Technological Analysis of Open Access and Cable Television Systems

Supplemental Report of January 2005

Prepared for

The American Civil Liberties Union
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1. Executive Summary

This Report presents the results of an engineering evaluation of broadband technology and technical issues regarding cable "open access." The Report was prepared by Columbia Telecommunications Corporation (CTC) at the request of the American Civil Liberties Union and the Center for Internet and Society at Stanford Law School. This Report is a supplement to CTC's eponymous report of December 2001.

The Report addresses some of the technical issues raised by the debate over whether cable system operators should be required to offer subscribers "open access" to Internet Service Providers (ISPs) that compete with the cable operator's own ISP. Specifically, this supplemental Report:

- Evaluates the technical capabilities of non-cable forms of broadband that seek to compete with cable networks.
- Describes the ways in which widely-deployed cable technologies facilitate monitoring and manipulation of Internet use and content.
- Describes how the engineering of cable systems has increased the cost and complexity of providing open access and technical competition.[1]

Each of these issues is summarized below and examined in detail in Sections 2 through 4 of this Report.

Finally, this Report suggests that the reader question whether the "open" systems claimed by the cable industry are really "open" from the standpoint of offering genuine options (as opposed to identical products that are simply rebranded) to consumers and precluding the cable operator from monitoring and manipulating customer data.

1.1. The Nation Still Lacks Technical Alternatives for Broadband

In Section 2, this Report evaluates existing and emerging broadband networks that are able to deliver broadband services to residences and businesses—the Report describes the technical status of these non-cable forms of broadband: Digital Subscriber Line (DSL), Satellite, 4G Wireless, Broadband over Powerline (BPL), and Fiber to the Premises (FTTP).

[1] This Report uses the term "technical competition" for lack of a better phrase to represent the technical ability to compete with or over cable broadband networks. We do not mean to make or suggest any point regarding economic competition, which is not the subject matter of this document. Rather, we are addressing the technical feasibility of competition—the technological capability of a competitor to offer services given the engineering issues inherent in the way the relevant technologies have developed.

The Report demonstrates that there exists no real competition to cable broadband networks from a technical standpoint—cable stands alone in its capacity, level of deployment, and capability. In other words, as among the various "pipes" from which one can receive broadband service, cable is the fattest, most robust, most ubiquitous, and most commonly-used. Other "pipes," such as wireless, powerline, and satellite, simply do not have the same technical capability or ubiquity and are not viable technical competitors.

It is important to distinguish between "pipe" and "services." These two distinct categories are frequently lumped together, which is not technically accurate. "Pipe" or "broadband network" refers to the medium over which one sends and receives data (and, increasingly, voice and video) over the Internet or private networks. "Services" are the various types of voice, video, and data transmissions that one can send or receive, such as, for example, Voice over IP from Vonage; email from Yahoo; streaming video from Disney. While there may be significant technical competition in provision of services such as voice, email, and children's video—there is not significant technical competition in provision of "pipe" -- the road over which all of those services run.

It is helpful to think of "pipe" using the traditional metaphor of the "Information Superhighway:" envision the services as the cars, trucks, and other vehicles -- and the "pipe" or network as the road over which the vehicles run. Without the road, the cars are useless. In the current technical environment, there is a nationwide, well-paved superhighway network called cable—and it has a ramp into almost every home in America. Significantly, it is privately owned and all traffic is controlled by the owner/operator. From a technical standpoint, there are no comparable highway systems—they have either not been built (usually because they are based on untested technology) or they reach fewer areas, have fewer lanes, and have technology potholes that make it difficult to compete with respect to speed and ease of travel.

1.1.1. Digital Subscriber Line

DSL represents a competing network—but of roads, not superhighways.

DSL does come closest to providing a worthy competitor for cable but it is still not comparable because it is based on lower-bandwidth infrastructure. DSL runs on telephone network copper wires, which simply cannot handle the same capacity as cable's hybrid fiber/coaxial (HFC) network.[2] As capacity requirements increase, DSL is likely to fall further behind cable.[3]

1.1.2. 4G Wireless

4G is the term applied to promising new wireless technologies that offer sustained data speeds of a few Mbps or more per user. These include technologies with standards developed by working

[2] See CTC's original report of December 2001 for a detailed description of HFC technology.
[3] The limitations of DSL are demonstrated by the efforts of the telephone companies to supplement their old copper phone networks with new FTTP networks (discussed below) in limited metropolitan areas.

groups of the Institute of Electrical and Electronics Engineers (IEEE) and known by IEEE standards numbers 802.11 (Wi-fi), 802.16 (Wi-MAX), and 802.20. 4G also includes new generations of wireless technologies planned by the current cellular providers.

4G receives significant cultural and press attention, but the excitement over this technology should not blur the fact that 4G, no matter how promising, does not currently represent an alternative broadband network. 4G does not have comparable capacity to cable, versions of 4G using unlicensed spectrum may be limited in range and subject to interference, and 4G is largely untested as a widespread broadband medium – a technology still in development.

1.1.3. Broadband over Powerline

BPL has received significant attention for its potential to bring broadband into the home over existing power lines. But BPL is only beginning commercial deployment in the United States, is subject to ongoing disputes regarding its interference with other services, and is nowhere close to widespread deployment or being proven as a credible technological alternative to cable. The BPL trials in the United States to date have been small and have not demonstrated its capability to scale to larger networks. In addition, BPL offers lower capacity per user than cable.

1.1.4. Fiber to the Premises

If cable is the national information superhighway, FTTP represents the high-speed Acela train between Washington, New York, and Boston. FTTP is the holy grail of networking: a fat pipe all the way into the home or business--but in the near future only available for a lucky few located in the first areas of deployment. FTTP has seen limited deployments to date and it is currently unclear how much of the American population it will eventually serve.

1.1.5. Satellite

Satellite technology has proven itself a technical competitor to cable television for delivery of one-way video and radio, but it is significantly inferior to cable modem service for Internet and interactive services. Satellite broadband cannot match cable for bandwidth, it is far more costly, and satellite transmission entails a latency and delay issue that makes widespread Internet use unlikely utilizing existing technologies.

1.2. Cable Technology Facilitates Monitoring and Manipulation of Internet Use

Section 3 provides a technical analysis of how ubiquitous cable technologies enable cable operators to control and monitor the content, usage, and personal information of the transmissions Americans send and receive over the Internet.

The technologies enable the network operator to select "policies" for individual users, applications, and portions of the network. These policies are essential to the functioning of the systems as engineered, but they also enable technical practices of which few consumers are aware, such as:

- Speeding (or slowing or blocking) transmission for any reason the operator wishes, including, for example, the political viewpoint of the site at issue, or whether the site has a commercial relationship with the operator.
- Slowing or blocking content that competes with the operator's own products, such as Voice over IP or Video on Demand.
- Blocking or limiting peer-to-peer traffic.
- Monitoring and/or recording data regarding customers' message transmissions and Internet use.

A number of different network technologies enable such practices. Section 2 of this Report discusses some of the prevalent technologies in cable Internet systems that could be used in this fashion, including traffic management techniques, PacketCable, Deep Packet Inspection, and traffic management software. All these technologies are legitimately used to manage and operate data networks, but also enable practices of monitoring and manipulation.

To our knowledge, the Federal Communications Commission has not investigated whether cable operators are using these technologies to monitor or manipulate the Internet use of cable system customers.

1.3. The Engineering of Cable Modem Systems Limits Technical Competition

Section 4 describes how technical competition on cable systems—by multiple Internet service providers on the same cable system, or by service/device providers such as TiVo--has been made more complex and expensive by the ways in which cable modem networks and equipment were engineered—with the end result of precluding or limiting the technical capability of competitors to offer their products over cable.

1.3.1. Specifications such as DOCSIS are based on a single-provider model and therefore complicate open access

The early designs and specifications for cable modem networks were based on an assumption of a single provider and central control by that provider (on the model of traditional cable video services). Those design choices have greatly complicated the task of offering open access.

Such specifications as CableLabs' Data Over Cable Service Interface Specification (DOCSIS) were developed without the goal of providing connectivity between cable modem users and multiple ISPs. As a result, DOCSIS itself has limited capability to deal with such essential technical issues in open access as connectivity of multiple provisioning systems to common CMTS hardware; capability for interference-free segmenting of capacity between multiple service providers over a common transport network; separate physical interfaces for connectivity to separate ISPs; and means for ISPs to separately control Quality of Service (QoS).

1.3.2. Operator hardware and software is proprietary and therefore complicates the ability of competitors to operate on that system

The design choices of the cable industry have also created significant technical advantages for the cable operators in competing with other service providers -- because competitors face technical obstacles to operating on the operators' proprietary systems.

The equipment used in various cable systems is frequently not interoperable with other systems. As a result, a third-party vendor is at a significant disadvantage developing a competitive product for use on a digital cable system. By nature of the engineering of the cable systems, these would-be competitors face technological challenges that seriously disadvantage their innovations relative to similar offerings by the cable provider.

1.4. Some "Open" Systems May Enable the Same Monitoring and Manipulation

The authors of this Report intended to return to a subject raised in the 2001 report—an evaluation of the accuracy of the cable industry's claim that many of their systems are "open." As in the 2001 report it supplements, this Report uses the term "open access" to refer to the ability of competing Internet Service Providers to offer services over cable systems, assuming both of the following essential technical requirements are met: (1) the technical architecture or its configuration enable ISPs to offer the services they wish without constraints imposed by the cable company for non-technical reasons; and (2) the technical architecture or its configuration precludes the cable company from manipulating or monitoring the content of the data transmissions sent and received by the ISPs' customers.

Under this definition, simple access by multiple ISPs -- of a rebranded product controlled by the cable operator – does not qualify as open access because the cable company controls and limits the services the ISP can offer and the cable operator is able to manipulate and monitor data.[4]

[4] In rebranding scenarios, the operator decides which ISPs are granted access to the system. Consumer choice is limited to those providers that have agreements with the cable operator. Further, the operators usually retain

Similarly, a system does not meet the definition of open access if the technical operation of the "open" cable system enables the cable operator to manipulate and monitor transmissions using such technologies as those described in Section 3.

At the time of the initial report, the "open" systems publicized by the cable industry were frequently in fact merely rebrandings – scenarios under which consumers may have choice among ISPs on the system, but are receiving largely the same product from all ISPs, a product created and controlled by the cable operator. As a result, these "open" systems may have offered price competition, but they did not offer *technical* competition of differentiated products.

Since the time of the initial report, more cable systems, particularly those of Time Warner Cable, have given competing ISPs opportunity to offer service over their systems—but the terms of their relationships are secret; there is no publicly-available information regarding those arrangements; and there is no way for consumers to know if they are indeed being offered choice—or if they are offered a product that is still subject to Time Warner's technical capability to monitor and manipulate.

Given the complete lack of public information on this subject, this Report cannot draw conclusions about how "open" access on those systems has been set up—we can only caution that claims of open access be regarded as incomplete unless those arrangements do indeed meet the definition of open access--access that is not simply rebranded and is free of transmission monitoring and manipulation.

To our knowledge, the FCC has not evaluated the technical setup of these "open" systems to determine whether they are indeed open with respect to the issues raised here.

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significant control over what services the ISPs can provide consumers, and the ISPs generally are limited to rebranding the connection to the Internet backbone that is selected and set up by the operators.

2. Technical Status of Other Broadband "Pipes"

This Section presents an analysis of the technical status of non-cable forms of broadband that seek to compete with cable, including Digital Subscriber Line (DSL), Broadband over Powerline (BPL), Wireless Broadband, Satellite Broadband, and Fiber to the Premises (FTTP). For each technology, the analysis addresses the current state of development and deployment of these technologies, and the capabilities of these technologies relative to those of cable Internet systems.

From a technological point of view, cable remains the dominant form of broadband in almost all areas. FTTP and Wireless Broadband may begin to provide comparable or better performance than cable in the next few years, but their deployment in that period is likely to be limited to the (largely metropolitan) areas selected by the providers for initial deployment and to the communities that build their own municipal networks. DSL is widely deployed, but DSL and the telephone infrastructure over which it runs do not have the capacity of the cable infrastructure. BPL is only beginning to be deployed in larger systems and is not yet proven in the United States. Satellite is expensive and has technical limitations that impair its performance relative to wired and fixed wireless technologies.

2.1 Digital Subscriber Line

DSL is usually provided by the local telephone company over the same type of twisted-pair copper line as standard analog telephone service (also known as "Plain Old Telephone Service" or "POTS"). Currently, DSL is one of the primary technologies for residential and business Internet services, and its significance is second only to cable Internet technology.

DSL is widely deployed and is a proven technology. However, it more limited in capacity than a cable system. The telephone wires used by DSL have a much more limited frequency range than cable. As a result, most DSL subscribers do not receive the data speed that cable subscribers can receive.

Another result of DSL's limited data capacity is that DSL providers are more limited in offering video services than cable. While cable was designed from the beginning to carry multiple video channels and can deliver these channels directly into a television, DSL can only be an effective video platform if the particular DSL deployment is specially engineered for high speeds and if it uses IP video encoding technology and set-top converters (Section 2.1.3).

Partly as a remedy for the limitations of DSL, Southwestern Bell Corporation (SBC) and Verizon Communications are in the process of constructing FTTP networks (Section 2.4).

2.1.1. Technical Description

DSL makes use of unused frequencies on POTS systems to transmit digital data.[5] POTS systems use only frequencies from 0 to 3400 Hz, because this limited range of frequencies easily transmits the human voice. Theoretically, therefore, the frequencies above 3400 Hz on the same copper wires are free to transmit high-speed data or other services.

Standard telephone system architecture dictates the type of connection a subscriber receives over DSL – as with phone service over the same network, each DSL subscriber has a dedicated physical connection to the telephone central office. This differs from a cable modem network, in which customers share the physical network connection with everyone else in a neighborhood.

As with other broadband technologies, DSL service is "always on," meaning that there is no dial-up required to initiate a connection (although many providers do require entry of a login and password for use, and there is a delay while authentication takes place). Users do not receive "busy signals" from their provider.

There ideally should not be interference between voice and DSL on the same line, because they use different parts of the frequency spectrum. To ensure the separation of the two services on the same phone line, a low-pass filter is attached to those lines that are attached to a phone rather than a DSL computer.[6] Without the filter, DSL signals can create annoying background noise for voice calls.[7] The low-pass filter permits through the phone only frequencies below 4 kHz and blocks any frequencies above 4 kHz. Voice is preserved but data is blocked, and phones can be used without interference from the DSL service on the line.

DSL has been rapidly deployed by phone companies and adopted by consumers and businesses, with particular success in commercial areas where cable modem service is often not available. This fast, successful deployment is due in part to the ubiquity of copper wire for telephone service throughout the country. As the market for broadband emerged, the phone companies were able to capitalize on infrastructure that already runs to most homes and businesses. This infrastructure reduced the need for extensive hardware and cable installation.

Even in densely populated areas, DSL service might not be universally available. DSL requires proximity of the subscriber to the telephone central office. The central office is the building that contains telephone switching and multiplexing equipment and connects to the telephone network and Internet via a fiber optic ring. The central office is the telephone counterpart of the cable hub site where the CMTS router is located.[8]

The farther a subscriber is located from the central office, the slower the bit rates provided by DSL. This "slowing" results from the tendency of any transmission line to lose its highest frequency signals over long distances. As a result, high-speed DSL communications become difficult once the line extends more than a few miles from the central office because DSL uses

[5] http://computer.howstuffworks.com/dsl1.htm, accessed July 12, 2004.
[6] http://computer.howstuffworks.com/dsl6.htm, accessed July 13, 2004.
[7] http://www.excelsus-tech.com/index.cfm?fuseaction=products.Category&id=2, accessed August 10, 2004.
[8] http://ae.spirentcom.com/Resources/glossary.htm#c, accessed June 21, 2004.

the highest frequencies on the telephone wire. In general, DSL in the few Mbps range (comparable to cable modem) is only available if the line is 18,000 feet or shorter.

Some DSL carriers are addressing this problem by constructing fiber optic extension cords and locating outdoor enclosures (containing DSL access multiplexers known as DSLAMs) between the central office and customers to expand their coverage area. Many telephone companies now claim they can provide DSL to over 90 percent of their customers.[9]

In addition to the problems associated with distance, a heavily-utilized central office may not have the router capacity or Internet backbone capacity to support its customers. The central office would become a bottleneck that could slow overall data speed.[10]

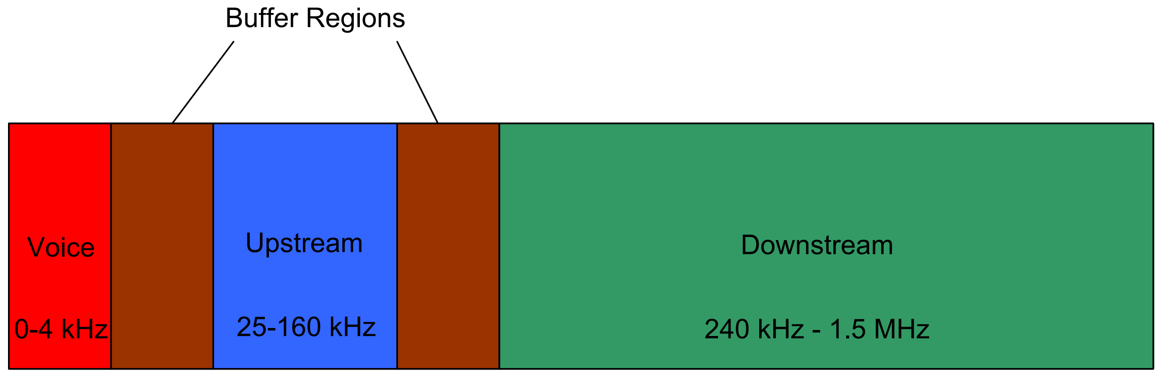
DSL modems and central office equipment are not as highly standardized as cable modem technology. Although DSL subscribers can self-install their modems, they must obtain their modem from the DSL service provider. There is not a marketplace of equipment at electronics stores that interfaces directly with the DSL line. Instead, the subscriber purchases home networking or wireless appliances that interface with the DSL modem provided by the DSL provider.

DSL deployment relies on millions of miles of copper wires, many of which were installed decades ago and may be damaged or low in quality. Because of the age of the physical plant, some lines may not support DSL or may work only for very short distances from the central office. Lines may also have been installed with low-pass filters that block the frequencies needed for DSL communications. For those lines, DSL deployment will be more costly and complex, because the filters must be removed.

