A MULTICRITERIA DECISION-MAKING FRAMEWORK FOR HYBRID LIGHT FIDELITY NETWORK

By

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May 2024

Chairman : Professor Shamala a/p K Subramaniam, PhD
Faculty : Computer Science and Information Technology

Demand for faster internet communications has been significantly on the rise, this is apparent given available spectrum scarcity and increasing demand for wireless services which leads to spectrum crunch problem. It occurs when more devices rely on wireless communication, overloading the limited spectrum resources. Accordngly, this causes slower data rates and performance degradation. To fulfil the growing need for a better wireless connection, Light Fidelity (Li-Fi) has emerged as a solution. Unlike radio-based communication systems, Li-Fi transmits data by Visible Light rather than Radio Frequencies. Li-Fi has various benefits, including quicker data transfer, more bandwidth, less network congestion and interference. Li-Fi has numerous advantages, including but not limited to faster data transfer rates, more bandwidth and reduced network congestion, in addition to zero interference. Combining both technologies Wi-Fi and Li-Fi offers various benefits, including increased data transfer speed, and enhanced network and user capacity. Despite the hybrid approach suitability and strength, it still faces problems when encountering situations with Access Point Assignment (APA), Network Selection (NS), load balancing, and Handover (HO) problems. All these problems affect user connections in terms of maintaining a stable connection, specifically, HO leads to connection disruption of user from the access point (AP), the APA problem refers to choosing most suitable AP based on multiple factors, and balancing the load for connected users is challenging. The fluctuation of different variables values complicates the decision-making process in the midst of the three problems. Therefore, considering multi criteria measurement and evaluation will is anticipated to offer more robust decision-making mechanism which can assist users in addressing such problems. Different attempts were made to address these issues, where fuzzy logic, and load balancing techniques were used in the hybrid approach, however, these techniques did not consider dealing with various APA parameters simultaneously while also considering their levels of significance in the decision-making process presented in the APA process. Therefore, this research aims to establish a more robust decision-making mechanism for Hybrid Li-Fi networks for APA and NS problems by proposing an integrated Multi Criteria Decision Making (MCDM) solution. The proposed MCDM integrated methodology utilizes Analytic Hierarchy Process (AHP) and Višekriterijumsko Kompromisno Rangiranje (VIKOR) for factors/criteria weighting and alternatives ranking of AP and NS. All mentioned problems above were addressed using the proposed MCDM mechanism through 4 main phases, including, identification phase, weighting phase, selection phase, and evaluation phase. Different experimentations and simulations were conducted, and the results presented a unique solution which is different and more efficient in comparison with the benchmark works utilized in APA and NS tasks. Moreover, an enhanced LB approach was developed which provides better higher system throughput and increases user fairness for the connected users. In addition, the proposed work aims to reduce the HO rate. The proposed work findings indicate significant improvement that outperforms the benchmark works regarding system throughput, user fairness, HO rate, and switching probability. The proposed approach has been validated and evaluated using two means, that include sensitivity analysis, and MATLAB simulations.

Keywords: AHP-VIKOR, Hybrid Network, Li-Fi, MCDM, VLC

SDG: GOAL 4: Quality Education, GOAL 9: Industry, Innovation, and Infrastructure, GOAL 11: Sustainable Cities and Communities, GOAL 13: Climate Action.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KERANGKA PENGAMBILAN KEPUTUSAN MULTIKRITERIA UNTUK RANGKAIAN HYBRID LIGHT FIDELITY

Oleh

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Permintaan yang semakin meningkat untuk komunikasi internet yang lebih baik dan lebih pantas telah meningkat dengan ketara. Ini sangat jelas disebabkan oleh kekurangan spektrum yang tersedia kerana peningkatan permintaan untuk perkhidmatan komunikasi tanpa wayar yang menyebabkan isu yang dikenali sebagai "Kesempitan Spektrum." Masalah ini berlaku apabila lebih banyak peranti dan aplikasi bergantung kepada komunikasi tanpa wayar, yang menyebabkan sumber spektrum yang terhad menjadi berlebihan. Akibatnya, kesesakan ini menyebabkan kadar data menjadi lebih perlahan dan prestasi yang lebih teruk.

