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Review Article

A LITERATURE REVIEW ON POWER LINE COMMUNICATION (PLC) AND THEIR APPLICATIONS

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Abstract: Power line communication (PLC) is mostly intended for carrying not merely the electric power but also the data over the conductors and as the application amends so do the need to alter the technologies, like the prerequisite to alter the technology in case of home automation and for internet access and in order to produce a adequate level of separation among them, they are ordinarily differentiated by means of frequency alteration. In general, the transformer existent at the substation generally prevents the propagation of signal. Data rates and the distance differ in accordance with power line communication standards. For the power line communication various authors or researchers presented their views and technology. In this paper, we present the literature survey on the power line communication technology.

Keywords: PLC, Channel model, Smart Grid, Multiple scheme.

Introduction: The capability offered by electrical wires to carry both the electrical power and simultaneously achieve data-transmission, referred to as power line communications (PLC), has been given lots of considerations during the last 20 years. This happens in analysis, simulations and practical implementations. The above statement is justified by (i) the number of research outputs published by researchers from universities and industry, (ii) the advancements made by standardisation organisations (SDOs), and (iii) the increasing number of PLC modems and development platforms available in the market today. [2] In Power line communication technology, medium -voltage and low-voltage electrical network is used to provide communication services. Concept of communication over power line is very old; it has a history of about hundred years [5]. In early days communication was started using very low frequencies. In 1938, Englishman Edward Davy proposed a method in which measurements to be taken of battery level of sites far from the telegraph system between Landon and

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Liverpool. [2] In 1897 a technique for remote measurement of electrical network meters communicating over electrical wiring was being patented by him. After so many years, in 1950 the first PLC system known as "Ripple Control" was being developed over low- and medium-voltage electrical networks, uses the carrier frequency between 100Hz to 1 KHz. That was single directional. In 1960, the first industrial system, named as Pulsadis, developed in France, uses the power approximately hundred kilovoltamperes (kVA). Then the first CENELEC band PLC systems appeared, extending from 3 to 148.5 kHz, and allowing bidirectional communications over the LV (low voltage) electrical network, for instance, for meter readings (remote meter readings) as well as for a great number of applications relating to the home automation field (intruder alarm, fire detection, gas leak detection, and so forth). Much less power needed to be injected, since the power was reduced to levels of approximately a hundred milliwatts. It is the result of extensive research on high band width data transmission on the power line medium. Although, the first application of power lines started low frequency levels, today powerline communication is used for high frequency applications that are also known as Broadband powerline (BPL).Today, due to increasing demand of networking in home, offices, buildings, industrial organizations etc, the power lines are considered as a medium for high speed data (>2Mbps) transmission [4,5]. PLC Broadband technology is capable of transmitting data via the electrical supply network, and therefore can extend an existing local area network or share an existing Internet connection through electric plugs with the installation of specific units. The organization of the rest of paper is done as follows: Section II discusses the earlier work done by the various researches in the field of power line communication. Section III; briefly explain the application of power line communication in wired and wireless medium. Section IV discusses the channel model of Power line communication. Section V presents the overall conclusion of this research work.

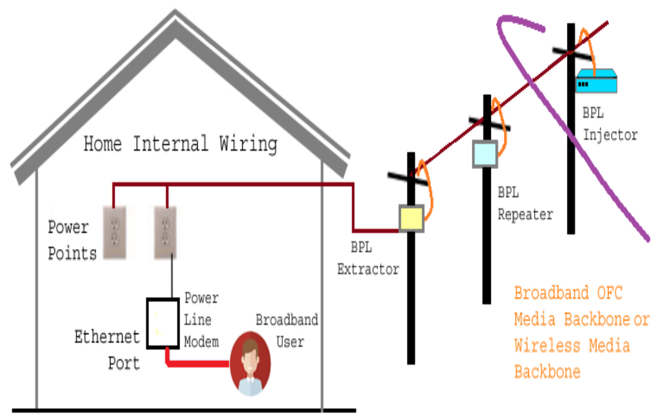

Fig. 1 Power Line communication for Home automation

Related work: *Gonçalo Cabral (2009)*, The efficient communication systems development that use like environment of transmission the net of energy (Power Line Communication) needs a detailed knowledge of the channel's estates, such as the capacity, the noise, the setting of interference and the function of transference, currently the OFDM modulation is utilized in power line communication in information transference application with high debits, due to its robustness against interferences and spectral efficiency. It was with the objective of obtaining the transfer function of the power line that the experiences presented in this report were carried out.[6] *Berger et al. (2015)*, reviews important aspects of MIMO PLC, highlighting its similarities and main differences with classical wireless MIMO. It focuses first on the peculiarities of the electrical grid, with a survey of PLC channel and noise characterization in a MIMO context. It further estimates MIMO PLC channel capacity adhering to the electromagnetic compatibility regulations currently in force. In addition, MIMO signal processing techniques most suited to PLC environments are discussed, allowing for throughput predictions. It is found that Eigen beam forming is the best choice for MIMO PLC: the full spatial diversity gain is achieved for highly attenuated channels, and maximum multiplexing gain is achieved for channels with low attenuation by utilizing all spatial streams. It is shown that upgrading from a conventional single-input–single-output PLC configuration to a 2 × 2 MIMO configuration, the throughput can be more than doubled while coverage is increased. The survey concludes with a review of specific MIMO PLC system implementations in the specifications ITU-T G.9963 and HomePlug AV2.[7]

