An Overview of Broadband communication over Power Lines

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Abstract

Broadband over power lines are Systems for carrying data on conductors used for electric power transmission. Power line communication technologies can be used for different applications ranging from home automation to internet access.

With the spread of broadband technologies in the last few years, there are yet significant areas in the world that do not have access to high speed internet, as compared with the few internet service providers in existence, the additive expenditures of laying cables and building necessary infrastructure to provide DSL in many areas most especially rural areas is too great. But if broadband is served through power lines considering the fact that it exist all over the country, there will be no need to build new infrastructure. Therefore, anywhere there is electricity, there could also be broadband.

Broadband over Power line is designed to offer an alternative means to provide high speed internet access, voice over Internet protocol (VOIP) and other broadband services, using medium and low voltage lines to reach customers and businesses by combining the principle of wireless networking, modems and Radio. Researchers and developers have created ways to transmit data over power lines into homes at speeds between 500kilobits and 3 megabits per second which is equivalent to the cable DSL (Digital Subscriber Line) and this is achieved by modifying the present power grids with specialized equipments.

With this knowledge, the broadband power line developers could partner with power companies and Internet service providers to bring broadband to everyone with access to electricity.

INTRODUCTION

The main aim of power line communication is to use the power supply system for communication purposes. Broadband over Power Line (BPL) can provide a vast coverage for broadband services. They have the potential to provide simplified in-house interconnection of computers and peripherals, and cost effective last-mile delivery of broadband data services. The power line communication systems consist of terminal devices that are plugged into to the electrical power supply network and allow data to be transmitted via the network to other terminal devices plugged into or attached to the network. The use of the existing electrical power supply network wiring reduces costs and provides convenient access to broadband interconnection between devices. This technology can however achieve 14 Mbps raw data rate and it has the potential for up to 200 Mbps. which makes it competitive with cable and DSL technology.

Historically, power line communications systems are known to be limited to low data rates typically less than 500 Kbit/s. These low data rate systems are used in applications such as the remote control of switches in domestic installations and by power supply authorities.

BPL ARCHITECTURE

The International Organization for Standardization (ISO) 7-layer Open Systems Interconnection (OSI) Communications Reference Model is defined in ISO-

7498. In this model the first layer is defined to be the Physical layer. For BPL, layer 1 is inclusive of all the in-place, power line distribution systems, the electrical power line distribution system, and the in-home electrical wiring down to the wall sockets. In some configurations, however, the power line transformers are bypassed, which excludes them from being part of the communications system architecture. A BPL Access network is usually comprised of a base station and a number of users connected via BPL modems. The modems can provide various standardized user interfaces into the BPL network. For example, a BPL modem can provide the user with a standard IEEE 802.3 (Ethernet) interface for connecting a personal computer to the network. The BPL modem connects to the power line transmission medium by means of a BPL specific (e.g., vendor proprietary) interface. Typically, BPL user interface modems provide the Medium Access Control (MAC) lower sub layer and the Logical Link Control (LLC) upper sub layer functions of the Layer 2 of the OSI model in addition to the physical layer. The modems also provide the Network Layer functionality of Layer 3 by supporting Internet Protocol (IP) routing. The manufacturers of existing BPL systems developed proprietary solutions for the MAC layer that are incompatible. The basic BPL components of injectors, repeaters, and couplers have been implemented in a variety of systems architectures, which feature different modulation techniques and designs at the Physical layer, MAC, and LLC.

The Physical layer channel impairments in BPL systems include: noise, multipath, strong channel Selectivity, and non-linear channel characteristics. To combat these impairments a number of different technologies have been employed that range from spread spectrum to Orthogonal Frequency Division Multiplexing (OFDM). BPL channel impairments reduce the available bandwidth to users, which is of most concern, because BPL access networks operate in a shared transmission medium where subscribers compete to use the same transmission resources.

BPL TECHNOLOGY

The general technical idea of Power Line Communication is to modulate a radio signal with data and send it through power lines in a band of frequencies which are not used for supplying electricity. The used frequencies and the modulation scheme have a significant influence on the efficiency and the speed of the BPL service. The modulation scheme which is used in BPL is orthogonal frequency division multiplexing (OFDM). This is a multi-carrier transmission technique which has been recently recognized as an excellent method for high speed data communication.

Orthogonal Frequency Division Multiplexing (OFDM) was first used on military high frequency radio links starting in the 1960s. It performs services at the physical layer of the OSI model.

OFDM is based on the idea of frequency division multiplexing (FDM), which is a technology that uses multiple frequencies to transmit multiple signals in parallel at the same time. However, In FDM, about fifty percent of the total spectrum is wasted due to guard bands which are needed between sub-carriers to ensure that they do not overlap.

