Berkshire Connect

Assessment of Technology Options

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Technology Assessment

Background and Purpose.

The firm of Flack + Kurtz Consulting Engineers was retained to provide technology design and business planning services for Berkshire Connect. One of the initial tasks was to make an assessment of the infrastructure technologies that may be appropriate to the telecommunications needs of Berkshire County. In addressing this task, we reviewed the work previously accomplished by the Berkshire Connect Steering Committee and the Critical Users subcommittee, applied our own experience and investigated additional areas that appeared promising, or were suggested by the Steering Committee.

On October 15, 1998 we presented the initial draft Technology Assessment Report to the Steering Committee. Since that time, we have received and reviewed the Committee's comments and suggestions. Also, with the input and assistance of the Committee, we have evaluated private initiatives and reviewed right-of-way and regulatory issues. This final report updates and refines our previous conclusions and now includes recommendations. Financial projections were included in earlier drafts of this report, but are not included in the final report. A detailed cost analysis has been developed separately and will be incorporated into the business plan.

Infrastructure Hierarchy.

The telecommunications infrastructure needed to serve Berkshire County is not a single entity. It is a hierarchy of elements, each of which has different characteristics and may lend itself to different technological solutions. For purposes of our evaluation, we found it convenient to break the infrastructure down into four parts:

- ***The local loop.*** This is the "short haul" infrastructure connecting the end user directly to the local point of presence – AKA the "last mile." Typically, the local loop transport medium is copper cable but it could also be optical fiber, CATV cable or radio. Traditionally, the local loop cable is owned and maintained by the incumbent local exchange carrier (ILEC), but it may also be provided by a competitive local exchange carrier (CLEC) a Cable TV (CATV) provider or even the end user.

- ***The building or campus backbone***. This is the infrastructure within a large office building, complex of buildings or a campus. It provides local distribution, local interconnectivity and aggregation of demand for a geographically clustered community of users. It is a special case of the local loop and is typically privately owned by the using business or institution. Media usually include both copper and optical fiber cable.

- ***The regional backbone.*** This is the "medium haul" infrastructure connecting the local point of presence to the global backbone. Media typically include optical fiber, coaxial cable and/or microwave facilities. The regional backbone is typically owned and maintained by the LEC, but it may also be privately owned or provided by a CLEC, a competitive access provider (CAP) or an interexchange carrier (IXC).

- ***The global backbone***. This is the "long-haul," worldwide network of high capacity infrastructure. It is provided by a number of facilities-based and non-facilities based carriers and service providers using a variety of technologies, including satellite, microwave and optical fiber media. This infrastructure is accessible via nodes already in place in larger population centers such as Albany, NY or Springfield, MA. One of the primary goals of the Berkshire Connect initiative is to facilitate access to the global backbone from anywhere in the county.

Candidate Technologies.

Because of the wide diversity in user needs and hierarchical nature of the required infrastructure, we expanded somewhat on the range of technologies originally examined by the Critical Users subcommittee. After some deliberation, we felt that the following wireless and terrestrial technologies should be evaluated:

- ***Satellite point-to-multipoint radio***. Satellite technology has traditionally been used for long-haul communications, but the introduction of satellite-based digital TV distribution raises the possibility of using satellites for local data distribution, especially in remote areas.

- ***Terrestrial point-to-point radio (Microwave).*** Microwave technology has been very widely used for medium- to long-haul backbone communications since the 1950's. Until recently, maximum link capacity has been approximately 45 Mbs (DS-3), however some systems now offer up to 155 Mbs (OC-3) capacity over short to medium distances, up to 35 miles between repeaters, depending on terrain and other physical factors.

- ***Terrestrial point-to-multipoint radio.*** Local Multipoint and Multichannel Multipoint Distribution Services (LMDS/MMDS) use newly allocated radio spectrum to provide medium to high capacity one and two-way data communications within a local area. These are cellular technologies with a cell radius of about 2 to 5 miles. Repeaters and/or multiple cells can extend coverage to a larger area.

- ***Owned Optical fiber (Fiber Build).*** Optical fiber can provide very high capacity digital services over any distance. Private users, institutions, CLECs and IXCs have constructed and successfully operated their own optical fiber networks for campus, metropolitan, regional and long-haul networks.

- ***Leased Optical fiber (Dark Fiber).*** Spare fiber strands may be leased from ILECs, CLECs or other operators, if available. The customer provides the electronics to "light up" the fiber.

- ***Leased service (DS-1, DS-3).*** CLECs and ILECs have offered these services to end users for may years. They are delivered via copper fiber and/or microwave facilities.

- ***Cable TV.*** Most Cable TV providers are upgrading their entertainment TV distribution systems to provide data services up to 10 Mbs (typically 1 Mbs) via cable modems attached to CATV distribution cables.

- ***Digital subscriber lines (xDSL).*** This relatively new technology can provide data transmission speeds up to 52 Mbs (typically, 128 Kbs to 8 Mbs) using existing copper local loop facilities.

Evaluation Factors.

In evaluating each technology, we tried to assess its general characteristics, availability, relative costs and applicability to one or more elements of the required infrastructure hierarchy. The specific factors we looked at included:

- ***Capacity and scalability***. Capacity is the available bandwidth or speed of transmission of a facility. For digital services, capacity is usually expressed in bits per second or in terms of various time division or synchronous digital hierarchy levels such as DS-1 or OC-3. Scalability describes the ability to adjust the capacity of a facility up or down to meet changing demand.

- ***Reliability***. The concept of telecommunications system reliability is often misunderstood. Reliability (or availability) is the percentage of time (usually per year) that the system is expected to be operational. It is defined as:

  MTBF/(MTBF+MTTR);

  where MTBF is mean time before failure and MTTR is mean time to repair. Thus, reliability depends not only on the frequency of failure, but equally on the speed of repair. The common conception that optical fiber is more reliable than microwave, for example, is not necessarily true. If a type of facility (e.g., fiber) seldom fails, but takes substantial time to repair, it can be less reliable than one (microwave) that fails more often, but is quickly restored to service. It is also important to note that systems consist of may elements, not just the transmission medium itself. Thus, telecommunications failures are frequently caused by power outages which affect the system's electronics. Interdependencies of this type must be taken into account when comparing technologies.

- ***Relative cost***. These include initial and recurring costs to provide a given service capacity. In some cases, additional costs such as license fees, site leases and right-of-way leases will add significantly to the total cost. Incremental costs to expand, upgrade or re-deploy a facility should also be considered.

