Broadband Over Powerline 2004: Technology and Prospects

Broadband over powerline is being hailed as the next major Internet pipeline — and perhaps the key to developing an advanced power delivery system for the 21st century. It works and holds promise, and electric utilities are beginning to test whether it is a viable business in commercial-scale deployments. Some believe that with a careful implementation approach, BPL can be a winner. This White Paper summarizes the status of BPL development and lays out some of the issues confronting the electric utility industry as it considers BPL deployment.

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Executive Summary

After years of development, technology to deliver high-speed data over the existing electric power delivery network has emerged in the marketplace. Called broadband over powerline (BPL), this technology offers an alternative means of providing high-speed Internet access, voice over Internet Protocol (VoIP), and other broadband services, using medium- and low-voltage lines to reach customers' homes and businesses.

Thanks largely to advances in signal processing, BPL works — or can be made to work. Technical feasibility has been demonstrated in more than a dozen limited field tests, and BPL as a business is about to be tested for the first time in Manassas, Virginia and Cincinnati, Ohio, where BPL networks are being built to reach thousands of customers. The City of Manassas Electric Department network will make BPL available to the city's 35,000 residents by late 2004. In Cincinnati, Cinergy's Current Broadband is creating a network that will pass 55,000 customers by the end of 2004, ultimately extending to 260,000 customers. PPL Telcom is also deploying an "advanced market trial," which is relatively large in scope, with a network that has passed about 16,000 homes, 1,200 of them having subscribed as of September 2004. This may lead to a wider-scale commercial operation.

The Feds Promote BPL as the "Third Wire"

A federal policy push is furthering the potential for BPL deployment, as well as fueling media coverage. The Telecommunications Act of 1996 mandated wide availability of broadband service, but the U.S. languishes behind countries such as South Korea, Canada, Belgium, and many others in the percentage of homes thus served. In South Korea, for instance, 60 - 70% of households have broadband service, compared to about 25% of U.S. households. Since high-speed communications are an obvious economic driver, President George W. Bush declared in March 2004 that broadband access should be made affordable to all Americans by 2007. He also stated in April 2004 that America needs "technical standards to make possible new broadband technologies, such as use of high-speed communication directly over powerlines."

To that end, the Federal Communications Commission (FCC) has proposed rulemaking to help overcome BPL's potential to cause interference with radio and telecommunications signals. The FCC has proposed measures to mitigate interference, and rules are slated for release by late 2004.

The FCC and others have hailed BPL as a potential "third wire" that may help increase the availability and the affordability of broadband services in a market dominated by just two options: digital subscriber line (DSL) and cable. According to FCC Chairman Michael Powell, "Magic things happen when you have three competitors: three forms of technology, better choice, better innovation, and better prices for consumers."[1]

Considerable Challenges Face BPL Development

The availability of technology that works, the development of guidelines for mitigating interference, and the announcements of the first commercial-scale tests of BPL have engendered considerable interest in BPL among electric utilities, with dozens now evaluating whether they should deploy BPL.

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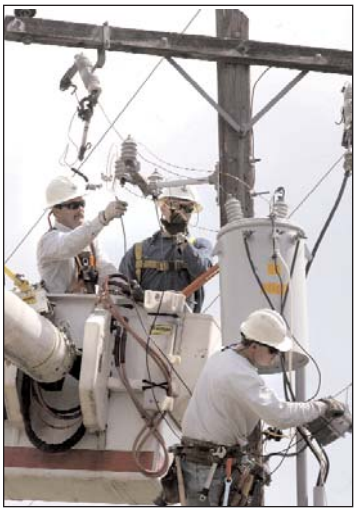
Can electric utilities be winners in the competitive broadband environment envisioned by the FCC? Several questions need to be answered first. Chief among them is how to obtain sufficient revenue from a BPL service to offset deployment costs in the face of falling Internet access prices. Also of considerable interest is the potential to leverage BPL for utility applications, such as automatic meter reading, load control, and demand response measures such as critical peak period or dynamic pricing. There is also interest in BPL's potential to serve as a communications system that can support the network management of the power delivery system. Could the combined benefits of a system allowing for consumer telecom services, other consumer services, **and** core utility network communications help make the business case for BPL? For example, would the ability to read meters remotely, along with advanced diagnostics, direct load control, and outage management offer a sufficiently robust business model for utilities when combined with BPL consumer services?

As part of assessing these issues, utilities are exploring several key questions:

Can BPL consumer services be profitable?

Network costs for widescale BPL deployment have not yet been demonstrated. Equipment suppliers have typically been reluctant to publish specific figures about costs, because they can vary depending on the density of the area to be served, the distribution network topology, and other factors. Costs also vary by vendor. However, cost estimates cited by equipment suppliers for an urban or suburban setting typically range from $50 to $150 per home passed, and another $30 - $200 per home for consumer premises equipment (modems).[2] Costs per broadband subscriber, rather than just costs per home passed, will ultimately determine profitability — and will depend on the percentage of customers passed that sign up for BPL Internet access and other services.



Source: Greg Gilbert/The Seattle Times

Making the business case by selling just fast Internet access may be difficult. Bundling of broadband consumer services — and perhaps utility-related applications like direct load control — will likely be needed. For example, Internet service provider Earthlink advises utilities that BPL will need to reach a cost of less than $20 per home passed and less than $100 for consumer premises equipment to make large-scale BPL deployment price competitive and profitable, *if Internet access is the only service offered*.[3]

Earthlink's estimates are based on assumptions of revenue of $20 per month from subscribers and a 10% market penetration rate. Many in the BPL industry consider these assumptions of revenue and market penetration low. For instance, commercial BPL deployments now underway assume market penetrations of 20% rather than 10%. But even with higher revenue and higher penetration rates than Earthlink assumes, BPL profitability will likely require revenue from other services such as voice over IP and video on demand — and cost reductions or savings related to meter reading, direct load control, increased reliability, or other utility applications.

Earthlink's cost threshold estimates are based largely on forecasts of falling Internet access prices. Indeed, the first commercial BPL deployments are competing on price, and have set their fees to be competitive or below cable and DSL prices. The City of Manassas charges $27 per month, and Cinergy's Current Broadband service ranges from $29 to $39 per month, depending on speed. At these prices, both organizations believe they can realize positive cash flow within a few years. Cinergy's Current Broadband estimates it will be "cash flow neutral" by the end of 2007.[4] However, DSL providers have already started lowering their prices to be more competitive with cable.

And as BPL becomes a serious threat, both cable and DSL providers are likely to compete aggressively. Although faced with their own funding limitations and debt, these companies are not likely to be complacent about losing market share. Any company offering BPL in the consumer market, and competing only on the basis of price of Internet access could find profitability elusive.

Will alternative technologies, most notably fiber and wireless, emerge as the major broadband providers?

Verizon announced plans to launch broadband over fiber in 2004 in selected U.S. markets, and other "Bells" could look to fiber as a means to boost network speeds and offer bundles of services now beyond the capability of DSL lines. In addition to fiber, wireless broadband service providers may become larger players in the broadband mix. Today's wireless broadband systems are relatively slow at 200 - 300 kilobytes per second (kbps) — compared to speeds of 1 megabyte per second (Mbps) or more from most DSL, cable, and BPL providers — but deployment of this technology is underway or planned in some cities and towns, the largest to date being Philadelphia. Such wireless service, albeit not at the performance levels or speeds of BPL, can be less expensive to build and can mean relatively inexpensive Internet access in some locations.

In addition, although still nascent, long-distance fixed wireless, known as WiMax, enjoys support from major companies such as Intel and has potential to become a major broadband technology in coming years, especially for rural locations and other areas underserved or unserved by DSL and cable. Another possible alternative is a satellite-based Internet access system, although satellite systems are typically expensive and do not have the performance quality and speed of BPL.

When and how will regulatory questions be resolved?

A number of regulatory questions must be addressed pertaining to BPL. The outcome of final guidelines on methods of mitigating interference from the FCC (Part 15.109[f]) is awaited in 2004. And how state regulators will address cross subsidization and revenue, rights of way, and access to poles is of particular importance. In commercial deployments to date, regulators have been cooperative and supportive of creating BPL networks, however, regulatory action or inaction could have a significant impact on the business case for BPL, pointing to the need for a proactive approach with regulators on this issue.

Will BPL enable cost-effective utility applications?

A BPL network could serve as a communication system for utilities, allowing for many applications related to grid management and utility services such as demand response or automated equipment monitoring and management. Utility applications are viewed by many as an important part of the bundle of services that could make the business case for BPL in the near- or mid-term. Others, such as the Consolidated Edison Company, which is an investor in equipment supplier Ambient, are taking a long-term view and see BPL technology as a potential key to developing the IntelliGrid™, an advanced network capable of near real-time, two-way monitoring, sensing, and control of the power delivery system to provide enhanced asset management and system optimization. EPRI's analysis of the business case for the EnergyPort™ — a digital control and communications hub that would enable a number of utility applications — indicates that a communications network such as BPL could enable a compelling return on investment based on the value of energy and network management. However, the value of BPL for core applications will likely vary considerably from utility to utility depending on multiple factors including deployment costs and potential for integration with existing communication systems. Some BPL developers are looking first to consumer broadband services, with energy-related applications such as outage detection to follow for areas served by BPL.

