



Cairo University

## **OPTIMUM DESIGN OF MULTIPLE ACCESS POINTS VISIBLE LIGHT COMMUNICATION SYSTEMS**

By

**Mai Badawi Sayed Ali Kafafy**

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

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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**Title of Thesis:**

Optimum Design of Multiple Access Points Visible Light Communication Systems

**Key Words:**

Visible Light Communication; Illumination; System Design, Power Consumption, Multiple Access

**Summary:**

This thesis answers a number of crucial questions on designing multi-user indoor visible light communication systems with multiple access points. These questions include the effect of the multiple access, illumination conditions, and room occupancy on the performance of visible light communication systems and its power consumption. The thesis formulates and statistically characterizes the power consumed by orthogonal and non-orthogonal multiple access techniques to support multi-users with specific quality of service. It also derives formulas to decide which lamps should support visible light communication in buildings that use their already existing lighting infrastructure. It also provides a methodology to jointly optimize the design of visible light communication alongside illumination. This joint design is suitable for buildings whose lighting is yet to be designed or renovated. All the design depend on information that is readily available to the system designer. The thesis also proposes a resource allocation algorithm to maximize the power efficiency of systems that allow hybrid visible light and radio frequency communications.

# **Disclaimer**

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the reference section.

Name: Mai Badawi Sayed Ali Kafafy

Date:

Signature:

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# Table of Contents

<b>Disclaimer</b>	<b>i</b>
<b>Acknowledgements</b>	<b>ii</b>
<b>Table of Contents</b>	<b>iii</b>
<b>List of Tables</b>	<b>vi</b>
<b>List of Figures</b>	<b>vii</b>
<b>List of Abbreviations and Symbols</b>	<b>x</b>
<b>Abstract</b>	<b>xiv</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Visible Light Communication . . . . .	1
1.2 Thesis Contribution . . . . .	3
1.3 Thesis Organization . . . . .	5
<b>2 Literature Review</b>	<b>6</b>
2.1 VLC modulation techniques . . . . .	6
2.1.1 Intensity modulation/ Direct detection . . . . .	6
2.1.1.1 Single Carrier Modulation . . . . .	7
2.1.1.2 Multi-Carrier Modulation . . . . .	8
2.1.2 Color Modulation . . . . .	9
2.1.3 Intensity and Color Modulation . . . . .	11
2.1.4 Dimming schemes . . . . .	12
2.2 VLC multiple access techniques . . . . .	14
2.2.1 Frequency Division . . . . .	14
2.2.2 Interleave Division . . . . .	14
2.2.3 Code Division . . . . .	15
2.2.4 Spatial Division . . . . .	15
2.2.5 Wavelength and Color Division . . . . .	16
2.2.6 Power Division . . . . .	17
2.3 MIMO Techniques . . . . .	19
2.4 Interference Mitigation . . . . .	21
2.5 Designing VLC systems . . . . .	23
2.6 VLC Experiments and Commercial Products . . . . .	24
2.6.1 Experimental Rates . . . . .	25
2.6.2 Commercial Rates . . . . .	25
2.7 Hybrid VLC/RF systems . . . . .	25
2.8 Power Efficiency . . . . .	27

