Integrated Solutions for Ubiquitous Use of Electricity and Cyber Services

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Abstract**--With the development of Broadband over Power Lines (BPL) technology, the electricity and cyber services require a new system's view of developing hybrid infrastructures with integrated services. This paper mainly explores the following three questions: a) what is state-of-the-art BPL research and applications?, b) what are the opportunities for integrated electricity and cyber services?, c) where the research should lead us and why? Existing efforts, including research issues and commercial products, solutions and services are presented in this paper. Status of the standardization in this area is also discussed. Besides the research topics, this paper points out the educational and training issues that will need to be addressed in the future by the education programs at various levels.**

Keywords--BPL, integrated cyber and electricity services, power line communication, smart grid

I. Introduction

Broadband over Power Lines (BPL), also known as power-line Internet or Powerband, generally refers to high speed (in the order of megabytes) systems that transmit information through ordinary power lines. It should not be confused with the older power line communication (PLC) technology which is different and refers to low speed systems used for automation and control [1].

Broadband over Power Line technology uses existing electric wires to provide symmetric digital communication services at multi-megabit data rates to enable services such as high-speed Internet access, Voice over Internet Protocol (VoIP), video, and in-home networking. BPL enables PCs, telephones, and multimedia devices to exchange information between one another and the Internet and other networks by simply plugging into existing electrical outlets. Comparing to regular cable or DSL connections, the ubiquitous availability of electrical outlets would allow people in remote locations to have access to the Internet with relatively small equipment investment by the utility. Additionally, BPL adds intelligence to the electric distribution system, enabling Smart Grid Services such as two-way automated meter reading (AMR), outage detection, demand side management, power quality management and much more, resulting in improved electric network reliability, security, and efficiency as well as increased customer service quality. Various BPL services have been shown in Fig. 1.

Existing BPL service providers include HomePlug Alliance, Current Technologies Ltd., Intellon, etc. HomePlug was founded in March 2000 by leading technology companies to provide a forum to create specifications for home power line networking products and services [2]. Current Technologies Ltd. deals with building and delivering BPL equipment and solutions. Some of the solutions put forth by Current are: access BPL, in building BPL, smart grid services, and VoIP [3]. Intellon Corporation designs and sells integrated circuits (ICs) for powerline communications [4].

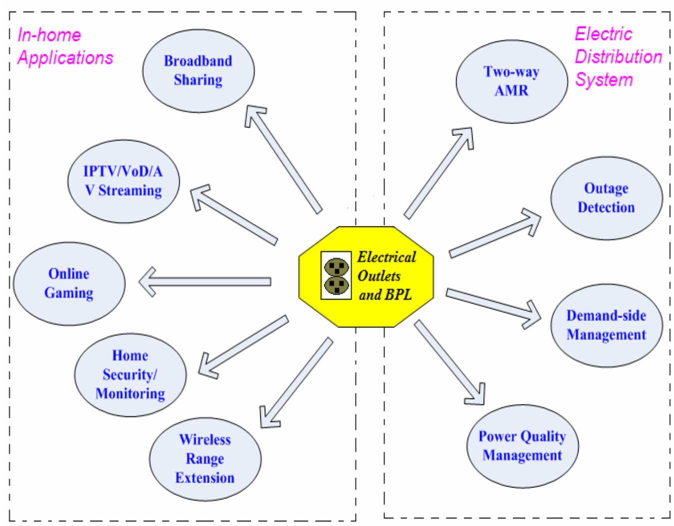

Fig. 1. Various services that can be provided using BPL technology

During the past few years, efforts are made by several organizations (including IEEE, HomePlug, OPERA and PLCforum) to develop standards to realize coexistence between various power line technologies. So far it is not clear which standard is better. There are currently three BPL related IEEE working groups. They are the IEEE P1901, IEEE P1675 and IEEE P1775. The IEEE P1901 Working Group announced in early 2007 that it has developed more than 400 requirements for the standard [5]. HomePlug Powerline Alliance has defined standards such as HomePlug 1.0, HomePlug 1.0 Turbo, HomePlug Access BPL, etc. OPERA project is divided into two phases, lasting 24 months each. A complete set of PLC access system prototypes has been developed in Phase 1 [2, 6]. Within PLCforum, manufacturers, energy utilities and other organizations share visions, problems and solutions, pushing coexistence,

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interoperability and standardization so that technology is not a market-limiting factor [7].

