UNIVERSITI PUTRA MALAYSIA

LOAD BALANCING WITH SHADOWING EFFECTS HANDOVER IN LI-FI AND RF HYBRID NETWORK

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By

SALLAR SALAM MURAD AL-BAYATI

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Approval

DEDICATION

"It Is My Genuine Gratefulness And Warmest Regard That I Dedicate This Work To My Father and Mother, and my Brother.

Thanks for always being there for me.

Abstract of thesis presented to the Senate of University Putra Malaysia in Fulfilment of the requirement for the degree of Master of Computer Science

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BY

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Abstract

Light Fidelity (LiFi) uses light emitting diodes (LEDs) for high speed wireless communications. a hybrid network combining light fidelity (Li-Fi) with a radio frequency (RF) wireless fidelity (Wi-Fi) network is considered. An additional tier of very small Li-Fi attocells which utilise the visible light spectrum offers a significant increase in wireless data throughput in an indoor environment while at the same time providing room illumination. Importantly, there is no interference between Li-Fi and Wi-Fi. A Li-Fi attocell covers a significantly smaller area than a Wi- Fi access point (AP). This means that even with moderate user movement a large number of handover between Li-Fi attocells can occur, and this compromises the system throughput. Dynamic load balancing (LB) can mitigate this issue so that quasi-static users are served by Li-Fi attocells while moving users are served by a Wi-Fi AP. However, due to user movement, local overload situations may occur which prevent handover, leading to a lower throughput. LiFi can significantly alleviate the traffic bottlenecks in high density RF scenarios, typically present in an indoor environment. Hence, a combination of LiFi and RF networks becomes a promising candidate for future indoor wireless communications. In a practical indoor scenario, the optical interference from neighbouring LiFi access points (APs) and the blockages of line-of-sight (LoS) optical channels induced by people and objects are the main factors that cause significant optical channel variations. This research studies LB in a hybrid Li-Fi/Wi-Fi network by taking into account user mobility and handover signalling overheadsl, and also In this study, the effect of these two factors on the system throughput of a hybrid LiFi/RF network is investigated. Furthermore, a dynamic LB scheme is proposed, where the utility function considers system throughput and fairness. In order to better understand the handover effect on the LB, the service areas of different APs are studied, and the throughput of each AP by employing the proposed LB scheme is analysed. In order to offer a fair comparison, area data rate, which is defined as the system throughput in a unit area, is used for performance evaluation. The simulation shows that there is an optimal distance between two neighbouring LiFi APs to achieve the highest area data rate. In addition, the area data rate increases with the density of blockages when the blockage density is below a certain threshold.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk ijazah MASTER OF SCIENCE