Who will invest in BPL?

The strategy of leveraging infrastructure investment for both a consumer communications service and for utility applications has appeal. But it also has considerable risk. Many factors key to the business case — regulations, technology costs, revenue per subscriber, and the advent of alternative technologies — are all areas in which electric utilities have little ability to exert control. This has been reflected in the modest investments seen so far in BPL. A few utilities have invested in BPL technology development companies, and those engaged in deployment have taken a measured approach so far, with a phased implementation to ensure risk mitigation.

Broadband over powerline technology works — or can be made to work. The task of the industry now is to determine the business case for offering broadband services to customers, while addressing the potential value and practicality of BPL power delivery system applications.

BPL Technology

Powerlines, like phone lines and cable lines, have sufficient capacity to carry signals other than those they typically carry. In fact, powerlines have been used to carry data for many years using available carrier current technology that enables delivery of low-speed data over both short and long distances — and high-speed data over short distances. But high-speed, long-distance data transmission over powerlines has been hampered until recently by characteristics of the electric environment and electromagnetic compatibility issues, as described in "Overcoming technical challenges" on page 5. These include the presence and variability of electric noise, attenuation of data signals, and the complexity of sending data through or around distribution system transformers.

Enabling Technology

Prior to recent developments and innovations, technical obstacles made high-speed, long-distance data transmission over powerlines unreliable and uneconomic. But digital circuits are now available that can help manage noise, attenuation, and help circumvent and/or bypass the transformer. Sending broadband signals over the high-voltage, long-haul lines is still too difficult, but equipment can be placed at critical locations along medium-voltage distribution powerlines to create a communications connection to the utility customer. This communications network is, in turn, connected to fiber or T-1 lines — the so-called "backhaul" that connects the BPL network to the Internet.

Innovations that make BPL possible:

Advanced methods for modulating data signals. Foremost among the technical advances that enable BPL is how data signals are coded and modulated. These methods rely on adaptive algorithms to counter noise on the system and reduce radio interference. For instance, orthogonal frequency division multiplexing (OFDM) methods separate data signals, spreading them over a very wide bandwidth, with each of the data streams modulated at a different frequency and phase. These data are transmitted over powerlines to a receiver with multiple and parallel receiver paths that extracts and reconstitutes the original data signals.

Faster chip sets. In effect, these are computers — not the general purpose computers we use every day, but highly optimized, dedicated computers. These digital signal processors enable high-speed transfer of data through a noisy path by performing mathematical operations that encode the data into a signal and send it, then receive the signal and decode it for extraction — all the while adjusting the encoding process to adapt to the communications environment. This requires elaborate equations and calculations that, if performed at the speed of computers of ten years ago, would not be fast enough to support broadband data transfer. The high speeds of the latest integrated circuits are essential to the high data-transfer rates.

Digital equipment to amplify signals. Repeaters or other amplification equipment are available that can boost and stabilize data signals. Placed at intervals of about 1000 feet to one mile, these signal boosters minimize signal deterioration.

Equipment to bypass or send signals through the transformer. Various methods are used to avoid attenuation at the distribution transformer. Usually this involves going around the transformer instead of through it. For example, one system can extract incoming data signals, converting them to a radio signal, which is sent to the customer premises. Amperion is one vendor using this approach. Or signals can be extracted from the medium-voltage side and converted to a different powerline signal and sent into the customer site over the secondary line. This method is employed by Current Technologies. Alternatively, the signal can be moved through the transformer, as equipment supplier Main.net does.

Overcoming technical challenges

Powerlines were not designed for data transmission; they were created to deliver power at 50 to 60 Hz. Broadband data are transmitted at different frequencies, so the data and the electricity can travel in the same wires; however, several obstacles have to be overcome to enable high-speed and long-distance transmission of data on powerlines:

High-frequency data signals encounter considerable and unpredictable electrical **noise** levels on powerlines. Noise consists of undesirable signals that potentially affect the data signal. Noise is generated on the power delivery system by energy consuming devices and appliances when the equipment is used — or by atmospheric conditions such as sunspots, by arcing and discharge at dirty insulators or faulty connections, by switching, by other nearby powerlines, and often by power sources as well. Other noise can be induced on the line — the line serves as a receiving antenna — by radio sources such as broadcast radio stations and other fixed and mobile radio sources.

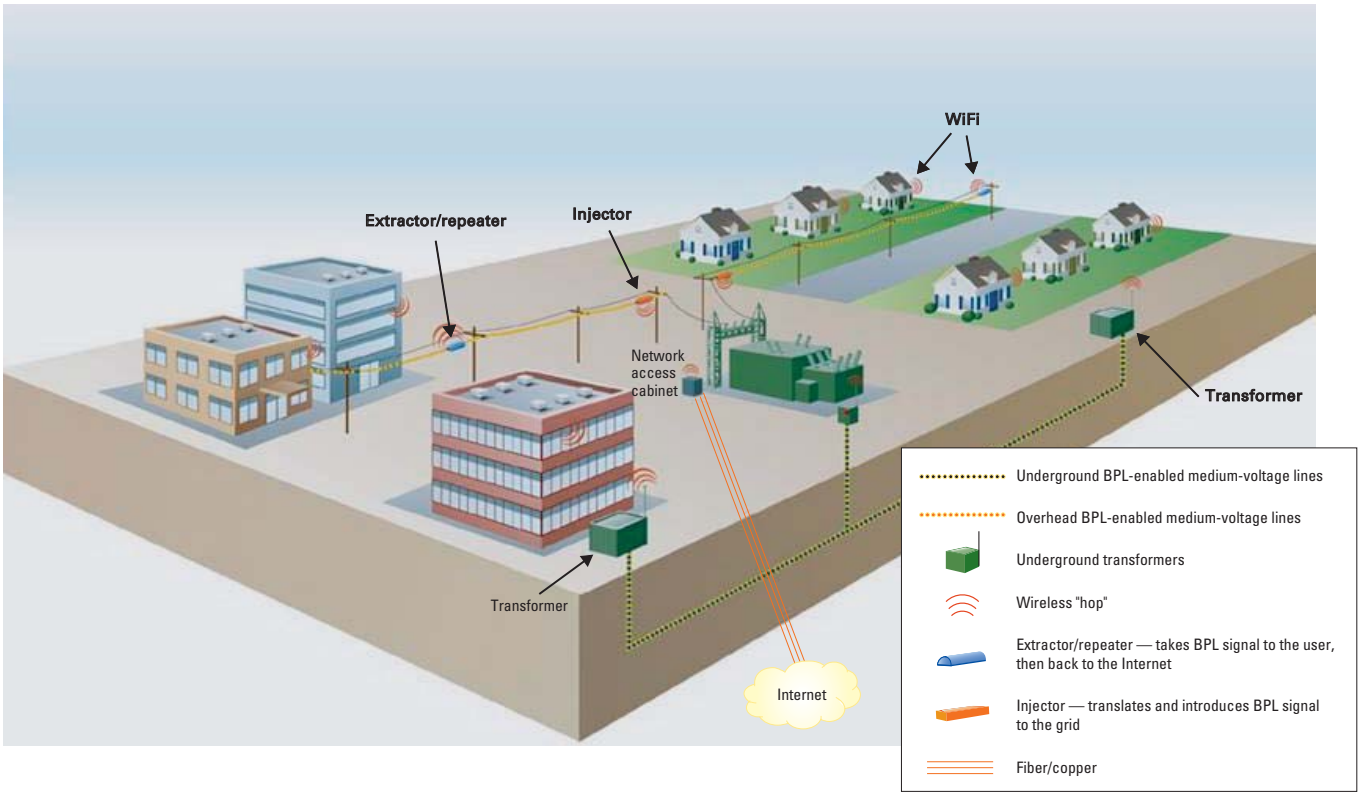
Attenuation, or reduction of signal strength, occurs either on longer lengths of the distribution feeder, or when a given feeder changes configuration several times — such as from overhead to underground or from cross arm to a more compact configuration. Attenuation must be overcome to enable long-distance data transmission. Higher-frequency data signals are typically attenuated much more seriously than lower-frequency signals. Signals lose energy as they propagate for several reasons, including the change in impedance on the line at every connection, splice, tap, standoff, or even a location where the line is close to something else. On a common U.S. electric distribution line, a BPL signal will travel less than a mile, and typically much less than a mile before it must be amplified. Feeders may require use of signal repeaters at intervals of 1000 feet to a mile or so to accomplish this amplification.

Attenuation problems at the distribution transformer closest to the customer have previously been a major barrier for BPL. Low-frequency signals, obviously including electricity at 60 Hz, can easily pass through the distribution step-down transformer as it reduces line voltage from medium-voltage (typically 4,000 to 13,000 volts) to the low, service-level voltage (120 to 240 volts) for the customer premises. But high-frequency signals, which for BPL are typically in the 2 MHz to 80 MHz range, are obstructed or severely attenuated by the transformer. Although some of the signals get through, signal components can be so weak that they are difficult to detect and reconstruct. Accordingly, many BPL technology suppliers simply bypass the transformer. At least one supplier has also developed a system with the ability to get enough signal through the transformer to operate effectively.

