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Broadband Over Power Lines

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Broadband over Power Lines

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Introduction

Despite the spread of broadband technology in the last few years, there are significant areas of the world that don't have access to high-speed Internet. When weighed against the relatively small number of customers Internet providers would gain, the incremental expenditures of building the necessary infrastructure to provide DSL or cable in many areas, especially rural, is too great. But if broadband could be served through power lines, there would be no need to build a new infrastructure. Anywhere there is electricity there could be broadband.

Technology to deliver high-speed data over the existing electric power delivery network is available and is used in some parts of the world. Broadband over Powerline (BPL) is positioned to offer an alternative means of providing high-speed internet access, Voice over Internet Protocol (VoIP), and other broadband services, using electric power lines to reach customers' homes and businesses. By combining the technological principles of radio, wireless networking, and modems it is possible to send data over power lines and into homes at speeds up to 3 megabits per second (Mbps). By modifying the current power grids with specialized equipment, the BPL developers could partner with power companies and Internet service providers to bring broadband to everyone with access to electricity.

Broadband over powerlines (BPL) allows customers to get high-speed internet connections through their electrical outlets. Users can plug a power line modem into an electric socket anywhere in their home, without requiring any special installation or wiring. Broadband over power lines (BPL) is the use of PLC technology to provide broadband Internet access through ordinary power lines. A computer would need only to plug a BPL modem into any outlet in an equipped building to have high-speed Internet access.

BPL may offer benefits over regular cable or DSL connections: the extensive infrastructure already available allows people in remote locations to access the Internet with relatively little equipment investment by the utility. Also, such ubiquitous availability would make it much easier to connect other electronics, such as televisions or sound systems.

Variations in the physical characteristics of the electricity network and the current lack of standards mean that provisioning of the service is far from being a standard, repeatable process. And, the amount of bandwidth a BPL system can provide compared to cable and wireless is somewhat of an unknown.

Deployment of BPL has illustrated a number of fundamental challenges, the primary one being that power lines are inherently a very noisy environment. The system must be designed to deal with these natural signaling disruptions and work around them.

Broadband over power lines has developed faster in Europe than in the United States due to a historical difference in power system design philosophies. Power distribution uses step-down transformers to reduce the voltage for use by customers. But BPL signals cannot readily pass through transformers, as their high inductance makes them act as low-pass filters, blocking high-frequency signals. So, repeaters must be attached to the transformers. In the U.S., it is common for a small transformer installed from a utility pole to service a single house or a small number of houses. In Europe, it is more common for a somewhat larger transformer to service 10 or 100 houses. For delivering power to customers, this difference in design makes little difference for power distribution. But for delivering BPL over the power grid in a typical U.S. city requires an order of magnitude more repeaters than in a comparable European city. On the other hand, since bandwidth to the transformer is limited, this can increase the speed at which each household can connect, due to fewer people sharing the same line. One possible solution is to use BPL as the backhaul for wireless communications, for instance by installing Wi-Fi access points or cell phone base stations on utility poles, thus allowing end-users within a certain range to connect with equipment they already have.

The second major issue is signal strength and operating frequency. The system is expected to use frequencies of 10 to 30 MHz, which has been used for many decades by amateur radio operators, as well as international shortwave broadcasters and a variety of communications systems. Power lines are unshielded and will act as antennas for the signals they carry, and have the potential to interfere with shortwave radio communications.

In this course, we will look at the different technologies used to deliver broadband to the end use, how BPL systems are actually designed and operated, the business model for BPL, and the regulatory hurdles that BPL most overcome to viable. Let's start with a look at the current status of broadband delivery in the U.S. today.

Chapter 1
Current Status of Broadband Delivery

Broadband access and services are delivered using a variety of technologies, network architectures and transmission methods. The most significant broadband technologies include:

- Digital Subscriber Line (DSL)
- Fiber Technologies
- Coaxial Cable
- Wireless
- BPL (Broadband Over Power Lines)

The use of fast Internet connections has grown rapidly over the last few years. Currently, Coaxial Cable (Cable Modems) and Asymmetric Digital Subscriber Line (ADSL) dominate the industry. Table 1 shows a comparison of the various access technology options.

Table 1
Access Technology Options

Technology	Max Speeds	Remarks
Satellite	500 Kbps	Requires clear view to the south Weather can affect reception
BPL	5 Mbps	Same speed for Upload/Download Number of users affect speed
DSL	8 Mbps	Limited to within 18,000 ft of DSL central station equipment
Coaxial Cable	30 Mbps	Number of users affect speed
Fiber Optic Cable	1 Gbps	High costs to deploy

The following is a detailed description of each of the above referenced access technologies.

Digital Subscriber Line (DSL)

DSL is a high-speed connection to Internet that uses the same wires as a regular telephone line. A standard telephone installation in the United States consists of a pair of copper wires. This pair of copper wires has sufficient bandwidth for carrying both data and voice. Voice signals use only a fraction of the available capacity on the wires. DSL exploits this remaining capacity to carry information on the wire without affecting the line's ability to carry voice conversations.

Standard phone service limits the frequencies that the switches, telephones and other equipment can carry. Human voices, speaking in normal conversational tones, can be carried in a frequency range of 400 to 3,400 Hertz. In most cases, the wires themselves have the potential to handle frequencies of up to several-million Hertz. Modern equipment that sends digital data can safely use much more of the telephone line's capacity, and DSL does just that.

Advantages of DSL

- Simultaneous Use - Phone line can be used for voice calls and the Internet connection at the same time.
- A much higher speed when compared to regular modem (up to 8 Mbps vs. 56 Kbps).
- Does not necessarily require new wiring, the existing phone line can be used.
- Providers generally include modem as part of the installation.

Limitations of DSL

- The quality of connection depends upon the proximity to the provider's central office, closer the better.
- Receiving data is faster than sending data over the internet.
- DSL is not available everywhere.

There are several variations of DSL technology. Often the term "xDSL", where "x" is a variable, is used to discuss DSL in general. Listed below are descriptions of eight different versions of DSL.

1. Asymmetric DSL (ADSL)

It is called "asymmetric" because the download speed is greater than the upload speed. ADSL works this way because most Internet users look at, or download, much more information than they send, or upload.

2. High bit-rate DSL (HDSL)
Providing transfer rates comparable to a T1 line HDSL receives and sends data at the same speed, but it requires two lines that are separate from a normal phone line.

3. ISDN DSL (ISDL)
Geared primarily toward existing users of Integrated Services Digital Network (ISDN), ISDL is slower than most other forms of DSL, operating at fixed rate of 144 Kbps in both directions. The advantage for ISDL customers is that they can use their existing equipment, but the actual speed gain is typically only 16 Kbps (ISDN runs at 128 Kbps).

4. Multi-Rate Symmetric DSL (MSDSL)
This is Symmetric DSL that is capable of more than one transfer rate. The transfer rate is set by the service provider, typically based on the service (price) level.

5. Rate Adaptive DSL (RADSL)
This is a popular variation of ADSL that allows the modem to adjust the speed of the connection depending on the length and quality of the line.

6. Symmetric DSL (SDSL)
Like HDSL, this version receives and sends data at the same speed. While SDSL also requires a separate line from the phone, it uses only a single line instead of the two used by HDSL.

7. Very high bit-rate DSL (VDSL)
An extremely fast connection, VDSL is asymmetric, but only works over a short distance using standard copper phone wiring.

8. Voice-over DSL (VoDSL)
A type of IP Telephony, VoDSL allows multiple phone lines to be combined into a single phone line that also includes data-transmission capabilities.

Table 2 is a summary of the DSL variations and how they compare.

Table 2
DSL Technologies Comparison

DSL Type	Sending Speed	Receiving Speed	Effective Distance	Lines Required
ADSL	800 Kbps	8 Mbps	18,000 ft	1

HDSL	1.54 Mbps	1.54 Mbps	12,000 ft	2
IDSL	144 Kbps	144 Kbps	35,000 ft	1
MS DSL	2 Mbps	2 Mbps	29,000 ft	1
RA DSL	1 Mbps	7 Mbps	18,000 ft	1
SDSL	2.3 Mbps	2.3 Mbps	22,000 ft	1
VDSL	16 Mbps	52 Mbps	4,000 ft	1

Most homes and small business users are connected to an *asymmetric DSL* (ADSL) line. ADSL divides up the available frequencies in a line on the assumption that most Internet users download, much more information than they send, or upload. Under this assumption, if the connection speed from the Internet to the user is three to four times faster than the connection from the user back to the Internet, then the user will see the most benefit.

Precisely how much benefit a user will see depends on how far the user is from the central office of the company providing the ADSL service. ADSL is a distance-sensitive technology: As the connection's length increases, the signal quality decreases and the connection speed goes down. The limit for ADSL service is 18,000 feet, though for speed and quality of service many ADSL providers place a lower limit on the distances for the service. At the extremes of the distance limits, ADSL customers may see speeds far below the promised maximums, while customers nearer the central office have faster connections.

ADSL technology can provide maximum downstream (Internet to customer) speeds of up to 8 megabits per second (Mbps) at a distance of about 6,000 feet, and upstream speeds of up to 640 kilobits per second (Kbps). In practice, the best speeds widely offered today are 1.5 Mbps downstream, with upstream speeds varying between 64 and 640 Kbps.

Distance is a limitation for DSL but not for voice telephone calls. This is because the voice signals are amplified with *loading coils*. These loading coils are incompatible with ADSL signals, so a voice coil in the loop between a telephone and the telephone company's central office will disqualify a user from receiving ADSL. Other factors that might disqualify a user from receiving ADSL include:

- Bridge taps - These are extensions, between the user and the central office, that extend service to other customers. While the users would not notice these bridge taps in normal phone service, they may take the total length of the circuit beyond the distance limits of the service provider.

- Fiber-optic cables - ADSL signals cannot pass through the conversion from analog to digital and back to analog that occurs if a portion of a telephone circuit comes through fiber-optic cables.

ADSL uses two pieces of equipment, one on the customer end and one at the provider end:

1. At the customer's location, there is a DSL transceiver, which may also provide other services. Most residential customers call their DSL transceiver a DSL modem. However the correct term is an "ATU-R", which stands for *ADSL Transceiver Unit - Remote*. Regardless of what it is called, the transceiver is the point where data from the user's computer or network is connected to the DSL line. The transceiver can connect to a customer's equipment in several ways, though most residential installations use Universal Serial Bus (USB) or 10BaseT Ethernet connections. Most of the ADSL transceivers are simply transceivers, but the devices may combine network routers, network switches or other networking equipment in the same box.

2. The DSL service provider has a DSL Access Multiplexer (DSLAM) to receive customer connections. The DSLAM at the access provider is the equipment that enables DSL. A DSLAM takes connections from many customers and aggregates them onto a single, high-capacity connection to the Internet. DSLAMs are generally flexible and able to support multiple types of DSL, as well as provide additional functions such as routing and dynamic IP address assignment for customers. VDSL is seen by many as the next step in providing a complete home communications/ entertainment package.

VDSL operates over the copper wires in much the same way that ADSL does, but there are a couple of distinctions. VDSL can achieve incredible speeds, as high as 52 Mbps downstream and 16 Mbps upstream. That is much faster than ADSL, which provides up to 8 Mbps downstream and 800 Kbps upstream. However, VDSL's is distance sensitive. It can only operate over the copper line for a short distance, about 4,000 feet.

Compared to a maximum speed of 8 Mbps for ADSL or cable modem, it is clear that the move from current broadband technology to VDSL could be as significant as the migration from a 56K modem to broadband. However, the key to VDSL is that the telephone companies are replacing many of their main feeds with fiber-optic cable. Some phone companies are planning *Fiber to the Curb* (FTTC), which means that they will replace all existing copper lines right up to the point where a phone line branches off to a house. Most companies expect to implement *Fiber to the Neighborhood* (FTTN). Instead of installing fiber-optic cable along each street, FTTN has fiber going to the main junction box for a particular neighborhood.

