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PROMISES FULFILLED AGAIN

Verizon Pennsylvania's Infrastructure Development

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I. INTRODUCTION

On June 28, 1994, the Pennsylvania Public Utility Commission approved an alternative regulatory plan (ARP) filed by Bell Atlantic-Pennsylvania. A portion of the ARP included the Network Modernization Plan (NMP).[1] Created in accordance with statutory obligations, the NMP portion of the plan sets forth commitments and obligations designed to ensure the deployment of an advanced telecommunications network throughout the Commonwealth. Specifically, the plan's objective is to achieve universal broadband availability by December 31, 2015. Now that the Company has adopted an alternative regulatory plan, Pennsylvania law Chapter 30, 66 Pa. C.S. § 3003(b) mandates that three network development requirements be met:

1. A commitment to broadband availability (defined as speeds of at least 1.544 Mbps) with 100% of the network equipped with broadband availability by December, 2015.
2. A reasonable balance of broadband deployment between rural, urban, and suburban areas (using the 2015 timetable).
3. A deployment of broadband facilities in or adjacent to public rights-of-way abutting public schools, industrial parks, and health care facilities**.**

There are several noteworthy points. First, Pennsylvania legislators limited their mandate to specifying only a broadband *capacity*, or transmission rate (1.544 Mbps), rather than any specific technology. This was both prudent and insightful. As we discuss below, the question of how that capacity is provisioned (i.e., which network technology is employed) and what services are ultimately provided to take advantage of available capacity are matters of

[1] Verizon filed supplements to its Network Modernization Plan on September 26, 1994 and March 2, 1995.

supply and demand that are best determined by the market. Second, under Pennsylvania law, incumbents are left alone to determine over time which *technology* will most efficiently allow it to fulfill the obligation to provide the required broadband capacity. Technological innovation occurs over time and present production alternatives that efficient firms constantly evaluate as they make least-cost production decisions. To date, Verizon-PA has considered three technologies and is currently employing xDSL along with T1 and fiber optic facilities as the most efficient means to fulfill its obligation to provide the required broadband capacity.[2] While Verizon's xDSL technologies provide transmission speeds up to 1.5 Mbps, the Company's fiber-based technologies such as Asynchronous Transfer Mode (ATM), Transparent LAN Service (TLS), Fiber Distributed Data Interface (FDDI), and High Capacity Service (HiCap) offer significantly higher transmission rates of 155 Mbps, 100 Mbps, 100 Mbps, and 622 Mbps respectively.

Finally, Pennsylvania legislators did not specify any particular broadband *service*. As this report discusses below, broadband services evolve over time as the consequence of consumers' tastes and willingness to pay. It would be imprudent to mandate the availability of any particular service in a market that is in the earliest stages of development. Indeed, services that were envisioned only 15 years ago (e.g., high speed facsimile) do not exist today in their original form. Pennsylvania legislators were acting in the best interests of consumers when they left broadband technology and broadband services unspecified in the law.

The remainder of this report is presented in three sections. The first section generally discusses broadband and its development over time. From this review we see how technological development, service innovation, consumer's tastes and willingness to pay have evolved over time. Second, we review Verizon's Network Modernization Plan and critically evaluate the company's achievement of the commitments contained that plan. We find that Verizon-PA has met or exceeded all requirements of the plan to this date. Finally, we also explore other measurements of network modernization available from public sources. Relying on Federal Communications Commission (FCC) reports we evaluate nine different measures relating to technological development across the United States and we find that Verizon-PA is

[2] Other technologies considered were hybrid fiber coax (HFC) and switched digital video (SDV).

among the industry leaders in creating an advanced telecommunications network in Pennsylvania. Notably, we find that Verizon is among the industry leaders in deploying fiber throughout its Pennsylvania network. Coupled with Verizon's other achievements under the plan, i.e.,

- 100 percent of Verizon-PA's central offices are equipped with digital switches;
- 100 percent of Verizon-PA's network is controlled by an Intelligent Network Signaling protocol;
- 100 percent of all Verizon-PA's consumers have Integrated Services Digital Network (ISDN) service available;
- 100 percent of all Verizon-PA's Interoffice Facilities (IOF) are fiber; and,
- 100 percent of all schools, health care facilities and industrial parks in Verizon-PA's service territory have broadband facilities readily available;

we conclude that Pennsylvanians are among those citizens most well served with a modern, forward-looking efficient network.

II. BROADBAND DEVELOPMENT

The term “broadband” originated when the industry needed a handle for services that required bandwidth (or capacity) greater than the standard telephone. In fact, the 1998 edition of Newton’s Telecom Dictionary defines broadband as just that: “a transmission facility that has a bandwidth greater than a voice grade line of 3 kHz.” Services that could be provided over voice grade lines, on the other hand, were called “narrowband” services. Traditional modems (14.4 kbps, 28.8 kbps, and 56 kbps), for example, operate over a standard voice grade line.[3] Even before the Internet, consumers used 14.4 kbps modems to connect to electronic bulletin boards and other computer-based electronic services. At the time when “narrowband” and “broadband” concepts were first introduced these handles provided a sufficient distinction between voice-grade-bandwidth and non-voice-grade-bandwidth transmission capacity, technology and services. However, as the Internet developed throughout the 1990s, and technology pushed the envelope of transmission speeds to higher rates, the meaning of the term “broadband” became less clear. It was in the midst of this communications revolution that the FCC, for the first time, defined “broadband” for the entire industry. Some background is helpful to understand the environment under which the FCC created this definition.

In 1996, on the heels of the phenomenal growth of the Internet, Congress—acting to ensure that everyone would have an opportunity to reach the information superhighway—formally addressed *broadband* as it affected all Americans. The Telecommunications Act of 1996 included a section titled “Advanced Telecommunications Incentives” that was intended to ensure the deployment of broadband services across the country. Section 706 of the Act requires the FCC to determine whether “advanced telecommunications capability” is deployed on a reasonable and timely basis to all Americans[4] and, if not, mandates that the Commission “shall take immediate action to accelerate deployment of such capability by removing barriers

[3] The term “kbps” is kilobits per second, signifying the speed of a connection. Computer information is transmitted in “bits”, so 56 kbps would mean that 56,000 bits are being transmitted per second. Similarly, 1.5 Mbps would be 1,500,000 bits being transmitted per second.

