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PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	POLSAR
User-Project Title	POwer Line Communications for the SmARt grid
Main-scientific field	Telecommunications
Specific-Discipline	Smart grids and communication

Lead User of the Proposing Team:

Name	Andrea M. Tonello
Phone	+39 0432 55 8042
E-mail Web site	tonello@uniud.it www.diegm.uniud.it/tonello
Nationality	Italian
Organization name, web site and address	DIEGM - University of Udine Via delle Scienze, 208 33100 - Udine – Italy Wireless and Power Line Communications Lab (WiPLi Lab)
Activity type and legal status of Organization	Higher Education Institution
Position in Organization	Aggregate Professor

Additional Users in the Proposing Team:

Name	Massimo Antoniali
Phone	+39 0432 55 8040
E-mail	massimo.antoniali@uniud.it
Nationality	Italian
Organization name, web site and address	DIEGM - University of Udine Via delle Scienze, 208 33100 - Udine – Italy Wireless and Power Line Communications Lab (WiPLi Lab)
Activity type and legal status of Organization	Higher Education Institution
Position in Organization	Ph.D. student

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Name	Fabio Versolatto
Phone	+39 0432 55 8046
E-mail	fabio.versolatto@uniud.it
Nationality	Italian
Organization name, web site and address	DIEGM - University of Udine Via delle Scienze, 208 33100 - Udine – Italy Wireless and Power Line Communications Lab (WiPLi Lab)
Activity type and legal status of Organization	Higher Education Institution
Position in Organization	Ph.D. student

Name	Salvatore D'Alessandro
Phone	+39 0432 55 8044
E-mail	salvatore.dalessandro@uniud.it
Nationality	Italian
Organization name, web site and address	DIEGM - University of Udine Via delle Scienze, 208 33100 - Udine – Italy Wireless and Power Line Communications Lab (WiPLi Lab)
Activity type and legal status of Organization	Higher Education Institution
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Date of submission	31 January 2011
Re-submission	YES_____ NO___x___
Proposed Host TA Facility	University of Stratchlyde
Starting date (proposed)	June 2011

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Summary of proposed research

The POLSAR (POwer Line Communications for the SmARt grid) project proposes a feasibility study of using power line communications (PLC) technology to remote control and coordinate different entities in the Distribution Network and Protection Laboratory (D-NAP) of the Institute for Energy and Environment at the University of Strathclyde.

The purpose is to demonstrate the possibility to overlay today's systems based on sensors, dedicated cables and wireless devices needed for digital communications among different entities and for monitoring and controlling grid activities by using PLC technology with the purpose to migrate to advanced remote control and monitoring Smart Grid applications.

The PLC channel characterization is fundamental to understand whether PLC technology can be applied with success. Theoretical performance evaluation (rate, delay, etc.) based on-site measurement campaign and tests with PLC devices already available in the market will be accomplished to identify gaps, if any, of using PLC solutions in a harsh environment such as in the D-NAP.

State-of-the-Art

In recent years we have assisted to an increased interest towards the development of advanced technologies that allow the remote control, the monitoring and performance analysis of various devices that are part of the electrical grid at the generation, transmission, distribution and customer's level. The electrical grid is evolving towards a Smart Grid, namely, a distributed complex large scale system that needs to smartly manage flows of electricity produced by big or small plants. The management of the Smart Grid requires a pervasive telecommunication infrastructure that allows a bidirectional, reliable, short and long distance communication.

Among the communication technologies, the power line communications (PLC) technology is very interesting since it allows for exploiting the grid capillarity and it can provide high performance and robustness [1]. In fact, the electrical infrastructure is pervasively deployed and its exploitation for communication purposes via PLC does not require any additional cable which lowers the costs.

The frequency bands dedicated to PLC for Smart Grid applications vary among the continents [2]. In EU, the CENELEC issued the standard EN 50065 which specifies four frequency bands to allow communications over LV distribution power line networks. The band A (3-95 kHz) is reserved exclusively to power utilities. The band B (95-125 kHz) can be used for any application. The band C (125-140 kHz) is dedicated to in-home networking systems. The band D (140-148.5 kHz) is reserved to alarm and security systems. The situation in US and Asia is different. In fact, FCC and ARIB allow PLC devices to work on the band 3-500 kHz. The PLC devices that work in the frequency bands above specified are classified as narrow band devices.

This is to distinguish them from broadband devices that work in the band 2-30 MHz and allow high rate communication typically for in-home applications such as high speed Internet connection and networking. In addition, high bandwidth and scalable functionalities of broadband power line

will provide a cost-effective possibility to migrate to advanced remote control and monitoring Smart Grid applications [3].