This paper starts with a presentation of current BPL research areas, and then continues with a discussion of the opportunities of ubiquitous integrated services. Finally, the paper proposes several future exploratory research areas. Conclusions are given at the end.

II. CURRENT RESEARCH AREAS

Broadband over Power Lines has generated much enthusiasm in the past few years because the power grid provides an infrastructure that is much more extensive and pervasive than any other wired alternative. Meanwhile, complicated problems for BPL applications also exist. For example, how to shift data from high-voltage transmission lines to lower-voltage lines through transformers without data elimination is one of the first problems engineers have to face.

Channel Modeling is one of the areas that have been investigated in detail and different models have been developed [8]. Now that standardization activities for power line communications have started within IEEE and ETSI, it is necessary to work toward the definition of both a commonly agreed upon channel model and a set of standardized transfer functions. Investigation is yet to be done to establish a set of common topologies that can be considered as representative of the majority of topologies that can be found in the field. Several noise models for the channel have also been developed and work is going on regarding optimum modulation and coding techniques to maximize error free data rates.

A. Characterizing Power Line Channel

As noted by Biglieri in [9], optimization of a data transmission scheme can only be accomplished on the basis of an accurate channel model. A lot of work has been done in this area but no consensus has been reached on the channel model, not only due to the wide variability of power-line environments but also due to the fact that an adequate understanding of the power line channel has only been recently attained. Two types of channel model have been used so far: parametric and deterministic. The parametric model is based on fundamental physical effects, which were analyzed during a great number of measurements. The relevant parameters are derived from channel measurements. Some basic ideas into this direction were first published in [10]. Arguing that the parametric model is only able to describe partially the underlying physics of power line signal propagation, the deterministic model addresses the problem of modeling the indoor power line channel by taking into consideration wiring and grounding practices [8, 11].

Besides, a highly noisy environment impairs the power-line channel. It is illustrated that for periodic impulsive noises, modeling is straightforward due to deterministic behavior. For random impulse events, a stochastic model is needed.

B. Overcoming the Constraints of Power Line Communication Channel

The power line is not suitable for high speed communication. A lot of research has gone into finding ways to make the impossible possible. The selection of a modulation scheme for PLC must account for three major factors [9, 12, 13]:

- The presence of noise and impulse disturbances which creates a relatively low SNR;
- The time-varying frequency-selective nature of the channel;
- Electromagnetic compatibility regulatory constraints which limit the transmitted power.

The papers dealing with modulation and coding techniques for the power line channel suggest different methods. Most of them agree on Orthogonal Frequency Division Multiplexing (OFDM) being best suited since the channel is frequency varying. Table I shows details about the advantages and disadvantages in implementation of three approaches: OFDM, Direct Sequence Spread Spectrum (DSSS), and Single Carrier, provided by Current Technologies.

TABLE I
COMPARISON OF COMMUNICATION SCHEMES

	OFDM	Spread Spectrum	Single Carrier
Spectral efficiency	Good	Poor	Moderate
Robustness against channel distortions	Excellent	Not Good	Good
Robustness against impulsive noise	Fair	Fair	Good
Ability to adapt to channel changes	Excellent	Fair	Good
EMC aspects	Good	Good/Excellent	Poor
Implementation costs	Fair	Poor	Poor

C. BPL Applications under Development

- *Power Line Local Area Networks (LANs)*

Power-line networks use the wires that already exist inside walls, tapping into the same circuit that moves electricity to every room in the house. Using the power lines as a LAN is in some situations more effective than other LAN alternatives. It can offer better coverage than wireless and it means fewer wires cluttering the house compared to other wired alternatives like phone or Ethernet.

A lot of research has gone into the feasibility of BPL LANs. Reference [14] discusses the market perspectives, regulatory activities and commercial applications of BPL while reference [15] takes a closer look at the technical characteristics of the BPL LANs and the underlying complexity involved in achieving it. Reference [16] gives details of how HomePlug 1.0 protocol and the Discrete Multi Tone (DMT) modulation scheme are used in some BPL networks.