- ***Technological risk***. What is the risk that a given technology will not provide the desired solution? Mature technologies have been proven in the field and usually pose less risk in terms of availability, performance, reliability and cost, than do "leading edge" or unproved technologies. On the other hand, the most mature technologies be at greater risk of obsolescence before their costs are fully recovered.

- ***Lead time.*** How quickly can the technology of choice be deployed and available for service? Construction of a fiber backbone may take months or years. A satellite earth station can be deployed in hours, if the required transponder capacity is available on an existing satellite.

- ***Special considerations***. Every technology has special characteristics which must be considered. Cable and optical fiber need rights-of-way. Microwave systems need no right-of-way, but they do need line-of-sight, antenna structures and, usually, licensing. Quality of service (QOS) is also a consideration, although with digital technologies, the QOS is more a function of the electronic or electroptic components of the network than of the specific transmission medium.

Qualitative comparison.

Having evaluated the candidate technologies on the basis of the above considerations we developed a qualitative comparison. While simplified comparisons of this type should be used with caution, owing to the number variables involved, it is obvious that some technologies are inherently more suitable to the needs of the Berkshire region than others. Point-to-multipoint satellite data transmission, for example, does not compare favorably in most categories and the technology is in its infancy (very risky). Leased dark fiber, on the other hand, has many advantages and should be considered seriously, if it can be made available. The following matrix summarizes the comparison:

Technology	Capacity	Scalability	Reliability	Relative Cost	Technological Risk	Deployment Lead Time	Applicability
Satellite	High	Low	High	High	Medium	Very Low (if available)	Local loop
Microwave	High	Medium	High	Medium	Low	Medium	Regional Backbone, Campus, Some Local Loop
LMDS	High	Medium	High	Low	High	Low	Local Loop, Campus
Owned Fiber	Very High	Very High	High	Very High	Low	Very High	Regional Backbone, Campus, some Local Loop
Leased Fiber	Very High	Very High	High	Medium	Low	Low (if available)	Regional Backbone, Campus
Leased T1/T3	High	Medium	High	Very High	Low	Medium (if available)	Regional backbone, Local Loop
CATV	Medium	Low	Medium	Medium	Medium	Low (if available)	Local Loop
xDSL	High	Low	Medium	Medium	Medium	Medium	Local Loop

Summary of Conclusions and Recommendations.

In evaluating the technologies potentially available to meet the needs of the Berkshire Region, the Berkshire Connect Critical Users subcommittee previously concluded that no *single* solution is likely to meet all of the diverse needs of the region's users. We agree with this conclusion. Given the demographic and geographic diversity of the region and the character of the existing infrastructure, it is likely that the optimal solution will differ by user community and location. It is also likely that as technology, user demand and cost factors change over time, the optimal mix of solutions will also change.

Based on the availability, cost and performance characteristics of the technologies evaluated, we have reached the following preliminary conclusions:

- The Berkshire Region's telecommunications needs will be best met by a combination of technologies, whose composition is likely to change over time.

- Satellite technology, in its current state, is probably not well suited to the needs of the Berkshire Region and should not be given priority consideration at this time.

- Terrestrial point-to-point microwave technology offers significant advantages for some applications and should be considered under specific circumstances.

- Terrestrial point-to-multipoint radio (LMDS/MMDS) technology can provide significant advantages in local loop applications, but entails significant technological risk. This technology should be considered for remote/low user density applications and where quick deployment is necessary.

- User-owned optical fiber is very costly and difficult to implement compared with leased fiber. In may be a good local loop solution for clusters of users, otherwise, it should be considered only if leased fiber is not readily or economically available.

- Leased optical fiber offers very significant cost and performance advantages over other technologies in backbone applications and should be considered the preferred backbone solution, when and where available.

- Leased T1 and T3 services are costly and not universally available. If these services can be offered by a CLEC under interconnect agreements, much more favorable pricing can be obtained. Leased services should be considered pending establishment more cost-effective services.

- Cable TV can offer a useful supplement to the other technologies available for local data distribution, especially to residences. Berkshire Connect should encourage its deployment, but should not consider it a primary local loop application or become directly involved in its implementation.

- Digital subscriber lines (xDSL) can provide a very good local loop solution where suitable cable infrastructure is available. Berkshire Connect should consider direct involvement in its implementation.

[**NOTE: ADDITIONAL RECOMMENDATIONS PROVIDED SEPARATELY]**

Discussion and Evaluation of Specific Technologies

The evaluations which follow provide a more complete description of each technology and discuss the salient characteristics of each.

Satellite technology.

General description. Artificial satellites launched into orbit around the earth for communications, scientific research, remote sensing, surveillance, meteorology, navigation and other purposes can be classified as GEO (Geostationary Earth Orbit), MEO (Medium Earth Orbit) or LEO (Low Earth Orbit) system according to the heights of their orbits.

GEO satellites are satellites launched into a circular orbit above the equator, at a height of about 36,000 km. In this orbit, a satellite appears to be “stationary” and can therefore be used for telephony, data transmission, TV broadcasting and other applications using dish antennas on the ground, which point to a fixed position in the sky. GEO satellites are big and expensive to build and launch. At such a great distance, the signal reaching the earth from the satellite is extremely weak. Large amounts of power are needed to transmit signals from the earth to the GEO satellite. In spite of these limitations, the use of GEO satellite systems for communications and other purposes is now well established, world-wide.

LEO satellites orbit the earth at a much lower heights, between 300 km and 1,500 km. LEO satellites are widely used for mobile handset communications. Although data transmission is possible over these mobile systems, it is slow and expensive (>$3.00/minute).

Recently, delivery of digital TV over satellites has become prevalent. It was thought that similar technology would be used to deliver local loop data services similar to LMDS/MMDS and xDSL, but no such products are currently on the market.

MEO orbits have greater heights than LEO orbits, usually between 5,000 and 15,000 km. To obtain world-wide continuous 24 hour real time coverage from LEO and MEO orbits for communications, much more than one satellite are needed. For example, 24 satellites are required for MEO orbit and between 48 and 840 satellites have been proposed in LEO orbits.

Capacity and scalability. The capacity (amount of data that system can handle) and scalability (the system expandability) of satellite communication is directly related to modulation (changes the data to the signal) / demodulation (changes the signal back to the data) method and operating frequency band. For example, commercial satellites operate in frequency bands: C band (4/6 GHz), Ku band (11/14 GHz), and Ka band (20/30 GHz). In each case, the lower frequency used for downlink (satellite to earth terminal) transmission and the higher frequency band for uplink transmission.

