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THE CONFERENCE PROCEEDINGS OF

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17th International Conference on **K**nowledge in
Telecommunication **T**echnologies and **O**ptics 2017

SEPTEMBER 4th – 6th, 2017
Malenovice, the Czech Republic

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Preface

This event is organized by the Department of Telecommunications of VSB - Technical University of Ostrava and the Department of Telecommunications and Multimedia of the University of Zilina. This year, the conference will be held in Hotel KaM near Beskydy Mountains.

The conference KTTO is an occasion to share new information, recently achieved advances and knowledge in the field of telecommunications. The researchers, especially Ph.D. students, are kindly invited to contribute and submit their papers and the conference offers to the researchers, engineers and scientists a unique occasion to establish their new collaborations, ideas of research projects and to present their recent research results.

The selected papers will be published in a special issue of the journal Advances in Electrical and Electronic Engineering (AEEE) dedicated to the KTTO 2017 conference in November 2017. The AEEE journal has been covered by Elsevier since 2011 and papers and the published articles in this special issue will be indexed in SciVerse SCOPUS.

We wish you to have a great time during the KTTO 2017 conference.

On behalf of the organizing crew

Lukas Sevcik

Content

- Content..... 2
- Programme 4
 - Invited Speaker..... 8
 - Session 1 9
 - Session 2 10
- Abstracts of Presented Papers 13
 - Dimensioning of home subscriber server in IP multimedia subsystem 13
 - HUMAN DETECTION SYSTEM BY FUSING DEPTH MAPS-BASED METHOD AND CONVOLUTION NEURAL NETWORK-BASED METHOD 15
 - IMPACT OF CONSTANT RATE FACTOR ON OBJECTIVE VIDEO QUALITY ASSESSMENT 17
 - INFLUENCE OF BIT DEPTH ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS 19
 - DEVELOPMENT OF METHOD FOR SERVICE SUPPORT MANAGEMENT IN VEHICULAR COMMUNICATION NETWORKS 21
 - A NEW METHOD FOR FACE RECOGNITION USING CONVOLUTIONAL NEURAL NETWORK..... 23
 - INFLUENCE OF CHROMA SUBSAMPLING ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS 25
 - DEVELOPMENT AND EVALUATION OF AUTOMATED SYSTEM FOR RFID TAG PERFORMANCE MEASUREMENTS . 27
 - A NOVEL DERIVATIVE-BASED CLASSIFICATION METHOD FOR HYPERSPECTRAL DATA PROCESSING..... 29
 - ANALYSING OF PRIMARY USER’S INFLUENCE IN CR-MANET 30
 - SOCIAL BASED MOBILITY MODEL WITH METRICS FOR EVALUATION OF SOCIAL BEHAVIOUR IN MOBILITY MODELS FOR MANET-DTN NETWORKS 32
 - TRANSMISSION CAPACITY ESTIMATION FOR THE MEDIUM VOLTAGE LEVEL OF SMART GRID 34
 - SIMULATION OF THE APPLICATION LAYER IN NARROWBAND NETWORKS WITH CONDITIONAL DATA INJECTION XML SCHEME BASED ON UNIVERSAL DATA GENERATOR 36
 - SOFTWARE IMPLEMENTATION OF SECURE FIRMWARE UPDATE IN IOT CONCEPT..... 38
 - EXACT THROUGHPUT ANALYSES OF ENERGY-HARVESTING COOPERATION SCHEME WITH BEST RELAY SELECTIONS UNDER I/Q IMBALANCE 41

Enabling D2D Transmission Mode with Energy Harvesting and Information Transfer in Heterogeneous Networks	43
Committees	46
CONTACT	48
KTTO CONFERENCE ORGANIZATIONAL COMMITTEE	48
Sponsors	49