OFDM is much more spectrally efficient than FDM. It reduces the required bandwidth by squeezing sub-carriers tightly together until they actually overlap with each other. This is accomplished by keeping the sub-carriers orthogonal in the complex domain so that they do not interfere with each other. Cyclic Prefix (CP) and variants of Phase Shift Keying (PSK) modulation techniques such as Binary PSK (BPSK), DBPSK, and DQPSK are used to eliminate the need for equalization. Forward error correction (FEC)

with data interleaving are used to reduce the effects of impulsive noise events.

OFDM has been adopted for numerous technologies including: Asymmetric Digital Subscriber Line (ADSL) services, IEEE 802.11a/g, IEEE 802.16a, Digital Audio Broadcast (DAB), Digital Terrestrial Television Broadcast, DVD in Europe, 4G, IEEE 802.11n, IEEE 802.16, and IEEE 802.20. There is no single OFDM standard that has been universally adopted. Instead, there are similar but different versions of OFDM and several proprietary implementations as various companies attempt to acquire better market penetration through improved efficiency and features.

The concept of OFDM is shown in figure below. The generation of orthogonal signals is done by using an IFFT (inverse fast Fourier transform) block. Using OFDM modulation the data is injected onto power lines.

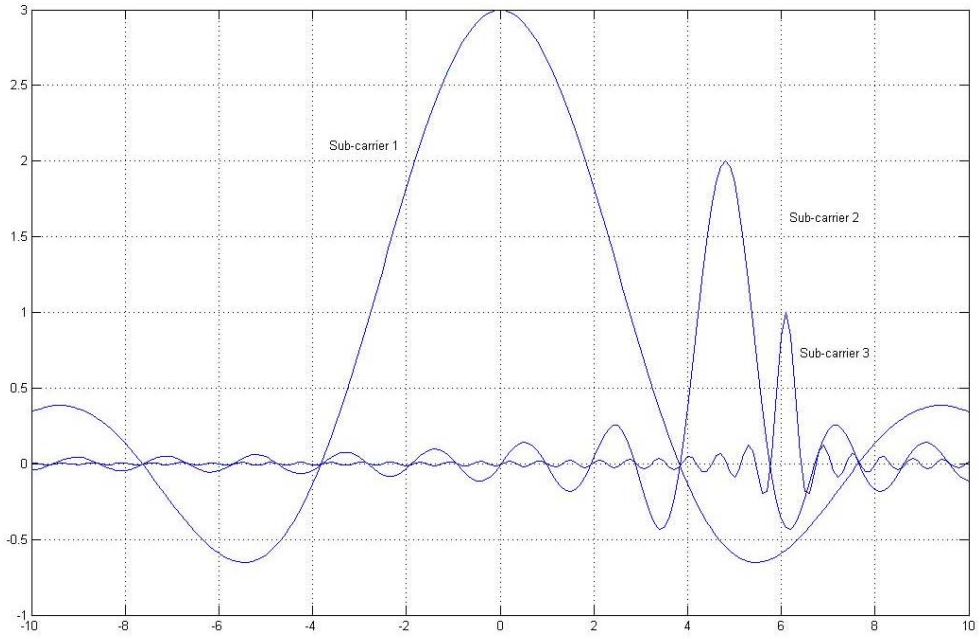

Figure1: Frequency rate of Multi-Rate OFDM

TYPES OF BPL

There are two main types of BPL, The Access BPL and the In-Home BPL.

Access BPL provides internet and other broadband services like voice (IP Telephony), Video, surveillance systems and entertainment (gaming) for homes and offices, utilities metering (electricity/water/gas) services. It is comprised of injectors which serve as the interface between internet backbone and medium voltage power lines and are also used to inject high frequency signals unto medium or low voltage power lines, Extractors used to retrieve the signals and provide the interface between end-users and medium-voltage power lines. Extractors are placed at each distribution transformer which provides low voltage electric power for a group of homes in that area. BPL signals can propagate for 1000 to 3000 feet before they become too distorted and weak. Repeaters are then used to regenerate and amplify the signals to prevent loss due to attenuation.

The Federal communication commission has defined Access BPL as: "A carrier current system installed and operated on an electric utility service as an unintentional radiator that sends radio frequency energy on frequencies between 1.705 MHz and 80 MHz over medium voltage lines or low voltage lines

to provide broadband communications and is located on the supply side of the utility service's points of interconnection with customer premises."

On the other hand, in hybrid systems a combination of power lines and wireless transmission is used. In this scenario the injected BPL signal onto medium voltage lines is extracted and delivered to the end user by using a wireless channel such as WIFI. Another scenario came up which is based on capturing a wireless signal and injecting it to low-power lines to be delivered to the end users. The Figure below shows an example of an end-to end Access BPL system while and a hybrid BPL system.