By placing a VDSL transceiver in a home and a VDSL gateway in the junction box, the distance limitation is overcome. The gateway takes care of the analog-digital-analog conversion problem that disables ADSL over fiber-optic lines. It converts the data received from the transceiver into pulses of light that can be transmitted over the fiber-optic system to the central office, where the data is routed to the appropriate network to reach its final destination. When data is sent back to the computer, the VDSL gateway converts the signal from the fiber-optic cable and sends it to the transceiver.

Coaxial Cable

Cable modems allow subscribers to access high-speed data services over cable systems that are generally designed with *hybrid fiber-coaxial* (HFC) architecture. Cable modem service is primarily residential, but may also include some small business service.

Cable modems compete with technologies like Asymmetrical Digital Subscriber Lines (ADSL). Following is a look at how a cable modem works and how cable television channels and web sites can flow over a single coaxial cable.

In a cable TV system, signals from the various channels are each given a 6-MHz slice of the cable's available bandwidth and then sent down the cable to the house. The coaxial cable used to carry cable television can carry hundreds of megahertz of signals and therefore, a large number of channels. In some systems, coaxial cable is the only medium used for distributing signals. In other systems, fiber-optic cable goes from the cable company to different neighborhoods or areas. Then the fiber is terminated and the signals move onto coaxial cable for distribution to individual houses.

When a cable company offers Internet access over the cable, Internet information can use the same cables because the cable modem system puts downstream data—data sent from the Internet to an individual computer—into a 6-MHz channel. On the cable, the data looks just like a TV channel. So Internet downstream data takes up the same amount of cable space as any single channel of programming. Upstream data—information sent from an individual back to the Internet—requires even less of the cable's bandwidth, just 2 MHz, since the assumption is that most people download far more information than they upload.

Putting both upstream and downstream data on the cable television system requires two types of equipment: a Cable Modem on the customer end and a *Cable Modem Termination System* (CMTS) at the cable provider's end. Between these two types of equipment, all the computer networking, security and management of Internet access over cable television is put into place.

The first users to connect to the Internet through a particular cable channel have virtually the entire bandwidth of the channel available for their own use. The disadvantage of coaxial cable however, is as new users, especially heavy-access users, are connected to the channel all users will have to share bandwidth, and may see performance degrade as a result. It is possible that, in times of heavy usage with many connected users, performance will be far below the theoretical maximums. The cable company can resolve this particular performance issue by adding a new channel and splitting the base of users.

Another benefit of the cable modem for Internet access is that, unlike ADSL, its performance does not depend on distance from the central cable office. A digital CATV system is designed to provide digital signals at a particular quality to customer households. On the upstream side, the burst modulator in cable modems is programmed with the distance from the head-end, and provides the proper signal strength for accurate transmission.

Cable industry has extended the broadband services offering to over 90 percent of homes passed by cable systems. The cable industry expects that industry-wide facilities upgrades enabling the provision of broadband Internet access to residential customers will be completed in the near future.

Fiber Technologies

In recent years, carriers have begun constructing entirely fiber optic cable transmission facilities that run from a distribution frame in an incumbent local exchange carrier's (ILEC's) central office to the loop demarcation point at an end-user customer premise. These loops are referred to as *fiber-to-the-home* (FTTH) loops. FTTH technology offers substantially more capacity than any copper-based technology. One example is a company that has a FTTH system today using commercially available equipment that delivers transmission speeds up to 500 Mbps shared over a maximum of 16 subscribers. This system can also provide up to 500 Mbps symmetrically to one subscriber if desired. The speed an actual user will experience depends upon the time of day and the number of users online. A typical FTTH system can deliver up to 870 MHz of cable television video services or IP video services along with multiple telephone lines and current and next-generation data services at speeds in excess of 100 Mbps.

There are three basic types of architectures being used to provide FTTH. The most common architecture used is *Passive Optical Network* (PON) technology. This technology allows multiple homes to share a passive fiber network. In this type of network, the plant between the customer premises and the head-end at the central office consists entirely of passive components – no electronics are needed in the field. The other architectures being used are *Home Run Fiber* or

Point-to-Point Fiber, in which subscribers have a dedicated fiber strand, and active or powered nodes are used to manage signal distribution, and hybrid PONs, which are a combination of home run and PON architecture.

Although FTTH technology is still in its infancy, the deployment of FTTH is growing significantly. Also, the equipment costs for FTTH have decreased significantly. In addition to FTTH technologies, some carriers are constructing *fiber-to-the-curb* (FTTC) facilities that do not run all the way to the home, but run to a pedestal located within 500 feet of the subscriber premises. Copper lines are then used for the connection between the pedestal and the network interface device at the customer's premises. Because of the limited use of copper, FTTC technologies permit carriers to provide high-speed data in addition to high definition video services.

Wireless

Wireless broadband alternatives include unlicensed wireless such as WiFi and WiMax, Fixed Wireless, such as MMDS and LMDS, and Satellite delivery systems.

Unlicensed Wireless

Since the FCC first allocated spectrum in the 902-928 MHz band for use on an unlicensed basis there has been an increasingly rapid expansion of products and markets in bands designated for unlicensed use. This *Industrial, Scientific, and Medical* (ISM) band was the first to experience the large-scale introduction of devices such as cordless phones, security alarms, wireless bar code readers, and data collection systems. A number of original equipment manufacturers continue to provide equipment for point-to-point and point-to-multipoint systems for such applications as Supervisory Control and Data Acquisition (SCADA). In addition, there are several providers of wireless local area network equipment in this band.

Wi-Fi, short for *Wireless Fidelity*, is a term that is used generically to refer to any product or service using the 802.11 series standards developed by the Institute of Electrical and Electronics Engineers (IEEE) for wireless local area network connections. Wi-Fi networks operate on an unlicensed basis in the 2.4 and 5 GHz radio bands and provide multiple data rates up to a maximum of 74 Mbps. The bandwidth is shared among multiple users. Wi-Fi enabled wireless devices, such as laptop computers and smart phones, can send and receive data from any location within signal reach of a Wi-Fi equipped base station or access point (AP). Typically, mobile devices must be within approximately 300 feet of a base station.

The Wi-Fi technology features a creation of a "wireless cloud" that covers a hot-spot area. The specific dimensions of the coverage area vary based on environmental and power specifications of the equipment in use. Typically, coverage radius is in the range of 300-500 feet.

Environmental conditions, like weather and line of site, can affect the ability to reach target customers.

With the expansion of Wi-Fi access to the Internet there has been a rapid growth of hot-spots. Networks of hot-spots consisting of many access points have been constructed to cover larger areas such as airports.

The IEEE 802.11 wireless LAN standards describe five radio link interfaces that operate in the 2.4 GHz or 5 GHz unlicensed radio bands. These are summarized in Table 3.

Table 3
IEEE 802.11 WLAN Radio Link Interfaces and Highlights

Standard	Max Bit Rate	Typical Rates	Frequency	Remarks
802.11	2Mbps	1 Mbps	2.4 GHz	-
802.11a	54 Mbps	23 Mbps	5 GHz	Short range Not compatible with 802.11b Doesn't penetrate walls well.
802.11b	11 Mbps	4.5 Mbps	2.4 GHz	-
802.11g	54 Mbps	19 Mbps	2.4 GHz	Compatible with 802.11b Strong signal delivery
802.11n	300 Mbps	74 Mbps	2.4/5.0 GHz	-

Wireless Local Area Networks (LANs) based on the IEEE 802.11 or Wi-Fi standards have been quite successful, and therefore the focus in wireless is moving towards the wide area. While WiFi dominates in the local area, the wide area market is still very much open.

The cellular carriers got into this market first with their 2.5G/3G data services, but they were positioned to offer essentially add-on to voice service. The real competition to cellular data services may come from emerging data-oriented technology, WiMax.

Worldwide Interoperability for Microwave Access, or WiMax, refers to any broadband wireless access network based on the IEEE 802.16 standards.

WiMax includes fixed systems employing a point-to-multipoint architecture operating between 2 GHz and 66 GHz. WiMax based *broadband wireless access* (BWA) or, also known as wireless DSL, will offer data rates between 512 Kbps and 1 Mbps. The key will be to deliver low-cost, indoor, user installable premises devices that will not have to be aligned with the base station i.e., the antenna in the premises equipment would be integrated with the radio modem.

WiMax is designed to deliver a metro area broadband wireless access (BWA) service. The idea behind BWA is to provide a fixed location wireless Internet access service to compete with cable modems and DSL. WiMax systems could support users at ranges up to 30 miles and is intended as the basis of a carrier service.

The WiMax standards include a much wider range of potential implementation to address the requirements of carriers around the world. The original version of the 802.16 standard, when released addressed systems operating in the 10 GHz to 66 GHz frequency band. Such high frequency systems require line-of-sight (LOS) to the base station, which increases cost and limits the customer base. Also, in LOS systems, customer antennas must be realigned when a new cell is added to the network. Since the initial release, the 802.16a standard has changed the playing field. The standard 802.16a describes systems operating between 2 GHz and 11 GHz. These lower frequency bands support non-line-of-sight (NLOS), thereby eliminating the need to align the customer unit with the base station. Table 4 presents a summary of WiMax (802.16) radio links.

Table 4
Summary of WiMax (802.16) Radio Links

Standard	Spectrum	Configuration Line of Sight	Bit Rate (Mbps)	Mobility	Channel Bandwidth (MHz)	Cell Radius (Miles)
802.16	10-66 GHz	Yes	32-134	Fixed	20, 25, 28	1-3
802.16a	2 – 11 GHz	No	74	Fixed	1.25 – 20 Selectable	3 - 5
802.16e	< 6 GHz	No	< 15	< 75 MPH	1.25-20 With sub-channels	1 - 3

Wi-Fi implementations use unlicensed frequency bands. WiMax, on the other hand can operate in either licensed or unlicensed spectrum. Within 802.16a's frequency range (2-11 GHz), there are four bands that are especially attractive:

- Licensed 2.5 GHz MMDS: The FCC has allocated 200 MHz of licensed radio spectrum between 2.5 – 2.7 GHz for Multichannel Multipoint Distribution Service (MMDS).

- Licensed 3.5 GHz Band: A band of licensed spectrum approximately equal to MMDS has been allocated in the 3.4 to 3.7 GHz range in most of the world.

- Unlicensed 3.5 GHz Band: The FCC has opened an additional 50 MHz of unlicensed spectrum in the 3.65 to 3.7 GHz range for fixed location wireless services.

- Unlicensed 5 GHz U-NII Band: In the U.S., 555 MHz of unlicensed frequency has been allocated in the 5.15 to 5.35 GHz and 5.47 to 5.825 GHz bands. This spectrum is called the *Unlicensed National Information Infrastructure* (U-NII) band, the same band used for 802.11a wireless LANs.

Wi-Fi and WiMax represent wireless applications from two completely different perspectives. Wi-Fi is a local network technology designed to add mobility to private wired LANs. WiMax, on the other hand, is designed to deliver a metro area broadband wireless access (BWA) service.

The idea behind BWA is to provide a fixed location wireless Internet access service to compete with cable modems and DSL. While Wi-Fi supports transmission ranges up to a few hundred feet, WiMax systems could support users at ranges up to 30 miles. While Wi-Fi is targeted at the end-user, WiMax is intended as the basis of a carrier service. Besides the difference in transmission range, there are a number of improvements in the radio link technology that separate WiMax from Wi-Fi. Table 5 presents a comparison of Wi-Fi and WiMax Technologies.

Table 5

A comparison of WiMax and Wi-Fi

	Wi-Fi (802.11a)	**Wi-Fi (802.11b)**	**Wi-Fi (802.11g)**	**Wi-Fi (802.11n)**	**WiMaz (802.16a)**
Primay Application	Wireless LAN	Wireless LAN	Wireless LAN	Wireless LAN	Broadband Wireless
Frequency	5 GHz U-NII	2.4 GHz U-NII	2.4 GHz U-NII	2.4 – 5.0 GHz U-NII	2 GHz (licensed) 11 GHz (un-licensed)
Bandwidth	20 MHz	25 MHz	20 MHz	20/40 MHz	1.25 – 20 MHz
Duplex	Half	Half	Half	Half	Full
Technology	OFDM	Direct	OFDM	OFDM	OFDM*

	(64-channels)	Sequence Spread Spectrum	(64-channels)		(256-channels)
Mobility	In Development	In Development	In Development	In Development	Mobile WiMax

Fixed Wireless Technologies

Point-to-point microwave connections have a long history in the backhaul networks of phone companies, cable TV companies, utilities and government agencies. In recent years, technology has advanced to enable higher frequencies and smaller antennas. This has resulted in lower cost systems that could be sold by carriers for the last mile of communications.

