A Mayor's Guide to Broadband

The Six Leading Access Technologies

A plain-English primer. Which solution is right for your community?

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How are developers and municipal officials supposed to keep track of broadband technology when the proponents speak a new language filled with acronyms like HFC, FTTP, BPON, BPL and WiMAX? With the increasing focus on municipal broadband, they can't afford to be clueless when it comes to the questions of what technologies are available, how well they work and why one might fit a specific community's needs better than another.

Don't panic! We're not going to try to explain the deep technological details here. We hope we'll shed some light on terms mere mortals are likely to encounter and questions they might be asked. There is more to municipal broadband than just technology – funding and the role of municipalities versus the role of private business, to name a few other issues – but we'll leave these for a separate discussion.

Six Leading Solutions

There are six leading groups of **broadband access** technologies, with many specific flavors of each available:

- **HFC** (Hybrid Fiber Coax)
- **DSL** (Digital Subscriber Line)
- **FTTH** (Fiber to the Home)
- **Wireless**
- **BPL** (Broadband over Powerline)
- **Satellite**

Each of these technologies can provide millions of bits per second ("megabits per second" or **Mbps**) – a useful rough definition of what speed constitutes "broadband," although the Federal Communications Commission threshold, at 200 kilobits per second (**Kbps**), is only a fifth of a 1 Mbps connection. Some technologies are capable of much higher speeds – fiber can provide billions of bits per second ("gigabits per second" or **Gbps**).

■ HFC (Hybrid Fiber Coax)

The first broadband services in the United States were deployed by cable operators as an additional service carried over the hybrid fiber coax (HFC) networks they were starting to build. As its name implies, HFC uses both **optical fiber** and **coaxial** cables. Optical fibers are strung to neighborhoods and then connected to coaxial cables, which carry services the rest of the way to customer homes. Each fiber typically serves from 100 to 2000 homes, with 500 homes most common. Nearly all cable systems have been upgraded from all-coax to HFC – starting in the early 1990s.

Why not use coax throughout the system, as coax can carry a lot of bandwidth? Because signals traveling on coax lose their strength as distance increases. With fiber handling the long-haul, this problem is minimized.

Broadband was initially introduced as a faster way to connect to the Internet for Web browsing and email. As broadband has matured, innovation has led to its application to services beyond these **high-speed data** services. Today cable operators and independent providers such as Vonage are using broadband to provide a new form of digital telephone service, known as **Voice over IP** (**VoIP**) or **Internet telephony**. Some companies are starting to exploit the higher capacity of broadband to carry **video conferencing** and **video telephony**. Broadband is increasingly used to carry **video services** to personal computers and even to transmit video to the TV (**IP TV**).

In Web browsing, most of the information is coming **downstream** from the Internet to the person and very little goes **upstream** from the person to the Internet. Think about it. A few keystrokes you type into your computer can summon dozens of detailed Web pages. Thus, the speed needed downstream is much greater than the upstream speed. When downstream and upstream speeds are not the same, the transmission is called **asymmetric**; if they are the same, the transmission is **symmetric**.

Some services like Web browsing and video are highly asymmetric. Others like voice are inherently symmetric. Cable's HFC network was engineered for video and is inherently asymmetric – a good fit for today's service mix.

The HFC infrastructure can simultaneously carry many different kinds of services. Through a technique known as **multiplexing,** different services – broadcast television, video on demand, high-speed data and telephone service – are carried through different "channels" on the HFC infrastructure.

Cable modems are based on a **point-to-multipoint** (**PTMP**) architecture. A single **cable modem termination system** (**CMTS**) at a central cable **headend** connects through the HFC infrastructure to cable modems in hundreds of customer homes. The headend is where cable companies insert their programming into the network of fiber and coax. This is a very efficient way to use the expensive HFC and CMTS resources, although it requires users to share their

Broadband connection at side of home; inside, residents see an Ethernet jack.

bandwidth with their neighbors.

Early cable modem technologies were all proprietary. Because equipment from one vendor would not work with equipment from another vendor, cable operators were forced to buy all subsequent equipment from the same vendor once they had made an initial selection. The resulting high equipment prices slowed the initial deployments.