LOAD BALANCING DENGAN KESAN HADOVER HANDOVER DALAM LI-FI DAN RF HYBRID NETWORKS

OLEH

SALLAR SALAM MURAD AL-BAYATI

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Abstrak

Fidelity Light (LiFi) menggunakan diod pemancar cahaya (LED) untuk komunikasi tanpa wayar berkelajuan tinggi. rangkaian hibrid yang menggabungkan kesetiaan cahaya (Li-Fi) dengan rangkaian kekerapan wayarles (RF) frekuensi radio (RF) dipertimbangkan. Satu tiang tambahan dari attocells Li-Fi yang sangat kecil yang menggunakan spektrum cahaya yang kelihatan menawarkan peningkatan ketara dalam penghantaran data wayarles dalam persekitaran tertutup sementara pada masa yang sama menyediakan pencahayaan bilik. Yang penting, tiada gangguan antara Li-Fi dan Wi-Fi. Attocell Li-Fi meliputi kawasan yang jauh lebih kecil daripada titik akses Wi-Fi (AP). Ini bermakna walaupun dengan pergerakan pengguna yang sederhana, banyak penyerahan antara attocells Li-Fi boleh berlaku, dan ini menjejaskan sistem throughput. Pengimbangan beban dinamik (LB) dapat mengurangkan masalah ini supaya pengguna-pengguna kuasi statik disampaikan oleh attocells Li-Fi sementara pengguna bergerak disampaikan oleh AP Wi-Fi. Walau bagaimanapun, disebabkan oleh pergerakan pengguna, keadaan beban tempatan mungkin berlaku yang menghalang penyerahan, yang membawa kepada pencapaian yang lebih rendah. LiFi dengan ketara dapat mengurangkan kesesakan trafik dalam senario RF ketumpatan tinggi, biasanya terdapat dalam persekitaran tertutup. Oleh itu, gabungan rangkaian LiFi dan RF menjadi calon yang menjanjikan komunikasi tanpa wayar dalam masa depan. Dalam senario dalaman yang praktikal, gangguan optik dari titik akses LiFi jiran (AP) dan sekatan jalur optik saluran (LOS) yang disebabkan oleh orang dan benda adalah faktor utama yang menyebabkan variasi saluran optik yang ketara. Kajian ini meneliti LB dalam rangkaian Li-Fi / Wi-Fi hibrid dengan mengambil alih pergerakan pengguna dan penyerahan isyarat overheadsl, dan juga Dalam kajian ini, kesan kedua-dua faktor ini melalui sistem rangkaian rangkaian LiFi / RF hibrid disiasat. Tambahan pula, skim LB yang dinamik dicadangkan, di mana fungsi utiliti menganggap sistem dan keadilan sistem. Untuk lebih memahami kesan penyerahan ke atas LB, kawasan perkhidmatan AP yang berbeza dipelajari, dan penerapan setiap AP dengan menggunakan skim LB yang dicadangkan dianalisis. Untuk menawarkan perbandingan yang saksama, kadar data kawasan, yang ditakrifkan sebagai throughput sistem dalam kawasan unit, digunakan untuk penilaian prestasi. Simulasi menunjukkan bahawa terdapat jarak optimum antara dua AP LiFi jiran untuk mencapai kadar data kawasan tertinggi. Di samping itu, kadar data kawasan meningkat dengan kepadatan tersumbat apabila ketumpatan penyumbatan berada di bawah ambang tertentu.

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List of Tables

Table No. **Page no**

List of Figures

Table Of Contents

CHAPTER 1

INTRODUCTION

1.1 Background

The radio frequency (RF) spectrum has become a very limited resource due to the increasing demand of wireless and mobile data. Light Fidelity (Li-Fi) technology, which uses 300 THz licence-free and unused optical spectrum for wireless communication is proposed as a potential solution (Y. Wang, et.al, 2015). The increasing number of multi-media mobile devices and the extensive use of data-demanding mobile applications means that current mobile networks are at their maximum capacity due to the limited availability of the radio frequency (RF) spectrum (Y. Wang and H. Haas, 2015).

With the large-scale adoption of LEDs for lighting, Light Fidelity (LiFi) is gaining significant momentum in research. Exploiting the dual purposes of illumination and high speed wireless data communications, LiFi is an efficient and green technology for 5G (5th generation) and beyond 5G networks. Since the visible light range of the electromagnetic spectrum is greater than 300 THz, an enormous unregulated bandwidth resource can potentially be utilised in LiFi systems, and this is 600,000 times more than a 500 MHz WiGig (wireless gigabit alliance) channel which achieves up to 7 Gbps. Even though the current white LEDs function as first order low-pass filters in optical communications, research shows that the achievable data rate of a multiple LED system can achieve 100 Gb/s by using wavelength division multiplexing (WDM). Since most of the optical power lies in the line-of-sight (LoS) channel, a LiFi access point (AP) covers a spatially well-confined cell, referred to as an attocell. This means that a high spatial spectral efficiency can be achieved with a dense deployment of LiFi APs (Y. Wang, et.al, 2016).

In Li-Fi systems, a high data rate can be achieved by using intensity modulation and direct detection (IM/DD) with optical orthogonal frequency multiplexing (OFDM). Recently, transmission speeds of 3 Gbp/s by a single colour light emitting diode (LED) are reported. In indoor environments, a Li-Fi cell covers only a few square meters due to the intrinsic properties of light. Generally, there can be many light sources in a room, and high spatial spectral efficiency can therefore be achieved by Li-Fi. However, in spite of the dense deployment of access points (APs), Li-Fi does not provide a uniform coverage because optical signals are susceptible to blockages. When the light beams are blocked, the supported data rate is reduced due to the low optical channel gain. It has been shown that even though Li-Fi networks can provide very high data rates, the outage rate performance in multiuser environment can still be significantly low (Y. Wang, et.al, 2015).