Nassar et al. (2014), proposed a novel receiver for orthogonal frequency division multiplexing (OFDM) transmissions in impulsive noise environments. Impulsive noise arises in many modern wireless and wireline communication systems, such asWi-Fi and powerline communications, due to uncoordinated interference that is much stronger than thermal noise. We first show that the bit-error-rate optimal receiver jointly estimates the propagation channel coefficients, the noise impulses, the finite-alphabet symbols, and the unknown bits. We then propose a near-optimal yet computationally tractable approach to this joint estimation problem using loopy belief propagation. In particular, we merge the recently proposed "generalized approximate message passing" (GAMP) algorithm with the forward-backward algorithm and soft-input soft-output decoding using a "turbo approach. Numerical results indicate that the proposed receiver drastically outperforms existing receivers under impulsive noise and comes within 1 dB of the matched-filter bound. Meanwhile, with n tones, the proposed factor-graph-based receiver has only O(N log N) complexity, and it can be parallelized.[8]

Kuhn and Wittneben, evaluate the potential of PLC an analysis of the channel capacity of the power line at higher frequencies is needed. In this paper a detailed analysis of the link level channel capacity of Indoor PLC channels is presented at frequencies between 1 MHz and 30 MHz. This analysis is based on extensive measurements of the transfer function and the noise of these channels - for an office environment as well as for a home environment.[9]

Schwager et al. (2013), Power line communication, that is, using the electricity infrastructure for data transmission, is experiencing a renaissance in the context of Smart Grid. Smart Grid objectives include the integration of intermittent renewable energy sources into the electricity supply chain, securing reliable electricity delivery, and using the existing electrical infrastructure more efficiently. This paper surveys power line communications (PLCs) in the context of Smart Grid. The specifications G3-PLC, PRIME, HomePlug Green PHY, and HomePlug AV2, and the standards IEEE 1901/1901.2 and ITU-T G.hn/G.hnem are discussed.

Applications of PLCC:

As described previously, smart grid is a system which working with power grid and communication technologies on its applications. The best communication methods must be applied all the lines in power line systems to achieve the most effective distribution and transmission systems. Presently, the most important point is designing a communication system architecture that a solution for interconnected systems which can be using at the future smart grid applications [11]. Smart grid communication methods generally can be divided into wired and wireless communication methods.

A. Wired Communications:

Wired communication infrastructure can be divided into Fiber optics and PLC's. These methods' challenges and benefits investigated carefully. As described previously, Smart Grid networks can be included HANs, BANs, LANs, wired and wireless networks that connect power generation systems to end consumers in order to support a wide range of communication and control applications including demand response and distribution automation [12].

- **Fiber optics**

Substations and electricity companies which connected on the power system can reach high-speed level communicate on broadband with each other by Fiber optics technology. Despite the fact that it has a high initial setup cost disadvantage, is not affected by electromagnetic fields and wired communication has all the advantages of security through privileges are preferred by smart grid applications. It is not possible to steal information because from the privacy and security are very good about fiber cable [13].

- **Power line communication (PLC)**

Power line communication systems include all the advantages of fiber-optic cable and fast data communication along with the security of wireless communication methods. Communication is meaning that not just only internet connection, it means also every device connected to the network on power line. PLC can also control active and passivity of distribution lines. This is essential especially for substations located in countrified areas where there isn't any communication infrastructure. PLC technology usually uses for data communication medium and low voltage power lines [14]. PLC uses the existing wiring, so it is suitable for use in HAN and NAN [15], [16]. PLC technology provides high data transmission on short field.

Data communication technologies which used in PLC can be divided into BPLC and NBPLC.

1. Broadband Power Line Communication (BPLC):

BPLC uses a standard for high-speed, which has over 100 Mbps speed at the physical layer, communication assets by electric power lines. This standard [17] uses transmission frequencies below 100 MHz. It is applicable for all classes of BPLC devices, including BPLC devices used for the first-mile/last-mile connection, which under the 1500 m to the premise, to broadband services as well as BPLC devices used in buildings for LANs, smart grid applications and other data distribution which has less than 100 m distance between devices [17]. A wide area communication is available from home automation to access the internet through the power lines.