Programme

KTTO 2017

17th Knowledge in Telecommunication Technologies and Optics
2017

Monday – 4th September, 2017

13:00 – 14:00	Departure from Department of Telecommunications – Ostrava by cars
13:00 – 14:30	Departure from Ostrava – Svinov railway station by cars up to schedule – we will be waiting expecting trains from Prague, Zilina, Kosice and Bratislava in the case of their delay
14:00 – 19:00	Arrival, accommodation and registration at Hotel KaM
15:45	KTTO 2017 Opening session (Miroslav Voznak)
16:00 – 17:00	Invited speech of Prof. HAKKI GOKHAN ILK
17:00	Best paper Award (Miroslav Voznak)
17:10 – 17:30	Coffee break
17:30 – 19:00	Workshop of company IS-Wireless: Introduction to 5G educational software
19:30	KTTO 2017 Opening ceremony – banquet dinner and social evening

Tuesday – 5th September, 2017

07:30 – 08:30	Breakfast	
08:30	All conference participants collective photography – meeting at the front of the hotel KaM	
08:45 – 10:30	Session 1 - Networks, modelling and QoS, Chairman: Prof. HAKKI GOKHAN ILK	
10:30 – 10:45	Coffee break	
10:45 – 12:30	Session 2 - IoT, simulation and data processing, Chairman: Doc. JAROSLAV ZDRALEK	
12:45 – 13:45	Lunch	
14:00 – 14:45	Workshop of company ProfinetTest: Visibility into virtual network	
14:45 – 15:00	Coffee break	
16:00 – 18:00	Bowling at Hotel Petr Bezruc	Swimming pool / Whirlpool at Hotel Petr Bezruc
18:30	Dinner – grill party and social evening	

Wednesday – 6th September, 2017

07:30 – 08:30	Breakfast	
09:00 – 11:00	Sport activities (table tennis, billiard) / salt sauna at Hotel Petr Bezruc	
12:00	Lunch	
13:00	Departure from Hotel KaM by cars	
Approx.13:45	Arrival at Ostrava – Svinov railway station	
Approx.14:00	Arrival at Department of Telecommunications, VSB – TUO	

Detailed programme of the sessions

Session 1 - Networks, modelling and QoS, Chairman: Prof. HAKKI GOKHAN ILK

Juraj Skunda	Dimensioning of home subscriber server in IP multimedia subsystem
Jan Skapa	Human detection system by fusing depth maps-based method and convolution neural network- based method
Juraj Bienik	Impact of constant rate factor on objective video quality assessment
Juraj Bienik	Influence of bit depth on subjective video quality assessment for high resolutions
Sergej Jakovlev	Development of method for service support management in vehicular communication networks
Tomas Mizdos	A new method for face recognition using convolutional neural network
Miroslav Uhrina	Influence of chroma subsampling on subjective video quality assessment for high resolutions

Session 2 - IoT, simulation and data processing, Chairman: Doc. JAROSLAV ZDRALEK

Filip Benes	Development and evaluation of automated system for RFID tag performance measurements
Hakki Gökhan İLK	A novel derivative-based classification method for hyperspectral data processing
Martin Matis	Analysing of primary user's influence in CR-MANET
David Hrabcak	Social based mobility model with metrics for evaluation of social behaviour in mobility models for MANET-DTN networks
Jiri Vodrazka	Transmission capacity estimation for the medium voltage level of smart grid
Ondrej Vondrous	Simulation of the application layer in narrowband networks with conditional data injection xml scheme based on universal data generator
Lukas Vojtech	Software implementation of secure firmware update in IoT concept

Invited Speaker



[HAKKI GOKHAN ILK](#)

