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Program

	ISPLC- for general submissions	ISPLC- only for Invited Papers for Special Sessions
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9:45-10:15	*Coffee Break*	
10:15-11:55	M1: *Coding and signal processing for PLC*	M2: *Hybrid and emerging PLC technologies*
11:55-13:00	*Lunch*	
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10:15-11:55	T1: *Multiple access techniques and protocols*	T2: *Narrowband PLC*

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Wednesday, March 23

8:30-9:00	*Registration*	
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Sunday, March 20

Sunday, March 20, 18:00 - 21:00

Registration & Welcome Reception

5 min walking distance from the University)
Room: Mühle Bottrop

Monday, March 21

Monday, March 21, 08:30 - 09:00

Registration

Rooms: Lobby, S1

Monday, March 21, 09:00 - 09:15

Welcome of Conference Chair

Room: H2
Chair: Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

Monday, March 21, 09:15 - 09:45

K1: Devolo's High-Performance Access PLC Solutions for Smart-Grid Applications

Anil Mengi: Director Strategic Positioning at devolo AG

Room: H2

09:15 ***Devolo's High-Performance Access PLC Solutions for Smart-Grid Applications***

Anil Mengi (Devolo AG, Germany)

One of the core tasks when setting up an intelligent network is providing data communication. Reliable data communication ensures successful network operation not only in a smart metering scenario but also in network status monitoring, controlling renewable energy facilities and integrating electric charging station. As a global PLC market leader with over 28 million products sold, devolo has one of the world's largest development teams in the PLC field. In this talk, access PLC applications will be presented and discussed. Experimental and field results conducted in Germany will also be provided.

Monday, March 21, 09:45 - 10:15

Coffee Break

Room: Lobby

Monday, March 21, 10:15 - 11:55

M1: Coding and signal processing for PLC

Room: H1

Chair: José Antonio Cortés (Universidad de Málaga, Spain)

10:15 ***Asynchronous Impulsive Noise Mitigation Based on Subspace Support Estimation for PLC Systems***

Deep Shrestha (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Spain); Xavier Mestre and Miquel Payaró (CTTC, Spain)

In this paper, an asynchronous impulsive noise mitigation algorithm is proposed for power line communication (PLC) systems. There have been many studies done and proposals being made to mitigate asynchronous impulsive noise to enable PLC, e.g., in smart grid applications. Most of the schemes proposed so far are based on non-linear methods such as: clipping and nulling. Even though these non-linear schemes reduce bit error rate (BER) by a significant amount, we will show that our proposed scheme outperforms those non-linear algorithms. The performance improvement of our proposed algorithm over such schemes comes from the fact that, in our scheme, the identification of true locations of impulsive noise samples is very accurate, so that the reduction of the impulsive noise is only carried out at the contaminated samples of the received signal. This approach avoids typical problems encountered in clipping and nulling algorithms, where samples besides the ones containing the impulsive noise are also affected, thus creating additional distortion in the received signal. The superior performance of the proposed scheme will be demonstrated via numerical simulations.

10:35 ***SVD-based De-noising and Parametric Channel Estimation for Power Line Communication Systems***

Matthias Gay (University of Applied Sciences Mittweida, Germany); Lutz Lampe (University of British Columbia, Canada); Alexander Lampe (University of Applied Sciences Mittweida, Germany)

The frequency response of a power line communications (PLC) channel can be described quite accurately as a superposition of complex exponential functions. For this kind of signal there exist a number of methods based on the singular value decomposition (SVD) of a related Hankel matrix, that aim at either a de-noising or even a parameter estimation of the exponentials. We review these methods, extend one of them, and employ them for orthogonal frequency-division multiplexing (OFDM) based PLC channel estimation. Different from the more conventional channel estimation methods based on linear filters or time-domain sparsity, the methods we consider benefit from exploiting the parametric sparsity of the channel frequency response and are hence optimal in that sense. By means of simulation we compare their performance for PLC channels and discuss the suitability for different pilot models.

10:55 ***Narrow-Band Interference Error Correction in Coded OFDM-based PLC Systems***

Lucas Giroto de Oliveira (Federal University of Juiz de Fora & University of Duisburg-Essen, Brazil); Guilherme Colen and Moises Vidal Ribeiro (Federal University of Juiz de Fora, Brazil); Han Vinck (University of Duisburg-Essen & University of Johannesburg, Germany)

This work analyzes different error-correcting schemes for combating the effects of narrow-band interference in coded orthogonal frequency-division multiplexing-based narrowband power line communication systems. In this sense, we analyze an error-correcting scheme widely acclaimed in the literature, which is constituted by the concatenation of a Reed-Solomon (RS) code, a convolutional code and an bit interleaver, and an alternative error-correcting scheme with less computational complexity composed of an RS code concatenated with a short block code. Base on a comparative performance analysis of both error-correcting schemes in terms of bit error rate, we conclude that the alternative error-correcting scheme offers satisfactory performance in terms of bit error rate and considerable computational complexity reduction when compared to the usual one.

11:15 ***Unequal Error Protection for Impulsive Noise Channels in Power Line Communications***

Osama Mostafa (The American University in Cairo, Egypt); Karim G Seddik (American University in Cairo, Egypt); Ayman Y Elezabi (American University, Cairo, Egypt)

Communication over power lines has many application areas including smart grids, where data with different QoS may be transmitted. Power lines suffer from impulsive noise. In this paper, we present a study of power line communications with two and four priority levels of data using hierarchical QAM modulation and space-time block coding in impulsive noise with Bernoulli and Poisson arrivals. Hence, we achieve UEP on both of bit and symbol levels. Approximate closed-form expressions for the error probability are obtained for each priority level for both single carrier and OFDM in SISO and MIMO systems. The simplified expressions are used in a bit loading algorithm to provide UEP for the frequency-selective PLC channel. We conclude that single carrier modulation is preferable in the low SNR regime and OFDM is preferable at the high SNR regime. Finally, we describe three different MIMO architectures for use in PLC systems to allow more control on UEP levels.

11:35 ***Performance of LDPC Coded Modulations in Power Line Communications***

Carlo Tripodi and Gianluigi Ferrari (University of Parma, Italy); Riccardo Pighi (Selta Spa, Italy); Riccardo Raheli (University of Parma, Italy)

We discuss the performance of different coding schemes based on the use of short LDPC codes, which are suitable for the application in Power Line Communications (PLC) systems, where low latency and high spectral efficiency is requested. We identify the class of LDPC codes appropriate for this purpose in the codes used in IEEE 802.16e standard (WiMAX). We then propose different coding schemes and con- duct a performance analysis in terms of their capability of achieving the capacity in an Additive White Gaussian Noise (AWGN) channel, while keeping low the overall latency of the encoding/decoding process. We also consider the presence of bursty impulse noise, in order to investigate a typical PLC scenario. The analysis proves that WiMAX standard LDPC codes, used with proper coding schemes, achieve competitive trade-off between spectral and energy efficiency, maintaining the compatibility with the considered latency constraint. We also discuss their performance in the presence of impulse noise.