Multi-channel multipoint distribution service (MMDS) is located at 2.5GHz and was initially used to distribute cable television service. Now MMDS is being developed for residential Internet service.

MMDS wireless technology can be deployed to offer "two-way" service at throughputs ranging from 64 kbps to 10Mbps. However, MMDS systems require line of sight between transmitter and receiver. The lower MMDS frequencies (2 GHz) do not attenuate very quickly and services can be provided at up to 30 miles from the hub, equivalent to coverage of approximately 2,800 square miles. This is one of the largest coverage areas of any point-to-multipoint communications system available today.

Local multipoint distribution service (LMDS) is located in the bands of 27.5GHz to 28.35 GHz, 29.1GHz to 29.25 GHz and 31GHz to 31.3 GHz and is being used for point-to-multipoint applications similar to the 39GHz band - Internet access and telephony. LMDS, though, only has a 3-mile coverage radius and uses TDMA (Time-Division Multiple Access) so that multiple customers can share the same radio channel.

The technology uses a cellular like network architecture of microwave radios placed at the client's location and at the company's base station to deliver fixed services, mainly telephony, video and Internet access. The use of time-division multiple access (TDMA) and frequency-division multiple access (FDMA) technologies allows multiple customers within a 3-5 mile coverage radius to share the same radio channel. Customers can receive data rates between 64kbps to 155Mbps.

An LMDS system consists of four parts:

1. The *network operations center* (NOC) houses the *network management system* (NMS) equipment that manages large regions of the customer network.

2. A fiber-based infrastructure connects separate NOCs.
3. The base station, usually located on a cellular tower, is where the conversion from fiber infrastructure to wireless infrastructure occurs.
4. The customer premises equipment (CPE) typically includes microwave equipment mounted on the outside of a consumer's home or business as well as equipment located within the building, providing modulation, demodulation, control, and interface functionality.

Advantages of LMDS include:

- Low entry and deployment costs - Due to the fact that a large part of a wireless network's cost is not incurred until the CPE is installed, the operator is able to stage capital expenditures gradually with new customer acquisition.
- Speed of deployment - A fiber-less network requires no only a radio at the customer's location and another one on a tower in a central location. This enables a quicker deployment schedule than most broadband services.
- Demand-based build out - LMDS uses a scalable architecture combined with industry standards to ensure service can be expanded as customer demand increases.
- Variable component cost - Most wireline systems require a large capital investment for the infrastructure component. LMDS systems shift the cost to the CPE, which means the operator only spends money when a revenue-paying customer signs on.

Limitations of LMDS:

- The system requires line-of-site (LOS) between the CPE and base station hub. This could require the use of repeaters to forward signals over obstacles.
- LMDS signals are affected by moisture, which could result in "rain fade," or the disruption of signals as a result of heavy rain. Increasing the power used to transmit the signals can usually alleviate problems associated with rain fade.

Satellite Delivery Systems

Satellite Internet access is ideal for rural Internet users who want broadband access. Satellite Internet does not use telephone lines or cable systems, but instead uses a satellite dish for two-way data communications. Upload speed is about one-tenth of the 500 kbps download speed.

Two-way satellite Internet consists of approximately a two-foot by three-foot dish, two modems, and coaxial cables between dish and modem. The key installation-planning requirement is a clear view to the south, since the orbiting satellites are over the equator area. And, like satellite TV, trees and heavy rains can affect reception of the Internet signals.

Two-way satellite Internet uses Internet Protocol (IP) multicasting technology, which means that a maximum of 5,000 channels of communication can simultaneously be served by a single satellite. IP multicasting sends data from one point to many points (at the same time) in a compressed format. Compression reduces the size of the data and the bandwidth. Usual dial-up land-based terrestrial systems have bandwidth limitations that prevent multicasting of this magnitude.

The satellite data downlink is just like the usual terrestrial link, except the satellite transmits the data to the user via the same dish that used to receive TV signals. An example of a satellite delivery system is shown in Figure 1. As you can see in this figure, a second satellite is used to provide the data path to the Internet.

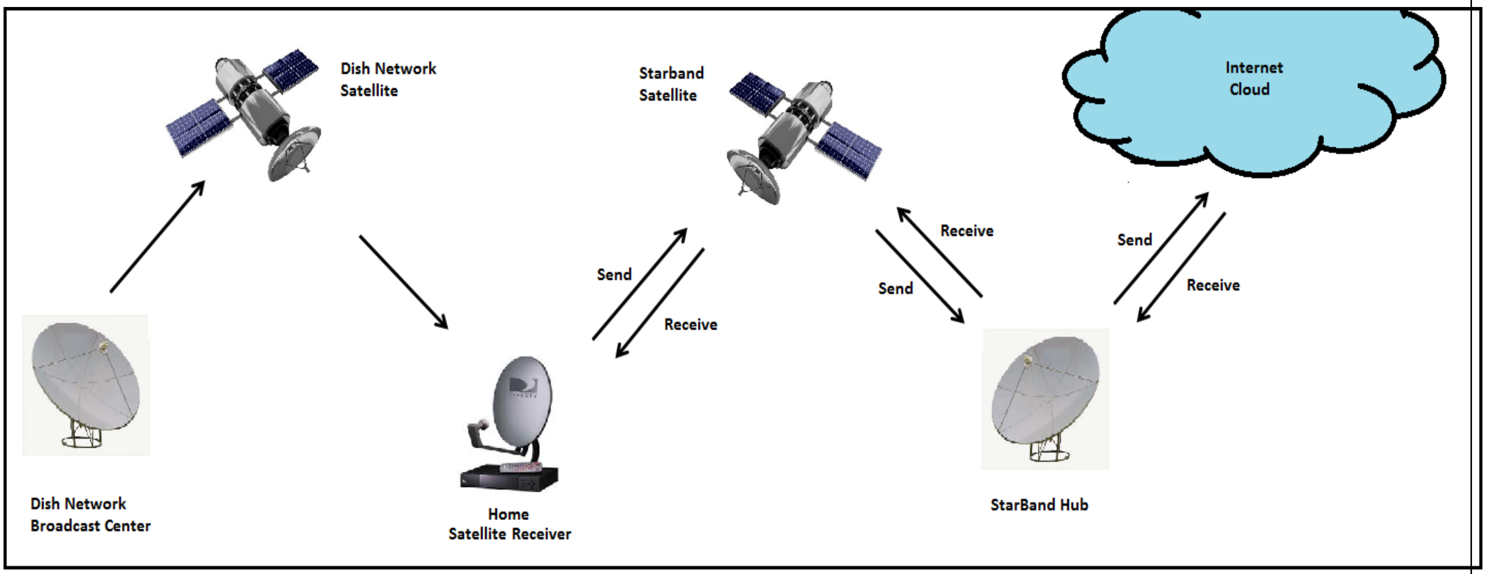

Figure 1

Chapter 2
Broadband over Powerline Technology

BPL is also sometimes called Power-line Communications or PLC and many people use the terms PLC and BPL interchangeably. The FCC has chosen to use the term "broadband over power line" for consumer applications. In order to make use of BPL the subscriber just installs a modem that plugs into an ordinary wall outlet and pays a subscription fee similar to those paid for other types of Internet service.

By combining the technological principles of radio, wireless networking, and modems, developers have created a way to send data over power lines and into homes at speeds equivalent to those of DSL and cable. By modifying the current power grids with specialized equipment, the BPL developers could partner with power companies and Internet service providers (ISPs) to bring broadband to everyone with access to electricity.

BPL technology has the ability to enable electric power lines to function as a "third wire" into the home, and create competition with the copper telephone line and cable television coaxial cable line. BPL is categorized as either Access BPL or In-Home BPL and they are defined as,

- *Access BPL* is a technology that provides broadband access over medium voltage power lines.

- *In-house BPL* is a home networking technology that uses the transmission standards developed by the HomePlug Alliance. In-house BPL products can comply relatively easily with the radiated emissions limits in the FCC's Rules, because the products connect directly with the low voltage electric lines inside a home or office.

Access BPL is used over what is called the "middle mile" and "last mile" of a telecommunications circuit. This is the portion of the network that connects end users, such as homes and business, to high-speed services and the Internet. For residential broadband service customers who get cable modem service, for example, the drop wire connecting the interface on a house to the cable company network and the wire from the interface connecting to the wall plates in the home would all be part of the last mile.

BPL modems use electronics designed to send signals over electric power lines, much like cable and DSL modems send signals over cable and telephone lines. Advances in processing power have enabled new BPL modems to overcome difficulties in sending communications signals over the electric power lines.

Overview of BPL

At a high-level, a powerline telecom network consists of three key segments, the backbone, the middle mile, and the last mile as shown below in Figure 2.

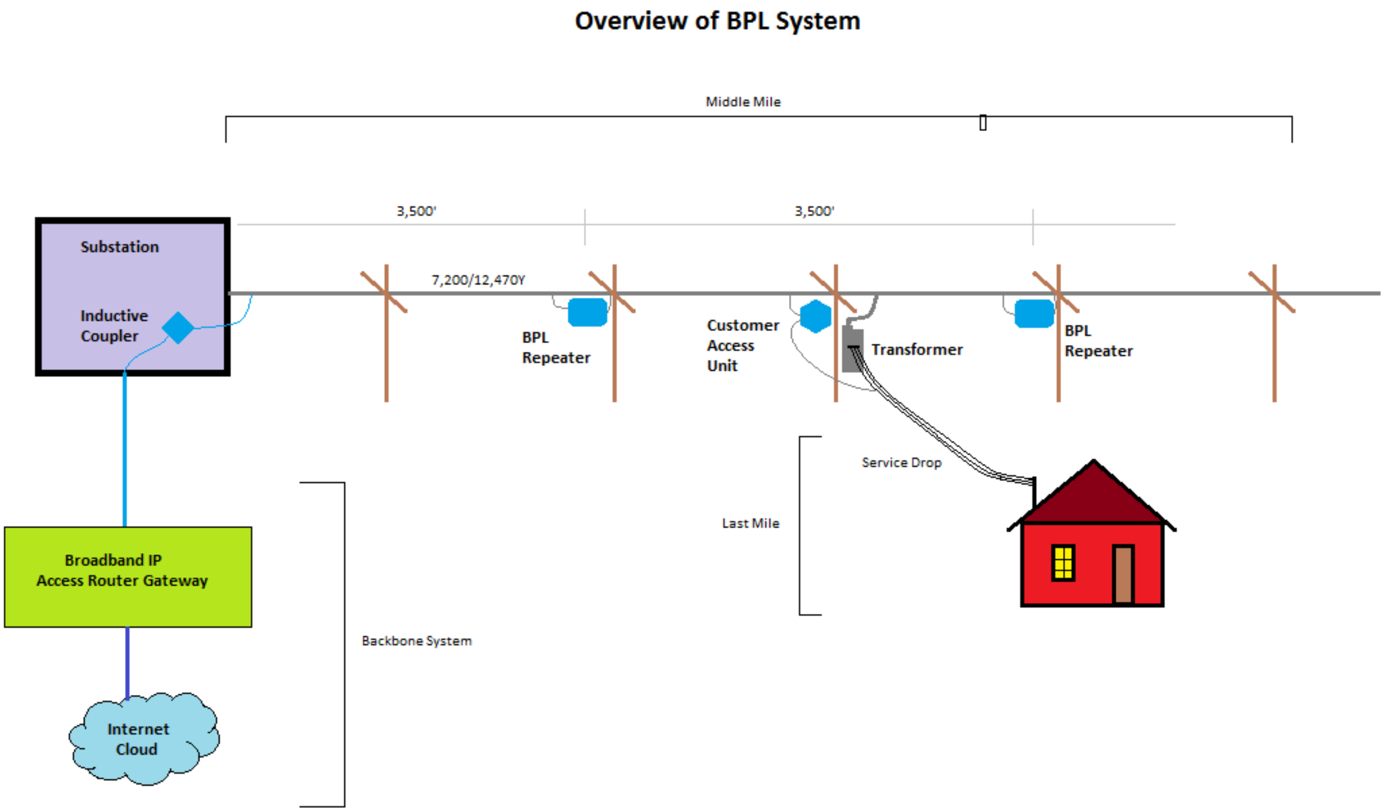

Figure 2

From the end user's perspective, BPL technology works by sending high-speed data along medium or low voltage power lines into the customer's home. The signal traverses the network over medium and low voltage lines either through the transformers or by-passes the transformer using bridges or couplers. The technology transports data, voice and video at broadband speeds to the end-user's connection. The user only needs to plug an electrical cord from the "BPL modem" into any electrical outlet then plug an Ethernet or USB cable into the Ethernet card or USB interface on their PC. The data signal can also interconnect with wireless, fiber or other media for backhaul and last mile completion. The actual hardware used for the deployment varies by manufacturer but typically feature some common characteristics.