Ankara University

KEYNOTE SPEECH OF PROFESSOR H. GOKHAN ILK

Stereo vision with geo-reference data and objects

Hyperspectral imaging and its applications

Detection and classification of encrypted data for storage and transmission

Session 1

Tuesday 5th September, 08:45 – 10:30

Networks, modelling and QoS

Chairman: Prof. HAKKI GOKHAN ILK

- 8:45 – 9:00** **Juraj Skunda** - DIMENSIONING OF HOME SUBSCRIBER SERVER IN IP MULTIMEDIA SUBSYSTEM
Juraj SKUNDA, Ivan BARONAK
skunda.juraj@yahoo.com, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovičova 3, Bratislava 812 19, Slovak Republic
- 9:00 – 9:15** **Jan Skapa** - HUMAN DETECTION SYSTEM BY FUSING DEPTH MAPS-BASED METHOD AND CONVOLUTION NEURAL NETWORK- BASED METHOD
Anh Vu LE, Jan SKAPA, Miroslav VOZNAK
jan.skapa@vsb.cz, Dept. Of Telecommunications, VSB-Technical University of Ostrava
- 9:15 – 9:30** **Juraj Bienik** - IMPACT OF CONSTANT RATE FACTOR ON OBJECTIVE VIDEO QUALITY ASSESSMENT
Juraj BIENIK, Miroslav UHRINA, Peter KORTIS
juraj.bienik@fel.uniza.sk, Department of multimedia and information-communication technologies, Faculty of Electrical Engineering, University of Zilina, Univerzitna 1, 01026 Zilina, Slovak Republic
- 9:30 – 9:45** **Juraj Bienik** - INFLUENCE OF BIT DEPTH ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS
Juraj BIENIK, Miroslav UHRINA, Peter KORTIS
juraj.bienik@fel.uniza.sk, Department of multimedia and information-communication technologies, Faculty of Electrical Engineering, University of Zilina, Univerzitna 1, 01026 Zilina, Slovak Republic
- 9:45 – 10:00** **Mindaugas Kurmis** - DEVELOPMENT OF METHOD FOR SERVICE SUPPORT MANAGEMENT IN VEHICULAR COMMUNICATION NETWORKS
Mindaugas KURMIS, Miroslav VOZNAK, Gintaras KUCINSKAS, Darius DRUNGILAS, Zydrunas LUKOSIUS, Sergej JAKOVLEV, Arunas ANDZIULIS
mindaugas.kurmis@ku.lt, Informatics and Statistics Department, Faculty of Marine Technologies and Natural Sciences, Klaipeda University, H. Manto str. 84, Klaipeda, Lithuania

10:00 – 10:15 **Tomas Mizdos** - A NEW METHOD FOR FACE RECOGNITION USING CONVOLUTIONAL NEURAL NETWORK
Patrik KAMENCAY, Tibor TRNOVSZKY, Richard ORJESEK, Miroslav BENCO, Tomas MIZDOS
tomas.mizdos@fel.uniza.sk, Department of multimedia and information-communication technologies, Faculty of Electrical Engineering,
University of Zilina, Univerzitna 1, 01026 Zilina, Slovak Republic

10:15 – 10:30 **Miroslav Uhrina** - INFLUENCE OF CHROMA SUBSAMPLING ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS
Miroslav UHRINA, Juraj BIENIK, Tomas MIZDOS
miroslav.uhrina@fel.uniza.sk, Department of multimedia and information-communication technologies, Faculty of Electrical Engineering,
University of Zilina, Univerzitna 1, 01026 Zilina, Slovak Republic

10:30 – 10:45 COFFEE BREAK

Session 2

Tuesday 5th September, 10:45 – 12:30

IoT, simulation and data processing

Chairman: Doc. JAROSLAV ZDRALEK

10:45 – 11:00 **Filip Benes** - DEVELOPMENT AND EVALUATION OF AUTOMATED SYSTEM FOR RFID TAG PERFORMANCE MEASUREMENTS
Pavel STASA, Jiri SVUB, Filip BENES
filip.benes@vsb.cz, Institute of Economics and Control Systems, Faculty of Mining and Geology, VSB-Technical University of Ostrava,
17. listopadu 15/2172, Ostrava-Poruba, Czech Republic

11:00 – 11:15 **Hakkı Gökhan İLK** - A NOVEL DERIVATIVE-BASED CLASSIFICATION METHOD FOR HYPERSPECTRAL DATA PROCESSING
Yucel CİMTAY, Hakkı Gökhan İLK
ilk@iee.org, Electrical and Electronics Engineering, Faculty of Engineering, Ankara University,
Gölbaşı, Ankara, Turkey

