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High-speed Power Line Communications

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Abstract
This is the idea of using existing power lines for communication purposes. Power line communications (PLC) enables network communication of voice, data, and video over direct power lines. High-speed PLC involves data rates in excess of 10 Mbps. PLC has attracted a lot of attention and has become an interesting subject of research lately.

I. Introduction

Electrical power lines were originally designed to transmit power from the generators to consumers at 50 or 60 Hz. Now efforts are being made to use the same ubiquitous power grid for long-haul data communication. This is a challenging task because power lines and communication systems operate at two extremes. Power lines operate at very low frequency and high power, while communication systems operate at very high frequency and very low voltage. While early power line communication (PLC) mainly employed narrowband communications, broadband (or high-speed) PLCs have emerged in the later 1990s [1].

PLC technology allows us to use the existing power infrastructure to provide high-speed networking. For example, in the home, a PLC network can be used in sharing Internet, printers, files, games, and distributed video.PLC competes with other in-home technologies such as wireless network. A typical, simplified high-speed PLC test bed is shown in Figure 1.

II. Advantages and Limitations

PLC has the following advantages [2]:

- Low cost: The obvious advantage of PLC is the deployment costs are limited to connecting modems to the power grid.PLC provides the mass provision of local access at a minimal cost.
- No wire: There is no need of laying new cables for the purpose of communications.The power line cables are already available. The existing cable infrastructure can be used for dual purposes.
- High date: The current rate has reached 200 Mbps and the theoretical limit is higher.
- Regulation: The regulatory restrictions on PLC are relatively minimal, provided it does not cause interference.

These advantages make PLC economically viable for broadband communications networking for homes and offices. PLC has become one of the most competitive technologies to solve "the last mile" problem of broadband network.

However, the use of PLC presents several technical challenges. First, the power grid differs from nation to nation and even within a nation. Second, power-line channels are inherently harsh, noisy, and frequency-selective. They have attenuation and phase shifts. Whenever a device turns on or off, it causes a pop or click on the line. Electromagnetic compatibility problems arise when electronic devices interfere with the power lines.Third, the power-line channel has a time-varying impedance [3].Fourth, cable attenuation at frequencies of interest is usually large and repeaters maybe needed to compensate for cable losses.

Power lines are generally unshielded and will radiate as antennas. This results in electromagnetic interference (EMI) on other communication systems. To minimize EMI, PLC needs to operate with limited signal power, which in turn may reduce its data rate.

III. Power Line Characteristics

PLC uses high-voltage (HV), medium-voltage (MV), and low-voltage (LV) power grids. High-voltage lines, with voltages ranging from 110 kV to 380 kV, consist of nationwide long overhead lines. Early PLC used narrow bandwidths on high-voltage lines. Their potential for broadband communication is limited. Medium-voltage lines, with voltages ranging from 10 kV to 30kV, network at a size of large cities. These typically may involve three phase transmission of few kilometers. Low-voltage lines, with 110 V in the US or 220 V in Europe, are used in private homes or buildings. These may typically involve three phase transmission of several hundreds of meters. Medium- and low-voltage lines are used as a communication network. Utility companies want to use this network to provide value added services to customers, especially for home networking, where every room in the house has multiple power outlets.

IV.   PLC Medium Access Control

PLC employs advanced physical (PHY) and medium access control (MAC) technologies to provide a high-speed network for transmitting voice, video, and data. The PHY layer is responsible for providing a 150 Mbps information rate over noisy power line channels. The MAC layer specifies how the resources are shared among multiple users. Carrier sense multiple access with collision detection (CSMA/CD) has been proposed for PLC [4]. This is a contention based protocol in which each user listens to the line before transmitting. When it senses collision, it waits for a random amount of time before transmitting again. CSMA with collision avoidance (CSMA/CA) is used in HomePlug standards. The MAC layer is based on a hybrid mechanism combining CSMA/CA and time division multiple access (TDMA).

Standardization

In spite the advantages of PLC, the fundamental obstacle for adopting this technology is lack of national or international standards [5]. Various associations such as IEEE Communications Society, HomePlug Alliance, andPLC Forum are working on developing standards. The PLCforum (www.plcforum.org) was created in 2000 as a leading international association that represents the interests of manufacturers, energy utilities and other organizations who are interested in PLC.

The first standard for PLC is the European CENELEC EN 50065 in 1991. The HomePlug Power Alliance was formed in 2000 to provide a forum for standardizing home power line networking products and services. It consists of 65 member companies such as GE, Intel, Comcast, Motorola, Sony, and Samsung. One of the standards is HomePlug 1.0.

V.   Conclusion

PLC involves transferring satisfyingly both energy and information over the electrical power distribution grid. With the ever-increasing need for high-speed communication within the home, PLC has become a good candidate as it exploits an already existing infrastructure. PLC is becoming a viable alternative to existing wireless technology for a home network environment. Important applications of PLC include broadband Internet access, wired local area networks, smart grid applications, automatic meter reading, direct load control, and distributed energy generation. In most of these applications, data rate and the associated bandwidth requirements are modest. The field of PLC is still evolving, aiming at utilizing power lines for the transmission of data.The field still constitutes an open and attractive research area. The major barrier to the widespread adoption of PLC technology is the lack of international standards.