The rule of thumb for the capacity in satellite communication is 10% of the operating frequency band. For example, in Ka band operation, it is reasonable to assume 2 to 3 gigabits of data transmitting and receiving capacity. However, capacity can be significantly affected by the applications and modulation/demodulation techniques.

Reliability. The reliability of the satellite communications system is really measured by reliability of three components; satellites, earth terminals and system software. The satellite itself is very reliable and it has multichannel back ups. If it does fail catastrophically, however, the mean time to repair (or restore) can be very high. Extremely rare events like the predicted Leonid meteor shower in mid-November, 1998 have the potential to disable many satellites at once. Usually, however, if the satellite communication system has a problem, it is more likely a problem with the earth terminal or system software. Satellites operating at the higher frequencies, (Ka and Ku) band can be adversely affected by heavy rainfall. Overall, the satellite communication system is very reliable; once a signal has penetrated the earth's atmosphere and gotten into space, little can corrupt a data stream.

Technological risk. Satellite transmissions were initially begun in the early 1960s, but many enhancements have been made over the years. The fundamental technology is quite mature and relatively risk-free, although point-to-multipoint applications are , as yet unproved.

Deployment lead time. The speed of implementation of satellite communication system depends on the size of the project. If one wants to have one's own satellite, it may take 3 to 5 years. If one wants to lease someone else's satellite network, then it depends on the size and the complexity of the project; usually less than 6 months of implementation time.

Special considerations.

The satellites were originally designed for a spacing of 4 degrees apart, based on a 360-degree circular orbit. However, as many emerging countries have sought to use satellite and radio rather than build wire-based network infrastructure, the satellites have been placed in closer orbital slots. They are now being positioned at 2 degrees increments. This can lead to congestion on the transmission paths, cause occasional interference and limit future parking slots. Satellite earth stations require FCC licensing.

Satellites do have certain advantages. They are distance insensitive -- the distance between two end points is not a consideration in the pricing. They require little regional infrastructure, making them good for remote areas applications. For areas where it is impractical to get wiring because no major development has occurred, a satellite link might be the only true solution. Broadcast capability: because the footprint is so large, the transmission can be to many locations simultaneously. An average satellite has 24 transceivers. Each transceiver can handle approximately 36 Mhz of bandwidth.

Some major disadvantages of satellites include cost and propagation delay. This delay is ¼ to ½ second, and can be disruptive to voice and asynchronous mode data protocols. Because of this delay satellites are not widely used for bi-directional communication systems. Because there are apparently no viable, bi-directional point-to-multipoint data services available via satellite, they would appear to offer no advantageous solutions for Berkshire County's telecommunications infrastructure needs.

Terrestrial Point-to-Point Microwave

General description. Microwave has been in wide use since the 1950's in long-distance carrier applications as an alternative to guided metallic or fiber optic cable transmission media. More recently, microwave technology, especially at the frequencies of 18 GHz and higher, has been used by private, industrial and utility users for medium and short-haul links.

Terrestrial microwave radio transmission systems consist of at least two radio transmitter/receivers (transceivers) connected to high-gain antennas (directional antennas that concentrate electromagnetic or radiowave energy in narrow beams). The operation is point-to-point; that is, communications can be established between only two locations. This is contrasted to point-to-multipoint systems which are described further on. Point-to-point systems have been used for short, intermediate, and, using repeaters, long-haul backbone applications. At one time, virtually all national long distance communications networks were based on microwave.

Capacity and scalability. The capacity and scalability of point-to point-microwave communication is directly related to modulation/demodulation method and operating frequency band. The carrier frequencies utilized by terrestrial microwave include 4, 6, 11, 18, 23, 26, 28 and 38 GHz. As technology improves, the operating frequencies are getting higher which can mean greater capacity.

A single radio channel has traditionally carried up to one DS-3 (45 Mbs), but some systems are now capable of operation at OC-3 (155 Mbs). The rule of thumb for the capacity in microwave communication is 10% of the operational frequency band. However, capacity can be significantly affected by the applications and which modulation and demodulation method is used.

Scalability beyond the maximum data rate requires a second radio channel. Because of frequency availability and equipment limitations, this is often not a viable option and, if available, has a high incremental cost. As an alternative, the standby equipment of monitored hot standby microwave links can be activated to provide a second radio channel, thus doubling capacity. The consequence of an equipment failure is then loss of half the link capacity.

Reliability and availability. The reliability of a well-designed microwave communication system can be as high as that of any other communications medium. However, as a transmission medium, the earth's atmosphere creates problems not encountered with cable-based systems. At all frequencies, trees, obstructions, and atmospheric anomalies can cause significant attenuation or signal loss. At the higher frequencies, heavy rainfall is a factor that must allowed for in the system design. Provision of an adequate fade margin will account for all these factors and provide for a very reliable system. Because many of the fading impairments that affect microwave systems are "self healing" overall availability can be higher than for cable based systems.

System	MTBF	MTTR	Availability	Bit-error Rate	Remarks
Radio components	High, similar to optical fiber electronics	Effectively zero for protected systems up to several hours depending on location)	Averages <1 to several unavailable minutes per year (varies with MTTR)	Low – up to 10^{-13} residual BER	Antennas and towers can be damaged by catastrophic weather conditions.
Path	High, but subject to fading and other impairments	"Self-healing" as conditions return to normal	Averages <1 to several unavailable minutes per year (varies with MTTR)	Transmission quality limited by fading, typically better than10^{-6}	Requires line of sight

Technological risk. The microwave communications technology is well proven. The local telephone companies, long-distance carriers, and users alike have all been successful in the use of microwave radio systems. Microwave was the predominant means of handling long-haul transmission in the U.S. before optical fiber was introduced.

Deployment lead time. The speed of implementation of point to point microwave communication system depends on the size of the project. Depending on the extent of construction required, and the sites to be procured, this effort could take from 6 to 36 months.

Special considerations. Modern digital microwave radio systems provide a feasible technical solution for telecommunications transmission links at distances up to 35 miles (much greater distances are achievable under special path engineering conditions) and can carry capacities up to N x 155 Mbs. Furthermore, digital radio relay systems in the microwave and millimetric bands provide economic transmission options, and network control and ownership. Such systems are increasingly being deployed in fixed telecommunications networks. Licensing and line-of-sight (but no ROW) are required. This is often a viable option when existing towers can be used, but it is less attractive (and more expensive) if sites must be procured and towers constructed. Local environmental considerations and permitting requirements can effectively preclude the deployment or expansion of microwave systems in some instances.