- 11:15 – 11:30** **Martin Matis** - ANALYSING OF PRIMARY USER'S INFLUENCE IN CR-MANET
Martin MATIS, Dominik NEZNIK, David HRABCAK, Jan PAPAJ, Lubomir DOBOS
martin.matis@tuke.sk, Dept. of Electronics and Multimedia Communications, Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Bozeny Nemcovej 32, Slovak Republic
- 11:30 – 11:45** **David Hrabcak** - SOCIAL BASED MOBILITY MODEL WITH METRICS FOR EVALUATION OF SOCIAL BEHAVIOUR IN MOBILITY MODELS FOR MANET-DTN NETWORKS
David HRABCAK, Martin MATIS, Lubomir DOBOS, Jan PAPAJ
david.hrabcak@tuke.sk, Dept. of Electronics and Multimedia Communications, Faculty of Electrical Engineering and Informatics, Technical University of Kosice, Bozeny Nemcovej 32, Slovak Republic
- 11:45 – 12:00** **Jiri Vodrazka** - TRANSMISSION CAPACITY ESTIMATION FOR THE MEDIUM VOLTAGE LEVEL OF SMART GRID
Jiri VODRAZKA
vodrazka@fel.cvut.cz, Department of telecommunication technology, Faculty of Electrical Engineering, Czech Technical University in Prague, Technicka 2, Prague, Czech Republic
- 12:00 – 12:15** **Ondrej Vondrous** - SIMULATION OF THE APPLICATION LAYER IN NARROWBAND NETWORKS WITH CONDITIONAL DATA INJECTION XML SCHEME BASED ON UNIVERSAL DATA GENERATOR
Ondrej VONDROUS, Peter MACEJKO, Zbynek KOCUR
ondrej.vondrous@fel.cvut.cz, Department of Telecommunication Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague, Prague, Czech Republic
- 12:15 – 12:30** **Lukas Vojtech** - SOFTWARE IMPLEMENTATION OF SECURE FIRMWARE UPDATE IN IOT CONCEPT
Lukas KVARDA, Pavel HNYK, Lukas VOJTECH, Marek NERUDA
vojtecl@fel.cvut.cz, Czech Technical University in Prague, FEE, Dept. of Telecommunication Engineering, Technicka 2, 16627, Prague, Czech Republic

12:45 – 13:45 Lunch

**14:00 – 14:45 Workshop of company ProfinetTest:
Visibility into virtual network**

14:45 – 15:00 COFFEE BREAK

**16:00 – 18:00 Bowling / Swimming pool / Whirlpool
at Hotel Petr Bezruc**

18:30 Dinner – grill party and social evening

Abstracts of Presented Papers

Dimensioning of home subscriber server in IP multimedia subsystem

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This paper describes mathematical methods of dimensioning HSS (Home Subscriber Server) in IMS. Today, still more and more growing requirements on QoS (Quality of Service). Optimal QoS has to be reached by optimization of used component in network architecture. Models that are used – Erlang C formula and Markov chains M/M/1/K & M//M/m/K are simulated in MATLAB. Then outputs are displayed in graphs..

Keywords

IMS, HSS, dimensioning of database, Markov models, Erlang C.

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HUMAN DETECTION SYSTEM BY FUSING DEPTH MAPS-BASED METHOD AND CONVOLUTION NEURAL NETWORK- BASED METHOD

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The depth images and the colour images provided by Kinect sensors of a robot operation system (ROS)-based perception sensor network (PSN) are used to enhance the accuracy of human detection. To this end, the proposed detection method combines the depth-based method which is fast but less accuracy called Openni with the deep learning-based method called faster region convolutional neural network which is accuracy but requires complex computational hardware configuration. To simultaneously leverage the advantages and relieve the drawbacks of each human detection method, one master and client system is proposed. The final goal is to make the final detection human system more accurate and ready for real time application. The experimental results demonstrate the outperforming of proposed method comparing with other conventional methods in challenge scenarios.

Keywords

Human detection, deep learning, fusion, ROS

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IMPACT OF CONSTANT RATE FACTOR ON OBJECTIVE VIDEO QUALITY ASSESSMENT

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This paper deals with the impact of constant rate factor value on the objective video quality using PSNR and SSIM metrics. Compression efficiency of codecs H.264 and H.265 defined by different CRF values was tested. The assessment was done for eight type of video sequences depending on content for HD, Full HD and Ultra HD resolution. Finally, quality of both mentioned codecs with emphasis on compression ratio and effectivity of coding was compared.

Keywords

Constant rate factor, H.264, H.265, PSNR, SSIM.

