investment associated with building entirely new infrastructure is very difficult for the incumbents to justify. Viewing the incumbent's incentives to invest in upgrades from the perspective of the two broadband definitions provided above, investment to meet definition 1 will be easier than that to meet definition 2. That is, it is easier to justify spending so that the local access link supports today's applications, while it is harder to justify spending enough to be in front of the demand so as to stimulate new applications.

Two types of non-incumbent investor have also entered the broadband market, tapping into venture capital that seeks significant returns--and generally seeks a faster investment pace. One is the competitive local exchange carrier, which obtains access to incumbent local exchange carrier facilities--primarily colocation space in central offices and the copper loops that run from the central office to the subscriber--to provide broadband using DSL. The other is the overbuilder, which seeks to gain entry into a new market by building new facilities, most commonly hybrid fiber coax for residential subscribers, but also fiber-to-the-premises and terrestrial wireless. Satellite broadband providers in essence overbuild the entire country, though with the capacity to serve only a fraction of the total number of households. The 2000-2001 drying up of Internet-related venture capital has presented an obstacle to continued deployment, and the CLECs have also reported obstacles in coordinating activities with the ILECs that control the facilities they depend on.

Because public sector infrastructure investment generally is based on a long-term perspective, public sector efforts could both complement and stimulate private sector efforts. The key segment of the public sector for such investment is likely to be sub-federal (state, local, regional), though the federal sector can provide incentives for these as well as private sector investment. But decision making for such investments is not a simple matter, and, if present trends are any indication, such investments will be confined to those locales that project the greatest returns from accelerated access to broadband or possess a greater inclination for a public sector role in entrepreneurship.

2.6. Investment, Risk Taking, and Timelines

The myth of the "Internet year," by analogy to a "dog year," is well known. Where the Internet is concerned, people have been conditioned to expect 1-year product cycles, startups that go public in 18 months, and similar miracles of instant change. The 2000-2001 downturn in Internet and other computing and communications stocks dampened but did not eliminate such expectations. In fact, some things do happen very rapidly in the Internet--the rise of Napster is a frequently noted example. These events are characterized by the relatively small investments required to launch them. Software can diffuse rapidly once conceived and coded. But this should not fool the observer into thinking that all Internet innovation happens on this timescale.

As noted earlier, broadband infrastructure buildout will be a capital-intensive activity. In rough figures, a modest upgrade that costs $200 per passing would cost $20 billion to reach all of the approximately 100 million homes in the United States. Broadband deployment to households is an extremely expensive transformation of the telecommunications industry, second only to the total investment in long-haul fiber in recent years. In light of these costs, the availability of investment capital, be it private sector or otherwise, imposes a crucial constraint on broadband deployment--it is very unlikely that there will be a dramatic one-time, nationwide replacement of today's facilities with a new generation of technology. Instead, new technology will appear piecemeal, in new developments and overbuild situations. Old technology will be upgraded and enhanced; a mix of old, evolving, and new should be anticipated. Whether national deployment takes the form of upgrades or new infrastructure, the relevant timescale will be "old fashioned"--years, not days or months.

As a consequence, observers who are conditioned to the rapid pace of software innovation may well lose patience and assume that deployment efforts are doomed to fail--or that policies are not working--simply because deployment did not occur instantly. One should not conclude that there is something wrong--that something needs fixing--when the only issue is incorrectly anticipating faster deployment.

Much private sector investment, especially by existing firms, is incremental, with additional capital made available as investments in prior quarters show acceptable payoff. As a result, the technological approach chosen by an incumbent is likely to make use of existing equipment and plant, and the deployment strategy must be amenable to incremental upgrades. The evolution of cable systems is a good example. The previous generation of one-way cable systems is in the process of being upgraded to hybrid fiber coax systems, and these in turn are being upgraded to provide two-way capability, greater downstream capacity, and packet transport capabilities. The various incumbents now in the broadband marketplace have very different technology and business pasts--the telecommunications providers selling voice service over copper, the cable television companies using coaxial cable to deliver video, the cellular companies constructing towers for point-to-point wireless telephony, and so forth, and each will evolve to support broadband by making incremental improvements to its respective technologies and infrastructure. Incumbents seeking to limit regulators' ability to demand unbundling have an incentive to avoid technologies that facilitate such unbundling.

Because they exist to take greater risks but possibly provide much greater returns by identifying new promising areas, venture capitalists seek to invest in opportunities that offer high payoff, not incremental improvements. So it is no surprise that the more mature technologies, such as cable and DSL, have attracted relatively little venture capital in recent years. Another investment consideration for the venture capitalist is the total available market, with niche markets being much less attractive than markets that have the potential to grow very large. Finally, because the eventual goal is usually to sell a company (or make an initial public offering) once it has been successfully developed, venture capitalists must pay attention to trends in the public equity markets.18

2.7. Uncertain Investment Prospects in the Private Sector

Over the past few years, broadband infrastructure has to some extent followed the overall trend of technology-centered enthusiasm for venture capital investment and high-growth planning. Broadband may similarly be affected by the current slowdown in investment and by the more careful assessment of business models to which companies are now being subjected. At this time, broadband providers, as well as Internet service providers more generally, are facing problems of lack of capital and cash flow. This could lead to consolidation, and perhaps to a slowdown in the overall rate of progress.

2.8. Investment Options for the Public Sector

If and when the public sector chooses to intervene financially to encourage service where deployment is not otherwise happening, it will have a different set of constraints. Governments have access to bond issues and other financial vehicles that best match one-time capital investments with payback over a number of years, and they also have access to a tax base that reduces the risk of default. If a major, one-time investment is to be made, the implication is that this technology must be as future-proof as possible, because it must remain viable for the period of the payoff. The most defensible technology choice in this case is fiber-to-the-home, with a separate fiber to each residence. Fiber has an intrinsic capacity that is huge, but the actual service is determined by the equipment that is installed at the residence and at the head end. With dark fiber running to each customer, the end equipment need not be upgraded for all the users at once but can be upgraded for each consumer at the time of his or her choosing. Thus, this technology base permits different consumers to use the fibers in different ways, for different services, and with different resulting costs for end-point equipment. The consumer can make these subsequent investments, reusing the fiber over the life of the investment. Upgrades are not, however, fully independent as they depend on the backhaul infrastructure. An upgrade will require not only new central office or remote terminal line cards, but also a compatible infrastructure beyond that; the remote terminal or central office rack itself may not be able to switch or route a higher-speed input due to hardware or software constraints.

Businesses look at risk as an intrinsic part of doing business and manage risk as a part of normal planning. Some investments pay off; others may not. For residential access, for example, demand may exceed expectation, or perhaps not, and a business will mitigate these risks by investment in a number of situations--communities, services, and so on.

In contrast, a municipality serves only its own citizens, so any risk of bad planning must be carried within that community. Further, the voter reaction to miscalculation may amplify the perception of the error, which can have very bad personal implications for individual politicians. Long-term investment in services that do not bring visible short-term value to the citizens may be hard for some politicians to contemplate, because the payoff from this investment may not occur in a time frame that is helpful to them. So a planner in the public sector must balance the fact that most sources of capital imply a long-term investment with the fact that citizens may not appreciate the present value of long-term investment, and may assess the impact of investment decisions based on short-term consequences. This may lead to decision making that is either more or less risk-averse (given the level of knowledge among the citizens and apparent level of popular demand) than the decision making of the private sector.

2.9. Moore's Law and Broadband

This report defines broadband deployment as an ongoing process, not a one-time transition. The first proposed definition of what it means for a service to be broadband reflects this reality: Access is broadband if it is fast enough on an ongoing basis to not be the limiting factor for today's applications. With that definition in mind, unfavorable comparisons are sometimes made between the sustained improvements in the performance-to-price ratio of computing (which relate to what is known as Moore's law, the 18-month doubling of the number of transistors on an integrated circuit) and improvements in the capacity of broadband access links. In fact, communications technologies, as exemplified by sustained improvements in fiber optic transmission speeds, have by and large kept pace with or surpassed improvements in computing. The gap one sees is between deployed services and underlying technology, not an inherent mismatch of technology innovation.

This committee spent some time exploring why broadband local access has not kept pace with other areas in computing and communications, and it considered how the economics of broadband service providers, long-haul communications providers, and computer equipment vendors might differ. In the end, the committee concluded that present understanding is too limited to reach definitive conclusions on this question. Why productivity growth in access has not kept pace with other communications sectors is an interesting question worthy of further research.

2.10. Economics of Scaling up Capacity: Congestion and Traffic Management

Once initial systems are deployed, successful broadband providers are almost certain to experience continued demands on their networks owing to increased subscribership and increased traffic per subscriber. These demands have implications both for how the access links themselves are configured and managed and for the network links between the provider and the rest of the Internet. This section provides an overview of traffic on the Internet and discusses some of the common misunderstandings about broadband technology.

The term "congestion" describes the situation in which there is more offered traffic than the network can carry. Congestion can occur in any shared system; it leads to queues at emergency rooms, busy signals on the telephone system, inability to book flights at the holidays, and slowdowns within the Internet. As these examples illustrate, congestion may be a universal phenomenon, but the way it is dealt with differs in different systems. In the telephone system, certain calls are just refused, but this would seem inhumane if applied to an emergency room (although this is sometimes being done--emergency rooms are closing their doors to new emergencies and sending the patients elsewhere). In the Internet, the "best effort" response to congestion is that every user is still served, but all transfers take longer, which has led to the complaints and jokes about the "World Wide Wait."

Congestion is not a matter of technology but of business planning and level of investment. In other words, it is a choice made by a service provider whether to add new capacity (which presumably has a cost that has to be recovered from the users) or to subject the users to congestion (which may require the provider to offer a low-cost service in order to keep them).

Shared links can be viewed as either a benefit or a drawback, depending on one's viewpoint. If a link is shared, it represents a potential point of congestion: if many users attempt to transmit at once, each of them may see slow transfer rates and long delays. Looked at in another way, sharing of a link among users is a central reason for the Internet's success. Since most Internet traffic is very bursty--transmissions are not continuous but come in bursts, as for example when a Web page is fetched--a shared communications path means that one can use the total unused capacity of the shared link to transfer the burst, which may make it happen faster.

In this respect, the Internet is quite different from the telephone system. In the telephone system, the capacity to carry each telephone call is dedicated to that one connection for its duration--performance is established a priori. There is still a form of sharing--at the time the call is placed, if there is not enough capacity on the links of the telephone system, the call will not go through. Callers do not often experience this form of "busy signal," but it is traditionally associated with high-usage events such as Mother's Day. In contrast, the Internet dynamically adjusts the rate of each sender on the basis of how many people are transferring data, which can change in a fraction of a second.

The links that form the center of the Internet carry data from many thousands of users at any one time, and the traffic patterns observed there are very different from those observed at the edge. While the traffic from any one user can be very bursty (for a broadband user on the Web, a ratio of peak to average receiving rate of 100 to 1 is realistic), in the center of the network, where many such flows are aggregated, the result is much smoother. This smoothness results from the natural consequences of aggregating many bursty sources, not because the traffic is "managed." With enough users, the peaks of some users align with the valleys of other users with high odds. One of the reasons that the Internet is a cost-effective way to send data is that it does not set up a separate "call" with reserved bandwidth for each communicating source, but instead combines the traffic into one aggregate that it manages as a whole.

