Cairo University

OPTIMIZED RESOURCE ALLOCATION AND INTERFERENCE MANAGEMENT ALGORITHMS FOR INDOOR OPTICAL WIRELESS COMMUNICATIONS.

By

Asmaa Ibrahim Mohamed Badr

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Optimized Resource Allocation and Interference Management Algorithms for Indoor Optical Wireless Communications.

Key Words:
Visible Light Communication; Modulation; Resource Allocation; Interference Management.

Summary:

In this thesis, we introduce an indoor optical wireless communication system that enhances the system capacity and mitigates the interference in the optical cell. The main objective of this work is to improve the signal to interference noise ratio (SINR) and the system reliability. The thesis is separated into main three parts: optical modulation, resource allocation and interference management algorithms. In the optical modulation, we introduce a multi carrier optical modulation technique that enhances the spectral and power efficiency for real constellation modulation techniques. As it uses all the available subcarriers to send an odd real data and clips the negative parts. In the resource allocation, we propose an optimized resource allocation technique with rate and power constraints that maximizes the total output data rate while satisfying the constraints and enhancing the computational complexity. By allocating power and subcarriers to each user depending on its SINR and rate constraint, respectively. In the interference management, we introduce an interference management algorithm that mitigates the inter cell interference at the cell edge. As the frequency band is divided into reused band that is used in the cell area and shared band that is used in the interference area.

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List of abbreviations

ACO-OFDM	Asymmetrical clipped optical OFDM
AP	Access point
AWGN	Additive white Gaussian noise
BER	Bit error rate
BPSK	Binary phase shift keying
DCO-OFDM	DC-clipped optical OFDM
DD	Direct detection
DFT	Discrete Fourier transform
FFR	Fractional frequency reuse
FOV	Field of view
IM	Intensity modulation
ISI	Inter symbol interference
LED	Light emitting diodes
LOS	Line of sight
MA	Margin adaptive
OCO-OFDM	Odd clipping optical OFDM
OFDM	Orthogonal frequency division multiplexing
OOK	On off keying
PD	Photo detector
PFR	Partial frequency reuse
PPM	Pulse position modulation
PWM	Pulse width modulation
RA	Rate adaptive
SINR	Signal to interference plus noise ratio
UE	User equipment
UFR	Unity frequency reuse
VLC	Visible light communications
WDM	Wavelength division multiplexing

List of symbols

σ	The standard deviation
Nc(k)	The clipping noise
Xc	Clipped Gaussian signal
C_{ACO}	Channel capacity of ACO-OFDM
m	Lambertian emission order
ω	Receiving angle
φ	Radiant angle
Ts	The optical filter gain
gc	Concentrator gain
Popt	Total optical power
Bsub	The subcarrier bandwidth
No	The noise spectral density
x(n)	N time-domain output samples
X(k)	K frequency-domain input symbols
SINRth	Threshold SINR
R	Total rate
Pk	Power assigned to user K
Nk	Subcarrier assigned to user K
Pelec	The power of the output electrical signal
φ1/2	Half power angle

Abstract

In this thesis, we introduce an indoor optical wireless communication system that enhances the system capacity and mitigates the interference in the optical cell. The main objective of this work is to improve the signal to interference noise ratio (SINR) and the system reliability. The thesis is separated into main three parts: optical modulation, resource allocation and interference management algorithms.

In the first part, we introduce a multi carrier optical modulation technique that enhances the spectral and power efficiency for real constellation modulation techniques. As it uses all the available subcarriers to send an odd real data and clips the negative parts. In the second part, we propose an optimized resource allocation technique with rate and power constraints that maximizes the total output data rate while satisfying the constraints and enhancing the computational complexity. As we allocate power and subcarriers to each user depending on its SINR and rate constraint, respectively. Finally, we introduce an interference management algorithm that mitigates the inter cell interference at the cell edge. As the frequency band is divided into reused band that is used in the cell area and shared band that is used in the interference area.

Chapter 1 : Introduction

Optical wireless communication using white light emitting diodes (LED) has been investigated for indoor areas. The utilization of the broad unlicensed visible light spectral band offers great promise in the optical wireless communication system, as it provides high speed secured transmission which has no interference with the existing radio frequency system (RF).

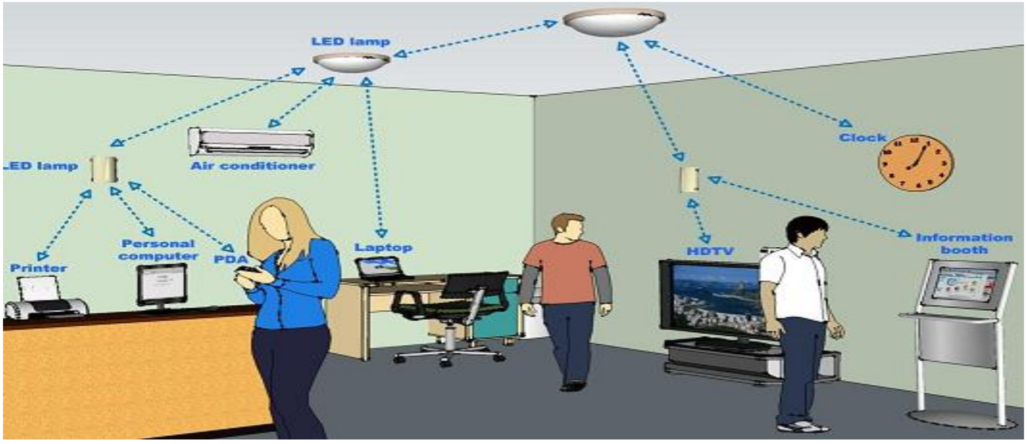

Figure 1.1: Indoor VLC system [35]

Visible light communication (VLC) has been proposed as a new wireless communication technology that uses the very appealing broad visible light spectral band [1]. VLC technology poses more advantages over the RF technology as it has unlicensed wide bandwidth, highly secured transmission as it can be received by users in the indoor area, low cost end devices and dual use of light emitting diodes (LED) for illumination and data transmission [3]. In the optical system, light intensity is used to transmit the data, where the transmitted signal is proportional to the power of the optical signal. On the receiver, a photodiode is used to detect the incident light with direct detection (DD) and generates the corresponding electrical signal proportional to the received optical power [4]- [6].