When WLANs are integrated in large-scale networks such as an operator network, it is necessary to propose management mechanisms and protocols that generate a reasonable signaling traffic into the network (M. Kassab, et.al, 2008). However, due to its sensitivity to the line of sight (LoS) blocking and non-uniform spatial distribution of data rates caused by co-channel interference (CCI), it is more beneficial to construct a hybrid LiFi/RF network than a stand-alone LiFi network (Y. Wang, X. Wu, and H. Haas, 2016). The advantages of a hybrid LiFi/RF network include: i) interference-free operation between LiFi and RF due to use of entirely different parts of electromagnetic spectrum; ii) high data rates enabled by the huge spectrum resource of LiFi; iii) ubiquitous coverage provided by RF. Thus, a LiFi/RF hybrid network can combine the benefits of both systems, achieving a high system throughput as well as a high user data rate, and providing high quality of service (QoS) to all wirelessly connected devices.Visible light communication (VLC), as a point-to-point communication technique, uses intensity modulation and direct detection (IM/DD) to transmit data. LiFi di_ers from VLC in that it stands for a complete wireless networking system including bidirectional communication, multiuser access, user mobility support, handover, etc (L. Yin, et.al, 2017).

In this study, user data rate is considered as the quality of service (QoS), and an average throughput requirement of each user over the working period is taken into consideration. In this study, a dynamic load balancing scheme which focuses on AP assignment for hybrid networks is proposed where the handover overhead is also considered. In the proposed scheme, users with high optical channel gains are preferentially allocated to Li-Fi APs. A data rate threshold is used to identify whether a particular user is served by a Li-Fi AP or a RF AP.

1.1.1 How does it work

LiFi allows for data to be transmitted by modulating the intensity of light, which is then received by a photo-sensitive detector. The light signal is then demodulated into electronic form. This modulation is performed in such a way that it is not perceptible to the human eye. LiFi can work indoors, outdoors, with the lights dimmed and is not strictly line-of-sight technology.

The way LiFi works is simple but powerful. When a constant current is applied to an LED light bulb, a constant stream of photons are emitted from the bulb which is seen as illumination. LED bulbs are semiconductor devices, which means the current, and therefore the illumination can be modulated at extremely high speeds which can be detected by the photo-detector. Using this technique allows for high-speed information can be transmitted from an LED light bulb. Radio frequency communication requires radio circuits, antennas and complex receivers, whereas LiFi is much simpler and uses direct modulation methods similar to those used in low-cost infrared communications devices such as remote control units. LED light bulbs have high intensities and therefore can achieve very large data rates.Figure.1.1 shows an example of cell phone connected to a Li-Fi access point and showing the infrastructure connected.