Terrestrial Point-to-Multipoint Communications (LMDS/MMDS)

General description. MMDS (Multichannel Multipoint Distribution System) was originally intended for wireless cable TV. MMDS broadcasts TV programs at microwave frequencies from a central point or headend to small receive antennas on subscribers' roofs. Wireless cable systems using MMDS are offering up to 31- 6MHz channels in the 2.5 to 2.7 GHz band. The most common frequencies used are between 2.1 and 2.7 GHz although some countries are trying higher frequencies up to 40GHz. There is currently a trial in New York using frequencies from 27.5 to 29.5 GHz.

LMDS (Local Multipoint Distribution Service) uses microwave signals in the 28GHz spectrum to transmit voice, video, and data signals within small cells 3-10 miles in diameter. A company called CellularVision in Brighton Beach, NY was awarded an LMDS pioneer's license. CellularVision currently operates the only commercial LMDS site in the US. CellularVision has recently been expanding the number of operating cells in the New York area and now claims more than 12,000 subscribers. Recently, we have been unable to obtain any definitive information about the status of CellularVision's operations. Another company has a nation-wide microwave/LMDS hybrid system under construction in Haiti.

There is not a clear functional distinction between LMDS and MMDS.

Capacity and scalability. General DLMDS is a microwave broadband service that will allow license holders to control up to 1.3 GHz of wireless spectrum in the 28 GHz Ka-band once FCC auctions have been completed. The 1.3 GHz can be used to carry digital data at speeds in excess of 1 Gbs. Scalability is limited by the bandwidth and number of channels available, although most local loop users will find it difficult to reach the limits of the high data rate available. Capacity can be increased by making the cells smaller.

Reliability. Even though these technologies have been around for a past decade or so, they have not been implemented on large scale. In theory, they are very reliable, assuming the cells are correctly engineered, however, there is currently little field experience with available products.

Technological risk. Because product production volume is currently low and the installed base is small, there are some risks involved with LMDS.

Deployment lead time. Normally, this kind of technology, will take 6 to 12 months to implement. There will be antenna siting issues, which may add to the lead time if existing structures cannot be used.

Special considerations. LMDS and MMDS require an area license. To date, U.S. service providers have invested over $600 million in LMDS licenses covering 800 markets. One license has been issued for the Berkshire County area and at least one is still available. Like most other radio-based systems, LMDS/MMDS systems need line-of-sight and are subject to atmospheric effects, good engineering can provide high reliability and good GOS. Major advantages of LMDS/MMDS is that they can economically provide service in areas where the local loop infrastructure is inadequate or the population is sparse. If business users are being served, nearby residential customers can be added at very little incremental cost. Because they are licensed on an area basis, these systems can be re-deployed to lower priority areas as wired infrastructure is improved in initial service areas.

Owned Optical Fiber Technology.

General description. A fiber build is an option that would be used primarily in the backbone infrastructure to provide regional connectivity. This option could also be used to connect high volume users/locations to the backbone facility. It would not be used as a local loop technology to the home or small office due to cost considerations. This option would require that a fiber optic route is established using new or existing rights-of- way (ROW), that fiber is installed along the ROW, and that electronics are installed to terminate the fiber at designated end points and intermediate points.

Capacity and scalability. The capacity of a fiber optic run is nearly inexhaustible. The capacity is determined by 1) the electronics terminating the fiber and 2) the number of fibers along a particular route. As for the electronics, SONET transport equipment is used almost exclusively in today's market. SONET provides "pipes" that can carry a wide array of transport services including basic telephony transport (DS1s and DS3s), ATM (Asynchronous Transfer Mode), Frame Relay using DS1 or DS3 circuits, and IP (Internet Protocol) that is often embedded in DS1s or DS3s. Common SONET fiber transmission speeds include:

- OC-1 (52 Mb/s) transporting up to 28 DS1s (1.544 Mb/s) or 1 DS3 (45 Mb/s)
- OC-3 (155 Mb/s) transporting up to 84 DS1s or 3 DS3s

- OC-12 (622 Mb/s) transporting up to 336 DS1s or 12 DS3s
- OC-48 (2.4 GB/s) transporting up to 1,344 DS1s or 48 DS3s.
- OC-192 (9.6 GB/s) transporting up to 192 DS3s, and
- Higher using DWDM (see below).

When using a cell based network, such as ATM, along with a SONET transport infrastructure, the capacity is much greater than that specified above. ATM networks use concentration and compression techniques that allow data and voice services to be combined and transmitted with greater bandwidth utilization. ATM networks also provide rerouting features that provide a level of redundancy and protection beyond that provided by SONET transmission equipment.

Fiber transmission systems are very scalable. A user can start with a lower cost, low capacity system such as an OC-3 and upgrade this system to an OC-12 or OC-48 as necessary. Equipment vendors differ on upgrade strategies; some enable seamless upgrades where all existing equipment is reused and others offer “forklift” upgrades where the old equipment is removed and made available to redeploy elsewhere. In all case, the media (fiber) does not require any change.

When a new fiber route is constructed, multiple fibers are run along the route, not simply a single pair. Multiple fibers are run since the cost of the fiber is small as compared to the actual construction costs. As a result, multiple transmission systems typically run along the same route. For instance, a route containing an OC-48 backbone ring may also contain an OC-3 loop ring used to link high capacity end-users in an area. Although the two fiber systems run along the same route, there are two independent rings each using a fiber pair. Each ring is terminated only in the buildings of interest, such as POP locations for the backbone ring and end-user locations for the loop ring. As such, the “capacity” of a new fiber build is really quite large given that multiple transmission systems run over the same route using different fiber pairs.

Reliability and Availability. Reliability covers a broad range of performance criteria for systems and equipment. These reliability measures include:

- Mean Time Between Failures (MTBF), which predicts how often systems and equipment fail,
- infant mortality, which predicts early fall-out,
- availability, which considers MTBF and Mean Time To Repair (MTTR) to provide a prediction of downtime for equipment or systems (typically expressed as minutes of outage per year), and
- transmission bit-error rate, which predicts steady-state performance.