The cable operators responded by working together, through Cable Television Laboratories (CableLabs), to create a common purchasing specification for cable modems. This specification–called **DOCSIS** (Data Over Cable Service Interface Specification) – is now a national and global standard. With dozens of vendors competing to provide a commodity product, the wholesale price of cable modems today is less than 10 percent of what it was when cable modems were first introduced. HFC is the most common broadband technology in the United States.

DSL

Telephone companies responded to cable modem services in the late 1990s with a technology known as Digital Subscriber Line or **DSL**. DSL multiplexes digital data over the traditional twisted-pair copper telephone line used for conventional voice service.

DSL comes in many "flavors" collectively known as **xDSL**. Most DSL deployments are based on Asymmetric DSL (**ADSL**). As its name implies, ADSL provides much higher data rates downstream than upstream – typically in a 3:1 ratio or higher. Symmetric DSL (**SDSL**) is mostly sold for business use. Very-high-rate DSL (**VDSL**) provides much higher speeds than ADSL, but over a much shorter distance; it is being used to provide IPTV services in densely populated areas.

All DSL systems are based on **point-to-point** (**PTP**) architectures. The DSL modem in a customer home is paired with a port on a DSL access multiplexer (**DSLAM**) at a telephone **central office**. Individual customers do not share the line with their neighbors. Telephone companies have promoted this as an advantage over cable. But everybody shares resources at and beyond the telephone central office or the cable headend and the real-world differences are small.

Just as cable operators worked together to bring about the DOCSIS standard, telephone companies have been working together through the DSL Forum to bring about a series of standards for DSL modems. As prices have dropped, DSL deployments have expanded rapidly. DSL is the most widely deployed broadband technology globally, because cable infrastructure is sparse outside of North America.

DSL technologies have a very limited range. ADSL typically runs out of steam about three miles from the telephone central office (**CO**), VDSL in half a mile or less. Many American families live in suburban homes a long distance from the CO, and beyond the range of DSL.

The obvious way to extend the range of DSL is to create a hybrid fiber copper network – extending fiber out to neighborhoods and then connecting the fiber to the existing copper twisted pairs in the same manner as HFC. This technique is sometimes called "fiber to the neighborhood" or **FTTN**.

The weak link in further DSL expansion is the twisted pair infrastructure to customer homes. While newer DSL technologies – such as **ADSL2+** and **VDSL2** – are designed to provide higher speeds, they require substantial investments in new fiber and equipment.

As telephone companies consider the expansion of DSL services – especially as they consider offering video services to compete with cable operators – they need to decide how far to extend the fiber. Do they extend fiber to the neighborhood with FTTN or extend farther to cover a small number of adjacent homes ("fiber to the curb" or **FTTC**)? Why not go all the way to individual homes?

Fiber To The Home

As we have seen, fiber is part of all cable broadband deployments over HFC, and part of many DSL deployments with FTTN or FTTC. The logical end game is to run a fiber strand to each individual home ("fiber to the home" or **FTTH**). This is also known as **FTTP** for "Fiber to the Premises," to make it clear that non-residential premises can use this service as well.

For many years, FTTH has seemed the ideal long-term broadband technology. Today's low-loss glass fiber optic cable provides many advantages over previously developed transmission media. A single fiber strand has a huge carrying capacity – probably sufficient for 100 years or more. Fiber's immunity to interference and its low signal loss means that signals can travel great distances without additional equipment.

Until recently FTTH has had a very high construction cost compared with HFC. Except for a few with no other options, most communities have made other choices or have decided to wait.

In the past few years, FTTH technologies have matured, competition has been driving down costs, and standards have started to emerge. As fiber economics have improved, it has become increasingly practical to use fiber all the way to the end user. Some pioneering communities such as Jackson, Tennessee and Provo, Utah are in the process of installing citywide FTTH; the UTOPIA project has committed to use FTTH for 14 more Utah cities.