The Internet is a huge network of networks that are connected through cables, computers, and wired and wireless devices worldwide. Typically, large Internet Service Providers (ISPs) lease fiber-optic lines from the phone company to carry the data around the Internet and eventually to another medium – such as, phone, DSL or cable line - into the homes. Trillions of bytes of data a day are transferred on fiber-optic lines because they are a stable way to transmit data without interfering with other types of transmissions.

The idea of using AC (alternating current) power to transfer data is not new. By bundling radio-frequency (RF) energy on the same line with an electric current, data can be transmitted without the need for a separate data line. Because the electric current and RF vibrate at different frequencies, the two don't interfere with each other. Electric utilities have used this technology for years to monitor the performance of power grids. There are even networking solutions available today that transfer data using the electrical wiring in a home or business. But this data is fairly simple and the transmission speed is relatively slow.

There are several different approaches to overcoming the hurdles presented when transmitting data through power lines. The power lines are just one component of electric companies' power grids. In addition to lines, power grids use generators, substations and transformers that deliver electricity from the power plant all the way to a plug in the wall. Figure 3 shows an overview of an electric power system in the United States. When power leaves the power plant, it travels to a transmission substation and is then distributed to high-voltage transmission lines. When transmitting broadband, these high-voltage lines represent the first hurdle.

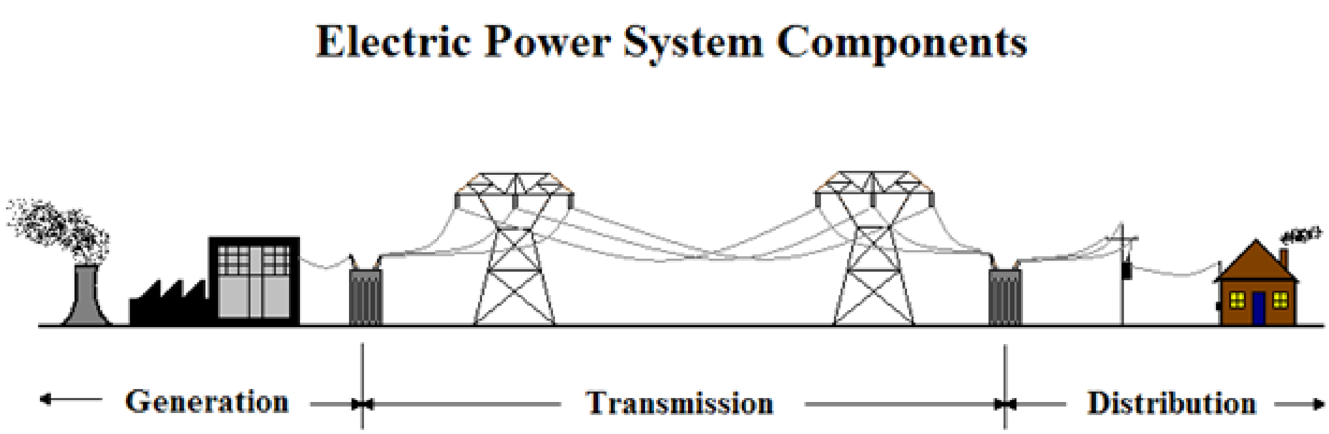

Figure 3

The transmission voltages are in the range of 100,000 to 765,000 volts. This voltage level is unsuitable for data transmission. It's too "noisy." In order for data to transmit cleanly from point to point, it must have a dedicated band of the radio spectrum at which to vibrate without interference from other sources.

Hundreds of thousands of volts of electricity don't vibrate on just one frequency. That amount of power jumps all over the spectrum. As it spikes and hums along, it creates all kinds of interference. If it spikes at a frequency that is the same as the RF used to transmit data, then it will cancel out that signal and the data transmission will be dropped or damaged en route.

BPL bypasses this problem by avoiding high-voltage power lines all together. The system drops the data off of traditional fiber-optic lines downstream, onto the much more manageable 7,200/12,470 volts of medium-voltage power lines.

Once dropped onto the medium-voltage lines, the data can only travel so far before it degrades. To counter this, devices are installed on the lines to act as repeaters. The repeaters take in the data and repeat it in a new transmission, amplifying it for the next leg of the journey.

In one model of BPL, two other devices are on the power poles to distribute Internet traffic. The *Extractor* allows the data on the line to bypass transformers, and the *Bridge*, a device that facilitates carrying the signal into the homes

The transformer's job is to reduce the 7,200 volts down to the 120/240-volt standard that makes up normal household electrical service. It is difficult for low-power data signals to pass through a transformer, so a coupler is needed to provide a data path around the transformer. With the coupler, data can move easily from the 7,200-volt line to the 120/240-volt line and into the house without any degradation.

Figure 4

The last mile is the final step that carries Internet into the subscriber's home or office.

In the various approaches to last-mile solutions for BPL, some companies carry the signal in with the electricity on the power line, while others put wireless links on the poles and send the data wirelessly into homes. A Bridge device facilitates both.

The signal is received by a powerline modem that plugs into the wall. The modem sends the signal to the in-home electrical devices.

BPL modems use silicon chipsets specially designed to handle the work load of pulling data out of an electric current. Using specially developed modulation techniques and adaptive algorithms, BPL modems are capable of handling powerline noise on a wide spectrum.

As shown in Figure 4, a BPL modem is plug-and-play and is roughly the size of a common power adapter. It plugs into a common wall socket, and an Ethernet cable running to the computer finishes the connection. Wireless versions are also available.

BPL Architecture

Access BPL equipment consists of injectors (also known as concentrators), repeaters, and extractors. BPL injectors are tied to the Internet backbone via fiber or T1 lines and interface to the medium voltage power lines feeding the BPL service area. Medium voltage power lines may be overhead on utility poles or buried underground.

Overhead wiring is attached to utility poles that are typically 35 feet above the ground. Three phase wiring generally comprises a medium voltage distribution circuit running from a substation, and these wires may be physically oriented on the utility pole in a number of configurations (e.g., horizontal, vertical, or triangular). This physical orientation may change from one pole to the next. One or more phase lines may branch out from the three phase lines to serve a number of customers. A grounded neutral conductor is generally located below the phase conductors and runs between distribution transformers that provide low voltage electric power for customer use. In theory, BPL signals may be injected onto medium voltage power lines between two phase conductors, between a phase conductor and the neutral conductor, or onto a single phase or neutral conductor.

The following is a description of some of the equipment used to provision BPL.

Inductive couplers are used to connect BPL modems to the medium voltage power lines. See Figure 5. An inductive coupler transfers the communications signal onto the power line by wrapping around the line, without directly connecting to the line. A major challenge is how to deliver the signal from the medium voltage line to the low voltage line that enters the house since the transformer that lowers the electric power from around 7,200 volts down to 120/240-volts is a potential barrier to the broadband signal.

Figure 5

A *Router* is a device that acts as an interface between two networks and provides network management functions.

A *Repeater* is a physical-layer hardware device used on a network to extend the length, topology, or interconnectivity of the physical medium beyond that imposed by a single segment. See Figure 6.

Figure 6

A *Concentrator/Injector* is a device that aggregates the end-user CPE data onto the medium voltage grid. Injectors are tied to the Internet backbone via fiber of T1 lines and interface to the medium voltage power lines feeding the BPL service area.

Figure 7

Extractors (also known at customer access units) provide the interface between the medium voltage power lines carrying BPL signals and the households within the service area. BPL extractors are usually located at each low-voltage distribution transformer feeding a group of homes. Some extractors boost BPL signal strength sufficiently to allow transmission through low-voltage transformers and others relay the BPL signal around the transformers via couplers on the proximate medium voltage and low-voltage power lines. Other kinds of extractors interface with non-BPL devices (e.g., WiFi) that extend the BPL network to the customers' premises. See Figure 7.

There are a number of types of BPL systems, using different approaches and architecture. All are Carrier-Current systems, a term used to describe systems that intentionally conduct signals over electrical wiring or power lines.

Part 15 of the FCC's Rules governs interference issues between unlicensed devices, including BPL modems, and other electronic devices. All electronic devices sold in the U.S. have to meet FCC radio frequency (RF) emissions limits. When BPL modems are installed on underground electric lines, the communications signal is shielded by the conduit and the earth and as a result is unlikely to cause interference to other communications services. The FCC is more concerned about the interference potential of BPL signals transmitted on exposed, overhead medium voltage power lines.

For long runs of power lines, signal attenuation or distortion through the power line may lead BPL service providers to employ repeaters to maintain the required BPL signal strength and fidelity. Figure 8 illustrates the basic BPL system, which can be deployed in cell-like fashion over a large area served by existing medium voltage power lines. Medium voltage lines, typically carrying 7,200 – 34,500 volts, bring power from an electrical substation to a residential neighborhood. Low voltage distribution transformers step down the line voltage to 240/120 volts for residential use.