Untuk memenuhi keperluan yang semakin meningkat untuk pengalaman sambungan tanpa wayar yang lebih baik, Light Fidelity (Li-Fi) telah muncul sebagai satu pilihan yang mungkin. Tidak seperti sistem komunikasi berasaskan radio, Li-Fi menghantar data melalui cahaya yang boleh dilihat berbanding frekuensi radio. Li-Fi mempunyai pelbagai manfaat, termasuk

kadar pemindahan data yang lebih cepat, lebih banyak lebar jalur, kurang kesesakan rangkaian, dan kurang gangguan. Li-Fi, yang terkenal dengan pelbagai kemampuannya, apabila digabungkan dengan Wi-Fi menawarkan beberapa manfaat seperti pemindahan data yang lebih pantas dan peningkatan kapasiti rangkaian. Namun, sistem hibrid ini masih menghadapi cabaran seperti Tugasan Titik Akses (TTA), Pemilihan Rangkaian (RR), pengimbangan beban, dan masalah Penyerahan Sambungan (PS), yang semuanya memberi kesan kepada kestabilan sambungan pengguna. Khususnya, PS menyebabkan gangguan sambungan, TTA melibatkan pemilihan titik akses yang terbaik, dan pengimbangan beban adalah mencabar.

Masalah-masalah ini timbul kerana perubahan nilai pembolehubah yang menyukarkan proses pembuatan keputusan. Beberapa usaha telah dilakukan untuk menangani masalah ini, termasuk menggunakan logik kabur dan teknik pengimbangan beban, namun pendekatan ini tidak mempertimbangkan pelbagai parameter APA secara serentak. Kajian ini mencadangkan pendekatan Pengambilan Keputusan Pelbagai Kriteria Bersepadu (KPKB) menggunakan kaedah Analytic Hierarchy Process (AHP) dan VIKOR untuk menangani masalah TTA dan NS dengan lebih baik dalam rangkaian hibrid Li-Fi. Pendekatan ini melibatkan empat fasa utama: pengenalpastian, pemberatan, pemilihan, dan penilaian. Eksperimen menunjukkan bahawa pendekatan ini meningkatkan throughput sistem, keadilan pengguna, dan mengurangkan kadar PS berbanding kaedah yang sedia ada. Hasil ini telah disahkan melalui analisis sensitiviti dan simulasi menggunakan MATLAB.

Kata Kunci: AHP-VIKOR, Li-Fi, MCDM, Rangkaian Hibrid, VLC

SDG: MATLAMAT 4: Pendidikan Berkualiti, MATLAMAT 9: Industri, Inovasi dan Infrastruktur, MATLAMAT 11: Bandar dan Komuniti Lestari, MATLAMAT 13: Tindakan Iklim

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LIST OF ABBREVIATIONS

4G	Fourth Generation (Wireless Technology)
5G	Fifth Generation (Wireless Technology)
AHP	Analytic Hierarchy Process
AHP-VIKOR	Analytic Hierarchy Process - VIKOR method
ACS	Atto-cell Selection
APA	Access Point Assignment
AP	Access Point
APS	Access Point Selection
BID	Bidirectional
BS	Base Station
CCI	Co-channel Interference
CDMA	Code Division Multiple Access
DCO	Direct Current Optical
DCO-OFDM	Direct Current Optical Orthogonal Frequency Division Multiplexing
DL	Downlink
DM	Decision Matrix
Fi-Wi	Fiber-Wireless
FL	Fuzzy Logic
FoV	Field of Vision
FSO	Free Space Optics
Gbps	Gigabits per second
HO	Handover
HHO	Horizontal Handover
HDAP-OFDM	Hybrid DC-Biased Asymmetrically Clipped Pulse-Amplitude-Modulated Optical OFDM