Although several commercial PLC devices have been developed for smart grid applications, their performance has not been deeply studied yet, or at least it is not reported in publications. It appears that such devices exhibit several gaps so that a new generation of devices has to be developed. To this end, it is very important to identify such gaps and perform an in-depth analysis of the grid characteristics in terms of propagation channel and disturbances. This will allow the understanding of the PLC channel properties, and consequently the analysis of the achievable performance and the design of transmission methods [4] that can overcome the attenuation, the frequency selectivity due to impedances mismatches and the unstationary noise sources that make the power line link a hostile media for communications.

Many works are related to PLC channel analysis and modeling. In [5], a detailed investigation of the statistical behavior of the in-home communication channel is reported. The results are obtained using a developed statistical bottom-up channel simulator that uses an in-home topology model derived from the observation of wiring practices and norms. The developed channel simulator constitutes a powerful theoretical framework for the generation and analysis of statistically representative channels with a strong connection to physical reality and close match to the results obtained in the measurements campaigns.

Measurement activity is an essential factor in the relation between theory and practice. In [6], the results of a channel measurement campaign over the LV distribution network of a large cruise ship in the band 0-50 MHz are summarized. The data have been used to study the statistics of the channel, and in particular the average channel gain, the root-mean-square delay spread, the coherence bandwidth, and link capacity, as in [5].

References

[1] http://ftp.powersystemsdesign.com/index.php?option=com_content&view=article&id=1584:plc-for-the-smart-grid&catid=110:2010-september

[2] H.C. Ferreira, et al., Power Line Communications: Theory and Applications for Narrowband and Broadband Communications over Power Lines, J. Wiley & Sons, 2010.

[3]http://pem.billion.com/download/datasheet/Datasheet-Billion-SG5000-Smart-Grid-AMI-Module.pdf

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[5] A. M. Tonello and F. Versolatto, “Bottom-Up Statistical PLC Channel Modeling-Part II: Inferring the Statistics” in *IEEE Trans. Power Del.*, pp.2356-2363, vol. 25, n. 4, Oct. 2010.

[6] M. Antoniali, A. M. Tonello, M. Lenardon and A. Qualizza, “Measurements and Analysis of PLC Channels in a Cruise Ship,” to appear in proc. of *IEEE Int. Sym. on Power Line Commun. and Its Appl. (ISPLC 2011)*, Udine, Italy, Apr. 2011.

Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest

The project POLSAR is dedicated to the analysis of performance of PLC technology for smart grid applications. This will be done by studying existing technology and performing channel characterization via measurement followed by the development of channel models. It is planned to perform a measurement campaign in the Distribution Network and Protection Laboratory (D-NAP) of the Institute for Energy and Environment at the University of Strathclyde.

Objectives

- Feasibility study of using power line communications (PLC) technology to remote control and coordinate different entities in the Distribution Network and Protection Laboratory (D-NAP) of the Institute for Energy and Environment at the University of Strathclyde.
- Evaluation of the correct functioning and performances of PLC networking devices (e.g. modems) available in the market.
- Analysis of the PLC communication channel and noise (background noise and disturbances) in order to evaluate the theoretical achievable performance for communications over the mains grid.

Expected Outcome

An overall description and characterization of the PLC channel and relevant disturbances in order to demonstrate the effective possibility to adopt PLC technology to remote control and monitor the different entities that are part of the Distribution Network and Protection Laboratory (D-NAP) of the Institute for Energy and Environment at the University of Strathclyde. It is expected that this feasibility study will open new horizons in terms of remote controlling with the elimination of existing dedicated cable infrastructures. Furthermore, it will allow to demonstrate the use of PLC for smart grid applications and attract the interest of utilities in the electrical sector.

Fundamental Scientific and Technical Value and Interest

This project is part of research activities on the Smart Grid topic. The purpose is to overlay today's systems based on sensors, dedicated cables and wireless devices needed for digital communications among different entities and for monitoring and controlling grid activities. The PLC channel characterization is fundamental to understand whether PLC technology can be applied with success. Theoretical performance evaluation (rate, delay, etc.) and tests with PLC devices already available in the market are of particular interest to identify gaps, if any, when they are used in a harsh environment such as in the D-NAP.