Reference [17] represents theoretical and field test comparisons of the performance of 802.11 a/b wireless networking and the HomePlug 1.0 protocol addressing such issues as channel stability, reliability and Quality of Service (QoS). For example, [17] reports that the HomePlug 1.0 standard supports physical data rates of 14 Mb/s and is thus comparable to the 802.11b declared data rates (11 Mb/s). Reference [18] reports successful large scale trials in Europe. It also explains how the in-home power line LANs can be extended to the transformer using OFDM.

- *Vehicular Communication*

Without exception, vehicles have a power distribution system based on metallic conductors of some type. Researchers in [19] have attempted to take advantage of this power distribution network to perform two functions - as an infrastructure supporting both power delivery and broadband digital connectivity. They have studied the possibility of making use of existing power cables on board the NASA Orbiter (also knows as the Space Shuttle) for providing a backup LAN based on power line communications, and analyzed the wiring and grounding practices on board the Space Shuttle with the objective of quantifying the theoretical performance of a power line modem operating on the existing power line infrastructure of the Space Shuttle. In particular, the channel transfer function of a typical power line link on board the Space Shuttle is calculated and its theoretical capacity evaluated. This approach can be used in other vehicles as well. For instance in large naval vessels, it would be useful to have an alternate communication network and research is ongoing in this area.

III. OPPORTUNITIES FOR UBIQUITOUS INTEGRATED SERVICES

This section gives some examples of what may be the future applications that will rely on BPL technologies and integration of various services. As a result, three categories of solutions are envisioned as discussed below: a) Integrated solutions for ubiquitous cyber services, b) Integrated solutions for ubiquitous smart grid electricity services, c) Solutions for integrated ubiquitous cyber and electricity services. Other application considerations are also covered.

A. Ubiquitous Cyber Services

- *Distance Learning*

One example of the distance learning is continuing education, which extends to a broad spectrum of post-secondary learning activities and programs. The methods to deliver continuing education include traditional types of classroom lectures and laboratories. However, most continuing education makes heavy use of distance learning, which utilizes online/Internet delivery. Student may communicate with teachers online. And in addition to individual study, other types of distance education such as online group study, real-time online examination, even seminars and workshops through Internet can be used to facilitate learning [20].

Since only 15% of American homes have access to broadband Internet, and even fewer in rural areas, BPL can provide distance learning through ubiquitous electric lines. The electricity is available to a large percent of the homes in the USA; hence access to Internet can be significantly enhanced using the same wires. This can turn the opportunities for distance learning into the most powerful way of reaching and educating all segments of the population. With low cost of computers, this may be the most effective way of educating the nation.

- *Tele-medicine*

Another possible BPL application is Tele-medicine, or Tele-health. Tele-medicine generally refers to the use of communications and information technologies for the delivery of clinical care. It is a rapidly developing application of clinical medicine where medical information is transferred via Internet or other networks for the purpose of consulting, and sometimes remote medical procedures or examinations. Tele-medicine may be as simple as two health professionals discussing a case over the telephone, or as complex as using satellite technology and video-conferencing equipment to conduct a real-time consultation between medical specialists in two different countries.

Applications based on BPL technique can benefit patients in countries where traditional delivery of health services are affected by distance or lack of local specialist clinicians. In the case of the USA, good candidates are rural areas and areas with poor neighborhoods. Also, emergency medical services may be offered most effectively using BPL based Internet, particularly in traffic congested cities and to the elderly and handicapped that have difficulty going to a medical facility.

- *Tele-work*

BPL applications can also facilitate Tele-work. Tele-work is a work arrangement in which the daily commute to a central place of work is replaced by telecommunication links. Comparing to related terms (e.g. telecommuting, e-commuting, e-work, working at home, or working from home), Tele-work is a broader term, referring to substituting telecommunications for any form of work-related travel, thereby eliminating the distance restrictions of telecommuting [21]. A successful Tele-work program requires a management style which is based on results and not on close scrutiny of individual employees. This is referred to as management by objectives as opposed to management by observation. American Long distance Tele-work is facilitated by such tools as virtual private networks, video-conferencing, and Voice over IP. It can be efficient and useful for companies as it allows staff and workers to communicate over a large distance, saving significant amounts of travel time and cost.