FTTH is not a single technology. There are many ways of implementing FTTH, some proprietary and some based on evolving standards. Some are PTMP and some PTP; some **active** and some **passive**; some symmetrical and some asymmetrical.

All FTTH networks connect an optical network unit (**ONU**) at or near the customer home through optical fibers with an optical line termination (**OLT**) at a **serving office**. Some fiber networks are PTP with one or more fiber strands running all the way from an ONU in each home to a dedicated **port** on the OLT; others are PTMP with several ONUs – often 32 or more – sharing a single OLT port.

All fiber networks have **active components** – ones that require power and in some way process information – in the OLT and the ONU. **Active fiber networks** have additional active components – repeaters, relays and amplifiers – in the field between the OLT and the ONU. **Passive optical networks** (**PONs**) eliminate all active components between the serving office and the customer's location; the only elements in the path are passive splitters or couplers that work to pass or restrict light, and have no power or processing requirements.

Active components, by their nature, are more subject to failures than elements that do not include power or processing. Passive networks must be assembled more carefully, however, because the signal must be maintained over long distances without extra processing. Until 2004, passive networks were generally a bit cheaper. The cost of active components has come down with increasing volume, and some say active may now be cheaper.

There are several different types of PON architectures. **APON** is based on a standard called **ATM**. **BPON** ("Broadband" PON) combines APON with analog video. **EPON** is based on 100 Mbps Ethernet and **GPON** on Gigabit Ethernet. BPON is widely used in Japan.

Many of the latest FTTH systems are based on **Ethernet**. Long used for local area networking within businesses and some homes, Ethernet is now being applied to FTTH as well. While Ethernet is designed as a PTMP technology, some vendors are taking advantage of its very low cost by deploying Ethernet in a PTP architecture, carrying all services over an Ethernet channel dedicated to an individual home. UTOPIA has selected a standards-based PTP approach.

Because a single fiber can carry multiple signals using different wavelengths or "colors," it is possible to carry many different channels through the same fiber. Several FTTH technologies exploit this by carrying traditional analog video along with digital data in the same fiber. On the home side of the ONU, the analog video is identical to that from traditional cable networks, and standard cable-ready TV sets can tune broadcast video channels without set-top boxes.

- BPON, being deployed by Verizon in many cities, combines ATM with analog video.
- Jackson, Tennessee is deploying a system that combines Ethernet with analog video.
- By contrast, since the UTOPIA network is using IP rather than analog video, video service providers will need to provide interface boxes for each analog TV.

Wireless

Terrestrial wireless (as opposed to satellite-based wireless) is a rapidly developing form of broadband access. **Wi-Fi** – a form or wireless networking based on the **IEEE 802.11** standards – has emerged in the past five years from nowhere to installations in millions of homes. Most notebook PCs are now sold with Wi-Fi built in.

Most Wi-Fi systems today are based on the most-recent **802.11g** standard. A new **802.11n** standard promising higher speeds and greater range is in development and products should reach the market during 2006. Some vendors are already selling "Pre-N" systems based on the "multiple input multiple output" (**MIMO**) technology that will be a key element in the new standard.

Over the past few years, Wi-Fi has become available at tens of thousands of **hot spots**. Most provide high-speed Internet access at a nominal hourly or daily fee. Some communities, such as Seattle and New York City, have created free municipal hot spots in public places such as parks and downtown streets.

The latest development is to cover an entire city with Wi-Fi. These "**metro Wi-Fi**" offerings are based on innovative "**mesh networking**" technologies. The mesh approach links Wi-Fi devices to each other in a way that allows the network to heal itself in case a device becomes defective. All municipal networks and hot spots support standard Wi-Fi client devices such as those built into notebook PCs. Today the **network nodes** are based on proprietary mesh technologies, but this is being standardized so network nodes from different vendors can operate in the same network. Chaska, Minnesota is an example of a community that has deployed metro Wi-Fi to make both outdoor and in-home broadband service available to all citizens at a low cost; recently Philadelphia and other larger cities have announced plans for similar deployments.

