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Smart Monitoring and Meetering Using Power Line Communication

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***Abstract*- This project deals with the implementation of power line network in the field of electricity billing. In the present scenario power line communication (PLC) is one of the economical ways of communication of data. Even though there are new methods of wireless communication methods, practically it is very much time consuming to install such a system, and also it is highly cost consuming method. But the power lines which already exist and connect every household in a particular area is more advantageous as it does not require any new installation or erection for establishment of communication channels, and thus is not a time consuming one. One biggest advantage of this system is that it can be readily implemented, unlike the other modern methods. The power line network can also be used for creating emergency response networks. This project eliminates the need for employing EB meter readers and this set of employees can be used elsewhere.**

***Index Terms*- Power line communication, metering, monitoring.**

I.INTRODUCTION

The communication flow of today is very high. Many applications are operating at high speed and a fixed connection is often preferred. If the power utilities could supply communication over the power-line to the costumers it could make a tremendous breakthrough in communications. Every household would be connected at any time and services being provided at real-time. Using the power-line as a communication medium could also be a cost-effective way compared to other systems because it uses an existing infrastructure, wires exists to every household connected to the power-line network. during the last years the use of internet has increased. if it would be possible to supply this kind of network communication over the power-line, the utilities could also become communication providers, a rapidly growing market. on the contrary to power related applications, network communications require very high bit rates and in some cases realtime responses are needed (such as video and tv). this complicates the design of a communication system but has been the focus of many researchers during the last years. systems under trial exist today that claim a bit rate of 1 mb/s, but most commercially available systems use low bit rates, about 10-100kb/s ,and provides low demanding services such as meter reading.

II. BASICS

Power-line communications systems operate by adding a modulated carrier signal to the wiring system. Different types of power-line communications use different frequency bands. Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power-line communications. we can classify the PLC channel modelling works of the current literature in four categories:

- Noise modelling. The power spectral density of the noise is very much dependent on location and time. Moreover, the measurements show that it consists of colored background noise, periodic impulse noise (synchronous and non synchronous with the main), narrowband noise and asynchronous impulsive noise. In order to model the additive noise, statistical parameters are extracted after many measurements, resulting in random variables (with specific probability density function, pdf) as modelling parameters.
- Top-down approach for transfer function modelling. This is a phenomenological approach, and we can say that in this case the transfer

function is computed with a posterior methodology, i.e. an empirical approach. An empirical model determines the modeling parameters from measurements, is easy to implement and computationally efficient, but is prone to measurement errors.

- Bottom-up approach for transfer function modelling. This is an analytical approach, and we can say that in this case the transfer function is computed with a priori methodology, i.e. a deterministic approach. A deterministic model derives the modelling parameters from a theoretical basis, is computationally more intensive in comparing to the empirical approach, but allows predicting the change in the transfer function due to any change in the network, since all parameters are properly formulated.
- Simulation tools. Some efforts have been devoted to develop simulation tools. The basic idea is to implement an algorithm based on any of the developed PLC channel models. These tools allow verifying the reliability and accuracy of the models, and sometimes having a friendly human machine interface (HMI).

Segments

For the purpose of understanding, PLC can be broadly viewed as:

1. Narrowband PLC
2. Broadband PLC

Narrowband PLC works at lower frequencies (3-500 kHz), lower data rates (up to 100s of kbps), and has longer range (up to several kilometers), which can be extended using repeaters. Broadband PLC works at higher frequencies (1.8-250 MHz), high data rates (up to 100s of Mbps) and is used in shorter-range applications.

Recently, narrowband Power Line Communication has been receiving widespread attention due to its applications in the Smart Grid. Another application that narrowband PLC has been used in is smart energy generation, particularly in micro-inverters for solar panels.

Broadband PLC, in contrast, has mainly found acceptance as a last-mile solution for Internet distribution and home networking. With its high data rates and no additional wiring, broadband PLC is seen as an exciting and effective technology for multimedia distribution within homes. This optimism in the market is reflected by the recent acquisitions of Intellon by Atheros, Coppergate by Sigma, DS2 by Marvell, and Gigle by Broadcom, all in the Home Area Networking (HAN) segment.

There is another way to classify Power Line Communication and that is:

1. PLC over AC lines
2. PLC over DC lines

While most companies are currently geared towards providing AC-PLC solutions, PLC in DC lines also has applications. Two such applications are PLC over the DC-bus in distributed energy generation, and PLC in transportation (electronic controls in airplanes, automobiles and trains). This use reduces wiring complexity, weight, and ultimately cost of communications inside vehicles. However, in this article, we will be dealing mostly with narrowband PLC over AC lines.

III.WORKING OF PLC

PLC is like any other communication technology whereby a sender modulates the data to be sent, injects it onto medium, and the receiver de-modulates the data to read it. The major difference is that PLC does not need extra cabling, it re-uses existing wiring. Considering the pervasiveness of power lines, this means with PLC, virtually all line- powered devices can be controlled or monitored!

