Indoor optical wireless communication systems and networks

Welcome to this Special Issue on Indoor Optical Wireless Communications, in which we explore recent research and development in the area. There is an increasing demand for ultra broadband wireless access networks and the wireless multimedia applications and video which exploit their capability, coming from end users such as hospitals, teaching environments, and retailers. Currently there are two main technologies, radio and optical, capable of offering these services. Radio has the advantage of being available ubiquitously, both outdoors and indoors, and it also offers mobility, but will be challenged to provide the required high bandwidth. On the other hand, the optical wireless option could provide a cost effective, flexible, secure and ultra-high speed solution to the emerging challenges facing the system and service providers. The last few years have seen a considerable interest in both outdoor and indoor optical wireless communications from materials and devices through to systems and networks. It has already been used in applications from more complex wireless LANs such as those being specified by the IEEE 802.11 and ETSI (HIPERPLAN) to simple remote controllers for home appliances. The purpose of this special issue is to bring together the latest development in the area of indoor optical wireless communications systems and networks.

In order to increase the speed of optical wireless systems multiple-subcarrier (MS) systems have been used. However since the average optical power is proportional to this d.c. bias, it is important to minimize the bias signal. The paper by Kitamoto and Ohtsuki discusses MS schemes and proposes new parallel combinatory multiple-subcarrier (PC-MS) system. PC-MS not only can decrease the d.c. bias but it can also offer higher information per symbol interval than the conventional MS system with $N$ subcarriers.

Indoors wireless optical channels are limited not only in transmitted optical power, but also in signalling bandwidth. This bandwidth constraint arises due to multipath dispersion in indoor settings as well as due to response time limitations of optoelectronic components. The paper by Hranilovic presents an overview of theoretical and practical issues in the design of signalling for bandwidth constrained intensity modulated direct detection optical wireless channels. A survey of modulation design is also presented together with results on the channel capacity of indoor wireless optical channels with particular emphasis placed on recently derived asymptotically exact bounds. The use of multiple emitters and receivers in wireless optical channels is also discussed with particular emphasis placed on techniques, which exploit spatial dimensions to improve spectral performance.

As in RF communication system, noise and path loss are also major problems in indoor optical wireless communications. The use of large area photodetectors in conjunction with narrow bandwidth optical filters can minimize the problems of path loss and noise, but at the cost of reduced bandwidth. A paper by Ramirez-Iniguez and Green overcomes this problem by using an optical antenna (which is basically an optical concentrator (OC)) in conjunction with a small area photodetector. This improves the collection efficiency by transforming light rays.
incident over a large area into a set of rays that emerge from a smaller area. They show that the lenses can be designed to provide a prescribed angular response in order to limit the central wavelength shift in thin-film optical filters. They can also be designed for any specific field-of-view (FOV), which allows greater rejection of unwanted background radiation and higher gains. Design methods and properties of different optical antennas are also explained.

One of the major difficulties with the diffuse indoor IR environment is the ISI caused by multiple reflections a signal undergoes before arriving at the receiver, thus limiting the maximum data rate. There are a number techniques to combat ISI such as; band limiting filters, match filters (MF), the zero forcing equalizer (ZFE) and the minimum mean square error equalizer (MMSE). The paper by Dickenson and Ghassemlooy gives a review of traditional performance enhancing techniques and compares them with the proposed novel wavelet and artificial intelligence equalization and detection mechanism. It is shown that data rate greater than 250 Mb/s is achievable, with bit error rate performance, for dispersive channel, almost indistinguishable from that of the traditional match filter MMS-based receiver for OOK RZ. The paper further postulates that such a method may be simplified by modifying parameters such as window size, and that it may be implemented with more complex modulation schemes.

Indoors optical wireless channel characteristics are significantly different than the RF channel, therefore statistical propagation models adopted for RF channel do not apply, thus the need for a fresh approach. Carruthers and Carroll propose statistical modelling for the indoor optical wireless channel, where they investigate the characteristics of a large set of channel impulse responses. The paper show that channels with line-of-sight paths must be modelled separately from those of fully diffuse channels. They show that the distribution of the channel gains in dB for the LOS component and LOS with all reflections follow a modified gamma distribution and a modified Rayleigh distribution, respectively. Similar results for distributions of channel gains of diffuse channels and of rms delay spreads are also presented. The paper also describes a method for generating a channel impulse response, statistically realistic, for a given transmitter–receiver separation in an indoor environment.

Modulation scheme for optical wireless communications is the subject of the next paper by Aldibbiat et al. In this paper an alternative modulation scheme known as anisochronous dual header pulse interval modulation (DH-PIM) with built in symbol synchronization capability has been introduced. DH-PIM symbol structure, spectral profile, bit error rate analysis; power requirement and system simulation are presented. It is shown that this scheme offers shorter symbol length, improved transmission rate and bandwidth requirement compared with digital pulse interval modulation and pulse position modulation. Two type of DH-PIM schemes are investigated and results presented show that the power penalty due to intersymbol interference for non-dispersive and dispersive channels is marginally higher than PPM, but it offers the same bit rate at much less bandwidth requirement.

Finally, indoor wireless network is the subject of the next paper. Indoor multipoint wireless connectivity is governed by the Infrared Data Association Advanced Infrared (AIr) protocol. Many researchers have investigated the performance of AIr that was based on a bi-dimensional Markov chain model. Chatzimisios and Boucouvalas present an alternative and simpler derivation of the AIr performance analysis. The proposed new derivation is based on elementary conditional probability arguments, which is more elegant than the original, and can be applied to any CSMA/CA MAC protocol. The paper studies the average packet delay for the AIr protocol by deriving simple mathematical equations, and also determine the significance of both
link layer and physical parameters, such as burst size, minimum CW size value and minimum turnaround time on Air packet delay performance.

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