M2: Hybrid and emerging PLC technologies

Room: H2

Chair: Anil Mengi (Devolo AG, Germany)

10:15 ***Inter-Building PLC-VLC Integration Based on PSK and CSK Techniques***

Alain Richard Ndjiongue, Hendrik C Ferreira and Thokozani Shongwe (University of Johannesburg, South Africa)

This paper reports the implementation on an integration technique used to combine power line communications (PLC) and visible light communications (VLC) channels in inter-building scenarios. Phase-shift keying (PSK) is used to convey the information over the PLC link and colour shift keying (CSK) technique is used on the VLC link. The colour wheel method is exploited to map PSK symbols to colours. We define a parameter x, which represents different magnitudes of the PSK complex symbol observed over the PLC channel. x is adjusted to an optimal value to meet the requirement of the CSK design. The bit error rate (BER) is analyzed and the performance of the system is presented for multiple values of the modulus of the detected PSK symbol. A practical implementation is performed to verify the PSK-CSK mapping method. The impact of the sun rays on the red-green-blue (RGB) symbols is analysed and the interference source is highlighted.

10:35 ***Experimental Validation of a Hybrid Wireless Power Transfer - Power Line Communication System***

Sami Barmada, Marco Raugi and Mauro Tucci (University of Pisa, Italy); Marco Dionigi and Paolo Mezzanotte (University of Perugia, Italy)

In this paper the authors perform measurements and simulations of a coupled Wireless Power Transfer and Power Line Communications system: a two coils resonator system is built according to the authors' previous work and the first experimental results are here presented. The system demonstrates its potential and could be used in applications where both wireless power and data transfer are needed, such as vehicles battery charging.

10:55 ***Contactless Power Line Communications At 2.45GHz***

Arnold De Beer (University of Johannesburg, South Africa); Frank Igboamalu (University of Johanneasburg, South Africa); Ashraf Sheri and Hendrik C Ferreira (University of Johannesburg, South Africa); Han Vinck (University of Duisburg-Essen & University of

Johannesburg, Germany)
In this paper it is shown how a power line can be used to conductively carry and re-radiate 2.45GHz Wi-Fi signals over a distance. This can be useful when a conventional RF links' line-of-sight operation at 2.45GHz is obscured for example in multiple story buildings where Wi-Fi has difficulty penetrating. Commercial Wi-Fi modems were used to transfer data on a power line for up to 65m (non-energised) and up to 20m in a typical industrial energised situation. One modem was coupled to the power line, the line used as a travelling wave antenna and the second modem used in normal RF mode. This was compared to a direct RF link - where both modems were used in RF mode. Although a RF link performs better at long distances, with line of sight or few obstacles, the contactless power line configuration compared well in performance for a distance of up to 40m.

11:15 ***Enhancing Transmission Efficiency of Broadband PLC Systems with In-Band Full Duplexing***

Gautham Prasad, Lutz Lampe and Sudip Shekhar (University of British Columbia, Canada)
In this paper, we investigate the feasibility of In-Band Full-Duplexing (IBFD) for Broadband Power Line Communication (BB-PLC) systems, to potentially double the throughput and spectral efficiency. IBFD accomplishes this through simultaneous bidirectional communication over the same powerline in the same frequency band, by applying echo cancellation (EC) to suppress the interference caused by the self-transmitted signal. In light of various EC schemes employed in Digital Subscriber Lines, Ethernet, co-axial cables and recently in wireless systems, we investigate the specific requirements and constraints in BB-PLC, and present solutions for an effective IBFD implementation for such systems. We then use our simulated EC gain values to examine the overall data rate gains obtained by IBFD under different channel attenuations and PLC noise conditions, to determine if we truly obtain a 100% increase in throughput at all conditions.

11:35 ***In Band Full Duplex PLC: The Role of the Hybrid Coupler***

Federico Passerini (University of Klagenfurt, Austria); Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)
In Band Full Duplexing (IBFD) has recently become attractive for the power line communications (PLC) community. In this paper we analyze the role of the first stage of a PLCIBFD modem: the hybrid coupler. An analytical analysis of its influence on the signal transfer function is performed and some simulations using a measurement database are also included. Possible hardware implementation of a PLC hybrid coupler are finally discussed.

Monday, March 21, 11:55 - 13:00

Lunch

Room: Lobby

Monday, March 21, 13:00 - 13:30

Official Welcome / Press

Room: H2

Monday, March 21, 13:30 - 14:50

I1: IEEE 1901.2

Viet-Hung N'Guyen; Philippe Chiummiento; Gerd Bumiller

Room: H2

"A Proof of Concept on a IP-based Smart Metering Architecture Using IEEE 1901.2" (Daniel Rohrmoser: Project leader at Salzburg AG & Gerd Bumiller: Professor at Univeristy of Applied Sciences Ruhr West).
"PLC P1901.2 in Itron RIVA™ ACT Mesh Network: OPNET modeling and simulation" (Viet-Hung N'Guyen: Senior R&D engineer at Itron).
"Physical characterization of PLC communication on the FCC band. Cases studies in the environment of European cities" (Philippe Chiummiento: R&D Manager at Itron).

M3: Noise and interference mitigation

Room: H1
Chair: Riccardo Pighi (Selta Spa, Italy)

13:30 ***On the Suitability of the Middleton Class A Noise Model for Narrowband PLC***

José Antonio Cortés (Atmel Spain); Alfredo Sanz (University of Zaragoza & Atmel Spain SAU, Spain); Pedro Estopiñán (Atmel Spain, Spain); Jose-Ignacio Garcia-Nicolas (University of Zaragoza & Atmel Spain SAU, Spain)

This paper analyzes the suitability of the Middleton canonical class A distribution to model the noise amplitude in narrowband power line communications (NB-PLC). The study has been accomplished using 311 noise registers measured in the CENELEC-A band. Obtained results indicate that this model has a quite limited capability to represent the measured noise, since only 14.47% of the registers have amplitudes drawn from this distribution. Nevertheless, the analysis of these successful cases provides practical information for the utilization of the model. Hence, 56% of these cases can be adequately modeled by truncating the infinite sum in the class A probability density function (PDF) to two terms, which makes it equivalent to the Bernoulli-Gaussian model. It is also shown that the values of the impulsive index and the Gaussian to impulsive power noise ratio are inversely related.

13:50 ***On the Impact of Noise Power Estimation for Soft Information Generation in OFDM-based PLC Systems***

Hongjian Gao (China Electric Power Research Institute, P.R. China); Weilin Liu (State Grid Corporation of China, P.R. China); Kai Wan (State Grid Smart Grid Research Institute, P.R. China); Jianqi Li (China Electric Power Research Institute, P.R. China)

In this paper, a sub-optimal log probability ratio is proposed as soft decision information for the Viterbi decoding in OFDM based PLC system with differentially modulated QPSK, which requires average noise power on each subcarrier. A simple method to determine average the noise information is described. Potential narrow band interferer, which may negatively affect the quality of the soft decision information, is detected and erased. Performance evaluation by using simulated channel model and by using real field data shows that a proper consideration of frequency dependent noise power in the soft decision information can lead to a significant reduction of erroneous received packet compared to the case where a constant noise power over all subcarrier is assumed.

14:10 ***Resource Allocation in OFDM-based PLC Systems Impaired by Additive Impulsive Gaussian Noise***

Guilherme Colen (Federal University of Juiz de Fora, Brazil); Lucas Giroto de Oliveira (Federal University of Juiz de Fora & University of Duisburg-Essen, Brazil); Han Vinck (University of Duisburg-Essen & University of Johannesburg, Germany); Moises Vidal Ribeiro (Federal University of Juiz de Fora, Brazil)

This work outlines a procedure for choosing the gap from the Shannon capacity curve in order to solve resource allocation problems in orthogonal frequency-division multiplexing-based power line communication systems impaired by impulsive Gaussian noise. In this regard, we perform statistical analyses of additive impulsive Gaussian noise models in order to measure the effect of the noise information on the proposed technique. Next, we solved resource allocation problems under symbol error rate constraint to verify the correctness of the proposed technique.