There are two standards for DSL service. The first is carrier-less amplitude/phase system (CAP). This standard was developed first, relatively easy to implement, and widely deployed. CAP splits the frequency spectrum of the copper wire into three regions: voice, upstream (user to server), and downstream (server to user). Each of these three regions utilizes a distinct portion of the frequency spectrum. The three channels have wide gaps between them to reduce interference among them. To illustrate, in one potential scenario of a three-channel separation, voice occupies roughly from 0 to 4 kHz, upstream occupies 25 to 160 kHz, and downstream occupies 240 kHz up, going as high as 1.5 MHz in some DSL systems.[11] Each equipment vendor or DSL service provider may use different ranges for upstream and downstream, but voice will always be restricted to 4 kHz and below. Figure 1 illustrates one example of how a DSL system may break down its frequency spectrum using CAP.

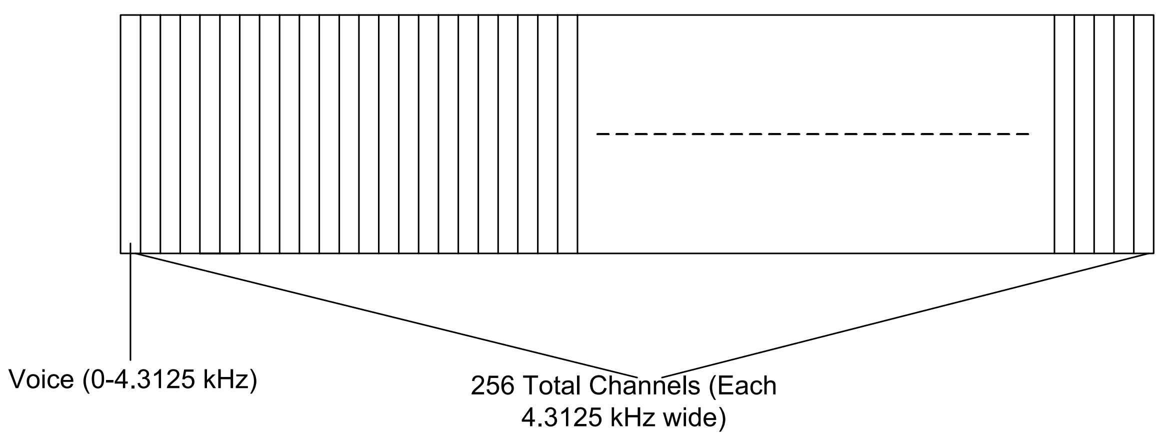
Figure 1: An Example of Frequency Spectrum using CAP

[9] http://www.dslprime.com/News_Articles/news_articles.htm, accessed October 14, 2004.
[10] https://secure.linuxports.com/howto/intro_to_networking/c6627.htm, accessed July 13, 2004.
[11] http://computer.howstuffworks.com/dsl4.htm, accessed July 14, 2004.



The second standard is DMT, or discrete multi-tone. DMT has surpassed CAP in use and is generally used in newly deployed DSL systems. In DMT, a DSL data signal is split into 256 channels of 4.3125 kHz each, each of which has a different modulation scheme.[12] Data transmissions move dynamically among channels, searching for the best channels to maximize speed and clarity. As a result of this constant monitoring and movement, DMT is more complex than CAP but is also more flexible and efficient.[13] Figure 2 shows a schematic of a DMT system.

Figure 2: DMT System

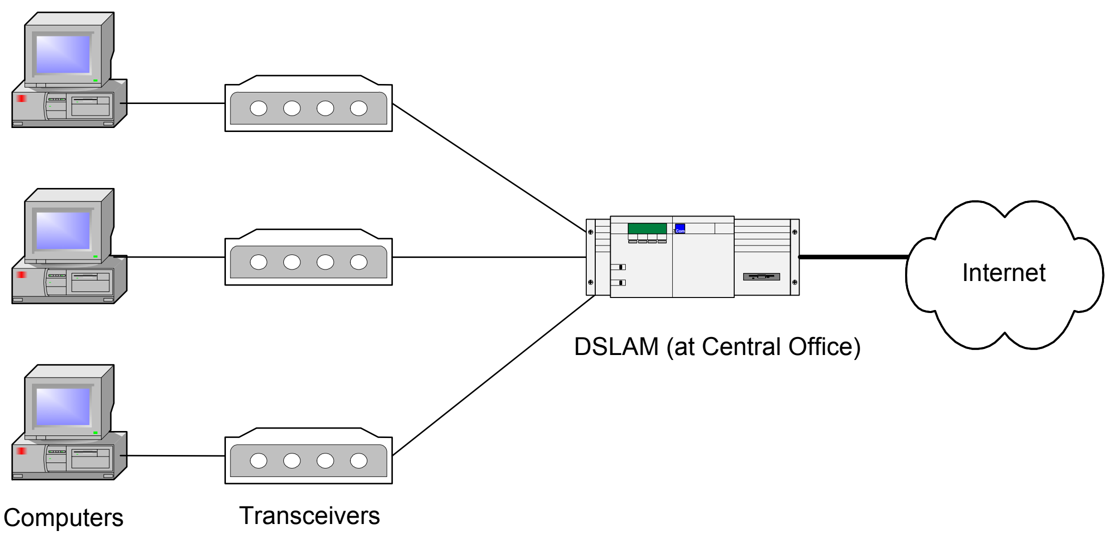


Under either CAP of DMT, DSL requires two key devices to transmit data from the server to the user or vice versa. First, each user has a DSL modem or transceiver attached to their computer. Second, at the telephone company central office is a DSL Access Multiplexer (DSLAM). These two devices communicate over a dedicated copper line.

[12] http://searchnetworking.techtarget.com/sDefinition/0,,sid7_gci748455,00.html, accessed July 12, 2004.
[13] http://computer.howstuffworks.com/dsl5.htm, accessed July 12, 2004.

At the DSLAM the subscriber links are aggregated onto one high-bandwidth line that connects to the Internet (upstream). The DSLAM forwards communications from the Internet to each user over their separate lines (downstream).[14] A DSLAM can support multiple types of DSL (such as CAP or DMT).[15] Figure 3 shows a schematic of a common DSL network.

Figure 3: Schematic of a Common DSL Network



There are several different types of DSL. Most common is ADSL, or asymmetric DSL. In ADSL, downstream bandwidths are much higher than upstream bandwidths, because more spectrum and bandwidth is reserved for downstream over upstream transmission. ADSL is geared toward homes and small offices that typically download more information from the Internet than they upload. ADSL data rates vary greatly, depending on the distance from the central office and the level of service purchased by the subscriber. Downstream rates range from 256 kbps to 9 Mbps and upstream rates range from 64 kbps to 768 kbps.[16]

The other widely-deployed form of DSL, G.Lite, is a scaled-down version of regular ADSL. The G.Lite standard was approved in 1998 and first became available in 1999. G.Lite is easier to deploy than ADSL, in part because it can operate without installation of a splitter on the subscriber's telephone line.[17] G.Lite also has other cost-cutting features that make it cheaper than ADSL but also slower.

G.Lite has downstream data rates of 1.5 Mbps downstream and 384 kbps upstream.[18] At these rates, users need to be less than 15,000 to 18,000 feet from the central office or data rates will

[14] http://whatis.techtarget.com/definition/0,289893,sid9_gci213915,00.html, accessed July 13, 2004.
[15] http://computer.howstuffworks.com/dsl9.htm, accessed, July 13, 2004.
[16] http://encyclopedia.thefreedictionary.com/ADSL, accessed, July 13, 2004.
[17] http://whatis.techtarget.com/definition/0,289893,sid9_gci213915,00.html, accessed July 13, 2004.
[18] http://www.dsllife.com/tutorial/ADSL_Tutorial_files/frame.htm, accessed July 13, 2004.

decrease significantly.[19] G.Lite is expected to become the most widely deployed form of DSL for home users because is cheaper to deploy than ADSL but still provides fairly high data rates.[20]

Higher data rate forms of DSL are less widely deployed in the United States. ADSL2+, the newest ADSL standard, provides 24 Mbps up to 3,000 feet. Very high rate DSL (VDSL) is widely deployed in Asia and offered in limited trial markets in the United States.[21] It supports transmission over short distances: downstream rates of 55 Mbps up to 1,000 feet from the central office, 27 Mbps up to 3,000 feet, and 13 Mbps up to 4,500 feet.[22]

2.1.3 Advanced Services

Two technological factors have made it possible for DSL to offer integrated data, voice, and video. First, DSL technologies have evolved to support higher bandwidths farther from the central office. Second, video and voice technologies have become available using IP technologies well-suited to DSL. As a result, DSL providers no longer need to find a way to make their system carry multiple "channels" of traditional television or carry a parallel phone circuit within their line. Instead, they can use IP video streaming technologies and Voice over IP to provide video and voice over an Internet-like link, while making the entire package appear to the subscriber undistinguishable from standard cable television or POTS.

In Western Illinois, municipal telephone providers are introducing digital TV over their DSL phone lines. Initially the system will offer 125 video and 45 music channels, including pay-per-view. Advanced video services such as VoD and other interactive services will be added in the future.[23] Digital television using DSL lines has gained momentum over the past few years with several other small markets. For example CT Communications offers Urbana and West Liberty, Ohio digital TV using DSL. Services include digital television, VoD, high-speed Internet access using a television or computer, and telephony services.[24] Video services over DSL have also emerged in Spain and France, where the state telephone companies have begun similar programs.

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[19] https://secure.linuxports.com/howto/intro_to_networking/c6627.htm, accessed July 13, 2004.
[20] http://whatis.techtarget.com/definition/0,289893,sid9_gci213915,00.html, accessed July 13, 2004.
[21] http://www.nwfusion.com/edge/columnists/2003/1124bleed.html, accessed November 20, 2004.
[22] http://www.dslforum.org/about_dsl.htm?page=aboutdsl/tech_info.html, accessed July 13, 2004.
[23] http://www.tutsystems.com/pressroom/pressreleases/showdetail.cfm?id=286, accessed October 22, 2004.
[24] http://www.ctcn.net/tv.htm; accessed October 22, 2004.

2.2 Broadband over Power Line

2.2.1 Introduction

Broadband over Powerline (BPL), also known as Powerline Carrier (PLC) communications, uses the existing electrical power grid to provide subscribers with high speed Internet access. BPL interconnects a communications network to the local electrical grid and transmits RF data along neighborhood power lines. Power utilities are conducting functional trials of broadband communications to residential and commercial consumers, and some are in the process of wider deployment. BPL technologies currently offer access speeds of 100 Kbps up to 2 Mbps.

If it is successful in broader deployments to large numbers of customers, BPL has the potential to compete with cable and DSL. The speed of the current BPL technology is comparable to residential DSL deployments and is not as fast as most residential cable modem deployments. BPL's potential is greatest in locations not currently served by cable and DSL technology. As all residences and businesses have powerline, in theory, BPL could have greater penetration into U.S. households than either cable or DSL. BPL may be especially viable in small towns or cities where cable providers may not offer cable modem services and the local power utility can relatively cheaply offer the service.

However, since BPL requires repeaters (hardware that amplify data signals) at each transformer, BPL may not be cost-effective in low-density rural areas. BPL has yet to be activated in a large (few thousand or more subscriber) system, and its scalability has yet to be demonstrated in the United States.

2.2.2 Technical Description

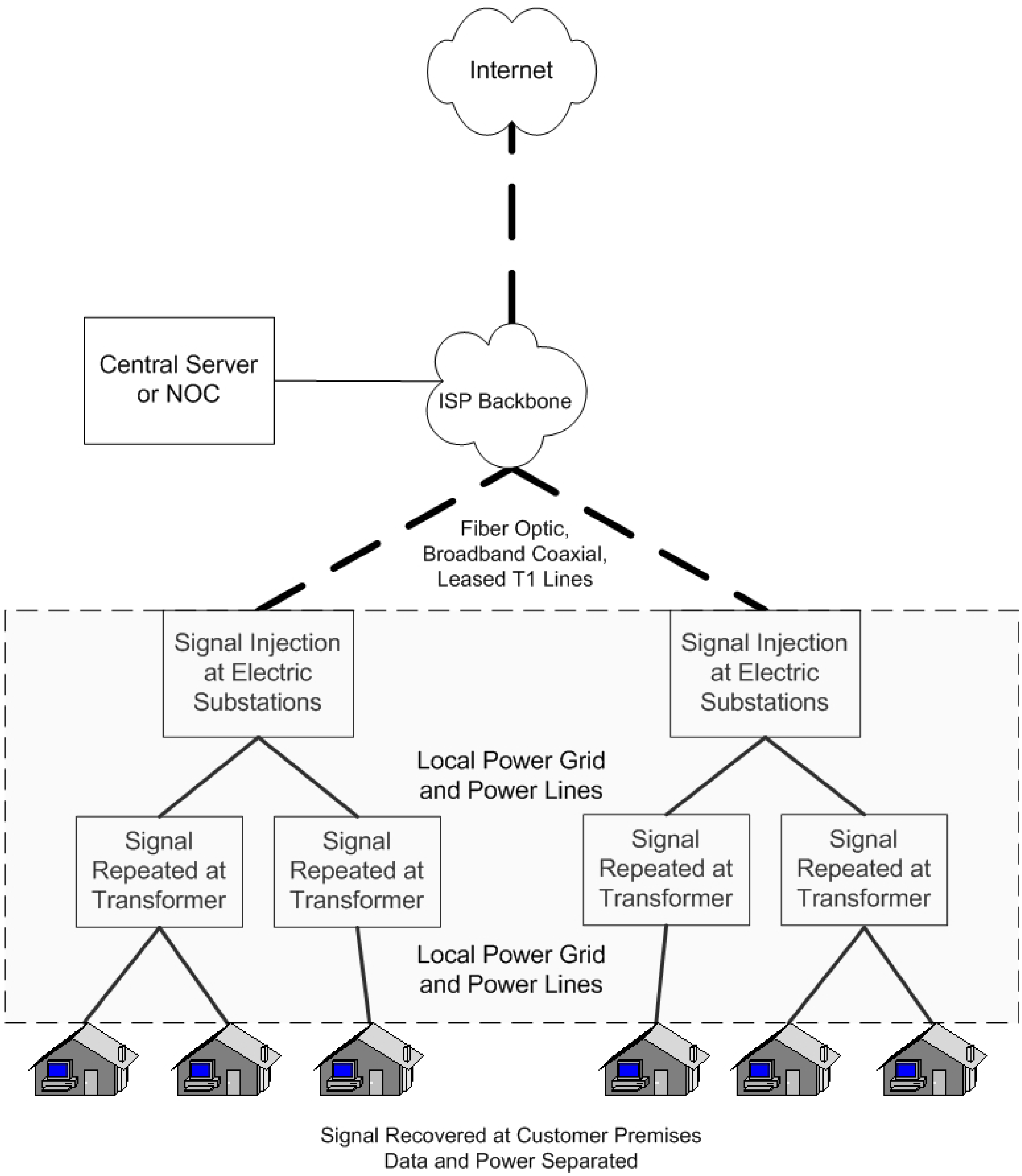
BPL uses existing low and medium-voltage electric grids to transmit data. Current BPL technologies transmit data at frequencies in the 1 MHz to 80 MHz range. Below this frequency range, less bandwidth is available, and access speeds may not qualify as broadband. Above this frequency range, the physical properties of copper power transmission lines tend to attenuate the signal to the point where broadband data applications are not possible.

The transmission frequencies overlap with several frequencies used over the air. These include the lowest television channels, amateur radio, and AM radio. The frequencies are also in the same range as used over twisted-pair telephone lines for the highest-speed versions of DSL service, those used over cable-TV lines for television and cable modem services, and over data communications cables in indoor building wiring. Because of this overlap and the fact that electrical lines at certain frequencies tend to radiate fairly strong signals, interference with other signals (such as amateur radio) is a significant concern.

The method of transmitting this signal through power lines differs with each manufacturer and company. Most BPL schemes have a central server or network operations center (NOC) for the system that monitors and controls the equipment and the Internet Service Provider (ISP) backbone. Internet service is extended via fiber optics to local electric substations or access points in the power network, where the data is inserted onto the power grid.

The data is repeated and extended through the neighborhood electrical grid and recovered at customer premises using filters to separate the power signals from the data signals. Figure 4 illustrates a high-level overview of BPL operation.

Figure 4: BPL Overview



The power grid transports Internet service over the "last-mile" from the substation to the subscriber. The BPL model shown in Figure 4 shows connection of the ISP backbone to the local power grid using dedicated fiber optics or leased circuits. Using this model, the data signal is transmitted only over medium and low voltage power lines.

One of the challenges of BPL involves transition of the data signal from medium voltage to low voltage lines. The transformers that step the voltage level down on the local power grid act as low-pass filters and can effectively block all frequency signals such as BPL data from transitioning past the transformers onto the low voltage lines. This technological issue is handled differently by different companies; some methods involve installation of equipment at transformers to allow data signals to bypass the transformer, others use modulation techniques that allow the signal to pass through the transformer, and others use wireless technology to bypass low voltage lines altogether.

2.2.3 Potential Concerns

2.2.3.1 Interference

Power lines, especially aerial lines, can radiate high frequency signals such as those introduced by BPL. BPL signals, which reside in the 1 MHz to 80 MHz range, occupy many of the same radio frequencies used by amateur radio and the federal government, although not government public safety radios. When BPL signals leak or radiate from power lines, there is the potential for interference with the established communications channels that occupy the spectrum BPL uses for transmission over power lines. As BPL technologies have advanced, the possibility of widespread deployment of BPL has generated debate among proponents and opponents of BPL, including parties who may be impacted by any interference resulting from leakage of BPL signals into the air, such as amateur radio operators and federal government agencies. Over-the-air signal ingress into power lines may cause similar interference or degradation to BPL services.

Opponents say that electrical power lines were not designed for higher frequency data signals and that it is too leaky at these frequencies. Proponents say that BPL can meet all FCC regulations and that BPL should be allowed.

2.2.3.2 Lack of Standardization

One potential problem that may become more evident as BPL deployment grows is the current lack of standardization in BPL systems and technology. Although many BPL architectures contain similarities, few regulatory or industry efforts are underway to develop commonality in the methods and technologies used for implementation of BPL. HomePlug is an industry group that has developed standards primarily for powerline communications in home networking, but their standard does not currently extend to the carrier network outside the premises[25].

[25] http://www.homeplug.org/, accessed October 20, 2004.

Different BPL companies currently use technologies that are not often not interoperable and use different business plans, architectural models, and RF technologies. The equipment, modulation techniques, and operation schemes are often proprietary, and therefore, as in the early days of cable modem technology, power utilities and BPL ISPs will need to be especially concerned about the fortunes and business plans of their equipment supplier.

2.2.3.3 Bandwidth

The bandwidth of current BPL trials and deployments ranges between 300 Kbps and 2 Mbps, which is comparable to cable modem and DSL offerings for residential and small business use. However, as demand increases and BPL technologies become more refined and faster, BPL data speeds are likely to increase. The absence of standards creates a risk in that a BPL provider will be beholden to the upgrade path of its equipment vendor, or otherwise may need to replace its entire installed base in order to upgrade.