[4] Section 706 (b).

to infrastructure investment and by promoting competition in the telecommunications market."[5] Congress loosely defined "advanced telecommunications capability" as (1) "without regard to any transmission media or technology," and (2) "as high speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology."[6]

It was in this context—i.e., in order to monitor the status of broadband deployment—that the FCC defined broadband, or "advanced telecommunications" as the Act used the term. Following its Notice of Inquiry,[7] the Commission evaluated comments from numerous parties on the subject of "broadband" and how best to monitor its development. The Commission ultimately issued a decision in 1999 that defined broadband as a transmission capacity rate over 200 kbps.

> … we define "broadband" as having the capability of supporting, in both the provider-to-consumer (downstream) and the consumer-to-provider (upstream) directions, a speed (in technical terms, "bandwidth") in excess of 200 kilobits per second (kbps)[8]

It is also useful to review the transmission capacity rate that other members of the telecommunications community argued constituted "broadband." For example, WorldCom and MCI filed comments that characterized broadband as "any transmission facility that has a bandwidth of greater than 1.5 Mbps bandwidth," ensuring "sufficient capacity, or bandwidth to permit the transmission of sizeable amounts of information or bits."[9] AT&T also filed comments in the proceeding, stating that "given the current state of technology [broadband services] should include telecommunications facilities that can support information transfer at speeds greater than 128 kbps," which is the speed provided by ISDN.[10] The Progress and

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[5] Section 706 (b).

[6] Section 706 (c)(1).

[7] Notice of Inquiry, Docket No. 98-148, August 7, 1998.

[8] Report, CC Docket No. 98-146, February 2, 1999 ¶20.

[9] Joint Comments of MCI Communications Corporation and WorldCom, Inc., CC Docket No. 98-146, September 14, 1998, at 6.

[10] Comments of AT&T Corp, CC Docket 98-146, September 14, 1998, at 5.

Freedom Foundation also filed comments, suggesting that broadband be defined as transmission of 1.5 Mbps in the downstream direction and 384 kbps in the upstream direction.

Another source for the definition of broadband service is in federal legislation. There have been a number of bills that have been introduced in the House of Representatives and US Senate which include a definition of broadband for purposes of the bill. For example, the Broadband Internet Access Act of 2001 (S. 88 and H.R. 267) defined broadband service as 1.5 Mbps in the downstream direction and 200 kbps in the upstream direction, the Broadband Competition and Incentives Act of 2001 (H.R. 1697) defined broadband service as 1.5 Mbps in the downstream direction and 128 kbps in the upstream direction, and the Broadband Regulatory Parity Act of 2002 (S. 2430) defined broadband services as a service capable of transmitting at a rate that is generally not less than 256 kilobits per second in at least one direction.

The following table summarizes a number of different definitions for broadband service.

Broadband Capacity

	Downstream (Mbps)	Upstream (Mbps)
FCC	0.200	0.200
AT&T	0.128	0.128
MCI & WorldCom	1.500	
Progress & Freedom Foundation	1.500	0.384
Association for Local Telecommunications Services[11]	0.100	0.100
David Gabel[12]	0.256	0.256
Residential Broadband Users Association[13]	0.256	0.256
Broadband Competition and Incentives Act of 2001 (H.R. 1697)	1.500	0.128
The Broadband Regulatory Parity Act of 2002 (S. 2430)	0.256	
Broadband Internet Access Act of 2001 (S. 88)	1.500	0.200
Internet Freedom and Broadband Deployment Act of 2001 (H.R.1542)	0.384	

The table demonstrates that while there is a consensus that the "broadband" transmission capacity rate should be greater than the capacity obtainable over a standard voice grade line, there is no industry consensus on a specific transmission capacity rate. At a maximum, the range of suggested rates never exceeds 1.5 Mbps in the downstream direction and 384 kbps in the upstream direction. Markets for any service develop as the confluence of

[11] HAI Consulting, "Economics and Technology of Broadband Deployment," Prepared for The Association For Local Telecommunications Services, September 25, 1998, in response to Memorandum Opinion and Order and Notice of Proposed Rulemaking, CC Docket No 98-147, August 7, 1998.

[12] David Gabel and Florence Kwan, "Accessibility of Broadband Telecommunications Services by Various Segments of the American Population," Telecommunications Policy Research Conference, August 2000. Gabel and Kwan defined advanced services as "available where a customer can obtain either xDSL or cable modem services."

[13] http://www.rbua.org/announce/03-16-01.php. The RBUA represents users of cable modems, DSL, and other broadband technologies.

demand and supply considerations. Demand develops as a consequence of consumers' tastes and willingness to pay. Supply develops as a consequence of available production technologies, their costs and service providers' willingness to innovate. There is little or no incentive, for example, for service providers to expend research and development resources to develop services that can take advantage of a transmission capacity rates beyond 1.5 Mbps if the technology being implemented throughout the U.S. is currently 1.5 Mbps. Similarly, it makes no sense for equipment manufacturers (e.g., modems, network cards etc.) to develop equipment commensurate with faster transmission capacity rates when the industry (consumers and producers together) are focused on services that operate within the range of 200 kbps – 1.5 Mbps.

A. Broadband Technologies

There are a number of different technologies that providers use to bring broadband services to consumers. While the most common technologies are Cable Modems and Digital Subscriber Line (DSL), demand for other technologies such as Fixed Wireless and Satellite is growing. Bandwidth capability, reliability and cost are all factors that contribute to demand for various broadband technologies. The tables below summarize the typical bandwidth realized and capital cost per home served of the most common broadband technologies. A discussion of each technology immediately follows the tables. An important note is that the technologies below are primarily intended to provide access to the Internet for residential consumers. Businesses often have additional broadband requirements, particularly for high speed data networks and intra-company networks. For example, businesses in Pennsylvania purchase HiCap and Frame Relay services that operate at significantly faster transmission rates (up to 34 Mbps and 45 Mbps respectively).

Downstream Broadband Technology Transmission Rates Realized by Residential Users[14]

Broadband Technology	Typical Realized Transmission Rate (Mbps)	Maximum (Mbps)
Cable Modem – Hybrid Fiber Coax (HFC)	0.500 – 1.000	27
ADSL	0.256 – 0.500	8
Fixed Wireless	2.000	5-10
Satellite	0.400	1
Fiber	1.000 – 100.000	622

Upstream Broadband Technology Transmission Rates Realized by Residential Users[15]

Broadband Technology	Typical Realized Transmission Rate (Mbps)	Maximum (Mbps)
Cable Modem – Hybrid Fiber Coax (HFC)	0.256 - 0.500	10
ADSL	0.256 - 0.500	0.640
Fixed Wireless	0.500 – 2.000	2
Satellite	0.030 – 0.040	0.150
Fiber	1.000 - 100.000	155

Typical Cost of Broadband technologies[16]

Broadband Technology	Capital Cost per Home Served
Cable Modem – Hybrid Fiber Coax (HFC)	$400
ADSL	$500
Fixed Wireless	$650-1300
Satellite	$1000 + Cost of Earth Station
Fiber	$2000-$6000

[14] Emy Tseng, "Competition in Fiber to the Home: A Technology and Policy Assessment," Massachusetts Institute of Technology, September, 2001, at 17.