14:30 ***Adaptive Threshold Based Frequency Exclusion Algorithm for Broadband PLC***

Risto Vuohtoniemi, Janne Lehtomäki and Juha-Pekka Mäkelä (University of Oulu, Finland)

Unshielded electrical cables act as antennas during PLC (Power Line Communication) communication causing unintentional interference for wireless communication. In order to control this interference, PLC systems need to stay silent on frequencies used for wireless communication. In PLC standard CENELEC EN 50561-1, these frequency exclusion requirements are partly adaptive and depend on whether the frequencies are actually used for communication. For reliable detection of the presence of wireless communication signals, we use MED-FCME LAD ACC algorithm. This algorithm is tested with actual power line measurements in the 50-52 MHz frequency range. This frequency range is reserved for radio amateur communication and is especially difficult case for signal detection due to varying power levels with SSB-modulated voice communication. The results verify that the studied method performs well, providing means for more intelligent spectrum utilization and reduction of interference levels in a broadband cognitive PLC-network.

Monday, March 21, 14:50 - 15:20

Coffee Break

Room: Lobby

Monday, March 21, 15:20 - 16:40

I2: ITU-T G.9903 (G3-PLC)

Anil Mengi; Thierry Lys; Mr. Safaei; Cédric Lavenu; Sebastian Ponzelar;

Room: H2

Chair: Anil Mengi (Devolo AG, Germany)

"G3-PLC Access Technology for the Roll-outs" (Anil Mengi: Director Strategic Positioning at Devolo AG).
"The results and outcomes of the ERDF G3-PLC deployment in France" (Thierry Lys: Technical Project Manager at ERDF).
"Field Trial on G3-PLC (CENELEC A)" (Mr. Safaei Netz Nieder Austria).
"SoGrid (G3-PLC over HV)" (Cédric Lavenu: Research Engineer at EDF R&D).
"G3-PLC EMC for the FCC Band" (Sebastian Ponzelar:university of Duisburg-Essen and Devolo AG).

M4: Broadband channel characterization and modelling

Room: H1

Chair: Cornelis J. Kikkert (James Cook University, Australia)

15:20 *Gains and Limits of MIMO Technology for Safety-Critical PLC Applications*

Leyna Sadamori (ETH Zurich, Department of Computer Science); Thomas Hunziker (Lucerne University of Applied Sciences and Arts); Stephen Dominiak (Lucerne University of Applied Sciences and Arts, Switzerland)

Many Power Line Communication (PLC) systems operate on top of multi-conductor infrastructures, which allows for the adoption of Multiple Input Multiple Output (MIMO) techniques. Current channel models for MIMO PLC do not consider terminal conditions and are focused on optimizing the average case. For safety-critical applications, however, the line terminations are important, as system performance has to be guaranteed for any conditions — including the worst case. In this paper, we present an analytical and a SPICE-simulated channel model based on transmission line theory that is capable of incorporating terminal networks. Further, we evaluate the channel capacity and compare three different systems that could be deployed in a multi-conductor environment: A Single Input Single Output (SISO) system, multiple parallel SISO systems and a MIMO system. With our channel model we show that the terminal conditions have an impact on the overall signal attenuation, but also that they affect the relative cross-talk level compared to direct channels. Although we can confirm existing findings that MIMO techniques do provide performance gains, our results show that this is only true above a certain signal-to-noise ratio (SNR). For low SNRs, these gains decrease and in worst case, the gains over a SISO system are lost. Also, parallel SISO systems do not offer robust performance gains over single SISO systems, which discourages their use for safety-critical applications.

15:40 *Random Channel Transfer Function Generation for Broadband Indoor MIMO PLC*

Kassim Khalil, Marc Gazalet, François-Xavier Coudoux, Patrick Corlay and Mohamed Gharbi (IEMN-DOAE UVHC)

Multiple-input multiple-output (MIMO) techniques have only recently been considered for broadband power-line communications (PLC). Today, large-scale measurement results on MIMO power-line channel characteristics are available. Modeling the MIMO-PLC channel is as important as it is difficult due to the large variability of PLC networks. In previous work, we proposed a MIMO random channel generator for indoor broadband PLC systems based on a single-input single-output one presented in the literature. The proposed MIMO channel generator targets the European MIMO PLC field measurements. In this paper, further explanations on the proposed model as well as new results for the channel transfer function are provided.

16:00 *Characteristics of the PLC Channel: Reciprocity, Symmetry and Port Decoupling for Impedance Matching*

Marco De Piante (University of Udine, Italy); Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)

This paper analyzes the reciprocity, symmetry and port decoupling effect in real home PLC networks. The reciprocity has an impact on the fact that the input and output ports of a PLC link are decoupled, and the study on the symmetry can explain the reason for the decoupling effect. The analysis of experimental data in the band 2-100 MHz shows that the PLC channel is reciprocal and that the input-output ports are largely decoupled. In turn, the port decoupling property implies that impedance matching at the transmitter and receiver ports can be implemented independently one from the other. That is, the choice of the receiver impedance does not have effect on the choice of the transmitter impedance and vice versa, in home broad band PLC systems.

16:20 *Analysis and Modeling of Impact of Household Loads on Broadband PLC Performance*

Hamid Bouassam (CED Science Engineering, ESTC, Lab. RITM, Hassan II University Casablanca, Morocco); Virginie Degardin (University of Lille & IEMN, France); M Rifi (ESTC-UH2C, Morocco)

In-home Power Line Communication (PLC) enables new and highly convenient networking functions without any additional cables to mains-powered devices. The development of PLC systems for internet, voice, and data services requires the knowledge of the channel in terms of attenuation, phase and noise. To characterize the channel propagation, channel transfer function can be measured or modeled. In this paper we propose a comparison between measurements and simulation results obtained with a deterministic propagation channel model, simulating in-home power network. The impedance of realistic households loads are also modeled and their impact on the transfer function of PLC channel and the communication capacity is analyzed. The coherence bandwidth and the delay spread are calculated from simulation results of the various transfer functions.

Monday, March 21, 16:40 - 17:00

Coffee Break

Room: Lobby

Monday, March 21, 17:00 - 18:00

P1: Future of CENELEC A Band

Room: H2
Chair: Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

Can we use CENELEC-A Band in the future ?

Monday, March 21, 19:00 - 21:00

TC-PLC Meeting

(8 min walking distance from the University)
Room: Rathausschänke Bottrop

Tuesday, March 22

Tuesday, March 22, 08:30 - 09:00

Registration

Rooms: Lobby, S1

Tuesday, March 22, 09:00 - 09:15

Invitation to the next ISPLC

Room: H2

Tuesday, March 22, 09:15 - 09:45

K2: G3-PLC in Germany - Practical experiences for Smart Metering

Jan-Philipp Blenk: Smart metering communication department at Vattenfall Metering Hamburg GmbH

Room: H2

09:15 *G3-PLC in Germany - Practical Experiences for Smart Metering*

In 2015 Vattenfall performed a large scale pilot of G3-PLC with an installation of nearly 1.000 modems in Berlin and Hamburg. This pilot was to answer the question, whether G3-PLC is a suitable technology for the smart meter rollout in Germany. Therefore, the specific situation, that in Germany only around 10% of the meters are remotely read, but with highest security requirements, had to be taken into account. The pilot proved G3-PLC as a reliable solution with sufficient bandwidth even in areas with a high-density of smart meters and ranges that exceeded the expectation by far.