2.2.4 Potential Advantages

In addition to providing high speed Internet access across the power grid, deployment of BPL may improve monitoring of the power grid and may provide the opportunity for low-cost metering and remote monitoring and control of power infrastructure.

2.2.4.1 Outage Detection and Management

Deployment of BPL systems through local power grids may provide electric utilities the opportunity to monitor their systems to a greater extent than previously possible. Depending on the architecture, BPL node and repeater equipment may be installed on many if not all of the transformers and electric substations in a neighborhood. With constant status monitoring throughout areas with BPL service, any loss of power where BPL equipment is located can be immediately detected at the BPL NOC, in contrast to waiting for customers to call the utility company when they notice an outage. BPL network monitoring may also aid in more accurately determining power outages, allowing power utility staff to respond more quickly.

2.2.4.2 Remote Monitoring and Control of the Power Grid

Once devices on the power grid have been equipped with modems and status monitoring equipment, control of many components can be done remotely. One option is the reading of meters over BPL. The BPL NOC could collect accurate usage information for billing without estimating or sending technicians into the field. The BPL NOC could also send signals to the meters to connect or disconnect service without the need for a site visit. Furthermore, status monitoring at transformers and switches would allow for accurate load monitoring of the power system to more accurately determine the power needs of the system, creating a more efficient power system.[26]

2.2.5 Examples of BPL Networks

BPL deployment is underway by commercial and municipal power companies. It is being deployed by large regional operators and by small communities.

2.2.5.1 Manassas, VA

Main.net, a BPL manufacturer, completed a one-year trial pilot project in the City of Manassas, Virginia, in September 2003. The trial involved nine residential customers and one commercial account in an area with underground power lines, and was considered successful enough for the City to begin deployment throughout the rest of Manassas. The citywide deployment is also planned to use the Main.net technology.

The Main.net BPL system in Manassas provides last-mile distribution to extend broadband Internet access to residents over local power lines. Fiber optic lines were extended to a transformer by the City of Manassas, which operates a 60-mile fiber optic network in the area. This fiber optic cable provided the Internet backbone for the Main.net to bridge data onto the power grid in the neighborhood. The system utilizes frequencies between 2 and 20 MHz. Users receive symmetrical service (same speeds for both downstream and upstream) ranging from 300 Kbps to 1.8 Mbps.

A proprietary Main.net "concentrator unit" (CU) is installed at the transformer and connected to City fiber optics. The CU acts as a node for the BPL system, bridging the data onto the power lines. Each CU can serve 50-75 homes, with a distance limitation of approximately 1,500 ft to 1,800 ft. While users closest to the CU may experience access speeds of up to 1.8 Mbps, the users at the end of the power line from the CU will still receive at least 300 Kbps.

A "repeater unit" (RU) is installed at each transformer in the area served by a CU in order to strengthen the signal both downstream and upstream.

Each user has a network termination unit (NTU), which is like a modem. The NTU can plug into any outlet and interface via Ethernet to a computer.

2.2.5.2 Spain

In October of 2003, the Spanish government granted three of its largest electrical companies permission to start offering BPL services. The government also mandated that by October 2005, at least 40 percent of the customers must have access to BPL. The motivation behind this was to give more choices to consumers by offering more competition to ADSL and cable. One electric

[26] http://www.tmcnet.com/usubmit/2004/Oct/1083088.htm, accessed October 14, 2004.

company already began deployment with over 30,000 customers now able to get Internet via BPL. This deployment contains two services: a cheaper service promising only symmetric 100 kbps and a more expensive service providing symmetric 600 kbps. If this first deployment goes well, the companies will look into quickly expanding their services, especially to areas that do not have access to either DSL or cable services.[27]

2.2.5.3 Wake County, NC

Progress Energy and the ISP Earthlink have jointly begun trial deployment to consumers of BPL in three Wake County neighborhoods to 500 homes. This BPL network uses power lines, fiber optics, and wireless equipment to provide broadband to the consumers. Progress Energy is delivering Internet and data via both fiber and power lines to relay points in the neighborhoods. Earthlink installs wireless access points along transformers or electric poles to transfer the fiber and BPL signals to wireless. Consumers access the Internet wirelessly. As of this writing, customers pay $19.95 per month for the first three months and $39.95 per month thereafter.[28]

2.3 Wireless Broadband

2.3.1 Introduction

Wireless broadband can potentially provide broadband access to subscribers without building wired infrastructure to individual subscribers. Wireless broadband technologies encompass a range of technological approaches. The currently deployed technologies can be broadly classified as either 1) carrier-based "cellular" technologies or 2) "hotspot" deployments primarily by individual users, businesses, governments or institutions using unlicensed spectrum. Future technologies are likely to incorporate fusions of these two models.

Most of the wireless broadband technologies of the first model can be classified as either third generation ("3G") or fourth generation ("4G") wireless. 3G broadband technologies include Verizon's BroadbandAccess service (using the CDMA2000 1xEV-DO technology).

The second model technologies are dominated by IEEE 802.11 wireless LAN (WLAN), also known as "Wi-Fi," an important local area wireless protocol that can have implications in larger networks if used with technologies such as mesh networking.

The 4G technologies have attributes of both the first and second models and include IEEE 802.16 (WiMAX) and IEEE 802.20 (MBWA).

[27] http://www.broadbandhomecentral.com/report/backissues/Report0311_3.html, accessed October 14, 2004.
[28] http://www.bizjournals.com/triangle/stories/2004/02/16/daily25.html, accessed August 6, 2004.

The cellular carrier-based broadband wireless solutions currently advertise data speeds of 300 to 500 kbps, with maximum speeds of 2 Mbps in some circumstances.[29] The speed is comparable to DSL and not as fast as cable modem communications. Although the systems offer mobile services, they are typically limited to metropolitan areas.

The "hotspot" deployments can be significantly faster than DSL or cable modems, with speeds per user of several Mbps, depending on utilization of the hotspot. However, service is only available where hotspots are deployed. A few small cities, including Cerritos, California, have deployed hotspot networks in a citywide mesh, and a few larger cities are considering the same. At the moment, service via hotspot is limited in coverage.

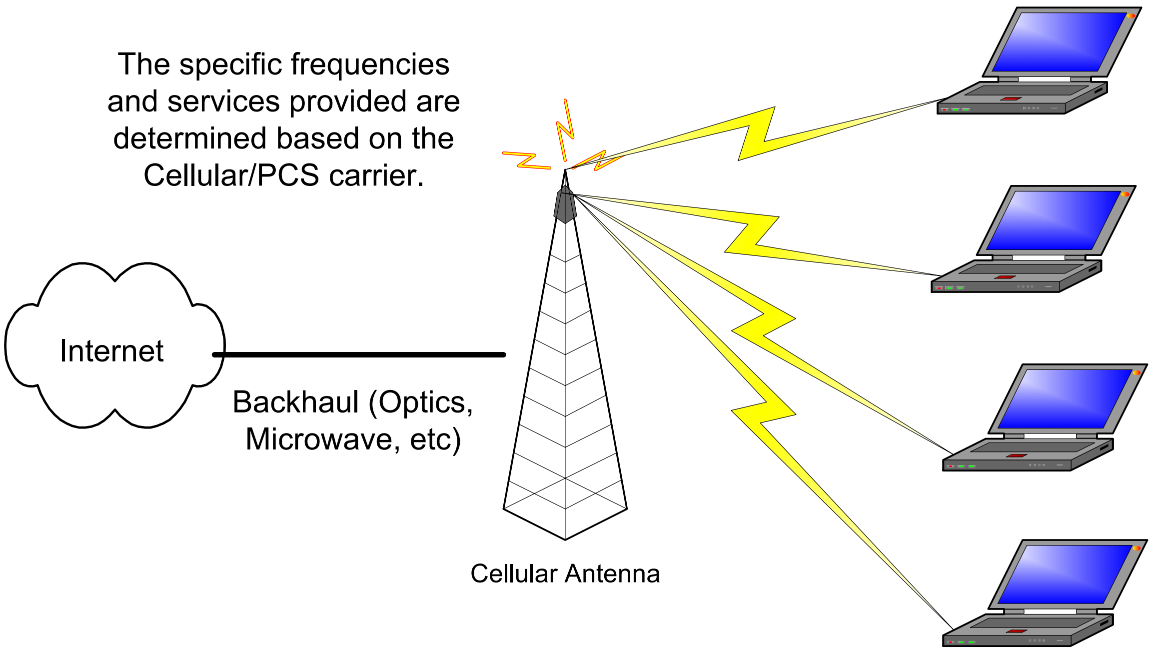
Wireless broadband is rapidly evolving in capacity and coverage, and it may someday provide competition with cable. However, outside of a few metropolitan areas, it may take many years for wireless to provide comparable of capacity and coverage as cable.

2.3.2 Technical Description

Figure 5 illustrates a cellular data/Internet network. Users access the Internet wirelessly through a cellular antenna in the cellular area. The antenna and the corresponding base station then access the Internet through wired or wireless high-speed backhaul communications. This backhaul can be optical fiber, T1, or microwave communication. This is the type of network that the cellular/PCS service providers such as Verizon Wireless, Cingular, Nextel, Sprint, and T-Mobile use.

Figure 5: A Schematic of a Simple Cellular/PCS Internet Network

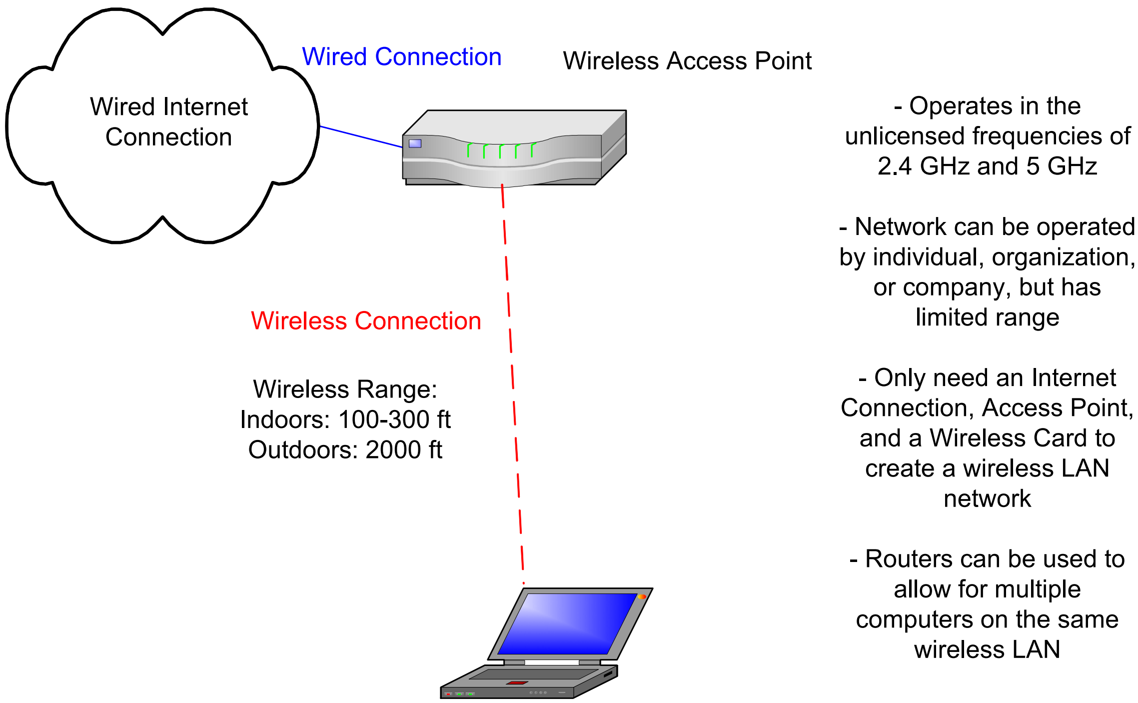
[29] http://www.verizonwireless.com/b2c/mobileoptions/broadband/index.jsp?action=broadbandAccess&cm_re=Home%20Page*Bottom%20Nav*For%20Business%20-%20Broadband%20Access, accessed January 29, 2005.



The cellular/PCS carriers provide services in licensed frequency ranges, and users who use these services are dependent on the carriers for the network.

The second model is to install 802.11 access points, also known as "hotspots." 802.11 utilizes unlicensed frequencies, so anyone can set them up. Figure 6 shows a general schematic of an 802.11 network.

Figure 6: A General Description of an 802.11 Network



2.3.3 3G Technologies: CDMA2000 1xEV and W-CDMA

2.3.3.1 Currently Available: 1xEV

Both of these 3G technologies, corresponding to the first model of carrier-provided services, use code division multiple access (CDMA). CDMA is a spread spectrum technology. Spread-spectrum transmits a signal over a frequency bandwidth that is much larger than the bandwidth of the actual signal.[30] The technique uses frequency hopping, meaning that the carrier frequency carrying the signal constantly changes. The transmitter and receiver know which frequencies are being used, but outsiders do not know this sequence, making spread-spectrum relatively secure. In addition, spread-spectrum technology is very tolerant to sources of electromagnetic interference, because the noise and interference is effectively averaged over a wide frequency band.[31]

CDMA2000 1xEV is an evolution of CDMA networks that were originally developed by Qualcomm in the 1990s, and is part of the group of CDMA protocols that are used in the United States by Verizon Wireless and Sprint. CDMA2000 1xEV comes in two stages, and each stage

[30] http://encyclopedia.thefreedictionary.com/spread%20spectrum, accessed June 30, 2004.
[31] http://encyclopedia.thefreedictionary.com/Frequency%20hopping, accessed July 1, 2004.

utilizes 1.25 MHz frequency channels. The first stage is 1xEV-DO (Evolution Data Only). In EV-DO systems, the full RF channel is allocated to only data services.[32] This technology supports peak data transfer speeds of 2.4 Mbps downstream with typical average data rates range from 300-500 kbps. 1xEV-DO has sufficient capacity to support applications such as video conferencing, and "always on" Internet service.

Currently, Verizon Wireless offers 1xEV-DO in 14 metropolitan cities, including Philadelphia, and eight major airports, and Verizon states that it hopes to have deployed 1xEV-DO throughout the country by the end of 2005.[33] For unlimited broadband use, Verizon charges $80 per month. Sprint is also interested in deploying 1xEV-DO, but the exact timeframe is not publicly known.

This technology does not have sufficient capacity to support broadcast-quality video. It may enable the user to view MPEG-1, MPEG-4, WM9, and other Internet-quality video. It is a platform for high-speed Internet for PCs and personal data assistants (PDA).

2.3.3.2 In Development: 1xEV-DV and W-CDMA

The second stage in the evolution is CDMA2000 1xEV-DV (data and voice), which provides voice and high-speed packet data on the same RF channel.[34] 1xEV-DV can support data rates up to 3.1 Mbps downstream (base station to user) and 1.8 Mbps upstream, and uses the same 1.25 MHz channel size. As a result, it is backward compatible with all CDMA2000 1x and 1xEV systems.[35] Currently, DV systems have not been deployed commercially, as this service is still in its test phase.

W-CDMA is offered by the wireless carriers that use GSM as their base wireless protocol, including Cingular/AT&T and T-Mobile. By using CDMA and wide 5 MHz channels, W-CDMA can provide data rates up to 2 Mbps, particularly during off-peak hours when there are fewer users, but rates do decrease as more users are on the network. At high data rates, W-CDMA can support advanced multimedia and video data transfer.[36] W-CDMA is also capable of supporting new features like mobile teleconferencing and music downloads.

In the United States, W-CDMA is not in use yet, mainly because it requires large 5 MHz channels, and the wireless providers that would use GSM/W-CDMA do not have enough spectrum allocated from the FCC to allow for W-CDMA deployment as of now. Cingular/AT&T is planning to test W-CDMA systems in four trial cities in the 1900 MHz band, the same band used for GSM, although Philadelphia is not one of these four cities.[37] The FCC is also considering allocating more spectrum for 3G services; however, until this spectrum is

[32] http://encyclopedia.thefreedictionary.com/CDMA2000, accessed July 1, 2004.
[33] http://www.usatoday.com/tech/wireless/phones/2004-06-22-sprint_x.htm, accessed July 16, 2004.
[34] http://www.cdg.org/technology/3g.asp, accessed June 24, 2004.
[35] http://www.cdmatech.com/news/releases/2004/040322_ericsson_cdma2000_1xevdv.jsp, accessed July 15, 2004.
[36] http://www.umtsworld.com/technology/wcdma.htm, accessed, June 23, 2004.
[37] http://www.dailywireless.org/modules.php?name=News&file=article&sid=2721&mode=&order=0&thold=0, accessed June 23, 2004.

allocated, W-CDMA will have to co-exist with current systems at 1900 MHz and consequently not become widely deployed.[38]

An advantage of 3G technologies over fixed broadband technologies such as DSL is that 3G services can be accessed anywhere within that carrier's 3G network. Also, 3G technologies do allow for user mobility and handoff between antennas.

These services are marginally suitable for broadcast-quality video. Particular techniques of deployment (dense deployment of antennas) may enable these technologies to compete with cable. However the WLAN and 4G solutions are better suited for integrated voice, data, and video deployment.

2.3.4 Wireless LAN (802.11) Standards

The first IEEE 802.11 standard was approved in 1997 to support wireless local area networks (WLANs). 802.11 was first conceived for enclosed areas such as a house or office building. The user has a built-in or external wireless card for a laptop or PDA to connect to the network from any location within the boundary of the wireless signal.

