Abstract

Power Line Communication uses the existing power lines within a home, building or an outdoor power distribution network to transmit data from one device to another. With a well-designed power line solution, devices should be able to communicate using the existing wiring infrastructure. This makes power line communication one of the most cost-effective means for networking devices. But as power lines were designed to carry power and not data, it takes a very sophisticated transceiver to reliably communicate over power lines. Many electrical devices connected to the power lines adversely impact the data that is being transmitted.

Keywords

Signal over power lines, narrowband/broadband PLC, home automation, signal processing

Introduction

Power-Line Communication, PLC, is type of communication possibility where the signal distribution is united with power distribution into same physical carrier. So far, in order to create a communication or to distribute the signals between electrical applications, rooms, buildings, villages, cities, counties or continents, the additional channel of signal had to be created. Weather it has been a pair of wires or optical cable, the need of new transition lines had to be created.

At present communication era, there have being developed several solutions to improve the quality, safety, speed and cost effectiveness of communication systems over distances. One of the solutions, which can be called rather “reasonable”, is Power-Line Communication. Power lines are seen as possible carriers of different type of communication signals thus increasing the communication spreading possibilities and decreasing the costs of overall wiring in buildings. This kind of bound system of power distribution and signal distribution is seen as alternative to primary and/or additional signal distribution solutions. PLC is potentially the network with the deepest capillarity in the world, since power lines are almost ubiquitous. PLC is a term used to identify technologies, equipments, applications and services aiming at providing users with communication means over existing ”power lines”.

1. History of Power-line Communication

Digital communications over power lines is an old idea that dates back to the early 1920s, when the first patents were filed in this area. Since then, utility companies around the world have successfully used this technology for remote metering and control. These applications, however, require only very low bit rates. In 1930’s, the PLC was never seriously thought of as a medium for widespread communication possibility due to its low speed, low functionality and high deployment cost.

The first technique to make use of the power line for control messages was the Ripple Control method. This is characterised by the use of low frequencies (100-900Hz) giving a low bit rate and a demand on very high transmitter power, often in the region of several 10kWs. The system provided one-way communication technology, and among the applications provided was the management of streetlights and load control.

In the mid 1980’s experiments on higher frequencies were carried out to analyse the characteristic properties of the electric grid as a medium for data transfer. Frequencies (in the range of 5 to 500kHz) were tested in which the signal to noise levels were important topics for measurements as well as the attenuation of the signal by the grid. These tests were done both in Europe and in the U.S. SCANDA (Supervisory Control and Data Acquisition) technology was developed at this time to carry out these studies.

Bi-directional communication was developed in the late 80’s and early 1990’s and the main difference between these systems and modern systems today is that much higher frequencies and a substantial reduction of the signal levels are used on today’s power grid network. Since the 1997 experiment in a school of Manchester (United Kingdom) utility and technology companies continued to experiment with higher bandwidth data transfer across the electric grids in Europe and the U.S. Recently, new technology has led to integrated circuits and modems entering the market, providing high speeds over power line infrastructure at reasonable and falling cost.
1.2. PLC opportunities

New modulation techniques supported by recent technological advances have finally enabled this medium to become a realistic and practical means of communication. Recently, new technology has led to integrated circuits and modems entering the market, providing high speeds over power line infrastructure at reasonable and falling cost. Advances in PLC technology now allows for high speed, broadband communications over medium and low voltage mediums yielding extraordinary market opportunities [5].

More recently, there has been a growing interest in the possibility of exploiting the power grid to provide broadband Internet access to residential customers. The attractive feature of this idea is the presence of a vast infrastructure in place for power distribution, and the penetration of the service could be much higher than any other wired alternative. Access to the Internet is becoming as indispensable as access to electrical power. Since devices that access the Internet are normally plugged into an electrical outlet, the unification of these two networks seems a compelling option. There is also growing interest in the prospects of reusing in-building power line cables to provide a broadband LAN within the home or office. The major advantage offered by power-line-based home networks is the availability of an existing infrastructure of wires and wall outlets, so new cable installation is averted [1].

2. How does it work

The power line is transformed into a communication network through the superposition of a low energy information signal to the power wave [1]. In order to ensure a suited coexistence and separation between the two systems, the frequency range used for communication is very far from the one used for the power wave (50 Hz in Europe): 3 to 148.5 kHz for PLC narrowband applications, from 1 to 30 MHz for PLC broadband applications. A very wide range of narrowband (some kbps) and broadband (tens or even hundreds of Mbps) applications can be provided through access and in-home PLC solutions, for the benefit of end consumers and of utilities to increase their performances and improve their service quality. PLC topology is shown on figure 1.