Plan for experimental setup

Our team will work with the University of Strathclyde to define D-NAP operative condition and requirements. Temporary test outlets will be placed near every D-NAP device in order to evaluate

the channel transfer function among all pairs of test points. Background noise and disturbances will be measured. Several different test scenarios will be implemented by changing network conditions. This will be realized by acting over real time digital simulators (RTDS) and inductive and resistive impedances included in distribution network to simulate distribution-level transformer impedances.
Channel measurement will be made in the time domain using a signal generator to inject a pilot signal into the mains grid and a digital oscilloscope to acquire the received signal. It is expected to make measurements up to 50 MHz with the use of capacitive and/or inductive couplers. Disturbances and background noise measurements will be made using an oscilloscope and a spectrum analyzer.
An intensive testing campaign of commercial PLC adapters will be done realizing a temporary local area network (LAN) placing modems in test outlets. Connection quality and transmission rate will be evaluated and compared with theoretical achievable performances obtained by channel and noise measures analysis.

It will be desirable if the University of Strathclyde provides the necessary instrumentation (signal generator, digital oscilloscope and spectrum analyzer) to perform channel and noise measurements. The identification of the suitable couplers, or their ad-hoc design, will be done by our team of University of Udine based on the knowledge acquired in other measurement campaigns. The identification of the appropriate PLC modems will be done by our team while they procurement will be discussed after approval of the proposal.

Main work breakdown

Preparatory work

1. Identification of the appropriate instruments (signal generator, digital oscilloscope and spectrum analyzer), the suitable couplers in the market or ad-hoc design of them, and PLC adapters (modems).
2. Study of the network under test.

On-site testing

1. Intensive channel and noise measurement campaign
2. Testing of commercial PLC adapters (modems).

Analysis

1. Statistical analysis of measurement results.
2. Analysis of achievable performance.

Dissemination

1. Writing of reports and technical papers to conferences and journals.

Originality and Innovation of proposed research – Broader Impact

The distribution network and protection laboratory of the Institute for Energy and Environment at the University of Strathclyde comprises a series of generators, loads, controls, protection devices, switches and various power equipments. The laboratory infrastructure control is made by sensors, dedicated Ethernet cables and wireless technology. Deployment of PLC solutions can provide significant benefits that include the delivery of high speed communication services and the support of low speed command and control application between entities without the need of dedicated cables or sensors. Very limited results are available about the characterization of the outdoor grid in terms of its ability to carry information signals. It is expected that new insights will be delivered which can pave the way to the development of innovative channel models for the test and design of PLC systems. The test campaign in the project can serve as a demonstrator that can show to utilities the benefits of the use of PLC technology.

Proposed Host TA Infrastructure/Installation – Justification

The distribution network and protection laboratory of the University of Strathclyde is the optimal scenario for testing power line solutions, both because remote control is needed and because it represents an harsh environment over which testing power line solution. In addition, the network can be configured to resemble a marine AC power system, which will allow simulating also that environment and gain new insights that can complement the ones already obtained by this research team [1].

References

[1] Project "**Sistemi di Bordo con Tecnologia Power Line**" supported by RINAVE Consorzio per l'Alta Ricerca Navale.

Synergy with ongoing research

The WiPLi Lab is involved in the **FP7 Integrated project OMEGA**, the Home Gigabit Access networks project. In this project channel characterization and modeling has been performed for LV in-home networks. Exchange of information and lessons learnt will be possible between the two projects.

The WiPLi Lab has recently submitted a proposal to the **FP7 EU-Brasialian call**. The collaborative project entitled SMARTPLC is about the design of a new family of PLC devices for the access part of the smart grid. Also the University of Strathclyde is among the partners. Therefore, it is expected that POLSAR will allow to strengthen the collaboration.

Dissemination – Exploitation of results

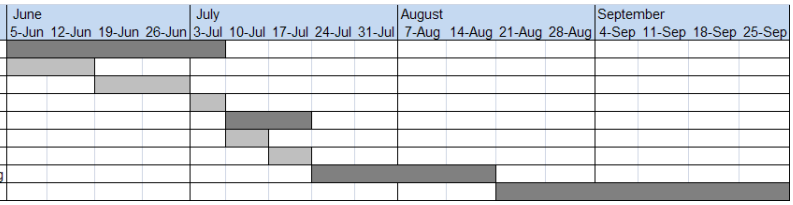
Dissemination will be implemented through some coauthored papers for journal or conference publication. Reports will also be written and possibly made publically available.

Exploitation of the results can be done by the involvement and the transfer of knowledge to utilities. If new solutions will be found, patent applications are also envisioned.

Time schedule

The project will last 4 months. One visit to the D-NAP facility is planned at the University of Stratchlyde. The use of the laboratory facility will be of 10 working days and will involve 3 people from our team.