Tuesday, March 22, 09:45 - 10:15

Coffee Break

Room: Lobby

Tuesday, March 22, 10:15 - 11:55

T1: Multiple access techniques and protocols

Room: H1

Chair: Lutz Lampe (University of British Columbia, Canada)

10:15 *Efficient Central Resource Management Algorithm for Time Slotted System with High PER*

George Hallak (University of Applied Sciences Ruhrwest, Germany); Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany); Jens Fey (Hochschule Ruhr West, Germany)

This paper presents an approach for a MAC layer design for PLC communication systems based on the cross layer design within OSI-Layer 2 included mesh-under routing capability presented in [1]. The classical stop and wait protocol to realize automatic repeat request (ARQ) as feature of the medium access control layer (MAC-Layer) was replaced by a packet to stream protocol, flexible segmentation on requirements of transmission mode and time slots with a pipelined selective repeat protocol as link-layer. This link-layer was placed above the PHY-, MAC- and routing-layer. In [1] the link-layer design is detailed described and analyzed. As results, a throughput close to the theoretical limits for packet error rates of 0% to more than 90% was presented. The introduced technology model is used in the management systems for disturbed power generators, smart meter and in many infrastructures where the devices are not only designed to communicate over a data network but also are developed to use into an internet of thinks. In this paper, we present our designed MAC protocol that avoids packet collision based on time slotted system with polling. The considered model takes into account the condition of deterministic communication behavior with ensured deliver time for commands and alarms. The proposed method reaches high efficiency even for unbalanced payload and different number of active slaves. The new designed protocol is tested in a discrete event simulation under different scenarios. The simulation results show an efficient data throughput even for channel with 20% packet error rate.

10:35 *Intraflow Network Coding on the Data Link Layer for Broadband PLC*

Ievgenii Anatolijovuch Tsokalo and Ralf J. Lehnert (Technische Universität Dresden, Germany); Frank H.P. Fitzek (Technische Universität Dresden & ComNets - Communication Networks Group, Germany)

This paper carries out a performance evaluation of network coding (NC) for power line communication (PLC) systems based on simulation and theoretical results. NC is deployed at the data link layer (DLL) where it could potentially improve the routing protocol, the MAC scheduler and the ARQ mechanisms. In this paper we focus solely on the combination of NC and ARQ mechanisms. Nevertheless, based on the G.hn standard, we are able to achieve a significant improvement in data rate and latency. We show the optimal setup of NC parameters like generation and symbol size to achieve the best performance of the ARQ mechanism in PLC systems.

10:55 *Adaptive Layer Switching for Smart Grid Applications in Power Line Communications*

Stanislav Mudriievskyi (Technische Universitaet Dresden, Germany); Ralf J. Lehnert (Technische Universität Dresden, Germany)

The ongoing changes from the conventional electrical grid towards the smart grid bring new use cases to the communication technologies. These influence the selection of the appropriate communication system according to the requirements of the smart grid applications. The power line communications (PLC) is the most native communication technology for the smart grid as it uses the same medium for energy and data transmission. In order to meet the smart grid application requirements perfectly the corresponding PLC system should be dynamically adapted. Usually an adaptation on the specific layer is done. This adaptation is dependent on a number of parameters that describe e.g. physical channel state (disturbances), logical repeater structure, number of active nodes in the network, channel access scheme. In the known PLC systems adaptation is also done at the medium access layer (MAC) layer. Typically TDMA or CSMA/CA channel access scheme or a combination of both is adapted. It is known, that both of them have their advantages and disadvantages depending on the offered traffic in the network. In this paper the mechanism of switching of the access mechanism depending on network load is proposed and investigated.

11:15 *Smart Blacklisting: a Solution to Increase Performance of Blacklisting in LOADng for Low Density Networks*

Gaston Bayot Katumba and François Van Trimpont (University of Mons, Belgium); Véronique Moeyaert (Université de Mons (UMONS) & Faculté Polytechnique, Belgium); Sébastien Bette (University of Mons - Faculty of Engineering, Belgium)

G3-PLC is emerging as an attractive communication standard for smart metering applications. This standard includes different mechanisms and protocols allowing to deal with the poor transmission performance of the power line channel. In particular, all nodes of the network can act as relay. In 2014, G3-PLC standard, the ITU-T G9903 recommendation, proposed the LOADng protocol to perform the routing. Blacklisting is a mechanism included in this protocol that deals with bad quality links by ignoring them. However, the blacklisting mechanism suffers from a lack of performance when the density of nodes is too low. Indeed, some bad quality links are the only ones possible to reach some farther nodes so that by blacklisting them, these farther nodes cannot be reached anymore. This is why a solution had to be developed in order to solve this problem. Our solution is the smart blacklisting mechanism that highly reduces the probability of blacklisting a critical link. In this work, we highlight the problem of blacklisting in low densities and compare the performance of the blacklisting and the smart blacklisting. For that purpose, we developed our own simulator in the Contiki/Cooja platform in which we have implemented the LOADng

protocol as well as the different features of G3-PLC networks. Based on our tool, we report the results we obtained for different node densities and for different link qualities with the classical blacklisting mechanism, without it and with the smart blacklisting mechanism.

11:35 *A Delay and Throughput Study of Adaptive Contention Window Based HomePlug MAC with Prioritized Traffic Classes*

Muharrem Ayar and Haniph A. Latchman (University of Florida, USA)

Power Line Communication (PLC) has become an integral part of home area networks (HANs) with increasing deployment of intelligent and connected devices. The advent of smart devices creates a heterogeneous type of network with a variety of throughput and delay sensitive applications that must coexist in the HAN. Meeting the quality of service (QoS) for various applications requires high MAC throughput, low channel access delay and prioritized channel access for certain types of data. The Medium Access Control (MAC) protocol for PLC, defined in HomePlug and IEEE 1901, exhibits significant degradation in MAC throughput and increasing channel access delay when the number of users increases. PLC MAC layer issues have received relatively modest attention of researchers compared with physical layer problems and as a result relatively little improvement in MAC throughput and delay performance has been reported over the standard IEEE 1901 protocol. This paper studies an adaptive contention window PLC MAC protocol with a view to assessing access delay performance of this modified protocol, with the throughput and prioritized traffic classes. In the adaptive protocol, each node observes the channel status and adaptively finds the optimum contention window size. Results demonstrate a significant improvement in both MAC efficiency and access delay for the highest priority class in the presence of lower priority classes. Whereas the MAC efficiency drops down to 10% in standard protocols, the proposed adaptive MAC protocol retains its efficiency at about 81% for up to 100 users. Also, the channel access delay is for the modified protocol is maintained under 200 ms for 100 users compared to more than 1000 ms for the standard HomePlug MAC.

T2: Narrowband PLC

Room: H2

Chair: Alfredo Sanz (University of Zaragoza & Atmel Spain SAU, Spain)

10:15 *Performance Assessment of OFDM-based Narrowband PLC for Advanced Metering Infrastructure*

José Antonio Cortés (Atmel Spain); Alfredo Sanz (University of Zaragoza & Atmel Spain SAU, Spain); Pedro Estopiñán (Atmel Spain, Spain); Jose-Ignacio Garcia-Nicolas (University of Zaragoza & Atmel Spain SAU, Spain)

In this paper, the performance of actual narrowband power line communications (NB-PLC) systems used in Advanced Metering Infrastructure (AMI) is assessed. The study combines bit-rates estimations obtained from channel measurements with actual frame error rates obtained in a field trial. Performance achieved in rural, semiurban and urban environments is analyzed, along with the influence of the type of cables deployed in the underlying low voltage (LV) network. The structure of an AMI is strongly dependent on the number of customers connected to the medium to low voltage (MV/LV) transformers. This number is so low in some regions of North and South America, that placing the data concentrator at the medium voltage (MV) side of the network is the most cost-effective solution. The feasibility of this solution in both the CENELEC-A and the FCC bands is investigated.