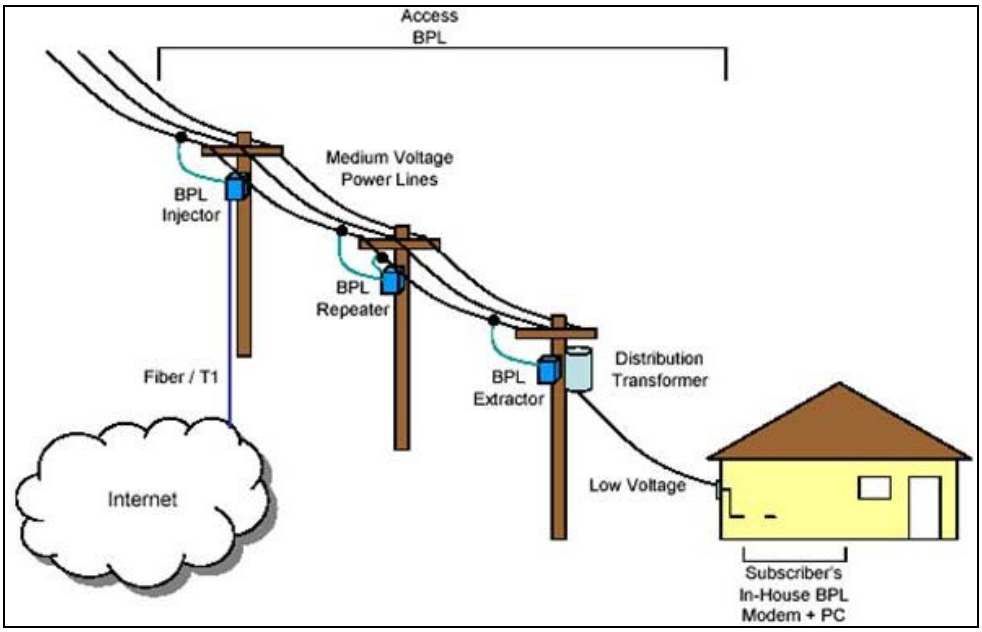

Figure 2 Showing Access BPL

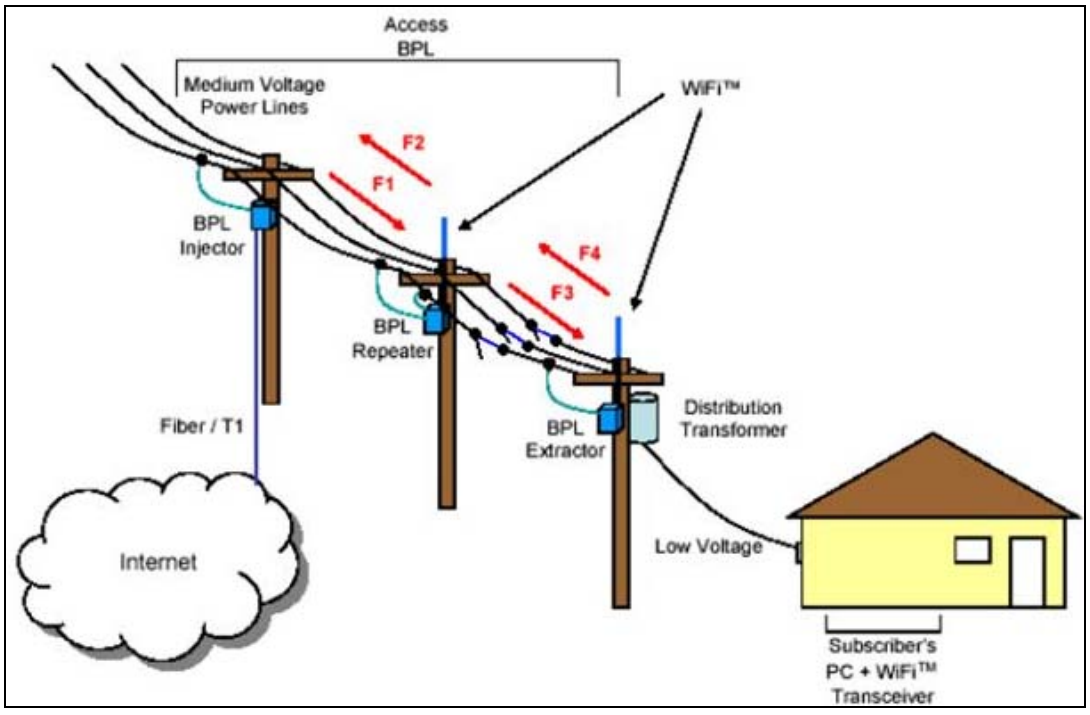

Figure 3 Showing Hybrid BPL

In-Home BPL modems utilize the existing house wiring to provide local area network (LAN) that can be used throughout the home. These applications occur within a single building with both ends of the communications link within the same building. The building might be a house, an apartment block or an office building. The path over which the transfer of data occurs within these buildings is relatively short - typically it is less than 100 m between devices.