For dial-up Internet users, the primary bottleneck to high throughput is the modem that connects the user to the rest of the Internet. If broadband fulfills its promise to remove that bottleneck, the obvious question is, Where will that bottleneck go? There has a been a great deal of speculation about how traffic patterns on the Internet will change as more and more users upgrade to broadband. Some of these speculations have led to misapprehensions and myths about how the Internet will behave in the future.

Cable systems have the feature that the coaxial segment that serves a particular neighborhood is shared. This has led to the misconception that broadband cable systems must slow down and become congested as the number of users increases. This may happen, but it need not. Indeed, shared media in various forms are quite common in parts of the Internet. For example, the dominant local area network standard, Ethernet, which is a shared technology with some of the same features as HFC cable modems, has proved very popular in the market, even though it, too, can become congested if too many people are connected and using it at once. Cable systems have the technical means to control congestion. They can allocate more channels to broadband Internet, and they can divide their networks into smaller and smaller regions, each fed by a separate fiber link, so that fewer households share bandwidth in each segment. Whether they are, in fact, so upgraded is a business decision, relating to costs, demand, and the potential for greater revenue. Of course, less sharing would tend to reduce the cost advantage of HFC relative to other higher-capacity solutions such as FTTH.

DSL is generally thought to suffer from fewer access network congestion problems because the user has a dedicated link from the residence to the central office. It is true that the user will never see contention from other users over the dedicated DSL link; however, it also means that the user can never go faster than the fixed dedicated capacity of this link, in contrast to being able to use the total unused capacity of a shared system.

Both the cable and DSL systems bring the traffic from all their users to a point of presence (central office or head end), where this traffic is combined and then sent out over a link toward the rest of the Internet. This link from the termination point to the rest of the Internet is, in effect, shared by all of the subscribers connected to that point of presence, whether the broadband system behind it is a shared cable system or a dedicated DSL system, making the link a common source of congestion for all of the subscribers. The cost of the link depends on both the capacity of the physical link and the compensation that must be paid to other Internet providers to carry this traffic to the rest of the Internet. The cost of these links can be a major issue in small communities where it is difficult to provision additional capacity for broadband. So there is an incentive not to oversize that link. The economics and business planning of this capacity are similar for a cable or a DSL system.

The fact that the links from the point of presence to the rest of the Internet are often a source of congestion illustrates an important point. The number of users whose traffic must be aggregated to make the total traffic load smooth is measured in the thousands, not hundreds. So there may be a natural size below which broadband access systems become less efficient. For example, if it takes 10,000 active users to achieve good smoothing on the path from the rest of the Internet, then a provider who gets 10 percent of the market,19 and who can expect half of his users to be active in a busy hour, needs a total population of 200,000 households as a market base in a particular region.

Even if the broadband local access links themselves are adequately provisioned, bottlenecks may still exist, owing to such factors as peering problems between the broadband service provider and the rest of the Internet, host loading, or other factors. Performance will also be dependent on the performance of elements other than the communications links themselves, such as caches and content servers located at various points within the network (or even performance limitations of the user's computer itself). These problems, which will inevitably occur on occasion, have the potential to confuse consumers, who will be apt to place blame on the local broadband provider, whether rightly or wrongly.

2.11. Notes

1 One estimate provided to the committee is that aerial installation is almost twice as inexpensive as when the infrastructure must be buried.

2 Paul Kagan Associates. 2001. The Kagan Media Index, Jan. 31, 2001.

3 Working Group on Digital Subscriber Line Access (T1E1.4). 2001. American National Standard for Telecommunications--Spectrum Management for Loop Transmission Systems (T1.417-2001). Standards Committee T1. Alliance for Telecommunications Industry Solutions, Washington, D.C.

4 The practical upper limit for data transmission over coaxial cable has not been well explored. The upper cutoff frequency for a coaxial cable is determined by the diameter of the outer copper conductor. Smaller cables (1/4-inch- to 1/2-inch-diameter) probably have a cutoff frequency well in excess of 10 GHz. It is unclear what the upper limit is on modulation efficiency. The 256 quadrature amplitude modulation (QAM) currently in wide use allows 7 bits per hertz, but in short, passive runs in neighborhoods, much more efficient modulation schemes are possible, suggesting that HFC could evolve to speeds exceeding 100 Gbps to small clusters of customers.

5 In the 1970s, researchers worried about the possibility of fiber degradation over time. A number of experiments were conducted and no degradation effects were found. Thus--barring an accidental cut--the only reason fiber is replaced is when some new transmission scheme reveals the old fiber to have too much eccentricity of the core or too much material dispersion. These factors have only come into play in very particular situations. For example, when OC192 (10 Gbps) transmission was introduced, there were concerns that old fiber with an out-of-round cross-section would cause problems. But in the end, only a limited amount of fiber required replacement to support the new, higher-speed transmissions.

6 "Protocol transparency" refers to the ability to run any communications protocol over the fiber by changing the end equipment and/or software. Other communications media display some degree of protocol transparency, but with fiber, the large RF spectrum on an individual fiber is entirely independent of other fibers (in contrast to DSL, which has crosstalk issues; wireless, which has obvious spectrum-sharing; and HFC, which also has shared spectrum). This transparency property only holds true over the fiber segments that are unshared--where passive splitting is done, all must agree on at least the time division multiplexing (TDM) or wavelength division multiplexing (WDM) scheme, and where active switching is used, all must agree on the

packet protocol. True protocol transparency--and true future-proofing--is thus greatest in a home-run architecture.

7 Deployment of fiber deeper into incumbent telephone networks also raises interesting questions about how one would implement unbundling, which was originally premised on unbundling a copper loop running from the central office to the subscriber. Issues such as colocation become more complicated when the loop terminates at a curbside pedestal or controlled environment vault. Colocation is even more complicated if fiber is pushed deep enough that it reaches to the poletop or even into the home. Aesthetic and practical concerns limit the size and number of these remote terminal units, which in term complicates the provision of colocation space.

8 Paul Shumate provided estimates to the committee of 20 percent lower capital expenses and a $500 life-cycle cost savings.

9 One example of recent explorations is a 1999 pilot test by the German company VEBA (now part of e.on), which demonstrated a 2-Mbps per customer result in a trial involving eight households. Results were found to be good enough to suggest more extensive testing and plans for commercialization (involving AVACON A.G., a regional utility). This service uses a device attached at the meter that in turn provides connectivity at each power outlet in the household, providing Internet data and telephone and other value-added services.

10 For more on powerline communications technology, see David Essex, 2000, "Are Powerline Nets Finally Ready?" MIT Technology Review, June 21, available online at <http://www.technologyreview.com/web/essex/essex062101.asp> and John Borland, 2001, "Power Lines Stumble to Market," CNET News.com, March 28, available online at<http://news.cnet.com/news/0-1004-200-5337770.html?tag=tp_pr>.

11 Efforts in this direction include systems that install fiber in existing sewer pipes.

12 Connectivity may be either to a single gateway within the home (which in turn is connected through a home network to computers within the home) or directly to individual computers within the home. (As home networks become more commonplace, some of which themselves use short-range, low-cost wireless links, the former will likely dominate.)

13 In response to a proposal submitted by participants in the old wireless cable industry, the FCC amended the rules to permit licensees to provide high-speed, two-way services, such as high-speed Internet access, to a variety of users. With wireless cable distribution of video entertainment programming proving a nonstarter, the commission concluded that two-way wireless could produce a continuing stream of leased channel revenues for the educational licensees (viable competition for hardwire cable was also a consideration).

14 See, for example, David Leeper, "A Long-term View of Short-Range Wireless," 2001, IEEE Computer, June, pp. 39-44.

15 This economic challenge has been seen in the case of satellite voice services, where terrestrial cellular voice service, which is much cheaper and requires much smaller handsets, was deployed on a more widespread basis than was contemplated when the initial Iridium business plans were formulated. If terrestrial broadband services discussed above are deployed over enough of the world during the time it takes to design and launch a LEO satellite broadband service, the pool of underserved users with the wealth to purchase this new satellite service may be too small to recover the high up-front cost.

16 From Mark MacDonald at Marconi.

17 For example, information supplied to the committee by Time Warner Cable is that take-rates have reached 17.5 percent of subscribers in Boston, Massachusetts, and 25 percent of subscribers in Portland, Maine.

18 In a white paper written for this project in mid-2000, George Abe of Palomar Ventures characterized venture capital investing as "faddish" and observed that "there is a bit of a herd mentality." There are hints that with the 2001 market drop, venture capitalists have adopted a longer-term view and are seeking well thought-out opportunities rather than chasing fads.

19 For an examination of the smoothing phenomenon, see David D. Clark, William Lehr, and Ian Liu, "Provisioning for Bursty Internet Traffic: Implications for Industry Structure," to appear in L. McKnight and J. Wroclawski, eds., 2002, Internet Service Quality Economics, MIT Press, Cambridge, Mass.

3. LUDs and Municipal Networks

The deregulation of gas, electric and telecommunications utilities presents municipalities with new opportunities and risks.

3.1. Local Government has a Critical Role to Play

Of all levels of government, town, city, and county governments are the most intimately involved with local telecommunications infrastructure as a user, landlord, regulator, economic developr, and as your community's infrastructure provider of last resort.

Local government is a large, and often the largest, user of telecommunications within a community: You have buildings all over town schools, libraries, public work depots, police and fire stations, courthouses, and administrative building all of which need at least basic telephone service, and increasingly need data and video services as well. You operate a switchboard, 911 service, police and fire radios; central computers must be accessed from outlying buildings; schools and libraries need access to the Internet, to name just a few examples. You have a direct interest in the availability and cost of telecommunications services.

As does any large purchaser, local government's build/buy decisions, vendor selection, and negotiating strategies can have significant effects on what is available to others in a community. While you must act to meet your own needs in an effective and affordable manner, government has a broader set of responsibilities than do private firms in meeting government needs, you have a public responsibility to ensure that your actions do not harm non-government users in your community.

Local government owns facilities critical to providing telecommunications services, including public rights-of-way, antenna towers, water towers where antennas can be placed, and public safety facilities already zoned for antenna construction. Government has responsibilities to obtain fair compensation for use of these increasingly valuable public assets, and to make sure that they are used to public benefit.

Local government has a variety of regulatory responsibilities. Government has responsibilities to maintain public safety, minimize public inconvenience caused by construction activities, and prevent construction activities of one utility from disrupting operation of other utilities. The construction of telecommunications facilities requires that you establish appropriate zoning, process zoning variances, establish construction codes for telecommunications facilities, process building permits, perform inspections, and the like.

Local Government is the infrastructure provider of last resort. To the extent that the private market does not meet the telecommunications needs of your residents and businesses, your community will look to government for an answer.

Chances are, telecommunications issues are already on your community's agenda: franchise renewals, applications for new franchises, applications to lease rights-of-way, applications to build wireless towers, etc.

Burying Your Head in the Sand Is Not An Option: The Telecommunications Act of 1996 mandates a level playing field, forbids barriers to entry, and requires that you process applications in a timely manner. You can neither turn applicants away, nor negotiate a single franchise and turn away other applicants. On the other hand, if you simply grant all requests without conditions, you could easily have Main Street dug up 5 times next year, by 5 different carriers resulting in a permanent traffic jam, a costly reduction in pavement life and no new revenue to compensate for incurred costs. Even worse: chances are high that the Telecommunications Act has invalidated your current ordinances. If you don't revise your ordinances, you may stand to lose current franchise revenues, and find yourself hauled into court by carriers.

While you may have some leeway to act deliberately for example, by imposing a six-month moratorium on applications while you draft a new telecommunications ordinance inaction will simply land you in court, and ill-considered action will lead you into trouble.