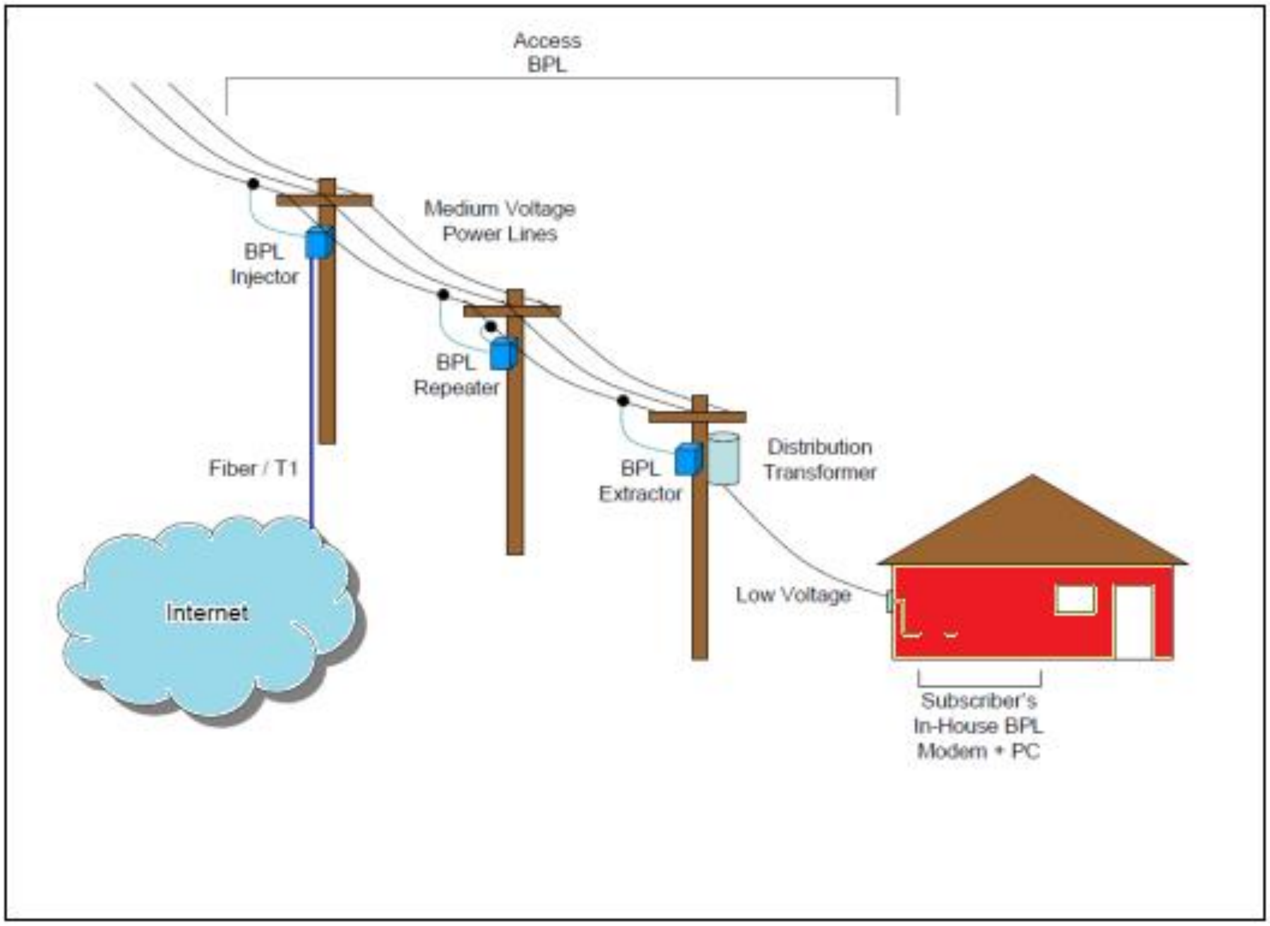

Figure 8

There are three different network architectures used by BPL equipment vendors. These architectures are described below.

Architecture 1 - OFDM

This architecture employs *Orthogonal Frequency Division Multiplexing* (OFDM) to distribute the BPL signal over a wide bandwidth using many narrow-band sub-carriers. At the BPL *injector*, data from the Internet backbone is converted into the OFDM signal format and is then coupled onto one phase of the medium voltage power line. An injector also converts BPL signals on the medium voltage power

> **Orthogonal frequency-division multiplexing** (OFDM) is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

lines to the format used at the Internet backbone connection. The two-way data are transferred to and from the low-voltage lines, each feeding a cluster of homes, using BPL *extractors* to bypass the low-voltage distribution transformers. The extractor routes data and converts between access and in-house BPL signal formats. The subscribers access this BPL signal using in-house BPL devices. To span large distances between a BPL injector and the extractors it serves, repeaters may be employed. See Figure 9.

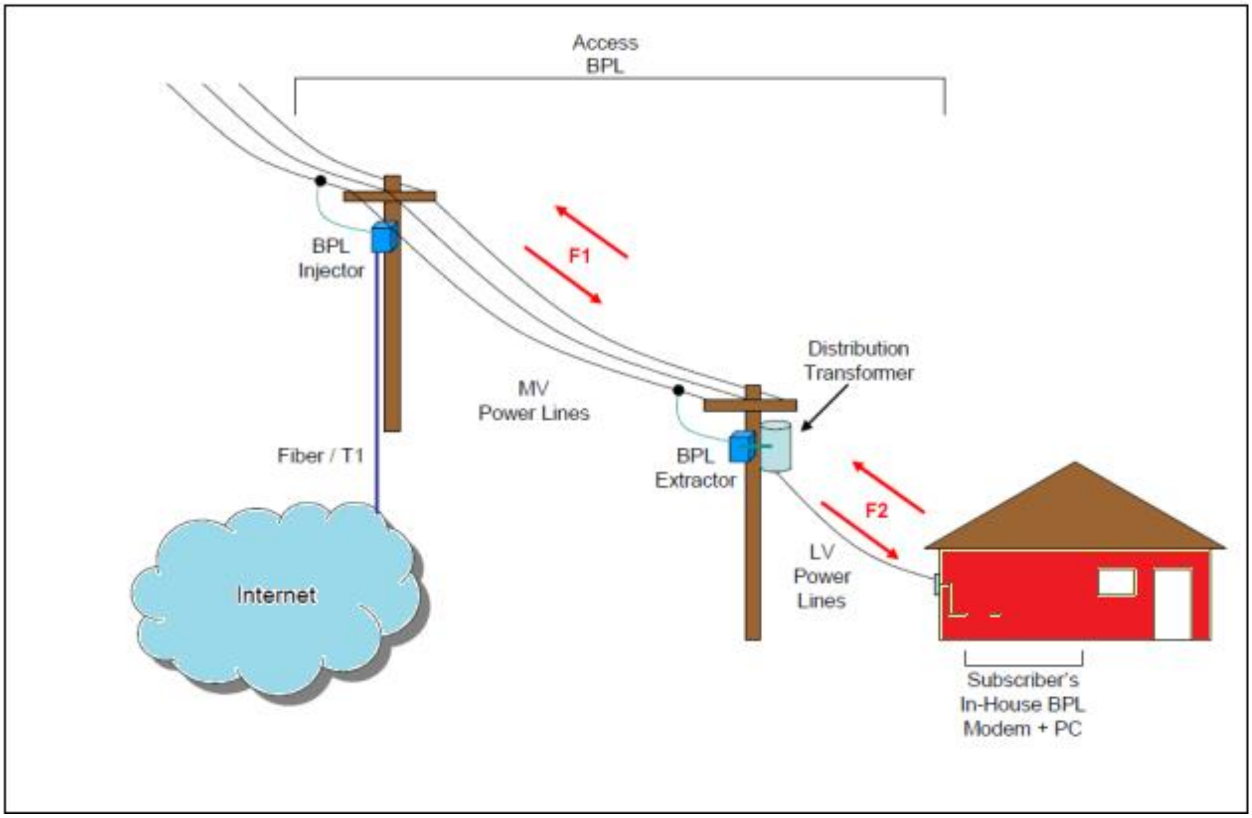

Figure 9

The injector and extractors share a common frequency band (F1) on the medium voltage power lines, different than the frequency band (F2) used on the low-voltage lines by the subscriber's in-house BPL devices. In order to minimize contention for the channel, *Carrier Sense Multiple Access* (CSMA) is used with *Collision Avoidance* (CA) extensions. This type of system is designed to accept some amount of co-channel interference between quasi-independent BPL cells without the use of isolation filters on the power lines, as all devices on the medium voltage lines operate over the same frequency band. The BPL signal may be sufficiently tolerant of co-channel BPL interference to enable implementation of two or three of these systems independently on adjacent medium voltage power lines. This system couples BPL signals into one phase line.

Architecture 2 – OFDM/WiFi

The OFDM/WiFi model uses OFDM as its modulation scheme, but differs from the first model in the way it delivers the BPL signal to the subscribers' homes. Instead of using a device that uses Low-voltage power lines, this model extracts the BPL signal from the medium voltage power line and converts it into an IEEE 802.11 WiFi signal for a wireless interface to subscribers' home computers as well as local portable computers (see Figure 10). Technologies other than WiFi might also be used to interface to subscribers' devices with the BPL network, the important point being that BPL is not used on low-voltage power lines.

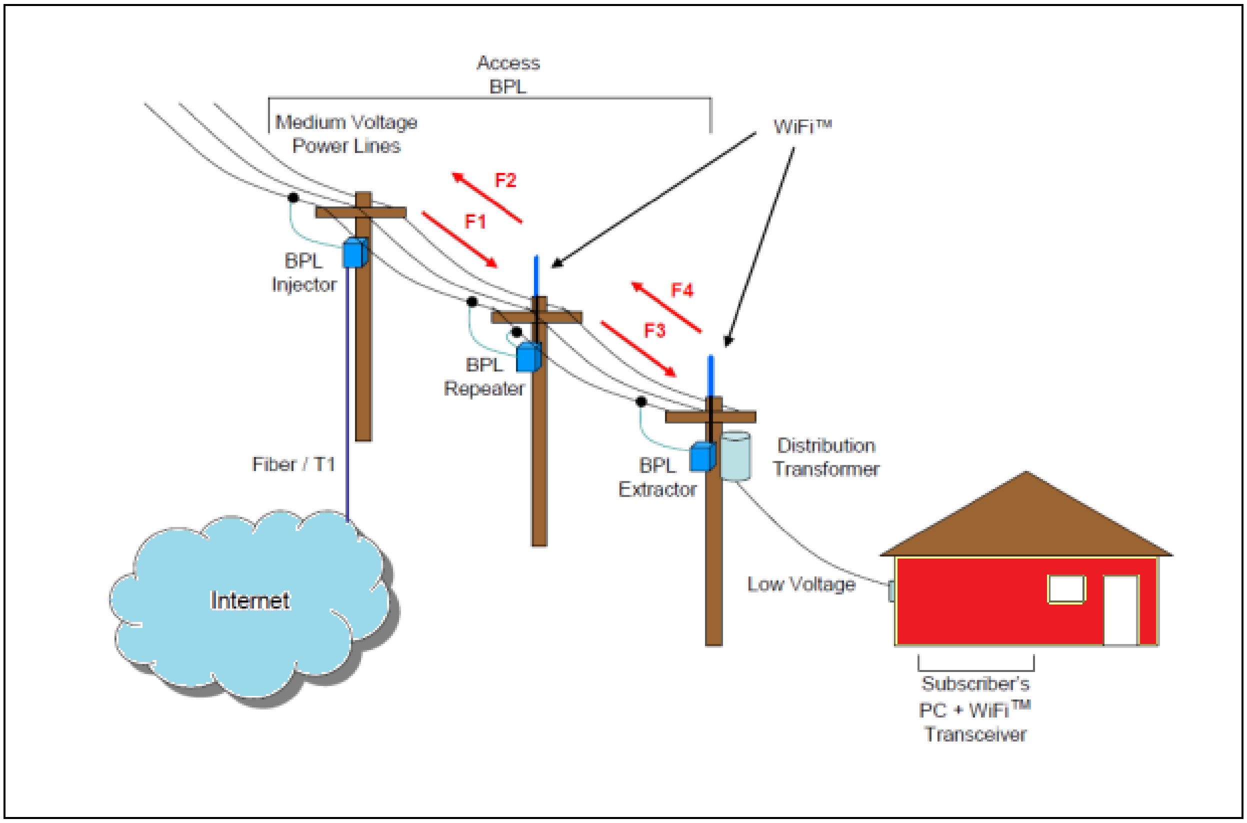

Figure 10

This system uses different radio frequency bands to separate upstream and downstream BPL signals, and to minimize co-channel interference with other nearby access BPL devices. To span large distances between a BPL injector and the extractors it serves, repeaters may be employed.

Like the injectors, BPL repeaters transmit and receive on different frequencies, and they use different frequencies from those used by the injector and other nearby repeaters. Repeaters may also provide the capabilities of an extractor when outfitted with a WiFi transceiver. This model couples BPL signals onto one phase of the medium voltage power line.

Architecture 3 - DSSS

This model uses *Direct Sequence Spread Spectrum* (DSSS) to transmit the BPL data over the medium voltage power lines. All users within a BPL cell share a common frequency band. In order to minimize contention for the channel, Carrier Sense Multiple Access (CSMA) is used.

Like the first model, this type of system is designed to accept some amount of co-channel interference between cells, as all devices operate over the same frequency band. Each cell in the system (see Figure 11) is comprised of a concentrator (injector) that provides an interface to a T1 or fiber link to the Internet backbone, a number of repeaters (extractors) to make up for signal losses in the electric power line and through the distribution transformers feeding clusters of dwellings, and customer premises BPL equipment, used to bridge between the user's computer and the electrical wiring carrying the BPL signal. Adjacent cells typically overlap and the customers' BPL terminals and repeaters are able to communicate with the concentrator that affords the best communication path at any time.