10:35 *Experimental Characterization of Outdoor Low Voltage Cables for Narrowband Power Line Communication*

Mariam Ait Ou Kharraz (EDF R&D & CentraleSupelec, France); Mohammed Serhir (Departement de Recherche en Electromagnetisme, Supelec, France); Dominique Picard, Peter Jensen, Cedric Lavenu and Alban Jeandin (EDF R&D, France); Vincent Audebert (EDf R&D, France)

Accurate measurements of common properties of the propagation channel is a major concern for narrow band power line communication (PLC) systems in the frequency band between 9 kHz and 500 kHz. Precise knowledge of both the attenuation and the characteristic impedance of low voltage cables are an important part of the characterization of the propagation channel. This paper presents a method for experimental assessment of these parameters. Measurement results of underground and overhead line twisted cables are obtained and analyzed as these are the most representative cables used in low voltage (LV) distribution networks. Using LCR-Meter, two variants of the measurement method are proposed to investigate the real and imaginary parts of the propagation constant. The influence on the characteristic impedance is discussed and the transmission line characteristics are presented as a function of the frequency for both type of cables. One of these variants makes use of approximations, so the effects of this approximation on the secondary parameters are outlined.

10:55 *Data Rate Optimization on PLC Devices with Current Controller for Low Access Impedance*

George Hallak (University of Applied Sciences Ruhrwest, Germany); Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

Access impedance of power line channel is mostly frequency dependent. PLC devices manufactures determine the transmitted signal on the electrical power grid as voltage based on EN50065-1. However, the transmitted signal (voltage) often does not reach the specified signal in EN50065-1 because of the energy efficiency rules of PLC devices. The power consumption limitation of PLC devices is realized by reduction on the power amplifier (PA) output voltage level. The PA output reduction is implemented by

current regulator based on current measurement. As a consequence of the PA output level reduction, the transmitted signal reduces at the transmitter and receiver side which reduce the performance of the PLC systems and the data rate as well. In this paper we present the effect of the access impedance by reducing the data rate of PLC systems. In our simulation, we find the achievable data rate considering access impedance values related to EN50065-1 and measurements done in China and Austria. We introduce optimization algorithms to improve the achievable data rate by disabling subcarriers in frequencies with low access impedance which increases automatically the signal on the other subcarriers with sufficient access impedance. These algorithms can be combined with most of PLC standards since the modification on the transmitted signal is only produced from the PLC channel and the receiver should be able under specific constraints to handle these changes.

11:15 ***Resistive Shunt On-line Impedance Analyzer***

Cornelis J. Kikkert (James Cook University, Australia); Shucheng Zhu (The University of Adelaide, Australia)

This paper describes a new low cost instrument to accurately measure power line impedances on-line. Computer simulation is presented, which shows that the fundamental accuracy of the Resistive Shunt On-line Impedance Analyzer is better than 0.1% from 0.5 Ω to 50 kΩ and from 1 kHz to 10 MHz. Hardware measurements of a wide range of resistors and on-line impedance measurements at different locations are presented.

11:35 ***Designing a Power-Line-Communication-Based LoM Protection Concept with Application of Software-Defined Radios***

Anton Poluektov, Antti Pinomaa and Jero Ahola (Lappeenranta University of Technology, Finland); Antti Kosonen (Lappeenranta University of Technology & Institute of Energy Technology, Finland)

Islanding condition in an electricity distribution grid occurs when a distributed generator (DG) continues to power parts of the grid, when connection with the power utility is lost. This situation can cause severe and fatal personal injuries, equipment damage, and power quality degradation. In this paper, communication-based anti-islanding, that is, a loss-of-mains (LoM) protection system for electricity distribution grids in Finland is proposed and studied. The LoM protection concept is based on power line communication (PLC). Detailed analyses of the electrical grid environment, channel characteristics, and a suitable operational frequency band and range for the PLC are presented. Software-defined radios (SDRs) are applied as a flexible platform in designing and testing a PLC-based anti-islanding protection system. Laboratory tests are carried out, the results are analyzed, and recommendations for future studies are made.

Tuesday, March 22, 11:55 - 13:00

Lunch

Room: Lobby

Tuesday, March 22, 13:00 - 13:30

K3: Broadband Powerline Communication for Access Networks

Eugen Mayer: Managing Director at Power Plus Communications AG

Room: H2

13:00 ***Broadband Powerline Communication for Access Networks***

Eugen Mayer (Power Plus Communications, Germany)

As the leading Broadband Powerline (BPL or B-PLC) integrator in Europe, Power Plus Communications has for many years contributed to European standardisation efforts, significant test programs and industry roll outs. As a Founder and COO of PPC, Eugen Mayer will outline some of PPC's most recent projects, and share insights into how B-PLC contributes to the digitalisation of the Energy Industry. His presentation will describe some of the demands and new applications in the utility field and show where powerline has been successfully deployed to meet them.

Tuesday, March 22, 13:30 - 14:50

I3: ITU-T G.9904 (PRIME 1.4)

Jose Antonio Cortes; Alfredo Sanz; Inigo Berganza

Room: H2

Chair: Alfredo Sanz (University of Zaragoza & Atmel Spain SAU, Spain)

"PRIME 1.4: the evolution of the ITU-T G.9904 towards the FCC band" (Jose Antonio Cortes: Associate Professor at

University of Málaga-Communication Engineering department).
"Evolution of implementation and certification of NB-PLC" (Alfredo Sanz: Director of Operations & Technology, Power Line Communication Products at ATMEL).
"Utility perspective: experience and roadmap. Standards and regulation." (Inigo Berganza: Manager of Telecommunications Integration at Iberdrola).

T3: Standards

Room: H1

Chair: Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)

13:30 *IEEE 1905.1 Hybrid Home Networking Standard and Its Implementation with PLC, Wi-Fi and Ethernet Technologie*

Anil Mengi (Devolo AG, Germany); Abdesselem Kortebi (Orange Labs, France); Helmut Lucht (Devolo, Germany); Marcin Brzozowski (IHP, Germany); Michael Koch (Devolo AG, Germany); Olivier Bouchet (Orange Labs, France); Oliver Maye (IHP GmbH, Germany)

This paper considers "hybrid networking" with a convergence mechanism at layer 2.5 as addressed by the IEEE 1905.1 standard. The developed hybrid infrastructure network provides a seamless integration of three different communication technologies: Ethernet, Wireless LAN, and Power line Communication (PLC). The IEEE 1905.1 standard enables a global view of the network topology regardless of the technologies running in the home network. Among other functions, it allows the use of parallel links to transmit flows and to reroute traffic in case of links degradation or failure. The major benefits of this implementation include the ease of use for the end users, the auto network configuration, the improved network diagnostic and the increased robustness.

13:50 *Development, Validation and Utilization of an ITU-T G.9903 PHY Simulator for Communication Performance Evaluation*

Aurélien Van Laere (University of Mons - Faculty of Engineering, Belgium); Christopher Wawrzyniak (University of Mons (UMONS), Belgium); Sébastien Bette (University of Mons - Faculty of Engineering, Belgium); Véronique Moeyaert (Université de Mons (UMONS) & Faculté Polytechnique, Belgium)

Power Line Communication (PLC) technologies allow the transmission of data through the power lines and as such are very interesting to be used as access methods in the smart-metering paradigm. However those systems are prone to be affected by a wide variety of impairments (selective fading, reflections, variable noise, etc.). In the case of a wide scale smart-meter roll-out, a tool allowing a DSO to estimate the performance of a G3-PLC communication without the need to install test modems would be efficient. In this perspective, this paper presents a compliant ITU-T G.9903 G3-PLC PHY software simulator for both the CENELEC-A and FCC bands. The ultimate goal of this simulator is to evaluate the impact of different impairments on a G3-PLC communication. As an example, the impact of the packet size, the frequency band chosen and the effect of a measured transfer function of a MV/LV disconnected power transformer is discussed in this paper.