Your challenge is to draft telecommunications policies, plans, ordinances, and regulations that allow you to process applications efficiently, recover costs, receive fair compensation for use of public property, minimize public danger and inconvenience, meet government telecommunications needs, and ensure that your community obtains the full range of telecommunications services needed by your citizens and businesses.

3.2. Selecting a Strategy to Meet Your Telecommunications Needs

You can best serve your community by working strategically developing an integrated approach to policy, legislation, regulation, procurement, and use of public assets that will yield the infrastructure your community needs. The most effective strategy for your community will depend on the situation you find yourself in, but will probably fall into one of the following categories:

Do Nothing , and rely on the private sector to meet your community's needs. There is little to recommend this approach. You will still have to process permit and franchise applications and will end up doing so reactively and inefficiently. You will still have to purchase services to meet government needs, and again, without forethought and planning, you will end up doing so in the least efficient manner. And chances are, carriers will cherry pick serving only those customers that yield a high return on investment.

Focus on Meeting Government Needs. There are many opportunities to save money by consolidating telecommunications purchasing and staff across departments, and possibly across jurisdictions. There are opportunities to obtain services as part of compensation packages for use of public property. You may also be able to reduce costs by operating government-owned facilities (e.g. by stringing fiber-optic cable between buildings). However, there can be serious drawbacks to a strict focus on government needs:

If you achieve cost savings through inter-agency or inter-jurisdiction cooperative purchasing, carriers may well recoup lost profits by raising prices to residential and small business users.

If you make large purchases of existing services such as analog phone lines from an incumbent telephone carrier there will be few incentives for that carrier to install new services, and only a limited remaining market to attract new carriers to your community.

Similarly, if you build a private network to carry government traffic, you may not leave enough business in the marketplace to induce carriers to upgrade services, or to offer services at all.

Use Government Purchases to Shape Market Conditions. Just as government's purchasing actions can harm non-government users, government purchases also have the power to promote services for non-government users. Government purchases can help create a market for new services: federal purchase of airmail services launched the airline industry, today's Internet was born from federal purchases of network services to support academic researchers. You have the option of structuring your telecommunications purchases with the specific goal of shaping your community's telecommunications infrastructure. Some examples:

Government buildings are located throughout your community in rich and poor neighborhoods, in low and high density areas, in residential and business districts. For a carrier to meet government needs, that carrier must have a backbone network that reaches all parts of the community.

Purchasing services is preferable to spending the same funds on government-operated infrastructure. Purchases can provide an incentive to carriers to serve your community, and a stable funding base upon which to develop infrastructure.

Make use of common-user facilities (e.g. Internet-over-cable tv) as opposed to private facilities (e.g. a cable I-net). In this way, carrier investments will be make in systems that serve all users in your community.

An RFP for advanced services, to be delivered to all government buildings, is a good way to attract the attention of both existing and new carriers.

Cooperate with Private Purchasers. A further step is to band together with other purchasers to increase your purchasing leverage. From a technical and economic point of view, a single community-wide network makes far more sense than lots of small networks and individual purchases. If you can orchestrate a community-wide purchase of telecommunications services, you will have created a buyer's market in which your community will be able to obtain precisely the infrastructure it needs.

Strategic Partnership(s) to Develop Infrastructure. To the extent that you own telecommunications resources such as conduit, government-operated networks, towers there are opportunities to enter into strategic partnerships with private firms. For example, Anaheim, California's Public Utilities Department operates a 50-mile fiber optic network to meet internal needs. Anaheim recently signed a contract under which SpectraNet International will lease 60 fibers from the City in order to serve businesses, residents, and government. The City will receive both cash and in-kind compensation.

Develop Community-Controlled Infrastructure. Finally, your most ambitious option is to develop community-owned infrastructure either government owned (i.e. a municipal telecommunications utility), or a telecommunications cooperative. For example, in June 1990, Glasgow, Kentucky's municipal electric company completed a 120-mile broadband network for control of its electric transmission and distribution facilities which has resulted in operational savings of $175,000/year. With a two-way broadband network already paying for itself in operational savings; with all the staff of an operating utility (installation, 24-hour repairs, billing, customer service); and with every home and office in town as an existing customer; providing telecommunications service seemed a natural step to take. Today, Glasgow's Electric Plant Board has 50% of Glasgow's cable tv market and offers high-speed Internet service through the city $24.95/month buys 24-hour-per day, 4 megabit-per-second Internet access, with 48 channels of cable tv thrown in for good measure.

3.3. Getting Started

As with any infrastructure issue, it is difficult to move forward without engaging stakeholders and gaining their support. A good first step is to form a Telecommunications Task Force, that brings together all the major users in town both public and private sector in a structured forum.

You can use a task force to detail current telecommunications use throughout your community, identify emerging needs, identify resources available for meeting needs (existing carriers and their plans, government owned facilities, private networks), and then to select a strategy appropriate for your community. A task force can also be a focal point for organizing cooperative purchasing efforts.

From there, your next steps will be to (re)write ordinances, regulations, and permitting procedures, and to incorporate your selected strategy into government plans and budgets. If you decide on a strategic partnership, or community-owned infrastructure approach, this will be the time to get started.

This article is excerpted from Telecommunications Strategies for Local Government A Practical Guide, published by Government Technology Press. Telecommunications Strategies for Local Government is a comprehensive handbook providing detailed directions on how to organize a Telecommunications Task Force, how to perform a community-wide needs assessment, how to evaluate carrier plans, and how to select and implement a telecommunications strategy appropriate to your community. In handbook is accompanied by a diskette containing model documents from municipalities around the country, and 6 bi-monthly updates to help you keep pace with fast moving changes in the telecommunications arena.

4. Municipal Networks Go the Last Mile

by Lynne Montgomery
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http://www.civilrightsforum.org/rural1oct2001.html

Reports and news stories indicate that rural areas are lagging behind in access to high-speed Internet service, telephone service and getting good television reception. Residents have tried to get a phone line installed just to have the basic telephone service that most people take for granted, they are quoted exorbitant prices as high as $40,000 or $50,000 to have a telephone wire run to their house. Phone companies are reluctant to run phone lines to many rural areas because it is not cost effective to run a wire over miles of land to reach only one or two houses. Even in areas where phone companies are building fiber optic networks, they are reluctant to run them the "last mile" or up to each house due to cost. Rural communities have been in this stalemate for decades. Some counties and towns have decided to take matters in their own hands and create their own networks (Municipal Networks) to provide their residents with telephone service, high-speed Internet access and cable service.

Towns and cities around the country have built their own municipal networks. A brief description of three towns around the country follows:

In 1989, Glasgow, Kentucky, a small town with 14,000 residents started operating their own municipal network. The main reason they decided to do so was competition. They wanted alternatives to the telephone and cable monopolies in their community. Now, 12 years later, at least 8,000 homes in Glasgow subscribe to the cable and high-speed Internet services provided by the municipal network. The town reports that the greatest benefit is the amount of money that remains in Glasgow's economy as a result of the lower rates charged by the municipal network. The competition with Verizon has saved an estimated six million dollars for the residents of Glasgow.

Grant County, Washington began its plans for a municipal network, called Zealous Innovators of Public Power (ZIPP), after legislation was passed in March 2000 that allows public utility districts to provide wholesale telecommunications services across their fiber optic networks. ZIPP is still building its network and plans to expand the fiber optic network to every home and will provide phone service, high-speed Internet service and cable service. Some people in Grant County who have never had phone service now have the opportunity. The reason ZIPP has been created is because Grant County became frustrated with Qwest and Verizon, the private companies that serve the area, which only offered broadband service to parts of the county, not the county as a whole.

Wadsworth, Ohio is another city that decided to create its own network. In fact it was one of the first sites in the state to install a community-wide fiber optics network. The Wadsworth Communication Network (WCN) was installed in 1993 in order to serve the city's telecommunications needs. WCN operates its own cable system and has its own television studio. Residents get a good rate on cable television and have the opportunity to produce and broadcast their own television programs locally. All of the schools in the city are connected which allows students to take Advanced Placement classes and university classes from schools around the country. In the future, WCN plans to add Internet access, automated meter reading, telephone service, security system monitoring and traffic signaling to its list of services.

The towns that built their own municipal network have reaped many benefits especially in rural areas. Households now have phone service and high-speed Internet access that they would have gotten decades late, and possibly never, if it had been left to market forces alone. These networks have given people without phone service the ability to call an ambulance in the case of emergency, give a potential employer a number to call and keep in touch with family and friends. Most importantly, these networks have provided rural areas with the ability to connect with far away communities helping to end geographic isolation. These rural communities are now more able to fully participate in an economy that relies heavily on technology.

Telephone companies and cable companies are against cities and counties operating their own networks because they feel municipal networks have advantages that the private companies do not. They complain that municipal networks are able to get bond financing that is tax-exempt for their projects which is less expensive and the government that is licensing the municipal network owns the network. The private companies also fear the loss of business. In areas where municipal networks are operated, private companies have been forced to lower their prices and improve their services in order to keep customers in that area.

Private companies are fighting to keep municipal networks out of the picture. In ten states they have succeeded by convincing the government to limit or outright prohibit municipalities from providing telecommunications services. Virginia is one such state. Bristol, VA built its own municipal network, and like other municipalities across the country, has filed lawsuits claiming these laws prohibiting municipal networks are in violation of the 1996 Telecommunications Act. Bristol succeeded in its lawsuit and the federal judge struck down the law that prevented municipalities from entering the telecommunications business.

For more information on Glasgow, Kentucky's network, go to: "http://www.glasgow-ky.com/lan/"; for information on ZIPP in Grant County, go to: http://www.gcpud.org/zipp/; for more information on Wadsworth, Ohio, go to: http://vh80022.vh8.infi.net/communities/wadsworth/moreabout/ ; for more information on the Bristol, VA legal proceedings, please see: http://www.bristolnews.com/MGB2Q8XX7OC.html or http://www.bristolnews.com/archive/MGBCG2BGCNC.html.

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5. Echo of the TVA Comes over the Municipal Data Networks

by Andy Oram
American Reporter Correspondent

CAMBRIDGE, MASS.—So you don't want to move to the Coast, and you're tired of hanging around your small town waiting for a telecom or cable company to provide high-speed data access. Go ahead and build your own network! Hundreds of municipalities have done it. But legal challenges to the practice are also mounting.

Gainesville, Florida did it. According to Ed Hoffman of Gainesville Regional Utilities, the city-owned electrical company, their data network started as a critical piece of the electrical infrastructure. Now they reach into several thousand homes.

The utility planned on using its network for purely internal purposes, like controlling power flows and monitoring subsystems. Bellsouth couldn't offer the town enough capacity, and what it offered was too costly.

So about five years ago the electric company partnered with the local Shands Hospital, which needed a high-speed network for transmitting patient data, to build 100 miles of fiber network serving the city and parts of the surrounding county.

Using their extra capacity, they offered high-speed point-to-point service to businesses and government institutions, followed by Internet service to both institutions and residences. "There's no end to our capabilities," says Hoffman.

Do private Internet providers complain about the competition? Once in a while they do, but they also rush to link into the high-speed backbone offered by the city network. Hoffman believes that the network has improved the environment for private ISPs, all in all.

Tacoma, Washington tried every private angle possible before building its own network. Like Gainesville, the electric company in Tacoma wanted a high-bandwidth network that could read meters remotely, pinpoint power failures during storms, and control power stations.