For fiber transmission systems, reliability and availability can be broken into two components:

1) Electronics
2) Fiber

As summarized below, fiber systems in a fully-diverse ring configuration are very reliable since traffic always has two paths to reach a “node” or drop-off site. If fiber is cut in one direction (e.g., east), the traffic still gets to the destination from the other direction (e.g., west). Conversely, reliability predictions for linear topologies are variable and more difficult to predict. Linear topologies can lead to long outages and low availability since once a fiber cut occurs, all downstream nodes are affected. A qualitative summary of reliability predictions for fiber systems is provided below:

System	MTBF	MTTR	Availability	Bit-error Rate	Other
Electronics	High	2-6 hours (depending on location of equipment)	High – 1 min unavailable per year (varies with MTTR)	Low – great performance – 10^{-9} or better	
Fiber (diverse ring)	High (ring protects against failures)	NA	High	Transmission quality limited by electronics	Rings make for a reliable system
Fiber (non-diverse)	Variable	Many hours to more than one day.	Variable	Transmission quality limited by electronics	Linear systems can be unreliable

Technological risk. The technology associated with fiber builds and SONET electronics is well proven. There are no substantial technology risks. There are a substantial risks associated with securing ROWs and managing the initial build project.

Deployment lead time. The speed of delivery or implementation of a fiber build program is gated by the time required to establish Rights of Way and the actual build of the fiber network. Depending on the extent of the build, this effort could be exceedingly long and could easily take 12 to 18 months or longer.

Special considerations. Due to the costs associated with fiber builds, fiber builds are only used for backbone applications or to connect cluster areas (such as campus or office parks) to the backbone network. Fiber builds are not a strategy for local access to end-users.

Even though fiber requires a ROW and relatively expensive electronic components, it has some significant advantages over conventional, metallic cable. Since it is non-conductive and non-electronic, it can be strung on electric transmission towers and can even share ductbank with electric feeder cables. In some cases, this can simplify the ROW requirement.

Note that a backbone in and of itself is of limited value. Traffic must get on and off the backbone to take advantage of the projected lower costs associated with the new backbone. Some alternatives would include local loop options such as xDSL and LMDS, as discussed elsewhere.

Leased (Dark) Fiber

General description. Leased Dark Fiber is a technology option that could be used to reduce the start-up costs associated with the fiber build strategy and to reduce the implementation interval. This option replaces the aerial or buried fiber cable construction with a leased fiber strand. The electronic equipment is still required.

Dark fiber can be leased from multiple sources. The most notable source is the Incumbent Local Exchange Company (ILEC), which is Bell Atlantic. Other sources of fiber in Berkshire County include the local Cable TV companies; independent telephone companies, such as Richmond Telephone, within their serving area; and other third parties including Qwest, a coast-to-coast provider of dark fiber and fiber services. Qwest is not offering dark fiber to Berkshire County at this time[1]. NEON, a dark fiber provider in Eastern Massachusetts, does not have fiber west of Springfield. The local gas utility, the local electric utilities, the railroads, and Tennessee Gas Pipeline do not have dark fiber in Berkshire County.

As such, Bell Atlantic is the prime candidate for dark fiber leasing. Bell Atlantic has fiber connecting all central offices in the county. A dark fiber tariff issued by Bell Atlantic is under review by the Massachusetts Department of Telecom and Energy (DTE). This tariff will make it possible for a registered CLEC to lease fiber strands from Bell Atlantic. A copy of the “Bell Atlantic Unbundled Dark Fiber Service Description” and a separate listing of proposed rates are enclosed as appendices. The rate is very favorable. The tariff specifies $66/fiber pair/month plus additional costs as compared to costs of $150 to $200 per fiber pair from other dark fiber providers, such as NEON in Eastern Massachusetts.

The Bell Atlantic tariff has numerous restrictions regarding the fiber strands that can be used for the dark fiber lease thereby limiting the application of this tariff. A few examples of these restrictions are provided below.

1. The fiber strand must be continuous within an existing cable sheath. A strand is not considered continuous if splicing is required to provide continuity. Some provisions for time and material splicing are provided.
2. Bell Atlantic will not construct new or additional facilities.
3. Bell Atlantic will reserve a reasonable quantity of fibers in any cable to be designated as maintenance spares that are not available for lease as Unbundled Dark Fiber.
4. The dark fiber strands must be considered to be “spare” meaning that the strands are not allocated for growth or network survivability and not allocated for another customer (current or in near future).

[1] Per discussion with Qwest.

5. An entity inquiring about the availability of dark fiber strands must be a registered CLEC and must provide a written request designating the two locations between which dark fiber is desired.

As a result, an entity must first be a CLEC before requesting information on fiber availability. The CLEC must choose two end-points such as central offices from two adjacent towns. And, before dark fiber can be offered along the span, the fiber strands must be “spare” where spare means not allocated for growth or maintenance.

Bell Atlantic has fiber throughout Berkshire County connecting Bell Atlantic facilities and connecting Bell Atlantic to end-customers. The amount of “spare” fiber, which is available for dark fiber lease, is unknown. It is likely that dark fiber will be available in some instances for some specific applications such as,

1. connecting a CLEC to an end customer or campus (by having the CLEC collocate at a Central Office and use fiber strands from the CO to the customer), and
2. obtaining connectivity between adjacent towns by leasing fiber strands between central offices.

It is possible, but perhaps unlikely, that a CLEC could get connectivity throughout the county by specifying point-to-point segments from town to town. Likewise, a CLEC could possibly obtain connectivity to Springfield by networking many point-to-point segments together. However, as the number of segments increases, so does the likelihood that Bell Atlantic has one or more spans without available fiber along the way. Bell Atlantic is not required to do any construction to support the tariff. If any construction is done, costs are passed to the interested CLEC.

The examples that follow assume that connectivity can be provided by Bell Atlantic dark fiber in order to compare costs with the other technologies. It is not known at this time whether or not this can actually be accomplished.

Capacity and scalability. The capacity and the scalability of a dark fiber system are directly comparable to the fiber build scenario with one main exception. With a dark fiber alternative, a company leases a single fiber pair from a fiber provider, and if a second ring system is required, more fiber is required. Bell Atlantic must first determine whether or not additional pairs are available. If so, the second set of fibers is leased thereby doubling the monthly fiber costs. With the fiber build strategy, there are many fibers available for use at any time with no incremental monthly cost.

Reliability and availability. The reliability and availability of a dark fiber system are comparable to the fiber build scenario above. Fiber systems in a ring configuration are reliable whereas linear topologies can lead to long outages. The primary difference between a fiber build and a dark fiber network is that in the dark fiber scenario, the fiber plant and its maintenance are controlled by the owner (Bell Atlantic), not the CLEC. The reliability of the resulting system, therefore, depends on Bell Atlantic.