Potentially harmful radio frequency interference (RFI) has been one of the most serious potential obstacles to BPL. BPL systems have been shown to produce RF interference with nearby radio receivers, within up to 75 meters for mobile radios and 150 meters for fixed radios, according to the American Radio Relay League (ARRL). Also, various elements or structures in or near the powerlines readily become radiators or antennas at the high frequencies at which BPL data are transmitted. This presents a problem of interference with a variety of radio services. Many in the utility industry probably recall that when Nor.web introduced a now defunct BPL system in the United Kingdom, street lamp poles located within the system turned into antennas, broadcasting the data signal as radio waves. Unfortunately, this interfered with the BBC's broadcast, a major problem that helped lead to the venture's demise.

However, many of today's BPL systems can adjust operating frequencies, "notching out" frequencies that are interfering, and using other adaptive techniques. Vendors claim that harmful radio interference will not be a problem in commercial deployments and FCC tests at pilot sites in 2004 are encouraging. But the potential for radio interference has engendered considerable and vigorous opposition to BPL by amateur radio operators, as well as concern from the National Telecommunications and Information Administration (NTIA), which has called for rigorous technical solutions to address interference. Wider-scale deployment and the upcoming FCC guidelines will likely help address this issue.

An example of a broadband over powerline system



Today's broadband over powerline systems have three primary parts:

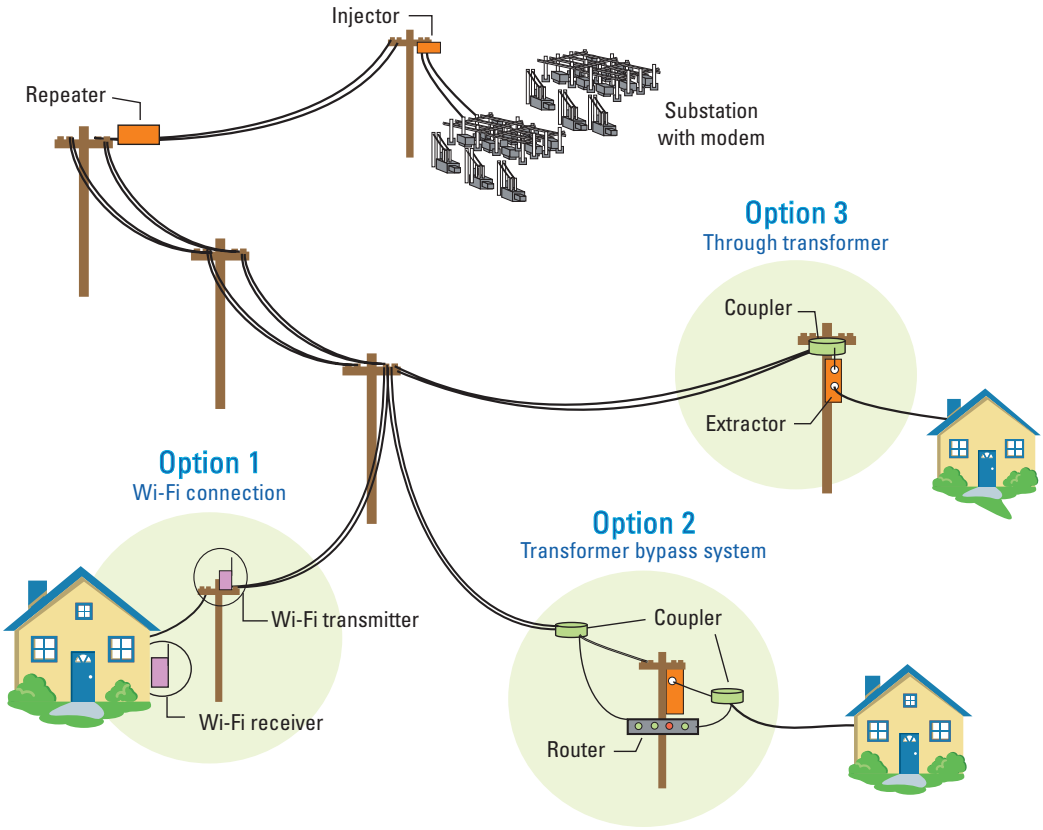
1) Internet access at the substation (or another location) connected via "backhaul," which can be fiber, fixed wireless, or other communication systems. In this scheme, a wireless fidelity (Wi-Fi) system carries the signal between the network access cabinet and the injector at the medium-voltage line.

2) Devices on the medium-voltage lines that enable digitized data to be conveyed through the lines (extractor/repeater)

3) Devices to enable the data to bypass or go through the transformer to connect to the consumer premises equipment (modem). In the system shown, Wi-Fi equipment is used to connect to the customer site. Other systems may rely on devices such as couplers and extractors to move the data around or through the transformer as shown in the figure on p. 7.

Source: Amperion. Property of Amperion and used with permission

Basic BPL with different system architectures



BPL vendors offer different system architectures, which feature various signal modulation schemes and modes for bypassing or going through the transformer. In Option 1, orthogonal frequency division multiplexing (OFDM) is used for distributing data, and at the customer site, a wireless fidelity (Wi-Fi) system is used to transmit data between the medium-voltage line and the customer premises, avoiding the transformer. Another approach, as shown in Option 2, also involves use of OFDM, but relies on BPL extractors that route and convert data between the medium-voltage line and the low-voltage lines.

Option 3 involves a different modulation method, direct sequence spread spectrum, to transmit data through the transformer, with a coupler and an extractor (repeater) to make up for signal losses through the distribution transformer.

Standards and Specifications

Development of standards for safety and reliability of BPL installations are a natural part of wide-scale adoption of the technology, as are standards for interoperability and for integration with Internet service providers. As of October 2004 the following initiatives are underway relating to BPL standards and specifications:

IEEE P1675™, A Standard for Broadband Over Power Line Hardware — The Institute of Electrical and Electronics Engineers (IEEE) recently initiated development of standard P1675, which will address installation and safety of BPL. IEEE P1675 is intended as a comprehensive standard for installing the required hardware on distribution lines, both underground and overhead. It also will include installation requirements for the protection of those who work on BPL equipment and requirements to ensure such systems do not place the public at risk. The standard is targeted for completion in mid-2006.

According to Terrence Burns, Chair of the IEEE Standards Working Group, "Power companies face a number of issues in doing this, for example, how to assess the performance and safety of repeaters/routers, medium- and low-voltage coupling hardware, and other equipment before buying. Other issues include how best to put this equipment in place and how to keep the overall system operating well and prevent it from interfering with power delivery. The new standard will help with these concerns."[5]

HomePlug™ BPL — The industry consortium HomePlug Alliance[6] is engaged in creating harmonized specifications that will allow to-the-home and in-the-home technologies to work together. As part of this, the HomePlug Alliance is developing an access BPL specification. "Plug and play" units such as the one pictured can double as both a home networking node and as the customer premises equipment (modem) for Internet access. Note that BPL is not a necessary element to allow for in-home powerline networking using HomePlug modems. In fact, they can be used independent of how the Internet signal reaches the home, for example with cable or other Internet access services.

Such off-the-shelf units, which are being used in the Current Broadband deployment, were not built for BPL. Hence, specifications that will aid the connection with the to-the-home BPL system are considered important to enhance use of HomePlug modems with any BPL system. To that end, the HomePlug Alliance is inviting utilities to work with the manufacturers, Internet service providers, network operators, and others in the group to create a market requirements document leading to specifications. As part of the process, utilities are asked to participate in working group meetings. Interested parties should contact Brian Wenger of Earthlink at brianw@corp.earthlink.net, tel 626.351.7169.

Informal working groups — Trade/professional groups have fostered user groups that are exchanging experiences, addressing development activities, and providing information and education to policy makers and the public. These include the United Powerline Council, a part of the United Telecom Council (UTC, www.uplc.utc.org) and the Power Line Communications Association (PLCA, www.plca.net).

HomePlug Modem

Source: Current Broadband with permission

Regulations

At the "big picture" or federal level, policy makers are supporting BPL. It has potential to help meet the goals of the Telecommunications Act of 1996, which promotes universal access to broadband services. Affordability is also being promoted, and in a speech on March 26, 2004 President George W. Bush called for universal and affordable broadband access by 2007.

At present, the choice available to most customers is limited to digital subscriber line (DSL) from the local exchange carrier (ILEC) or cable modem access from the local cable television provider. Many customers, particularly those in isolated rural areas, have no access to broadband, except perhaps by expensive satellite service.

Since the power delivery system provides nearly universal reach, BPL has considerable appeal as a means to accomplish federal policy goals. In fact, in April 2004 President Bush called for technical standards that specifically encourage broadband over powerline.

As part of the federal effort to remove barriers to BPL implementation, the Federal Communications Commission (FCC), which regulates use of the communications spectrum, issued a proposed rule under Part 15 of current rules for measures to mitigate radio interference caused by broadband over powerline. Comments have been received on this proposal, and a final rule is scheduled for release in late 2004. FCC Chairman Michael Powell has also used his position to help encourage BPL development, issuing statements during visits to BPL test sites in support of BPL as the "third wire" that will increase competition, availability, and affordability.