Steve Klein of Tacoma Power reports disdainfully that the local phone company wasn't even interested in looking at the financial pay-offs from building the network. Their switches were designed for short voice calls and tended to go down during critical transmissions of data. The project didn't fit into their business plans, because it would require serious capital investment while they were getting along fine milking their existing infrastructure. "As a monopolist," said Klein, "I knew of what I speak."

Next he tried the cable company. It was a mom-and-pop operation taken over by TCI, which showed no desire to invest in improved infrastructure. And while the competing telephone companies were sympathetic, they were too small. "They were used to going down the main highway signing up some large business nearby, not stringing wires to a whole neighborhood."

When Tacoma Power decided to build the network itself, it submitted its plans to a consulting group at the Stanford Research Institute, which pointed out that a small increase in investment could provide enough extra capacity to let them lease out service.

The city-owned hybrid network (fiber backbone and copper to residences) provided such a superior product to its competition that Klein says "we have to take care not to grow too fast." Current Internet service uses a television screen and an attached keypad, but it is unbelievably cheap at $9/month. And fast, at 128 kilobits with an increase soon to 256 kilobits. “My infrastructure will pay for itself just meeting energy needs,” boasts Klein. “The rest is icing on the cake.”

Klein does not want to expand his electrical company to be in the market for all possible services a network can carry. So more competition is coming soon, as network capacity will leased to any and all interested ISPs.

Cities are well aware of their social impact when they build data networks. Over and over I heard people say that their students, their businesses, and their workers need high-speed Internet access. Mike Thompson of Pioneer Internet in Iowa says bluntly, “If small communities don’t invest in the technology to keep businesses and provide the same educational opportunities as cities, these communities will die.”

Glasgow, Kentucky is home to a passionate advocate of public infrastructure, William J. Ray. Still bearing the old American pride in the Tennessee Valley Authority, Ray says that municipal utilities are a key part of what government is meant to do.

The goal of city-owned telecom networks, according to Ray, is the same as that of municipal electrical utilities many decades ago: to offer services priced way out of reach by the private companies price. He refers to “cost-based rate versus market-based rate”—in other words, the city provides a service at cost instead of trying to make a profit. The Glasgow data network was in the red for nine years, but last year for the first time it started to show a profit.

The proponents of municipal networks I interviewed were united in their disappointment over the 1996 Telecom Act. Its promised competition never came—certainly not to those small towns with the ill fortune to be classified as “third-tier communities.” And so the movement to build municipal networks takes on steam.

These networks are spreading like wildfire across the Iowa prairie. Almost 40 towns and cities in that state have voted to build data networks. The story I heard from the assistant town clerk of Hawarden, Patty Anderson, was familiar.

The city council of Hawarden got “tired of hearing complaints from residents” about phone service; her own phones were unusable in a heavy rain. Businesses warned that they needed advanced applications like videoconferencing; one with customers as far away as Taiwan and Scotland said it would move out of town if they could not get a high-speed data connection.

In October 1994, a special referendum to allow the building of a communications network brought out 65% of the voters and passed with 96% of the ballots. The network offered cable before telecom. But they made their first phone call over the municipal network on October 20, 1998—and were forced to shut down by the Iowa Supreme Court on October 21.

The court ruled that an Iowa law enabling cities to build “communications networks” referred just to cable TV, not to telephony or data. They have since rescinded their decision, but because they have not issued another ruling the phone service remains disconnected.

Hawarden got caught in a nationwide struggle over the rights of cities to offer telecom services—including Internet service—on their networks, a struggle going increasingly to the opponents. Most recently, Texas ruled against the cities, and the FCC refused to step into the dispute; another case in Missouri has just gone before the FCC.

Opposition does not seem to come from any anti-government ground-swell among the citizens—after all, they're the ones voting to build the networks—but from telephone and cable companies. When I heard how the schools had to shut down their phones, I was ready to pick up a shotgun and join the good people of rural Iowa in defending their networks. But at the receiving end of the barrel I found not the cash-stuffed national monopolists I expected, but a group of small independent operators.

Iowa, it seems, has more independent phone companies than any other state. Judy Pletcher, a spokesperson from their representative body, the Rural Iowa Independent Telephone Association, claims they are state-of-the-art. The dissatisfied cities building municipal networks, she says, are customers of big national companies.

There's no dispute from Pletcher that national telephone companies are leaving Iowa for more lucrative contracts. GTE has announced that it's selling all its local exchanges; U.S. West sells a bunch of exchanges on a routine basis. But RIITA is picking up the service and is convinced they can provide everything the cities are doing for themselves.

RIITA's opposition is typical of telecom companies. They believe that cities are competing with them unfairly—by using taxes, by avoiding the payment of taxes and fees private firms have to pay, or by other kinds of cross-subsidy. Their complaints are summarized by the call for a "level playing field."

The most disturbing concern raised by Pletcher was that cities who go their own way are making it harder for others to get service. What about the even smaller towns and the rural residents who can't afford to build a network? Private companies, according to her, are committed to serving everybody in the communities they enter.

Proponents of city networks deny that they're using tax money unfairly. Comparisons are very hard to make because the conditions under which public and private companies operate are so different. As Ray says, "Cross-subsidization is in the eyes of the beholder." Jim Baller, who represents many city utilities, says "publicly-owned entities generally make payments in lieu of taxes that are often higher than the taxes paid by private entities."

Baller points out that the criticism of city networks goes back at least 80 years, when cities developing their own electrical grids were lambasted by private utilities as "hotbeds of Bolshevism." He casts doubt on the whole "level playing field" debate as being "like a debate over religion." Instead, he wants us to "ask ourselves, honestly and realistically, 'How are we going to ensure that all Americans promptly get the full benefits of the Information Age?'"

Bellsouth spokespersons told me they are "in favor of competition, including having municipalities enter our marketplace," and that, "As a policy, Bellsouth has no objection to municipalities offering telephone service as long as they're regulated the same way we are and don't use tax money."

In Kentucky, Bellsouth introduced a bill requiring cities to collect the same fees private companies do, including a 6% state tax, a 3% school tax, universal service fund subsidies, and a lifeline service subsidy. The bill was withdrawn, but will be reintroduced in the year 2000. Meanwhile, according to Bellsouth spokesperson Ellen Jones, the phone company is talking with local town officials.

While the tax restriction may seem to be a show-stopper for public facilities, cities have actually been able to work within it. The Gainesville network, for instance, started paying property and sales taxes a year ago, after Florida passed a law sponsored by Bellsouth and other companies.

Most cities fund networks by floating bonds, and as shown in this article, they are finding it quite feasible to pay off the bonds from revenues. But even these bonds could be considered unfair competition because they're tax-free, says Iowa state representative Jack Drake.

Drake is the representative who introduced the original bill that Hawarden used to justify building its network. But Drake is a partisan of the level playing field movement, and says his bill was meant to apply only to cable TV service, just as the Iowa court ruled.

Luckily, he says, all parties are sitting down to talk out differences, hoping to reach agreement and thus head off a ruling by the court.

The true competitive advantage that cities have is size. They take on the job of providing access to everybody at the same time, and they can count on subscription rates of 80% or more.

But most of all, cities are committed to providing key services to citizens. They have proven that they can jump in where private companies dawdle.

Municipal networks invert everything we hear from free-market propagandists about the stifling effects of government and the drive inherent in private companies. If government was an enemy of innovation, the city-owned utilities would never have even tried to get into the data business.

Baller reprimands companies that support level playing field laws: "I have a problem with keeping people from helping themselves when you know you can't help them." And Ray scoffs, "It's OK for cities to build water systems or electrical utilities, but we'll draw the line at telecommunications services."

But eight states have passed laws limiting or prohibiting city data networks. We will not really know the future of these enterprises until we get a ruling on them from the FCC or the U.S. Supreme Court.

The day after this article was published, on February 17, Hawarden got its municipal phone service back. The Iowa Supreme Court ruled that the Iowa law allowed municipal networks to offer telephone service.

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6. The Hard Questions in Broadband Policy

March 23, 2001 Platform Independent
By [1]Andy Oram
http://www.webreview.com/pi/2001/03_23_01.shtml

Broadband policy is on everybody's agenda today, but the hard questions are being addressed by only a few.

During a period of life most people try to forget, I learned from my high school teachers the key to academic success: how to score well on standardized tests. "Answer the easy questions first," they said, "then go back and answer the hard ones if you have time."

This is not a bad strategy for policy makers, either. It is the route taken by Congress, the Federal Communications Commission, and advocates for Internet service providers in opening up new possibilities in broadband. They decide such general questions as "Should all providers have access to cable networks?" and leave the thorny issues of oversight, cost, and equitability for later.

But maturity has taught this former high school student some tough lessons. There is no intellectual training comparable to 20 years of showing technical documents to computer engineers who rip them to shreds, plus five years of showing policy papers to law professors who rip them to shreds. I've found I can't hide from the hard questions.

So in this article I will focus on the hard questions that I see as remaining to be answered in broadband. And I'll start from the top, with the questions that are most difficult--because these are the ones that generate the most points for the right answers.

6.1. How do we provide truly universal access to symmetric broadband?

I'm going to whisk right by cable modems and ADSL. (They come further down the list of priorities.) Limited in their reach and puny in upstream bandwidth, they were never meant to be more than stopgaps. They don't meet the promise held out by our society's leaders: to bring the entire public high-speed connections that allow them to get education, government information, telecommuting, reality TV, and medical consultations everywhere, all the time.

Wireless is great in some geographic areas, but is hampered by obstructions and weather in others. It's generally more subject to crowding than wires, and somewhat less reliable. Satellite promises universal accessibility but hasn't been tested with large numbers of subscribers. Right now, it seems like nothing will really meet our needs but fiber to the home.

It's always been assumed that fiber to the home is prohibitively expensive to build. But that canard is now challenged by Miles Fidelman, the founder and president of the [2]Center for Civic Networking, who advises local governments on Internet technology and policy. He points out that fiber by itself is cheaper than copper, because it's essentially made of sand. Fiber is also lighter, which allows you to put more of it on a pole without danger of toppling it.

Besides the cost of digging up the ground--which is being done now anyway when new developments are built--the reason fiber used to be expensive was the equipment used at the endpoints. But the cost of this equipment has dropped to the point where fiber is now completely competitive, coming to between $1000 and $2000 per subscriber. [3]Worldwide Packets is one manufacturer already offering such equipment.

So, according to Fidelman, there is no economic reason to use copper instead of fiber when building new developments. As for established homes, several experts have suggested fiber co-ops. In this model, customers band together to bring fiber to a neighborhood. Each home has to pay for the short line from the home to the pole. But by pooling resources, neighbors can afford a line from their poles back to the central office.

The radical notion of customers owning their own infrastructure—kind of the ultimate in peer-to-peer networking--has made headway in Canada, according to François Menard, a product developer with years of experience in telecom and now a fiber network project manager at the consulting engineering firm [4]IMS Experts-Conseils. Where the E-Rate in the United States hamstrings schools into leasing conventional service from phone companies, many schools in Canada are investing the same money into stringing long fiber cables to form their own private networks. Government buildings are starting to do the same.

In Quebec, schools are spaced so that one can go from one to another in no more than 75 kilometers. This makes it easy to bypass the commercial Internet backbone and routing system and to route traffic by the crude but effective mechanism of hopping from one host to the next. This also means that the users, not the Internet provider, define what kinds of services are permitted.

"The regulatory regime in Canada is really favorable to building infrastructure," says Menard. Anyone can become what is termed a "nondominant carrier" by registering a three-sentence letter. They can then attach to almost any facilities.