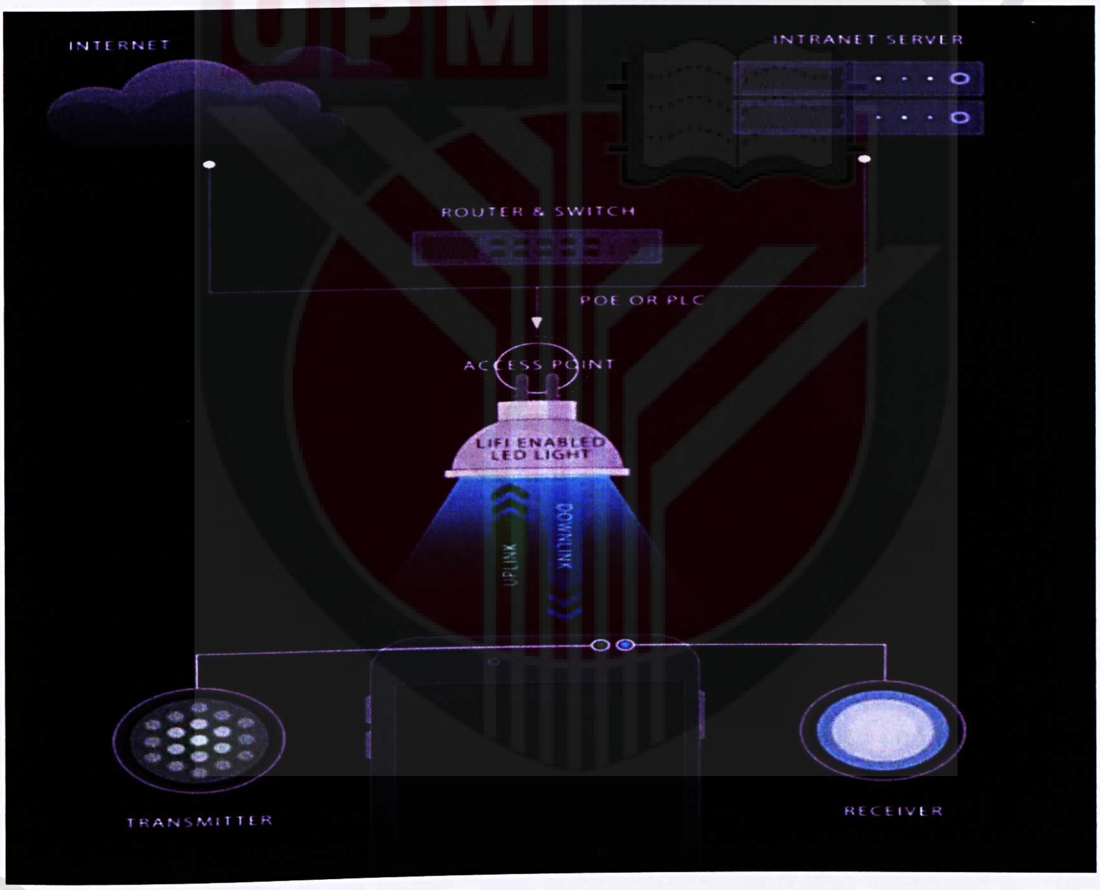

Figure 1.1: Li-Fi connectivity overview (www. purelifi.com)

1.1.2 Applications

Security

The inherent security advantages of using light for wireless communications allow companies to enhance security for their wireless networks significantly. The ability to strictly define the communication area of a LiFi access point allows precise partitioning of the office environment. In addition, the technology requires proprietary hardware before anyone can access the system.

Smart lighting

Anywhere there is LED lighting infrastructure there can be a wireless LiFi communication network. That LiFi network can provide added value providing enhanced efficiency and control. Each LiFi access point (LED Light) in a LiFi network has a unique IP address allowing facility and IT managers the ability to harness the power of a small cell network.

Hospital and Healthcare

LiFi offers an unprecedented opportunity for connectivity within hospitals and healthcare facilities. LiFi does not emit electromagnetic interference and therefore does not interfere with medical instruments, nor is it interfered with by MRI scanners.

Enterprise Wireless Solutions

LiFi networks for daily work, conference streaming, remote desktops along with video, can provide an enhanced user experience with the confidence of robust security. The directionality of light propagation can effectively reduce interferences in heavily populated offices. Wireless off-loading to LiFi releases spectrum for connecting other devices.

Smart Transport

LiFi can not only provide high speed, secure and reliable wireless communications for users of transport, LiFi can also enable vehicle to vehicle communications.

Smart Cities

LiFi can enable the realisation of truly smart cities. Street lights, building lights, and transportation lighting can all communicate wirelessly. LiFi can relieve public wireless congestion as an offloading facility for radio frequencies.

Smart Home and Lifestyle

LiFi in the home will enable simple, secure, reliable and robust wireless communications. Similar to the enterprise environment LiFi can offer data aggregation and wireless offloading. Smart homes can be truly wireless, and users can intuitively understand the best coverage locations by seeing the light. No longer will home users need to worry about "man in the middle" attacks, as they can simply draw the curtains and shut their doors to secure their LiFi networks.

1.1.3 Li-Fi Benefits

Secure: Light can be contained. Light cannot travel through walls, which means a LiFi signal can be secured in a physical space. pureLiFi's technology also enables additional control as data can be directed from one device to another. Users can see where data is going.