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INFLUENCE OF BIT DEPTH ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS

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This paper deals with the influence of bit depth on the subjective video quality assessment. To achieve this goal, eight video sequences, each representing a different content prototype, were analysed. Subjective evaluation was performed using the ACR method. The analysed video sequences were encoded to 8 and 10-bit bit depth. Two most used compression standards H.264 and H.265 were evaluated with 1, 3, 5, 10 and 15 Mbps bitrate in Full HD and UHD resolution. Finally, the perceived quality of both compression standards using the subjective tests with emphasis on bit-depth was compared. From the results we can state, that the practical application of 10-bit bit depth is not appropriate for Full HD resolution in the range of bitrate from 1 to 15Mbps, for Ultra HD resolution, it is appropriate only for videos encoded by H.265/HEVC compression standard.

Keywords

Bit depth, ACR, H.264, H.265, Subjective quality assessment.

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DEVELOPMENT OF METHOD FOR SERVICE SUPPORT MANAGEMENT IN VEHICULAR COMMUNICATION NETWORKS

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In this work the method and prototype for managing the quality of wireless communication channel is presented. The proposed methodology, based on multi-criteria information utility assessment process is designed. It allows for heterogeneous context awareness data collection subsystems integration by transforming the acquired data to the highly dynamic intelligent transport systems. Each element of this intellectual transport system runs as a separate component having a specific environmental monitoring and control elements. Evaluation of context information utility allowed realizing the methods and algorithms that adaptively reduce the load on the wireless channel, and the transmitted and stored data volume without losing the enriched contextual information quality, which allows developing more complex, heterogeneous services. It is believed that the obtained scientific results will have positive affect in the future research and development of context awareness and service adaptation systems.

Keywords

VANET, context-aware, vehicular communication networks.

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A NEW METHOD FOR FACE RECOGNITION USING CONVOLUTIONAL NEURAL NETWORK

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In this paper, the performance of the proposed convolutional neural network (CNN) with three well-known image recognition methods such as Principal Component Analysis (PCA), Local Binary Patterns Histograms (LBPH) and K-Nearest Neighbour (KNN) is tested. In our experiments, the overall recognition accuracy of the PCA, LBPH, KNN and proposed CNN is demonstrated. The all experiments were implemented on the ORL database and the obtained experimental results were shown and evaluated. This face database consists of 400 different subjects (40 classes/ 10 images for each class). The experimental result shows that the LBPH provide better results as PCA and KNN. These experimental results on the ORL database demonstrated the effectiveness of the proposed method for face recognition. For proposed CNN we have obtained a best recognition accuracy of 98.3 %. The proposed method based on CNN outperforms the state of the art methods.

Keywords

Face recognition system, PCA, LBPH, KNN, neural networks.

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INFLUENCE OF CHROMA SUBSAMPLING ON SUBJECTIVE VIDEO QUALITY ASSESSMENT FOR HIGH RESOLUTIONS

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This paper deals with the influence of chroma subsampling on video quality measured by subjective metrics. The evaluation was done for two most used video codecs H.264/AVC and H.265/HEVC. Eight types of video sequences with Full HD and Ultra HD resolutions depending on content were tested. The experimental results showed that observers do not see the difference between unsampled and subsampled videos, so using subsampled videos is preferable - 50% of amount of data can be saved. Also, the minimum bitrates to achieve good and fair quality by each codec and resolution were determined.

Keywords

Chroma subsampling, H.264, H.265, MOS.

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DEVELOPMENT AND EVALUATION OF AUTOMATED SYSTEM FOR RFID TAG PERFORMANCE MEASUREMENTS

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Automatic identification technologies are beginning to be applied more and more in different sectors of human activity. The first and necessary step towards implementation of automatic identification and data collection into company processes is proper selection of suitable data carrier (RFID tag). On this basis, there can be further expansion into the logistic chain and subsequent application of middleware and the EPCIS systems and whole application framework of EPC Global Network.

The paper discusses the development of device for directional characteristics measurements of RFID tags marked objects. Current procedures for carrying out laboratory tests of UHF RFID devices rely on relatively high involvement of human labor associated with higher risk of measurements errors. The newly developed system that performs great part of manual operations autonomously reduces the risk of measurement errors and enables experiments to be performed faster, more accurate and in repeatable manner.