The Canadian telecom commission created this favorable situation without really meaning to: A 1995 decision gave broad rights to budding carriers because the government was desperate to break the dominant phone company's hold on the telephone network. They didn't think about the Internet at that point, but the radical decentralization created by the bill now provides room for burgeoning Internet competition.

Now Australia is looking to Canada as a model for how to promote broadband competition. Menard believes the way forward is to allow practically anyone to register as a carrier, give them the right to build facilities (such as by expropriating public rights of way), and keep municipalities from granting franchises to create monopoly carriers. In the U.S., by contrast, competing phone carriers have great difficulty stringing their own fiber, and instead are forced to buy it from an existing carrier at high cost.

Fidelman and Menard, like many public-interest commentators, believe the private phone monopolies are too happy with their position to build the new infrastructure; their obsolete copper is subsidized in a dozen ways by current regulatory regimes. Governments or community organizations have to pick up the slack. Even in the U.S., many local governments are trying to build municipal fiber networks, or to offer service on existing networks built by municipal electric companies. Ironically, they often run up against lawsuits by phone companies.

These companies, having left small towns in the lurch and declaring they can't afford to offer residents broadband access, now try to stop the cities by claiming that municipal networks are unfair competition! The hypocrisy of this position is highlighted by the practice in most cities of offering their networks in a nondiscriminatory manner to all ISPs. Certainly, there are minor issues worth debating (such as whether tax-free bonds should be used to fund networks that compete with private ones) but the principal of municipal broadband is in the best tradition of American self-reliance.

Whether or not local governments build municipal networks, Fidelman recommends they take other actions to allow the development of broadband. These include updating building codes if necessary, and requiring developers to lay the conduit for fiber when digging up neighborhoods.

Bruce Kushnick, who is the executive director of the New Networks Institute, a public-interest group doing telecom research, pointed out in his book [5]The Unauthorized Biography of the Baby Bells & Info-Scandal that local phone companies made promises throughout the1980s and 1990s to build fiber to the home for millions of Americans. Utility commissions across the country reduced regulation and allowed the Bells to collect billions in fees to build out fiber.

Of course, it turned out that fiber to the home was incredibly expensive at that point, and there were few applications to make it worthwhile. So the Bells never built the network. (They kept the money, though.) Kushnick thinks that, if the fiber had been laid, a wealth of new businesses would have sprung up to offer services and we wouldn't be experiencing the Internet downturn we have now.

6.2. Can broadband ever be affordably priced?

The plague of failures among companies offering ADSL indicates that something is wrong with current pricing. Some people hasten to round up the usual suspects--incumbent telephone companies. Kushnick points to numerous complaints filed in various states by ISPs documenting that incumbents offer worse service to competing ISPs than they offer to the company affiliated with the incumbent. Overpricing is also alleged, as in a [6]ruling by the Kentucky Public Service Commission that BellSouth discriminated against [7]Iglou Internet Services. The complaint was one frequently echoed around the country: BellSouth charged high rates for purchasing single lines and reserved reasonable, wholesale rates for extremely large purchases that would be available only to a very large service provider. In a market where small ISPs line up customers a handful at a time, this pricing excludes competition.

But other observers express a more thoroughgoing pessimism. It's true, they say, that ADSL from the incumbent phone companies (and cable modem access from cable companies) is priced so low that there is no room for competition. But perhaps, they say, it's not due to overcharging. Instead, incumbents are cross-subsidizing their own services.

For an incumbent phone company, phone bills from the mass of captive phone users could help pay for ADSL. For a cable company, Internet service is almost always bundled with television and other services, so determining the actual costs is impossible for an outsider. Some companies apparently absorb the cost of Internet service in order to hold on to customers who might otherwise take their television business elsewhere. The partnerships between cable companies and ISPs (Excite@Home and Road Runner) show that the cable companies are explicitly subsidizing Internet access through their content offerings.

And even if an ISP managed to get a cheap line to the customer, it would still have to reserve bandwidth for that customer on the line it buys to its network access point (one of the major Internet routers). For instance, an ADSL line carrying up to 1.4 Megabits to a customer has to be backed up with the equivalent of a 1.4 Megabit T1 line on the other end.

And the equipment required to connect to the phone company or cable company system is extremely expensive. According to Chris Savage, head of the Telecom/Internet Practice at [8]Cole, Raywid & Braverman, it will get worse if phone companies continue doing things like SBC's Project Pronto.

Today, most neighborhoods still have copper running from the company's central offices to the home. The distance can range up to several miles and can contain clunky equipment that rules out the use of DSL. Project Pronto is stringing fiber all the way to within a mile or so of each home (often less).

This is an excellent solution for the incumbent phone company, but now an ISP wanting to offer service comparable to the incumbent--or a competing phone company serving ISPs--has a very unpleasant choice. It could reproduce what the incumbent is doing and string its own fiber to each neighborhood of 500 to 1000 homes. But since this is not at all cost-effective; most competing carriers and ISPs will instead be reduced to reselling the phone company's service, or simply letting the phone company carry its traffic.

While most neighborhoods still have copper running from the company's central offices and the home, Project Pronto is stringing fiber past the central offices to within a mile or so of each home (often less). Now, an ISP wanting to offer service comparable to the phone company--or a competing phone company serving ISPs--would have to string its own fiber to each neighborhood of 500 to 1000 homes in order to get to the clean copper needed to offer DSL services. This is not at all cost-effective; most competing carriers and ISPs will instead be reduced to reselling the phone company's service, or simply letting the phone company carry its traffic.

Lawrence Hecht, creator of the [9]Internet Public Policy Network, which identifies experts that provide consultation to ISPs and others on Internet policy, still holds out hope. He says, "There are two popular business models for providing high-bandwidth content: Get an exclusive relationship with the content provider, or use the network access points to cache content." The first option is the well-known strategy pursued by cable companies, most notably AOL Time Warner. It's limited to large conglomerates and holds the risk of discriminating in terms of content. But the second option is available to small ISPs through the strategy of banding together and buying access to network access points.

"Vertical integration of the content and the pipe is not necessary," says Hecht. "What's really necessary is to get content near the edges of the network where you want it to be delivered."

For small nonprofit and educational organizations, Hecht looks for government support. It would be great, he suggests, if companies involved in streaming media and caching donated servers to nonprofit and educational use, while lobbying governments to provide matching funds for these institutions to develop content. For the companies, it would educate customers about their services and promote wider use. "If you're talking about democratizing the media," claims Hecht, "you can't stick to text; you have to consider streaming audio and video."

6.3. How do we promote competition on the existing local telephone and cable networks?

Five years after the Telecom Act tried to open up competition in U.S. phone service, it has emerged only for sizeable businesses--and other countries have even less competition. While incumbent Bells are supposed to foster competition before they can offer long-distance service in their areas, some are getting into long distance on the basis of pretty thin evidence. Congress is threatening to cut the whole discussion short and give the Bells everything they want.

And some critics of the incumbents say that long distance is not a very juicy carrot anyway. According to Savage, the incumbent's costs for providing a local connection between a long distance company and an end user run about 0.2 cents per minute, perhaps even less. But the incumbent charges 2 cents per minute (10 times that amount) to the long-distance company in federally mandated access charges. So the local companies are already profiting nicely without having to offer long-distance service directly.

Cable in the U.S. is a horse of an entirely different color--what Menard calls a "gray-zone," because the FCC and the courts are still trying to decide what regulatory regime it falls under. It was not the FCC, but the Federal Trade Commission that insisted as part of its consent decree approving the AOL Time Warner merger that competing ISPs be allowed onto their cable network.

American ISPs are looking to models from Canada, where the Canadian Radio-Television and Telecommunications Commission ruled as far back as 1996 that nonprogramming services over cable could be regulated as a common carrier. Chris Taylor of the Canadian Cable Television Association says, "Third-party access is a reality here in Canada. At this point in time, it's a limited reality, but details about tariffs (rates for ISPs to lease service from cable companies) are still being worked out by the CRTC, and it's likely to grow. Some cable companies were quite keen on third-party access from the beginning. But all companies have accepted that it's the reality and are working to make it successful."

Legal classifications, and even regulated tariffs, do not suffice to create a level playing field. The devil is in the details. Cable companies can manipulate the underlying architecture to discriminate against competing ISPs in many ways:

- While routing packets to the ISP (by checking the source address or by other means), the cable company can choose a lower quality of service (QoS).
- The cable company can simply divert its own customers' traffic to the Internet before it reaches the Point of Interconnection where traffic for other ISPs have to go to be routed to the proper ISPs.
- The cable company can put competing ISPs on an entirely different router, once again with a lower quality of service.

These things are not a problem in Canada, Taylor claims. "By law, the cable companies cannot offer a different quality of service to third-party ISPs." The difficulties we've had in the U.S. with local phone competition over the past five years offer the lesson that true competition requires lots of regulation, and lots of checking up, when one competitor is using facilities provided by another.

And the longer we wait, the more people will sign up for the cable company's service (which they are pushing aggressively), and the more inertia will emerge against changing ISPs. This is particularly true if customers who want to switch have to buy a new cable modem to replace one that only understands how to reach a single ISP.

6.4. How do we provide adequate resources on shared cable networks?

A cable network is like an Ethernet LAN: when one person is sending a packet, everybody else has to wait. This means that high-bandwidth use on the cable network is a zero-sum game, and can easily degenerate into a tragedy of the commons. Furthermore, the small upstream bandwidth requires companies to ban servers and even peer-to-peer applications--like the barely alive Napster.

Many ISPs pride themselves on offering guaranteed quality of service and fancy configurations such as VPNs. On cable networks, most of these enhancements are prohibited by cable companies in order to conserve shared bandwidth. Small ISPs stay alive by differentiating themselves. But on a cable network, they have limited options to do so. And the options are at some remove from their primary job of moving traffic, lying in such ancillary services as Web hosting, backups, and customer service (assuming the customer problem is not on the cable network).

Taylor warns, "ISPs have to be aware that as their use of the shared network grows, and as the number of ISPs sharing it grows, congestion will occur. And it takes time to segment the network to relieve the congestion. But the cable companies' own customers use the same network as all the other ISPs and are subject to the same capacity constraints. So there's a huge incentive for the cable company to make sure the network is as efficient as possible."

Can multiple ISPs peacefully co-exist? Taylor says, "Requirements are being imposed on cable modems to ensure that the quality of service to that modem's user, as well as usage across the whole network, is appropriate." Fidelman suggests that the quality-of-service features on modern routers might be used to apportion bandwidth to different ISPs.

6.5. Who will pay for content?

Although infrastructure companies are hurting these days, the really serious wounds have been sustained by content providers. The value of banner ads is increasingly being questioned, simply because so many users ignore them. The science of banner ads is also being questioned. Agencies rubbed their hands with glee when they realized that click-throughs could be counted, but that's actually a pretty crude measure of an ad's reach. Meanwhile, paying by the click-through has a distorting side effect: it insulates advertisers from their own bad judgment. They don't have to worry about paying much for advertising on a site whose readers aren't interested in them.

Perhaps you don't trust corporate sponsors; you could argue that the Web would become smaller but better if content were provided by educational institutions and nonprofits. These, too, however, find it a strain to keep providing updated, high-quality content. It takes highly trained staff just to make sure links are visible in the right places and go to the right pages, much less format and display new material in a timely manner. Micropayment schemes are complicated, will take a long time to put into place, and don't reflect the kind of casual browsing experience most people look for. So by the time we hook up all Americans to broadband, they may have nothing worth looking at.