Competition and Classification

A number of jurisdictional and classification issues remain to be resolved that will influence the business case for BPL (as well as for its competitors). 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 1934, most notably common carrier requirements.

As of October 2004, the FCC has two proceedings that address the issue of broadband regulatory classification: one dealing with cable modem services and another dealing with all wireline broadband Internet access services generally. In the cable modem proceeding, the FCC has already declared cable modem to be an information service, but that declaratory ruling has been appealed and vacated by the U.S. Court of Appeals for the 9th Circuit. The Circuit Court decision has been appealed to the Supreme Court. In the wireline broadband proceeding, the Commission tentatively concluded that all such services are information services. A decision on this tentative conclusion is still pending in 2004.

If considered an information service, BPL service would be free from many if not all common carrier regulations. Even if BPL is classified as an information service, the Commission may decide to require that it contribute to the **universal service fund (USF)**, based upon a percentage of its gross revenues. The fund is designed to ensure that rural and low-income customers receive a similar level of telecommunications service as those in non-rural areas. USF contributions are typically passed onto customers by carriers and appear on phone bills as USF charges.

Regulations related to voice over Internet Protocol, a service that will likely be bundled with BPL Internet access, may also be imposed on BPL providers. The FCC is considering requiring VoIP to comply with 9-1-1 requirements and the Communications Assistance for Law Enforcement Act (CALEA). Compliance with these requirements raises challenging technical issues and the cost of compliance could be significant.[7]

Rights of way rules, often established decades ago, may also affect BPL deployment. 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.

Reliability and safety of the power delivery system and provision of quality of service are the main concerns for state commissions. In addition, affiliate transaction policies and **cross subsidization** issues loom large. 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 they may require creation of unregulated BPL subsidiaries or implementation of accounting rules that guard against cross subsidization. How cross subsidization should be prevented is open to interpretation, and states may vary in their assessment of what is a proper way to compensate ratepayers for asset transfer.

The National Association of Regulatory Commissions (NARUC) has formed a **BPL Task Force** to explore the potential for BPL and investigate what individual states may do to complement the FCC and others engaged in this area. Although the tenor of regulator comments in public statements is supportive of the technology and encouraging of a "light handed and fair" approach to regulation, many issues must be addressed by the states. To date, trials in Pennsylvania and the commercial deployment in Ohio have been supported by state commissions, but these approvals are contingent on subsequent reviews.

As for municipalities, though they do not have to deal with state commissions, restrictions on offering telecommunications services may be an obstacle for BPL deployment. Restrictions apply in about a dozen states.

Utilities interested in developing BPL are well advised to communicate with their regulators and governing bodies to gauge their level of knowledge and support for BPL. Some utilities, PPL Telcom, for example, initiated a demonstration of BPL for regulators to educate them about the technology, and the company is managing its development program so that regulatory issues are addressed at appropriate points in the process.

Alternative Broadband Technologies

Initial commercial deployments will help reveal how well BPL can compete with established DSL and cable services. But considering what the technology picture may be in a few years is also important, because BPL will need to be competitive as new networks are built and other alternative technologies emerge. (See **Table 1** at the end of this White Paper for an overview of existing and emerging Internet access technologies.)

Fiber and advanced wireless broadband are the new alternative broadband access systems most likely to emerge in the next few years.

Fiber — Verizon announced that it would use a fiber network — in which an optical fiber runs from the telephone switch to the customer's premises — to offer bundled broadband services in selected U.S. markets in 2004. The first service will be offered in Keller, Texas, with plans to expand into Tampa, Florida; Dallas, Texas; and Huntington Beach, California. This fiber-to-the-home network promises very fast speeds, reported to be 30 Mbps, compared to 1.5 Mbps DSL lines.[8] This will enable the company to offer multiple bundled services that include video on demand, telephone, and Internet access at a discounted price. Cable TV over the network is planned for 2005. Video services are a cornerstone of the revenue base for the service.

Besides Verizon, other companies that offer DSL, as well as others in the telecommunications industry, are looking to the potential of new fiber networks that offer high-speed performance. The high cost of building such a network has impeded development of this broadband alternative, but

according to Xilinx, a manufacturer of programmable logic devices, advances in resource sharing circuits (passive optic networks), fiber, chipsets that compress digital video, and other components are lowering costs.[9] At least one BPL equipment supplier considers fiber networks to be the leading competition for BPL in the long term, with costs of fiber networks being reduced to $800 - 900 per home passed.

Wireless broadband, provided by cell carriers such as mobile phone providers, offers lower performance than BPL, but systems are relatively inexpensive to build. Relying on what are essentially cell tower build-outs, cost of deployment ranges from about $10 to $20 per home passed, depending on whether the system relies on unlicensed or licensed spectrum.[10] Data rates are predicted to reach 200 - 300 kbps by 2005.[11] The city of Philadelphia, which is building a citywide Wi-Fi network to provide Internet access to its 1.5 million residents, estimates the network cost will be about $10 million, much less than other broadband networks would require.[12] If more such networks are built in coming years, and prices charged to customers are low, wireless networks could be a lure for dial-up customers.

WiMax, which stands for Worldwide Interoperability for Microwave Access, is the latest generation of fixed wireless technology. Backers claim it can deliver high-speed Internet access at point-to-point ranges of 25 miles or more. The high speeds promised by this technology (75 - 100 Mbps) offer not only fast Internet access but will also enable other broadband services requiring high bandwidth, such as streaming video. The critical factor in development of WiMax is standardization. Standards developed by IEEE (802.16) will encourage vendors and chipset makers to produce interoperable plug-and-play products, leading to scale production and ultimately lower prices. WiMax is only in test stages, and applications have yet to be proven, but the technology has been widely publicized and has spurred considerable enthusiasm — although perhaps some overly high expectations.

This broadband alternative does enjoy support from major companies, most notably from Intel, which recently announced a deal with Proxim to co-develop WiMax equipment. The WiMax Forum, a multi-vendor industry association, expects the first WiMax products to be available in 2005, but deployment, per most telecommunications analysts, is not likely until 2006 at the earliest. WiMax is likely to be expensive at first, since customer premises equipment needed to use the system is now quoted at about $300 per unit, and monthly costs to customers would therefore need to be relatively high. BPL vendors believe their next-generation technology can compete on performance against WiMax and can beat WiMax on price. However, cost reductions are widely expected, so this technology is one to watch — and is a potential contender for the future broadband market, particularly in rural areas.

Satellite broadband is another alternative, particularly for areas that do not have DSL and cable, although its adoption has been limited by performance and price. Direct satellite broadcast systems have been adapted from one-way to two-way communications systems for high-speed Internet access. Speeds of satellite broadband are about 500 kbps for download; speeds for upload are slower. Contracts have required an initial purchase of apparatus including the satellite dish, antenna, and separate modems for uplink and downlink. Satellite Internet access has tended to be used where some form of broadband access is required, where no other options exist, and where the installation and monthly costs (>$50/month) are acceptable. These installations have not been competitive on a cost or performance basis with other broadband offers. Satellite broadband service does not support voice over IP, another drawback of this technology.

WildBlue Communications, in partnership with the National Rural Telecommunications Cooperative (NRTC), is a broadband satellite system slated for activation in 2005 that promises faster speeds. Service packages with up to 1.5 Mbps download speed and 256 kbps upload data rates are being promoted by the NRTC. No specific prices are yet publicized, although a WildBlue representative says it is likely to be about $50/month.[13] Bundling of Internet access and DIRECT TV, using one satellite dish, is also planned as a means of making the service more financially attractive for providers and users.

BPL Tests and Deployments

Several companies offer BPL technology. In the U.S., the most vigorous testing and marketing is being done by Ambient, Amperion, Current Technologies, and Main.net. Other players, some relatively new to the market, are also involved. **Table 2** at the end of this White Paper profiles several of these companies.

To date, both laboratory tests and more than two dozen field tests or trials of BPL have been conducted. These tests, mainly focused on technical performance, show that the technology works. Typically, they have been small in size, ranging from 4 to 100 participants, who get the broadband service free for participating in most cases. Many tests have also entailed evaluation of utility applications such as remote monitoring or energy management. Two utilities in particular are focusing on these grid management applications, Consolidated Edison Company and Hawaiian Electric Company. **Table 3** profiles selected utility tests and pilots underway in 2004.

Speed

Speeds comparable to DSL and cable, 1 - 3 Mbps, have been achieved in BPL systems. Speeds in the commercial BPL deployments now underway range by system and vendor. In Manassas, Virginia, which is using first generation Main.Net equipment, user speeds range from 286 kbps to 800 kbps. In Cincinnati, Ohio, Current Broadband is selling Internet access at 1 - 3 Mbps. At PPL Telcom, speeds of 1.5 Mbps are advertised. Speeds are symmetrical, meaning that upload and download are at the same rate, a selling feature for BPL, since DSL and cable typically have much lower upload speeds. Vendors report that second-generation BPL equipment will enable providing 5 Mbps or more to the home.