No Interference: Radio frequency technology such as Wi-Fi is vulnerable to interference from a wide range of devices such as cordless phones, microwaves and neighbouring Wi-Fi networks. LiFi signals can be defined by the area of illumination, which means interference is much simpler to avoid and even stop altogether. This also means LiFi can be used in RF hostile zones such as hospitals, power plants and aeroplanes.

Data Density: Data density offers a greater user experience as it reduces the need to share the wireless bandwidth with other users. LiFi can achieve approximately 1000 times the data density of Wi-Fi offering more data per square metre. This is an important factor for wireless efficiency.

Location Services: LiFi systems are fully networked, and each LiFi enabled light has it a unique IP address which means advanced geofencing can be deployed simply in a LiFi network.

Efficiency: LiFi allows the repurposing of light for communications as it uses the same infrastructure. LED lights are already widely efficient, and LiFi gives them another purpose, connectivity.

Smart Lighting: Any private or public lighting including street lamps can be used to provide LiFi hotspots, and the same communications infrastructure can be used to monitor and control lighting and data.

1.2 Motivation

On the account of the continuing increase of wireless traffic, it can be anticipated that the current RF spectrum resource will no longer fulfil the future wireless data traffic demand in spite of the efforts on further developments in RF wireless communication technology. Therefore research has been focused on higher frequency spectrum resources. In particular, the millimetre-wave (mmWave) communication and optical wireless communication (OWC) (L. Hanzo and H. Haas, et.al, 2012) are two of the most popular research areas. In mmWave communication, the spectrum in the range from 30 GHz to 300 GHz has been considered for high speed broadband services (M. Elkashlan, et.al, 2014). A considerable amount of spectrum resources are expected to be released for wireless communication. In mmWave links, signal propagation experiences significant atmospheric loss due to the absorption by water vapour and oxygen [10].

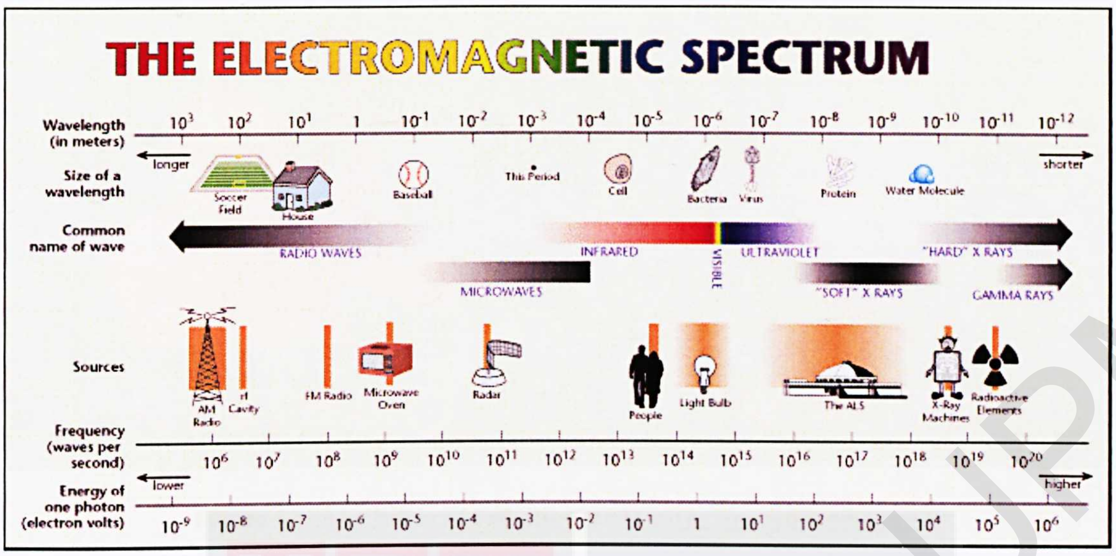

Figure 1.2: The electromagnetic spectrum (http://www2.lbl.gov)

The optical spectrum for OWC includes the infrared (IR) and visible light (VL) (S. Dimitrov and H. Haas, 2015). Figure 1.2 shows that the total frequency bandwidth of optical spectrum is several hundred THz, which is much wider than any RF spectrum ("DIN Standard 5031: Optical Radiation Physics and Illuminating Engineering," 1982)(H. Haas, 2013). With further development in coherent transmission and detection techniques in OWC, the huge capacity with this wide spectrum bandwidth is possible to be achieved in the future.