In figure 1, three levels of the PLC network can be differentiated, which are described below.

- **The PLC Access Network:**
  The low voltage grid serves as the access part of the telecommunication network, where PLC technology is used. The access network interconnects the PLC modems or CPEs (Customer Premises Equipment) through the low voltage power lines with the PLC Transformer Equipment (TE). The conventional electric socket becomes a connection point to telecom services. CPEs are located in the end user’s home and TEs in the MV/LV substations, which are the parts of the distribution network [5].

![Fig.1. PLC access and distribution network [5]](image)

The access network has two segments:
- The first one, from the CPE to the Repeater through the in-building power lines and in some cases through the low voltage grid.
- The second section from the Repeater through the low voltage power lines to the TE in the MV/LV substation. The powerline modem could be linked to an existing LAN on the customer’s premises, enabling several users to connect and share the high-speed connection. It is also straightforward to use the in-house electric network for setting up a home network. The conventional socket could constitute a connection point to the PLC network.
• The PLC Distribution Network
The distribution network interconnects the PLC TEs installed in the MV/LV substations. This interconnection has a wide array of possible solutions, which can be combined:
- The medium voltage power grid can connect different MV/LV substations using PLC medium voltage equipment, thus serving as a distribution network.
- Also, existing fiber optics connecting the MV/LV substations can be used in the distribution network.
• Interconnection to the Service provider’s networks (Internet, PSTN network):
At some point on the PLC Distribution Network it is necessary to interconnect to the Service provider’s networks in order to provide the Internet and telephony services. Other value added services, such as video streaming and multimedia services can also be set up in this segment of the network, and could be provided by the PLC operator directly. Depending on the services to be offered, there is a great deal of flexibility in the kind of telecom equipment needed for the interconnection. In general, switching equipment will be required for the selected solution. One of the advantages of PLC is that phone calls between the final users located in the same distribution network do not need to be switched to other telecom operators’ PSTN (public system telephony network) network. This means that the voice service is provided at no extra cost for the PLC operator when both the caller and receiver are PLC users [5].

Narrowband applications include home control, home automation, automatic meter reading, remote surveillance and control of home appliances, etc. Broadband applications include (for access PLC) Internet access, telephony, TV and (for in-home PLC) Internet access sharing, computer resource sharing and AV whole-house distribution. The asymmetric speed in the modem is generally from 256 kbit/s to 2.7 Mbit/s. In the repeater situated in the medium voltage stations, the speed from the head ends to the Internet is up to 135 Mbit/s. To connect to the Internet, utilities can use optical fiber backbone or wireless link.

Any electrical devices connected to the power line can be networked to communicate with each other. Some examples of narrowband applications include Intelligent Electricity Meters. This solution enables utilities to network all of their electricity meters and to read them from a remote central location (Automated Meter Reading). A Power Line Smart Transceiver-based meter can also enable utilities to remotely switch on/off power to a facility as well as detect any tampering of meters or unauthorized power consumption. Networked home appliances, where every device in a home, can now communicate with each other as well as with the local electricity meter. These devices could include the refrigerator, washer/dryer, AC/heating, lighting system, security system, pool heating, etcetera. As a result, utilities and consumers can monitor and manage power consumption more effectively (Demand Side Management) thereby increasing cost savings and convenience.

PLC is mainly a “last mile” technology, but several electricity suppliers are using PLC in the medium voltage grid, in addition to their plans for using it in the low voltage grid for user access. Most of the electricity suppliers already have fiber or other infrastructures that provide data to the points that connect the medium voltage rings with the low voltage lines. These points are the medium to low voltage transformers. In the worst case, the infrastructure needed to deliver power line to the customers is not more expensive than the equivalent core networks and Broadband Access Servers in the case of xDSL, with the advantage that the power grid has a higher penetration than the copper pair, and is subject to lower bit-rate errors, offering higher bandwidth. The use of PLC technology as an access technology to deliver broadband capabilities has several key benefits, mainly related to the fact that power wires are already installed in any location where information could be delivered.

2.1. Main advantage
The main advantage of PLC over other technologies is that no new cabling is required, as all the cables are already there. This technology allows a fast, simple, modular and selective deployment. Investments and operational cost are similar to xDSL and lower than in cable services. Current generation of PLC equipment offers broadband services at transmission rates equivalent to or better than other access technologies [4].