When discussing communication technology, it is often useful to refer to the 7-layer OSI model. Some PLC chips can implement only the Physical Layer of the OSI model, while others integrate all seven layers. One could use a Digital Signal Processor (DSP) with a pure software realization of the MAC and an external PHY circuit, or an optimized System-on-Chip (SoC) solution, which includes the complete PLC – MAC and PHY. The Cypress CY8CPLCXX series is an example of the latter, with a ready-to-use Physical and Network layer, and a user-programmable application layer. Before moving on to the applications of PLC, let’s first understand the various aspects of the Physical layer by viewing it as three segments on the basis of data rate.

Table 1. PLC technology classification on the basis of data rate

	Low Data Rate	Medium Data Rate	High Data Rate
Data Rate	0-10kbps	10kbps-1Mbps	>1Mbps
Modulation	BPSK, FSK, SFSK, QAM	PSK+OFDM	PSK+OFDM
Standards	IEC 61334, ANSI/EIA 709.1, .2, UPB	PRIME, G3, P1901.2	G.hn, IEEE 1901
Frequency range	Upto 500kHz frequency	Upto 500kHz	In MHz
Applications	Contol and Command	Control and command, Voice	Broadband over powerline, home networking

A.Plc Frequency Bands.

The electronic appliances used in different powerline networks in domestic, professional and industrial environment, produces some electromagnetic emissions which interfare in with the nearest devices, that's why a soecial frequency band has been allotted for the powerline communication. The PLC signal is modulated in amplitude, frequency, or phase around a carrier frequency [1]. National or international standards organizations have set down rules that should be followed for the utilization of each frequency band, from zero to tens of gigahertz. Two frequency bands are allocated to PLC; for low bit rate powerline communication 3 to 148 kHz and for high bit rate 2 to 20 MHz.

B. Modulation Schemes.

A variety of modulation schemes can be used in PLC. Some of these are Orthogonal Frequency Division Multiplexing (OFDM), Binary Phase Shift Keying (BPSK), Frequency Shift Keying (FSK), Spread-FSK (S-FSK) and proprietary schemes too (for example Differential Code Shift Keying (DCSK) from Yitran). In the table below, BPSK, FSK, SFSK and OFDM are compared on the basis of two important criteria – bandwidth efficiency and complexity (cost). OFDM in particular offers high data rates, but requires computational horsepower to churn out Fast Fourier Transforms (FFT) and Inverse-FFT (IFFT), as required by the scheme. On the other hand, BPSK, FSK are robust and simple but offer lower data rates. The current trend is to move towards OFDM with PSK modulation (G3 and probably P1901.2). Such heavy computation will require DSP capability, whereas FSK, PSK and SFSK can be accomplished by a microcontroller.

Table 2. Comparison of Modulation Schemes

Modulation Scheme	Bandwidth efficiency	Complexity
BPSK	Medium	Low
FSK	Medium	Low
SFSK	Low	Medium
OFDM	High	High

C. Standards

Various standards have been developed in order to ensure reliable communications and inter-operability, especially for the smart grid and home networking. Examples of such standards are:

Table 3. Specifications of narrowband PLC standards

Standard	Technology	Frequency band	Bit rate (kbps)
G3-PLC	OFDM	36-90.6kHz	5.6-45
PRIME	OFDM	42-89kHz	21.4-128.6
IEEE P1901.2	OFDM	9-500kHz	Coming Soon
ANSI/EIA 709.1,.2	BPSK	86, 131kHz	3.6-5.4
KNX	S-FSK	125-140kHz	1.2
IEC61334	S-FSK	CENELEC-A	2.4

These, along with the organizations that govern them like CENELEC, FCC, ARIB, Homeplug Power Alliance specify ranges for operation of PLC. If a worldwide standard for PLC were to be established, this would have a positive impact on adoption of PLC. So far, the G3-PLC standard is touted as the most robust scheme available, and the IEEE 1901.2 working group is committed to developing a universally acceptable standard.

D. Frequencies

Different regions of the world have different frequency bands allocated to narrowband PLC. The table below summarizes the different frequencies available for narrowband PLC communication in the respective region.

Table 4. Narrowband PLC frequency ranges for various regions

Region	Regulatory Body	Frequency Band	Note
Europe	CENELEC	3-95kHz 95-125kHz 125-140kHz 140-148.5kHz	A - Energy providers B -Reserved for users C - Reserved for users, regulated CSMA access D -Reserved for users
Japan	ARIB	10-450kHz	
China	EPRI	3-90kHz 3-500kHz	Not Regulated
USA	FCC	10-490kHz	

Where:

CENELEC - European Committee for Electro technical Standardization.

ARIB – Association of Radio Industries &Businesses

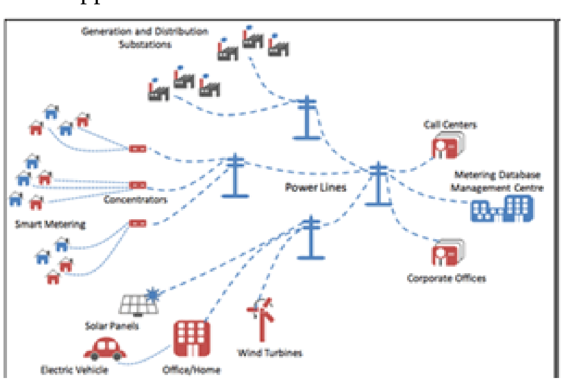
EPRI – Electric Power Research Institute
FCC – Federal Communications Commission.