Technological risk- There are minimal risks with this strategy.

Deployment lead time. Given that the fiber backbone from Bell Atlantic exists today, implementation time is greatly reduced from the fiber build strategy, assuming the desired quantities of fiber are actually available in the necessary locations. Long lead times could exist, however, is any construction is required.

Special Considerations. As with the fiber build strategy above, the dark fiber lease strategy provides a means for offering a backbone service to the county. Traffic must get on and off the backbone to take advantage of the projected lower costs associated with the new backbone. Some alternatives would include local loop options such as xDSL and LMDS, as discussed below. Note: Dark fiber will be made available from Bell Atlantic where spare fiber is available. If spare fibers do not exist, Bell Atlantic is not required to perform the build out, and if they do, the customer pays the construction costs.

Dense Wavelength Division Multiplexing (DWDM)

General description. Dense Wavelength Division Multiplexing or DWDM is not a separate technology, but rather a special technique used to greatly to increase the capacity of a conventional owned or leased fiber optic system. Instead of carrying a single optical wavelength, a fiber optic transmission span is segmented into multiple optical wavelengths. Each wavelength can carry the equivalent of a single wavelength system. For instance, where a typical span carriers one OC-48 signal at 2.4 GB/s, a DWDM system can carry 32 to 40 such OC-48 signals for up to an aggregate of 100 GB/s.

DWDM systems are very expensive and are used primarily where fiber is a very scarce resource. As an example, a long distance carrier would use a linear DWDM system to aggregate traffic on long haul span. As another example, a metropolitan service provider that is short on fiber could use a DWDM system in a ring topology to access high bandwidth end-users in a city (here, high bandwidth means OC-12 on up).

It is unlikely that there is an application for this technology in the Berkshire network at this time. However, in the future (five to ten years), the number of very high bandwidth applications in the region may explode due to the nature of the companies this project is working to attract (media and related companies). This could necessitate the use of DWDM technology to reduce fiber needs.

Capacity and scalability. DWDM provides the greatest amount of bandwidth per span available today. Systems are currently available that provide up to 80 wavelengths per span, although the more typical is 32 to 40 wavelengths. Systems are in development that would provide 400 GB/s on a single span. That's 160 OC-48 systems operating at 2.4 GB/s each, or 215,000 DS1s!

Reliability and availability. As with dark fiber and fiber build solutions, the system reliability of a DWDM system is limited by the network topology and whether a linear topology or a ring topology is deployed. DWDM systems are available in linear and ring configurations, although ring configurations are much newer to the market.

As for the DWDM technology itself, much of the multiplexing and demultiplexing of optical wavelengths is done using passive components (components not requiring power) resulting in highly reliable equipment. And it should be, given the large amounts of traffic present on each span. Where distances between spans are large, optical amplifiers are required thereby reducing reliability.

Technological risk. Although Wave Division Multiplexing (WDM) has been available for over 15 years, this product area utilizing DWDM technology is quite new. Linear DWDM systems are well proven in the field; however, metro-DWDM products are in early stages. Many new metro products are planned for release in summer 1999.

Time will work to the benefit of Berkshire Connect for this product line. As the need for a Metro or linear DWDM network emerges in subsequent years, product features and prices will have stabilized.

Deployment lead time. Not applicable.

Special considerations. See above.

Leased Service – Leased OC-3 and Leased DS3.

General description. Leased capacity is an alternative to building a network using fiber or microwave. It's one possible solution to "get started" quickly with limited capital expenditures. A CLEC has two primary options for obtaining leased capacity from Bell Atlantic:

1) resale of dedicated access services and
2) purchase of bandwidth from Bell Atlantic using Unbundled Network Elements.

Resale of Dedicated Access Services: In the first, the CLEC purchases services from Bell Atlantic's Access Tariff at wholesale rates and resells the services to end-customers. The

“Access Tariff” is Bell Atlantic’s published tariff for end-user services. The wholesale rate for access services in Massachusetts is 29.47% (roughly 30%), see the appendix on resale rates. One issue here is that “resale” rates apply for services that are “resold” to an end-customer. For a CLEC to purchase a DS3 or OC-3 from Bell Atlantic, obtain the services at the wholesale rate, and use the circuit for a network backbone, the CLEC would need to “resell” the service to an end-user. Perhaps this means that the CLEC forms a separate entity that looks like an end-customer.

Unbundled Network Elements: CLECs typically purchase services from Bell Atlantic off Interconnect Agreements. Interconnect agreements specify the pricing and services that Bell Atlantic offers to other registered telecommunications providers, such as CLECs, for unbundled network elements (UNEs). Rates and services differ from those offered in “Access Tariffs”, which are for end-customers. Unbundled network elements are those parts of the network that an Incumbent Local Exchange Carrier (ILEC), such as Bell Atlantic, must offer to competitors as part of the Telecommunications Act of 1996.

As such, the second means for a CLEC to purchase leased capacity from Bell Atlantic is to purchase the corresponding UNEs. The costs associated with purchasing capacity using UNEs is less expensive than a CLEC purchasing services off the access tariff at wholesale rates, i.e., 30% off. However, the savings is lessened given that a strategy using UNEs is more capital intensive for the CLEC as described below.

With reselling, the CLEC never touches the circuit. A CLEC purchases a circuit from point A to point B, and Bell Atlantic does all the work in between. The CLEC just pays 30% less for the circuit. As an example, a CLEC can purchase a DS3 to go between its hub facilities for resale purposes and Bell Atlantic provides the circuit.[2] In contrast, when a CLEC purchases an UNE from an ILEC, the CLEC “meets” the ILEC at a central office either through physical collocation or virtual collocation. The CLEC is required to purchase equipment to terminate the circuit and pay the costs associated with collocation.

With physical collocation, the CLEC leases space in a Bell Atlantic central office and pays set-up fees, power fees, space rental, and interconnect fees. With virtual collocation, the CLEC transfers ownership of a fiber multiplexer to Bell Atlantic who installs and maintains the equipment in the central office on behalf of the CLEC. Most CLECs prefer physical collocation and use virtual collocation only as a last resort. However, in an area such as Berkshire County where retail rental costs are low and where the expected penetration from a given CO is low, virtual collocation can prove to be much more cost effective. The examples that follow use virtual collocation

[2] Unfortunately, the ILEC has the ability to pass the special costs, such as construction costs, on to the customer significantly increasing the costs associated with this alternative.