14:10 *Layer-2 Security for PLC - a Comparison Between ITU-T G.9903 and IEEE 1901.2*

Stefan G. Hoffmann (Hochschule Ruhr West, Germany)

This paper describes the layer-2-security functions of two narrow-band power line communication standards, namely ITU-T G.9903 and IEEE 1901.2. We describe how access control, authentication, confidentiality and integrity for network devices are achieved in both of the standards. We compare the approaches by using two practice-oriented installation scenarios and by evaluating the security methods.

14:30 *Towards Bidirectional Power Line Communication with Digital Load-Side Transmission*

Lukas Lohaus and Colin de Vrieze (RWTH Aachen University & Integrated Analog Circuits and RF Systems, Germany); Arne Rossius and Ralf Wunderlich (RWTH Aachen University, Germany); Stefan Heinen (RWTH Aachen, Germany)

The unidirectional power line communication technology 'Digital Load-Side Transmission' (DLT), which is typically used for controlling light sources in homes or small offices, has evolved into an official IEC standard [1]. However, the DLT methodology lacks a return channel enabling bidirectional communication. This paper presents a method to overcome the described limitation, proposing a system concept of receiver and transmitter for backward modulation in DLT systems that complies with the existing standard for DLT forward transmission [1]. The developed architectures of receiver and transmitter have been implemented and tested in a hardware realization using the results of [2]-[4]. Measurement results prove the feasibility of the derived bidirectional DLT system concept while the additional power consumed for backward transmission is kept within reasonable limits. Robustness of the proposed system is verified by recording the averaged 'telegram error rate' (TER) for both, forward and backward transmission, when the system is connected to 230VRMS, 50 Hz mains.

Tuesday, March 22, 14:50 - 15:20

Coffee Break

Room: Lobby

Tuesday, March 22, 15:20 - 16:40

I4: IEEE 1901 for access networks

Scott Willy; Felix Streit; Ernst Siegler

Room: H2

"Introduction to the IEEE1901 Access standard" (Scott Willy: Product Manager at Avisto Telecom).
"Network Management for IEEE1901 Access networks" (Felix Streit: Head of IT and Consultant IT Security, PPC).
"BPL at EnBW: project experiences and measurement results" (Ernst Siegler: Manager Service and Telecommunication, Netze BW GmbH).

T4: Security and energy efficiency of relay networks

Room: H1

Chair: Bamidele Adebisi (Manchester Metropolitan University, United Kingdom)

15:20 *Physical Layer Security of Cooperative Relaying Power Line Communication Systems*

Abdelhamid Salem (University of Manchester, United Kingdom); Khaled M. Rabie (Manchester Metropolitan University, United Kingdom); Khairi A. Hamdi (University of Manchester, United Kingdom); Emad Alsusa (Manchester University, United Kingdom); Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)

Power-line communications (PLC) have enabled many smart grid applications over the past years. Secure communications over such channels, however, remains a crucial aspect for the successful realization of smart grids. Many techniques have been proposed in the literature to achieve this and the most recent of which is the adoption of physical layer security for PLC systems. Unlike the existing work, in this paper, we investigate physical layer security of cooperative relaying PLC systems with artificial noise in the presence of an eavesdropper. The system performance is evaluated in terms of the ergodic secrecy capacity. In light of this, we derive a mathematical expression for the ergodic secrecy capacity and validate it with Monte Carlo simulations. Results reveal that the proposed system can significantly enhance the security of PLC systems.

15:40 *The Optimal Power Allocation for Security in Multicarrier Relay Power Line Communication*

Young-Jun Yoon, Ji-won Choi and Seong-Cheol Kim (Seoul National University, Korea); Jong-Ho Lee (Gachon University, Korea); Yong-Hwa Kim (Myongji University, Korea)

The physical layer security in broadband power line communications (PLCs) is considered to find the optimal power allocation that maximizes the secrecy rate in two-hop relaying multicarrier systems. In two-hop relaying systems, the optimal transmission scheme of each subcarrier is the one of the followings: No transmission, Direct transmission and Relay transmission. There are also five cases classified according to channel states between PLC nodes. In three cases, the optimal scheme is determined uniquely. In other two cases, the optimal scheme turns out to depend on the transmit power of the subcarrier. This increases computational complexity highly such that finding the optimal power allocation is impractical. In order to resolve this problem, we suggest the suboptimal power allocation and evaluate its performance in PLC network. The performance is compared to the other schemes such as the uniform power allocation and non-cooperative schemes.

16:00 *Improving Energy Efficiency in Dual-hop Cooperative PLC Relaying Systems*

Khaled M. Rabie and Bamidele Adebisi (Manchester Metropolitan University, United Kingdom); Abdelhamid Salem (University of Manchester, United Kingdom)

Energy efficiency (EE) in multi-hop cooperative communication systems, both wireless and wired, is increasingly becoming more and more critical. This has recently been extended to include power line communications (PLC). In this respect, we propose in this paper to enhance the EE of a dual-hop amplify-and-forward (AF) cooperative relaying PLC system by considering energy-harvesting (EH) at the relay node. The energy harvester exploits the high noisy PLC channel feature as well as the transmitted signal power to forward the source information. In light of this, we derive an analytical expression for the EE and verify it with Monte Carlo simulations. The performance of the conventional relaying system, i.e. without any EH, is also considered to clearly quantify the achievable gains. The results show that the proposed system can considerably improve the EE of PLC systems and that increasing the channel variance will always make the proposed system more energy-efficient.

16:20 *Energy Efficiency Performance of Decode and Forward MIMO Relay PLC Systems*

Wafae Bakkali (Orange Labs & Telecom Bretagne, France); Pascal Pagani (Telecom

Bretagne, France); Thierry Chonavel (Institut Télécom; Télécom Bretagne & Université Européenne de Bretagne, France); Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)

In this paper, we investigate the energy efficiency performance of Multiple-Input-Multiple-Output (MIMO) relay-assisted Power Line Communication (PLC) networks. We consider a half-duplex Decode and Forward (DF) relay system and compare its performance for both uniform time allocation and optimized time allocation strategies. Based on realistic MIMO PLC channels, obtained from the European Telecommunications Standards Institute (ETSI) Specialist Task Force (STF) 410 field measurement campaign that was performed in six European countries, we show that depending on the idle power consumption of MIMO PLC modems in the relay network, possible energy saving gain can be obtained by using DF MIMO PLC relays.

Tuesday, March 22, 16:40 - 17:00

Coffee Break

Room: Lobby

Tuesday, March 22, 17:00 - 18:00

P2: Future of frequency between 500 kHz to 1.8 MHz

Room: H2

Chair: Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

What shall we do with frequency from 500 kHz to 1.8 MHz?