BPL technology from a variety of providers has been demonstrated to be technically sound. The technical challenge appears to be increasing levels of performance, as alternative technologies offer increasingly higher speeds. The economic challenge is to do so at a competitive cost.

BPL Enters the Marketplace

Announcements of the first commercial deployments of broadband over powerline for consumers occurred in 2004. The City of Manassas, Virginia municipal electric utility is in the process of making BPL available to customers within the 10-square-mile city limits by the end of 2004. The city has 15,000 meters and a population of 35,000.

For a small municipality to be among the first movers in BPL commercialization is not a surprise. In this case, the combined factors of a fairly small territory, an existing 60-mile fiber network, and market conditions that offer potential for broadband growth have helped create a reasonable business case. Moreover, the municipality needs not be concerned with the level of uncertainty in regulatory oversight that investor-owned utilities must resolve.

PPL Telcom is also doing a commercial deployment in eastern Pennsylvania in Emmaus and in Hanover and Whitehall Townships. Customers are charged from $34 to $40 per month for the service, with price differences based on features such as web hosting and email. The company's BPL network has passed about 16,000 homes as of October 2004. According to PPL Telcom, the system is an "advanced market trial," and the company plans to decide by the end of 2004 whether to proceed with a widescale deployment in PPL Electric's service district, which has 1.4 million customers.[14]

Cinergy and partner Current Communications, through an unregulated unit, Current Broadband, are building out a network that will make powerline broadband services available to 55,000 customers in Cincinnati, Ohio by the end of 2004, with

Source: Current Broadband with permission

plans to extend the network to 260,000 homes in its territory. Cinergy has also formed a joint venture with Current Technologies, called ACcess Broadband, to provide broadband systems and services to municipalities and electric cooperatives.

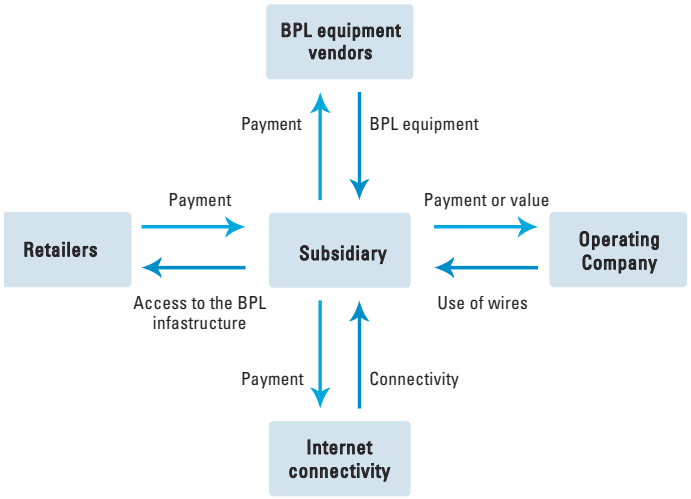
As an investor in BPL, Cinergy has a vested interest in a large-scale BPL network build-out, not only on its own merits, but also as a model for potential clients. The status of commercial BPL deployments as of 2004 is provided in **Table 4**.

Utilities can consider wholesale or retail approaches to BPL, applying three basic simplified models:

- A landlord arrangement, leasing the wires to a third party, probably with a maintenance arrangement
- A partnership or contract with an Internet service provider (ISP); the utility builds and owns the infrastructure, and the ISP handles all aspects of selling to and servicing the customer
- The utility handles all aspects of the system, including serving as the Internet service provider

Each of these options offers varying degrees of risk and reward, but based on interviews with managers of BPL projects, consensus favors a wholesale approach, entering partnerships with those who already have experience. The figure below is a business model that is illustrative of a wholesale approach for a large investor-owned utility in which a subsidiary is involved, showing the various parties and the flow of services and payments between them.

Wholesale business model



Each organization will assess BPL according to its own economic objectives, risk tolerance, and procedures. Several factors to consider in this analysis are:

Cost

Cost per home passed and estimated cost per subscriber will include costs of equipment and installation — as well as cost over time, including maintenance and equipment replacement and upgrades. Telecommunications equipment typically has a life cycle of less than eight years,[15] but according to vendor Current Technologies, the life cycle of BPL equipment is expected to be 10 - 15 years to meet utility requirements. Cost of backhaul, the communications link to the Internet such as fiber or fixed wireless systems, is also a critical factor.

Network cost data for wide-scale BPL deployment are not yet demonstrated. Main.net, the provider for the Manassas, Virginia deployment cites costs of $75 per home passed, and up to $300 for consumer premises equipment. Amperion reports a cost per home passed of $50 - $150.[16] Some equipment suppliers promise cost reductions as scale of production increases and as anticipated improvements in digital technology take place. Some companies have predicted reductions of about 30% from higher-volume production, but these have not yet manifested.

For its planning purposes, Earthlink advises that BPL costs need to drop below $20 per home passed and $100 per consumer premises for equipment if a utility is looking at offering only broadband Internet access. Eathlink's fast-Internet-only business case assumes offering a service that can survive in an environment of prices as low as $20 per month and a modest 10% market penetration.[17] However, as previously noted, many utilities and BPL developers believe a 20% market penetration is achievable, and bundling services such as voice over IP and video on demand will enable revenue higher than $20 per customer per month.

Market Size and Price

Revenue from broadband services will depend on both the market penetration of the service and its price. The number of broadband customers is growing and this sector constitutes a huge market, but one that will vary over time. Growth in the U.S. broadband market is universally expected. Individual markets vary widely, but nationwide, the total percentage of households with Internet access is at about 60%, and about 25% of households have broadband. By 2008, the percentage with broadband is expected to double to about 50% of households.

Pricing naturally affects market size. Prices for residential broadband service have already dropped in some cases, as DSL providers compete for market share against cable companies, lowering the price from over $40 per month to as low as $27 in select markets. Nationwide, DSL and cable broadband services range from about $26.95 to $49.95 per month. And slower speed dial-up services are typically $15 to $20 per month.

BPL networks will be built first in areas that offer the most cost-effective installation — most likely suburban areas, particularly those that may be underserved by DSL or cable. However, competition with DSL and cable in areas where BPL is deployed is likely. For instance, in the areas targeted by Current Broadband, a considerable proportion of customers already has access to DSL and cable. Therefore, a factor to consider is the price at which cable and DSL customers would switch to BPL — and the relative importance of various service features and value propositions. What combination of price and features will promote switching? And what hurdles might need to be overcome, such as the need for customers to change their email addresses?

It remains to be seen whether $28 to $40 per month BPL prices will lure dial-up customers, persuade cable or DSL customers to switch, or make much of a dent in the market that has not opted for Internet access at all. However, conventional wisdom among telecommunications analysts is that the monthly price point at which broadband becomes appealing to the mass market — those with dial-up or no service — is about $25 - 30. Availability of bundled services that include Internet access as well as items such as telephone and video, at a lower aggregate price than buying each service separately, may also influence customer buying behavior. (See Building Services and Average Revenue per User, page 15.)

Current Broadband representatives report that they anticipate their market will come largely from dial-up customers wishing to upgrade their service. They also see some potential for customers who want to switch from cable, citing dissatisfaction with cable company customer service. Current Broadband is in the early stages of marketing in 2004, but is encouraged by the fact that of those who responded to the venture's initial mailing, nearly half are cable company switchers.

Of the initial 55,000 homes passed in 2004, Current Broadband hopes for about 20% penetration, or about 10,000 to 15,000 actual subscribers. Bill Grealis, a Cinergy Vice President of Current Broadband, reports that as of July 2004, the company achieved a response rate of 15 - 20% from the initial 2,000 households targeted with direct mail marketing pieces.[18] Both Current Broadband and the City of Manassas view a 20% market share as an achievable target and the basis for a reasonable business case.

Current Broadband is offering its service to consumers at different prices, depending on connection speed. Monthly prices range from $29.95 for 1 Mbps to $39.99 for 3 Mbps. The announced prices are just under the local competition's monthly fees, creating an opportunity for Current Broadband to compete on price to gain market share. Time Warner Cable charges $44.95 per month, and Cincinnati Bell comes in slightly lower at $41.95. At these prices, Current Broadband anticipates "having a positive cash flow in three years, and our target is 260,000 homes passed by that time."[19]

Likewise, the City of Manassas is basing its business case on a 20% market share in its 15,000-meter municipality. Price will be $26.95 per month. Although the number of existing pilot project users is at only 200 as of mid-2004, over 1,300 people are on the waiting list, and little marketing has yet been done. A marketing campaign will be initiated when the network is completed later in 2004.

The Differentiating Features of BPL

Current Broadband is touting lower monthly costs, high-speed (1 - 3 Mbps), always-on service, and "true plug and play" as major selling points. An existing in-home network using the electrical wiring of the home is another feature promoted, as well as the fact that customers will be able to get the same speed both ways (upload speed is slower than download speed for other broadband services).