References

[1]   M. O. Ahmed and L. Lampe, "Power line communications for low-voltage power grid tomography," IEEE Transactions on Communications, vol. 61, no. 12, Dec. 2013, pp. 5163-5175.

[2]   H. Li, Y. Sun, and F. Jia, "Application of power line communication to the home network," *Proceedings of IEEE International Conference on Communication Technology*, 2008, pp. 521-524.

[3]   T. E. Sung and A. Bojanczyk, "Power-line communications and smart grid," in K. Iniewski (ed.), *Convergence of Mobile and Stationary Next-Generation Networks*. Hoboken, NJ: John Wiley & Sons, 2010, pp. 317-348.

[4]   A. Majumder and J. Caffery, "Power line communications: an overview," *IEEE Potentials*, vol. 23, no. 4, Oct./Nov., 2004, pp. 4-8.

[5]   S. Galli and O. Logvinov, "Recent developments in the standardization of power line communications within the IEEE," *IEEE Communications Magazine*, July 2008, pp. 64-71.

[6]   C.K. Lim et al., "Development of a test bed for high-speed power line communications," *Proceedings of PowerCon 2000*, pp. 451-456.

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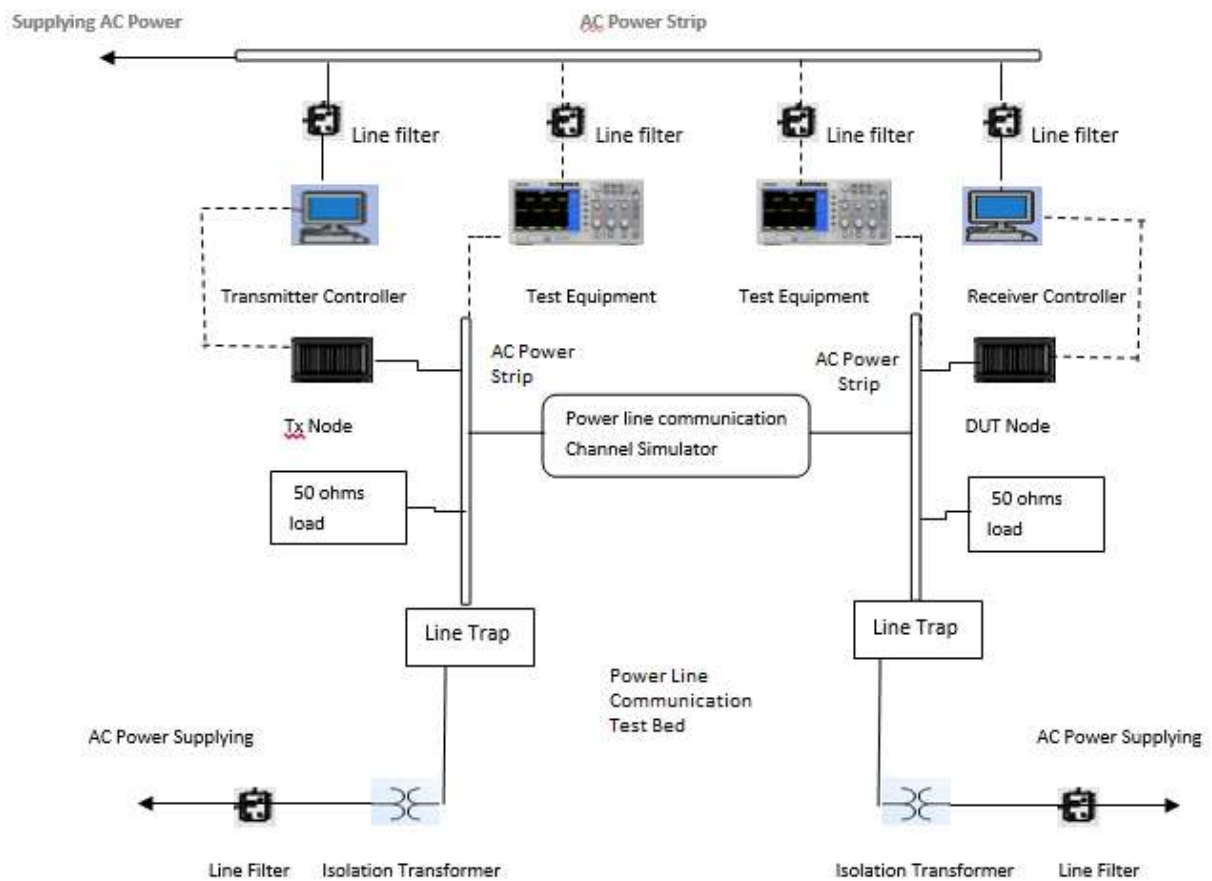
Figure 1 – A typical high-speed PLC test bed [6].