HDC	Hybrid DC
HDC-OFDM	Hybrid DC-Biased Asymmetrically Clipped Optical OFDM
IEEE	Institute of Electrical and Electronics Engineers
IAT	Inter-Arrival Time
IR	Infrared
IR4.0	Fourth Industrial Revolution
IR5.0	Fifth Industrial Revolution
ISP	Internet Service Provider
LB	Load Balancing
LED	Light Emitting Diode
Li-Fi	Light Fidelity
LR	Literature Review
LOS	Line of Sight
MCDM	Multi-Criteria Decision-Making
MATLAB	Matrix Laboratory
ML	Machine Learning
Mininet	Mininet Emulation Environment
NAF	Networks Assignment Factory
NLOS	Non-Line of Sight
NS	Network Selection
OCC	Optical Camera Communication
OFDM	Orthogonal Frequency Division Multiplexing
OWC	Optical Wireless Communication
PHY	Physical Layer
QoS	Quality of Service
RAN	Radio Access Network

RF	Radio Frequency
SNR	Signal-to-Noise Ratio
TDMA	Time Division Multiple Access
THz	Terahertz
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UAV	Unmanned Aerial Vehicle
UL	Uplink
UE	User Equipment
V2X	Vehicle-to-Everything
VHO	Vertical Handover
VL	Visible Light
VLC	Visible Light Communication
VIKOR	Vise Kriterijumska Optimizacija Kompromisno Resenje
WDM	Wavelength Division Multiplexing
Wi-Fi	Wireless Fidelity

CHAPTER 1

INTRODUCTION

An annual growth rate of 50% in global data transmission is due to increased connectivity, high data transfer rates, and the automation of industrial processes. Fourth Industrial Revolution IR4.0 and fifths Fifth Industrial IR.5.0 These intelligent systems, enabled by increased connectivity and Internet of Things (IoT) devices, can collect and analyze vast amounts of data to optimize production processes. These systems rely on the spectrum for real-time communication and coordination, which offers faster data speeds and lower latency, but it also requires a broader spectrum range to deliver these capabilities. Moreover, different applications within IR 4.0 and IR 5.0 may have varied spectrum requirements.(Kai Lennert Bober et al., 2022; Kouhini et al., 2021; Mukku et al., 2019). For example, smart cities, autonomous vehicles, and intelligent factories may all require other portions of the spectrum. This is because each application has unique data transmission needs and may operate on different frequencies. All this can lead to a problem called spectrum crunch (Bian et al., 2019). The spectrum crunch refers to the scarcity of available spectrum due to the increasing demand for wireless communication services. As more devices and applications rely on wireless connectivity, the limited spectrum resources may become congested, leading to slower data speeds and degraded performance. This is especially apparent given that every new year brings a rise in the number of people who use wireless connectivity devices (Bian et al., 2019; Christy et al., 2022; Irshad et al., 2018). To address this issue, regulators and industry stakeholders are exploring solutions such as spectrum sharing, dynamic spectrum access, and new technologies to alleviate the spectrum crunch and ensure efficient use of available resources. The utilization of more extensive spectrum technologies other than those using radio frequencies is warranted, and among such technologies is Light Fidelity (Li-Fi), which can support a spectrum that is a thousand times larger. Li-Fi is a light-based wireless networking standard also recognized as (IEEE 802.11bb) and is considered the newest communication technologies networking standard under IEEE 802.11(Qureshi & Asghar, 2023).

Li-Fi employs visible light communication instead of Wi-Fi using RF (Tsonev et al., 2015), and it provides a better data transfer rate of up to 224 Gbps (Pravin & Sundararajan, 2018). Achieving such speed using Li-Fi is possible thanks to its capacity to manufacture the tiny cells required for quicker connectivity. The origin of Li-Fi can be linked back to the photophone, invented by Alexander Graham Bell in the 1880s, which was the first documented research in visible light communication (VLC) (Lelinadevi et al., 2023). In 2006, researchers from the State University of Pennsylvania proposed combining power transmission with LED technology for broadband access. The European Union's OMEGA Project: Open Market Energy Generation Allocation in deregulated electricity markets (Contreras & Conejo, 2002) aimed to develop a high-speed domestic service network with maximum performance. In 2008, the US National Science Foundation conducted tests to enhance intelligent lighting wireless communication networks. It can be seen that research works in the European Union and the US contributed significantly to the establishment of Li-Fi, especially after Hass' 2011 TED talk showcasing wireless data transmission by light bulbs. In 2012, Hass assessed the Li-Fi Product Marketing Business, which combined Li-Fi instruments with LED lights, becoming the first market-built equipment. Despite its recent history in the research and development area, Li-Fi offers various benefits that might be adopted by businesses throughout the world.