PPL Telcom is also touting fast speed, which is advertised at 1.5 Mbps, as well as symmetrical speed for upload and download. Prices at $34 to $40 are competitive with local cable service. Likewise, the Manassas service will be competing on price and speed. The Manassas system is significantly faster than dial-up (which only achieves 56 kbps) and approaching DSL, although it does not reach cable speeds. The first generation Main.net technology in Manassas performs at 286 kbps to 800 kbps, depending on the number of users on the system. As with other BPL systems, speeds are symmetrical for upload and download.

Bundled Services and Average Revenue per User

One potential drawback of BPL compared to cable is that it does not yet bundle services offered by the competition — Internet access and TV for example, making it potentially less appealing to customers. As a result, Current Broadband and other BPL providers are planning or investigating services to add to their mix. Additional services can translate not only into greater market share, but also the ability to boost average revenue per user.

The first additional service planned for bundling with BPL Internet access is voice-over-IP (VoIP) — telephone service over the broadband network. Current Broadband is planning to provide VoIP in coming months. The City of Manassas is testing voice-over-IP as a potential service offer as well, although issues of address identification for 9-1-1 calls and some billing issues need resolution before it makes a decision. PPL Telcom is also testing VoIP. Video on demand is another potential service to bundle for competitive advantage and is expected as part of the Current Broadband offer sometime in 2005.

The need to keep up with the competition's offerings — and offer multiple services — is one of the main reasons that BPL developers are enthusiastic about the high performance and speed they anticipate with second-generation BPL equipment. Speeds are predicted by one vendor to be able to reach 5 Mbps or more in next-generation BPL networks. Digital processing speed is the main reason for the improved speed; for instance, a new chip to be released by Spanish company DS2 should be able to process 200 Mbps.

The single most important issue in a BPL deployment will be to maximize revenue to deal with the anticipated falling Internet access prices. This will almost certainly involve offering bundled services, not just Internet access.

Are Multiple Services — Including Utility Applications — the Key?

While broadband Internet access may be the "killer app" 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 case is developed.

For instance, value-added services ranging from the entertainment and VoIP already planned for some BPL networks to home management functions such as security and energy management could be offered. Several of these services are listed in the sidebar. BPL could serve as the network between customers and the utility, and it could also serve as the basis of a system that performs a variety of functions on the customers' behalf. This system could relay information to the end user (energy prices, bill and energy use data, weather forecasts, etc.) and could make preauthorized, automatic decisions for customers as well (load shedding, thermostat settings, etc.). Customers could modify and interact to the extent they desire.

Utility-based functions are promising. Using BPL networks to meet existing internal utility communication needs could improve the business case for BPL consumer services, fostering greater broadband deployment and use.

The first commercial systems plan to include utility applications as networks are built out. For instance, the City of Manassas municipal electric utility has integrated data from the BPL network management system to help locate outages. At present, when a repeater at a transformer is out, it shows up as an alarm on a monitor at the operations center. When calls come in reporting an outage, staff at the operations center can check the status of BPL devices in the area and help pinpoint outage locations. The City says integration with outage mapping systems is down the road, but believes this will be of considerable value, along with functions such as distribution switching, fault detection, automated meter reading, and others.

Likewise, Cinergy's Current Broadband is investigating outage detection and restoration confirmation, along with automated meter reading, as initial utility applications of its BPL network. Enhanced power distribution services including remote switching, power quality monitoring, direct load control, and peak-shaving options are also factors in the company's business case.

Planned BPL development at Hawaiian Electric Company (HECO) will feature utility applications as the company undertakes a phased approach to testing and commercial deployment. HECO is actively considering both at-the-premises and on-the-grid applications. On-premises functions being evaluated include direct load control and advanced meter applications such as time-of-use rates and remote data collection. Potential on-the-grid applications range from outage detection to distributed generation monitoring and control to distribution automation (opening switches and breakers).

BPL customer services and applications

Value-added customer services

- Voice over Internet telephony
- Automated monitoring and control of end-use equipment, including demand response and load shedding
- Billing data and energy consumption data
- Real-time building security monitoring/reporting
- Automated inventory tracking of various goods such as fuel stocks
- Dynamic price information
- Video on demand
- Streaming audio delivered through a stereo or computer
- Real-time, interconnected Internet-based games
- Transmission of data/telephone/fax without multiple fixed lines

Utility network management

- Automated meter reading
- Automated connect/disconnect
- Recloser operations
- Power quality monitoring
- Distribution system data monitoring
- Load control/demand-side management
- Outage detection
- Lightning detection and notification
- Fault location
- Voltage control
- Dynamic pricing communication
- Staging area command center
- Distributed resource control and dispatch
- Crew management
- Security monitoring

The Outlook for BPL and EPRI's Initiatives

"The humble electrical outlet is getting an upgrade."
— San Jose Mercury News

"New interest in an obvious idea." *— New York Times*

"The Internet through electric wires? It's almost here."
— The Wall Street Journal

"Time to bid goodbye to fat cable margins"
— Financial Times

Real progress has been made in BPL technology, which has fed a press eager for stories about innovation. But the business merit of wide-scale broadband over powerline is still to be proven as the first commercial networks are being built. EPRI believes this technology could succeed commercially, but utilities will need a measured approach to development to mitigate risk and address the issues touched on in this paper, whether they be regulatory approvals, attracting a consumer market of sufficient size with bundled services, or meeting cost thresholds that enable competition with other broadband providers.

Since deployments are still in early stages, it is unknown whether extending BPL system-wide for utility applications will be cost effective. It is certainly an area of considerable promise, however, as a preliminary assessment by EPRI indicates offering multiple services and using BPL for utility applications could have considerable impact on the business case. For instance, BPL could be the communications system that supports the **EnergyPort™**, a meter, device, or a set of devices that serves as the communications and control hub for the customer. As envisioned by EPRI, the EnergyPort, also referred to as the Consumer Portal, is part "portal," part "gateway," and part smart electric meter. It would facilitate the communication enabled by the BPL network and the services based on that communication. (See www.e2i.org/e2i/ceids for more information and an online demo of the functions that the EnergyPort [Consumer Portal] supports.)

EPRI's Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) evaluated the business case for applications of the EnergyPort, and found that the case can be compelling. The assessment showed that a dozen or so applications are the most promising opportunities. In particular, the economics of demand response, avoided costs of new generation and T&D, and other energy optimization features make a strong basis for deployment. The CEIDS analysis showed that investment in a communications system that enables energy and network management could be worth roughly seven times the initial expenditure. This preliminary assessment could apply to BPL as well if utility-related applications are part of the services enabled with a BPL network.

BPL represents one of the potential communications media that can facilitate the convergence of communication and electricity delivery, what EPRI refers to as the **IntelliGrid**. Primarily focusing on a system for functions such as once-a-month meter reading or other applications that do not require high bandwidth, however, is a limited vision of BPL for power delivery system applications. Rather, BPL has potential to enable more uses of existing infrastructure and offers a possible platform for **new** utility-specific applications. Although utility applications can have near-term impact on the business case for consumer broadband services, a longer-term view may reveal that the biggest benefit of BPL is for functions such as distribution system optimization. Benefits include condition-based maintenance versus schedule-based maintenance, potential prediction of failures, reduced energy losses, and increased capacity using existing assets.

EPRI Initiatives

By its nature, BPL is an obvious area for greater examination and development.

EPRI's primary role to date has been through work related to the EnergyPort, a key to providing energy-related, value-added services that could be part of a BPL network.

EPRI's CEIDS has taken on the technical challenge of developing robust designs that can effectively integrate two infrastructures, the external electric power delivery system and the in-building environment. CEID's work has centered on the standardizing of "object models" for EnergyPort functions. These functions include demand response, real-time pricing, load monitoring, energy management, distributed energy resource interfaces and control, power quality applications, preventative maintenance, and condition-based maintenance.

EPRI is also creating a detailed, comprehensive research plan for its highest technology development imperative, the intelligent grid. This research plan, which accounts for technical, business, and regulatory issues, will examine the role BPL may play in actualizing the IntelliGrid. Other research needs related to BPL are also being explored, with input from industry stakeholders.

In addition, on the retail side, Primen, which is part of the EPRI Family of Companies, is developing research projects related to BPL, designed to address market issues in the context of communications-enabled customer services provided or desired by utilities.

To be a part of the EPRI initiatives related to BPL, the EnergyPort, and the IntelliGrid, please contact Clark Gellings at cgelling@epri.com. For information on market issues related to BPL, please contact Karen George at kgeorge@primen.com.

