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2022
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Permutation Coded Multiple Access and MIMO Techniques for Hybrid Powerline and Visible Light Communication

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A thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, South Africa, in fulfilment of the requirements for the degree of Doctor of Philosophy

in the

Optical Communication Lab
School of Electrical and Information Engineering

April 2022

Abstract

Smart homes, smart cities, smart mines, wearables and connected cars are just but a few areas where the internet of things (IoT) has developed and will continue to grow. This growth, demands increasingly wide coverage areas, high capacities and data rates to maintain reliable and ubiquitous connectivity of several smart devices and machines, regardless of their environment and geographical locations. These connectivity demands present a challenge on the current commonly used standalone radio frequency (RF) networks. This challenge on the RF networks presents an opportunity for hybrid networks where various communication technologies complement each other to achieve the device-to-device and device-to-infrastructure connectivity. A hybrid of powerline communication (PLC) and visible light communication (VLC) technologies, is one of the cost-effective schemes recently proposed to achieve high-speed communication in both indoor and outdoor environments, since both constituent technologies seem ubiquitous. However, being an emerging and developing integrated scheme, various areas of the hybrid PLC and VLC (HPV) system still require optimisation. As such, this work investigates indoor coded multiple access (MA) and multiple-input multiple-output (MIMO) techniques for hybrid power-line and visible light communication (HPV) systems, with practical channel considerations. A specific focus is placed on the system error rate performance enhancement and complexity reduction.

First, an MA optical wireless communication system using permutation codes (PCs), is investigated. It is proposed and shown that a soft-decision (SD) decoder based on the Hungarian and Murty's algorithms for solving linear programming problems, precisely referred to as the HM decoder, can simultaneously decode multiple permutation codewords (PCWs). Additionally, the work shows that the SD HM decoder enhances the reliability of the MA optical wireless communication system and reduces the system complexity when compared to the hard-decision decoders based on exhaustive search methods. Furthermore, the properties of the different combinations of (PCWs) and their decodability by the HM decoder are studied. Then, a generalised space-time coded MIMO (GSTC-MIMO) scheme, whose encoder is adapted to the HM decoder for reliability enhancement of the system, is proposed. These results provide the motivation to apply and extend the encoder adaptation principle to the design of MA permutation codebooks, where the assignment of user disjoint codebooks is based on the judicial criteria of the combination properties of the PCWs from the different user codebooks.

The power-line communication (PLC) channel is inherently susceptible to impulse noise because of electrical devices randomly connecting to the power grid. This adversely affects the error performance of the HPV system. To mitigate the effect of the impulse noise, two schemes are proposed. The first scheme is a combination of orthogonal frequency division multiplex (OFDM) and M-ary frequency shift keying (MFSK), aided with permutation codes (PC OFDM-MFSK). This scheme well mitigates the impulse noise in PLC systems, however, with a reduced data rate when compared to a system employing classical OFDM. Hence, a generalisation of the permutation coded scheme is introduced to enhance the data-rate of the HPV system. The second, is a novel scheme based on a time-diversity concept that uses the Hermitian symmetry structure to introduce data repetition to produce some redundancy of the transmitted data. This strengthens the resistance to occasional high-peak impulse noise in the PLC channel. It is shown in this work that by using the time-diversity Hermitian symmetry (TDHS) scheme, the probability of the effect of impulse noise on data symbols through a PLC channel, is drastically reduced by 75%. As a result, the overall system's bit error rate (BER) and goodput performance, is enhanced.