6.6. What will happen to wages and working conditions?

We all talk about progress and innovation in the communications industry. Most of the time we assume that goes along with competition and privatization. But while those often have benefits, they are also sometimes code words for union-busting. It would not be fair to lower costs by making workers put in 12-hour days (one of the main issues in last year's Verizon strike) or slashing their wages in half. To sum up, people are infrastructure too.

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7. Other Mechanisms for Increasing Access to Broadband

7.1. Loans and Grants

One avenue being pursued by governments, foundations, corporations, and civic groups is partnering to leverage resources and carry out programs that expand access for underserved rural and urban populations. Loans or matching grants could be considered for other instances of community-initiated efforts to develop local broadband networks.

Programs of telecommunications regulatory agencies are complemented by other kinds of programs that may also contribute to connectivity as part of a broader set of programs that support economic development and quality of life in underserved areas. The federal government has supported community access through the Department of Housing and Urban Development's Neighborhood Networks program39 and the U.S. Department of Education's Community Technology Center grants.40 The Rural Economic Development Act of 1990 (P.L. 101-624) created the Rural Development Administration within the U.S. Department of Agriculture (USDA), which has other relevant entities and programs, and the Rural Electrification Administration makes loans and provides technical assistance to rural telecommunications providers. For example, the USDA's Rural Utilities Service41 supports rural electricity, water, and telecommunications infrastructure through loans, grants, and technical guidance. The Rural Utilities Service launched a 2001 pilot program to provide $100 million in 10-year loans to companies building broadband infrastructure in rural areas. The program is targeted to communities with up to 20,000 residents, and following the FCC lead, uses a 200-kbps transmission threshold to qualify for broadband status.42 Telephone cooperatives provide telephone service and a range of data services in a number of rural areas, and rural telephone companies have been active in deploying broadband services.43 Cooperatives can help aggregate demand across a widely distributed set of customers.44 There are also focused cooperative financing organizations.45 Finally, a variety of corporate initiatives have also provided support for community network access.

The federal government has also intervened in the form of the e-rate program, originating in the Telecommunications Act of 1996 and launched in 1998, to provide funds (partial or matching support) for high-speed access for schools, libraries, and health care facilities.46 The e-rate program uses funds raised from taxes levied on particular communications services to expand public access broadband services through these facilities. The program is associated with significant increases in school connectivity, where its influence has been to accelerate, enhance or complement, or enable that connectivity, and there is evidence that it is supporting increases in the bandwidth of connections sought by schools (e.g., movement from "plain old telephone service" to T1 and then T3 lines).47

Local points of presence and applications have also been supported through an evolving effort that has been more like a demonstration program--the Technology Opportunities Program (TOP) (originally the Telecommunications and Information Infrastructure Assistance Program)--at the U.S. Department of Commerce's National Telecommunications and Information Administration (NTIA). The program began in 1994 and focuses on model uses in public sector and nonprofit contexts. Whereas some $2 billion have been awarded under e-rate, TOP awards total about $150 million.48

Collectively, these programs increase awareness, foster deployment and use, and extend broadband beyond those consumers most likely to go after it on their own.

7.2. Tax Incentives

Another option for promoting access is to provide tax incentives for investment in high-cost areas. Tax options to promote broadband deployment in high-cost and/or low-income areas are appealing on two grounds. First, they avoid long-recognized economic distortions associated with funding universal service goals through revenues raised by taxing certain services within the specific industry (the approach used for basic telephone services, and now, through the e-rate, for broadband connections to schools and libraries). Such levies applied selectively within an industry can distort relative prices and, thereby, choices made by the users of communications services.49 Selective, within-industry levies of this type also may create financial incentives for investments in economically inefficient facilities and services that bypass the providers and services subject to the internal tax. Thus, ILECs have frequently argued that many of the investments in network facilities by CLECs were motivated by the financial payoff to be realized by providing long distance carriers and local businesses with the opportunity to avoid local access charges; similar thinking for plans to use cable plant to offer local service was also one of the reasons AT&T offered for its purchase of cable operator Tele-Communications, Inc. (TCI). Investments motivated by the avoidance of extra charges created by policy interventions rather than the pursuit of production cost-driven competitive advantage are inefficient and a waste of societal resources. Tax credits (and other subsidies such as the high-cost fund support mechanism) still may provide incentives for what is ultimately uneconomic activity.

Second, reliance on tax credits to finance broadband deployment would mean that the federal government would have to consider the financing of communications policy goals in the context of the larger set of societal trade-offs that necessarily must be addressed in setting and allocating federal budgets. To the extent that tax credits are used, they would put the financing of communications policy goals squarely within the traditional budgetary process. This might force a better integration of communications policy goals into the larger set of societal goals addressed through various types of federal funding, so that the relative merits of communications policy goals might be appropriately assessed in comparison with other social policy goals in the allocation of scarce government resources. Because telecommunications spending would compete against many other interests, it might also mean less-stable funding for telecommunications programs.

7.3. Vouchers

Another way of putting financing "on the books" is to issue vouchers, similar to food stamps. As a budget line item, a voucher program is even more evident in the decision-making process. Broadband-specific vouchers might be a useful tool for promoting broadband penetration. It is important, however, that such vouchers be targeted as narrowly as possible to specific groups of consumers (e.g., low-income consumers or those living in high-cost service areas) who are not likely to subscribe in the absence of such aid. There is little point in subsidizing purchases that would be made without the subsidy. Vouchers are especially attractive in situations in which infrastructure deployment is not an issue (service providers already have an incentive to build out an area), but to which some subset of potential customers in a built-out service area would not subscribe at prices that service providers would have to charge to cover their costs.50 In these circumstances, a voucher can be a highly specific instrument for encouraging subscriptions that would not happen otherwise. It is less clear that vouchers have advantages over direct payments to service providers if the goal is to promote infrastructure deployment in areas that might not otherwise be served. To the extent that providers might compete to offer services to customers in such areas, there is the danger that competitive lowering of service prices would transfer some portion of the voucher to consumers' pocketbooks rather than to covering infrastructure expenses. A more efficient approach in these areas might be to let providers bid for the right to serve these territories.

7.4. Research to Develop Technology Alternatives

Finally, there is the option of supporting research as a means of promoting access. Much of the excitement associated with progress in broadband technologies and the diffusion of fiber builds on research and development that has enabled new technological approaches and/or lowered the costs or increased the performance of existing approaches. The federal government is key in supporting basic research and fostering public dissemination of the results of research. Units of the U.S. Department of Defense (notably the Defense Advanced Research Projects Agency, or DARPA), the National Science Foundation (NSF), and other federal organizations are key supporters of communications R&D. Most of that R&D recently has focused more on technologies and components that enhance network backbones or development of applications that run over high-speed networks than on local access networks. But DARPA has had a program aimed at fiber in the distribution network, and NSF and DARPA have supported a variety of wireless networking research.

7.5. Looking Forward

For policy makers, the threshold issue is how to determine whether government intervention to accelerate broadband deployment is necessary or desirable. It appears that the problem is not whether most areas will ultimately have some form of broadband service, but rather that in rural areas deployment will occur well after such services are available in more densely populated areas or that the technology options and/or performance will be different in rural areas.

The leading broadband technologies today (in terms of installed base and technology maturity) are both wire-based, and it seems likely that for the near term at least, distance and population density will deter their rapid deployment in remote or sparsely settled areas. Because of the added per-passing cost of serving rural areas, different kinds of technical strategies may need to be sought there as compared with those for other (denser) areas; an example would be greater emphasis on wireless links from residences to a fiber backbone (possibly leveraging local government or electric and water utility rights-of-way).51 With broadband satellite services--which may be able to serve these areas more cost-effectively than the wireline alternatives could--having recently been introduced to the market, one finds a situation where there is some form of broadband available in even the most remote areas of the continental United States. It is also encouraging that the initial offering prices of the Starband service suggest that the "rural penalty" may be small (recurring charges for satellite service at $60 per month versus the $30 to $50 per month typical of cable or DSL). However, it is unclear at this point whether these services will be able to achieve and maintain sufficient performance levels to serve as adequate substitutes for the functionality of wireline services, or how their cost and price will compare in the long run with wireline service in more densely populated areas.

At today's broadband penetration levels, it seems premature to make conclusions about the shape of deployment. Consumer technologies generally display an S-shaped adoption curve, which is marked by an initial period of slow adoption, followed by more rapid expansion, and, finally, a leveling off of adoption in the later stages. In the case of narrowband Internet access, NTIA data collected over the past half-decade show that overall access has expanded greatly and that some disparities--such as across sex and race/ethnicity--have narrowed over time, primarily through expansion of dial-up household access and access in the workplace or public facilities. However, this access has largely leveraged near-ubiquitous public telephone network lines, and thus, with the exception of some instances where line quality is very poor, has not been hampered nearly as much by technological and economic constraints on where and when new facilities are deployed as broadband would be. Widespread dial-up use suggests that wide segments of the population find Internet access to be of value, and thus suggests widespread demand for broadband. In the case of residential broadband, deployment has been growing rapidly from a presently small base, from which vantage point it is hard to infer the long-term adoption rate, patterns of availability, or the ultimate level of adoption.

To the extent that policy makers are simply uncertain about the pace of broadband deployment, the benefits of government intervention to accelerate that process would have to be clear and substantial in light of the risk that such intervention may have unintended and undesirable consequences. Although government policies likely contributed to the high penetration of telephone service in rural areas, application of such policies to broadband could, in theory, deter future entry by competing broadband providers that cannot match the below-cost rates resulting from averaging and other distributional policies. Another risk is that by picking particular technologies or defining particular services, some government programs aimed at bringing a technology to all may end up freezing the technology deployed. Policy makers seeking to promote rapid, efficient broadband deployment should assess the effectiveness of strategies that help avoid these risks--including demand stimulation and aggregation, grant and loan programs, and municipal initiatives fostering market entry and competition. This analysis would require policy makers to collect and review reliable broadband data on an ongoing and timely basis. The development of a comprehensive, national universal service program may well become desirable in the future, once the pace and scope of broadband deployment become clearer.

7.6. The Local Role in Broadband

Seeking to accelerate or enhance the delivery of telecommunications services in their communities, a number of cities, counties, and states have considered or launched initiatives aimed at facilitating, encouraging, or directly building infrastructure for broadband. Historically, the direct local role with respect to telecommunications has been limited largely to negotiating cable franchises. In addition, local governments--absent preemption from higher levels--have control over local features of the deployment environment, such as public rights-of-way, zoning, permitting, and so on. These practical issues affect decisions about special facilities, such as "carrier hotels" and data centers. Local government influence has been expressed in conflicts over siting for terrestrial wireless towers and satellite dishes. Local governments also control access to rights-of-way and proposals for local investment in conduit that can be deployed once and that contain cable or wire supporting multiple providers and services. Today, communities are exploring how to use these points of leverage as well as other mechanisms and incentives to promote broadband deployment.

Local governments have a direct interest in neighborhood, community, municipal, and regional infrastructure, and it is within the community that existing government, corporate, university, and school networks are deployed. Local governments may be in a better position than national providers are to collect and verify local marketplace information, such as discovering and/or aggregating latent demand for broadband services, and these governments involve people whose jobs involve satisfying local interests. Indeed, where local entities have moved to provide local infrastructure, it has typically been when no commercial firm was willing to invest in a given community.