ID	Task	Task Name	Start	Finish
1	1	Preparatory work	5-Jun	10-Jul
2		Identification of instrumentation, couplers and PLC devices		
3		Study of network under test		
4		Test points placement		
5		On-site testing	10-Jul	24-Jul
6		Channel and noise measurement		
6		PLC modems test		
6		Analysis	24-Jul	21-Aug
6		Dissemination	21-Aug	2-Oct



Description of the proposing team

DIEGM - Dipartimento di Ingegneria Elettrica, Gestionale e Meccanica – WiPLi LAB

The University of Udine comprises 10 faculties, more than 16.500 students enrolled in undergraduate and graduate programs, and offers 19 doctoral schools in various fields. It has been recently ranked among the best 8 universities in Italy. The Department of Electrical, Mechanical and Management Engineering (DIEGM) brings together scientists and teachers with homogeneous interests and with an interdisciplinary engineering experience. It employs about 100 faculty and research members. A Ph.D. program in information and industrial engineering is coordinated by the department.

Research is conducted in micro-electronics, electromagnetic fields and compatibility, antenna design and propagation, computer networks, signal processing, and telecommunications.

Within the DIEGM the laboratory of wireless and power line communications (WiPLi Lab) lead by prof. Tonello, will conduct research in the project POLSAR. The WiPLi Lab has gained significant experience in power line communication spanning from measurements [4] and channel modeling [2],[5], to physical layer design and signal processing for communications [1], to cross layer optimization [3]. It is furnished with state-of-the-art lab measurement equipments and an anechoic chamber.

Experience

The WiPLi Lab has participated to: the **EU FP5 CRAFT WIRENET** for the development of a ultra wide band system for communications over power lines; the **EU FP6 CRAFT** project **AGAVE** about the development of a navigation system in industrial environment based on ultra wide band modulation; the **EU FP7 Integrated Project OMEGA** (2008-2011) about next generation in-home gigabit networks; to two **POR/FESR EU-regional** projects (2010-2013) one of which is dedicated to PLC for smart homes and appliances; a project with the consortium RINAVE for the evaluation of the power line technology in naval environments (2008-10).

Key staff involved

Andrea M. Tonello received the doctor of engineering in electronics (cum laude) in 1996, and the doctor of research in electronics and telecommunications in 2002 (both from the University of Padova, Italy). In February 1997 he joined as a member of the technical staff Bell Labs – Lucent Technologies where he worked on the development of base-band algorithms for cellular handsets first in Holmdel, NJ, and then with the Philips/Lucent Consumer Products Division in Piscataway, NJ. From September 1997 to December 2002 he was with the Bell Labs Advanced Wireless Technology Laboratory, Whippany, NJ. He was promoted in 2002 to Technical Manager, and was appointed Managing Director of Bell Labs, Italy. He has conducted research on wireless and he has been responsible for fostering research initiatives with industrial and academic institutions. He has also been involved in the standardization activity for the evolution of the IS-136 TDMA technology within UWCC and TIA.

On January 2003 he joined the UNIUD, where he is currently an Aggregate Professor. He is the founder of the Wireless and Power Line Communication Lab. He has been the scientific responsible of a number of national an EU projects.

Dr. Tonello received several two best papers (about PLC) awards, a Lucent Bell Labs recognition of excellence award in 1999 and Royal Academy of Engineering Distinguished Visiting Fellowship to visit the University of Strathclyde in 2010 to carry out research on PLC and the smart grid. He is the author/coauthor of more than 100 papers, standard contributions and holds 6 patents.

He is the Vice Chair elected of the IEEE ComSoc Technical Committee on Power Line Communications, an associate editor ff IEEE transactions on vehicular technology, he is in the editorial board of ISRN Communications and Networking.

He has been the chair of the Workshop on PLC in 2009, the TPC Co-chair of the IEEE International Symposium on Power Line Communications (ISPLC) 2007, and he is the general chair of IEEE ISPLC 2011.

References

[1] A. M. Tonello, "Wide Band Impulse Modulation and Receiver Algorithms for Multiuser Power Line Communications," *EURASIP Journal on Advances in Signal Processing,* vol. 2007, doi:10.1155/2007/96747.

[2] A. M. Tonello and F. Versolatto, “Bottom-Up Statistical PLC Channel Modeling-Part II: Inferring the Statistics” in *IEEE Trans. Power Del.*, pp.2356-2363, vol. 25, n. 4, Oct. 2010.

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