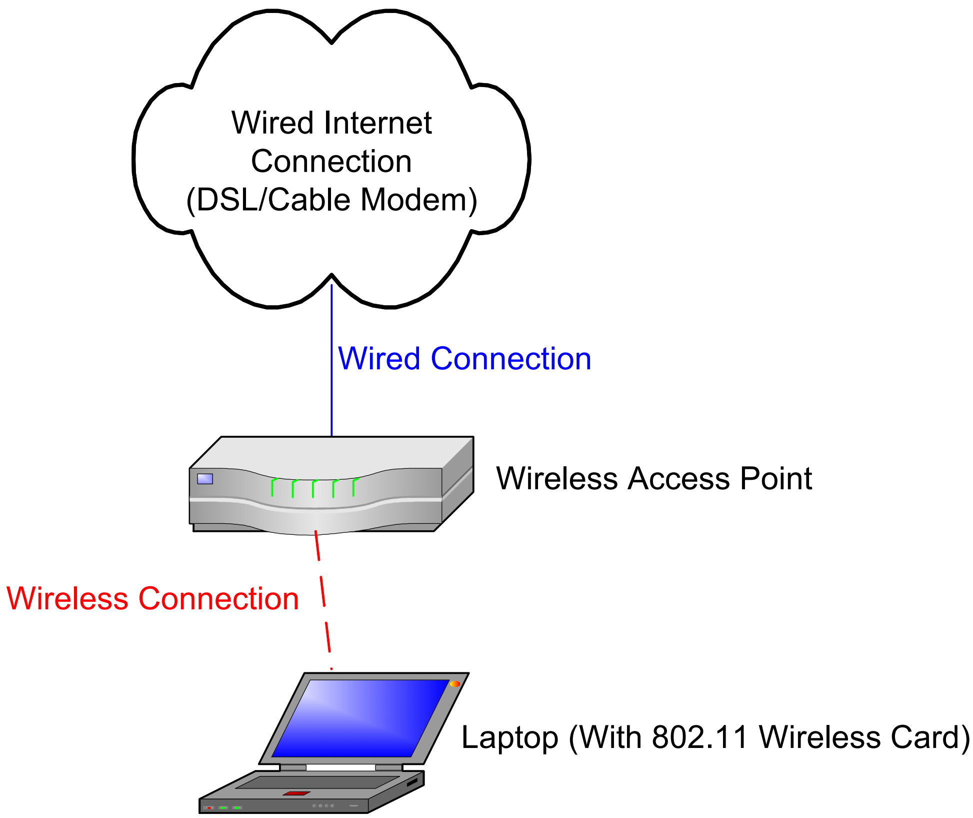
802.11 uses two unlicensed frequency bands: the 2.4 GHz band and the 5 GHz band. Unlicensed spectrum makes deployment easy and available to anyone. However, it creates the potential for interference, since each user must accept all interference that is present. For example, two neighbors may both be using wireless LANs that interfere with each other's signal and reduce network performance. Potential interference also arises from the many other devices using the 2.4 GHz spectrum, including cordless phones, baby monitors, and walkie-talkies.

An 802.11 "hotspot" has a relativly small coverage area centered around a wireless access point (WAP). The WAP is where the WLAN connects to a wired Internet connection, such as T1, DSL, or a cable modem. People within a certain radius of a hotspot can obtain broadband wireless access. Typical ranges are around 100 to 300 feet indoors and 2,000 feet outdoors.[39]

Figure 7 illustrates the typical set-up of a wireless access point and how it connects to a wired broadband connection.

[38] http://www.tutorgig.com/ed/Universal_Mobile_Telecommunications_System, accessed July 15, 2004.
[39] http://www.phonescoop.com/glossary/term.php?fid=60, accessed July 2, 2004.

Figure 7: Schematic of a Hotspot using a Wireless Access Point



The 802.11 standard supports encryption, theoretically limiting its use to those who are authorized by the WAP administrator. In practice, the encryption technology has some weaknesses and cannot be relied upon where security is critical. Secure implementations of 802.11 require use of separate encryption technologies, such as those supported by virtual private networking (VPN) or by more advanced versions of 802.11.

802.11 is widely deployed for home and business use. Some Internet users have also constructed informal grassroots networks that use 802.11 technology to share Internet service in a neighborhood or across a metropolitan area. Governments have used it to connect facilities that do not have wired communications. Governments use it in indoors and outdoors for official internal use or to provide data network or Internet access to the public.

Although 802.11 was intended as a private network solution, it is also being deployed by carriers and Internet service providers. T-Mobile and Verizon provide "hotspot" Internet service in public areas such as airports, coffee shops, and parks. Users pay a fee and must sign in with a password. Service providers and system integrators have built 802.11 networks covering neighborhoods and small cities, often in partnership with the local governments or economic development groups, with hardened WAPs installed on utility poles or other outdoor fixtures.

The first 802.11 standard to be widely deployed is 802.11b, which remains the most common standard today. 802.11b provides 11 Mbps aggregate bandwidth, which typically supports at least one to two Mbps of bandwidth per user in the 2.4 GHz range as long as the network is not congested and interference is low. Another standard, 802.11a, supports aggregate bandwidth of 54 Mbps in the 5 GHz band.

802.11a's very large bandwidth can potentially also be used as a "last-mile" connection between buildings, especially if a directional antenna is used. 802.11a can also potentially support backhaul communications between Wi-Fi wireless access points and the Internet or core network. 802.11g is another emerging standard that supports 54 Mbps in the 2.4 GHz range.[40]

In general, IEEE 802.11 standards have made possible relatively inexpensive equipment and network solutions for provision of fixed Wireless LAN services. Their ubiquity and popularity continue to grow.

The 802.11 standards currently do not support mobility very readily. Hand-off between access points and other features geared for mobility are either under development or are provided as part of proprietary solutions.

The City of Philadelphia is considering widespread deployment of outdoor 802.11 access points for access by the public to the Internet. The details of the deployment are still being planned. The deployment may be a partnership with wireline service providers, who may contribute to the backhaul solution. The deployment may also use mesh networking.

2.3.5 Mesh Networking

In a mesh network, data travels through the network either through users' devices or through multiple, interconnected WAPs with routing capability. This is in contrast to a regular wireless LAN network, where every user has a dedicated path to a hotspot directly connected to wired Internet service. The mesh network has one or more connections back to the wired data network or Internet. In a dense network, there are many potential paths from a user to the wired network. Thus, if even one element of the network fails, there are other paths for a user to reach the Internet.[41] Thus, no user is fully dependent on only one path and the network is dynamic and reliable.[42]

Mesh networking can potentially enable large-scale, reliable wireless network in which users can send data through other users. Individual WAPs support a transmission radius of up to thousands of feet, but mesh networking can potentially enable a WLAN to cover an entire city if WAPs are deployed in sufficient density. Vendors of 802.11 mesh networking solutions include Tropos Networks.

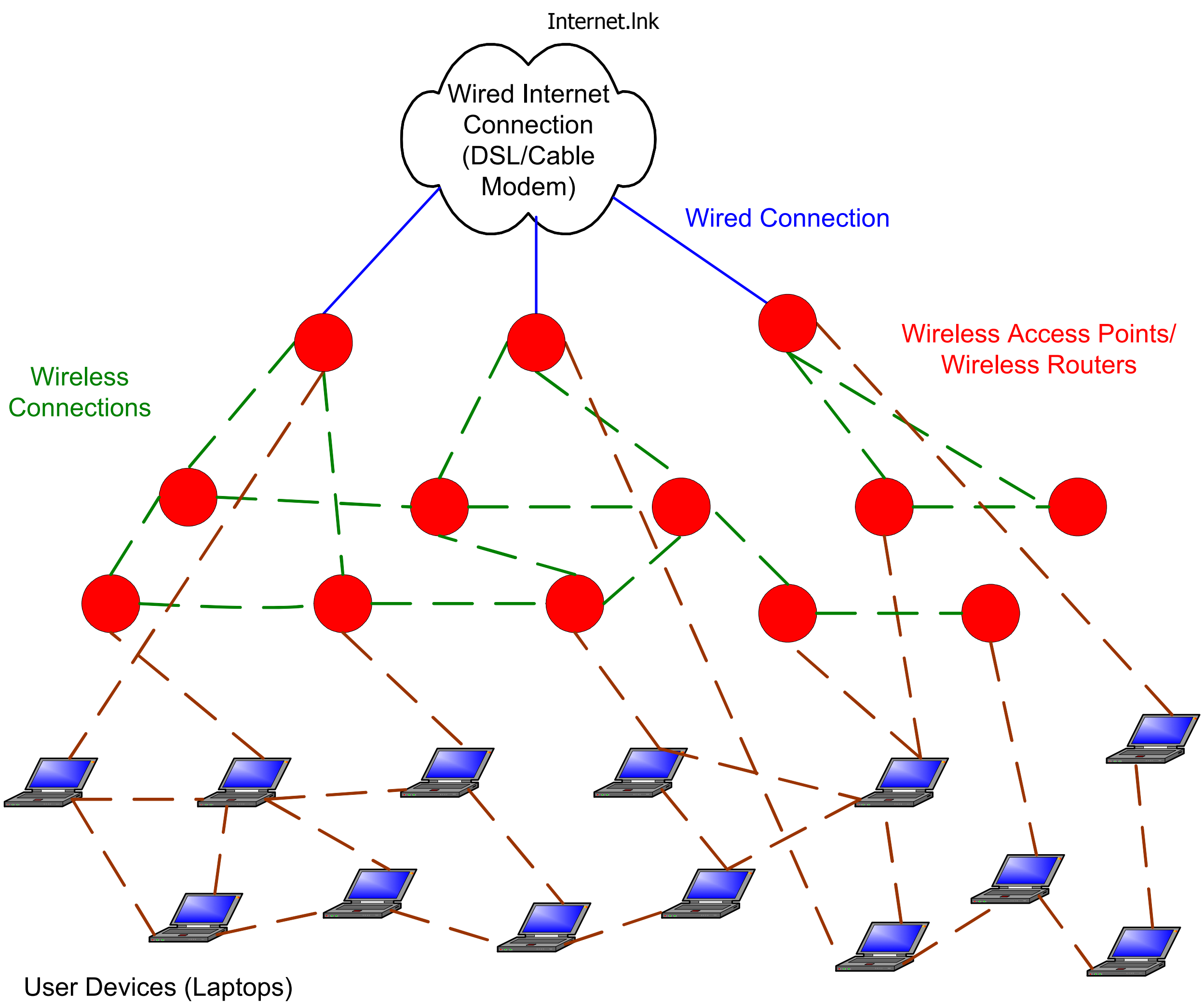
[40] http://wi-fiplanet.webopedia.com/TERM/8/802_11.html, accessed June 25, 2004.

[41] http://searchmobilecomputing.techtarget.com/gDefinition/0,294236,sid40_gci870763,00.html, accessed July 2, 2004.

[42] http://www.pcmag.com/article2/0,1759,1132760,00.asp, accessed July 2, 2004.

Figure 8 illustrates a mesh network.[43]

Figure 8: Schematic of a Mesh Network



San Mateo, California is an example of a city that is using 802.11 technology to create a mesh network to provide wireless broadband. The San Mateo Police Department utilizes a Wi-Fi network (IEEE 802.11b) to provide broadband access at data rates above 1 Mbps to officers equipped with any device (laptop, PDA, etc.) compliant with the 802.11b standard. Tropos Networks access points are utilized to provide a mesh network topology, in which only a few of the access points are connected to the City's network. Most of the access points relay communications from client devices wirelessly to neighboring access points. The network

[43] http://www.meshnetworks.com/pages/technology/intro_technology.htm, accessed July 2, 2004.

currently consists of more than 30 access points in a 2½ square mile portion of downtown San Mateo. There are plans to continue extending coverage throughout the City.

Police officers are able to roam within the coverage area without manually reconnecting, with the ability to access LawNet, the San Mateo County multi-jurisdictional criminal justice intranet, the California Gang Database, the California Sex Offender Database, the AmberAlert system, the Department of Motor Vehicles database, and streaming video for traffic monitoring. Using a NetMotion VPN server, allowing advanced encryption and download management as users pass in and out of the coverage area.

One of the limitations of the technology is that multiple hops between access points will create latency in overall network performance. The 802.11 protocol adds small delays in order to listen for other users. When a signal travels across multiple 802.11 access points, these small delays become noticeable and may impair certain applications, particularly voice and live video, which are relatively time-sensitive.

2.3.6 4G Wireless WAN Standards (802.16 WiMax and 802.20 MBWA)

802.16 WiMax and 820.20 are 4G technologies designed to provide wireless broadband connectivity with similar data rates as those provided by LAN technologies. These technologies are also classified as wireless metropolitan area networks (WMAN). Thus, these technologies could serve as competitors to cable or DSL. The technologies are also intended to improve upon 802.11 technologies by supporting greater range, mobility, and quality of service. These enhancements may enable 4G technologies to support telephone, broadcast-quality television and business-grade data services and to provide a more flexible and robust solution than current 802.11 networks.

Originally, WiMax (802.16) was intended to provide the "last-mile" from backbone communications to individual homes or businesses. Wireless is potentially cheaper and easier to implement than new cable construction, because, instead of installing new cable underground, a wireless solution would involve installing antennas. The first 802.16 standard was developed for fixed wireless, meaning for stationary users in homes and businesses. It was designed for data rates of up to 120 Mbps in the frequency range of 10-66 GHz. However, in this frequency band, communication requires direct line-of-sight between antennas.

The 802.16a standard uses frequencies between 2-11 GHz. The bandwidth in this frequency range is lower, but direct line-of-sight transmission is not needed at these lower frequencies.[44]

802.16a supports long-distance transmission of wireless data at high bandwidths. It features a maximum aggregate bandwidth of 70 Mbps, and the antennas may have a range of 31-miles.[45,46]

[44] http://www.nwfusion.com/news/tech/2003/1103techupdate.html, accessed June 24, 2004.
[45] http://www.computerworld.com/mobiletopics/mobile/story/0,10801,87555,00.html, accessed June 25, 2004.

802.16a is designed for service to stationary users. 802.16a was approved in January 2003. There are also versions of 802.16 that operate in unlicensed frequency spectrum.

The WiMAX community is developing 802.16e, a standard for both mobile and stationary users. 802.16e is intended to operate in the 2-6 GHz frequency range in licensed bands for user speeds up to 75 mph. The optimal range for 802.16e is 4-6 miles, though in rural areas, a theoretical 31-mile radius may work.[47] 802.16e is designed to support mainly local or regional roaming.[48] This technology is developed to be backward compatible with the previous 802.16 standards.

Another group is simultaneously developing another 4G wireless broadband standard, known as IEEE 802.20 or Mobile Broadband Wireless Access (MBWA). This standard is geared towards supplying wireless broadband Internet to fast moving terminals, such as high-speed vehicles.

The 802.20 standard is designed for licensed frequency bands under 3.5 GHz, works for user speeds up to 155 mph, and has about a 15 km (9.32 miles) or higher coverage area. 802.20 is designed to support global roaming.

There are trial deployments of 802.16 and 802.20 today. Nextel has introduced broadband wireless internet that gives speeds on the order of 1.5 Mbps downstream and 375 kbps upstream using an 802.20 type technology developed by Flarion, but as of now this is only available in the Raleigh-Durham area of North Carolina.[49] In Seattle, Washington, the Internet service provider Speakeasy has announced the launch of a stationary WiMAX service aimed at businesses. The trial program requires a stationary antenna attached to an office window and will provide up to 3 Mbps at a cost estimated at $650 per month. The trial is starting with 10 to 12 users, and the company plans up to four base stations covering the entire Seattle metropolitan area and full commercial deployment in 2005.[50]

British Telecom has introduced fixed WiMAX in four small cities in Britain, and, if the technology is successful, the company might launch WiMAX throughout the country.[51] Therefore, while there are trials of 802.16 and 802.20, it is not yet clear how successful the technology or trials will be, or when or if the technology will be widely deployed.

Manufacturers including Intel and Proxim hope to deploy the hardware and software for fixed WiMAX by early 2005 and for mobile WiMAX (802.16e) by the end of 2005.

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[46] It is important to note that these are theoretical maximum performance parameters. An actual deployment will share the 70 Mbps aggregate bandwidth among many users in a particular physical area. As with cellular technology, most deployments will have shorter range, because of the desire to serve fewer simultaneous users (and therefore smaller physical areas) in the same service area. In short, the deployment will likely resemble the current cellular deployment in number and location of antennas—though individual users will experience significantly greater performance relative to 3G technologies.

[47] http://www.intel.com/cd/ids/developer/asmo-na/eng/strategy/94553.htm, accessed August 5, 2004.

[48] http://www.intel.com/cd/ids/developer/asmo-na/eng/strategy/95510.htm?page=3, accessed August 5, 2004.

[49] http://www.mobilepipeline.com/showArticle.jhtml?articleID=17602183, accessed June 28, 2004.

[50] http://seattlepi.nwsource.com/business/198924_speakeasy10.html?searchpagefrom=1&searchdiff=5, accessed November 15, 2004.

[51] http://www.pocketpcwire.com/brief.asp?5676, accessed August 5, 2004

Both 802.16 and 802.20 are designed for symmetric upstream and downstream bandwidths, which makes them suitable for business applications and for two-way interactive video. In addition, both 802.16 and 802.20 leave some flexibility in their designs, such as the size of frequency channels, what part of the frequency spectrum can be used, and how to deal with modulation and access schemes. For example, 802.16 can use 3.5 MHz, 5 MHz, and 10 MHz, frequency channel widths depending on the amount of spectrum the user or carrier is allocated.[52] Vendors can adapt these standards to fit their needs in order to provide better service or to provide service within their confines. In addition, both 802.16 and 802.20 are protocols that can provide low latency communication, which is needed for real-time services such as video and Voice over IP. 802.16 can also switch to higher latency and better error control schemes to transfer sensitive information that needs to be error free.[53]

4G wireless technologies are clearly potential competitors with cable and DSL providers. They provide comparable bandwidth and, with the use of IP-based data, video and voice technologies, they can provide performance and functionality that, from the user's perspective, is indistinguishable from cable and DSL. Moreover, most planned 4G deployments are designed for mobility, which provides a unique advantage that cable and DSL cannot match.

2.3.7 Antenna Structure

4G providers may need to deploy significant numbers of new antennas, potentially in the public right of way (utility poles, signal cabinets, light posts) and will likely need to interconnect them via fiber optic cable plant. 4G subscribers may need to mount small antennas on their homes, businesses, and vehicles for peak performance. While traditional wireless carriers may have a key role in deploying the service, there may need to be partnerships with power companies, telephone companies, transit authorities, departments of transportation and public works, and cable operators in order to locate antennas, interconnect with the antennas and construct the network. There may also be deployment by government and non-profit entities. Because there is an unlicensed spectrum version of 802.16, there may also be grassroots and community organizations involved in deployment.

4G may require in some environments a distributed antenna network. Some providers are already using distributed antennas in their 3G deployments for increased capacity and to avoid constructing new monopole towers. In distributed networks, carriers use several small low-powered antennas instead of one large high-powered antenna in a given region. Each antenna in a distributed network serves a smaller area, and all the antennas are connected using some type backhaul, such as fiber, to the base station. In a standard cellular network, there is usually a set of antennas on one tower that communicates with the base station. In a distributed network, the many antennas "work together" in the network and communicate with the base station. An advantage of this is in cases where the community does not want a tall antenna in the

[52] http://www.wimaxforum.org/news/downloads/WiMAXWhitepaper.pdf, accessed August 5, 2004.
[53] http://www.intel.com/cd/ids/developer/asmo-na/eng/strategy/95510.htm?page=2. accessed August 5, 2004.

neighborhoods due to aesthetic purposes. Also, distributed antennas can re-use frequencies more often because each antenna serves a smaller area and number of customers. Figure 9 illustrates a regular cellular network, while Figure 10 illustrates a similar situation using a distributed network.