Direct-sequence spread spectrum (DSSS) is a modulation technique where the transmitted signal takes up more bandwidth than the information signal that modulates the carrier or broadcast frequency. The name 'spread spectrum' comes from the fact that the carrier signals occur over the full bandwidth (spectrum) of a device's transmitting frequency.

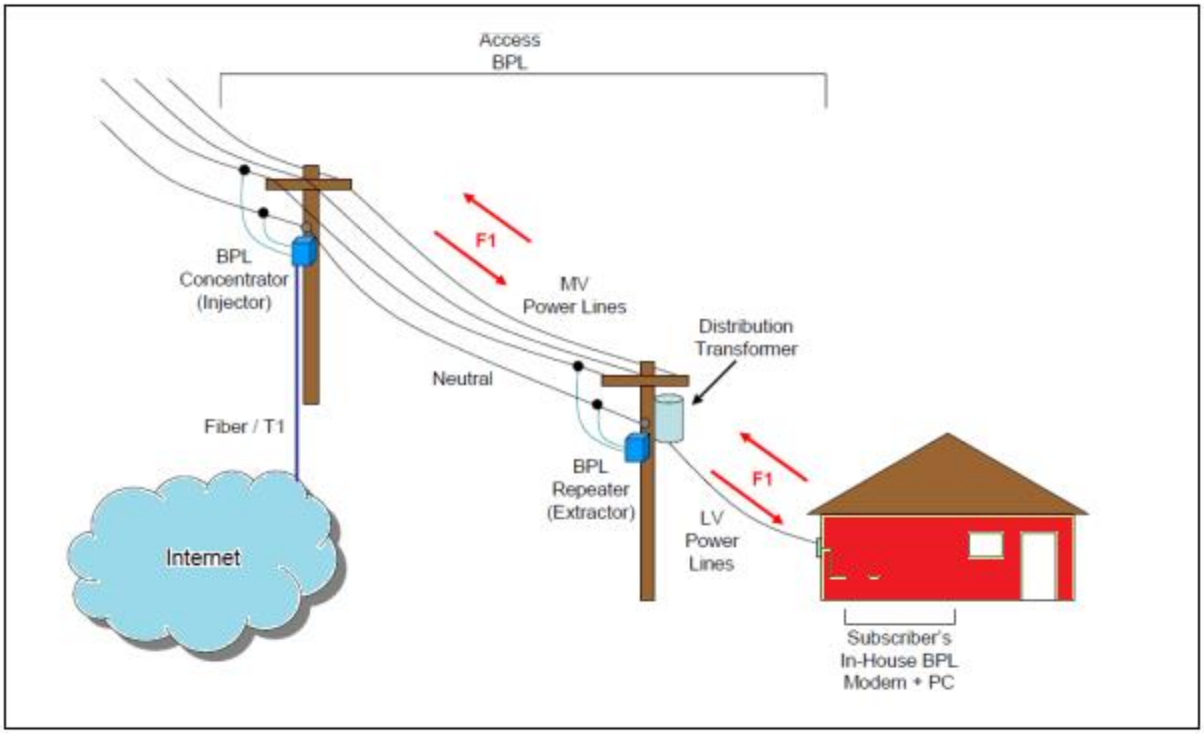

Figure 11

This system couples the BPL signal onto the power line using a pair of couplers on a phase and neutral line.

Future Systems

BPL manufacturers and service providers anticipate a wide range of applications that may be offered to their subscribers. High quality, multi-channel video, audio, voice over Internet Protocol (VoIP), and on-line gaming applications are expected to rapidly increase the demand for additional bandwidth. To support the typical subscriber at 1 Mbps, BPL systems are expected to operate at speeds of 100 Mbps or more on the medium voltage power lines in the future.

A number of BPL vendors have suggested use of frequencies up to 50 MHz At least one vendor is considering use of 4 MHz to 130 MHz, while excluding frequencies that are actively in use by licensed services. One solution put forward in an attempt to mitigate interference with licensed services is to attenuate or “notch” BPL signals in frequency bands where licensed services are in nearby use. Future BPL systems may be able to accomplish this automatically without system operator intervention. To implement this solution while simultaneously maximizing the useable bandwidth, BPL systems are expected to use new modulations that can support more subcarriers that are more finely spaced.

As data rates and bandwidth requirements grow, the BPL systems may require operation at greater transmitted power levels but not necessarily with higher power density than is used today. BPL may employ techniques to dynamically adjust the power level to maintain a minimum signal-to-noise ratio (SNR) over the entire BPL spectrum, while limiting emissions to levels compliant with FCC Part 15 rules. One proposed solution is to adjust the transmitted power to maintain a constant SNR across the BPL spectrum, with a hard limit based on Part 15 rules. The challenge will be to develop the control mechanism that can maximize transmitted power while simultaneously limiting the radiated emissions, perhaps in conjunction with frequency agility.

The judicious use of blocking filters will enable optimal segmentation of BPL networks into cells of various sizes having low conducted co-channel interference from neighboring cells. This will enable a greater level of frequency reuse than what is currently available.

Chapter 3
BPL Business Model

The current focus of most electric utilities is using BPL for an intelligent electric distribution grid. Power companies have often employed low-speed power line communication for their own internal use—to monitor and control equipment in the power grid. This could result in lower electric power costs, greater reliability and increased security.

Some electric utilities have considered entering the end-user BPL communications business either singularly or with a telecommunications provider such as an ISP, a *Competitive Local Exchange Carrier* (CLEC), or a long distance company looking for an alternative last mile path to their customers.

> A **competitive local exchange carrier** (CLEC), is a telecommunications provider company competing with other, already established carriers such as an ILEC.

Each utility must assess BPL according to its own business objectives, risk tolerance, and procedures. The factors to evaluate are cost, market size and price, differentiating features of BPL, bundled services and average revenue per user, and the utility applications. While broadband Internet access may be the primary application that is the impetus for deployment of BPL networks, the range of potential applications using such a communications network is enormous and needs to be considered as the business model is developed.

The Broadband market is generally divided into the following categories though providers may operate in one or more segments:

- The last mile: This is the portion of the network that connects end users, such as homes and business, to high-speed services and the Internet. For residential broadband service customers who get cable modem service, for example, the drop wire connecting the interface on a house to cable company's network and the wire from the interface connecting to the wall plates in the home would all be part of the last mile.

- The middle mile: This portion of the network consists of high-speed fiber backbones and other "middle-mile pipes" that connect computers to networks, connect those networks into the complex that constitutes the Internet, and deliver traffic among ISPs, content providers, online service companies, and other customers.

- Internet service providers (ISPs): These are companies that receive and translate internet-bound data and help customers obtain online information from the Internet.

- Content providers: This part of broadband consists of companies that provide information, goods, and services available to consumers through the Internet.

These characteristics and distinctions are based on network functionality and the fact that each of these categories has its own economic properties with distinct regulatory issues. Currently there is very little competition in the provision of middle-mile services, which means existing providers can discriminate against their customers. Content providers, on the other hand, raise competitive issues in terms of their ability or willingness to engage in exclusive contracts for the carrying of their content, as well as posing challenges in the area of consumer protection and free speech.

The last mile and the middle mile are most relevant for utilities because they relate to the wires portion of the electricity network, the industry's easiest entry into the broadband industry.

A partnership between a utility and an external third party service provider offers strategic value as each player can focus on what it does best. Utilities have operated as monopolies and, while good at building infrastructure they lack experience in competitive environment. On the other hand, ISPs operate in a very competitive environment. The key success factors include effectively marketing to customers, cost effective customer acquisition and a high quality customer service.

Current broadband environment is competitive with both cable modem providers and DSL providers aggressively marketing their services and other alternate providers looking at entering the market. Customer service appears to be a key differentiator with most of the consumers. A utility partnership with an ISP or CLEC might leverage key strengths: The utility could focus on network management while the ISP could focus on marketing. The opportunity to work together could also involve shared investment.

BPL may offer a number of significant benefits in the delivery of broadband services to homes and businesses. This technology could increase the availability of broadband and improve the competitiveness of the broadband services market. Access BPL could facilitate the ubiquitous availability of broadband services and bring valuable new services to consumers, stimulate economic activity, improve national productivity, and advance economic opportunity. The very nature of BPL is expected to create the opportunity for providing new and innovative services to virtually any location with electric outlets. The National Telecommunications and Information Administration (NTIA) states that "BPL holds great promise as a new source of innovation and competition in the broadband marketplace". It believes that BPL has the potential to open new avenues of Internet access, to enable new and expanded services for utility companies, and to create a new platform for further advances in communications technology

Consumer Benefits

The supporters of BPL expect it to improve the competitiveness of the market for broadband services. It offers the long sought third wire (other two being telephone and cable) for last-mile delivery of broadband communication services to residences and small businesses. In the areas already served by other broadband providers, BPL will increase competition, which in turn will bring better service and lower prices for consumers.

BPL is likely to be slightly more expensive for the consumer than traditional services such as coaxial cable, DSL, or even wireless. However, it promises to be significantly less expensive than either satellite or FTTH systems. See the graph in Figure 12 for the expected relative cost comparisons among the different technologies.

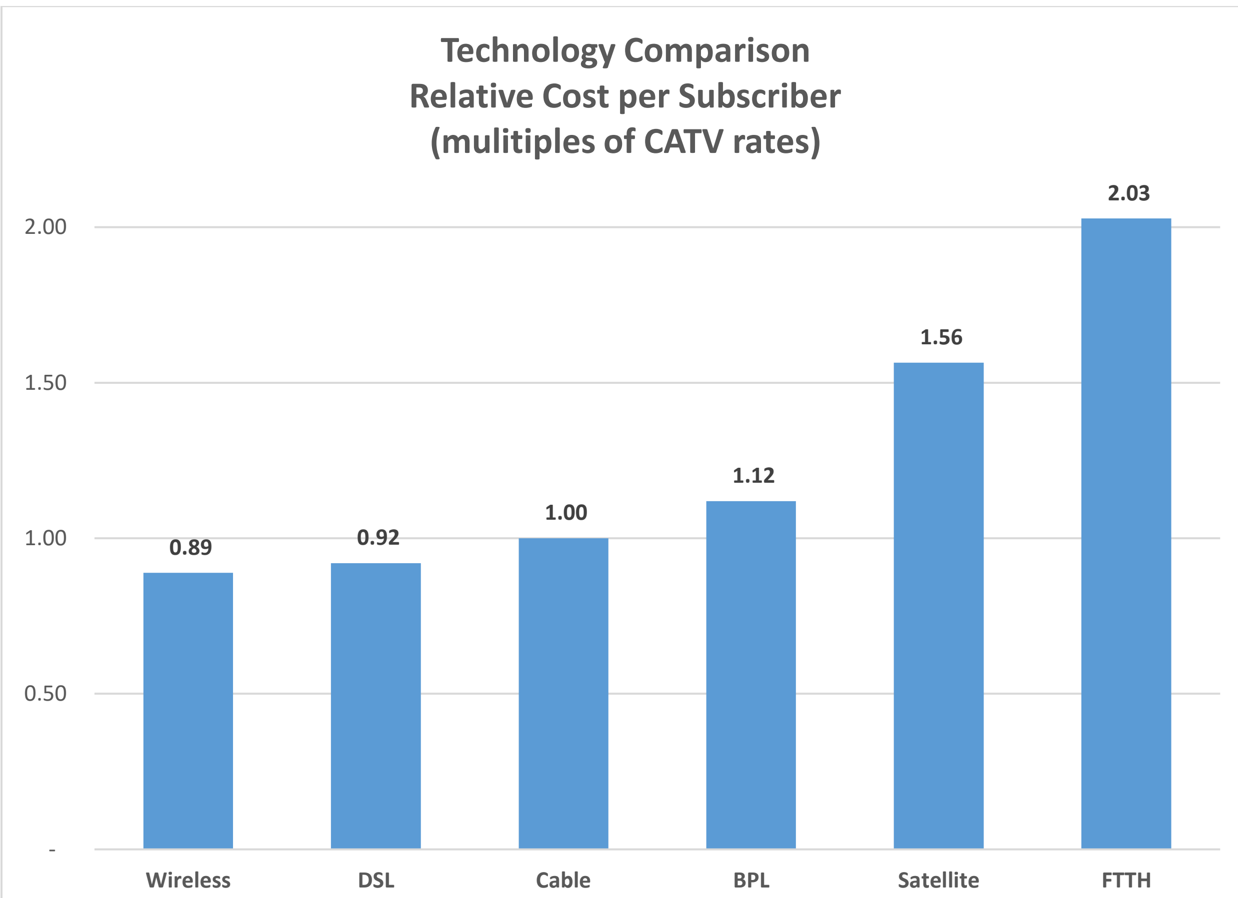

Figure 12

An interesting aspect of BPL is that every electric device is connected to the electric distribution network. Potentially, BPL could let the electronics in every electric device talk to each other. Of course, a Wi-Fi, Bluetooth or other wireless device could be placed in every appliance. But BPL may be a better solution. Those who had PC's before the Internet exploded remember the difference in functionality between a standalone PC and a networked PC. Networking every electric device together over the power lines might result in a similar growth in productivity and convenience for the home and office.