Every building, be it office, apartment or house, has the network already installed. This permits a computer, or any other kind of device, with a CPE card or adapter, to be plugged into any socket in any room and receive and send the signal. Therefore, no extra wires are required, neither in the house nor in the utility, and the user is not restricted to a few outlets in the house, as is usually the case. One may note that even if it is desired to use a wireless network within the building, this reduces to a simple matter of plugging the base station into any power socket. It can foresee the impact on a wider spectrum of applications in existing infrastructure such as traffic lights, information panels, metering systems, to vending machines and of course for home networking and industrial automation. [2] PLC is seen to be competitive solution to both narrow- and broadband information exchange solutions between different sources. PLC offers the opportunity for the PC to be integrated into the household as never before. As part of the household power grid, PCs could easily be programmed to turn off lights and control security devices.
3. Challenges associated with PLC

Like any new development, there are challenges associated with communicating over power lines. Power lines were designed to carry power and not data. The system has a number of complex issues, the primary one being that power lines are inherently a very noisy environment. Every time a device turns on or off, it introduces a pop or click into the line. Energy-saving devices, such as compact switch-mode power supplies often introduce noisy harmonics into the line. The system must be designed to deal with these natural signalling disruptions and work around them. The second major issue is signal strength and operating frequency. The system is expected to use frequencies in the 10 to 30 MHz range, which has been used for decades by amateur radio operators, as well as international shortwave broadcasters and a variety of communications systems (military, aeronautical, etc.). Power lines are unshielded and will act as antennas for the signals they carry, and have the potential to completely wipe out the usefulness of the 10 to 30 MHz range for shortwave communications purposes [4].

This means it takes a very sophisticated transceiver to reliably communicate over power lines. Many electrical devices connected to the power lines adversely impact the data that is being transmitted. The quality of the signal that is transmitted over power lines is dependent on the number and type of the electrical devices (televisions, computers, hair dryers, etc.) connected to the power lines and switched on at any given time. The quality of the signal is also dependent upon the wiring distance (not physical distance) between the transmitter and the receiver as well as the topology (wiring architecture) of the power line infrastructure in the home/building. All of the above impediments could vary between buildings, neighbourhoods, and the power grids in various countries, making a universal solution even more challenging.

Despite the enormous potential as discussed in previous sections, there is some skepticism about the technology and its commercial viability. This is due to several technical problems and regulatory issues that still remain to be solved:

- The power line channel is a very harsh and noisy transmission medium and extremely difficult to model.
- The power line channel poses unique challenges to the modem designer, such as the choice of appropriate modulation, coding, and detection schemes. Also channel modelling, medium access, and many other aspects of communications architecture is to be further developed.
- Regulatory issues naturally arise due to the unshielded nature of power line cables, which are both the source and target of electromagnetic interference.

Although there are not enough standard regarding the development, installation and security of PLC, IEEE has created IEEE P1675, IEEE P1775 and IEEE P1901. [4]

4. Comparing competitive solutions

There are a number of technologies currently available in the market that offers broadband last mile connectivity. Power line communications is now in a position to emerge as a significant competitor to the technologies such as DSL and cable modems.

Wireless communication and powerline communication both make it possible to set up a local-area network with no new wires. The advantage of using one or the other technology is not as considerable as might be supposed. The two technologies are comparable in cost, and their throughputs are comparable as well. While PLC may in some cases provide an alternative for Wireless Fidelity (WIFI), or vice versa, the two technologies also can be used cooperatively. While Power-Line Communication has the advantage of using any power socket for power and communication, it is no operable in some locations that lack power sockets. On the other hand, while wireless certainly has the mobility advantage, it has been shown that wireless signals are not able to penetrate multiple concrete walls. By combining PLC and WIFI, it is possible to reduce “dead zones” problems and also to provide another broadband access options to users. [1]

5. Vision of PLC developers

Turn each point in your electric distribution network, including every meter and transformer, into an information source to improve service quality and reduce costs. A world could be imagined where we can instantly create a home network for data, high-quality video and audio from room to room without adding a single new cable. Just plug in a device and it is instantly connected to the Internet as well as all of the entertainment appliances around the home. Homes and businesses can be provided with inexpensive broadband connections for Internet access, telephony and high-speed data transfer without the need to dig in any new cabling.

References

2. Jordi Pale, Powering the Next Generation Internet, 2003, 6power.