Figure 9: Illustration of a Regular Cellular Network

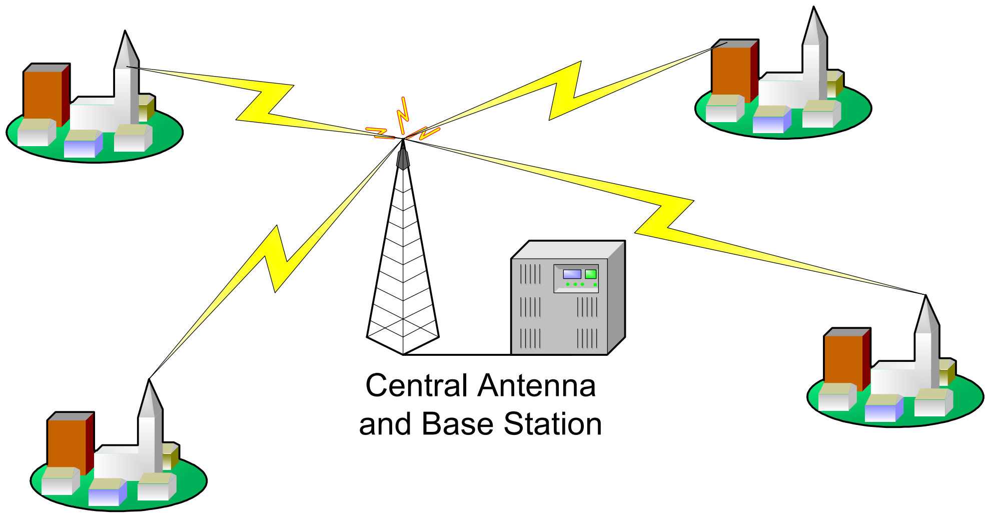
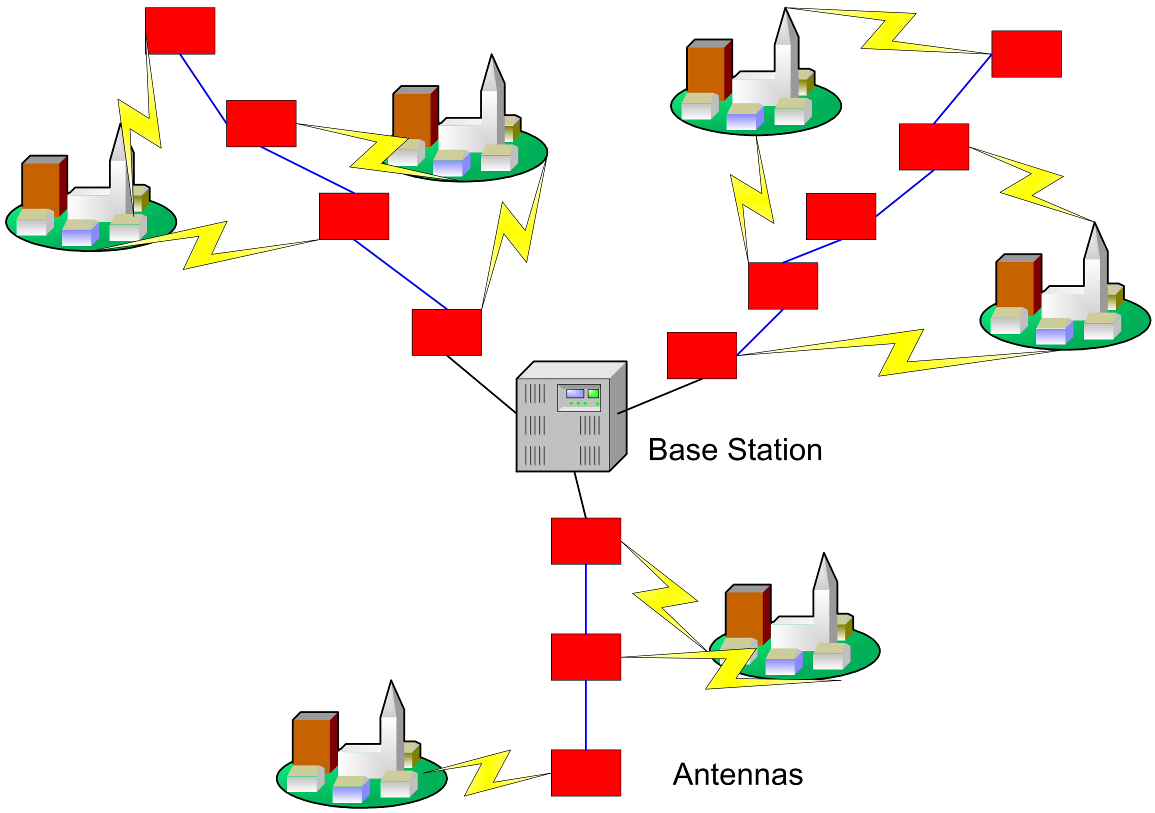


Figure 10: Illustration of a Distributed Network



2.4 Fiber to the Premises

2.4.1 Introduction

Fiber to the Premises (FTTP) technology will become available to millions of homes and businesses throughout the United States in the coming years. Many phone companies have chosen to build FTTP systems to address the limitations of DSL and to compete with cable and wireless companies.

A range of service providers, including telephone companies and municipal power utilities, are providing direct fiber optic service to homes and businesses. Direct fiber optic service has the capability of much greater bandwidth than networks using DSL, cable-TV, or wireless technologies.

As of mid-2003, only 22,000 residences in the United States received high-speed Internet and other services via a direct fiber optic connection.[54] FTTP can be expected to grow rapidly as Verizon and SBC build fiber to millions of customers in 2005 and 2006.

Fiber optics theoretically have almost unlimited capacity. In practice, the capacity is determined by the electronics at each end of the fiber. Upgrades to fiber optic technology have occurred at a fast pace in the last few years, making the future of the technology bright. As an illustration, the widespread wide area fiber technology of the late 1990's was 100 Mbps Ethernet or 155 Mbps ATM, and the current wide area fiber technology is 1000 Mbps and 10,000 Mbps Ethernet. Every few years, fiber transmission speeds have increased by a factor of ten in the marketplace. The available capacity per user of current FTTP technology is ten times faster than via cable modems and can be upgraded by orders of magnitude without changing the outside cable plant.

Unlike copper or coaxial networks, optical networks do not require amplifiers or power. The signal loss associated with fiber optic cable is so low that a signal can travel miles from the central office to the subscriber without amplification. The only outside plant equipment are the splitter/combiners, which do not require power. Thus, while it is costly to initially build an optical infrastructure, maintenance of the network is significantly cheaper than copper and coaxial networks that use amplifiers and active equipment.[55]

Another advantage of FTTP is that it is much more resistant to interference than DSL or other signals. For example, AM radio, pagers, consumer electronics, and other signals can cause interference with DSL and cable signals, but optical signals will not be effected by outside interference.

It is still costly to deploy FTTP. With the present equipment available, it is estimated building an FTTP network could cost anywhere from under $1500 to $3000 per home depending on the type of FTTP network used, bandwidths required, or previous infrastructure.[56] The cost is primarily due to the electronics at the end of the fiber and can be expected to fall precipitously once the equipment is mass-produced.

2.4.2 Technology: PON Networks/Optical Networks

There are different optical fiber networks that can be deployed. One such network would be a dedicated fiber pair from the central office to each house or office. This deployment would be relatively costly to build, due to the large amount of fiber needed. It would only be practical in small communities or for the most demanding business or institutional subscribers. Figure 11 below shows this approach.

[54] http://www.washingtonpost.com/ac2/wp-dyn?pagename=article&contentId=A38106-2003Feb6&notFound=true, accessed July 26, 2004.
[55] http://www.cpau.com/fth/faq.html, accessed July 27, 2004.
[56] http://www.convergedigest.com/DWDM/DWDMarticle.asp?ID=11812, accessed August 11, 2004.

A more practical approach to FTTP is to share fiber among multiple subscribers using splitters and combiners. In such a network, known as a passive optical network (PON), costs are significantly less for fiber construction. Figure 12 shows this approach.

Figure 11: Schematic of Dedicated Fibers from Central Office to Homes

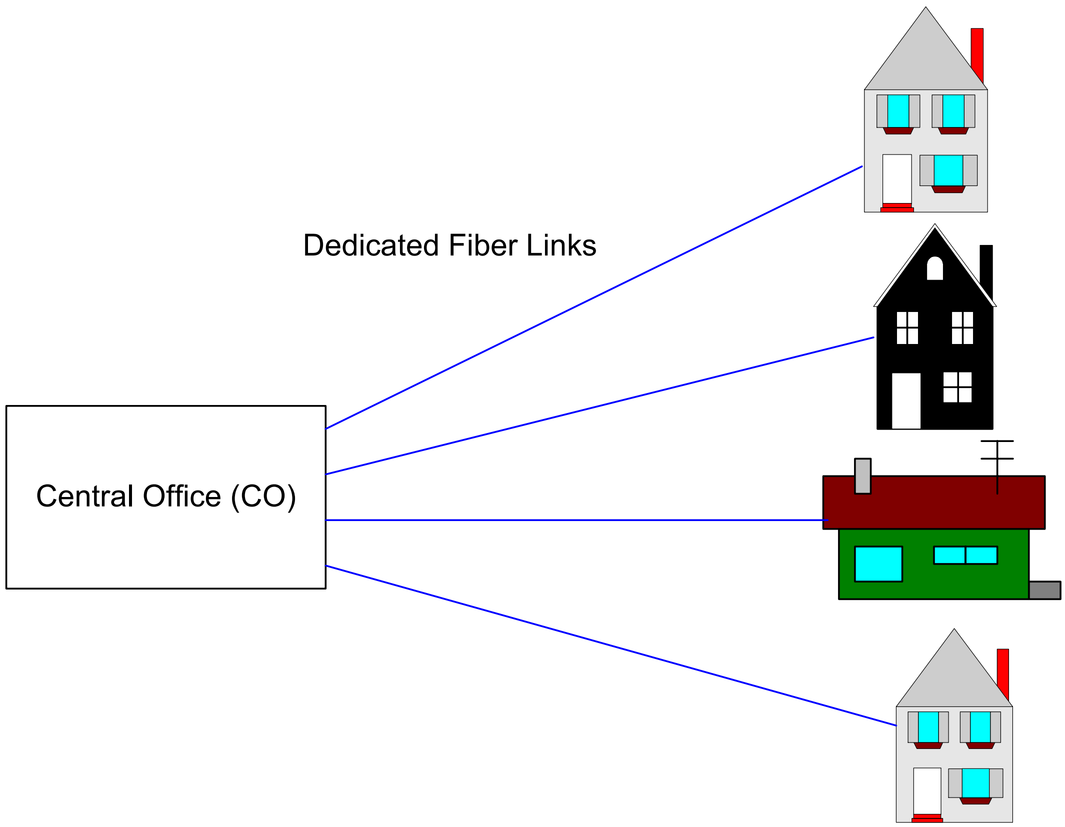
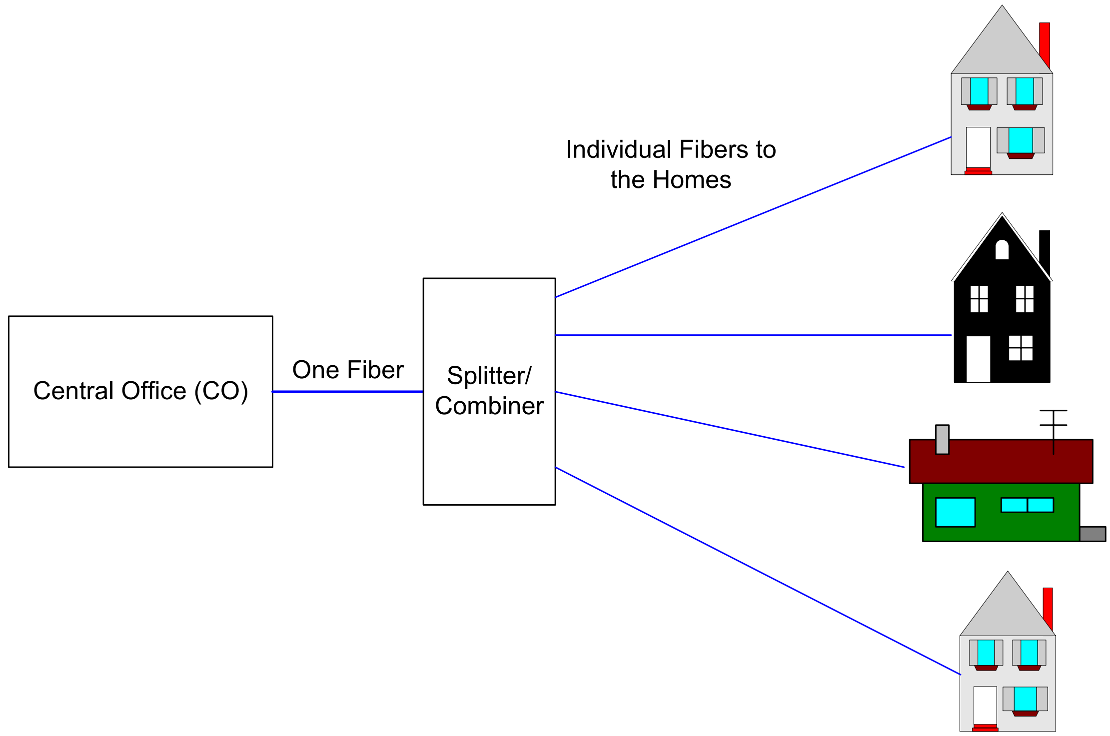


Figure 12: Schematic of a Partly Shared Fiber Network



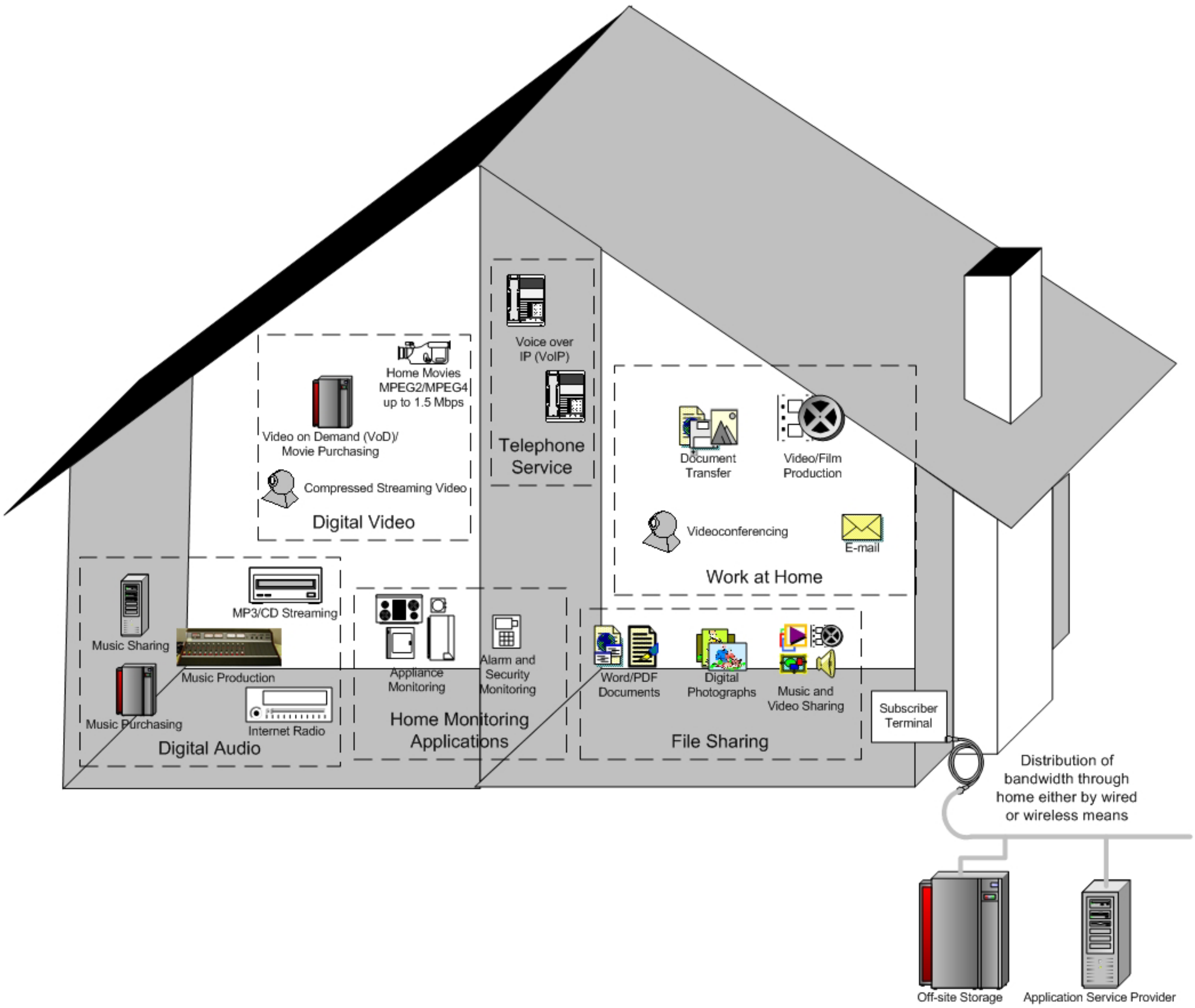
In a PON, the central office contains an Optical Line Terminal (OLT) and each subscriber has an Optical Network Terminal (ONT) on the premise. In a standard PON, anywhere from 1 to up to 64 ONTs can share one fiber coming from the OLT.

The OLT is a device that connects the optical network to a wide area network backhaul and is the PON counterpart to the cable CMTS or the DSLAM. The OLT is able to send voice, video, and Internet through the fiber network, and is the interface between the users on the optical network and the network outside the optical network.

The ONT is the user's interface to the network and can support several connections within the home. ONTs convert the incoming optical signals into electrical signals, or vice versa for upstream communications. An ONT typically has an AC power connection and a battery-backup to power the device. It also has standard RJ-11 telephone interfaces, a 10/100BaseT RJ-45 Ethernet connector, and a standard video connection for TV.[57] Figure 13 shows typical applications using FTTP. Newer versions may also include 802.11 wireless connectivity.

[57] http://www.cpau.com/fth/faq.html, accessed July 29, 2004.