As broadband Internet become available and electric lines are commonplace, more and more workers will have enough bandwidth at home, via BPL based Internet connections, to use these tools to link their home office to their corporate intranet and internal phone networks. This can change patterns of the traffic, work hours and productivity, all important aspects of the workforce management. This opportunity has not been fully explored in the past and will be brought to the full attention as a solution for creating new jobs and inventing new workforce management. With an increasing cost of fuel, tele-work is a viable alternative to everyday costly commute to and from work.

B. Ubiquitous Smart Grid Electricity Services

- *Demand Response*

It is well known that reliable operation of the electricity system necessitates a balance between power supply and load in real time. This is not an easy task given the fact that both supply and demand levels could change rapidly due to many reasons such as the generator forced outages, transmission line outages and unexpected load change. Demand Response (DR) can be defined as controlling the changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time. With the electricity demand growing faster than the supply, most of the operating margins in the electricity markets around the USA are really tight and DR may be the most effective way of maintaining market reliability and efficiency of electricity supply. For effective DR programs to be implemented [22], it is important for the participants to have access to the electricity markets, as well as to have an effective way of communicating the price signals.

Once BPL and the concept of smart grid have been introduced, great changes can take place in traditional DR services. The new architecture of DR services will involve two layers. On the first layer, customers monitor and get real-time information from market operators or utility companies. On the second layer, interaction and communication between suppliers and customers will help the overall power system to achieve better efficiency by keeping the fluctuations in demand side as close to the expected as possible [22]. Having access to the electricity markets through the Internet that comes over the same wires that provide electricity gives advantages of easy market information access and real-time price signal determinations, all in an integrated system, which are necessary for an efficient and flexible DR operation.

- *Plug-in Hybrid Electric Vehicle (PHEV)*

The applications of PHEV have been intensively explored in recent studies because of its promising future [23, 24]. There are three essential aspects in PHEV applications: a) how much power is needed in a particular Grid to Vehicle (G2V) charging event?, b) how much power PHEV can provide in Vehicle to Grid (V2G) delivery service?, and c) how to select the location of a charging station from the planning standpoint and from the point of a moment when one wants to use it in a given circumstance? Temporal and spatial dynamics affect the interactions between the electricity and transportation. Since PHEV has the ability to plug into power grid, the “on board wired or wireless Internet” based on BPL technique is practical for the communication purpose. For example, to estimate the value of selecting a charging facility at a particular location, dynamic traffic information is needed to know how many vehicles will be at that location at each point in time. The on board Internet system on a certain vehicle can provide control center with the information they needed. On the other hand, PHEV drivers can decide when and where to charge/discharge according to real-time G2V and V2G market prices provided by control center via the on board Internet system [23].

The BPL based Internet in this case becomes available through wireless interfacing means from each end-location where the electricity is available such as traffic lights, homes and offices. This connection may be used to interface the on-board vehicle BPL Intranet with the BPL-based public Internet so that the information about selection of a charging/discharging station location may be made on-line and in real time. After the location is selected, and the PHEV is connected to the electric outlet, the BPL Internet may be used to decide what services should be provided in the V2G or G2V domain. Further more, the Internet connection may be used to manage the particular session of charging/discharging the PHEV at that and other locations, including the management of an aggregation scheme which makes a fleet of PHEV work as a team. This situation is similar to the Demand Response (DR) application discussed earlier, except much more complex due to the fact that PHEV are mobile and as such represent distributed load/generation that may be activated at different locations and at different times [24].

- *Outage Management*

Traditionally, when outage happens in power system, users loose power, and they may not be able to communicate directly with utility service center for information about the reason and extent of the damage. This may become a major problem, particularly in the case of severe losses of electricity that may affect a broader region resulting in a brown-out or black-out. If the electricity has been lost due to an operating contingency, and the wires are still in tact, the Internet service that uses those wires may be maintained through out the outage. This will become perhaps the only communication option between the customers and utility company [25].