The electromagnetic spectrum is a continuum of electromagnetic waves with artificial divisions based on the frequency and wavelengths of the waves, while the Infrared radiation (IR) is electromagnetic radiation with longer wavelengths than those of visible light, and is therefore invisible to the human eye, although it is sometimes loosely called infrared light . Figure 1.3 shows an example of the IR.

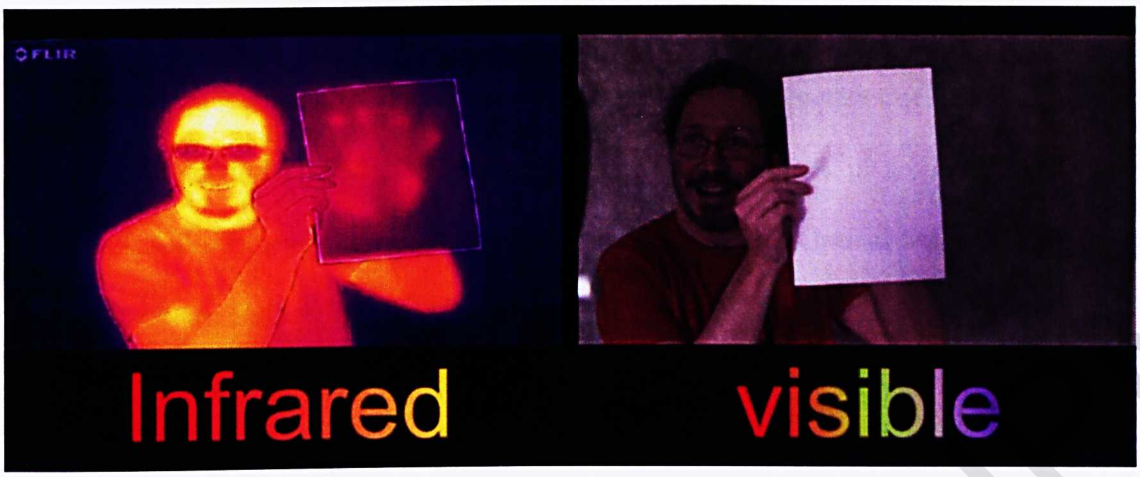

Figure 1.3: The Infrared radiation (IR) (https://en.wikipedia.org)

The main advantages of OWC over RF communication can be concluded as follows (S. Dimitrov and H. Haas, 2015) : i) the optical signal does not interfere with any RF-based wireless systems; ii) OWC can be used in any radio radiation restricted area, such as intrinsically safe environments; iii) and the optical spectrum resource is unlicensed. In particular, OWC using VL, namely visible light communication (VLC), has the potential to be densely deployed using the existing lighting infrastructures, which is expected to be cost-effective. The following Figure 1.4 shows a comparison between Li-Fi and Wi-Fi.

Parameter	Li-Fi	Wi-Fi
Speed	***	**
Data density	***	*
Security	***	**
Reliability	***	**
Ecological impact	*	**
Device-to-device connectivity	***	***
Obstacle interference	***	*

* LOW ** MEDIUM *** HIGH

Figure 1.4: how Li-Fi compares to Wi-Fi (www. purelifi.com)

1.3 Problem Statement

In indoor environments, a Li-Fi cell covers only a few square meters due to the intrinsic properties of light. Generally, there can be many light sources in a room, and high spatial spectral efficiency can therefore be achieved by Li-Fi. Optical wireless link can be a subject of shadowing, and sometimes, even blockage, caused by moving or stationary objects. Interference from neighbouring LiFi (APs) and the blockages of (LoS) optical channels induced by people and objects are the main factors that cause significant optical channel variations. In spite of the dense deployment of access points (APs), Li-Fi does not provide a uniform coverage because optical signals are susceptible to blockages.This means that even with moderate user movement a large number of handover between Li-Fi attocells can occur, and this compromises the system throughput. However, due to user movement, local overload situations may occur which prevent handover, leading to a lower throughput (Y. Wang, et.al, 2015).