Metro Wi-Fi addresses different needs than FTTH. While FTTH provides a unified infrastructure to carry the full range of services – video, data and voice – to the home, metro Wi-Fi provides mobility to support users who want to access the Internet while they're away from home. Some communities – such as Saint Cloud, Florida – are planning to deploy both FTTH for new construction and metro Wi-Fi throughout the community to serve both sets of citizen needs. Wi-Fi alone has been used to serve homes as well; residents typically pick up the signal with an inexpensive router and then retransmit it within their homes.

Because Wi-Fi was designed with a short range suitable for the inside of buildings, it requires many network nodes to cover larger areas. It is well suited for higher-density areas, but less so for lower-density areas. Wi-Fi networks based on 11n will have greater range, but the problem still remains to some extent.

WiMAX is the latest buzzword in wireless. Based on newly developed **IEEE 802.16** standards, WiMAX provides a PTMP wireless infrastructure capable of much greater distances than Wi-Fi. Like Wi-Fi, WiMAX is based on a widely supported standard, and many vendors are competing to offer compatible products. The earliest WiMAX products have just started to appear on the market, and products that have passed certification testing for interoperability will be on the market later in 2005.

The second generation of WiMAX – known as **802.16e** or **mobile WiMAX** – is now in development. Mobile WiMAX will be deployed in a cellular pattern similar to today's cellular voice networks, and will support "portable broadband." People will be able to use broadband wherever they are, even in a car. Major WiMAX supporters such as Intel say that future notebook PCs will support both Wi-Fi and mobile WiMAX. Municipalities can use mobile WiMAX to enhance communications with fire, police and ambulance services.

The first deployments of mobile WiMAX will take place during 2006 in the major cities of Korea, under the name "WiBro" ("wireless broadband"). If these prove successful, some communities may consider deploying mobile WiMAX.

BPL

Just as existing telephone lines and coaxial cable can be adapted to carry broadband, so too can existing electrical lines – the "third wire" to everyone's home. Recently developed technologies, known as "powerline communications" (**PLC**) and "broadband over powerline" (**BPL**), can provide broadband speeds over the electrical wiring that runs overhead or underground in every community.

BPL technologies outside the home are all proprietary today. A standard called HomePlug has been applied to powerline communications inside the home, and an effort is underway to extend this standard to BPL. Several other standards efforts are underway, and it will probably take some time for BPL technologies to mature sufficiently for durable standards to be widely accepted.

Many municipal and investor-owned power companies have run trials of BPL over the past few years, and the technologies are maturing. Several trials have now moved into full-scale deployment. The best-known of these is in the city of Manassas, Virginia. The Utility Department in Manassas, a suburb of Washington, DC, views BPL broadband services as a natural complement to the electricity, water and sewer services it already supplies to the city's businesses and citizens.

Although amateur "ham" radio operators say BPL can interfere with radio transmissions, the FCC has approved deployment of BPL with suitable limitations on interference.

Satellite

Because satellite beams cover a very large area ("footprint"), they are ideal for broadcast television. Communications satellites can also be used to deliver broadband services but the large footprint is a serious problem – it's not very efficient to use a channel covering many states to deliver a service to an individual home.

A new satellite with "spot beam" antennas covering a much smaller area was launched in 2004, and broadband service launch is planned for the second quarter of 2005. Unlike earlier "one way" satellite broadband services, which used telephone lines for upstream communications, this will be a full "two-way" service using the satellite for both directions.

Spot beam satellites will bring broadband service to homes in low-density areas not previously served by broadband providers. Because satellite broadband providers are directed to homes out of range of ground-based broadband, satellite is probably not a good fit for community broadband except in very exceptional cases.

The Right Solution for You

The economics of fiber have improved to the point where few communities would consider older solutions such as HFC and DSL that combine fiber with copper. BPL is in its infancy. Satellite is appropriate only in special circumstances. Thus FTTH (or FTTC) and wireless are the two main choices for communities. FTTH looks particularly good in new "greenfield" construction, where its installation cost is low. How do you choose between them – and then the specific "flavors" of each?