[15] *Ibid.*

[16] Carnegie Mellon University and 3 Rivers Connect, "Digital Rivers Final Report," April 11, 2002, Section 2, page 5.

1. Cable Modem (Hybrid-Fiber Coax)

An HFC network is one that has been upgraded with fiber-optic cable installed from the provider premises (e.g., the central office or the cable head-end) to a neighborhood node. Then coaxial cable runs from the node to each individual business or home. Each node serves about 500 to 1,000 end users.[17] While HFC can be used for both cable television and Internet services, adding video dial tone capabilities (discussed below in the section on broadband services) can more than double the capital cost per home.[18]

2. Digital Subscriber Line

Digital Subscriber Line (DSL or xDSL) is a technology employed by telephone companies to provide a broadband transmission capacity rate using existing copper plant.[19] It is a modem-based technology which means that (1) it can be quickly provisioned to subscribers; (2) the equipment is portable and may be recovered and reused when a customer terminates service; and (3) it makes network upgrades less problematic because upgrading only requires changing equipment on the ends of the copper cables.[20]

There are a number of reasons why incumbent telephone companies like Verizon offer broadband services over existing copper facilities. To begin, the copper is already installed. Second, technology continues to increase the capacity transmission rates that are attainable over copper distribution plant. While many telecommunications analysts are excited over the prospects of Fiber to the Home (or FTTH, which we discuss below), there are other analysts who continue to question the need for fiber when the capacity transmission rate of copper continues to meet the demands of the market. A senior analyst with Aberdeen Group summarizes the issue when he says "You've got ADSL [asymmetric digital subscriber line],

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[17] Emy Tseng at 17.

[18] Nosa Omoigui, Marvin Sirbu, Charles Eldering, and Nageen Himayat, "Comparing Integrated Broadband Architectures from an Economic and Public Policy Perspective," Telecommunications and Internet Policy, Brock, G. ed. (Lawrence Erlbaum: Washington, DC, 1996).

[19] There are various flavors or DSL, such as ADSL, or SDSL. Therefore, DSL as a general technology is also referred to as xDSL, where x can be any of a number of letters signifying specific capabilities.

[20] G Young, KT Foster, and JW Cook, "Broadband Multimedia Delivery Over Copper," BT Technology, October 4, 1995; Emy Tseng.

SDSL [symmetric DSL] and eventually VDSL [very high data rate DSL]. It's continually pushing the envelope of the copper plant."[21] Other analysts similarly are not convinced that copper itself has hit an absolute bandwidth (i.e., capacity transmission rate) ceiling. Modem technology climbed steadily from 100 bps to 53 kbps, all over voice grade lines, and as one analyst put it, "at each stage, scientists told us how they achieved the dramatic increase in bandwidth, and the stories usually ended with 'and this is all we can wring out of this technology.' It's never been true."[22]

This underscores how important the evolution of transmission capacity rate technology is to the evolution of the overall broadband market. As technological change increases the transmission capacity rate of the existing copper network, the relative cost of making increased bandwidth available to broadband service providers falls.[23] This, in turn, provides more incentive for service providers to develop new service concepts that take advantage of the increased transmission rates at prices within reach of enough consumers to make the venture profitable. As new service concepts are made available to consumers at lower and lower prices, the demand side of the market develops tastes for new services that are within the willingness to pay of a large number of customers. This is a natural synergistic process that, over time, will result in an overall broadband market with faster transmission rates and more attractive services.

Local exchange carriers have been using DSL technology beginning in the mid 1990s when it became apparent that DSL was a cost-effective technology to bring broadband services to the market over the existing telephone network. Companies like Verizon had experimented with HFC and Switched Digital Video systems, only to run into cost, reliability and performance issues.[24] Another important issue that arose during construction of these earlier broadband architectures was the lack of vendor support for the technologies. According to

[21] Brian Washburn, "Fiber Home Economics," Tele.com, November 27, 2000.

[22] Tom Yager, "Will Fiber Optics Overtake Copper In The Backbone," InfoWorld, March 23, 2001.

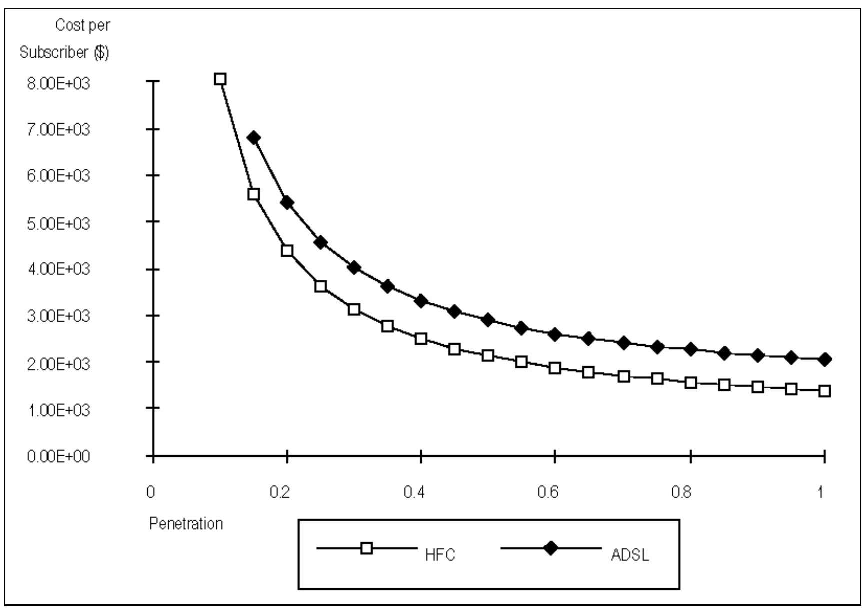
[23] This is enhanced when, like in Pennsylvania, 100 percent of all interoffice facilities are fiber and all switches are digital.