Local initiatives are not without their critics, however. For instance, while local decision makers may see benefits from broadband, it can be as hard for them as for service providers to predict and elicit consumer demand52 and design sustainable business models for municipal broadband enterprises. Telephone and cable incumbents tend to protest local efforts to serve more than government users with services procured or provided by government entities.53 Critics also argue that locally based efforts are less likely to be commercially sustainable in the long run, suffering regularly from lack of access to capital to support upgrades. Local efforts may also have insufficient economies of scale to be viable in the long run, and risk becoming overly politicized.

Local and regional broadband initiatives cover a wide range of possibilities, from focusing on local government infrastructure to facilitating access for the community at large. Local approaches vary for obvious reasons--size, local market desirability, and whether existing providers have been introducing broadband service. This variation may ultimately limit what can be learned or replicated from any specific instance, but an informal network of supporters of local efforts has fostered the exchange of relevant information, including approaches to architecture, contracting, and financing, to maximize opportunities for local officials to learn from others.54

The examples listed in Box 5.2 indicate the sorts of initiatives that have been undertaken at the local or regional level.55 They include, for example, public operation of a multiservice network, where a municipal or county agency is the operator, providing retail services to the end user. Municipal service monopolies are not unusual--water or sewer authorities are the dominant model, and public power utilities are found in a number of locales--but the high level of complexity and rate of change in telecommunications technology compared with water or electricity supply pose a risk. And as noted above, this approach may raise objections from private sector providers, who see the public service as being unfairly subsidized. However, if there is no private sector provider on the horizon, it may be an attractive option.

Another option is some form of public-private partnership. Again, this raises concerns about the risk in a government body's entering into what may be a long-term relationship with a selected private sector player. If the relationship sours, it may be difficult to replace the private sector player. This sort of approach runs the same risk as that with exclusive cable franchising--communities may derive revenue or other benefits from the arrangement, but the partner may not deliver the level or quality of service desired. Additional complications arise if the public sector has contributed funding to the venture.

The drawbacks of the approaches listed above argue that local governments concentrate on taking steps to encourage and facilitate competition among private sector players rather than creating new quasi-monopolistic entities. As a public sector partner with multiple private providers, a public agency would not be competing with a private sector retail service provider. Another advantage of this strategy is that it means that private sector providers do not have to negotiate with each other to obtain access to facilities, which reduces the need to regulate their conduct.

Easing access to rights-of-way is the simplest step, but this may not be enough to induce new entrants. Another option is for a local or regional government agency to install fibers (or conduits through which fibers can later be pulled) and use this investment to lower the barriers to entry by private sector players by making the infrastructure available to them. This approach can be implemented in a number of ways. One is the "fiber condominium" model, in which a locality declares its intention to build out fiber along its streets and invites any interested parties to purchase some share of the fibers installed (and possibly installs additional dark fiber for future use). Typically, some provision is made to lease colocation space for service providers at the fiber termination points. Alternatively, the locality may enter into partnerships with one or more private sector companies to install (and possibly maintain) the fiber. The town itself can sign up, as can schools and municipal departments, businesses and other private sector players in the town, citizens themselves, and any interested broadband providers. The locality provides the motivation and coordination for joint action--it shares in the cost of the common construction, but it may also prohibit the digging up of streets again for some period after the construction. By avoiding the extra cost of uncoordinated overbuilding--keeping down the per-passing costs--this approach attempts to provide competition at per-passing costs comparable with those of a single provider. Local and regional government or quasi-governmental agencies can also act in effect as anchor tenants that underwrite some of the cost of installing infrastructure, reducing the costs for other government agencies, private sector firms, or even individual customers. The consequence of this action is that more providers may be motivated to enter the market in the town.

Finally, localities may choose to launch experimental pilot projects to explore new technologies, system architectures, or business models. State or federal grants can help support communities exploring options or enable them to purchase facilities that today are more costly than they will be in the future when suppliers are able to achieve scale economies in the production of such equipment. Such pilot efforts can demonstrate the viability of systems, demonstrate the extent of demand for them at the local level, and support achievement of scale in use, either by closing access gaps or increasing interest in use. The state or federal role is appropriate, given that results of the experiment can help inform future private sector or public sector initiatives using similar systems. New developments can also build in broadband infrastructure, as is beginning to happen (Box 5.3).

The risk in all of these possibilities is that the local government will not be equipped with the knowledge or skills to negotiate with a large private sector provider. If the town does not act carefully, there is risk of industry capture, an outcome in which a private sector provider manipulates the situation to the point where the town becomes dependent on it and thus loses any power to negotiate or foster competition. With some notable exceptions, local governments are less likely to be familiar with the technology and business side of networking than they are with more traditional government operations, which places them at a disadvantage in planning or acquiring networking infrastructure or services than a private sector firm would be. The risk can be minimized if the town sticks to a facilitating role at the infrastructure level and encourages competition from the outset. Still, industry is not monolithic, and some companies can be expected to favor and others to resist local efforts to foster market entry. Local governments, especially in smaller communities, often have limited capabilities. Action at the higher levels of government is an important part of this local approach as well, to coordinate experiences, to catalog best practices, and to define the playing field with overarching regulation that prevents the obvious forms of mutual abuse.

7.7. Notes

1 For example, the original schemes for allocating radio and television licenses had a political connection, with licenses allocated geographically.

2 Bills that would provide financial incentives include H.R. 267, Broadband Internet Access Act of 2001; H.R. 1415, Technology Bond Initiative; H.R. 1416, Broadband Expansion Grant Initiative; H.R. 1697, Broadband Competition and Incentives Act; H.R. 2139, Rural America Broadband Deployment Act; H.R. 2401, Rural America Digital Accessibility Act; H.R. 2597, Broadband Deployment and Telework Incentive Act; H.R. 2669, Rural Telecommunications Enhancement Act; S. 88, Broadband Internet Access Act; S. 150 Broadband Deployment Act; S. 426, Technology Bond Initiative; S. 428, Broadband Expansion Grant Initiative; S. 966, Rural Broadband Enhancement Act. Bills that would support research include H.R. 2401, Rural America Digital Accessibility Act, and S. 430, Broadband Rural Research Investment Act.

Bills that would change ILEC regulation include H.R. 1542, Internet Freedom and Broadband Deployment Act; H.R. 1697, Broadband Competition and Incentives Act; H.R. 1698, American Broadband Competition Act; H.R. 2120, Broadband Antitrust Restoration and Reform Act; S. 1126, Broadband Deployment and Competition Enhancement Act; and S. 1127, Rural Broadband Deployment Act. S. 500, the Universal Service Support Act, would extend universal service fund coverage for broadband. S. 1056, the Community Telecommunications Planning Act, would provide support for community planning grants. (National Journal's Technology Daily. 2001. Broadband Bill Status. National Journal, Washington, D.C. Available online at <http://nationaljournal.com/pubs/techdaily/briefroom/billstatus/broadband.htm>.)

3 For instance, companies have announced a number of innovations in the mechanics of deploying fiber, such as V-group splicing, blow-in of fiber into conduits, and robotic installation in sewer pipes.

4 For an earlier discussion of different industry cultures, see Computer Science and Technology Board, National Research Council. 1996. The Unpredictable Certainty: Information Infrastructure Through 2000. National Academy Press, Washington, D.C.

5 Communications Assistance for Law Enforcement Act, 47 USC 1001, PL 103-414.

6 In the 1950s, for example, advances in microwave technology (originally developed for the government during World War II) created an alternative system for transmitting telephone calls over long distances, in lieu of AT&T's embedded system of wires. In 1958, the FCC authorized large businesses to use microwave facilities to construct their own private networks. In 1969, the commission took the next step and permitted firms to compete directly with AT&T for certain types of services. And in the 1980s, with divestiture bringing the realities of competition closer, AT&T executives came to revise their own assessment of the costs of adding fiber in their long-distance network as competitor actions, such as Sprint's "pin drop" advertisements, made the case more compelling.

7 In the case of "1+" access, for example, the FCC did not specify the particular types of modifications to existing telephone switching equipment that were required to provide "1+" access. Instead, it mandated the performance requirements that the carriers would have to satisfy and allowed the carriers, working with equipment manufacturers, to develop the specific technical modifications.

8 Some argue that both the FCC and AT&T were slow to cultivate cellular telephony, where deployment and commercial service lagged key innovations considerably; that the granting of licenses for UHF television channels proved to be a costly diversion of resources and spectrum; and that the approach taken to standard-setting for advanced ("high-definition") television serves to slow progress in that arena. See, for example, "A Very Long Distance: A Regulatory Call Put Cell Phones on Hold," Technology Review, May 2001, p. 110.

9 At a June 2000 workshop, Thomas Krattenmaker of Mintz, Levin (and previously the FCC and academia) observed: "I would say that any regulation or any response you propose to the FCC that is predicated on your ability to predict what technology will prevail, when, will be a useless recommendation . . . . We are just rife with suggestions, too many of which the Commission has adopted, that were based on some ability to know when technology and which technology was going to be deployed. I don't think we're capable of knowing that, and I know the commissioners are not--they're not selected on that [basis]."

10 Casual observation shows that the FCC has engaged a single Internet-oriented individual in its Office of Plans and Policy since the mid-1990s, and beginning in the late 1990s it engaged chief technologists with Internet expertise, but there are limits to what a couple of specialists in staff positions can accomplish.

11 Steps taken include the 1998 establishment of a Technical Advisory Council and the 2001 launch of an agencywide "Excellence in Engineering" initiative, including hiring and training measures.

12 Broadband Second Notice of Inquiry, Federal Communications Commission (FCC, 2000, "Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996: Second Report," CC Docket No. 98-146, FCC, Washington, D.C., August 21).

13 For example, in remarks to the committee, Sprint's Jim Hannan said of his MMDS offering, "We don't have effective models . . . so we really don't understand how the network behaves. We're pushing it every day." Hannan observed that projected upstream-to-downstream traffic

ratios were much higher than what was observed when Sprint deployed its network; this was attributed largely to customer use of Napster.

14 For example, in June 2001, AT&T announced that its Boulder, Colorado, open access trials were successful (Richard Williamson, "AT&T Completes First Open Access Cable Trial," Interactive Week. June 7). Earthlink subscriber information as of October 2001 indicates that its services are available over Time Warner Cable systems in several markets and that more markets will be added in the near future.

15 For example, the National Telephone Cooperative Association (NTCA) commissioned a white paper that concluded that the entry of competitors would decrease the take-rate achievable by any single carrier, which could substantially undermine the financial case for DSL in rural areas where it is already constrained even without competition. NTCA linked the issue to its call for only incumbents to be eligible to receive universal service high-cost-area support payments (Telecommunications Reports, January 15, 2001, p. 6).

16 See, for example, Oliver E. Williamson, 1975, Markets and Hierarchies, The Free Press, New York.

17 Facilities-based competitors may still make use of some facilities such as backhaul circuits that are owned by other telecommunications companies, including the ILECs, and all facilities-based competitors must at some point interconnect with the other ISPs that make up the Internet.

18 This is somewhat analogous to the separation that has occurred with electricity deregulation in a number of states, whereby the electric utility's generation and distribution operations are separated and customers can choose which generation company to purchase power from.

19 The FCC has an unbundled network elements (UNE) remand process for removing network elements from the list of required elements to be unbundled if they can reasonably be self-provisioned or are available in the market.