BPL Business Models

Several potential models have been proposed for BPL. Some utilities may make their lines available to a third party that would then install BPL equipment. Others may decide to offer broadband directly. Listed below are three fundamental business models available to electric utilities including: a Landlord Model, Developer Model, and the Service Provider Model.

<u>The Landlord Model</u>

The *Landlord Model* emphasizes partnering with an existing communications company which would give an electric company immediate access to operations and marketing expertise and personnel without having to invest in either the expenses or the personnel. The value brought to the table by the electric company, of course, would be its power line network.

Cautious utilities that want to avoid capital or operating exposure will look to enter into such partnership arrangements as part of a landlord strategy. The landlord business model is a very stable structure and can be risk-free if positioned correctly. This model allows for small returns for small investment and effort. The benefits of the Landlord Model for an electric utility include,

- No need to invest funds in building out the broadband network,
- The utility doesn't have to operate the BPL system, and
- Regulations can be managed to allow for value creation to be maintained by the utility without requiring that all proceeds are returned to the ratepayer base.

<u>The Developer Model</u>

The *Developer Model* involves building the infrastructure and offering wholesale access. Utilities seeking to leverage their core competencies in building and maintaining networks will look to this model.

Those electric companies that are reluctant to incur the marketing costs associated with selling retail broadband services may want to consider marketing to a smaller group of customers—traditional broadband companies. Traditional broadband companies are those that primarily or exclusively sell communications services, such as broadband. There are many companies that already have personnel experienced in the marketing and selling of broadband services but that have failed to thrive due to the high costs of building networks. In fact, many of these companies must rely on ILECs to provide broadband service to their customers.

An **incumbent local exchange carrier (ILEC),** is a local telephone company was in existence at the time of the breakup of AT&T into the Regional Bell Operating Companies (RBOCs).

BPL presents electric companies with the opportunity to sell broadband services to these companies. By upgrading their electricity networks to include broadband capabilities, electric companies could make ready-made last-mile broadband networks for competitive broadband companies that seek to eliminate their dependency on ILECs, which are their direct competitors for customers. The benefits of the Developer Model for an electric utility include,

- Regulations do not prevent opportunities to leverage the utility's position in the market,
- Internal skills are present to construct a BPL network that is economically able to compete with other players,
- Viable candidates to serve as the BPL service provider are available in the market,
- Interest or capability does not exist in running the network and the operations, and
- Attractive segments of the market exist, enabling select build opportunities.

The Service Provider Model

The Service Provider Model is one in which the utility interfaces with the customer. Aggressive utilities seeking to offer retail broadband services may consider the service provider model. The service provider business model involves the highest risk, but can feature tremendous upside.

Electric utilities are certainly poised to provide this service because they already own the poles and lines that access virtually every residential and business customer in the United States. Providing broadband service to these customers would simply require adding equipment to their wires. The feature of BPL that would make it more attractive than DSL or cable modem is that BPL customers would immediately have in-house networks without having to purchase and install additional wiring in their homes.

The challenge with providing retail service, however, is that there are marketing costs that some companies may be unwilling or unable to absorb. The cost of advertising to create market share where none exists can be overwhelming. An electric company deciding to enter this retail market would also have to hire or retrain staff with expertise in marketing broadband services. Any utility interested in pursuing the service provider model will need to address market, operational, and network build issues. The benefits of the Service Provider Model include,

- Regulations allow for joint marketing, thus enabling a superior projected market penetration performance,
- Internal skills are present to construct a BPL network and maintain it during operations,

- Skills needed to support marketing, operations, and network management are in house, and
- The market is an attractive one that offers solid promise for financial returns.

Competitors

The main competitors to BPL – or maybe we should say those that BPL will be a competitor with – include Cable TV companies, ILEC DSL services, and wireless services provided by either a CLEC or ILEC.

Cable as a competitor
Cable is a shared medium and all subscribers from the Head-End share the available bandwidth. Many cable networks have been upgraded to *Hybrid Fiber Co-axial* (HFC) networks and therefore many products and services can be bundled through cable such as video, data and voice.

As the dominant providers of broadband access, cable companies are seeking ways to solidify their position. One trend is the continued emergence of tiered service levels as a way of enticing lower potential customers while retaining margins on higher value customers. Among the offerings by cable companies are VoIP and digital cable.

Cable has extended the broadband services offering to over 90 percent of homes passed by cable systems. The cable industry expects that industry-wide facilities upgrades enabling the provision of broadband Internet access to residential customers will be completed soon.

In addition to expanding the reach of upgraded broadband facilities, cable operators have increased download transmission speeds from 200 kbps to over 30 Mbps. Cable companies have also continued to upgrade equipment used to deliver broadband services. *Data over Cable Service Interface Specification* or DOCSIS, has continued to develop the critical interface requirements for cable modems and cable modem termination systems used for high-speed data distribution and connection to the Internet.

The cable industry is also pursuing *Next Generation Network Architecture* (NGNA), which is in part a competitive response to wireline broadband providers and in part a response to Direct Broadcast satellite's (DBS) Digital Video Recorder (DVR) technology. The NGNA project seeks to define the features of a next-generation all-digital cable network, which could have broad implications for functionality and cost. The effort involves rethinking cable's basic technologies, including everything from encryption strategies to set-top boxes that can be dramatically upgraded via software uploads, to create more carriage capacity by completely migrating cable service from analog-to-digital transmission so that all services could be provided utilizing IP.

A number of cost factors effectively form the pricing floor for cable companies. These factors include:

- Programming and labor costs have been rising steadily, and in excess of inflation rates,
- Cable companies have collectively invested over $75 billion, or over $1,000 per customer in network upgrades, and
- Cable companies view satellite providers and not DSL providers as key competitors for pricing.

DSL as a Competitor

DSL technology can be provisioned on most of the existing phone networks and comes in many different versions. ADSL is the most common DSL-type currently deployed by service providers.

DSL deployments have lagged behind that of cable modem. Once projected to exceed the penetration of cable modem, DSL's market penetration today is barely one-half of its broadband counterpart. Key Issues are:

- DSL is primarily a low-margin product; providers view DSL as a mechanism to sell Value Added Service ("VAS"),
- ILECs effectively controlled the provisioning process and prevented data local exchange carriers (DLECs) from being able to effectively serve customers,
- ILECs have been relatively slow to aggressively deploy DSL for fear of cannibalizing their T1 business, and
- DSL is slow with 1.5 Mbps to 3.0 Mbps in most areas.

Wireless as a competitor

Hot spot coverage is growing dramatically and this trend is expected to continue. This continued growth affords the industry opportunities to benefit from economies of scale, as already low equipment costs will continue to push downward. While Wi-Fi application is moving forward, there are several concerns that are also being addressed:

- Convenience and simplicity vs. Network security - Radio signals typically extend beyond the physical boundaries that are part of planned signal propagation. In many instances network security breaches have occurred when users failed to implement Wired Equivalent Privacy (WEP).
- Limited market reach due to short range - A concern for developers is that customer reach may be limited to extend the business beyond a pure hot spot. However, new

technologies are expected to increase reach and offer a greater chance to develop a broadcast access market play.

- A format to establish IP roaming has not yet been established – This is essential for a viable long-term growth strategy. A pure hot spot market approach does not necessarily depend on roaming agreements to be in place; however a growth strategy necessitates roaming agreements.
- Interference issues - High degrees of deployment can cause interference in the Industrial, Scientific, and Medical ("ISM") spectrum band.

Chapter 4
Regulatory Issues

BPL technology provides the opportunity to have true competition for broadband service. Given the applications and services it can offer it is incumbent upon regulators to adopt a uniform set of rules and regulations that will facilitate the provision of BPL service in the United States while ensuring that public interest concerns are protected. In order to provide broadband access to all citizens, the FCC and the states are defining and adopting a regulatory scheme that removes unnecessary barriers to market entry and permits electric companies to be competitive in the marketplace.

Even though the Telecommunications Act of 1996 mandated that broadband service be widely available in the United States, the actual market for that service today is a duopoly—with customers in most jurisdictions connecting to the internet through either their incumbent local exchange carrier (ILEC), which provides broadband service through digital subscriber lines (DSL), or their local cable operator, which provides the service through a cable modem. Duopoly does not necessarily provide consumers the opportunity to get the best combination of rates and services, and many now are looking to electric companies as a third competitive provider of broadband.

The Federal Communications Commission (FCC) promulgated rules in 2004 that provides regulatory guidelines for the provisioning of BPL. In this ruling, the FCC has clearly established the rules and, some say, illustrates an endorsement of BPL by the FCC. The FCC and others have hailed BPL as a potential "third wire" that may help increase the availability and affordability of broadband services in a market dominated by digital subscriber line (DSL) and cable modem service. As part of the federal effort to remove barriers to BPL implementation, the FCC issued a change to Part 15 rules for measures to mitigate radio interference caused by broadband over powerline. The FCC ruling in 2004 would essentially help overcome BPL's potential to cause interference with radio and telecommunications signals.

However, a number of jurisdictional and classification issues remain open. For example, are the broadband services offered via BPL considered an information service or a telecommunications service? This has implications since telecommunications services are subject to regulations under the Telecommunications Act of 1996, most notably common carrier requirements.

Reliability and safety of the power delivery system and provision of quality service are the main concerns for state commissions. In addition, affiliate transaction policies and cross subsidization issues are major concerns. State Commissions are obligated to prevent the unfair use of an asset developed with ratepayer funds for the benefit of shareholders. They are also obligated to ensure that electric utilities do not have an unfair advantage over competitors. Thus several solutions such as creation of unregulated BPL subsidiaries or implementation of accounting rules that guard against cross subsidization may be considered.

The state regulators will also need to address rights of way, and access to poles issues. For instance, some municipalities may seek to charge fees for BPL rights of way. Pole attachment rules may also need to be addressed because of potential interference problems.

In this ruling, FCC recognized the legitimate concerns of licensed radio services, and therefore, established new technical requirements for BPL devices that require, among other things, that BPL avoids specific frequency bands and frequency exclusion zones.

The FCC explained that the rules would require the equipment to mitigate interference by either notching (reducing power) or shifting frequencies of operation, or by shutting down remotely. Many of the BPL technologies already have that capability. At the same time, the FCC will also exclude BPL from operating on certain frequencies on a local or nationwide basis in order to protect certain licensed operations that are life and safety related. The FCC also will only require limited disclosure of BPL operations for a publicly accessible database to provide notice and BPL operator contact information to licensees that experience interference. Finally, there will be new measurement guidelines that are “consistent and repeatable” and that BPL equipment authorization will be subject to a certification process rather than simple verification by the manufacturer. According to the FCC, these rules remove uncertainty and ensure licensed services are protected.

The FCC believes that the revised Part 15 rules will help promote and foster the development of the BPL technology with its associated benefits while at the same time ensure that existing licensed operations are protected from harmful interference.