[24] Verizon-Pennsylvania response to Staff Interrogatory I-10, March 20, 2002; Bell Atlantic-Pennsylvania, Second Biennial Update to its Network Modernization Plan, June 3, 1998, at 11.

Verizon, during the testing and initial builds of their SDV network, vendors were significantly behind schedule in their development efforts.[25] This was likely due to the fact that the vendors were noticing the change in the overall broadband market towards Internet-based services, and devoting their own resources to products for which the future prospects were brighter.

In terms of the cost differences between broadband technologies, there is a particularly relevant study from 1995. The study looked at the cost of a video dial tone infrastructure for local exchange carriers with two architectures: DSL and HFC.[26] There were two scenarios within the study. The first scenario modeled a fixed cost comparison between DSL and HFC architectures retrofitted into a residential local loop. The second scenario modeled new installations. The results were telling for local exchange carriers. The following graphs are taken directly from the study.

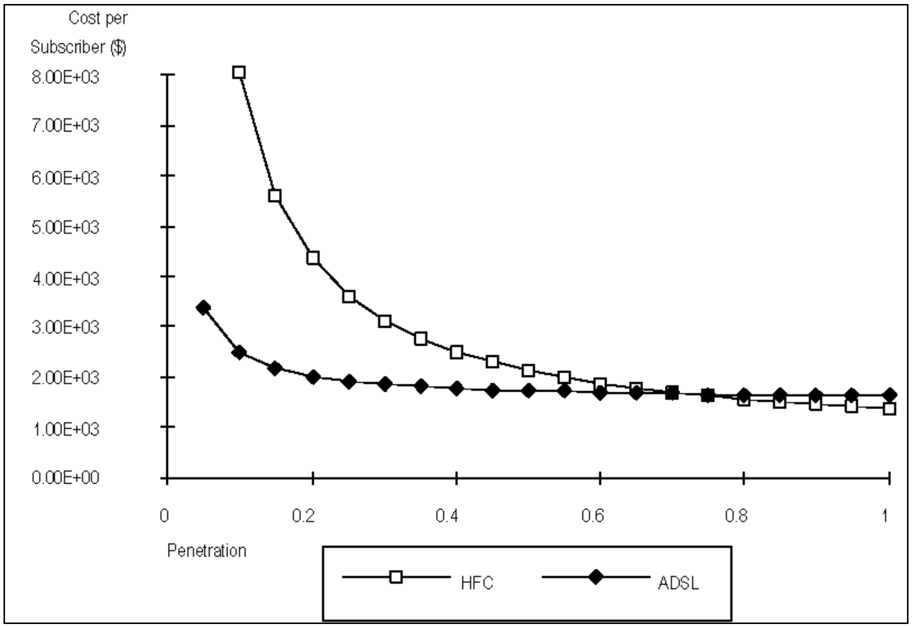
Cost of New Installation DSL vs. HFC



[25] Verizon-Pennsylvania response to Staff Interrogatory I-10, March 20, 2002.

[26] Joseph P. Bailey, “Modeling the Economics of Imperfect Interoperability for Telecommunications,” 3rd International Conference on Telecommunications Systems Modeling and Analysis, March 16-19, 1995.

Cost of DSL Retrofit vs. HFC New Installation



As the graphs illustrate, while it may have appeared that HFC was a better choice for new installations, the DSL option was better for retrofitting the network. Since telephone companies like Verizon have an installed network, most of their work would be retrofitting. This study therefore helps explain why companies like Verizon abandoned HFC and Switched Digital Video systems in favor of the DSL technology. Of course, as discussed below, video dial tone soon took a backseat as the Internet grew—creating a broadband service that provided customers with much more than just movies on demand.

3. Fixed Wireless

Fixed Wireless technology uses microwave facilities and spectrum to transmit data from points close to homes and businesses *into* the homes and businesses. It is attractive to providers because it allows them to avoid the large capital expenditure of deploying wireline facilities. For that reason, it also allows providers to quickly enter a market. There are, however, issues concerning the use of a fixed wireless technology, including

1. technical issues such as line of sight: fixed wireless receivers must be positioned in a certain way on roofs in order to receive signals most reliably.

2. rights-of-way: e.g., roof rights (finding sites for antennas), and

3. spectrum: lack of available spectrum in an area can limit fixed wireless capability.[27]

4. Satellite

Satellite systems use satellites orbiting the earth to provide broadband services. As the table above illustrates, however, there is limited upstream bandwidth capability The success of satellite systems in the future will depend, therefore, on improvements in technology and how future services use bandwidth.

5. Fiber to the Neighborhood

Fiber to the Neighborhood (FTTN) refers to a telecommunications network where fiber extends to a node close to homes and businesses but not entirely to the home. Telephone companies, for example, are using Digital Loop Carrier technology and deploying fiber from the Central Office out to a Remote Terminal (RT), which is essentially a pedestal or cabinet located in a customer neighborhood serving homes and business with a 9,000-12,000 feet range. Verizon-PA's DLC deployment in Pennsylvania extends to RTs throughout its infrastructure, and in creating this infrastructure, the Company has increased the amount of fiber in its network by 80 percent since 1995.[28] Verizon-PA's commitment to bring fiber closer to Pennsylvania's consumers is also evident in the Company's recent petition to amend its Network Modernization Plan. In the petition the Company proposes to extend fiber (or a comparable technology) to each and every RT in its network by 2015, with interim benchmarks.[29] This is the type of commitment that will keep Verizon's network positioned to accommodate emerging technologies to connect Pennsylvania consumers with broadband technologies (which could even include technologies like wireless local loops).[30]

[27] Emy Tseng at 18.

[28] Data obtained from the FCC ARMIS Data Retrieval System, 43-07, Table II.

[29] Verizon Pennsylvania Inc.'s Petition to Amend Network Modernization Plan, Docket No. P-00930715.

[30] *Ibid.*

6. Fiber to the Home

A Fiber to the Home (FTTH) network extends fiber all the way to the home or business. While fiber technology is currently capable of providing the greatest transmission capacity rate, the viability of FTTH has long been a question of consumers' willingness to pay, the availability of desirable consumer services, and equipment for consumers to use the services provided over the technology.[31] In order for consumers to take advantage of the bandwidth capabilities of FTTH, applications have to be developed that will use this bandwidth and consumers have to be willing to pay the price for these services—a proposition that hasn't materialized yet.