The impetus for community broadband generally comes from some set of unsatisfied needs. Because different technologies accomplish different goals, it is important to clarify and prioritize the objectives of any project. If you want to provide Internet access to bridge the digital divide, metro Wi-Fi might be a fast and relatively inexpensive way to do so. If the main driver is attracting high-tech companies with the goal of economic growth, then FTTH – while more expensive and time consuming – might be best.

Is your goal only high-speed Internet access, or does it also include telephone and TV services? If TV is part of the mix, must you support analog (standard) TV or is it acceptable to provide IPTV, which will require a special interface box for every television?

One of the most difficult issues to tackle is "how much bandwidth will be enough?" Voice services consume only small amounts, but data and especially video services can consume huge quantities. Planning bandwidth has great similarities to building new roads. In each case, once the paths are open, people discover them and they can become clogged with traffic very rapidly. The end result in both cases is unhappy users.

If you decide to carry all the services – voice, data and video – with IP technology, you'll want to construct a "bandwidth budget" for each home, allocating sufficient bandwidth for several channels of high-definition TV and several simultaneous phone calls, and competitive data speeds – this can easily amount to 30 to 50 Mbps. This is comparatively easy with most FTTH technologies, much harder with wireless.

- High-speed data services started out around 1 Mbps, but competition has been driving this higher. Speeds like 4 or 5 Mbps are now being offered at the same prices charged for 1 Mbps a few years ago. New technologies promise speeds of tens of Mbps with a goal of 100 Mbps for both cable and DSL.
- High definition TV takes a lot of bandwidth. With current technology, each channel needs about 20 Mbps. New compression schemes such as MPEG 4-AVC or Windows Media Video 9 can reduce this to 8 Mbps.

At the consumer end the broadband service connects to things like telephones, TVs and home computers. The service either needs to be compatible with the existing analog consumer equipment or some sort of converters will be needed.

- VoIP telephones have started to appear on the market, but the vast majority of homes still have traditional analog phones. VoIP services use an "analog telephone adaptor" (ATA) to connect to your existing telephones.
- For IP video services, you'll need an IP set-top box for each TV.

Short-Term Or Long-Term?

What is the time horizon for your city's involvement in broadband? Are you trying to solve a short-term problem or a long-term one? Wireless services – municipal Wi-Fi now and WiMAX soon – can be deployed quickly with a relatively low front-end investment. But standards are evolving rapidly, and any equipment will probably need to be replaced every few years to keep up with advances in technology. Starting with Wi-Fi or WiMAX now, with the idea of moving to fiber in a few years, may make financial sense because fiber costs are expected to continue dropping. But any changeover may be annoying to residents. And politically, residents may come to see the initial Wi-Fi cost as a "waste," even if it gets a network installed more quickly and even if it positions you to wait for lower fiber costs in the future.

If the underlying fiber infrastructure is planned and executed properly, you can avoid digging up streets for at least twenty years – probably more like fifty. The electronic equipment at the ends of the fiber will have a shorter life and will probably need to be replaced several times during the life of the fiber. Fiber is expensive and time-consuming, but a long-term investment.

Finally, a city-provided broadband infrastructure can upgrade city services. Many cities have installed fiber to interconnect municipal facilities and to connect them to the Internet. It is logical to extend these facilities for other city functions. Milpitas, California has deployed metro Wi-Fi to provide broadband access in all police and emergency response vehicles; officers can control video cameras to view an accident scene while they're on the way. Manassas is using BPL to control traffic lights. Other communities are using broadband for video security cameras, educational videoconferencing, and in-home health services for the elderly.

The People's Choice

What do your citizens want? Do they get acceptable broadband services from commercial providers, or do they think the city can do a better job? Are they looking to the city to supplement existing broadband services – for example by providing broadband for use outdoors in public places – or do they want the city to provide the complete broadband infrastructure like roads and other public services?

For further reference, our Web site contains many articles on broadband access. See http://www.broadbandhomecentral.com/guide_access_municipal.html for a discussion of municipal broadband, and http://www.broadbandhomecentral.com/guide_access.html for additional background on all broadband access technologies discussed in this article. ◆

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