Capacity and scalability. A leased DS3 provides the capacity equivalent to 28 DS1s between two designated points. A leased OC-3 provides 84 DS1s worth of bandwidth. If more capacity is required, a second DS3 or second OC-3 must be leased thereby doubling the monthly lease expense.

Reliability and availability. With the leased capacity option, the reliability and availability of the circuit are dependent upon the carrier providing the service, in this case, Bell Atlantic. Factors that impact the reliability and availability of the circuit include transmission media (fiber vs. microwave), the network topology (linear vs. ring), circuit routing (number and type of points between A and B), network design, network operations, and network maintenance. All of these factors must be discussed in detail with the supplier (Bell Atlantic) to gauge the resulting reliability of a given circuit. This detailed analysis must be done prior to considering leased capacity as a possible alternative.

Technological risk. There is little inherent risk in the technology given that Bell Atlantic would use existing network capacity to provide the circuit.

Deployment lead time. Speed of implementation is dependent upon available capacity in the Bell Atlantic network between the points of interest. An estimate is that it would take 30 to 90 days to provide the service given that capacity is available. If capacity is not available, implementation would be significantly delayed.

Special considerations. Leased capacity could provide a timely near-term approach to reducing costs in Berkshire County. The CLEC could put a backbone network in place using leased capacity from Bell Atlantic and tie end-users to the network using Bell Atlantic dedicated circuits as local loops. The "timeliness" and "cost-effectiveness" of the solution depend on the capacity of Bell Atlantic's network along the routes of interest. The start-up costs imposed by Bell Atlantic to upgrade the network could wipe out potential savings.

Leased Service – Leased DS1

General description. Leased DS1 services can be used to provide local connectivity to end users. This is one of several local loop options. Others include xDSL and LMDS, which are discussed elsewhere. The leased DS1 option is a resale option similar to the leased DS3 service above. In this case, a CLEC purchases a DS1 circuit from point A to point B and resells the circuit to an end-customer. The purchase price for the CLEC is 30% off the retail price. With this service, a CLEC can connect end-users to the CLEC's hub facility using DS1 circuits. Once at the hub, the traffic is groomed and concentrated onto higher bandwidth pipes for transport to other destinations, such as Springfield or Albany to access the global network.

Given that the leased DS1 option does not require much in terms of capital expenditures, it is one way for a CLEC to "get started" quickly, and gain access to local end-users without deploying a local loop network.

Bell Atlantic provides many leased, or dedicated, DS1 services to end-users today. The key difference is that the distance for the circuits will be much shorter given that the DS1 circuit is going from a customer's premises to the CLEC's hub, which could be in the same or an adjacent town. The customer's bill from the CLEC has two portions; the local loop piece (resold from Bell Atlantic) and the backbone piece (access to the global network). The combined bill should total less than a separate DS1 from Bell Atlantic for the entire distance.

From a technology perspective, Bell Atlantic uses either copper local loops (actual copper wires from the central office) or a combination fiber and copper network to access end-customers. If construction or network upgrades are needed to provide a new leased DS1 circuit, these costs are passed to the CLEC. This increases costs and speed of delivery.

Capacity and scalability. A leased DS1 is limited to 1.544 Mb/s of bandwidth. This is equivalent to the capacity required to transport 24 voice calls. Although the leased DS1 is not scalable, the bandwidth that it provides is more than sufficient for many small businesses and SOHO offices. In fact, the bandwidth may be too high for a given application. In this case, fractional DS1 leased services are also available.

Reliability and availability. Leased DS1s are typically provided over the existing copper plant using T1 repeater technology or HDSL technology. The copper plant is an unprotected and old infrastructure leading to unreliable service delivery. Storms knock out service and weather changes affect performance on the lines. However, a failure on a leased DS1 affects only a very localized group of end-users as compared to backbone failures that affect many. Where a combined fiber optic and copper network is used to deliver DS1 services, reliability is improved, but the implementation costs are higher.

Technological risk.- There is little inherent risk in the technology given that Bell Atlantic would use existing network capacity to provide the circuit.

Deployment lead time. Speed of implementation is dependent upon available capacity in the Bell Atlantic network between the points of interest. An estimate is that it would take 30 to 60 days to provide the service given that capacity is available. If capacity is unavailable, implementation would be significantly delayed.

Special considerations. Leased capacity could provide a timely near-term approach to providing higher bandwidths to end-users. When these copper local loops are combined with a less expensive backbone service, end-to-end costs should be less than if purchased solely through Bell Atlantic.

xDSL-based technologies.

General description. Digital Subscriber Line (DSL) technologies provide a means to increase the bandwidth capability of existing copper lines. DSL enables a service provider to offer services at 128 Kbs up to 2 Mbs over copper lines and outside plant that was originally designed to carry analog voice traffic. Many flavors of DSL exist today, such as HDSL, IDSL, SDSL, ADSL, and RADSL. Each offers its own advantages such as higher bit rate, farther distance capability, or adaptive rate features. Some are easier to implement than others, but none are child's play. If it were simple, more RBOCs would offer these enhanced services today to their constituents. A network diagram for delivering DSL services and product literature from Ascend are provided in appendices.

The Telecommunications Act of 1996 created "unbundled elements" whereby Incumbent Local Exchange Carriers (ILECs) are now required to separate, or unbundle, parts of their network. One such part is the local loop, or local wiring from the local CO to an end-user. This is seen as a critical piece in creating a competitive environment in the local loop. CLEC companies can now collocate in a central office, gain access to these unbundled local loops, and provide services directly to end-users. The CLEC pays a monthly charge per copper pair to the ILEC for use of the copper lines, see appendix for Unbundled Local Loop rates. Prices are regulated through an interconnect agreement that is negotiated between the ILEC and an individual CLEC. Pricing is consistent among interconnect agreements.

In order to recover the costs associated with unbundled local loops, such as loop rates, collocation costs, and equipment costs, CLECs must offer enhanced or higher bandwidth services over these copper pairs. Voice services do not provide enough revenue. CLECs have turned to xDSL technology to provide these high bandwidth services.

A Berkshire County CLEC could be formed that would offer xDSL services over the copper local loop. A couple points need to be made.

1) Bell Atlantic local loops are still used in this solution. BA would play a key role in delivering and maintaining service quality to end-users.
2) The copper pairs must be conditioned to carry digital signals at the desired bit rate. DSL is far more forgiving than DS1 transmission; however, upgrades are still required. Upgrades could include removing loading coils in the best case or could require that new copper be run from the CO to the end-site.
3) Time and money are issues. Costs for upgrades are passed on to the CLEC.
4) Many DSL technologies and products exist. Some are easier to work with than others. Products are getting better and cheaper every year.