The BPL-based Internet can maintain the information exchange between users and control center during outages. Important information may be issued and updated by power system control center and transmitted through wired or wireless last mile connection to every household during blackouts. Control centre can not only communicate with users about the extent of damage of outage events, but users can also obtain notification on when the power will be resumed. If the power restoration is one block after another, users can get the exact time when their section will return to normal. If the situation is out of control, for example when extreme whether such as earthquake or hurricane happens, the national emergency center can inform users immediately to escape from dangerous areas and guide them to safe places using BPL even if the electricity is lost and no other communication means are available.

Fig. 2 summarizes several solutions for cyber and electricity services discussed in the previous sections. As may be observed, mentioned services can be used simultaneously in various combinations. While full deployment of individual services may still present research challenges, an issue of integrating the services and using them simultaneously is the research topic on its own.

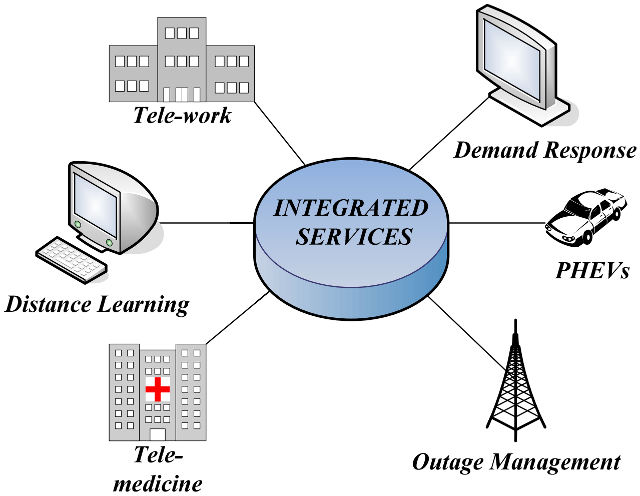

Fig. 2. Solutions for cyber and electricity services

C. Integration of Ubiquitous Cyber and Electricity Services

▪ *Market Participation for Individuals and Aggregators*

The future development of power systems will heavily depend on the ability to engage end-customers in the electricity markets. The end-customers may be engaged individually or through an aggregator. In either case, they could affect the electricity market if they are party to an agreement about particular ancillary service that is a part of the electricity market. Examples are the programs aimed at energy efficiency and peak demand control typically introduced to the market through demand response (DR) programs. Another example is where the end-customer participates in multiple markets such as carbon cap-and-trade or V2G and G2V PHEV-based markets. In any of the above mentioned situation three functions are critical to the concept to work: a) end customer has to have access to the information about the electricity market bidding options, b) end customer has to have means for providing his/her bids in a timely manner, and c) end customer has to have control means to engage itself in a particular scheme of providing/consuming power at his/her will [24].

Looking at the above mentioned three functions, it appears that BPL can be used to allow timely exchange of information as well as timely exchange of required controls regarding participation in the electricity network. Such situation asks for integrated ubiquitous cyber and electricity services. Using BPL, customer can get quick and widely available access to Internet that may be used to receive market information and provide bids. On the one hand, information provided by utility via BPL can help end customer decide to reduce his/her electricity usage during critical peak periods when prices are high without changing consumption pattern during other periods. Individual customers can also use BPL to respond to the price signals online issuing controls to engage themselves in an individual or aggregated generation, or load rejection pattern, to obtain best prices for such a service. This can indirectly optimize the power flow and reduce power congestion. Such interactions will reduce the negative impacts of generation or transmission constraints and improve overall system efficiency.

▪ *On-site Generation and Electricity Storage*

The future developments in the electricity sector will see a visible trend in the end-customer owning on-site generation and/or electricity storage. While traditionally this on-site generation such as small solar or wind energy system, with storage such as hot water tanks or batteries, have been envisioned being at a fixed location of a residential or commercial customer, with penetration of PHEV, this generation and/or storage capability may be mobile and used at different locations at different times for different purposes. The end customer owning on site generation and/or storage will have several issues to deal with: a) optimization of the use of its own generation and/or storage for personal or third party services, b) efficient control of the generation and/or storage if and when disconnected from the electricity grid (also know as the micro-grid mode), c) Efficient control of the generation/storage when connected to the electricity grid. The underlining capability in each instance is to have Internet services to communicate efficiently the required information and to have control capability to engage in the required electricity network actions [23].