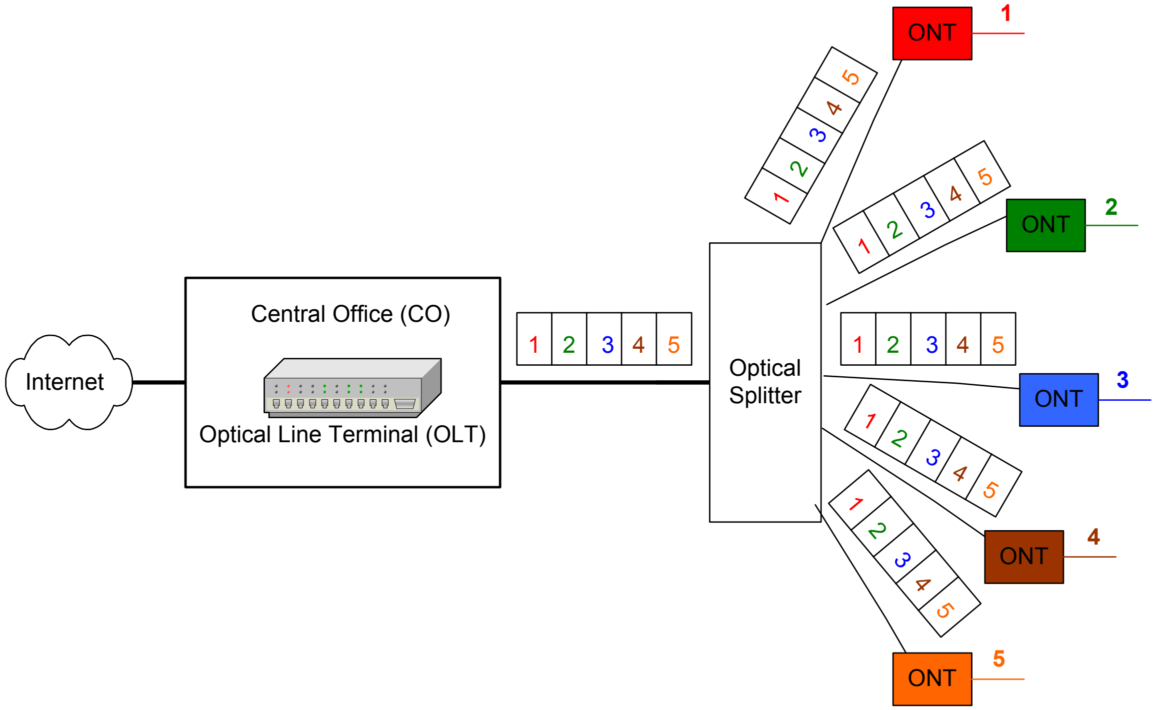
Figure 13: Residential High-Bandwidth User Applications



To support the multiple users, an access scheme is needed. The access scheme put forth by the International Telecommunications Union (ITU) is Time Division Multiplexing (TDM) for the downlink (from central office to user) and Time Division Multiple Access (TDMA) for the uplink (user to CO). In other words, each user has separate timeslots on the shared fiber. Future upgrades may require further enhancements such as use of multiple light wavelengths in order to increase capacity per user.

Each of the users on the network is assigned a time slot, and a fiber can support up to 64 end users. This passive splitter in the outside plant uses no power and works by passing or restricting light (optical signals). There are no active elements that need power anywhere in the PON other than at the central office or at the user's end, greatly reducing the plant maintenance burden relative to cable or telephone technology.[58] Figure 14 illustrates downstream communication on a PON.

Figure 14: General Diagram of Downstream Communication on a PON using TDM



TDMA is used for the uplink because (unlike at the central office where data comes from the Internet directly and is switched per user depending on the time slot) there are multiple ways to access the optical line that goes back to the central office because up to 64 users can share a single fiber. Users send information through their fiber, which reaches the passive splitter, which in this case acts as a passive coupler to combine the data in their designated time slots. This fiber then goes back to the central office where it is known which time slot corresponds to which user. Every ONT is time-synchronized with every other ONT, so that no ONT sends data during another ONT's time slot. Thus, when the data from each fiber reaches the passive coupler, each time slot will only contain data from one user.[59] Figure 15 illustrates upstream communication on a PON using TDMA.

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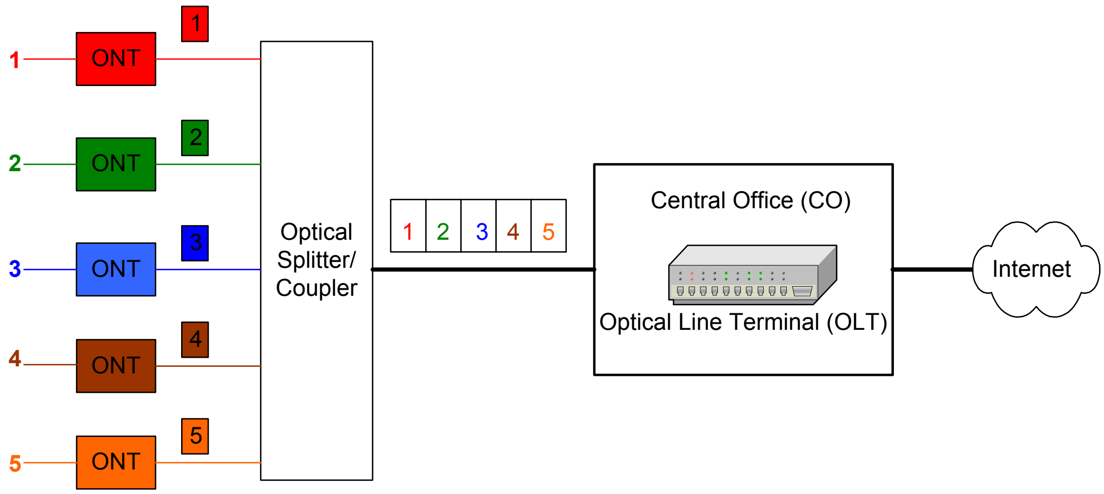
[58] http://www.ponforum.org/technology/default.asp, accessed July 28, 2004.
[59] http://www.iec.org/online/tutorials/atm_pon/topic02.html, accessed July 27, 2004.

Figure 15: General Diagram of Upstream Communication on a PON using TDMA



A different light wavelength is used for upstream and downstream signals. The standard downstream wavelength is 1550 nm, though some systems may support two different downstream wavelengths. In the case of the proposed Palo Alto, CA FTTP network, 1550 nm will be used for downstream video (cable television), while 1490 nm will be used for downstream voice and data.[60] 1310 nm is the wavelength used for upstream. Using separate downstream and upstream wavelengths results in optical isolation between the transmitters and receivers and also lower equipment cost.[61]

PON and FTTP technology has evolved in recent years. As stated above, bandwidths through fiber can reach up to 10 Gbps in some of the newer standards, and complex modulation and multiplexing schemes can further increase this number.

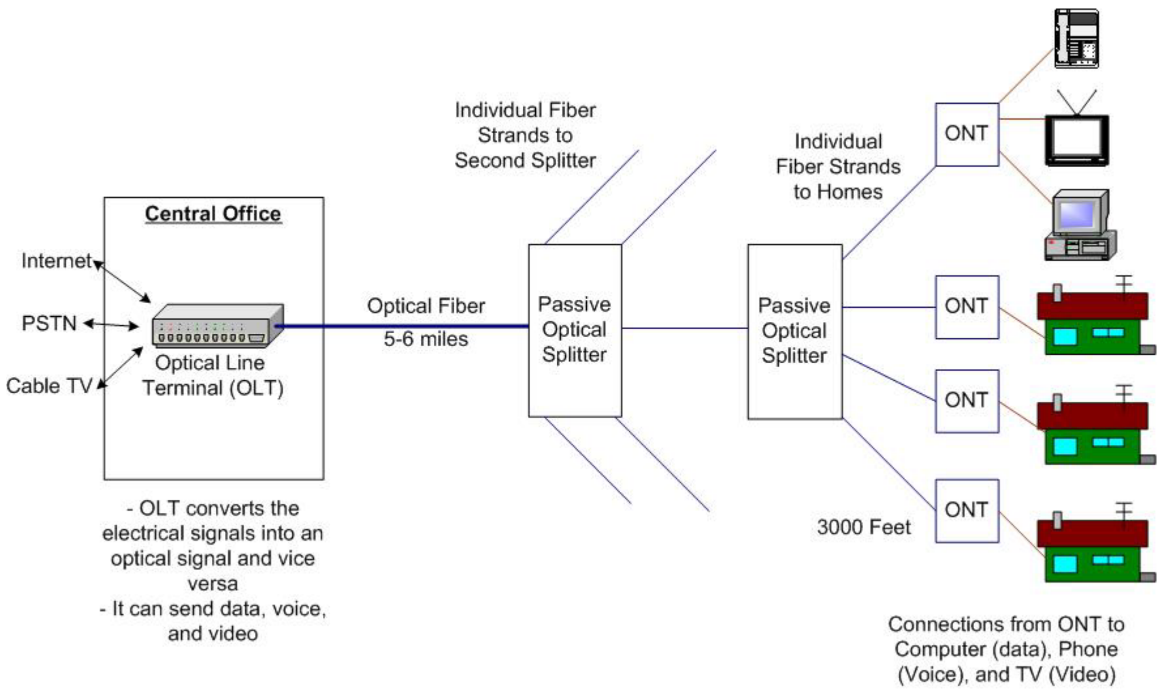
In 2003, the ITU approved a new set of standards for PON networks, calling the new standards G.984, also known as Gigabit PON (GPON).[62] GPON allows for data rates up to or exceeding 1.25 Gbps, and TDM/TDMA is used to share this bandwidth among many users.[63] There is also an Ethernet-based PON (EPON) protocol.

PONs can extend for longer distances from the central office without amplification than DSL signals. While different networks will have different distance limitations due to bandwidths or number of users, an FTTP network can operate over distances up to or even exceeding 33,000 feet from the central office. If only passive elements are in the field, the original fiber from the central office to the passive splitter can be up to 30,000 feet long, but with longer distances fewer users can be served from one fiber. For example, if the users are within 1 to 2 miles from the central office, then 1:32 or 1:64 splitters can be used, but as the users get to be 5 to 6 miles away,

[60] http://www.cpau.com/fth/faq.html, accessed July 27, 2004.
[61] http://www.iec.org/online/tutorials/atm_pon/topic02.html, accessed July 27, 2004.
[62] http://www.ponforum.org/technology/standards.asp, accessed July 30, 2004.
[63] http://www.ponforum.org/technology/gpon.asp, accessed July 30, 2004.

then 1:4 or 1:8 splitters are usually more appropriate.[64] After the passive splitter, optical signals can usually travel another 3000 feet through fiber without any amplification.[65] Figure 16 illustrates a PON and the hardware that is needed.

Figure 16: An Overview of a PON



As mentioned, Wave Division Multiplexing (WDM) is a possible evolution for optical networks from the TDM/TDMA system used now. TDM/TDMA uses time slots to allow multiple users to share a fiber, but it uses only one wavelength (or two). In WDM, separate wavelengths (different laser colors) are used to transmit data through optical fiber simultaneously, unlike with TDM/TDMA, where one carrier wavelength is used and split into multiple time slots for multiple users. The overall bandwidth of the fiber is aggregate, meaning that the bandwidths allowed for each carrier wavelength are added together to determine the total bandwidth of the fiber. WDM systems are convenient in some ways because they allow for communication companies to increase bandwidths on already installed fiber by just increasing the number of wavelengths used to transmit data through the fiber.

To upgrade to WDM, upgrades would be needed for the central office's multiplexer, a device that combines the different wavelengths, and at the ONT in order to separate the wavelengths to isolate the one wavelength that contains that user's data only. These equipment upgrades are

[64] http://lw.pennnet.com/articles/article_display.cfm?section=archives&subsection=display&article_id=42531&keyword=a-pon, accessed August 11, 2004.
[65] http://www.linktionary.com/f/fiber_home.html, accessed August 11, 2004.

comparatively expensive though when compared to equipment needed for other multiplexing schemes.[66] Because of pricing concerns and that TDM/TDMA systems are the industry standard for most FTTP networks today, WDM currently is not widely deployed for FTTP, but it could be a future evolution in FTTP networks in order to drastically increase bandwidths using already built FTTP networks.[67]

2.4.3 FTTP Implementations

The ZIPP Fiber Optic Network of Grant County, Washington serves a predominately agricultural population with relatively low population density (less than 13 homes per square mile). Beginning in the summer of 2000, the Grant County Public Utility District began building fiber optic paths to each home and business within the County to provide telecommunications services that were not otherwise offered, or were offered but could not compete with national standards.

All services offered through the ZIPP network are IP-based, including video (television services), voice using Voice over Internetworking Protocol (VoIP), and data (Internet broadband) services.

Currently, 19 ISPs offer 100 Mbps data services over the ZIPP network to residents, three providers offer telephone services, two providers offer television services, and two providers offers security and monitoring services.

As of September 2002, the ZIPP network had 3,000 customers, providing 96 percent with Internet service, 35 percent with digital television, and five percent with telephony services. The network has provided a multitude of services that were previously unavailable, and has brought more reliable and effective services to its customers.

In conjunction with Verizon Communications, a developer is providing FTTP to all residents in Brambleton, a Loudoun County, Virginia community. Brambleton residents are offered voice, video, and data services over fiber optics. Within ten years, approximately 6,000 homes will be served by FTTP. The Brambleton network utilizes a Passive Optical Network (PON) design, deploying no active devices outdoors and thereby increasing reliability and reducing the amount of maintenance required for outside plant. Each fiber feeds four homes, and connections to subscribers occur through an indoor-mounted optical to electrical converter (OEC).

Verizon will soon launch its first FTTP network in Keller, Texas (a community near Dallas, TX) by providing for optical connection directly to homes and businesses in the area. Verizon offers FTTP services under the name “Fios.” Verizon will provide broadband service up to 30 Mbps downstream via Fios. Verizon will charge $35 to 40 per month for downstream speeds of 5 Mbps and upstream of 2 Mbps and $45 to $50 per month for downstream speeds of 15 Mbps and

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[66] http://computing-dictionary.thefreedictionary.com/Wavelength%20division%20multiplexing, accessed July 28, 2004.

[67] PON System Overview. Terawave Communication; http://www.terawave.com/PONov.pdf, accessed July 29, 2004.

upstream of 2 Mbps.[68] Verizon also will provide the ONTs necessary to work with the FTTP service and will be using PONs in many of their FTTP networks. Verizon states that it will cost about $1000 to $1250 per home to build this network.[69]

Verizon's goal is to connect one million homes and businesses in nine states by the end of the year, concentrating first in Tampa, FL, Dallas, TX, and Huntington Beach, CA. Verizon has begun FTTP deployment in the Washington DC metro area. Verizon also hopes by next year to launch cable television services over the Fios network, allowing them to provide voice calls, broadband Internet, and video (TV) services via the same network.[70]

The Bristol Virginia Utilities (BVU) OptiNet fiber optic network was constructed by the municipal power utility. BVU OptiNet was built to provide voice, video, and data services to residences and business, including those within rural areas where video and high-speed data services were not previously offered.

BVU OptiNet is currently offering local and long distance telephone services. Features include caller ID, call waiting, voice mail, and an expanded local calling area to include communities across state lines (Bristol is located on the Virginia/Tennessee border). BVU also offers cable television services, unlimited dial-up Internet service, and expanded data services with up to three Mbps of bandwidth in the downstream direction and 512 kbps of upstream bandwidth. Other available services include web hosting, server collocation, security services, and storage.

2.5 Satellite Broadband

2.5.1 Introduction

Broadband via satellite is another means of access to the Internet at faster speeds than regular dialup service. Data rates for satellite broadband are usually 500 kbps downstream and 50 kbps upstream for some of the older systems, making these ones much slower than DSL or cable, but still about ten times faster than a dial-up modem.[71] New enhancements have been made to some satellite broadband systems, resulting in downstream rates up to or exceeding 1 Mbps and upstream rates up to 128 kbps.[72]

Its main advantage is for people who do not have access to wired broadband service such as cable or DSL, because it is available to anyone who can install a satellite dish facing the proper direction and does not require a provider to build cable or antennas.
A drawback of satellite broadband is that it is more expensive than other forms of broadband. Satellite service can cost as much as $99 per month, which is approximately three times

68 http://news.designtechnica.com/article4766.html, accessed July 16, 2004.
69 http://www.x-changemag.com/articles/411infra1.html, accessed August 11, 2004.
70 http://news.com.com/Verizon's+fiber+race+is+on/2100-1034_3-5275171.html, accessed July 26, 2004.
71 http://computer.howstuffworks.com/question606.htm, accessed July 20, 2004.
72 http://www.boston.com/business/technology/articles/2004/07/19/net_access_via_satellite_a_tough_sell/, accessed July 20, 2004.

Verizon's DSL charge and twice Comcast's cable modem charge. Installation is also more costly than other broadband types. Because it is more expensive, broadband via satellite's main niche will be for those who don't have access to other means of broadband.

Because of the long distance that satellite signals travel between the user and the Internet, the satellite system creates a delay in the signal. As a result, the quality of real-time applications, such as two-way voice and video communications, is often not as good as it is on wired or ground-based wireless networks.

2.5.2 Technical Description

The satellites involved in this technology orbit the Earth at the equator. As a result, customers in the United States must have a clear line of sight toward the south to receive satellite service. Heavy rains, high trees and buildings can affect the transmission of the data.[73]

Unlike DSL, which has a dedicated path to the Central Office, satellite broadband is more like cable service in which everyone on the network shares the path. Therefore, speeds are a function of how many people are trying to access the network at a given time. The more people trying to access the Internet, the slower the data speeds and vice versa.[74]

The general architecture layout of a broadband satellite system includes a satellite, user terminals, and the network hub station, which is connected to the Internet. Downstream (satellite to user) data is sent from the hub to the satellite, which then transmits the data to the user terminals. Upstream (user to satellite) communications works in the opposite manner.

One difference compared to other means of broadband is that satellite systems involve a delay because the data needs to be sent from the hub to the satellite orbiting Earth back to the terminal users. The average signal could travel 70,000 to 90,000 km (43,495 to 55,923 miles) long before reaching the user, resulting in a delay of 0.25 to 0.3 seconds, while DSL and cable systems have practically no delay (assuming the waves travel at speed of light). Furthermore, the receiver has to transmit it received the information correctly, resulting in another delay of 0.25 to 0.3 seconds. Therefore, there is an overall delay of average 0.55 seconds that other broadband systems don't have. In order to have this delay work within the confines of the Transmission Control Protocol (TCP), changes had to be made to the satellite gateway and the user terminals for proper implementation.[75]

Services that requires real-time communication between the two ends such as in video conferencing, Voice over IP, and gaming are not as practical via satellite as other means of broadband due to the latency of having to travel from Earth to the orbiting satellite and back to Earth. This delay, which can very from half a second to at times over a second depending on

[73] http://computer.howstuffworks.com/question606.htm, accessed July 20, 2004.
[74] http://hns.getdway.com/faqs.html#one, accessed July 22, 2004.
[75] Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) Background Book; http://www.dvb.org/documents/white-papers/DVBRCSbkgrbk1sted20021126.pdf, accessed August 10, 2004.

certain geographies and conditions, makes real-time communication impractical. For example, if making a phone call, there will always be a 1 second delay between the time one talks to the time the person on the other end receives the signal. This delay does not occur through land networks though because wired distances are usually much less than going through orbiting satellites.