Cost (not to be confused with price) estimates of fiber installation range from $25,000 to $750,000 per mile.[32] Insofar as incumbents like Verizon already have an existing copper plant, bringing fiber to each and every home (i.e., replacing copper with fiber) becomes a costly proposition. As a result, the use of FTTH is most prevalent with new upscale developments rather than in existing neighborhoods. Real estate developers, for example, have found that installing fiber to the home can increase the value of new housing developments.[33] What real estate developers are finding is exactly what we would expect in a developing market like that for broadband. As tastes and preferences become known, vendors move to meet those tastes and preferences—just as real estate developers are doing today with fiber.

B. Broadband Services

It is appropriate at this stage to turn from broadband *technologies* to broadband *services* and emphasize the distinction. Just as broadband technologies have changed over time, so too have broadband services. Importantly, at the time that Verizon-PA's NMP was proposed, broadband services were very different from what they are today. In 1993, broadband services consisted of "high speed" facsimile, "high speed computer communications," and video

[31] For example, a typical computer is sold today with the ability to connect to a copper network (Ethernet), but not a fiber network.

[32] Emy Tseng at 24.

[33] Brian Washburn, "Fiber Home Economics," Tele.com, November 27, 2000.

teleconferencing.[34] Today the use of the Internet has vastly altered the nature and need of each of these services. The Internet has revolutionized the delivery of broadband services. High speed facsimile has been replaced with documents that can be sent through email. High speed computer communication, which was text-based in 1993, is now a high speed integrated network of hundreds of computers with graphic interfaces. Back in 1993, computer communication consisted of email, distributed mailing lists, and bulletin board systems. Today, such communication channels are enhanced by chat rooms, instant messaging, online presentations, and more.

The concept of video teleconferencing has also expanded. It is no longer a stand-alone service exclusively marketed to the affluent corporate community. Today, anybody can buy a video camera for less than $100, connect to the Internet for less than $50 a month, and teleconference with anyone else on the Internet anywhere. In fact, companies like MeetingPlace.com are now offering video conferencing via the Internet:

> Now you can sign up your whole department and get unlimited Web Conferencing for an unbeatable $99 per month plus integrated Voice Conferencing for only $.06 per minute per participant.[35]

This is precisely the same service functionality that people were talking about back in 1993 when video teleconferencing was discussed in Verizon's Alternative Regulation Plan. The only difference now is that it is being offered over an entirely different broadband technology/service combination—the internet. Whereas video conferencing back in 1993 was assumed to require a bandwidth of 45 Mbps, today an ADSL access transmission system can deliver digital stereo sound and a picture quality comparable to that of a domestic VCR.[36] Indeed, when the FCC defined broadband as 200 Kbps it did so "because [200 Kbps] is enough

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[34] Bell Telephone Company of Pennsylvania, "The Bell Telephone Company of Pennsylvania's Alternative Regulation Plan," October 1, 1993, at 22.

[35] http://www.meetingplace.net/signup/default.asp

[36] G Young, KT Foster, and JW Cook, "Broadband Multimedia Delivery Over Copper," BT Technology, October 4, 1995, at 84.

to provide the most popular forms of broadband—to change web pages as fast as one can flip through the pages of a book and *to transmit full-motion video*."[37]

While it is impossible to predict what the future will hold for broadband services, it would not be unreasonable based on what we know today to assume that most broadband services in the next 10-15 years will be accessed via the Internet. For that reason, it is important to discuss two technical issues. First, there is the issue of *downstream vs. upstream transmission capacity rate requirements*. As Dr. Lee Selwyn (a recurring critic of Verizon's network modernization in Pennsylvania) has recognized, most current Internet users are predominantly downstream users.[38] That is, they read, view, or listen to information obtained *from* the Internet. There is much less demand for upstream bandwidth capacity, particularly from residential consumers. Upstream capacity is important for content providers—i.e., those service providers that make information available on the Internet. Thus, easily obtaining information from the Internet requires a greater bandwidth capacity in the downstream direction, and a speed of 1.5 Mbps virtually assures instantaneous transmission of the information.

Evidence from industry participants in general supports the same view. The National Cable and Telecommunications Association recently filed comments in response to a National Telecommunications and Information Administration (NTIA) investigation into the deployment of broadband services stating that a symmetrical view of broadband services

> does not properly account for the substantially greater demand of consumers to receive broadband transmissions. Consumers who choose to acquire cable modem service focus almost exclusively on the downstream capability. The vast majority of these residential customers do not operate servers in their homes. As a result, they do not need upstream speeds required to send sizeable quantities of information to others. Instead, they want to access data from the

[37] Report, CC Docket No. 98-146, February 2, 1999 ¶20.

[38] Lee L. Selwyn, Scott C. Lundquist, and Scott A. Coleman, "Bringing Broadband to Rural America: Investment and Innovation In The Wake of the Telecom Act," Economics and Technology, Inc., September 1999, at 6.

> internet or from other users, efficiently, primarily in the form of mouseclicks or text from a computer keyboard.[39]

AT&T also filed comments in NTIA's proceeding, stating,

> consumers, particularly residential consumers, spend most of their time on the internet downloading information…activities include participating in chat rooms, engaging in financial transactions and downloading MP3 music files. These applications do not require fast upstream transmission, but they benefit from improved downstream capacity…even Web pages created by a subscriber can be uploaded from a conventional PC.[40]

There is no reason to expect the current asymmetric transmission capacity requirement to change any time soon. Industry analysts and network providers today expect that broadband services in the next 10-15 years will likely require more downstream bandwidth relative to upstream bandwidth. For example, in a filing before the FCC, AT&T stated that "many broadband technologies that will be widely available to consumers in the near future support greater downstream bandwidth than upstream."[41]

The current and expected future demand for an asymmetrical transmission capacity means that broadband technologies like DSL and Cable Modems are well designed to accommodate Internet access now and in the future. Recall from the table above that these technologies generally offer faster transmission speeds downstream than they do upstream.

The transmission capacity rate alone is not, however, the only factor to consider when considering future broadband services. A second technical issue is *compression technologies.* Compression technologies (a service provider innovation) can dramatically affect the mix of services that can be offered over broadband facilities.[42] Consider MPEG-1 Layer 3, or MP3 as

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[39] Comments of the National Cable and Telecommunications Association, In The Matter of Deployment of Broadband Networks and Advanced Telecommunications, NTIA, Docket No. 011109273-1273-01, December 19, 2001.

[40] Comments of the AT&T Corp., In The Matter of Deployment of Broadband Networks and Advanced Telecommunications, NTIA, Docket No. 011109273-1273-01, December 19, 2001.