<b>3 System Model</b>	<b>29</b>
3.1 Lamp Model and VLC Channel . . . . .	29
3.2 Indoor Setup . . . . .	30
3.2.1 A Two-dimensional Corridor Model . . . . .	30
3.2.2 A Three-dimensional Room Model . . . . .	31
3.3 Users Positions . . . . .	32
3.4 Indoor Illumination Conditions . . . . .	32
3.5 VLC Performance Metrics . . . . .	33
<b>4 Minimizing VLC Power Consumption for NOMA and OMA Techniques</b>	<b>35</b>
4.1 Non Orthogonal Multiple Access (NOMA) . . . . .	35
4.2 Orthogonal Multiple Access (OMA) . . . . .	36
4.3 Performance Evaluation . . . . .	36
4.4 Statistical Characterization of VLC Power Consumption . . . . .	40
4.4.1 System Model . . . . .	41
4.4.2 PDF of NOMA VLC power consumption . . . . .	43
4.4.3 PDF of OMA VLC power consumption . . . . .	44
4.4.4 Simulation Results . . . . .	45
4.4.4.1 NOMA . . . . .	45
4.4.4.2 OMA . . . . .	49
4.5 Summary and Conclusions . . . . .	51
<b>5 Optimizing the Inter-distance between Transmitter in Multi-VAP Systems</b>	<b>52</b>
5.1 The Average Rate per User . . . . .	52
5.1.1 Water-filling based Power Allocation Technique (WFPA) . . . . .	54
5.1.2 Max-Min Rate based Power Allocation Technique (MMRPA) . . . . .	56
5.2 Numerical results . . . . .	57
5.3 Summary and Conclusions . . . . .	63
<b>6 Designing Multi-VAP Systems under Illumination and Communication Constraints</b>	<b>64</b>
6.1 Two-dimensional Narrow Corridors . . . . .	64
6.1.1 Formulation of the Multi-VAP System Design . . . . .	65
6.1.2 Effect of Design Parameters on Illumination Constraints . . . . .	66
6.1.2.1 Illumination Consistency Ratio . . . . .	67
6.1.2.2 Average Illumination . . . . .	69
6.1.3 Effect of Design Parameters on Objectives . . . . .	71
6.1.3.1 Power Consumption . . . . .	71
6.1.3.2 Achieved Rate per User . . . . .	72
6.1.4 Optimum Strategy for Multi-VAP System Design . . . . .	75
6.2 Three-dimensional Rooms . . . . .	83
6.3 Effect of Illumination and Room Occupancy on Average Rate per User . .	89
6.4 Summary and Conclusions . . . . .	93

<b>7 Power Efficiency of Multi-VAP Hybrid RF/VLC Systems</b>	<b>94</b>
7.1 Maximization of the system power efficiency	95
7.2 Joint Locally Optimal Bandwidth and Power Allocation Scheme	96
7.2.1 RF/VLC Power Allocation Subproblem	97
7.2.2 RF/VLC Bandwidth Allocation	99
7.2.3 Computational Complexity	101
7.3 Numerical Results	101
7.4 Summary and Conclusions	106
<b>8 Summary and Conclusions</b>	<b>107</b>
<b>References</b>	<b>109</b>
<b>List of Publications</b>	<b>125</b>