Most broadband satellite systems involve the Very Small Aperture Terminal (VSAT) concept. VSAT describes satellite communication systems that have fixed user terminals with relatively small antennas. VSAT antenna dishes tend to be on the order of one to two meters, though they can be smaller or larger depending on the strength of the satellite signal in that area. Even though they are small, the antenna dishes are usually mounted outdoors, and are connected to a satellite modem, which is indoors.[76] VSAT systems work at fairly high frequencies, which can contain broadband-type frequency bandwidths capable of supporting broadband and multimedia signals.[77]

Satellite broadband systems operate on higher frequencies compared to other wireless communications such as PCS (1.9 GHz). Satellite broadband usually uses the Ku (10.7-12.75 GHz) and Ka (19-22 GHz) frequency bands for most of its transmissions. Both of these bands are in the super high frequency band (SHF), part of the microwave spectrum. At these high frequencies, direct line of site is needed from antenna to receiver for transmission. Also, at frequencies above 10 GHz, rain is a major cause of signal attenuation, so during heavy rainfall, transmission does weaken.[78] Most of the satellites that currently are being used are the first generation Ku-band satellites. These satellites typically could have capacities up to 500 Mbps per system and cover large areas (such as North America).

The newer generation satellites may migrate to Ka-band systems. The Ka-band satellites cover less area because they have more focused ranges, but they have higher capacity, up to 30 Gbps per system. The Ka-band satellites with have a network design similar to cellular services in which each satellite is responsible for one segment of an area and then other systems will use a different frequency band to communicate with adjacent areas.[79]

Broadband via satellite has slightly different protocols and technologies depending on the carrier. The following is a general description of one common system for broadband satellite.

The protocol used in two-way broadband satellite communication is an evolution of Digital Video Broadcasting (DVB). DVB was first used for satellite digital television. The DVB protocols were developed and approved in the mid 1990s. Their purpose was to digitally encode and compress audio and video. Different modulation schemes were also used depending on the equipment. The more advanced schemes could encode more bits at one time, increasing channel

[76] http://www.groundcontrol.com/galileo_info.htm, accessed August 11, 2004.
[77] Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) Background Book; http://www.dvb.org/documents/white-papers/DVBRCSbkgrbk1sted20021126.pdf, accessed August 10, 2004.
[78] http://www.mlesat.com/Article9.html, accessed July 22, 2004.
[79] Dankberg, Mark and John Puetz. Comparative Approaches in the Economics of Broadband Satellite Services; http://www.viasat.com/_files/_08fe203b613bc02b87de181a370e2bdf/pdf/BBeconomics.pdf, accessed August 10, 2004.

efficiency.[80] The first DVB protocol was one-way from satellite to user because television did not require two-way data transmission at that point. In television communications, DVB involved point-to-multipoint communications because the signal from the satellite would be broadcasted to everyone with satellite receivers.

The downlink (from satellite to user) is a point-to-multipoint broadcast that uses time division multiplexing (TDM) to send data.[81] TDM is a method of transporting many sets of data over one medium (in this case wirelessly) by assigning each data set to a time slot. For example, if five signals need to share one transmission cable, then the medium may apportion communications between five time slots, where each signal is assigned to a designated time slot. At the end of the shared medium, the five original data lines are separated and retransmitted as individual signals.[82]

A return (uplink) channel (from user to satellite) was needed in order to implement two-way communication. In 1999, Return Channel via Satellite (RCS) was created by an ad-hoc group to give the standard DVB-RCS. RCS was important because it allowed for upstream communication from user to network along with interaction with the satellite network. RCS uses Multi-frequency Time Division Multiple Access (MF-TDMA), which is a combination of time division multiple access (TDMA) and frequency division multiple access (FDMA). In FDMA, each user has a specific carrier frequency and bandwidth assigned to the user and only to that user. In TDMA, each user's data is divided into groups of bits, and then each user is assigned a time slot where the user than only transmit during their allocated time slot.[83]

MF-TDMA is a mixture of TDMA and FDMA. In this system, the return channel's frequency spectrum is split into multiple frequency channels, the FDMA part. Then, each frequency channel is further split into multiple time slots, the TDMA part. Therefore, each user has access to one time slot on one frequency channel. In this system, many terminals/users are capable of transmitting information back to the network simultaneously. These slots on the return channel are dynamically allocated and the network can choose which frequency channel or bit rate to use. One problem associated with uplink is that in uplink, each terminal sends information back to the satellite, which is orbiting Earth over the equator, but each terminal has a different distance from the satellite than other distances. Because the TDMA portion splits the channel into time slots, if one terminal is farther from the satellite, it will take longer to reach the satellite, disrupting the time slot sequence from the different terminals. Therefore, the time slots tend to be larger than they are needed to contain the information in each burst in order to guard against this problem of different latencies from different terminals to the satellite. This means that fewer users can theoretically use each frequency channel in order to handle this problem. Some systems now use GPS along with other positing techniques to determine a terminal's position in relation to the satellite in order to compensate for the differences in time resulting in more efficient use of each

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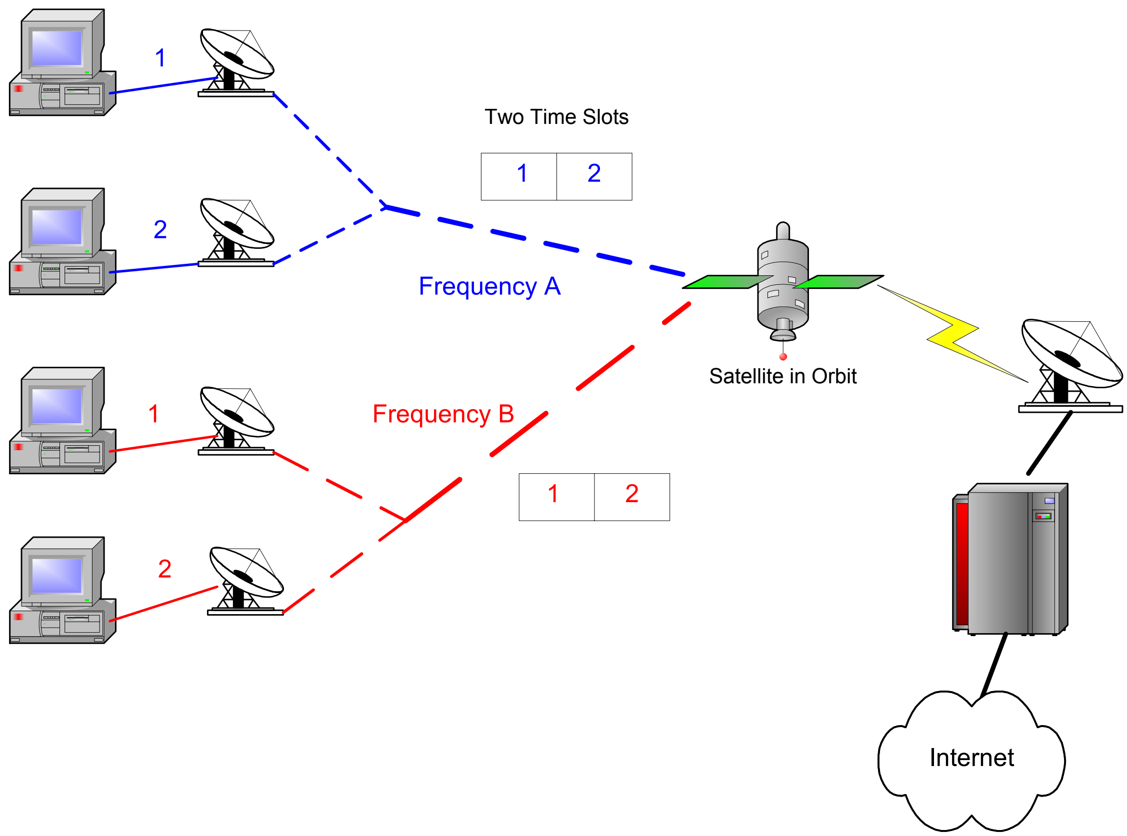
[80] http://encyclopedia.thefreedictionary.com/DVB-S, accessed July 21, 2004.
[81] Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) Background Book; http://www.dvb.org/documents/white-papers/DVBRCSbkgrbk1sted20021126.pdf, accessed August 10, 2004.
[82] http://searchsmallbizit.techtarget.com/sDefinition/0,,sid44_gci214174,00.html, accessed June 30, 2004.
[83] Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) Background Book; http://www.dvb.org/documents/white-papers/DVBRCSbkgrbk1sted20021126.pdf, accessed August 10, 2004.

frequency channel.[84] Figure 17 shows a simple example of a MF-TDMA system. The solid lines represent wired connections, while the dotted lines and yellow bolt represent wireless connections. This simplified system has two different carrier frequencies (A and B), and each frequency has two time slots (1 and 2).

[84] Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) Background Book; http://www.dvb.org/documents/white-papers/DVBRCSbkgrbk1sted20021126.pdf, accessed August 10, 2004.

Figure 17: Schematic of a Simplified Uplink MF-TDMA System



Internet Protocol over Satellite (IPoS) is a second standard that is used heavily by Hughes Network Systems and DirecTV in their broadband satellite Internet service (DirecWay). IPoS became an official standard in December of 2003, and Hughes has deployed this service to about 300,000 users so far, concentrated in the Americas.[85] DBS-RCS was an evolution technology first based on satellite TV, while IPoS was more specifically designed for broadband services.[86] IPoS and DirecWay operate in the Ku-band.

Hughes and DirecTV currently have a broadband system that is deployed throughout the country. They promise speeds of about 500 kbps downstream and 50 kbps upstream, though some of their newer systems may double these bandwidths. DirecWay has three satellites that cover most of North America. Each satellite has different coverage areas within the country, so one picks which orbiting satellite to use based on location and satellite coverage maps.[87] They have different pricing plans, but one of their standard plans is $60 per month for unlimited broadband

[85] http://www.hns.com/HNS/Rooms/DisplayPages/ LayoutInitial?Container=com.webridge.entity.Entity%5BOID%5B8AC7BC879B6E58449647D7E74BF278DF%5D%5D, accessed July 23, 2004.
[86] http://www.expresscomputeronline.com/20040517/newsanalysis01.shtml, accessed July 23, 2004.
[87] http://www.groundcontrol.com/coverage_001.htm, accessed August 11, 2004.

use, but the user also has to purchase $600 worth of equipment before deployment.[88] DirecWay does not recommend their broadband connection for real-time applications, such as on-line gaming, or VPN clients, due to the high latency. DirecTV has begun to market DSL service as a means for its customers to obtain high speed Internet access as opposed to its own satellite broadband service, DirecWay.[89]

WildBlue is another satellite broadband provide that will begin offering service in early 2005. Their recently launched satellite will support download speeds of 1.5 Mbps and upload of 256 kbps. The same latencies associated with other satellite broadband services will still apply and the service is mainly of benefit to those people who cannot receive cable or DSL service.[90]

[88] http://hns.getdway.com/home_service.html, accessed August 10, 2004.
[89] http://www.directv.com/DTVAPP/imagine/InternetAccess.dsp, accessed October 26, 2004.
[90] http://www.wildblue.com/faq/#2, accessed October 25, 2004.

3. Cable Modem Technology Facilitates Control over Content, Usage, and Personal Information

Widely-used network technologies currently enable cable operators to control access and the availability of bandwidth on their networks. The technologies enable the network operator to select "policies" for individual users, applications, and portions of the network.[91] Corporate and enterprise network administrators define policies for a range of purposes, such as ensuring the smooth operation of voice, video, and multimedia applications that require guaranteed performance or protecting the security of confidential information.

Cable modem networks share many of the networking technologies used in enterprise networks. As a result, the same management and provisioning can be implemented on a cable Internet system as on a corporate enterprise network. By utilizing industry-standard network management equipment and techniques, operators are able to categorize network traffic and network policies for Internet access for their customers. For example, network management technologies enable network operators to:

- Speed transmission to or from an affiliated site (or a site that has paid the operator for the privilege of special treatment).
- Slow or block transmission to or from a non-affiliated or non-paying site.
- In a cable modem network offering access to third-party ISPs, slow or otherwise obstruct traffic of customers of third-party ISPs while favoring the traffic of its own customers.
- Slow or block content that competes with the operator's other products. For example:
    - Voice over IP services that compete with the operator's own voice service.
    - Video streams that compete with the operator's Video on Demand or other video offerings over the cable system.
    - Video-conferencing transmissions that compete with the operator's own video-conferencing offering.
    - Transmissions from Internet sports sites that compete with the operator's pay-per-view offering of a major sports event.
- Block content on the basis of political or ideological objection to content.

[91] A "policy" is a direction programmed into the software of the network that determines how the network will allocate resources among users. To illustrate, the following are examples of potential network policies:

- Prioritize Voice over IP traffic.
- Limit public-area computers to the Internet and block them from accessing cable system servers.
- Block audio and video streaming to unauthorized users.

- Block or limit peer-to-peer traffic[92] such as Kazaa and BitTorrent.

- Maintain records of the content of customers' message transmissions and Internet usage.

Many network technologies could enable network operators to manipulate or monitor a subscriber's Internet usage. The following sections describe several prevalent technologies used on cable Internet systems including:

- Traffic management techniques.
- PacketCable.
- Deep Packet Inspection.
- Traffic Management Software.

All of these technologies are legitimately used to manage and operate data networks, but have the potential to enable practices of monitoring and manipulation.

3.1 Traffic Flow Management Techniques

3.1.1 Technical Description

Traffic flow management techniques enable routing and prioritization of network traffic based on the rules or policies set by the protocol or network administrators. Customers' data packets are "tagged" and routed according to those tags or policies. The router can recognize customers' traffic based on one or more of a number of factors, including:

- The source address of the data packet (the address of the originating computer).
- The content of the data packet.
- The size of the data packet.

Traffic flow management is made possible by the router's ability to analyze identifying numbers carried by data packets on the Internet. Much as a letter has an envelope with an address, a data packet has a header that contains numbers that identify, among other things, the content type also known as TCP or "port" and source and destination address. Traffic management techniques recognize these numbers and then treat them according to the policies programmed into the router.[93]

Many network technologies incorporate traffic flow management. Policy-based and content-based routing are two common terms used to describe routing protocols that incorporate traffic

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[92] "Peer-to-peer" describes non-hierarchical data networking where two or more locations on a network share information. Neither "peer" is a server (exclusively storing the data) or a client (exclusively requesting the data). Examples of peer-to-peer networking include Napster, Kazaa, and BitTorrent, where users obtain resources that can be located anywhere on the Internet and also make available resources to others.

[93] http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fqos_c/fqcprt1/qcfpbr.htm, accessed January 27, 2005.

flow management. Many router manufacturers have developed their own implementations of traffic flow management.

3.1.2 Recent Increases In Capability of Routing Technology Facilitate Manipulation and Monitoring

Over the past few years, traffic flow management techniques have become a standard feature in the core of enterprise and service provider networks, available in routers such as the Cisco 7200 and Juniper M-series. These techniques are therefore at the disposal of most cable modem service providers.

Network administrators frequently use traffic flow management to prioritize sensitive applications and limit their disruption by other, less critical network traffic. For example, prioritizing voice traffic can prevent calls from being dropped. In contrast, email and file transfers typically are assigned lower priority—a split-second delay in email or file transfer will likely not be noticeable to a user.

Traffic flow management techniques are also proposed as a method of enabling multiple ISPs to provide services over the same cable modem system. Internet traffic to and from customers of competing ISPs on the same system can be identified by their source and/or destination address, and their Internet traffic can be routed by the cable system to and from the appropriate ISP.[94]

However, there is potential that a cable provider can use traffic flow management techniques to manipulate its customers' Internet use (as well as that of the customers of other ISPs operating on the same, "open" cable system). These potential practices are inherent to the technology. In 1999, Cisco published a white paper entitled "Controlling Your Network – A Must for Cable Operators."[95] The white paper describes how network operators can use traffic flow management techniques to manipulate subscribers' Internet use. The paper markets the technology's capability to enable policies that govern bandwidth based on "IP address, application, precedence, port, or even Media Access Control (MAC) address."[96] The paper gives the example of using the technology to provide precedence and greater bandwidth to the operator's own video servers than to external, unaffiliated video servers.[97]

[94] http://www.juniper.net/solutions/literature/white_papers/552003.pdf, accessed January 27, 2005; Columbia Telecommunications Corporation, Technological Analysis of Open Access and Cable Television Systems, January 2001, pp. 27-31.

[95] http://www.cptech.org/ecom/openaccess/cisco1.html, accessed January 27, 2005. This white paper received some critical attention when it was released in 1999 (see, for example, http://news.com.com/Cisco+drawn+into+Net+control+battle/2100-1033_3-229285.html). To our knowledge, Cisco no longer makes the document publicly available. It is not currently available on Cisco's own website. The publicly-available copy cited to herein is archived on the website of an advocacy organization, the Consumer Project on Technology.

[96] http://www.cptech.org/ecom/openaccess/cisco1.html, accessed January 27, 2005.