Li-Fi offers multiple benefits over traditional Wi-Fi technology, including significantly faster internet connectivity than Wi-Fi. Additionally, Li-Fi operates through light waves, making it less susceptible to interference and congestion compared to Wi-Fi, resulting in a more stable and reliable connection. Moreover, it increased security because it uses light signals that cannot penetrate walls, making it more difficult for hackers to access the network (H Haas et al., 2015; LiFi.co, 2011; M. Rubaiyat Hossain Mondal et al., 2019b). This added layer of protection can give users peace of mind when transmitting sensitive data over the internet, increased security, and its ability to operate in areas with high electromagnetic interference, where Wi-Fi signals may struggle to perform effectively. Additionally, Li-Fi can be used in environments where radio frequency signals are restricted, such as hospitals or airplanes. (Kuppusamy et al., 2016; Shukla et al., 2022; Sudha et al., 2016; Vappangi & Mani, 2022). The freedom to use the entire optical spectrum is another advantage of Li-Fi technology; unlike Wi-Fi, which operates within a limited frequency range, the Li-Fi system allows for more efficient and versatile data transmission. This opens up possibilities for future generations to utilize the entire optical spectrum of advancements in communication technology, including the potential for even faster and more reliable internet connectivity without incurring fees. (H Haas et al., 2020; Romanov et al., 2020a, 2020b). The downlink propagation medium for Li-Fi is visible light, making it a novel, high-speed, fully networked wireless transmission system. When used in the uplink, infrared can prevent visible light from interfering with the downlink and keep a room at a constant level of the downlink connection refers to the data transfer that occurs between a base station (BS) and a user terminal (UE) (Harald Haas et al., 2017; Nor & Mohamed, 2019; Ponnimbaduge Perera et al., 2018). However, Li-Fi, like every other technology, has its issues and limitations, which can be listed in the next section.

1.1 Li-Fi Research Issues

Li-Fi signals have a short range, typically limited to the area within a room or a small space. This is because Li-Fi signals are transmitted using visible light, which cannot penetrate through walls or obstacles like Wi-Fi signals can (Yucebas & Yuksel, 2018). Moreover, light interference with the same spectrum frequency, including natural sunlight, can interfere with electronic devices, disrupting signal transmission and affecting image quality (Das et al., 2021; Lorriere et al., 2020; Pradhan et al., 2020). Moreover, Mobility interference issues occur when users are moving between two overlapping Li-Fi connection areas, and this can happen due to co-channel interference (CCI) within the service area. This results in data fluctuations and thus lower data rate for user, in addition to other factors, such as robustness of the communication link, service accessibility, network capabilities, and the direction of the receiver's field of vision (FoV), and receiver optical gain which all has their effects on data rate (Kouhini et al., 2022; D. Li et al., 2022; Manousiadis et al., 2020; Mohammad Dehghani Soltani et al., 2022). In addition, (shadowing and blockage) issues occur when there are obstructions in the way, the Li-Fi gadgets making them struggle to function correctly. This is understandable given the nature of the light and the fact that Li-Fi is a light-based medium, so any light obstructions will affect its connection, which causes the signal to be lost (Pant et al., 2020).