[41] Comments of AT&T Corp, CC Docket 98-146, September 14, 1998, at 6.

[42] In the computer industry, compression is the process of using a fewer number of bits to store the same information, or to store enough information to create a sufficiently good replication of the original information. For example, a 3-minute song on a CD requires roughly 50,000,000 bits of information. The same song can be

(continued...)

it is more commonly known. MP3 was created in 1985 as an audio compression component, and in 1992 was adopted by the Moving Pictures Experts Group to incorporate within their video compression technology MPEG-1.[43] The MP3 audio compression technology has dramatically changed the music industry. Record labels are scrambling to adapt to a rapidly changing environment that was made possible by compression technologies.

Most entertainment industry analysts expect that the film industry is next in line for a digital revolution. Film enthusiasts can already download illegal copies of movies from services like Kazaa and Morpheus over the Internet using transmission capacity rates available with DSL and cable modem services.[44] A compression program called DivX has been created by DivxNetworks, Inc. that enables anyone to encode a DVD movie. The DivX encoded movies are small enough that they can be downloaded from the Internet using a standard DSL or cable modem technology and viewed on a standard personal computer.[45] Additionally, there are internet sites like FastTrackMovies.com that also have a database of movies and television shows that consumers can download and view on demand. It is only a matter of time before services like *Video-On-Demand* are made available via broadband technologies like those offered in Pennsylvania today. As one analyst put it, "DSL service providers are perfectly positioned to offer Video on Demand services to their DSL subscribers at some point in the future."[46]

(...continued)

compressed to 4,000,000 bits of information, with minimal loss of sound quality using a compression technology like MP3.

[43] http://www.mp3-mac.com/Pages/History_of_MP3.html. The Moving Pictures Experts Group is not an industry group, but rather a subcommittee of the International Standards Organization/International Electrotechnical Commission.

[44] Indeed, the same downloads are available to consumers using 56 kbps modems and ordinary telephone lines. It just takes longer. Consumers making the choice to use 56 kbps modems and ordinary telephone lines indeed evidence that not all consumers are yet willing to pay for more rapid transmission capacity rates available via DSL or cable modem services.

[45] http://www.Divx.com

[46] Stuart McLeod, "The Network Letter: Debunking DSL Myths," The ATM and IP Report, September/October 2001.

C. Broadband is an Evolving Market

The take-away from reviewing broadband services is that the overall broadband market is not static; it is constantly evolving. Just as broadband technologies change (HFC, SDV, DSL, etc), so too do broadband services and the requirements of those services. The services that today's market is demanding are being met with broadband technologies like cable modems and DSL. Consumers today are demanding video teleconferencing, movies, music, and instant messaging. All these services are *currently* available over *current* broadband technologies. Tomorrow's services may also be available using current broadband technologies; nobody knows for sure until those services are created. Therefore, it simply doesn't make economic sense for anyone to build what some claim would be a better broadband network to each residential doorstep when there are no services yet available to make use of that network. Even if a network provider could offer faster transmission capacity rates directly to the door of each and every consumer in the U.S., to do so would likely be a huge waste of resources. There is currently no need for an ubiquitous presence of a very high-speed type of broadband technology today for residential consumers. In fact, due to the widespread use of 1.5 Mbps technology throughout the Internet by "surfers" and "hosts" alike, it is quite likely that even if a residential consumer were able to subscribe to a service offering transmission rates faster than 1.5 Mbps, they would rarely, if ever, use the full capacity of their broadband technology. Businesses, on the other hand, demand (and are provided with) faster transmission rates for data-centric services like Frame Relay and HiCap.

III. VERIZON'S NETWORK MODERNIZATION PLAN

Created in accordance with statutory obligations, Verizon's Network Modernization Plan (NMP) sets forth commitments and obligations designed to ensure the deployment of an advanced telecommunications network throughout the Commonwealth. While the statute does not specify a deployment schedule for broadband transmission capacity availability, the NMP outlines the overall deployment schedule and includes a specific deployment schedule for technologies necessary to support broadband services.[47] Also, the Company is required to provide the Commission with a status report indicating its achievement every two years. The First Biennial Update was filed on June 28, 1996, the Second Biennial Update was filed on June 3, 1998, and the Third Biennial Update was filed on June 14, 2000.

1. Deployment Schedules and Commitments

Appropriately, the Company's NMP does not require a specific broadband technology, but only sets the requirements for broadband transmission capacity availability. Additionally, the plan sets schedules for fiber and digital technology deployment in the network.

The technology commitments and measurement standards in the Company's NMP were summarized by the Commission in its June 22, 1995 order approving the plan as follows:

- Intelligent Network Signaling: Percentage of access lines whose service switch is equipped to provide CLASS and IQ services.[48] Commitment to 100 percent by 1994.
- Integrated Services Digital Network: Percentage of access lines whose serving switch is equipped to provide ISDN service, divided by total access lines. Commitment to 100 percent by 2000.
- Digital Switching: Percentage of access lines connected to a digital switch, divided by total access lines. Commitment to 100 percent by 2000.
- Interoffice Facilities:

[47] Although Chapter 30 does not require that specific broadband services be deployed, it does specify that broadband service is defined as a service provided at speeds of at least 1.544 Mbps.

[48] CLASS and IQ services are the trade names for a variety of call management and call processing services that intelligent network signaling capability allows.

  - Percentage of access lines where corresponding interoffice connections have a fiber optic (or comparable technology) presence, divided by total access lines. Commitment to 100 percent by 2000.
  - The number of fiber optic sheath kilometers.
  - The percentage of circuit links on fiber optic (or comparable facilities), divided by total circuit links. Commitment to 100 percent by 2000.
- Broadband Services:
  - Percentage of access lines that subscribe to broadband services or have broadband available, divided by total access lines. Commitment to 20 percent in urban, suburban, and rural areas by 1998, 50 percent by 2004, and 100 percent by 2015.
  - Percentage of broadband facilities in or adjacent to the nearest right of way to health care facilities, public schools and industrial parks—the entity will be counted as having broadband available when fiber optic facilities (or comparable technology) are located in or adjacent to the nearest right of way. Commitment to 100 percent by 2000.

2. Commitments Met

There are a number of technology commitments in the Company's NMP plan that have already been satisfied. The pace at which Verizon-PA has modernized its network enabled the Company to meet each of these commitments on time or ahead of schedule. The following table summarizes Verizon-PA's track record with these already-satisfied commitments.