The BPL infrastructure that provides both Internet services to efficiently communicate and monitoring services to sense the status of the electric grid and connect/disconnect the local generation allows end-customer to fully utilize his/her option in running and using the on-site generation and/or storage. It is interesting to note that BPL may be used to “jump” from a home to a home or a business to a business to utilize unused DSL Internet resources at a nearby location close to the home or business that experiences a slow down in the cable Internet service that they may own. This same function is functionally similar to the need to communicate for control purposes to engage aggregated on-site generators that may be available in a cluster at a residential subdivision or a business park. In both cases BPL is critical to the implementation of the concept by providing integrated ubiquitous services.

▪ *Future Home*

The power line home network makes the concept of a smart home all encompassing as can be seen from the Fig. 3 below.

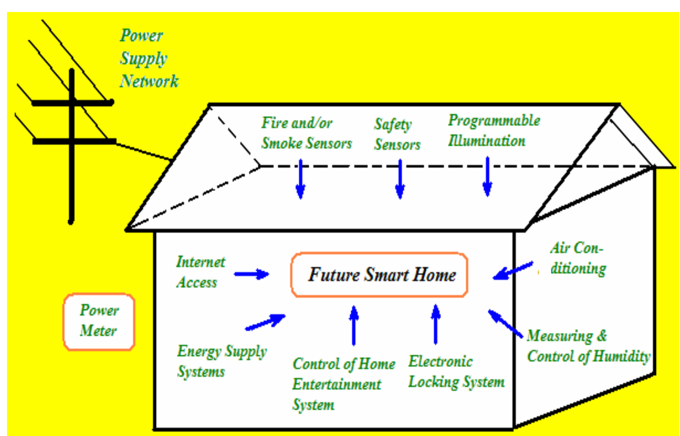

Fig. 3. Future smart home applications [6]

It not only includes the usual applications such as Internet and entertainment, but also has energy usage monitors, temperature and humidity control, safety sensors, burglar alarm system, etc.

BPL promises a bright future for bringing in great benefits and convenience to households. An integrated home system will be built by combining the operations of electric devices with wired or wireless Internet connections. Thus family members have access to use of both services, e.g. using intelligent network to control devices from microwave oven to anti-theft system, and using on board system to connect to Internet. All of this can be done even if the household only has electricity wires. All one needs to do to enjoy cyber services is plug into the nearest electrical outlet. Last but not least, BPL can introduce competition with other Internet service providers utilizing DSL or cable, which will help in bringing about more competitive pricing for cyber services.

IV. FUTURE EXPLORATORY RESEARCH

A. Communications and Internet Services

To assure the concepts proposed in this study are feasible, future research needs to address integration of different communication media and internet services. It is expected that the BPL will represent only a portion of the overall communication infrastructure used to implement proposed solutions. The rest may be implemented through wireless, fiber optic, microwave or other suitable media. This is expected due to the variety of communication infrastructures available in the utility environment. How the different infrastructures and media may be seamlessly integrated at all seven layers of the ISO Open System Interfacing still remains unresolved. In addition, how variety of Internet services that allow for high speed transmission of data, voice and picture that may be used for the ubiquitous services discussed in Section III will be implemented still remains a research topic [1].

B. Electricity Networks and Markets

For many of the concepts related to the ubiquitous electricity services further research in the electricity networks is required. Most of the research is related to the electricity market design that can fully integrated the new concept of the load as a resource or new role of the Plug-in Hybrid Electric Vehicles (PHEV) in the grid-to-vehicle (G2V) and vehicle-to-grid (V2G) operating mode. This new concept will assume that individual owners of vehicles or load resources will have an efficient way of generating aggregation partnerships so that they can participate in the electricity market as equal partners with other types of load serving entities [23]. In addition, it is expected that further research will introduce fundamental concepts for other types of electricity related markets such as carbon cap-and-trade, building-to-building (B2B), etc.