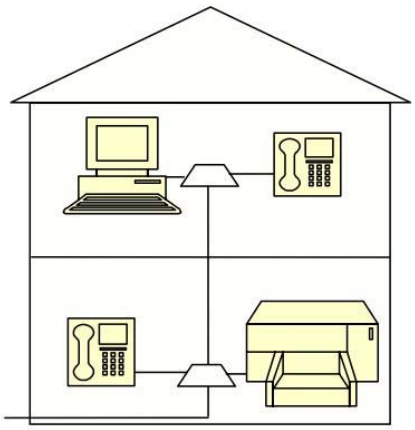

Figure 4 showing In-House Application

There are, however, some cities in overseas countries where the building density, the configuration of the AC power line network (e.g. underground) and the existing broadband data network infrastructure have been such that it has only been necessary to use outdoor power line communications systems over distances of a few hundred meters. This has allowed the use of devices with signal levels similar to in-house systems.

ADVANTAGES OF BPL

BPL has the ability to provide internet service by means of transmission line control protocol/ Internet protocol (TCP/IP) which can support voice, Data and video services the advantages therefore are;

Wide Coverage: BPL can provide wide coverage, since the power lines are already installed almost everywhere. This is advantageous especially for substations in rural areas where there is usually no communication infrastructure.

Cost: The communication network can be established quickly and cost-effectively because it utilizes the existing wires to carry the communication signals. Thus, PLC can offer substations new cost-saving methods for remotely monitoring power uses and outages.

DISADVANTAGES:

High noise sources over power lines: The power lines are noisy environments for data communications due to several noise sources such as electrical motors, power supplies, fluorescent lights and radio signal interferences .These noise sources over the power lines can result in high bit error rates during communication which severely reduces the performance of BPL.

Capacity: Power line is a shared medium and therefore, the average data rate per end user will be lower than the total capacity depending on coincident utilization, i.e., the number of users on the network at the same time and the applications they are using. Thus, possible technical problems should be comprehensively addressed with various field tests before the BPL technology is widely deployed.

Open circuit problem: Communication over the power lines is lost with devices on the side of an open circuit. This fact severely restricts the usefulness of PLC for applications especially involving switches.

Signal attenuation and distortion: In power lines, the attenuation and distortion of signals are immense due to the reasons such as physical topology of the power network and load impedance fluctuation over the power lines. In addition, there is significant signal attenuation at specific frequency bands due to wave reflection at the terminal points .Therefore, there is loss in signal due to high signal attenuation and distortion.

Security: There are some security concerns for BPL arising from the nature of power lines. Power cables are not twisted and use no shielding which means power lines produce a fair amount of Electro Magnetic Interference (EMI). Such EMI can be received via radio receivers easily. Therefore, the proper encryption techniques must be used to prevent the interception of critical data by an unauthorized person.

Lack of regulations for Broadband Power line communication: In addition to technical challenges, fundamental regulation issues of BPL should be addressed for substantial progress to be made. The limits of transmitted energy and frequencies employed for PLC should be determined in order to both provide broadband PLC and prevent the interference with already established radio signals such as mobile communications, broadcasting channels and military communications. In this respect, the Institute of Electrical and Electronics Engineers (IEEE) has develop a standard to support broadband communications over power lines.

BPL can be compared with other HFC cable and DSL technology as it is shown in table1.

Comparison	DSL	HFC Cable	BPL
Channel Media	Twisted Pair	Coaxial Cable	Electrical power lines
Availability of the physical media	More availability than cable	Limited availability	The most potentially available media
Speed	1mbps	1mbps to 6 mbps	5mbps and higher
Connection type	Not-shared	Shared	Shared
Security	More secure because of having a dedicated connection	Uses Encryption	Can use encryption
Estimated Prices per month	$27 to $49	$39 to $60	$28 to $ 39

CONCLUSION

BPL is one of the most exciting areas of innovation. It is a technology which needs further research and developments to be completely practical in a wide range. The major advantage of this technology is the already existing infrastructure for BPL even in rural areas which makes its deployment economically justified and also increases the potential coverage of the technology. On the other hand, the main issue with this technology is its interference with other radio systems. This issue has limited the deployment of BPL and to some extent has increased the cost of its deployment. However some companies claim that they have overcome the problem. The future still holds the widespread deployment of BPL.

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