# List of Tables

3.1	Simulation parameters . . . . .	34
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# List of Figures

1.1	Optical wireless communications . . . . .	2
2.1	Illustration of intensity modulation . . . . .	7
2.2	Variations of pulse position modulation . . . . .	8
2.3	color chormaticity diagram . . . . .	10
2.4	Two sets with metatametrically equivalent points . . . . .	11
2.5	VLC modulation techniques . . . . .	12
2.6	Analog and digital dimming . . . . .	12
2.7	Contour plot of the phase modulation in spatial light modulator . . . . .	16
2.8	An 18 LED angle diversity transmitter . . . . .	16
2.9	Orthogonal and non-orthogonal multiple access techniques . . . . .	17
2.10	VLC multiple access techniques . . . . .	18
2.11	VLC MIMO Techniques . . . . .	19
2.12	Techniques for hybrid RF/VLC load balancing . . . . .	27
3.1	VLC Tx-Rx link . . . . .	29
3.2	Side view of a 2D corridor . . . . .	31
3.3	The ceiling of an $L \times L$ room . . . . .	31
4.1	Lamp locations on the ceiling . . . . .	37
4.2	Illumination contours in the room (lux) . . . . .	37
4.3	VAP setup . . . . .	37
4.4	VLC power consumption Vs $R_{min}$ (at $ U =8$ users) . . . . .	38
4.5	VLC power consumption Vs $ U $ (at $R_{min} = 10$ Mbps) . . . . .	39
4.6	Bit error rate . . . . .	40
4.7	Statstical system model . . . . .	41
4.8	PDF absolute difference versus number of VAPs $ \tilde{V} $ (at $ U =1$ and $R_{min}=25$ Mbps) . . . . .	45
4.9	Scaled PDF of VLC power consumption per AP (at $ U =1$ and $R_{min}=25$ Mbps) . . . . .	46
4.10	PDF absolute difference versus number of users $ U $ ( $R_{min}=25$ Mbps at $ \tilde{V} =30$ ) . . . . .	47
4.11	PDF absolute difference versus minimum user rate $R_{min}$ (at $ U =4$ $ \tilde{V} =30$ ) . . . . .	47
4.12	Scaled PDFs of VLC power consumption per VAP (at $ \tilde{V} =30$ ) . . . . .	48
4.13	PDF absolute difference versus number of users $ U $ ( $R_{min}=25$ Mbps at $ \tilde{V} =30$ ) . . . . .	49
4.14	PDF absolute difference versus minimum user rate $R_{min}$ (at $ u =4$ $ \tilde{V} =30$ ) . . . . .	49
4.15	Scaled PDFs of VLC power consumption per VAP (at $ \tilde{V} =30$ ) . . . . .	50
5.1	Example of an Indoor Setup . . . . .	53
5.2	Optimal inter-VAP distance for different corridor dimensions (at $\lambda = \frac{2}{3}$ user/m, $F=1$ ) . . . . .	58
5.3	Optimal number of VAPs for different corridor dimensions (at $\lambda = \frac{2}{3}$ , $F=1$ ) . . . . .	59
5.4	Average rate per user (at $L=19$ m, $z=2.3$ m, $F=1$ ) . . . . .	60

5.5	Average, minimum, and maximum user rate (at $L=19m$ , $z=2.3m$ , $\lambda = \frac{2}{3}$ , $F=1$ ) . . . . .	60
5.6	Average rate per user (at $L=19m$ , $z=2.3m$ , $\lambda = \frac{2}{3}$ ) . . . . .	61
5.7	Comparison of 2D corridor approximation with 3D corridors (at $L=19m$ , $z=2.3m$ , $\lambda = \frac{2}{3}$ , $F=1$ ) . . . . .	62
5.8	Average rate per user for different lamp semi-angles at half intensity, $\theta_{\frac{1}{2}}$ , (at $L=19m$ , $z=2.3m$ , $\lambda = \frac{2}{3}$ , $F=1$ ) . . . . .	63
6.1	The interplay between the design parameters and the performance metrics . . . . .	66
6.2	Minimum $\theta_{\frac{1}{2}}$ required for different illumination consistency ratios . . . . .	68
6.3	Required number of LEDs per lamp for $IL_{req}=500lx$ . . . . .	70
6.4	Power consumption (at $IL_{req} = 500lx$ ) . . . . .	72
6.5	The two objectives (at $D = \frac{L}{5}$ and $IL_{req}=500lx$ ) . . . . .	73
6.6	Optimum $\theta_{\frac{1}{2}}$ for communication . . . . .	75
6.7	The optimum semi-angle choice for $L=19m$ , $D=L/5$ , $IL_{req}=500 lx$ . . . . .	77
6.8	The two objective plane for $ICR_{req}=0.5$ and $IL_{req}=500 lx$ . . . . .	78
6.9	The two objective plane for $ICR_{req}=0.7$ and $IL_{req}=500 lx$ . . . . .	79
6.10	Number of LEDs per lamp at different corridor widths (at $IL_{req} = 500 lux$ ) . . . . .	80
6.11	Power consumption at different corridor widths (at $IL_{req} = 500 lux$ ) . . . . .	81
6.12	The two objectives at different corridor widths (at $IL_{req} = 500 lux$ , $D=L/5$ ) . . . . .	82
6.13	Minimum to maximum illumination over 80% of the room . . . . .	84
6.14	Minimum to average illumination over 80% of the room . . . . .	84
6.15	$IL_{(x,y)}/IL_{avg}$ (at $D = \frac{L}{7}$ ) . . . . .	85
6.16	Minimum to average illumination (at $D = \frac{L}{7}m$ ) . . . . .	86
6.17	Total number of LEDs required for different illumination levels (at $D = \frac{L}{7}m$ ) . . . . .	86
6.18	Power consumption (at $IL_{avg}=500 lx$ ) . . . . .	87
6.19	The ARU and total power consumption (at $D = \frac{L}{7}m$ ) . . . . .	87
6.20	ARU . . . . .	88
6.21	ARU and $IL_{min}/IL_{avg}$ (at $D = \frac{L}{7}m$ , $IL_{avg}=500 lx$ ) . . . . .	88
6.22	Two objectives . . . . .	89
6.23	Average user rate for different illumination levels . . . . .	91
6.24	Average user rate and its lower bound Vs user density (at $IL_{avg} = 500 lx$ and $IL_{min}/IL_{avg} \geq 0.7$ ) . . . . .	92
6.25	Percentage of active VAPs Vs the user density . . . . .	92
7.1	A room with multi-VAPs and an RF AP . . . . .	94
7.2	Flowchart of joint power and bandwidth allocation . . . . .	96
7.3	Power efficiency versus the minimum required rate, $R_{min}$ , (at $ U =8$ users) . . . . .	102
7.4	Power Efficiency versus the number of users, $ U $ , (at $R_{min}=10$ Mbps) . . . . .	103
7.5	Ratio of VLC to hybrid rate versus the minimum required rate, $R_{min}$ , (at $ U =8$ users) . . . . .	103
7.6	Ratio of VLC to hybrid rate versus the number of users, $ U $ , (at $R_{min}=10$ Mbps) . . . . .	104
7.7	VLC system utilization versus the number of users, $ U $ , (at $R_{min}=10$ Mbps) . . . . .	104
7.8	Power efficiency for different receiver field of view, FoV, (at $R_{min}=5$ Mbps and $ U =8$ users) . . . . .	105