Frequency Spectrum

Let’s take a quick look at where BPL operates in the frequency spectrum and where conflicts are likely to occur. A number of BPL vendors have suggested use of frequencies up to 50 MHz At least one vendor is considering use of 4 MHz to 130 MHz, while excluding frequencies that are actively in use by certain licensed services. One solution put forward in an attempt to mitigate interference with licensed services is to attenuate or “notch” BPL signals in frequency bands where licensed services are in nearby use. Future BPL systems may be able to accomplish this automatically without system operator intervention. To implement this solution while simultaneously maximizing the useable bandwidth, BPL systems are expected to use new modulations that can support more sub-carriers that are more finely spaced.

Another BPL technology utilizes the 2.4 GHz and 5.8 GHz unlicensed bands. An implementation using multiple IEEE 802.11b/g WiFi chips sets has been used to demonstrate the concept of carrying data over medium-voltage power lines at rates exceeding 200 Mbps.

Currently, the frequency band breaks down as follows,

- AM radio: 535 kHz to 1.7 MHz
- Short-wave radio: 5.9 to 26.1 MHz. This is the only part of the radio spectrum that supports long-distance, intercontinental radio communication. The short waves are used for international broadcasting, aeronautical, maritime, disaster relief, and other services including the military
- Citizens-band (CB) radio: 26.96 to 27.41 MHz
- Television stations: 54 to 88 MHz for channels 2 through 6
- VHF: The "low-band VHF" frequency range is heavily used by volunteer fire departments, police, and other first responders
- FM radio: 88 to 108 MHz
- Television stations: 174 to 220 MHz for channels 7 through 13

See Figure 13 for a graphic of this portion of the frequency spectrum.

VLF	**LF 100 KHz**	**MF 1 MHz**	**HF 10 MHz**	**VHF 100 MHz**	**UHF 3 GHz**	**SHR 10 GHz**	**EHF 100 GHz**	**IR**	**Visible**

Figure 13

Interference and Radio Static

Powerline system is a type of *carrier current* system that electric utility companies have traditionally used for protective relaying and telemetry. They operate between 10 kHz and 490 kHz, although today many utilities rely on the 1-30 MHz bandwidth for BPL transmission. A carrier current system transmits radio frequency energy to a receiver by conduction over the electric power line.

BPL operates under Part 15 of the FCC's rules for unlicensed devices, as an unintentional, carrier-current emitter. Although carrier-current devices meet radiated emissions limits, not conducted limits like other broadband technologies, the power levels typically used by BPL systems are approximately 30 to 40 dB greater than the FCC limits for other unintentional emitters. It is not surprising that BPL poses a much higher interference threat than almost all other types of unlicensed emitters of RF noise.

A **carrier-current** device is any device that intentionally conducts signals onto the ac-mains or distribution electrical wiring.

Under Part 15 of the FCC's current rules, which regulate carrier current systems and powerline carrier systems, each is subject to different emission limits. The FCC also limits the amount of conducted radio frequency (RF) energy that may be injected into a building's wiring by an RF device that receives power from the commercial power source, including carrier current systems that couple RF energy onto the AC wiring for communications purposes.

This conducted energy can cause interference to radio communications by two possible paths. First, the RF energy may be carried through electrical wiring to other devices also connected to the electrical wiring. Second, at frequencies below 30 MHz, where wavelengths exceed 10 meters, long stretches of electrical wiring can act as an antenna, permitting the RF energy to be radiated over the airwaves. Due to low propagation loss at these frequencies, such radiated energy can cause interference to other services at considerable distances.

A BPL modem is considered an unlicensed device, like a cordless phone or garage door opener. All unlicensed devices are governed by the FCC's Part 15 rules. The FCC mandates that all electronic devices sold in the United States must meet certain radio-frequency emissions limits. These limits are in place to secure against interference with important transmissions like CB communications, air-traffic control and government channels.

Cable TV operators get around the interference problem by shielding all of their cables. Coaxial cable used in cable TV operations has a braided metal shield that surrounds the signal wire. Telephone cables are also shielded. Power lines, on the other hand, have no shielding. In most cases, a power line is a bare wire, or a wire coated in plastic. The interference concern is due to the lack of shielding on electric power lines.

From a regulatory prospective,

- Limits are stricter for Class B settings (residential) than for Class A (commercial, industrial, business environment),
- Emissions above 30 MHz are under stricter control than those below 30 MHz,
- Internal use of BPL for electric utility operations are likely to involve the low end of the 1-30 MHz range, thus reducing stress on Federal emissions limits,
- The FCC seeks to promote BPL deployment while preventing harmful interference to authorized radio operators, and
- FCC is taking a cautious approach that would permit deployment under existing emission limits, but which proposes additional safeguards to mitigate interference that might occur from BPL operations.

ARRL's position on Interference

From the advent of BPL, American Radio Relay League (ARRL) has strongly expressed its' concern that Access BPL - if not appropriately restricted - will cause interference to amateur operations. ARRL states that amateurs use very sensitive receivers and high gain outdoor antennas that could be located in close proximity to electric power lines.

ARRL contends that in an Access BPL system, the power lines would act as an efficient antenna covering an entire city, causing widespread interference to amateur operations. ARRL believes that the potential interference from Access BPL would be so severe as to warrant its exclusion from all bands allocated for amateur use. BPL represents a potential for interference that is almost without precedent. The interference potential of other forms of broadband, such as fiber-to-the-home, DSL and various forms of wireless broadband is much lower than it is with BPL.

Because power lines are not designed to prevent radiation of RF energy, BPL represents a significant potential interference source for all radio services using this frequency range. Overhead electrical power lines and residential wiring act as antennas and overhead power lines radiate the broadband signals as radio signals throughout entire neighborhoods and along roadsides. According to ARRL, interference has been observed nearly one mile from the nearest access BPL source.

Since BPL has the potential to generate 10,000 times more interference than other devices, extraordinary attention must be paid to its' electromagnetic-compatibility. To avoid causing interference, BPL must not use spectrum that is in use near another system or device. In residential neighborhoods, this includes the Amateur Radio Service, the Citizens Band Radio Service (CB), the reception of international shortwave broadcast and other radio use such as government time signals (WWV), etc. For BPL devices that operate above 54 MHz, there is also the potential for interference to broadcast television to occur.

Despite its significant interference potential, BPL can be successfully implemented in ways that can avoid widespread RFI problems. This means that BPL systems and devices must have sufficient filtering to reduce BPL noise in the amateur bands to a level comparable to other devices.

Some access BPL providers have installed systems that applied *spectral masks* (notching) on all HF and VHF amateur bands. ARRL has evaluated several of these notched access BPL systems and has determined that state-of-the-art spectral notching for the amateur bands provides a good general solution that prevents most interference problems. Considerable interference has been documented in all access BPL systems that did not notch the amateur bands.

The Communications Act of 1934 and the FCC Rules require that unlicensed emitters such as BPL systems must protect licensed radio services from interference, and that they must accept any interference to their operation that is the result of normal activity by licensed radio services. However, in practice it is often difficult to resolve such interference problems in the field.

Studies by the National Telecommunications and Information Administration (NTIA) show that the probability of interference from a BPL system operating at the FCC radiated emission limit on the same frequency as a typical two-way radio station is essentially 100% for distances of 600 to 1,200 feet from the power line, depending on the frequency. This means that unless BPL manufacturers voluntarily design their systems for reduced emissions, BPL system operators will have to take expensive steps to correct interference on a case-by-case basis. That may not be possible under some circumstances unless they turn off their systems. Of course, they will strongly resist having to do so. This is why radio operators are so concerned, and why BPL customers cannot be assured of receiving reliable broadband service until notching of the amateur bands is adopted by all implementers of BPL and made part of successful regulations.

According to a NTIA report, BPL signals "unintentionally radiate" from power lines. The NTIA also said that the then-current FCC Part 15 measurement techniques may "significantly underestimate" peak BPL field strength and that "interference risks are high under existing FCC Part 15 rules." The FCC rulemaking has only partially addressed these concerns.

Although ARRL says the present FCC BPL rules have not adequately protected licensed radio services from interference, if BPL systems and their designs avoid the use of locally used spectrum, interference can be avoided. For the Amateur Radio Service - because amateur stations use sensitive receivers and efficient antennas and with few exceptions are located in residential or rural areas - this requires that permanent notches in the amateur bands be used. Many in the BPL industry recognize this important principle.

Pole Attachments

BPL presents unique issues for pole attachment regulation, including access, rates, modifications, and surveys, all of which can impact BPL operational expenses. FCC has jurisdiction over investor-owned utilities, but not municipal power systems or electric cooperatives.

Pole attachments have been an issue since before BPL technology arrived on the scene. Pursuant to the adoption of the Telecom Act, an electric utility had to provide access to its poles—if the utility used its poles for any type of communications, including its own—to any company requesting access. Under the FCC’s rules, where access is mandated, the rates, terms, and conditions of access must be uniformly applied to all telecommunications carriers and cable operators that have or seek access. Utilities may deny access for reasons related to insufficient capacity, safety, reliability and other engineering purposes

Many electric companies have avoided the administrative costs of implementing a system for managing the access and use of its poles by avoiding any kind of communications assets on its poles. They would not be able to avoid it any longer, however, if they wanted to provide BPL service. Hence, these administrative costs would have to be factored into the costs of providing broadband services, unless the FCC could be convinced to create a BPL exemption as an incentive for electric companies to develop and deploy BPL networks.

Issues outstanding as they relate to BPL are:

- Does BPL equipment represent a pole attachment?
- Open access, safety, capacity, interoperability issues
- Occupied space and imputation issues
- Cost sharing and notice issues
- Cost sharing and competitive issues
- Local zoning restrictions, franchise fees, and right of way
- Private easements – state jurisdiction

Pole attachment obligations also need to be addressed in light of interference concerns. The FCC acknowledged that this is a potential problem: “The close proximity of BPL equipment on utility poles may affect the operation of cable television service and high-speed digital transmission service, such as DSL.”

Interestingly, the regulatory paradigm for Incumbent Local Exchange Carriers (ILEC’s) and the local cable provider has differed despite the fact that the FCC has jurisdiction over both modes of providing service.

Telephone companies that provide DSL service are regulated under Title II of the Communications Act of 1934, which includes common carrier provisions and obligations that are not shared by cable operators. These provisions, adopted based on the ILECs’ historical possession of monopoly power over their respective service areas, require them to provide network access to competitors on nondiscriminatory, cost-based terms (also known as *open access*). Federal and state regulators currently face the challenge of determining how much market share an ILEC must lose before those obligations are eliminated. Many ILECs believe the requirements are no longer necessary given the number of competitors that have taken away their potential customers.

Cable modem broadband service, in contrast, is not subject to open access obligations because the FCC deemed cable to be an information service only. This classification has been challenged in court and, if overturned, could open cable companies to the same requirements now imposed on ILECs. Many believe that cable's exemption from open access obligations has been unjust because of the lack of competition in the provision of cable services - after all, many U.S. cities and towns have only one cable company - and because it has given cable companies an unfair competitive edge over ILECs.

Standards

In seeking to help realize BPL its potential, the Institute of Electrical and Electronics Engineers (IEEE) developed Standard P1675, "Standard for Broadband over Power Line Hardware." IEEE P1675 gives electric utilities a comprehensive standard for installing the required hardware on distribution lines, both underground and overhead, which provide the infrastructure for broadband-over-power-line (BPL) systems. It also will include installation requirements for the protection of those who work on BPL equipment and to ensure such systems do not place the public at risk.

Summary

Deploying broadband over power lines holds promise has an alternative, or "third wire" into millions of home within the U.S. Tests have shown that 1) BPL does work and can deliver internet over power lines and 2) BPL system cause interference that must be managed. The interest in BPL has waned some since the turn of the century, but companies are still evaluating how BPL might successfully be deployed. Numerous technology and regulatory hurdles must be overcome to make this a viable alternative to DSL, CATV, and satellite delivery of broadband.

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