Intensity modulation with direct detection (IM/DD) becomes the most suitable technique to modulate the transmitted optical signal for VLC system due to its simplicity and low cost [2]. However, VLC system using IM/DD imposes more requirements on the transmitted signal format as it has to be positive and real signal, so real unipolar techniques as on off keying (OOK) and pulse position modulation (PPM) are commonly used in IM/DD systems. In high data rate systems like VLC, orthogonal frequency division multiplexing (OFDM) has been introduced as an effective solution to the inter symbol interference (ISI) [7]. However, classical bipolar OFDM signal based on Fourier transform (FT) is not used in optical wireless communication as it does not meet its requirements.

So, modified version of classical OFDM technique is introduced to get real and positive signal such as asymmetrical clipped optical OFDM (ACO-OFDM), DC-clipped optical OFDM (DCO-OFDM) [10]. In these techniques, Hermitian symmetry is imposed to the carriers in the frequency domain to generate real OFDM signal which decreases the spectral efficiency of the optical OFDM. The generated real signal is bipolar so the ACO-OFDM uses only the odd subcarriers to transmit the data and clips the negative parts at zero. Whereas, the DCO-OFDM uses all subcarriers to transmit the data, however, it adds a DC offset to the OFDM signal to be positive. Accordingly, ACO-OFDM is more power efficient than DCO-OFDM, as DCO-OFDM increases the power signal by adding DC offset, except the DCO-OFDM provides a better spectral efficiency than ACO-OFDM where the ACO-OFDM uses only odd subcarriers to send its data.

Different techniques for ACO-OFDM and DCO-OFDM are introduced in [21], where discrete Fourier transform (DFT) is replaced by real processing using discrete Hartley transform (DHT). The results suggest that DHT based OFDM has doubled the spectral efficiency of the classical ACO-OFDM and DCO-OFDM for real constellation with the same bit error rate performance (BER). As Hermitian symmetry is not required for the input signal.

In the proposed odd clipped optical OFDM (OCO-OFDM) and (MOCO-OFDM) based on FFT, Hermitian symmetry is replaced by odd symmetry of Fourier transform. Where odd symmetry of Fourier transform states that the output of the IFFT is pure real and odd signal for pure imaginary odd input. So, all the subcarriers are used in the communication process rather than odd subcarriers only for ACO-OFDM.

For standalone VLC systems, the coverage area of access points (AP) are overlapped to avoid dead zones, which causes co channel interference (CCI) at the user in the interference area (overlapping area). Hence, interference arises as a challenging problem in the VLC systems, so many interference management techniques have been investigated. We propose an interference management technique that assigns different frequency band to the cell edge users to enhance the signal to interference plus noise ratio (SINR). We also propose an optimized RA resource allocation with rate constraints for indoor VLC over DCO-OFDM using unity frequency reuse (UFR) and partial frequency reuse (PFR) and compare it with the allocation algorithm proposed in [8]. The results show that the proposed system satisfies the required users' rate and offers reasonable total rate with small number of iterations which enhances the computational complexity of the system.

The thesis is organized as follows. In Chapter 2, literature survey on the optical modulation, resource allocation and the interference management techniques are introduced. The proposed algorithms and the simulation results of the optical modulation are presented in chapter 3. Chapter 4 presents the proposed algorithms and the simulation results of the resource allocation. The proposed interference management technique with simulation results are introduced in Chapter 5. Finally, conclusions and future work are included in chapter 6.

Chapter 2 : Literature Review

In this chapter, we introduce the indoor VLC system model and the benchmarks techniques of the optical modulation, resource allocation and the interference management.

2.1. Indoor VLC system model

VLC systems like other communication systems mainly consist of sources, receivers and channels. The difference is in the nature of these parts, as in VLC optical sources and detectors will be used instead of the antennas in RF communications. Due to the nature of the optical signals some characteristics will change in the wireless channel between the transmitter and the receiver. In this section, these three main parts will be studied.

2.1.1. Light source

In optical communications, the sources used should have appropriate wavelength, line width, numerical aperture, high radiance with a small emitting surface area, a long life, a high reliability and a high modulation bandwidth, low cost. Light emitting diodes (LEDs) and laser diodes (LDs) which depend on the electronic excitation of the semiconductor materials can be used as they offer excellent brightness in the visible wavelength with small size and low forward voltage and drive current. Any source can be used depending on the application and their key features, LEDs are preferred for VLC systems as it can support both functions of illuminations and data transfer with low cost simultaneously. Table 2.1 shows Differences between LEDs and LDs.

Dual use of LEDs in VLC supports an advantage over the other communication systems. As light source is already installed everywhere, this infrastructure can support illuminations in addition to data transmission. This reduces the cost of installing VLC and saves the power consumed in the communication process. Also, the modulated signal is able to transmit digital data beyond the perception speed of human eyes.

The main drawback of the LED is its small electrical bandwidth, due to the fluctuations of the LEDs. RGB LED has been proposed to provide an electrical bandwidth higher the phosphor white LED, as it offers up to 813 MBPS.