Integrating Li-Fi with existing infrastructure is a complicated task that requires the development of new hardware and software, which require time and cost to be invested in research and development. The integration process involves collaboration with various stakeholders, such as network providers and device manufacturers, to ensure seamless compatibility and widespread adoption.(Paul et al., 2020; Pujapanda & Technologies, 2013). Amongst the most suitable solutions to address previous issues is combining Li-Fi with existing infrastructures to work in hybrid settings, such as (1) optical infrastructure such as Optical Camera Communication (OCC) technology, and (2) wireless infrastructure that includes Wi-Fi, RF, or mm-Wave technologies. However, this will lead to different problems in the new hybrid network, such as handover among different access points within both networks where the HO problem accrues due to the mobility of the user among other light sources. This is particularly important in scenarios where users are moving between areas illuminated by different types of light sources or different networks, such as moving from a Li-Fi area to a Wi-Fi area and vice versa. (G. Ma et al., 2022a; Mohammad Dehghani Soltani et al., 2020a).

The HO problem is worsened by the presence of frequent HO concerns that lead to disruption, packet losses, and delays. In addition, the increased number of HOs also effects the achieved data rate per user. Therefore, the higher HO rates lead to lower QoS, load balancing issues in a dynamic area with multiple users, and fluctuation of the values of criteria, parameters, and variables make the LB problem even more complicated. Another issue primary issue in the previous research revolves around selecting the most appropriate Access Point (AP) for users while considering multiple criteria. Neglecting to choose the most suitable AP/network for users could lead to poor QoS, such as achieved throughput and user fairness. With the increased number of AP and users, the sum of all criteria and fluctuations of values lead to lower accuracy of processing them when using traditional methods. Therefore, the achieved data rates might be lower than expected, and the loads for connected users might be unevenly distributed, especially when considering different data rate requirements per user, where one user may need higher data rate requirements.

It is clear from previous research efforts that the development of an efficient hybrid optical network infrastructure is significant for assigning users to a proper network (AP and Network), which is essential to ensure a better network experience for each user. Towards that end, FL methods have been previously used to connect users with APs and networks; however, FL methods have their main limitations, starting with the detailed considerations of multiple decision criteria that are different across the networks. In addition, these other criteria, which differ in their networking settings, also have not been considered in relation to their importance level/weight in FL research. Methods (Xiping Wu & Haas, 2019c), (Moh. Khalid Hasan et al., 2018). Finally, FL, a proper network and AP allocation mechanism based on various previous criteria with different levels of importance has not been considered in research. During user mobility (user movement), a high chance of multiple frequent handovers (HOs) is likely to occur amongst different APs/Networks (e.g., HO from Li-Fi to Wi-Fi network, vice versa, Wi-Fi to Wi-Fi, and Li-Fi to Li-Fi). This causes various HO types, including vertical HO and horizontal HO; having both HOs leads to reduced network performance for connected users. Moreover, because of the frequent HOs, load balancing issues occur, disrupting seamless transitions between networks and further complicating the network selection process, resulting in reduced QoS and system performance.

1.2 Problem Statements

The problem statements of this research are as follows:

- **Problem 1 (Criteria Importance and Prioritization problem)**

The first problem of this research is linked to the essential criteria necessary for decision-making (DM) purposes. The research shows that many hybrid Li-Fi APA studies have demonstrated the use of DM support techniques. The majority of research that employed fuzzy logic (FL) focused on assisting with APA/network selection difficulties; however, specific challenges remain unresolved. FL membership functions are used to assign each criterion to one of three degrees of relevance (low, medium, and high) without explicitly designating specific levels of importance to each criterion in the AP/network assignment process. Many criteria were assigned equal importance, as indicated in the over mentioned above. The neglect of the value of each criterion stems from a failure to assign appropriate weights to each criterion. Prior studies that mostly used FL models did not successfully conduct priority assessments and had challenges in efficiently managing weighted criteria and tradeoffs among different networking possibilities.

- **Problem 2 (Load Balancing Problem)**

The problem of load balancing takes place when HO occurs among users and APs alongside the APA problem. The need to balance the load among users is significant, especially when different users have different data rate requirements. Solving the HO and APA in a system without paying attention to the load could lead to poor distribution of resources, including data rates and capacities among users. The LB issue heavily impacts the achieved throughput and user fairness for connected users. The load balancing problem can be divided into a few categories, such as general load balancing and resource allocation issues. This research focuses on the general load-balancing problem. On the other hand, the LB problem is caused by additional factors that come from the HO occurrence, user mobility, and APS, wherein the load is continually changing, which impacts the achieved user fairness.