Commitment		Goal	Achieved
Intelligent Network Signaling	Serve 100 percent of access lines by switches equipped to provide CLASS and IQ services	1994	1994
Integrated Services Digital Network	Serve 100 percent of access lines by switches equipped to provide ISDN service	2000	1995
Digital Switching	Serve 100 percent of access lines with digital switches	2000	2000
Interoffice Facilities	Provide 100 percent of access lines with a fiber optic (or comparable facility) interoffice connection	2000	2000
	Provide 100 percent of circuit links on fiber optic (or comparable facilities)	2000	2000
Broadband Transmission Facilities	Make broadband facilities available to 100 percent of health care facilities, public schools and industrial parks using the nearest rights-of-way to the institutions	2000	2000

With the commitments cited above completed, Verizon has succeeded in making the backbone infrastructure of its network fully compatible with transmission capacity rates of virtually any conceivable magnitude. That is, as the market for broadband services develops, as service innovators avail themselves of new technology and affordable transmission rates, Verizon's network is well positioned to deploy the cost efficient technology required to bring a high bandwidth connection to any home or business in Pennsylvania. The preparatory work has been done to support the market-driven technologies and service innovations that were envisioned by the NMP.

In addition to completing these commitments, Verizon has also been rapidly installing fiber facilities throughout its Pennsylvania network. According to the Company's Third Biennial Update, as of the end of 1999, Verizon-PA had deployed over 911,000 miles of fiber optic cable in Pennsylvania, an almost 40 percent increase from the Second Biennial Update.[49] In fact, between passage of Chapter 30 and its Third Biennial Update, Verizon-PA installed more fiber in its network than it had in the preceding 15 years combined.[50]

With all the fiber in Verizon's interoffice network, the Company is well-positioned for the future demands of broadband should the technologies be fiber-based. The Company has one of the highest levels of fiber sheath kilometers in the country (31,359 km). However, an even better descriptive measure of network modernization is the ratio of fiber to copper sheath kilometers. This ratio eliminates the bias in favor of larger states, and offers a measure of the intensity to which fiber is employed in a network. Using this measurement, recent ARMIS Report 43-07 data indicates that Verizon's ratio of fiber/copper sheath kilometers in Pennsylvania ranks second among all former BOCs reporting data at the state level. Pennsylvania's high ranking is particularly significant considering that 37 of the 47 states that report BOC data have less than half as much fiber sheath in their network as Verizon does in Pennsylvania. Verizon-PA is clearly among the industry leaders in deploying fiber throughout the network.

3. Remaining Commitments

The Company has ongoing NMP commitments to make broadband transmission facilities available to its rural, suburban, and urban customers in Pennsylvania. In addition to committing to 100 percent availability by 2015, Verizon has committed to interim milestones. The table below summarizes these commitments, and the Company's estimated performance to date. Note that the reporting methods for 1996-1997 are consistent (reflecting consumers that have access to 2 spare fibers in the network); however in 1999 the Company changed its reporting method. In 1999 "broadband availability" also included consumers who could obtain DSL services at least 18kft from the central office.

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[49] Bell Atlantic-Pennsylvania, Third Biennial Update to its Network Modernization Plan, June 14, 2000, at 2.

[50] *Ibid.*

Broadband Availability[51]	1996	1997	1998	1999	2004	2015
Commitment (all areas)			20%		50%	100%
Achievement – Urban	30%	31%		78%		
Achievement – Suburban	21%	28%		57%		
Achievement – Rural	11%	19%		31%		

As the table reflects, by 1997 Verizon-PA had already exceeded its commitment for urban and suburban areas and was only one percent off from its 1998 commitment in the rural area. While the Company did not report estimates for 1998, the Second Biennial Update stated that Verizon-PA would meet its 1998 commitment. Indeed, by the end of 1999 Verizon had surpassed 30 percent availability for its entire serving territory. Today Verizon-PA has already met its 2004 commitment level for the urban and suburban consumers, and is on its way to meet its commitment for rural consumers in the next two years.

The Company is using a number of broadband-based services to meet its commitments. While the majority of residential consumers demand transmission rates suitable for Internet service (1.5 Mbps), other consumers demand higher transmission rates. Verizon is aggressively providing services for these customers that demand higher transmission rates as well. Some of these data-centric and transport-based services are listed in the table below.

[51] The concept of "broadband availability" is being used consistently with Verizon's use of it in their biennial updates. The estimations reported in this table were obtained from Verizon's Second, and Third Biennial Update.

Verizon Pennsylvania Service	Transmission Speed (Mbps)
Switched Multimegabit Data Service (SMDS)	34
Frame Relay	45
Asynchronous Transfer Mode (ATM)	155
Transparent LAN Service (TLS)	10
Transparent LAN Service (TLS)	100
Fully Distributed Data Interface (FDDI)	100
High Capacity Digital Data & Fast Packet Circuits (HiCap)	1.5
High Capacity Digital Data & Fast Packet Circuits (HiCap)	45
High Capacity Digital Data & Fast Packet Circuits (HiCap)	155
High Capacity Digital Data & Fast Packet Circuits (HiCap)	622
Fiber Optic SONET Rings	155
Fiber Optic SONET Rings	622
Fiber Optic SONET Rings	2,500 (2.5 Gbps)
Fiber Optic SONET Rings	10,000 (10 Gbps)

IV. PENSYLVANIA INFRASTRUCTURE BY COMPARISON

The NMP outlines a number of objectives and measurement standards for tracking the deployment of broadband facilities in Pennsylvania. However, there also exists a rich set of publicly available data that provides additional measurements, as well as an ability to compare Pennsylvania's overall infrastructure development to that of other states. The data is available from ARMIS reports, a set of annual reports by each Bell Operating Company. In particular, the ARMIS 43-07 report includes a number of measurements applicable to infrastructure development, some of which are already included in the NMP, and discussed above.

In Promises Fulfilled we used the measurements that are available from ARMIS 43-07, and calculated the Company's overall ranking among Bell Operating Companies (at the state level) with respect to infrastructure development.[52] Specifically, we compared the following measurements at the state level:

- Percent of switches that are digital.
- Percent of switches equipped with SS7.
- Percent of switches equipped with ISDN.
- Fiber carrier links as a percentage of total carrier links, where a carrier link is defined as a segment of the interoffice network disaggregated by technology (i.e., analog, digital); and by medium (i.e., copper, fiber, or radio).
- Digital circuit links as a percentage of total circuit links, where a circuit link is a link that exists between points A and B where voice frequency/DS0 cross-connects and/or analog/digital conversion occurs.
- The ratio of fiber strands to copper pairs terminated at the Central Office or Main Frame respectively.
- Ratio of fiber digital carrier working channels to copper working channels.
- Ratio of fiber digital carrier equipped channels to copper equipped channels.
- Ratio of fiber sheath kilometers to copper sheath kilometers.