7.9 Ratio of VLC to hybrid rate for different receiver field of view, FoV, (at $R_{min}=5$ Mbps and $ U =8$ users) . . . . .	105
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# List of Abbreviations and Symbols

## List of Abbreviations

2D	Two Dimension
3D	Three Dimension
5G	Fifth Generation
ACO-OFDM	Asymmetrically Clipped Optical OFDM
AP	Access Point
ARU	Average Rate
BER	Bit Error Rate
CAP	Carrierless Amplitude and Phase
CDMA	Code Division Multiple Access
CSK	Color Shift Keying
DCO-OFDM	DC biased Optical OFDM
DFT	Discrete Fourier Transform
DMT	Discrete Multi Tone
FDMA	Frequency Division Multiple Access
HCM	Hadamard Coded Modulation
HetNet	Heterogeneous Network
i.i.d	independent and identically distributed
IDFT	Inverse Discrete Fourier Transform
IDMA	Interleave Division Multiple Access
IEEE	Institute of Electrical and Electronics Engineers
IVD	Inter-VAP Distance
IVI	Inter-VAP Interference

LED	Light Emitting Diode
LiFi	Light Fidelity
LoS	Line of Sight
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output
MMRPA	Max-Min Rate based Power Allocation
NOMA	Non Orthogonal Multiple Access
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OMA	Orthogonal Multiple Access
OOK	On Off Keying
PAM	Pulse Amplitude Modulation
PAPR	Peak to Average Power Ratio
PDF	Power Density Function
PM-OFDM	Position Modulating OFDM
PPM	Pulse Position Modulation
PWM	Pulse Width Modulation
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RF	Radio Frequency
SC-FDMA	Single Carrier FDMA
SDMA	Space Division Multiple Access
SIC	Successive Interference Cancellation
SINR	Signal to Interference and Noise Ratio