2. Narrowband Power Line Communication (NBPLC):

NBPLC technology uses standard specifies communications for low-frequency, which has less than 500 kHz frequency value, assets through alternating current and direct current electric power lines. This standard supports indoor and outdoor communications with low voltage and medium voltage power lines through incorporating transformers in both long distance rural and urban applications with transmission frequencies less than 500 kHz. Application requirements and network conditions effected to data rates will be measured to 500 kb/s. This technology can be used with grid automation applications and within HAN communications scenarios. NBPLC is used with frequency spectrum from 9 to 140 kHz for PLC applications [18]. NBPLC technology seems to be cost-effective, has more security and reliability, can appropriate to meet the bandwidth requirements of especially in large scale smart grid communication applications [19]. In the below diagram Fig. 2 seems a BPLC and NBPLC technologies use in different length of transmission lines. When decide the most suitable communication method for smart grids, which has the lowest cost, the largest gain, error detection ability of loss and leakage rates.

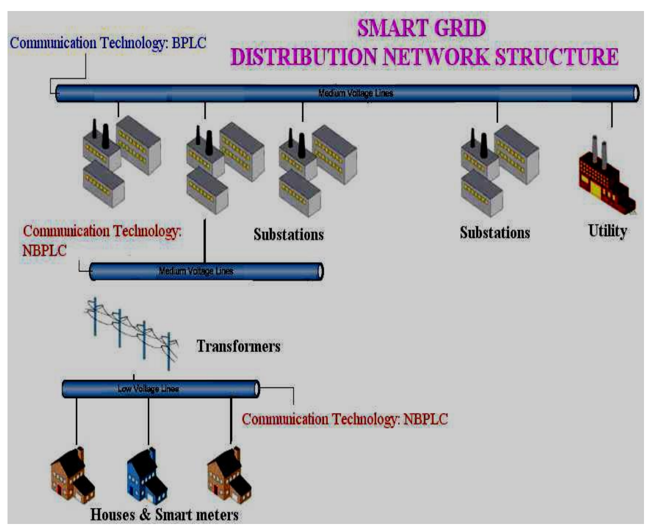

Fig. 2 Smart grid distribution network architecture

B. **Wireless Communication**

Wireless communication provides communication up to places where cannot be reached with cables but it has low data transmission rates. Also it has not a wide range transmission network, generally it is pointed to use in HAN and NAN communication with wireless communication. Wireless communication provides communication up to places where cannot be reached with cables but it has low data transmission rates. Also it has not a wide range transmission network, generally it is pointed to use in HAN and NAN communication with wireless communication.

- **Wi-Fi:**

Wireless-fidelity (Wi-Fi) is a technology which allows wireless communication of all devices that connected to it. Through the agency of Wi-Fi products, which want to connect a network, connect to LAN with Personal Access Points (PAPs). PAPs connect to wired internet network by a router and transmit receiver data signals to media as RF signals. In addition, PAPs are also used to strengthening received the RF signals from a wireless transmitter to go with increased range. All these connections are determined by IEEE 802.11a, 802.11b, 802.11g and 802.11 standards [20], [21].

- **WiMax**

WiMAX is Worldwide Interoperability for Microwave Access technology and a part of 802.16 standard series for Wireless Metropolitan Area Network (WMAN) [21]. According to this standard, it defined the wide operating range of 10-66GHz for communication infrastructure.

- **Cellular communication (satellite)**

Cellular communication uses 2G standards that defined for 1.9 GHz band and have GSM, IS-36 and IS-95 licenses. The 3G and 4G cellular technology operates on 824–894 mhz/1900 mhz spectrum range [22]. It used in the latest technology whereas LTE and LTE-A standards [23]. It has features that separate from other wireless communications technologies make it more applicable for smart grid. For example it has high volume capacity that can move huge amount of data on the smart grid applications. And the power grids are already being used it, therefore initial investment cost does not exist, so the data can be transmitted with existing infrastructure. In addition to the cellular communication system has developed infrastructure security [24].

- **Bluetooth**

Bluetooth technology operates in the 2.4 GHz ISM frequency band and it is able to transmit voice and data.

Bluetooth-enabled devices capable of transferring data at up to 24 mbps are the effective distance is about 10 to 100 meters. Bluetooth installed on small, high-performance integrated radio transceiver units. Each of these units, with addresses that are derived from the IEEE 802.11 standards and it is capable of high data transmission with low power consumption. This technology is suitable for the use of the Smart Grid LAN networks.