[52] William E. Taylor, Charles J. Zarkadas, Agustin J. Ros, and Jaime C. d'Almeida, "Promises Fulfilled: Bell Atlantic-Pennsylvania's Infrastructure Development," National Economic Research Associates, January 15, 1999.

Ranking the BOCs in each state on each of these indices and applying the same weight to each measurement yields an annual ranking for each BOC on a state-specific level; and comparing the annual rankings between different years indicates a measure of infrastructure development and network modernization over that period in that state by that BOC.

Our results three years ago (using data through 1997) indicated that in both 1992 and 1997 Verizon's infrastructure development in Pennsylvania ranked in the top ten among all BOC activity with respect to modern infrastructure development. Verizon-Pennsylvania was 7th overall in infrastructure development, maintaining its overall high ranking from 1992 to 1997. The Company was in fact 1 of only 4 in the top ten that had improved or maintained its standing from 1992 to 1997.

For this report we extended the ARMIS analysis to include data from 2001, reflecting the most current ARMIS data available. The new data tells the same story; Verizon-Pennsylvania continues to be an industry leader in modern infrastructure development. The Company maintained its top ten ranking through 2001, and in fact improved from 7th overall in 1992 and 1997 to 5th overall in 2001. This makes Verizon-Pennsylvania the only top-ten BOC to have improved or maintained its overall ranking over the nine year period from 1992 through 2001. In fact, Verizon-Pennsylvania is one of only two companies that has maintained a top-ten ranking in 1992, 1997 and 2001. Verizon's achievement is significant particularly because of the environment under which it has maintained its advanced telecommunications network. Since the Telecommunications Act was passed in 1996, incumbents have been required to unbundle and provide network facilities to their competitors at incremental cost-based rates. The limited amount of contribution included in such rates makes it more difficult for all incumbents to invest profitably in advanced network facilities, yet Verizon has continued to do so.

Verizon's investment in its Pennsylvania infrastructure is comparable to the Commonwealth's own infrastructure investment. Consider that in 2001 the Commonwealth of Pennsylvania had revenues of $39.5 billion. In that same year the Commonwealth spent $4.1 billion on its transportation infrastructure and $8.7 on public education – representing 10 and 22 percent respectively. Verizon-PA had 2001 revenues of $3.6 billion, and spent over $1 billion on its Pennsylvania infrastructure - roughly 28 percent of its income.

V. CONCLUSION AND SUMMARY

Pennsylvania legislators exhibited sound judgment and good foresight when they set their mandates regarding the broadband market in Pennsylvania. Legislation established a minimum broadband transmission rate and left the determination of what technology would best provide that facility and what services might be provided to the market. Indeed, broadband technology (the means by which high-capacity bandwidth is made available) and broadband services (those products that service providers make available to consumers) continue to evolve as the broadband market—both the demand and supply side—changes over time.

This report has reviewed broadband technologies and services and makes the following points. First, there is, and has been, no consensus regarding the desirability of any particular broadband transmission capacity rate. In the early days, it was thought to be anything greater than what was attainable over a 3 kHz line (currently 56 kbps). Today various industry participants characterize a transmission rate as low as 100 kbps to as high as 1.5 Mbps as broadband. The FCC defines broadband as a transmission rate of 200 kbps. Second, the predominate supply of "broadband" services takes place on DSL and cable modem transmission paths that typically accommodate a downstream bandwidth of 0.256 to 1 Mbps and a upstream bandwidth of 0.256 to 0.5 Mbps. In this environment, service providers have little or no incentive to devise and market services that require higher rates of transmission capacity. Third, bandwidth suppliers (like Verizon in Pennsylvania) would, if forced to make faster transmission capacity rates ubiquitously available to residential consumers, undoubtedly be expending resources to facilitate the delivery of a service that does not now exist. The natural evolution of the overall broadband market may well one day coalesce technology, production cost, consumer tastes and willingness to pay on a broadband platform with transmission rates faster than what is available today, but that day is not yet here.

We also critically reviewed Verizon's performance relative to its commitments under the Network Modernization Plan. According to the biennial updates from the Company, it has met each of its commitments to-date, in the process modernizing its signaling system, switches, and interoffice facilities. Verizon-Pennsylvania has also made broadband transmission facilities available to all of the health care facilities, public schools and industrial parks located in its territory. In accordance with its commitment, the Company is also well on the way to bringing broadband transmission facilities to all of its urban, suburban, and rural consumers by 2015 – already meeting its 2004 commitment level for all but the rural population in Pennsylvania.

Finally, we performed an analysis of Verizon-Pennsylvania's overall infrastructure development relative to other states. Relying on publicly available data we compare Verizon-PA's performance to ILEC performance in 47 other states in regards to placement of new technology. Our analysis is based on nine measures that reflect each companies' state specific performance relative to digital, SS7, ISDN and fiber technologies. This is similar to the analysis we performed in 1997 (see Promises Fulfilled) when we determined that Verizon-PA was 1 of only 4 ILECs that improved or maintained their standing between 1992 and 1997. Today, our analysis reveals that Verizon-PA has improved even more between 1997 and 2001. Today, Verizon's performance in Pennsylvania ranks as the 5th best, an improvement from 7th best in 1997. Indeed, Verizon-PA is one of only two companies that has maintained a top-ten ranking in 1992, 1997 and 2001.[53] Verizon's investment in Pennsylvania is all the more remarkable because the network unbundling requirements of the Telecom Act have made it more difficult for incumbents to recover the cost of new facilities they deploy. This analysis leaves little or no doubt about Verizon's commitment to place and maintain a modern and efficient infrastructure. Indeed, all evidence points to the conclusion that consumers in Pennsylvania can take advantage of one of the most modern infrastructures in the country.

[53] Verizon's accomplishments are all the more remarkable considering that the Telecommunications Act of 1996 was passed in the interim. The Act imposed significant obligations on the Company, requiring it to shift resources to Act-related activities, and reducing the Company's incentive to invest capital in facilities that would have to be turned around and sold at incremental costs to competitors in the market. See Randolph J. May, "Pennsylvania Faces a Choice To Continue To Promote Real Competition Or Not," Progress and Freedom Foundation, November 2002.