Tuesday, March 22, 19:00 - 23:00

Conference Banquet

(bus service provided)

Room: Wasserschloss Wittringen

Wednesday, March 23

Wednesday, March 23, 08:30 - 09:00

Registration

Rooms: Lobby, S1

Wednesday, March 23, 09:00 - 09:30

K4: The benefits if higher frequency, narrow band IEEE PLC communication coupled with a multi-PHY IEEE RF solution

Michael Bratovz: Director Smart Grid at Itron

Room: H2

09:00 *The Benefits If Higher Frequency, Narrow Band IEEE PLC Communication Coupled with a Multi-PHY IEEE RF Solution*

Communication needs for Smart Metering, Smart Grid and IoT are placing ever increasing demands on communication capabilities, reliability and performance. New challenges are arising due to increasingly harsh conditions in the field such as increased noise levels, reduced impedances and increased dynamic changes in conditions. The use of the wider FCC band that provides much needed relief to these pressures with the implementation of the P1901.2 IEEE standard that provides the necessary coexistence standards, ensures we can be effective in addressing these increasing demands. Inclusion of RF communication capabilities, embracing the possibility of the new 870 MHZ band dedicated for these purposes, rounds off a complete offering to deliver on the market needs.

Wednesday, March 23, 09:30 - 10:00

K5: Prime Alliance

Bernhard Rauscher: Managing Director of STMicroelectronics Application GmbH

Room: H2

09:30 *Prime Alliance*

Nowadays, different PLC technologies have been widely deployed on field, especially in Europe, to address modern smart metering programs. Actually, European regulations reserves CENELEC A band (i.e. between 3kHz to 95kHz) to Energy Utilities for PLC signaling purposes, setting limits for conducted emissions from any device connected to the grid. In particular, PRIME v.1.3.6 standard has been conceived to provide robust and performing PLC connectivity in CENELEC A band, exploiting state of the art OFDM modulation: more than 10 Million meters have been already successfully deployed on field, compliant with CENELEC A band PRIME v.1.3.6 specifications. Nevertheless, many factors are now bringing PLC standards to define new profiles to communicate over bands up to 500 kHz. Among those factors, the main ones are the increased demand for new Smart Grid systems worldwide beyond traditional metering infrastructures and the reduced frequency spectrum for noise at higher frequencies which improves PLC signal to noise ratio, so enabling higher performances PLC connectivity. PRIME Alliance already took into account these aspects throughout the new v.1.4 specifications, which include system band extension up to 500 kHz, along with other important telecommunication improvements. PLC implementations covering these new PLC features are becoming available in the market, opening the door for a massive adoption.

Wednesday, March 23, 10:00 - 10:30

Coffee Break

Room: Lobby

Wednesday, March 23, 10:30 - 12:10

W1: Powerline in constrained environments

Room: H1

Chair: Pascal Pagani (Telecom Bretagne, France)

10:30 *Power Transformer Modeled as a Transmission Line for Simple Simulation of Complex Topologies in the PLC Frequency Range*

Christopher Wawrzyniak (University of Mons (UMONS), Belgium); Véronique Moeyaert (Université de Mons (UMONS) & Faculté Polytechnique, Belgium); Francois Vallee (University of Mons, Belgium)

This paper presents the use of a power cable modeling approach based on the two port network theory and its application to power transformers. More specifically, it takes place in the frame of the evaluation of the capacity of the power network infrastructure to support narrowband PLC technology. In this context, a classical two-port network modeling approach of cable transfer function is transposed to other devices like LV-LV transformers. In order to evaluate the impact of derivations of the power network, a classical distribution system topology is also studied. Practically, the effect of power network components is modeled by a cascade of transmission matrices. A comparison between model results and measurement is performed to show the coherence of results.

10:50 *Power Line Communication in Automotive Harness on the Example of Local Interconnect Network*

Ghyoor Arshad Lodi (Ilmenau University of Technology, Germany); Andreas Ott (Melexis, Germany); Sher Ali Cheema (TU Ilmenau, Germany); Martin Haardt (Ilmenau University of Technology, Germany); Thomas Freitag (Melexis, Germany)

In recent years, the proliferation of electronic systems in modern cars has resulted in increased cost, complexity, and weight of the automotive wire harness. Moreover, the addition of nodes in to the existing wire harness, to provide additional functions, leads to an enormous routing effort. Power Line Communication (PLC) provides an attractive solution to these problems by providing an alternative medium of communication between the nodes through the vehicle's battery power line. In this work, a new transceiver architecture is proposed to provide PLC on the DC line in an automotive harness. The proposed scheme is based on the example of the Local Interconnect Network (LIN) where only the physical layer is changed. Here, we propose to use redundant transmission channels, which are spaced in frequency, to provide robustness against the severe power line channel attenuation. An improvement in channel gain for the worst-case scenarios is demonstrated through a statistical evaluation of this scheme. The results show that an efficient use of the frequency spectrum enables the support of up to 15 LIN buses on a single power line, while ensuring 3-level redundancy. A system-level design of the PLC system for LIN and its specifications are presented. A further improvement in the system performance in the presence of additive white Gaussian noise is demonstrated by applying simple channel coding technique.

11:10 ***Propagation Characteristics of a DC Biased Line for Hydraulic-Crane PLC***

Shinji Tsuzuki and Yoshio Yamada (Ehime University, Japan)

In recent years, mobile cranes have been larger, and enhancements of various safety devices and assist functions have also been demanded. In this paper, an over-winding detection circuit, which has been used commonly in hydraulic cranes, has been proposed to used as a PLC channel to realize a high speed network infrastructure between cab and boom-tip. The throughput performances of two types of cranes, truck-mounted crane and rough terrain crane, were measured by using HD-PLC adapters. It was shown that the best throughput value of 70Mbps was achieved when the proposing system of voltage-drive at the cab and current-reception at the tip was used. From the viewpoint of the transfer function and line impedance properties, the measured throughput performances have been evaluated.

11:30 ***Modeling of the Power-line Channel in Automotive Li-ion Batteries with Rogowski Coils as Coupling Elements***

Oliver Opalko, Damian Alonso and Klaus M. Dostert (Karlsruhe Institute of Technology (KIT), Germany)

A model of the transmission channel is essential for designing a power-line communication (PLC) system for a lithium-ion battery pack in electric and hybrid vehicles. Currently, measurements of lithium-ion batteries have to be performed by specially trained staff in safety chambers, because they might cause severe safety problems. A simulation model of the battery would therefore highly facilitate the analysis of different battery packs. Our approach is to extend an existing circuit-based model of the power-line channel with a 3-D electromagnetic (EM) model. The 3-D EM model is well capable of describing the inner environment of the battery pack as well as PLC coupling elements, which is necessary because power lines can also act as antennas. On the other hand, a fully detailed 3-D EM model cannot be simulated within a reasonable period of time. This article gives essential insights into future PLC systems for battery packs in order to ensure safe usage of electric and hybrid cars for the user and the environment.

11:50 ***Analysis of Channel Characteristics and Modeling of a Transformer for PLC-Based Loss-of-Mains Concept***

Antti Pinomaa, Anton Poluektov and Jero Ahola (Lappeenranta University of Technology, Finland); Antti Kosonen (Lappeenranta University of Technology & Institute of Energy Technology, Finland)

Loss-of-mains (LoM) protection is crucial in modern smart grids (SGs), where the number of distributed generation (DG) units has increased making the grids more complex. An LoM situation means that the DG unit(s) is/are still supplying the grid while the connection to the supplying electric power distribution grid is off. This can cause fatal injuries to humans and damages to the equipment. A power line communication (PLC) based LoM concept is introduced, where continuous signaling is used as an indication for the LoM protection from the primary substation through the MV grid, the MV/LV transformers, and each low-voltage (LV) grid to the customers. However, the MV/LV transformers constitute a barrier for the PLC. Thus, in this paper, the channel characteristics and modeling of the MV/LV transformer as a function of frequency in the frequency band from 100 Hz to 1 MHz is analyzed. A model for the transformer is compiled and verified by input impedance measurements.