Capacity and scalability. The capacity of a given DSL product is limited by the DSL technology used, the distance from the central office, and the quality of the copper line. A list of basic DSL types is provided below. In general, lower bit rate products can go farther distances within a given technology, and higher bit rate products require more complex modulation schemes that increase costs.

xDSL	Description	Upstream Data Rate	Dnstream Data Rate	# of pairs	Distance (ft)
IDSL	ISDN DSL	128 kb/s	128 kb/s	1	12,000
HDSL	High bit rate DSL (used for T1 or E1 applications)	1.544Mb/s	1.544Mb/s	2	18,000
SDSL	Symmetric DSL (single pair implementation of HDSL)	768 Kb/s 1.544Mb/s	768 Kb/s 1.544Mb/s	1 2	12,000
ADSL	Asymmetrical DSL-upstream bandwidth from user much lower than downstream bandwidth from network; many variations on bandwidth	32 Kb/s to 768 Kb/s	1.5 Mb/s to 8 Mb/s	1	18,000
RADSL	Rate Adaptive DSL-asymmetric service with adjustable data-rates	128 Kb/s to 1 Mbs	600 Kb/s to 7 Mb/s	1	21,000
VDSL	Very high-speed DSL	1.6 Mb/s max	13 Mb/s to 52 Mb/s		1,000 to 4,500
RADSL	Rate Adaptive DSL-asymmetric service with adjustable data-rates	128 Kb/s to 1 Mbs	600 Kb/s to 7 Mb/s	1	21,000

Reliability and availability. DSL services are provided over the existing copper plant, which is unreliable. However, xDSL technologies use robust modulation schemes that make transmissions more reliable than T1 repeater spans or analog modem data. As such, the effects of weather conditions are lessened. As with DS1 leased lines, copper cable breaks disrupt service until the line is fixed. This affects a very localize group of end-users as compared to backbone failures that affect many.

Technological risk. The risks associated with this technology are:

1) High costs to condition lines to carrier xDSL services.
2) Risk that new copper lines are required: time and money
3) Risk that Bell Atlantic begins to offer competing service with higher margins
4) Technology is still in flux.

Deployment lead time. Speed of implementation is dependent upon Bell Atlantic since Bell Atlantic would be responsible for conditioning/replacing copper lines. It would also take 30-90 days for CLEC to establish presence in CO.

Special considerations. Success in deploying DSL will depend on obtain a certain level of penetration from a given CO. It is a costly endeavor to offer service to only a few customers.

Cable TV-based Technologies.

General description. Regional Cable TV providers are another potential source of telecommunications and data services throughout the area. Cable TV providers, also referred to as MSOs (multiple service operators), own and maintain fiber and coax plant infrastructures primarily used to transport analog broadcast TV. The cable plant is arranged in a branch-tree configuration called a Hybrid Fiber Coax (HFC) network. A sample network topology is shown in the HFC topology appendix. The transmission is almost exclusive one-way, from the Cable TV company towards homes. This is called the downstream direction.

The typical HFC network consists of cable TV headends that distribute broadcast analog programming to smaller headends, called fiber nodes, using single mode fiber runs. The fiber nodes terminate the fiber and convert the programming onto coaxial cable for distribution to homes. Homes are served by coaxial cable. One fiber node typically serves 250 to 500 homes depending on home density.

The HFC network can also be used to carry enhanced services to subscribers' homes. These services include Pay-Per-View programming, cable modem access for the Internet, and phone services. These services require both downstream (to the home) and upstream (to the CATV headend) communications. A small frequency band is available on the coaxial cable to provide this upstream communications.

The available frequency spectrum is partitioned as follows:

0 – 50 Mhz (Upstream Communications)
100 - 500 Mhz (Downstream Analog cable TV, and
550 – 750 Mhz (Downstream Enhanced services (PPV, Cable Modem, Telephony).

A provider's network must be "upgraded" from a purely analog system to be able to offer enhanced services. Upgrades include

1) installing fiber and dividing service areas into smaller segments (250 to 500 homes per fiber node),
2) upgrading downstream amplifiers and network elements to be capable of transmitting up to 750 Mhz, and

3) installing upstream amplifiers and splitters to enable upstream transmission.

Capacity and scalability. The capacity of a Cable TV network is limited by the upstream bandwidth. The upstream channel is limited to less than 50 Mhz, and all upstream communications must occur over this channel without interfering with one another.

Cable modems have had success in areas where networks have been sufficiently upgraded to support service and where cable modem systems have been installed. In general, subscribers enjoy the "fast" access to the Internet, although access "bogs down" as many users log-in. Cable MSOs deploy cable modem services and other existing or future enhanced services to generate additional revenue. These other services include second lines or home shopping through the web. It is expected that the costs associated with implementing these services will drastically decrease with volume deployment.

Cable modem service is currently offered by Adelphia Cable Company in North Adams.

Reliability and availability. Traditionally, the analog cable TV network was designed to deliver a secondary communications service, analog TV. If the cable system went down, subscribers complained, but the ramifications were not severe. System status and alarm mechanisms were non-existent. Traditionally, cable companies were notified of outages not through an advanced surveillance system but from their end-users who call and complain. Systems have been upgraded; however, much of the old equipment is reused and surveillance is still limited. Customers still "perceive" that their cable service is unreliable. Actual statistics on outages are not readily available.

As for enhanced services such as cable modem service and telephony service, these services would be interrupted in conjunction with any cable TV failure that was due to outside plant problems.

Technological risk. The risks associated with delivering cable TV enhanced services are large. The technology is still new. Standards compliance, or the lack thereof, is still an issue. Products are expensive and the costs to implement are large due to the age and complexity of the outside plant. This is certainly a technology area that should continue to experience large improvements in reliability, cost, and features over the next few years.

Deployment lead time. One of the longest lead items associated with delivering enhanced services over the cable TV infrastructure is the outside plant upgrade. The status and reliability of the cable plant varies not only by service provider, but also by region within a service area. Plant upgrades take time and money.

Special considerations. Cable service providers are beginning to offer enhanced services within Berkshire County, such as the cable modem initiative in North Adams. A new access infrastructure developed as a result of Berkshire Connect does not interfere with cable company plans. In fact, the Berkshire Connect initiative may help stimulate end-user needs for home access thus increasing demand for Cable TV products. The two initiatives can work together to address different segments of the market. There may be opportunities for joint initiatives in the future.