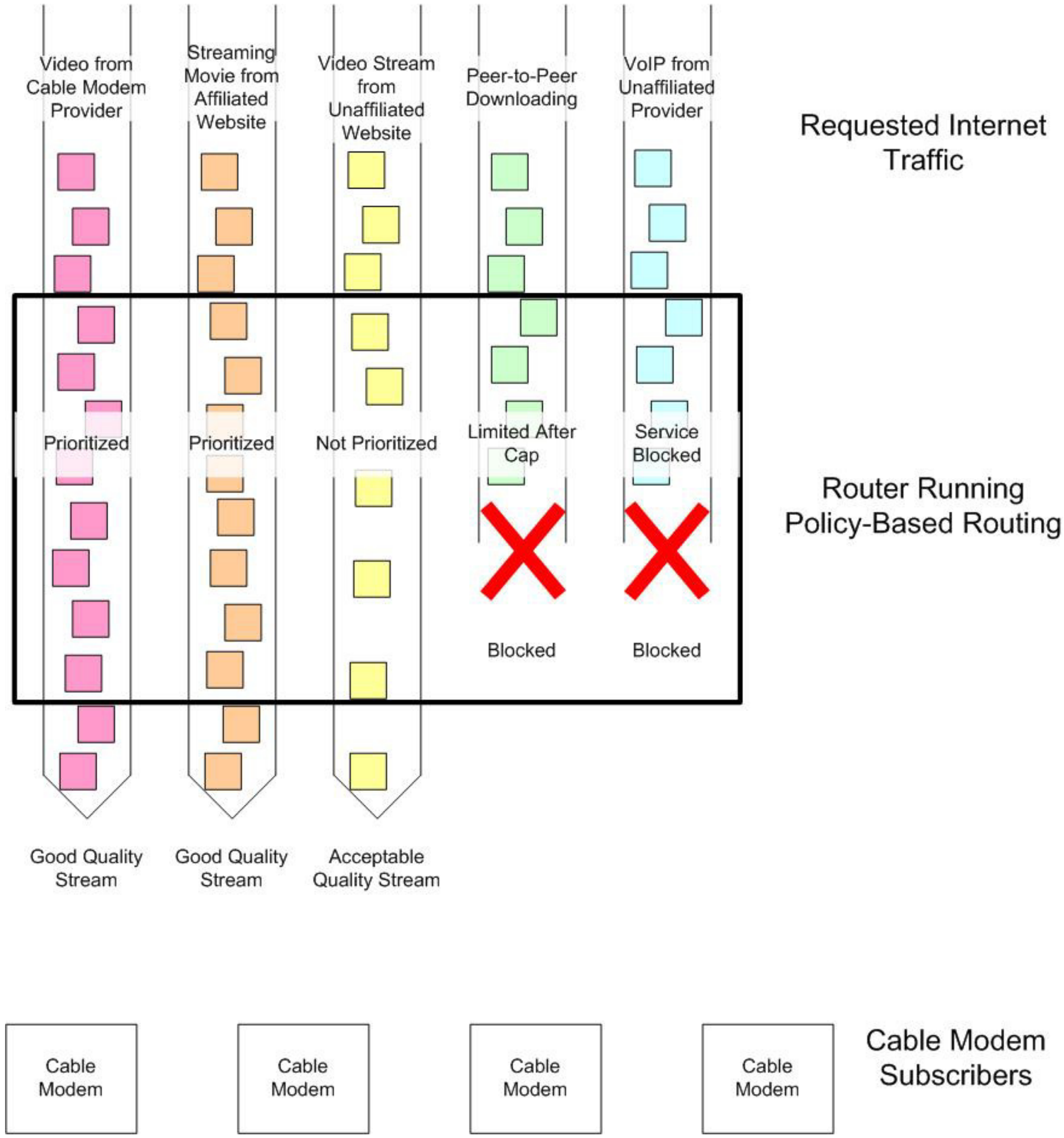
[97] http://www.cptech.org/ecom/openaccess/cisco1.html, accessed January 27, 2005.

Hardware and software vendors market traffic flow management techniques to limit peer-to-peer traffic over the cable modem systems. Cable providers are concerned about peer-to-peer traffic for several reasons: first, it is more costly to build a network to provide Internet capacity between peers located anywhere on the Internet than it is to enable customers to connect to Web servers, which tend to be closer to the Internet backbone. Second, peer-to-peer users often exchange large multimedia files or streaming media, which can be especially burdensome to a network.[98]

Monitoring software enables cable modem providers to analyze how much bandwidth is being used by different applications (such as email, web browsing, peer-to-peer traffic).[99] Cable providers can then program the routers and switches in the network to limit the bandwidth of certain applications or subscribers depending on how the policies are defined.[100] Figure 18 illustrates how policy-based routing could be used to increase the priority and guarantee the quality of affiliated content while blocking or limiting content from competitors or bandwidth-intensive applications.

[98] http://www.cedmagazine.com/ced/2002/1002/10c.htm, accessed January 29, 2005.
[99] http://www.allot.com/pages/product_content.asp?intGlobalId=5, accessed January 25, 2005.
[100] http://www.ellacoya.com/products/e30.shtml, accessed January 25, 2005.

Figure 18: Manipulation of Internet Use Facilitated By Policy-Based Routing



A cable Internet customer has no way of knowing if and how traffic flow management is being used and what policies cable system administrators are setting.

3.2 PacketCable

3.2.1 Technical Description

PacketCable is a suite of protocols designed by CableLabs (the research institute of the cable industry) to facilitate the use of applications that require guaranteed network performance, also known as quality of service (QoS). These applications include Voice over IP, teleconferencing, and real-time gaming.[101] PacketCable operates on cable systems that comply with DOCSIS 1.1 or higher standards; resources on the DOCSIS network are allocated for each PacketCable application run by a customer.[102] PacketCable provides a standard interconnection between a DOCSIS cable modem system, the Public Switched Telephone Network (PSTN), and other DOCSIS cable modem providers, enabling enhanced communications with standard telephone users and other cable modem subscribers.[103]

PacketCable provides QoS across the network to support applications that cannot tolerate delay.[104] Bandwidth can be reserved for each application that requires QoS. To differentiate between applications and to assign the proper resources, PacketCable systems can use deep packet inspection (DPI) to determine the type of application sending packets. DPI searches for markers in the data contained in IP packets to determine the application sending packets and type of information being sent. PacketCable can use this information and the network policies to determine the appropriate amount of resources to reserve for the communication.

Many of the major cable operators are deploying PacketCable to support Voice over IP services.[105]

3.2.2 PacketCable Facilitates Transmission Monitoring

PacketCable provides a telephone interface that enables law enforcement authorities to conduct wiretaps by directly connecting to the cable modem router at the hub or headend.[106] Because of this interface, PacketCable is the only widely-deployed packet-based voice network that facilitates eavesdropping on calls—competing providers such as Vonage and Packet 8 can only store and forward calls, essentially saving a copy of the call.

PacketCable was designed to comply with the electronic surveillance laws adopted under the Communications Assistance for Law Enforcement Act (CALEA). CALEA requires that law

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[101] http://www.packetcable.com/downloads/specs/PKT-SP-DQOS-I10-040721.pdf, accessed 27, 2005.
[102] http://www.packetcable.com/downloads/specs/PKT-SP-DQOS-I10-040721.pdf, accessed 27, 2005.
[103] http://www.neca.org/media/ChristopherLammers.pdf, accessed January 25, 2005.
[104] http://www.cisco.com/univercd/cc/td/doc/product/cable/cab_rout/cmtsfg/ufg_pkcb.pdf, accessed January 25, 2005.
[105] http://www.cedmagazine.com/ced/2004/1204/12a.htm, accessed January 25, 2005.
[106] http://www.ncta.com/pdf_files/Green_testimony_HEC-Telecom_9-8-2004.pdf, accessed January 25, 2005.

enforcement agencies (LEA) be able to intercept packets traveling over the data networks.[107] Although PacketCable security protocols encrypt data packets between the subscriber and the cable modem termination system (CMTS), packets can be decrypted at the CMTS for LEAs.

As a result of this design feature, PacketCable provides cable operators and anyone else with the appropriate access privileges to the CMTS with the ability to tap into telephone calls, in a similar manner as telephone lines can be accessed at telephone central offices.

3.3 Deep Packet Inspection

3.3.1 Technical Description

DPI is an extension of policy-based routing. It is more thorough and complete than PBR, because it can examine the packets beyond the packet header and look into the packet's application layer, also known as the data payload. Routers that use DPI can examine the data payload to determine the application originating the packet (such as Word, RealMedia, and VoIP client software) by searching for markers or characteristics of the packets that the router recognizes. Deep packet inspection also can search the data and headers for the type of information being sent (data, voice, video). Router administrators can establish policies that determine how the router should respond when receiving packets from different applications and of different data types.[108]

DPI is used in private networks to establish QoS for real-time applications and to manage the traffic in network connections. The policy settings for DPI are similar to those of policy-based routing. Network administrators may limit bandwidth, drop packets, and set packet precedence for varying types of data and applications. The deeper look offered by DPI adds flexibility in identifying applications, such as Kazaa, that deliberately hide their identity by constantly changing the information they place in packet headers. DPI is also useful in identifying packets created by worms and viruses.[109]

3.3.2 DPI Enables Traffic Manipulation and Monitoring

An unregulated single ISP cable modem system has the same latitude in setting policies as a private network. DPI is being marketed to ISPs as a tool for monitoring Internet traffic and limiting bandwidth intensive applications like peer-to-peer sharing. Network administrators can use DPI to establish QoS based on the application, data type, and user. Cable modem providers could use DPI to guarantee SLAs to its customers who pay for them by establishing priority to

[107] http://focus.ti.com/pdfs/bcg/voip_calea_wp.pdf, accessed January 26, 2005.
[108] http://www.nortel.com/products/01/alteon/2224/collateral/nn108280-052604.pdf, accessed January 27, 2005.
[109] *Ibid.*

their data packets over others. They could also decrease the priority for competing VoIP services or eliminate them altogether.

There is no engineering reason why DPI should always be limited to searching the data payload for application information. As computing power increases, DPI could be used to monitor the actual content of the data payload for specific content or keywords. This capability could enable the network administrator to search for particular words or phrases in e-mail or word processing files and match them to users.

3.4 Traffic Management Software

3.4.1 Technical Description

Many enterprise network administrators use traffic management software to analyze their Internet traffic and determine their bandwidth usage. Traffic management software typically resides on a server that is connected to the network such that it can receive all packets entering or leaving the network. The server receives packets as they travel in and out of the network. The software then analyzes the packets by searching the packet headers and payload. The traffic management software creates databases from the information gather from the packets and can provide details such as:

- Sites visited.
- Bandwidth consumption.
- Data sent and received.
- Applications accessing the Internet.
- Users accessing the Internet.[110]

After analyzing the results, network operators can use the software to block sites and limit bandwidth to certain users, applications, or sites.

3.4.2 TMS Enables Use Monitoring

As in a private network, traffic management software can be attached to the router at the headend to monitor the network traffic on the cable modem system. Similar traffic management policies can be used to block or limit bandwidth to certain sites and prohibit the use of certain applications.

Traffic management systems could allow cable providers to monitor Internet activity by individual users. Traffic management systems can list, by user, the sites visited, information sent and downloaded, and number of times visited.[111] This network activity information can be stored by the traffic management system and could be used for marketing or sold to third parties.

[110] http://www.dyband.net/Products/prodInfo/capabilities.htm, accessed January 26, 2005.
[111] http://www.lightspeedsystems.com/tools/contentfiltering.asp, accessed January 26, 2005.

4. Cable System Engineering Limits Technical Competition

The design and technology choices made during the early developmental stages of cable modem technology made "open" systems difficult and costly to achieve. The designers of cable's digital and interactive services assumed they were designing a system of central control by a single provider, in conformity with the model of the single-provider for traditional cable video services. This single-provider assumption was built into the designs and specifications for cable modem networks. The cable industry now argues that retrofitting those systems for open access is costly and complex. This claim is correct -- because these systems were engineered in a fashion that makes achieving technical competition far more difficult than it would have been had the earlier design process included consideration of open access.

Specifically, DOCSIS and the various cable television set-top boxes and management systems do not facilitate control or access by entities other than the cable provider or its contractors or suppliers. The required solutions often require additional components and engineering, and are therefore more complex and costly than they would have been had an open, competitive environment been part of the original architecture.

Many of the technologies discussed in Section III, including PacketCable, MPLS, and policy-based routing, can be added onto the cable system and used either to hinder or to facilitate competitive access for Internet-based services, depending upon their configuration.

This section of this Report provides illustrative examples of cable architecture that present significant challenges for competitive services and innovation by non-cable providers over a cable system – challenges that exist because of the design choices made by the cable industry itself.

4.1 Roadblocks to Openness in Cable Modem Access

Most cable modem networks today implement a DOCSIS 1.0-compliant platform. DOCSIS 1.0 became widely accepted by the cable industry following its finalization in 1997. DOCSIS was developed by a working group composed of several major cable multi-system operators, including Comcast, Cox, and Time Warner. The initial goals of DOCSIS were to provide a relatively simple, standard technology for the transport of IP data traffic over a cable system. The intent was that future versions of DOCSIS, as well as individual vendor systems, could incorporate advanced feature sets built on DOCSIS 1.0.[112]

Had DOCSIS been conceived from the outset as a means of providing connectivity between cable modem users and multiple ISPs, it would almost certainly have been designed differently. For example, it would have allowed for:

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[112] CableLabs, Press Release, December 11, 1996, "Cable Industry Issues Specification for High-Speed Data Delivery", (http://www.cablelabs.com/news/pr/1996/1996_12_11.html), accessed January 2005.

- Connectivity of multiple provisioning systems to common CMTS hardware, to allow multiple service providers to independently activate and configure service for a subscriber.

- Capability to segment capacity between multiple service providers over a common transport network in a way that would prevent the traffic of one service provider and its customers from impacting that of another service provider.

- Separate physical interfaces for connectivity to the separate ISPs.

- The means for the ISPs to separately control QoS, in order to provide multiple tiers of service for customers, optimize the service for different types of users, and guarantee QoS independently of the cable operator.

Even later versions of DOCSIS (1.1 and 2.0), which provide mechanisms for guaranteeing differing levels of QoS for certain types of traffic (and possibly different ISPs), provide no "out-of-the-box" means of simultaneously providing service via multiple ISPs. To achieve these goals, DOCSIS systems must be hobbled together with other technologies, even simply to allow segmentation of traffic for multiple service providers.

Many of the capabilities needed to segment traffic among multiple ISPs are in fact deployed in cable provider networks—these include IP-routers with source-based routing capabilities (see Section 3). However, the cable operator may not have deployed its routers in a configuration conducive to interfacing with multiple outside networks. A cable provider would therefore need to incur additional cost and complexity in engineering and connecting a cable system to third-party ISPs in a way that each ISP can independently manage provisioning, QoS, and capacity.

4.2 Cable Networks Technically Favor Proprietary Digital and Interactive Video Services

Beginning in the late 1990s, traditional cable video services began to migrate to digital technologies, which can provide more than ten times the channel capacity. Today, many cable systems are on the verge of migrating to a completely digital environment, enabling greater channel selection, on-screen interactive menus and guides, and VoD services.[113]

The systems enabling these digital interactive video services are mostly proprietary. The cable headend systems that manage interactive digital services and set-top boxes from many of the major manufacturers, including Scientific-Atlanta and Motorola, are not interoperable, preventing the consumer from having a choice in interface equipment for digital video services. As a result, it is difficult today for a third-party vendor to develop a competitive product for use on a digital cable system. Cable set-top box equipment is generally not interchangeable -- even

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[113] Jeff Baurngartner and Karen Brown, "Migrating toward and All Digital World", CED Magazine, February 2004 (http://www.cedmagazine.com/ced/2004/0204/02b.htm), accessed January 28, 2005.

between cable systems that are owned by the same provider but use a different proprietary digital cable platform.

As a result of the use of proprietary technologies, the innovators who seek to independently provide competition or new solutions over a cable system are fighting the architecture in place. By nature of the engineering of the cable systems, these would-be competitors face technological challenges that seriously disadvantage their innovations relative to similar offerings by the cable provider.

The digital video recorder (DVR) provides an instructive example. TiVo has offered an innovative product with some success, in part because there do exist technological options for an independent service provider such as TiVo to interface its hardware and software with a cable system. However, the solution requires the user to interface the TiVo with the cable operator's set-top converter, often by taping infrared transmitters to the front of the set-top converter to simulate a remote control device. The TiVo user must also be connected to a telephone line or to a broadband cable or DSL modem to update the programming guide. If the TiVo viewer wishes to tape multiple digital or premium programs at once, the viewer must connect to two or more cable set-top converters. In other words, a TiVo viewer needs to exert considerable effort (and expense) to make TiVo work with the equipment of the cable operator.

In contrast, the cable operator's own similar product is inherently designed to make installation and operation simple and smooth. After TiVo introduced its DVR product, cable operators introduced their own digital video recorder services. The cable operator services incorporated the converter and DVR function into a single device, delivered program guide information via the cable system itself, and facilitated recording of multiple channels at once. It is critical to note that the only conceivable entity that could have provided the service in this way was the cable provider or a partner of the cable provider. As it stands today, a cable set-top converter is required to present digital channels and to decode or descramble premium programming in nearly all digital cable systems.

Over time, the control of the cable system and its proprietary nature force TiVo and similar service providers to face serious technical challenges innovating and competing with the cable operators. The Telecommunications Act of 1996 envisioned this problem when it required that there be "commercial consumer availability" of the equipment used to access channels on cable systems, "from manufacturers, retailers, and other vendors not affiliated with any multichannel video programming distributor."[114]

To implement this regulation, the FCC required that operators make available separate "Point of Deployment" modules (now known as "CableCARDs") to handle security for premium content. This requirement was scheduled to go into effect in June 2000, but the cable industry sought and obtained delays and waivers. CableCARDs became available only in late-2004[115] and are not

[114] http://thomas.loc.gov/cgi-bin/query/F?c104:1:./temp/~c104EpEwuG:e227905, accessed January 29, 2005.

[115] Scientific Atlanta first presented a CableCARD at the 2004 Consumer Electronics Show (CES), and announced on January 6, 2005 that several digital television manufacturers have developed compatible televisions. Scientific-Atlanta, Press Release, January 6, 2005, "Scientific-Atlanta's CableCARD Expands Consumers' Options for

widely promoted by cable operators. Moreover, existing CableCARDs are more limited than those originally envisioned—they function only for one-way services; as a result, they cannot authorize and control viewing of Video on Demand or utilize other interactive services, such as on-screen program guides and gaming services.

The FCC is currently mandating that cable companies be required to use CableCARDs in its leased set-top converters by July 2006.[116]

TiVo announced recently it plans to produce a digital cable-ready DVR that will leverage CableCARD technology.[117] In theory, a TiVo with a CableCARD would eliminate the need for a separate set-top converter. As a result, TiVo would be more competitive from a technical perspective with the cable operator's own DVR product. Until that happens, however, TiVo faces significant technological disadvantages relative to the operators' DVR offerings – not because of a flaw in TiVo's engineering, but because of the inherent advantage to the operators built into the technology they developed.

Delivery of Cable Entertainment," (http://www.scientificatlanta.com/newscenter/newsreleases.asp?target=http://www.scientificatlanta.com/newscenter/releases/05Jan06-4.htm), accessed January 29, 2005.

[116] Cliff Edwards, Ronald Grover, and Catherine Yang, "Interactive TV: What's In the Cards?," Business Week Online (http://www.businessweek.com/magazine/content/05_05/b3918070_mz011.htm), accessed January 29, 2005.

[117] TiVo, Press Release, January 6, 2005, "TiVo Developing High-Definition, Digital Cable Ready DVR," (http://www.tivo.com/5.3.1.1.asp?article=234), accessed January 28, 2005.