- **Problem 3 (Handover (HO) Problem)**

The handover problem between various access points (APs) with multiple network types is the second problem of this study, particularly in hybrid networks. There are two different kinds of handovers: vertical handover (VHO) and horizontal handover (HHO). VHO happens when a user is allocated to separate APs from distinct wireless networks. At the same time, HHO occurs when a user travels between different access points within the same network, such as a Li-Fi AP to another Li-Fi AP. The factors that contribute to the HO problem encompass light signal blockages, shadowing, long-distance line-of-sight (LOS) connection, device orientation, receiver field of vision, and data volatility. Light signal blockages, shadowing, long-distance LOS connections, device orientation, receiver field of vision, and data volatility are some of the factors that contribute to the HO issue. These variables raise the possibility of packet losses, delays, poor user impression, broken connections, and data fluctuation. This HO problem can occur in all types of Li-Fi hybrid networks, including Li-Fi-Wi-Fi and Li-Fi -OCC. Frequent handovers increase the chance of connection disruption, leading to packet losses, delays, and a poor user impression.

This thesis focuses on three particular problems encountered in hybrid Li-Fi-Wi-Fi and Li-Fi-OCC networks: The selection of Access Points (APs) in a network and the selection of networks themselves have a detrimental effect on both network efficiency and user accessibility. The lack of weighted criteria in the fuzzy logic model for APS and NS affects decision-making and impairs assignment efficiency. User mobility affects handover and load balance, causing them to be problematic. Regular handover (HO) might result in disconnection and reduced data rates for stored user data. The thesis seeks to enhance these concerns in the future.

The study aims to create a novel solution by demonstrating advanced APS and network selection strategies. It also introduces weighted criteria and prioritization techniques using new decision techniques for hybrid networks. Additionally, the study optimizes handover mechanisms to improve the overall performance of hybrid Li-Fi-Wi-Fi and Li-Fi-OCC networks. Figure 1.1 illustrates the research issues and challenges faced in the area, which are the main aspects causing the problem of this research.