Keywords

Automated system, RFID tag, directional characteristics, RFID measurement chamber, software.

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A NOVEL DERIVATIVE-BASED CLASSIFICATION METHOD FOR HYPERSPECTRAL DATA PROCESSING

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In hyperspectral classification, derivative of reflectance spectra is used directly or by fusion with reflectance spectra. In this way, classification performance is improved. However, on the land cover, especially for plant species, the reflectance spectra may exhibit differences in course of plant age and plant maturity level. This situation makes traditional classification methods which are based on spectral similarity time-dependent. In addition, the problem of classification of the species which have similar spectral properties is still valid. As a solution to time dependency and spectral similarity problems, in this study, a new and more generic method based on spectral derivative is proposed. The method is tested for hyperspectral images which are captured at different time of the year and also for different places, in the life cycle of species. Test results show that proposed method successfully classifies the land cover time-independent and it is superior to the classical classification methods.

Keywords

Land cover, spectral derivative, classification, life cycle, time dependency.

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ANALYSING OF PRIMARY USER'S INFLUENCE IN CR-MANET

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The article provides guidelines of cognitive radio (CR) technology in the wireless communication based on IEEE 802.11x or other telecommunications access to sending data between devices in networks. CR is implemented in networks without infrastructure ad-hoc networks, mobile ad-hoc network (MANET). MANET with CR is the network, where the spectrum management is used more intelligent as it is in the typical ad-hoc network. CR is about spectrum sensing on each device in the network because there is no router. Devices with CR need to make spectrum sensing through all available frequencies in the technology. The main task of the router in the typical wireless network is manage the channels to each device. Devices just need to be connected to the router, then the router will pre-vent collision and interference between each frame during communication on the medium. Networks with CR consist of the primary users (PUs) and secondary users (SUs). The main difference between them is, that SUs can communicate on all channels, licenced/unlicensed, but PU activities cannot be affected by SUs. This main principle of CR technology was simulated and compared in Matlab environment.

Keywords

Cognitive radio, channel selection, MANET, spectrum sensing.

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SOCIAL BASED MOBILITY MODEL WITH METRICS FOR EVALUATION OF SOCIAL BEHAVIOUR IN MOBILITY MODELS FOR MANET-DTN NETWORKS

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In this paper, are described the basics of Social Based Mobility Model inspired by mobility of students alongside with Metrics for Evaluation of Social Behaviour in Mobility Models for MANET-DTN networks. These networks are mobile networks, where mobile devices are carried by humans. For simulation purposes, it is useful if mobility models designed to evaluate and tests performance of routing protocols are using mobility patterns and behaviour of humans. For these reasons, Students Social Based Mobility Model (SSBMM) was proposed as simulation tool with social mobility of nodes. To prove that SSBMM is really using social behaviour of nodes, Metrics for Evaluation of Social Behaviour in Mobility Models was designed. These metrics were adapted to the mobility of nodes in order to be able to reveal if the mobility of nodes in used mobility models is social. The performed simulations prove deviation of SSBMM from random mobility models. Described metrics reveal that SSBMM has strong social ties among nodes in comparison with random mobility models.

Keywords

MANET - DTN, Social behaviour, Mobility model, Students, Evaluation method.

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TRANSMISSION CAPACITY ESTIMATION FOR THE MEDIUM VOLTAGE LEVEL OF SMART GRID

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It is clear, that communication infrastructure will must be consequently extended to lower levels of energy grid, primary to medium and low-voltage levels. The information capacity of the backhaul part of the communication network will be continuously increased as a result of Smart Grid services expanding. In this paper, the data rate analysis of the backhaul links on medium-voltage power grid level is presented. The network model and calculation of aggregate data rate method for the medium-voltage section is designed. In next part, the experimental results of broadband power line communication are presented and these results are compared with aggregated data transmission requirements. Usability of broadband power line communication is discussed and gradual transition to optic fibre communications is predicted.

Keywords

Communication Networks, Smart Grid, Transmission Capacity, Broadband Power Line Communication.