Notes

1. "Something New Under the Sun," CBSNews.com (July 15, 2004).
2. Vendor cost data are a range based on information from vendors Ambient, Amperion, Main.Net, and Current Technologies; analyst data from David Shpigler, as cited by John Dizard, "Time to bid goodbye to fat cable margins," *Financial Times* (July 26, 2004), from www.ft.com.
3. Bill Tolpegin, personal communication (August 24, 2004), Corporate Development, Earthlink, Atlanta, GA, tel 404.748.7214, email tolpegin@corp.earthlink.net.
4. Bill Grealis, Executive Vice President, Cinergy Corporation, and President, Current Broadband, "The bundles of commercial deployment: The financial risk and potential rewards" (presentation at IQPC Broadband Over Powerline 2004 conference, Orlando, Florida, July 28, 2004).
5. Terrence Burns, Chair of the Broadband over Powerlines Working Group, tel 602.371.6443, email terrence/burns@aps.com, as cited in "IEEE Standard to Support Broadband Communications Over Local Power Lines," press release (July 20, 2004), http://standards.ieee.org.
6. The HomePlug Alliance includes companies involved in home networking, including retailers, hardware and software providers, consumer electronic suppliers, Internet service providers and others. Members of its board of directors in 2004 are Arkados, cogency, Comcast, Conexanty, DS2, Earthlink, Intellon, RadioShack, and Sharp.
7. Brett Kilbourne, personal communication (August 27, 2004), Director of Regulatory Services/Associate Council, United Power Line Council (ULPC), Washington, DC, tel 202.833.6807, email brett.kilbourne@ulpc.com.
8. John R. Quain, "Surfing and a suntan, Cities invest in open wireless broadband for everyone," U.S. News and World Report, USNews.com (September 19, 2004).
9. FTTx, The Technology Behind the Networks, http://www.xilinx.com (downloaded September 22, 2004).
10. Bill Tolpegin [3]
11. Bill Tolpegin [3]
12. John R. Quain [8]
13. JoAnne Dant, personal communication (September 8, 2004), October Strategies, publicist for WildBlue Communications, Denver, Colorado, tel 303.346.5527, email Joanne@october-strategies.com.
14. Al Richenbacher, personal communication (September 30, 2004), BPL Network Engineer, PPL Telcom, Allentown, PA.
15. Edward B. Fishler, on behalf of Southern Telecom, Inc., "BPL Business Case Analysis and Development at Southern Company," (presentation at IQPC Broadband Over Powerline 2004 Conference, Orlando, Florida, July 28, 2004).
16. Amy Burnis, personal communication (August 24, 2004), Marketing Director, Amperion, Andover, Massachusetts, tel 978-824-2017, email amy@amperion.com.
17. Bill Tolpegin [3]
18. Bill Grealis [4]
19. Alex Pardo, Director, Cinergy Ventures, "Cinergy and Its Path to a Commercial BPL Business Case Analysis," (presentation Primen Outlook 2004 Conference, Cambridge, Massachusetts, May 6, 2004).

Table 1. A profile of Internet access

Broadband competitors by technology type	Reach and limitations	Speed	Typical prices, residential customers, 2004	U.S. market	Status/ comments
BPL — broadband over powerline, defined as long-distance, high-speed transmission of data over the power delivery system.	The appeal of BPL is that it can be applied to the ubiquitous electric distribution network. In practice, the reach of the technology will depend largely on costs of deployment. Utility communications for meter reading, direct load control, distribution management, power quality monitoring, and other applications can be conducted using BPL.	Up to 3 Mbps in commercial deployment. Faster speeds (5 Mbps to home or higher) anticipated by vendors. Speeds are symmetrical (same for upload as download). Like cable, the number of users affects the speed.	Range from $28 - $39, depending on speed and features	The first commercial deployments in the U.S. were started in 2004.	BPL is offered to thousands of customers in Europe, where it is less costly to deploy because of structural differences in the electrical system.
Cable — use of cable TV providers' coaxial or fiber-coaxial systems to transmit broadband signals.	Cable has a considerable amount of unused capacity and affords bandwidth for high-speed Internet access. Any premises with cable TV wiring can be provided broadband services. Only available where cable has been installed, so some areas, especially in rural and suburban locations, do not have access. The speed of the signal varies by the number of users on the neighborhood network loop, so performance (speed) degrades with high numbers of users.	~1 - 3 Mbps[c] This speed is available through a single channel, which other users share. Multiple users may degrade performance, although the cable company can add another channel or split the users into small groups.	Range of ~$39 - $60/mo	17.7 million[a]	
Dial up — use of existing phone lines for Internet access. Data transmission speeds are limited with this option, so it *cannot provide high-speed Internet access*. However, it does provide low-speed access, which many customers find an adequate alternative to the higher-priced broadband services.	Dial-up services provide wide reach since the phone service network reaches almost all homes.	Up to 56 kbps	$10 - $22/mo	38 million[a]	

Table 1. A profile of Internet access (continued)

Broadband competitors by technology type	Reach and limitations	Speed	Typical prices, residential customers, 2004	U.S. market	Status/ comments
DSL (digital subscriber line) — use of existing copper telephone wires for broadband transmission. Employs data encoding techniques to transmit data at frequencies different than voice transmissions.	A residence must be within about 18,000 ft. of the DSL central equipment office to be able to use this option, limiting availability. Also, not all circuits in this proximity are DSL capable.	1.5 Mbps	$27 - $49/mo Average of $43/mo[b]	11 million[a]	Although it can provide Internet access and voice signals, DSL is not capable of transmitting television signals.
Fiber (FTTx) — use of optical fiber lines to home (FTTH) or business (FTTB) to deliver broadband services	Fiber to the premises is available in some locations, but its deployment has been limited by high cost. However, cost reductions enabled by passive optical networks and advances in other components are bringing costs down.	30 Mbps - 1 Gbps+	$28 - 65/mo, depending on locale, service features, and speed	~600,000[d]	Verizon has begun deploying fiber in some U.S. locations, and other "Bells" and telecom companies may follow suit.
Satellite — direct satellite broadcast systems have been adapted from one-way to two-way communications systems for high-speed Internet access. Internet access service requires a dish, an uplink modem and a downlink modem, and coaxial cable between the dish and modem.	Installation requires a clear view to the south (in the Northern Hemisphere), since satellites orbit over the equator area. Trees and even heavy rain may affect reception of Internet data.	500 kbps[c]	$50 - $60/mo; plus ~$600 for equipment installation	~225,000[a]	Cost and performance have made satellite Internet access a small niche market. Some analysts are promoting development of a combination satellite- wireless system to increase the market.
WiMax — a name referring to the next generation of fixed and long-range wireless networks. Worldwide interoperability for microwave access, based on a January 2003 IEEE standard (802.16), supports development.	has a range of only about 300 - 500 feet. This technology has a predicted point-to-point range of 25 miles or more.	Up to 75 - 100 Mbps	Not yet known, although predicted to be higher than cable and DSL; consumer premises equipment (modems) are expected to cost $300 when introduced	NA — Not yet a product	WiMax has received media buzz, but is not yet a product. Telecom industry analysts predict products will be introduced in 2005 and first deployments by perhaps 2006.[e]

a. Bruce Leichtman, personal communication (September 30, 2004), Leichtman Research Group, Durham, New Hampshire, tel. 603.397.5400, www.leichtmanresearch.com.
b. "Current Analysis Finds Average Consumer DSL Prices Have Dropped Below Those of Cable Modem Service for the First Time Ever," *Current Analysis*, September 15, 2003, downloaded from www.currentanalysis.com.
c. Speeds for cable and satellite Internet access are based on the download speed, which is assumed to require the greatest bandwidth. Uploading speeds are slower.
d. Federal Communications Commission Industry Analysis and Technology Division, Wireline Competition Bureau, "High Speed Services for Internet Access: Status as of December 31, 2003," (June 2004) www.fcc.gov/wcb/stats.
e. "WiMax Making Strides," and "WiMax Primed for Growth," *Planet*, October 10, 2003 and October 22, 2003, downloaded from www.wi-fiplanet.com.

For more information on how satellite Internet access, cable modems, DSL, and dial-up services work, see www.howstuffworks.com.
For more information on WiMax, visit www.wimaxforum.org, an organization created to promote deployment of broadband wireless access networks by using a global standard and certifying interoperability of products and technologies.

BPL Vendors/Technology Companies

Several companies offer BPL technology. In the U.S., the most vigorous testing and marketing is being done by Ambient, Amperion, Current Technologies, and Main.net. Other players are also involved. **Table 2** profiles several of these companies.