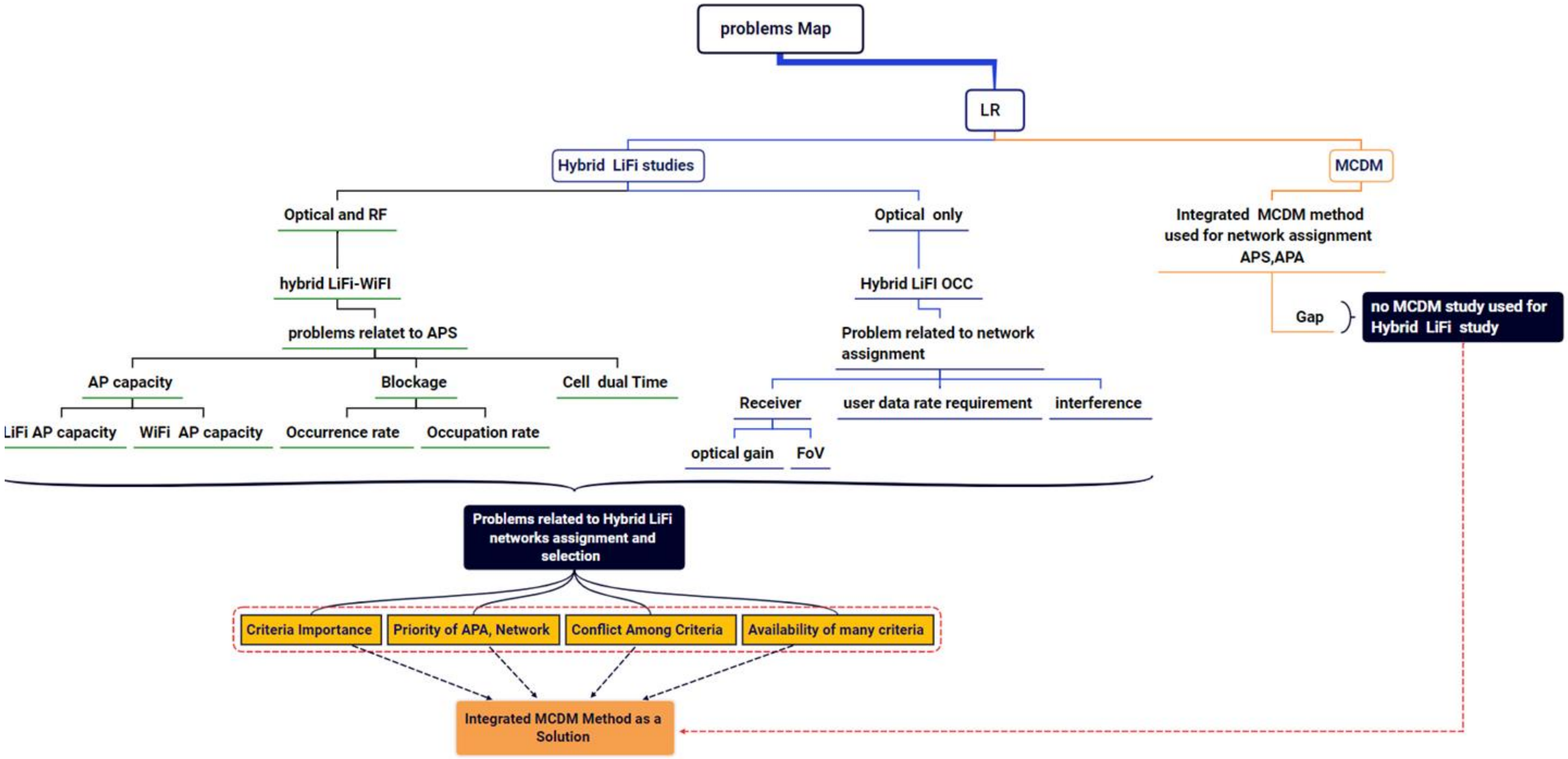

Figure 1.1 : Research Issues Map

1.3 Research Questions

The Research Questions of this research are as follows:

- What methodological approach can be developed to address the issue of Access Point Assignment (APA) with multiple criteria with different levels of importance in a hybrid Li-Fi Wi-Fi network?
- What method can be developed for load balancing in hybrid Li-Fi Wi-Fi networks that consider weighted and multiple criteria to enhance system throughput and increase user QoS?
- What method can be developed for the best network selection that can reduce handover number in hybrid Li-Fi-OCC networks that considers weighted and multiple criteria for optimal network selection?

1.4 Research Objectives

The objectives of this research are as follows:

- To develop an MCDM approach by using integrated AHP-VIKOR to solve the problem of criteria weighting determination and APA in a hybrid Li-Fi Wi-Fi network to enhance the user APAs selection process and enhance the system throughput.
- To develop an enhanced load balancing algorithm based on an integrated MCDM approach to enhance system throughput and increase user QoS.
- To develop an AHP-VIKOR method in a hybrid Li-Fi-OCC network for user mobility for a better network assignment process and reduce the multiple handover number to enhance the system QoS.

Table 1.1 : Relationship between Research Problems, Research Questions and Research Objectives

Research problems	Research Questions	Research Objectives
Criteria Importance and Prioritization problem)	• What methodological approach can be developed to address the issue of Access Point Assignment (APA) with multiple criteria with different levels of importance in a hybrid Li-Fi Wi-Fi network?	• To develop an MCDM approach by using integrated AHP-VIKOR to solve the problem of criteria weighting determination and APA in a hybrid Li-Fi Wi-Fi network to enhance the user APAs selection process and enhance the system throughput
Problem 2 (Load Balancing Problem)	What method can be developed for load balancing in hybrid Li-Fi Wi-Fi networks that consider weighted and multiple criteria to enhance system throughput and increase user QoS?	To develop an enhanced load balancing algorithm based on an integrated MCDM approach to enhance system throughput and increase user QoS.
Problem 3 (Handover (HO) Problem)	What method can be developed for the best network selection that can reduce handover number in hybrid Li-Fi-OCC networks that considers weighted and multiple criteria for optimal network selection?	To develop an AHP-VIKOR method in a hybrid Li-Fi-OCC network for user mobility for a better network assignment process and reduce the multiple handover number to enhance the system QoS.