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SIMULATION OF THE APPLICATION LAYER IN NARROWBAND NETWORKS WITH CONDITIONAL DATA INJECTION XML SCHEME BASED ON UNIVERSAL DATA GENERATOR

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In this article, we would like to deal with challenges and analysis approaches in the area of narrow band communication networks. Especially those networks which use TCP/IP protocol family. We also present a new universal data generator for OMNeT++ simulation environment. We created this generator to satisfy the evaluation, stress testing and benchmarking demands of more and more complex industrial and the Internet of Things networks. We also present the methods for evaluation and comparison of results obtained from simulated and real TCP/IP based networks in this article.

Keywords

Simulation, Industry 4.0, IoT, OMNeT++, TCP/IP, Traffic Generator

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SOFTWARE IMPLEMENTATION OF SECURE FIRMWARE UPDATE IN IOT CONCEPT

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This paper focuses on survey of secure firmware update in Internet of Things, design and description of safe and secure bootloader implementation on RFID UHF reader, encryption with AES-CCM and versioning with use of external backup flash memory device. Authentication is provided by the UHF RFID service tag.

Keywords

Firmware versioning, IoT, security.

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SECURITY-RELIABILITY ANALYSIS OF NOMA – BASED MULTI-HOP RELAY NETWORKS IN PRESENCE OF AN ACTIVE EAVESDROPPER WITH IMPERFECT EAVESDROPPING CSI

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In this paper, we evaluate system performances of a multi-hop relay protocol with presence of an active eavesdropper. In the proposed protocol, a source attempts to transmit its data to a destination with assistance of multiple intermediate relays. From the eavesdropping channel state information (CSI) estimated, the source and relays adjust their transmit power so that the eavesdropper cannot overhear the transmitted data. Moreover, to enhance throughput for the proposed system, non-orthogonal multiple access (NOMA) technique with a simple power allocation is also proposed. We derive exact closed-form expressions of the outage probability (OP) and throughput for the data transmission over Rayleigh fading channel. In addition, when the CSI estimation is imperfect, intercept probability (IP) at the eavesdropper is derived. Finally, Monte Carlo simulations are presented to verify the theoretical derivations.

Keywords

Multi-hop relay protocol, physical-layer security, non-orthogonal multiple access, outage probability, throughput, intercept probability.

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EXACT THROUGHPUT ANALYSES OF ENERGY-HARVESTING COOPERATION SCHEME WITH BEST RELAY SELECTIONS UNDER I/Q IMBALANCE

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In this paper, we propose an energy-harvesting cooperation scheme in which relays suffer in-phase and quadrature-phase imbalances (IQI) and harvest energy from a wireless transmit source. A best relay is selected based on end-to-end signal-to-interference-plus-noise ratios (SINRs) in both Amplify-and-Forward (called an EHAF protocol) and Decode-and-Forward (called an EHDF protocol) cooperation methods. We analyze and evaluate the system performance in terms of exact closed-form throughputs over Rayleigh fading channels. Simulation and analysis results discover contributions as follows. Firstly, the throughput performance of the proposed protocols EHAF and EHDF is improved when comparing with that of a non-selection cooperation scheme. Secondly, the EHDF protocol is more efficient than the EHAF protocol. Finally, the theoretical analyses are validated by performing Monte Carlo simulations.

Keywords

Energy harvesting, cooperative communication, I/Q imbalance, opportunistic relay selection, amplify-and-forward, decode-and-forward, throughput, and outage probability.

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Enabling D2D Transmission Mode with Energy Harvesting and Information Transfer in Heterogeneous Networks

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The concept of energy harvesting-assisted relay has been introduced to support the relaying transmission using device-to-device (D2D) communications for enhancing communication reliability. Motivated by the recent advance in heterogeneous network (HetNet) using relaying techniques, we consider the D2D communication provided by energy harvesting (EH) assisted relay where forward signal from a base station (BS) to the conventional cellular user (non-D2D user) and D2D user. We first derive the outage probability by taking into account the SNR and power allocation parameters, and propose the transmission mode for D2D link as well as non-D2D link. After deriving the outage probability of the D2D-HetNet, we explore the effects of the network parameters on the outage probability and throughput.

Keywords

Energy harvesting, HetNet, D2D, throughput, analysis.

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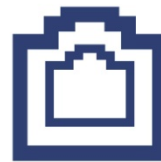
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