20 A Cisco white paper (Cisco Systems, Inc. 1999. "Controlling Your Network--A Must for Cable Operators," available online at <http://www.cme.org/access/broadband/cisco_MSOs_white_paper.html>) promoted technology for cable companies to control, perhaps preferentially, content flows from different providers. The white paper addresses cable operators' concern about bandwidth-hogging traffic from other content providers and service quality in a context where the operator has arranged for supply of certain known content and customer use of other content is unknown but could be large, while in the short term network capacity is finite. It speaks to cable operators' concerns about resource management by noting that Internet technology permits network resources to be managed. "Sustained service quality over the long term requires IP network control, being able to intelligently segment and manage resources by user type, service, destination, or application so that delivery quality does not suffer with growth or the addition of new services" (p. 2).

21 See, for example, Center for Media Education, 2001, Broadband Networks and Narrow Visions: The Internet at Risk, CME, Washington, D.C., available online at <http://www.cme.org/access/broadband/at_risk.html>.

22 For example, AT&T launched a recently concluded open access trial in Boulder, Colorado, at the end of October 2000 that connected eight ISPs: two AT&T affiliates (Excite@Home and WorldNet), two DSL providers (Winfire, Inc., and Flashcom, Inc.), two national ISPs (EarthLink, Inc., and Juno Online Services, Inc.), and two local ISPs (RMI.net, Inc., and FriendlyWorks, Inc.) ("ISP Offers 'Open-Access' Plan; AT&T Begins Trial in Boulder," Telecommunications Reports, November 6, 2000, p. 17).

23 See <www.buildingconnections.org>.

24 "Lawmakers Ask FCC to Hold Off on Building Access Rulemaking," Telecommunications Reports, September 4, 2000, pp. 9-10.

25 "Building Owners, Carriers Spar over FCC Proposal to Block Service, Extend Ban on Exclusive Pacts," Telecommunications Reports, January 29, 2001, pp. 27-28.

26 An example is the Real Access Alliance; see <www.realaccess.org>.

27 Peter Blum. 2001. Pole Attachment Rules: Establishing a State Policy. Slides from briefing to National Association of Regulatory Utility Commissioners' Summer 2001 Telecom Committee Meeting. Available online at <http://www.naruc.org/Committees/Telecom/pole_attachment.ppt>.

28 Section 224 of the Communications Act of 1934, as amended, 47 USC 224.

29 Global forums concerned with digital divide issues include the International Telecommunications Union Development Forum, the European Union, and the G-8. U.S. foundations looking at digital divide issues include the Markle and the Benton Foundations.

30 Andrew Cohill at June 2000 workshop of the Committee on Broadband Last Mile Technology.

31 "Phone Subscribership Holds Steady at 94.4%," Telecommunications Reports, December 18, 2000, p. 21, summarizing the FCC report Telephone Subscribership in the United States, which is available online at <www.fcc.gov/ccb/stats>.

32 See J.C. Panzar and S.S. Wildman. 1995. "Network Competition and the Provision of Universal Service," Industrial and Corporate Change, vol. 4, no. 4, pp. 711-719. See also David Gabel. 1999. "Recovering Access Costs: The Debate," in B. Cherry, S. Wildman, and A. Hammond IV, eds., Making Universal Service Policy: Enhancing the Process Through Multidisciplinary Evaluation. Lawrence Erlbaum Associates, Mahwah, N.J.

33 While the elasticities of the different customer classes are not well understood, it is likely that this results in a situation where customers with the least elastic demands pay the highest price, which is the general relationship that one gets with Ramsey pricing. An interesting question is whether this could be a competitive outcome. Historical work by Gabel and a formal model by Panzar and Wildman suggest yes, though elasticity was not an issue in the model. Furthermore, more traditional models of competition allow for price discrimination. Baumol and Willig have argued in New Zealand regulatory proceedings that competition will necessarily generate Ramsey prices. (See Panzar and Wildman, "Network Competition and the Provision of Universal Service," and Gabel, "Recovering Access Costs: The Debate," 1999.)

34 In most economic markets, the various products produced with common assets all make contributions to the common costs. Thus, for motion pictures, the fixed cost of producing a film is covered by earnings from theaters, videocassettes, pay television, and over-the-air broadcasting, not to mention foreign markets.

35 As noted by Richard Civille in his remarks before the committee in June 2000.

36 Full parity is not the goal. For example, rural customers have much smaller local calling areas (the areas in which local calls are covered by the monthly flat rate) and as a result may pay much higher total bills.

37 Some rural states adopted forms of rate deaveraging by, for example, requiring customers in some areas to pay a "zone charge" in addition to the averaged, basic rate.

38 An area of current debate is whether the high-cost fund should be explicitly expanded to cover broadband (and, a related question, whether caps on these funds should be relaxed to support advanced services build-out). Proponents of such changes argue that they are valuable mechanisms for enhancing rural infrastructure. For example, the Federal-State Joint Board on Universal Service's Rural Task Force recommended that the FCC adopt a "no barriers to advanced services" policy that would permit high-cost funds to be used in ways supportive of providing advanced services, including reducing loop lengths, removing bridge taps, and otherwise upgrading the network to support DSL (Rural Task Force, Federal-State Joint Board on Universal Service, 2000, Rural Task Force Recommendation to the Federal-State Joint Board on Universal Service, submitted to the Federal Communications Commission under CC Docket 96-45, Sept. 29, available online at <http://www.wutc.wa.gov/rtf/rtfpub.nsf>). Critics question whether the program should be expanded beyond traditional telecommunications services, and the impact of any increased transfer of funds from low-cost to high-cost areas.

39 See <http://www.hud.gov/nnw/nnwindex.html>.

40 See <http://www.ed.gov/offices/OVAE/CTC/factsheet.html>.

41 According to 7 CFR §1735.10 (a), "The Rural Utilities Service (RUS) makes loans to furnish and improve telephone service in rural areas. Loans made or guaranteed by the Administrator of RUS will be made in conformance with the Rural Electrification Act of 1936 (RE Act), as amended (7 U.S.C. 901 et seq.), and 7 CFR chapter XVII. RUS provides borrowers specialized and technical accounting, engineering, and other managerial assistance in the construction and operation of their facilities when necessary to aid the development of rural telephone service and to protect loan security." See <http://www.usda.gov/rus>.

42 "RUS Sets $100M for Rural Broadband Rollout," Telecommunications Reports, December 11, 2000, p. 7. See also <http://www.usda.gov/rus/telecom/initiatives/initiatives.htm>.

43 National Exchange Carrier Association (NECA). 2000. NECA Rural Broadband Cost Study: Summary of Results. NECA, Whippany, N.J. Available online at <http://www.neca.org/broadban.asp>.

44 Richard Civille, Michael Gurstein, and Kenneth Pigg. 2001. "Access to What? First Mile Issues for Rural Broadband," white paper; see Appendix C. See also the National Telephone Cooperative Association <www.ntca.org>, which publishes Rural Telecommunications.

45 See National Rural Utilities Cooperative Finance Corporation (<www.nrucfc.org>) and its affiliates.

46 E-rate involves discounts on eligible facilities' purchases of telecommunications and Internet services plus internal networking, with discounts varying with location (e.g., high-cost, low-income).

47 "Telcos, System Integrators See Rising 'E-rate' Revenues," Telecommunications Reports, September 11, 2000, pp. 46-48. "Poorer, Larger Applicants Get More 'E-rate' Funds, Study Finds," Telecommunications Reports, September 18, 2000, p. 29.

48 See <http://www.ntia.doc.gov/otiahome/top/grants/briefhistory_gf.htm>.

49 For example, contributions to the universal service fund have traditionally been built into charges that long-distance carriers pay local exchange carriers for completing their calls over local networks. Because such policy-driven charges must necessarily be recovered in the price of long-distance calls, the price of long distance increased relative to the price of local service and other communications services.

50 Note that, from a life-cycle or total cost perspective, decreases in the cost of equipment associated with use of broadband, "CPE," will also affect willingness to pay for service.

51 See Civille et al., "Access to What?," 2001.

52 Civille et al. ("Access to What?," 2001) argue for demand cultivation in combination with access promotion through community economic development programs. Their acknowledgment that growing demand may take work--that simple access is not sufficient--implicitly supports the view that accelerating deployment is risky.

53 "Private-sector carriers say they shouldn't have to compete with the entities that regulate their rates, grant them operating certificates and franchises, control their access to vital rights-of-way, and tax them" ("Community Size: The Difference in Cities' Telecom Choices?" Telecommunications Reports, December, 4, 2000, pp. 36-38).

54 One ongoing effort that attracted the attention of this committee has been the work of Bill St. Arnaud as part of Canada's CANARIE program. See <http://www.canarie.ca/>.

55 The Community Broadband Deployment Database, established by the National Regulatory Research Institute at Ohio State University for the Federal Communications Commission, lists more than 200 community broadband programs, covering a range of technologies, target user groups, and funding sources. See <http://www.nrri.ohio-state.edu/programs/telcom/broadbandquery.php>.

8. List of Acronyms

ADSL	asymmetric digital subscriber line
ANSI	American National Standards Institute
ASIC	application specific integrated circuit
ATM	asynchronous transfer mode
BLEC	building-focused local exchange carriers
CATV	originally community antenna television; now synonymous with cable TV
CDMA	code-division multiple access
CDPD	cellular digital packet data
CLEC	competitive local exchange carrier
CO	central office
CPE	customer premises equipment
DARPA	Defense Advanced Research Projects Agency
DBS	direct broadcast satellite
DHCP	dynamic host configuration protocol
DLC	digital loop carrier
DLEC	data local exchange carrier
DMT	discrete multitone transmission
DSL	digital subscriber line
DSLAM	DSL access multiplexer
DSP	digital signal processor
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FEXT	far end cross talk
FTTC	fiber to the curb
FTTH	fiber to the home
GEOS	geo-synchronous orbit satellites
HDSL	high-speed digital subscriber line
HDTV	high definition television
HFC	hybrid fiber coax
HPNA	Home Phone Networking Alliance
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ILEC	incumbent local exchange carrier
IP	Internet protocol
ISDN	integrated services digital network
ISP	Internet service provider
ITU	International Telecommunication Union
LAN	local area network
LEC	local exchange carrier
LEOS	low earth orbit satellites
LMDS	local multipoint distribution services
LOS	line of sight
MAC	medium access control
MDUs	multi-dwelling units

MIMO	multiple in, multiple out
MMDS	multipoint multichannel distribution service
MSO	multiple system operator
NEXT	near end cross talk
NII	national information infrastructure
NSF	National Science Foundation
NSP	native signal processor
NTIA	National Telecommunications and Information Administration
OFDM	orthogonal frequency division multiplexing
PCS	personal communications service
PEG	public, educational, and government
PON	passive optical network
POTS	plain old telephone service
PPP	point-to-point protocol
PSD	power spectral density
QAM	quadrature amplitude modulation
QOS	quality of service
RADSL	rate adaptive digital subscriber line
RF	radio frequency
RLP	radio link protocol
SDMI	Secure Digital Music Initiative
SDSL	symmetric digital subscriber line
SDTV	standard definition television
SONET	synchronous optical network
TDM	time division multiplexing
TDMA	time division multiple access
UDP	user datagram protocol
USB	universal serial bus
VADSL	very-high data rate asymmetric DSL
VDSL	very high speed digital subscriber line
VLSI	very large scale integrated circuit
VOD	video on demand
VoDSL	voice over DSL
VoIP	voice over Internet Protocol
VPN	virtual private network
VTIP	video telephony over Internet Protocol (IP)
W3C	World Wide Web Consortium
WAN	wide area network
WDM	wavelength-division multiplexing
WLAN	wireless local area network
WLL	wireless local loop