1.5 Research Scope

The study investigates hybrid Li-Fi networks, specifically in static hybrid Li-Fi-Wi-Fi and hybrid Li-Fi-OCC networks and develops a selection and evaluation of MCDM-based methodology using AHP MCDM methods. It presents two distinct static environments with unique network selection and access point assignment scenarios. It proposes two distinct matrices for evaluation to optimize the effectiveness of the AHP approach and guarantee the stability and dependability of the decision-making protocol. It offers a strong basis for future investigation and valuable applications in static hybrid Li-Fi networks. It can provide faster data transfer rates, enhanced security features, lower interference levels, decreased health hazards, easy integration with pre-existing infrastructure, and bright future possibilities for wireless communication applications. An LB-MCDM method is developed to showcase the effectiveness of integrated methods in selecting suitable networks and access points. Simulations are conducted to test the performance of the proposed methods and compare them to existing approaches, validating their efficacy in optimizing network resources within static Li-Fi environments.

1.6 Research Significance

The use of MCDM techniques, specifically AHP and VIKOR, for access point assignment in hybrid Li-Fi networks is significant for efficient resource utilization and enhanced user experience. By optimizing access point allocation based on factors like signal quality, user density, and bandwidth availability, this approach ensures better network performance, reduced handover rates, and improved reliability. Additionally, AHP-VIKOR enables more adaptive networks in dynamic environments, enabling informed decision-making and better network optimization. This research contributes to the advancement of academic research in networking and decision-making, bridging the gap between theoretical methodologies and practical network challenges. Overall, the significance lies in leveraging MCDM AHP-VIKOR for strategic access point assignment in hybrid Li-Fi networks, improving efficiency, adaptability, and user experience while advancing academic knowledge and industry practices. The presented research work in this dissertation is considered the first of its kind in using and developing MCDM-related research in the Li-Fi research area, which is expected to open new paths and directions for the upcoming Li-Fi studies.

1.7 Thesis Organization

This PhD thesis consists of seven primary chapters, each specifically focused on analyzing essential aspects of the MCDM Framework for APA/NS and Handover and load balancing in Hybrid Li-Fi Networks Using Integrated AHP–VIKOR Technique.

Chapter 1 provides an overview of the research and explains the background and origin of the research; it also identifies the problems and highlights the research objectives, research questions, and importance of the research. Chapter 2 provides an extensive examination of the current body of literature, delving into essential theories and empirical research concerning Hybrid Li-Fi Networks, as well as the accompanying challenges and constraints.

Chapter 3 explores the research methodologies of the benchmark works and their reimplementation, providing a comprehensive explanation of the selected study design, methods of data collecting, and analysis techniques used to investigate the research topics.

In Chapter 4, the results obtained from the AHP-VIKOR method for the Hybrid (Li-Fi-Wi-Fi) and (Li-Fi-OCC) Networks are presented. These findings are thoroughly examined and explained in relation to the research objectives. Chapter 5 presents the findings obtained from applying the LB-MCDM Algorithm in Hybrid Li-Fi Wi-Fi. Chapter 6 presents the final significant discoveries on Handovers, Switching Probabilities, and Network Selection in the context of the Hybrid Li-Fi-OCC Network.

Chapter 7 provides conclusions, clearly summarizing crucial findings, addressing constraints, and proposing potential directions for future research. Furthermore, appendices serve the purpose of offering supplemental material and providing in-depth information that supports the main body of the text.

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