When the light beams are blocked, the supported data rate is reduced due to the low optical channel gain. It has been shown that even though Li-Fi networks can provide very high data rates, the outage rate performance in multiuser environment can still be significantly low. In a hybrid Li-Fi/Wi-Fi network, fair and efficient load balancing (LB) can be a challenge due to the small size of Li-Fi attocells. Most of the recent research focuses on the resource allocation (RA) problem in static systems where users are assumed to be fixed (D. Tsonev, et.al, 2013), (M. Vegni and C. Little, 2012). However, in practical scenarios, some users will be moving. In an indoor scenario, the coverage of a Wi-Fi AP is beyond a single room whereas each Li- Fi cell in a Li-Fi network covers only a few square meters due to the rectilinear propagation of light. However, there are many light sources in a room for illumination purposes and Li-Fi harnesses significant gains by reusing transmission resources. As a consequence, when assuming user movement, users may experience many handovers between Li-Fi attocells.

1.4 Research Objectives

In order to evaluating average data rate for the users in all states and evaluating the data rate with consideration of blockage density. The objective is to :

1. Improve the performance of user data rates and outage of the required average throughput by introducing an effective a dynamic load balancing (LB) scheme.
2. To overcome the shadowing problem that effect the data rate given to the users, by balancing and AP assignment.

A dynamic load balancing scheme which focuses on AP assignment for hybrid networks is proposed where the handover overhead is also considered. users with high optical channel gains are preferentially allocated to Li-Fi APs. The limitation of LiFi, such as sensitivity to the LoS blocking and non-uniform spatial distribution of data rates caused by the co-channel interference (CCI) have initially been studied. In a practical scenario, objects such as people and furniture can block the LoS LiFi signals, which decreases the achieved SINR.The effects of optical CCI and blockages on user data rate are investigated. The aim is to develop LB schemes that ensure high user throughput,reduced handover overhead, fairness and stability in a hybrid Li-Fi/Wi-Fi system.

1.5 Research Scope

The scope of this project is to propose a reliable and efficient algorithm that consider mainly about load balancing and AP assignment with the exist of shadow that causes handover and blockages respectively, and to find out how the threshold affects the outage probability and the average data rate requirement.

The proposed scheme can be divided into two algorithms as follow:

1. *Dynamic algorithm with handover executed by the CU.*
2. *Load balancing algorithm in each state.*

1.6 Project Contribution

The main contribution of this project is introducing the load balancing algorithm with handover overhead consideration, beside the shadowing effects on the data rate area for all users in each state.The contribution of the project includes an investigation of the relation between threshold and data rates with user movement in all locations in order to obtain a stable network in the Heterogenous Li-Fi/RF network.

1.7 Thesis Structure

The project is written based on the standard structure of University Putra Malaysia to cover how the project research is accomplished and the remainder of the project is organized as follows:

In **Chapter 2,** a literature review of Li-Fi technology, VlC, optical communications, Wi-Fi and handover in both networks have been presented. However, journals, conference proceedings, seminars, thesis, and books and online resources have been used to enrich this chapter as the main references.

In **Chapter 3,** the design method of the Li-Fi/RF heterogenous network have been introduced. The methodology follows the load balancing algorithms and model used to evaluate data rate, data traffic and AP assignment. And investigating the handover overhead in co-channel interference (CCI).

In **Chapter 4,** shows the results and the Implementation of the proposed case of shadowing has been discussed. And has been evaluated and the generated results are discussed and presented.

In **Chapter 5,** the conclusion of the overall project, and the future work of the proposed load balancing algorithm with shadowing effects has been presented.

1.8 Summary

In this chapter, we introduced the Li-Fi network as a new wireless technology and why is it is needed and how does it work and compared with Wi-Fi.In this chapter, we clarified the need for load balancing in order to control the system and make the connection stable among users and Li-Fi/RF access points along with the movement of users and shadows based on defined scope and contribution.

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