- **ZigBee**

ZigBee takes its name from the zigzag area of the complex structure and based on the IEEE 802.15.4 standard. The purpose of that standard helps to creation of personal wireless networks which has low infrastructure cost, slow transfer rate and low power consumption. Although ZigBee has advantages like long battery life, requested network building, it has the disadvantage of not able to provide data flow in the larger sizes as Bluetooth and Wi-Fi. It is suitable for HAN areas accepted of the smart grid.

PLC is the most cost-effective wired communication in this dissertations result, and Wireless Communication have the best applicable network structures to provide deployment of smart grid communication, they are cost-effective technologies which minimize additional investment in infrastructure [1]. But wireless communication has more disadvantages than wired communications as cost, security, capacity, etc. Therefore the wired communication is more effective for smart grid applications. In the other applications, PLC is at the introduction stage or has just started growing. So, if minimized attenuation and noise problems of PLC, the most appropriate method can be used as is evident.

Table 1 summarizes the comparison of wired and wireless.

Technology	Advantages	Disadvantages
Wired PLC	• Available Infrastructure • Cost-effective • Extensive coverage • High capacity • Security	• Signal Attenuation • High Noise
Wired-optical fibre	• Stable characteristic • High Capacity	• Cost
Wireless	• Rapid Installation • Mature Technology	• Limited Coverage • Cost • Security • Capacity • Long Delay

Channel model:

The development of reliable power line communication systems is a severe challenge for a communications engineer, having to deal with very unusual channels that were not designed for signal transmission at high frequencies. A typical power line channel in an European low-voltage network is characterized as a star-shaped bus structure, exhibiting strong branching, which considerably impairs the signal quality with a great number of reflection points. Due to such a network structure, a complex echo scenario arises, leading to a frequency-selective fading, represented as notches in the magnitude of the frequency response [1]. Also, there is a low-pass characteristic that superposes selective fading. Therefore, the length of a link becomes crucial whenever 300m are exceeded, or even a smaller length, if the network is strong branched or if higher frequencies are used (i.e., above 10 MHz).

A. Multipath Model for Power Line Channels

In the literature, there are some proposals for a PLC channel model, but their practical value is generally very limited, because most of them represent bottom-up approaches describing the behavior of a network by a large number of distributed components. In contrast to these approaches, Zimmerman and Dostert [2] presented a model that considers the communication channel as a black box and described its transfer characteristics using a very few relevant parameters. These parameters are obtained by measurements done in the channel and not derived from component properties, decreasing the complexity of the channel model. Also, Philipps [3] proposed an echo model that describes the channel impulse response as the superposition of N Dirac pulses representing the superposition of signals from N different paths. Each of these impulses is delayed by a time and is multiplied by a complex factor that represents the product of reflection and transmission factors along each echo path.

This model is a realistic approximation of the effects of selective fading and, therefore, is well suited to indoor scenarios, where the low-pass characteristic is not relevant.

B. The Noise Model

When designing a communication system over power lines, it is necessary, not only the transfer function, but also the noise model. In opposite to most of other channels that are designed from the beginning, the interference scenario in a power line channel is much more complex than typical additive white Gaussian noise. There is not only colored broadband noise, but also narrowband interference and different types of impulsive disturbance [1]. Zimmermann and Dostert defined five general classes for interferences [4]:

- Colored background noise, has relatively low power spectral density (PSD), varying with frequency. It is caused mainly by the summation of numerous noise sources with low power.
- Narrow-band noise, mostly sinusoidal signals, with modulated amplitudes caused by ingress of broadcast stations.

- Periodic impulsive noise asynchronous to the main frequency, with a repetition rate between 50 and 200 kHz, with a discrete line spectrum spaced according to the impulse repetition rate. It is caused mostly by switched power supplies.
- Periodic impulsive noise synchronous to the main frequency, with a repetition rate of 50 or 100 Hz (in Europe). The impulses have short duration and have a PSD decreasing with frequency. Also caused by power supplies, mainly by the switching of rectifier diodes.
- Asynchronous impulsive noise is caused by switching transients in the network. The impulses have durations of some microseconds up to a few milliseconds with random occurrence. The PSD of this type of noise can reach values of 50 dB above the background noise.

Conclusion:

It is obvious that the application of broadband, cable TV, smart monitoring system PLC will be a useful completion of future communication systems the channel capacity of PLC channels is promising. our measurements for PLC channels found in an apartments or in an office. PLC can enhance the capacity of wireless networks cost effectively using transmitting power Perhaps PLC as suitable for outdoor networking as for indoor networking. Because the power line is a shared medium and for outdoor PLC the capacity is frequencies can be used for the longer distances in the outdoor application. In this paper, we present the literature study of power line communication by various researchers and it it found that this is cost effective and secure which requires less instruments for the installation for wired network but for wireless it is most costly, less secure and provide more delay. So in future need to develop such approach which provide more security and bandwidth too.

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