C. Interfaces between the Electricity and Transportation Networks

The research in this area is needed to get a full understanding of the benefit that may be obtained from exchanges between energy carriers used in transportation and electricity networks such as gasoline and electricity or hydrogen and electricity. In the case of the PHEV participation in the balancing of the use of energy, the interfacing between transportation and electricity is done through PHEV. Having the storage capabilities, and being able to use dual energy carriers (gasoline and electricity), PHEV can act as a mobile energy resource that can act as a load or a generator at different points in the network at different times. Study of the transportation and electricity networks aimed at modeling spatial and temporal characteristics of the PHEV agents is needed to have full understanding of the interdependencies between the two systems [14]. This understanding will help specify requirements for comprehensive BPL communication support for the new market participants.

D. Cyber Security and Electric Wire Interferences

Cyber security and interferences from open wires in the power system pose peculiar cyber security issues not widely investigated today. If the electricity and cyber services are integrated they pose a security risk since if attacked the entire fabric of the society interactions may be disturbed. Hence, the cyber security of the BPL Internet has to be of the highest quality. On the other hand, if a terrorist attack is performed this service may be one of the best means of interacting with population at large for giving instructions on what is going on and what everybody is expected to do. The open wire interference is slightly different issue; it is related to the electromagnetic interferences that communications in the spectrum may cause in other communication spectra if the energy of the communicated signal is excessive. While this area is tightly controlled by the FCC, it still remains an area of further research to better understand the impacts.

E. Education Related to Integrated Solutions for Ubiquitous Applications

Last but not least, the proposed concepts can only be pursued if the general population and researchers are fully aware of the potential. This potential needs to be communicated through various education programs from K-12 to college, as well as through continuing and community education. It is important for everybody involved in the development and potential use of the new services understands their benefits and training needed to use them, so when such services are ready that they become frequent users. Educating end-customer to take ownership of the electricity and internet services is not a trivial paradigm shift since from the time such services were invented the end-user acted as a passive user with very limited knowledge of the fundamentals. In the future, the user will have to be much more educated to be able to use the sophisticated services to its advantage. How to structure the education means and tools to facilitate the learning process in this multidisciplinary field remains a research challenge.

V. CONCLUSIONS

Broadband over Power Lines is a powerful technology still in its infancy. It promises competitive prices and great convenience for customers. More and more companies are beginning to join the investigation and testing of BPL services, which are not yet released because of technical and other obstacles.

This paper has identified current BPL research areas, and discussed the opportunities of ubiquitous integrated services. Besides, the paper has proposed several future exploratory research areas and pointed out the educational and training issues that will need to be addressed in the future.

Much more study is necessary to better understand and improve the performance of power lines for high bit rate transmission. It is still an attractive open area of research with many players interested in its growth. Though many preliminary studies have been done, BPL is yet to convince all its detractors that it is a financially safe bet and that it is here to stay.

Broadband over Power Lines has developed faster in Europe than in the United States. Part of this is due to a historical difference in power system design philosophies. On the other hand, unlike other industrialized nations, the US does not have a comprehensive strategy for BPL yet. The US Federal Communications Commission needs to notch up a strategy that allows BPL to flourish. The technology stands to benefit many people, particularly those in rural and underserved areas.

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VIII. Biographies

Ce Zheng (S'07) received his B.S. and M.S. degrees from North China Electric Power University, Beijing, China, in 2005, 2007 respectively, all in electric engineering. He has been with Texas A&M University pursuing his Ph.D. degree since August 2007. His research interests include applications in power system protection, digital simulation, power system analysis and control.

Mladen Kezunovic (S'77, M'80, SM'85, F'99) received his Dipl. Ing. Degree from the University of Sarajevo, the M.S. and Ph.D. degrees from the University of Kansas, all in electrical engineering, in 1974, 1977 and 1980, respectively. Dr. Kezunovic's industrial experience is with Westinghouse Electric Corporation in the USA (1979-1980), and the Energoinvest Company in Sarajevo (1980-1986). He also worked at the University of Sarajevo (1974-1980). He was a Visiting Associate Professor at Washington State University (1986-1987) and Visting Professor at the University of Hong Kong (Fall 2007). He has been with Texas A&M University since 1987 where he is the Eugene E. Webb Professor and Site Director of PSerc, an NSF Industry/University Cooperative Research Center. His main research interests are digital simulators and simulation methods for equipment evaluation and testing as well as application of intelligent methods to control, protection and power quality monitoring. Dr. Kezunovic is a registered professional engineer in Texas, member of CIGRE, and a Fellow of the IEEE.