W2: Recent results session

Room: H2

Chair: Han Vinck (University of Duisburg-Essen & University of Johannesburg, Germany)

10:30 ***Processes and Calibrations for an Accurate Access Impedance Measurements***

George Hallak (University of Applied Sciences Ruhrwest, Germany); Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

The accurate access impedance measurement of the PLC devices and power line enables the optimum design of the PLC system. This paper presents a description of an accurate access impedance measurement system with the calibration processes and procedures to remove all effects that disturb the measurements. Some impedance measurements are presented

10:40 ***Modelling a Single Phase Power Transformer Using On-line PLC Frequency Impedance Measurements***

Shucheng Zhu (The University of Adelaide, Australia); Cornelis J. Kikkert (James Cook University, Australia); Nesimi Ertugrul (University of Adelaide, Australia)

Wide frequency-range impedance measurements are desirable in PLC systems for modeling and characterizing critical components, such as transformers. By modeling transformers, a PLC coupler or bypass network can then be designed. Such models also allow the ability of transformers to pass PLC signals to be determined. The modelling of transformers shows that the resonances at high frequency are related to the structure and health of a transformer. Any changes of transformer impedance in the PLC frequency range can indicate if faults are developing in that transformer.

10:50 ***New Capacitive Coupler for Broadband PLC on Overhead Medium Voltage Lines***

Peter Grimm (Maxwell Technologies SA, Switzerland); Gianni Sartorelli (Sartorelli Hybrid Energy Systems, Switzerland)

This paper gives an overview of a new design of Capacitive Couplers for Broadband Power Line Communication on medium voltage overhead-lines and presents preliminary research results on the PLC

coupling unit and the signal-quality on a point-to-point BPL-Communication pilot line.

11:00 ***High Frequency Modeling and Analysis of Power Cables for Efficient Power Line Communications***

Hakan P Partal (Yildiz Technical Universty, Turkey)

High frequency modelling and analysis of power lines are presented in this paper for obtaining impedance, efficiency, and transmitted distance of power line communication (PLC) signals. Using a combined analytical and numerical modelling and simulation tools, a robust cable model has been derived and the results have been verified with measurements. Once the physical characteristics of a power cable are known, the model presented here can be used to establish an electrical model and simulate high frequency behaviors. Then as the communication signal travels over power lines, the impedance medium will be known which will help estimating any impedance mismatches, signal transmission ratio and reflection ratio over the lines. The PLC engineers can benefit from the cable simulation model presented here, for their PLC network design.

11:10 ***A Synthetic MIMO Channel Model***

Alberto Pittolo (University of Udine, Italy); Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)

The huge and increasing demand of data connectivity motivates the development of new and effective channel models, which are able to faithfully describe a real communication scenario. This is of fundamental importance since a good model represents a quick development tool for new standards or devices, allowing a considerable saving in time and costs. The aim of this paper is to discuss a novel top-down MIMO synthetic channel model, able to numerically emulate a real PLC environment. First, the most common channel modeling strategies are briefly categorize, highlighting strengths and weaknesses. Afterwards, the basic model approach is described considering the SISO scenario. The implementation strategy is then extended to the MIMO case. The validity of the proposed model is proved comparing the results obtained by the experimental and the simulated channels, in terms of both performance and statistical metrics. The focus is on the broadband frequency spectrum.

11:20 ***Channel Emulator for Level 2+ Simulators***

Florian Kohnen (Hochschule Ruhr West, Germany); Gerd Bumiller (Hochschule Ruhr West & University of Applied Sciences, Germany)

To test and develop PLC network protocols it is necessary to use a realistic emulation of the PHYlayer behaviour. The network descriptions of typical Layer 2+ simulators are based on adjacency matrices with point to point success rates. As soon as you will test protocols which allow that multiple transmitters are active at the same time on the shared medium an approach like this is not viable anymore, as it will neglect overlapping transmissions. This work will describe an advanced way to emulate the PHY-Layer behaviour of power lines without the described constraint. The presented emulator uses transmission powers, noises and attenuations on the channel considering verlapping transmissions to calculate SNIRs and receive probabilities dynamically.

11:30 ***Intraflow Network Coding for Improved Routing in Meshed Networks with Lossy Broadcast Channel***

Ievgenii Anatolijovuch Tsokalo and Ralf J. Lehnert (Technische Universität Dresden, Germany)

Network coding (NC) brings a new insight on data transmission. Normally a data packet once constructed on the source travels to the destination (eventually through multiple hops) unchanged. With NC it can be combined with other packets locating on intermediate nodes. A product of them will be sent further. Such NC property helps to approach the upper bound of the network capacity given by min-cut max-flow theorem. In broadcast networks it improves Extremely Opportunistic Routing (ExOR) by reduction of feedback messages. In networks with lossy channel it can be also used as a rateless code to bring dynamically adjustable redundancy. We exploit the NC properties in PLC to improve throughput and latency. The preliminary results show a great potential of this idea.

11:40 ***Enhanced Packet Capture Analysis for PLC Affected by AC Adapter***

Daijiro Ueno (TOYO University, Japan); Kenji Kita (MJHEP in University of Kuala Lumpur, Malaysia); Hiroyasu Ishikawa (Nihon University & College of Engineering, Japan); Hideyuki Shinonaga (Toyo University, Japan)

Some AC adapters of mobile phones may affect transmission of PLC (Power Line Communications) signals, and it was reported that two kinds of transfer functions periodically appear, synchronized with a half-cycle of the power-line frequency [1, 2]. The authors have proposed a novel packet capture analysis method to visualize the effects of the AC adapter for the PLC transmission [3, 4]. This paper proposes an enhanced analysis method to evaluate the instantaneous phenomena with better accuracy.

11:50 ***Improved Iterative OFDM-based PLC Receivers Using Multilayer Perceptron Based Approach***

Jie-Wei Chen (National Taiwan University, Taiwan); Ying-Ren Chien (National I-Lan University, Taiwan); Hen-Wai Tsao (National Taiwan University, ?)

Impulsive noise (IN) can significantly degrade the bit error rate (BER) performance for power-line communication (PLC) systems. One of our previous works proposed an iterative approach to mitigate the IN for frequency division multiplexing (OFDM) based PLC systems. However, this iterative approach cannot reconstruct the residual IN to a satisfied level. In this recent research result, we present a multilayer perceptron (MLP)- based IN detector to deal with this problem. Simulation results have confirmed that the proposed MLP-based IN detector can achieve about 4 dB Eb/N0 improvement when we fix the BER at 10−2.

12:00 ***Influence of Noise Generated by Distributed Energy Resources on Micro Grids Over Narrow Band PLC***

Itziar Angulo (University of the Basque Country UPV/EHU & Bilbao School of Engineering, Spain); Igor Fernandez, Amaia Arrinda and David de la Vega (University of the Basque Country, Spain)

Distributed energy resources generate interfering signals and electrical noise that may have influence on Power Line Communications. In this paper, the influence of a battery charger and a PV inverter on Narrow Band Power Line Communications is described through a measurement campaign and addressed by analyzing the topological evolution of the subnetwork and the generated MAC traffic. Results show that the considered energy resources generate remarkable disturbances that affect communications.

Wednesday, March 23, 12:10 - 13:00

Conclusion

Room: H2

Chair: Andrea M Tonello (University of Klagenfurt & WiTiKee srl, Austria)