Table 2. Selected BPL Vendors/Technology Companies

Company	Category	Products and services	Utility tests/comments
Ambient Corp 79 Chapel Street Newton, MA 02458 contact: John Joyce, CEO tel: 617.332.0004 email: John.Joyce@ambientcorp.com website: www.ambientcorp.com	BPL system design and integrator	PLC hardware and embedded software. Uses integrated circuits from DS2 to send signals on medium-voltage lines, and couples signal to low-voltage lines. Uses repeaters as necessary. Has patented inductive coupler that couples the customer voltage system (240 V) to the distribution primary voltage system (~4 kV to 24 kV) System analysis and design Installation support, maintenance services, and system upgrades	Consolidated Edison has an interest in Ambient. Earthlink also an investor. Ambient technology is being tested by: • Consolidated Edison • IdaComm • Others not publicly discussed
Amperion, Inc. Two Tech Drive Andover, MA 01810 contact: Jeff Tolnar, Vice President of Marketing and Sales tel: 978.824.2000 website: www.amperion.com	Medium-voltage line BPL system	Uses chipsets from DS2, 45Mbps raw data rate. Uses to deliver signal to the premises. Customers can choose either one or two 802.11 a/b/g radios, with an optional amplifier and an optional fiber port. Offers equipment for both overhead and underground powerlines. Three types of hardware provided: 1) signal injector — interface between network access connection (e.g., fiber ring, DS3, DS1) and an MV feeder 2) extractor device that connects the network to bandwidth destination 3) repeater/extractor that corrects for noise and retransmits down the MV feeder	Investors include American Electric Power (AEP), Cisco Systems, and Redleaf Group, Inc. Amperion technology is being deployed at: • AEP • PPL Telcom • Progress Energy • Southern Telecom • IdaComm • Penn Yan • PUC Telcom (Ontario) • Dacor • D-Tel • Others not publicly disclosed or outside North America
Current Technologies 12800 Middlebrook Rd., Suite 201 Germantown, MD 20874 contact: Terry Bernstein, Director of Marketing email: Terry.Bernstein@currenttechnologies.com tel: 301.515.7617 website: www.currenttechnologies.com	Turnkey service of system hardware & software, with installation, operation, and maintenance of system and full ISP services.	Proprietary data transfer system for medium-voltage lines; uses CT Bridge device to convert signal to HomePlug format for low-voltage line communications; CT Coupler used to couple medium-voltage and low-voltage signals.	Funded by venture fund Liberty Associated Partners, with minority investment by employees and Enertech Capital Partners Current has conducted pilots with: • Pepco • Cinergy • Hawaiian Electric

Table 2. Selected BPL Vendors/Technology Companies (continued)

Company	Category	Products and services	Utility tests/comments
GridStream Systems (formerly PowerComm) 55 Spray Road Fayetteville, TN 37334 contact: Wayne Sanderson, President, CEO tel: 931.438.3331 email: wsanderson@gridstreamtech.com website: www.gridstreamtech.com	System design, especially for serving rural areas	System that imposes signal between the phase line and neutral line of distribution primary circuits. Patented protection of modulation method over circuits as well as use of lightning arresters as coupling devices over medium- and high-voltage power lines. Uses HomePlug alliance compliant hardware for access over medium-voltage powerlines and from the transformer into the home. Can create hot spots with access point routers on repeaters.	Technology is being tested by: • Cullman Electric Cooperative, AL • Fayetteville Public Utilities, TN • Chelan County, WA • Winchester, TN
Main.net Powerline Communications, Inc. 12355 Sunrise Valley Dr. Suite 650 Reston, VA 20190 contact: Joe Marsilii, CEO tel: 703.476.4700 website: www.powerline-plc.com	System designer/integrator BPL network designer/operator	Adapted "last mile" solution from European low-voltage line applications to medium voltage; incorporating repeaters for higher-voltage distribution system communications. Deployable on both low- and medium-voltage grids.	Parent company is located in Israel. Outside of U.S., has 50 deployments, serving about 10,000 sites. • AmerenUE • Southern Telecom • City of Manassas, Virginia • Rochester Public Utilities • Pacific Gas & Electric Has formed a partnership with Hometown Connections to offer BPL equipment to American Public Power Association (APPA) members
PowerWan, Inc. 400 Channing Ave. Palo Alto, CA 94301 contact: Cliff Davidow, Founder & CTO tel: 650.960.3215 website: www.powerwan.com	System design and support services	System that eliminates need for coupling between medium- and low-voltage domains. Signal processing technique detects signal after passing through transformer. Requires high-capacity backhaul such as fiber.	Investors include Anila Group, a venture capital firm, employees, and unnamed utility. Technology is being tested by: • "Unnamed utilities" serving more than a dozen homes Recently announced a commercial deployment in China.

Tests and Deployments

To date, both laboratory tests and more than a dozen field tests or trials of BPL have been conducted, focused on technical performance. These tests have typically been small in size, ranging from 4 to 100 participants, who generally get the broadband service for free for participating. Many tests have also entailed evaluation of utility applications such as remote monitoring or energy management. Two utilities in particular are focusing on these grid management applications, Consolidated Edison Company and Hawaiian Electric Company. **Table 3** profiles selected utility tests and pilots underway in 2004. **Table 4** covers commercial deployments.

Table 3. Selected BPL utility field tests and pilots

Company name	Location	Equipment vendor	Phase	Number of participants	Installation types	When began	Comments
AEP	Dublin, OH	Amperion	Field test	NA	Residential Commercial		
AmerenUE	Cape Girardeau, MO	Main.net	Field test	55 (300 homes passed)	Residential	Mid-2002	
Arizona Public Service	Cottonwood, AZ	Not publicly disclosed	Field test	10 (~50 homes passed)	Residential Commercial	2004	
Central Virginia Electric Cooperative	Lovingston, VA	IBEC	Pilot	NA (4,000 homes passed)	Residential	2004	Being installed in 2004; will offer for $29.95/month as market trial
Chelan County PUD	Wenatchee, WA	GridStream Technologies and Main.net	Field test	30 homes passed for each technology	Residential	2004	Chelan County PUD owns fiber optic network
Consolidated Edison	Westchester, NY New York City	Ambient	Field test	15 (expanding to multi-family unit in NYC)	Residential Commercial	May 2002	Funding assistance provided for utility applications testing by New York State Energy Research and Development Authority (NYSERDA)
Cullman Electric Co-op	Cullman, AL	GridStream Technologies	Field test	13 (78 homes passed)	Residential	Fall 2002	
Fayetteville Public Utilities	Fayetteville, TN	GridStream Technologies	Field test	250	Residential	August 1997	Has 30-mile fiber network
Hawaiian Electric Co.	Oahu, Maui, Hawaii	Current Technologies	Field test	8 by end of 2004 Planning pilot of 500 - 1000 homes passed in 2005	Residential		Focusing on utility applications as well as consumer broadband services

Table 3. Selected BPL utility field tests and pilots (continued)

Company name	Location	Equipment vendor	Phase	Number of participants	Installation types	When began	Comments
IdaComm	Boise, ID	Amperion	Field test	37 (320 homes passed)	Residential	September 2003	Underground, suburban with fixed wireless fiber extension
IdaComm	Boise, ID	Amperion	Field test	25 (150 homes passed)	Residential		Aerial, rural/ suburban, direct fiber fed
IdaComm	Boise, ID	Ambient	Field test	6 offices, expanding to 30	Commercial		Multi-tenant and campus. Testing VOIP
Pacific Gas & Electric	Menlo Park, CA	Main.net	Field test	300 homes passed	Residential		
Penn Yan Municipal Utility	Penn Yan, NY	Amperion	Field test	60	Residential Commercial		
PEPCO	Maryland	Current Technologies	Field test	115	Residential	June 2003	
Progress Energy	Raleigh, NC	Amperion	Field test Phase 1 - technology test Phase 2 - market test	23 (45 homes passed) NA (420 homes passed)	Residential Commercial	January 2003 (to July 2003) January 2004 (to August 2004)	Evaluating future trial or commercial deployment
Rochester Public Utilities	Rochester, MN	Main.net	Field test	20 (may expand to 100)	Residential Commercial	July 2004	
Southern Telecom	Birmingham, AL	Main.net and Amperion	Field test	100 (1200 homes passed)		August 2002	

2004 witnessed the first commercial deployments of BPL. This table summarizes the status of these ventures.

Table 4. Commercial deployment status, 2004

Company name/ location	Number of participants, current (mid-2004) and forecast	Prices/ speeds	Services offered	Network build-out	System	Business model	Comments
Cinergy's Current Broadband Cincinnati, Ohio, extending into Northern Kentucky and Indiana	Current: ~400 Forecast: 20% of homes passed	$29.95/mo. for 1 Mbps $34.95/mo. for 2 Mbps $39.95 for 3 Mbps	Internet access; Voice-over-IP planned in late 2004; video on demand in 2005	Plan to pass 55,000 homes by end of 2004; extending network to 260,000 homes in 2005	Current Technologies system with HomePlug modems	Current Broadband is a joint venture of Cinergy Corporation and Current Communications.	Cinergy is an investor in Current Communications and has created an additional company, Access Broadband, to provide BPL services to electric cooperative and municipalities.
City of Manassas municipal electric utility Manassas, Virginia (in Washington, DC area)	Current: 200 from pilot Forecast: 20% of homes passed	$26.95/mo. for 286 - 800 kbps	Internet access and home page	Plan to pass about 15,000 homes and businesses by end of 2004	Main.net system tied to 60-mile fiber network	Works with third-party franchisee. City handles installation of equipment external to building; franchisee provides equipment, Internet access service, and back-office consumer services. City obtains 10% of revenue from BPL service; covers installation costs only. City and initial franchisee cancelled contract in 2004 and City seeking new partner.	Estimates cost per subscriber of $630 at 20% market penetration rate. Marketing planned after network build-out in late 2004.
PPL Telcom Headquarters: Allentown, PA. BPL service offered in Emmaus,PA and Whitehall and Hanover Townships	Current: 1,200 Forecast:NA	$34 - 40 (depending on features) 1.5 Mbps	Internet access and home page	~16,000 homes passed	Amperion and Main.Net	PPL Telcom is a subsidiary of PPL Corporation	Although marketing to consumers, this deployment is still considered a market trial. A decision on whether to offer BPL in the PPL Electric territory, which services 1.5 million customers, is expected by the end of 2004.