IV. APPLICATIONS

Earlier, we saw that PLC is widely used in the Smart Grid and in micro-inverters. As the market gets familiar with this technology, PLC should see wider adoption in other applications like lighting (e.g. traffic light control, LED dimming), industrial (e.g. UPS communicating to a network device, irrigation control), machine-to-machine (e.g. vending machines, a hotel's reception-to-room communication), telemetry (e.g. offshore oil rigs), transport (e.g. Electronics in cars, trains and airplanes) and indeed, applications of PLC are only limited by one's creativity. In this article, we will find out a little more about PLC in energy generation and conservation markets.

A. Smart Grid.

The 'Smart Grid' is essentially modernization of the transmission and distribution aspects of the electrical grid. This intelligent power distribution infrastructure enables two-way communication between the consumers and the utility. The consumers use home networks to communicate with their smart meter, which further communicates with the utility (Advanced Metering Infrastructure-AMI). The Smart Grid definition does not stop at energy utilization; supply of energy to the grid from Distributed Generation (DG) sources such as solar and wind fall into the same category. The DG system also includes Vehicle-to-Grid (V2G) - bi- directional sharing of electricity between Electric Vehicles (EVs) and Plug-in Electric Hybrid Vehicles (PHEVs) and the electric power grid. In this article, we will talk about AMI, Smart Appliances and V2G.



B. Advanced Metering Infrastructure:

The whole measurement and collection system that includes meters at the customer site, communication networks between the customer and a service provider, such as an electric, gas, or water utility, and data reception and management systems, that make the information available to the service provider, are referred to as AMI. The Smart Meters transmit the collected data through commonly available fixed networks such as Power Line Communications (PLC), Fixed Radio Frequency (RF) networks, and public networks (e.g. landline, cellular, paging) which is aggregated by a concentrator, sent to the utility and then to a Meter Data Management System for data storage, analysis and billing (see Figure 3). Studies show that Narrowband PLC is best suited for AMI with over a 100 million NB-PLC devices installed to date.

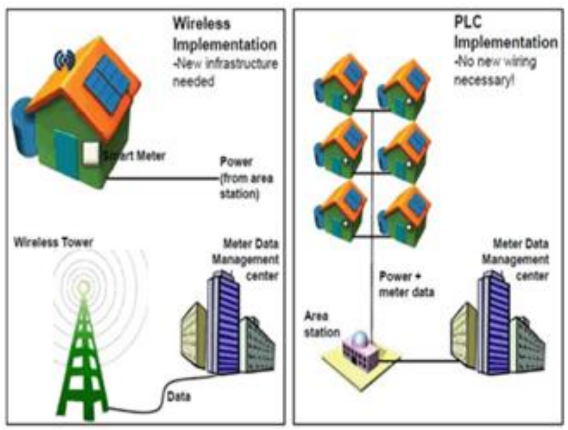
Utilities are investing billions of dollars in AMI systems. PLC solution for data transmission needs no new infrastructure, unlike wireless, as it uses the existing power cables. Power line carrier systems have long been a favorite at many utilities because it allows them to reliably move data over an infrastructure that they control. Utilities may also use public cellular as the backhaul for the AMI data due to its footprint, zero implementation cost and low monthly fee.

But on many occasions they may not be able to provide 100 percent coverage of a utility's entire customer base.

Alternatively, using wireless networks, RF solutions or PLC for data transmission will solve this issue. Rural utilities or the utilities located at challenging locations (for e.g. mountainous terrains) which are ill-served by wireless will have a difficulty communicating with the consumers. Additionally, wireless and RF solutions have reduced data rates in presence of interference like Bluetooth devices, cordless phones, concrete objects, hills and even trees. PLC can communicate to any location connected via the power line and has no line-of-sight requirement for data transmission. One of the most important considerations, due to the volume of network traffic inherent to the smart grid network, is congestion mitigation. As compared to wireless solutions based on ZigBee or Wi-Fi, PLC-based AMI have a proven track record of being better suited to avoid network congestion in emergency situations.

Another oft cited requirement is that of redundancy in the communication channel – with the ubiquity of power lines, deploying a redundant channel becomes more economical.

Various applications would include remote monitoring, outage management (which includes fault detection of MV equipment), Demand Response (i.e. managing customer consumption of electricity in response to grid supply conditions), island detection (i.e. ensuring that local grids are not being powered by the DG system when there is no power present from the electric grid) and fraud/theft detection.



C.SMART APPLIANCES

A Home Area Network (HAN) is a communication-enabled home where all electrical appliances are connected in a mesh through Wireless, RF or PLC. Electrical appliances, today, are connected in a network with two-way communication enabled, with each other as well as the substation. These Smart Appliances allow automation and control from single or multiple access points.

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