Integration of the Internet of Things With Light Fidelity: Potential Challenges a Review

Rozin Badeel[1]
rozinbabdal1987@gmail.com
Shamala K. Subramaniam*
shamala_ks@upm.edu.my
Zurina.M. Hanapi
zurinamh@upm.edu.my
Abdullah Muhammed
abdullah@upm.edu.my
Department of Communication Technology and Network, University Putra Malaysia(UPM), Malaysia[1]

ABSTRACT

With the rapid growth of connected devices, new issues emerge, which will be addressed by boosting capacity, improving energy efficiency, optimizing spectrum usage, and reducing cost, while offering improved scalability to handle the growing number of linked devices. This can be accomplished by integrating Light Fidelity (LiFi), which is known as one of the newest communication technologies that aim to improve the current technology by employing visible light communication (VLC) and the Internet of Things (IoT). LiFi represents an efficient solution for many IoT applications and use cases, including indoor and outdoor applications. However, given the availability of few academic works attributed towards studying these two technologies, integration together has been challenging and warrants considerable attention. Therefore, this research aims to present a review of LiFi technology integration with IoT. Many aspects presented in the literature, however, the focus of this review has been given to LiFi's overall characteristics and integration of a variety of cases and presenting its general challenges, followed by the integrati on opportunities and challenges of both IoT and LiFi. This work provides avenues for new research pathways and opportunities within the rich areas of LiFi and other technologies currently being extensively used and those that will be adopted in the future. It will also enable researchers to understand this area more deeply and its associated applications.

Keywords - **LiFi · IoT · Optical Communication.**

1. INTRODUCTION

Wireless data has become a resource that is fundamental to our daily routines, and operating in its absence seems impossible. Wi-Fi is accessible in virtually every location and is among the most widely used wireless technologies. However, the time we are permitted to use it is restricted. Radiofrequency (RF) technology, which makes Wi-Fi feasible, is rapidly running out of spectrum to handle the increasing digital revolution. Every new year brings a rise in the number of people who use wireless connectivity, bringing us one step closer to a phenomenon known as the "Spectrum "Crunch". This is a situation where there may not be enough accessible wireless frequency spectrum to handle an expanding number of consumer devices [1]. The insufficiency of accessible spectrum poses a significant risk to wireless networking and telecommunications; This might have considerable future repercussions [1]–[6]. In addition, we can employ a spectrum that is almost one thousand times larger than the total spectrum that is utilized for radio frequencies, which is

The result of another excellent communication technology known as Light Fidelity (LiFi) [5],[7].LiFi is one of the newest communication technologies that aims to improve current technology by employing visible light communication instead of Wi-Fi using radio waves [7].
Its introduction has two goals: to supply families with overhead lighting and to make data transfer easier. This technology can attain a maximum data transmission rate of 224 gigabits per second. LiFi enables a substantially greater number of access points than Wi-Fi radio frequencies. It can achieve higher data speeds required because of its capacity to manufacture the tiny cells required for quicker connectivity [8]. There are currently billions of mobile cell phones in use around the world and combined with the growing popularity of smartphones and tablets, this has resulted in a significant increase in the amount of daily data flow, especially during crises and pandemics [9], [10]. This includes the data generated and transferred by laptops, traditional personal computers, large data servers, and

Internet of Things (IoT) devices already in use [11]. In addition, the technology that is available today is being placed under a significant amount of pressure because of the ongoing need for faster and more secure data sharing. The communication infrastructure must be improved before IoT enables further growth and provides additional benefits. Either the existing wireless networks must be extended to cover different territories, or an alternate solution must be conceived and implemented [12]. In this article, a review of LiFi technology in terms of its applications in different places such as companies, schools, and hospitals are presented, it's the problems presently being faced by the IoT connection. Finally, challenges and opportunities that come due to the integration of this technology with the IoT are also presented.

2. LIFI APPLICATIONS

LiFi is still in its early stages of research and development, and it has several advantages that may be implemented in organizations worldwide. LiFi can be faster than typical office Wi-Fi networks and can handle more than 100 Gbps [13]. This is 14 times faster than WiGig and can help to maintain continuous online team collaboration while minimizing the costs associated with expanding bandwidth in office networks. Moreover, LiFi can provide an efficient signal range compared to other wireless communications where the signal from the led bulbs is short, and LiFi transmissions cannot also penetrate through barriers [14]. Even if the user location is far from the light source, it can still connect since LiFi delivers and receives data via light reflections [15], [16].

LiFi has constant internet access LiFi is powered by light, permitting connection to the internet from anywhere within the building that is furnished by light. They can take an online video call, such as a Zoom call, and movies from one room to another without disrupting the line connectivity. They can even visit the customary Wi-Fi dead zones, such as the basement, without fear of losing their internet connection and disrupting their work. Besides, when protecting sensitive enterprise information, LiFi's limited signal range is not a drawback but an advantage. To reduce the possibility of privacy violations and other frequent cyber concerns, businesses should encourage employees who deal with sensitive information to use the LiFi network instead of the office Wi-Fi.

Fig1. represents the LiFi network in the office and workplace Many European schools have started installing LiFi in the classroom, including four elementary schools in Belgium; Signify's Trulifi 6002 system has been implemented in three schools in Brussels, Flobecq, Aubange, and Wanze areas [17]. LiFi can reduce the amount schools usually pay to get more bandwidth for day-to-day activities for students and teachers. LiFi is expected to work well in a classroom with four solid walls and more than one light source. Moreover, LiFi uses special light-emitting diode (LED) bulbs that can be dimmed and send data. So, even if the teacher shows a PowerPoint presentation, students can still work online on their Chromebooks. In addition, classrooms on or near the ground floor of a building often have trouble connecting to Wi-Fi. However, since LiFi only needs special LED bulbs, it can make it easy for students to get online, by applying LiFi access points (APs) in the classroom, connecting many devices such as laptops, intelligent PowerPoint tablets, and projectors. Since protecting human life is paramount, focus on reliability and safety is warranted. There is concern that RF waves for data transmission might have adverse health effects [9] even when Wi-Fi does not work well. Fig2. The World Health Organization (WHO) indicates that these signals may cause cancer.

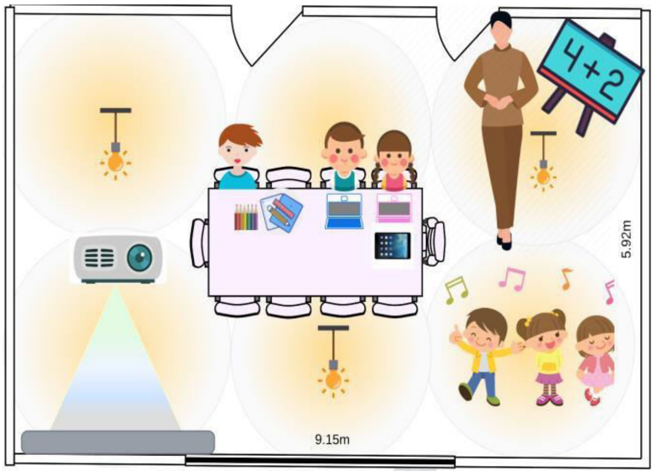

Fig 1. LiFi technology implemented in schools

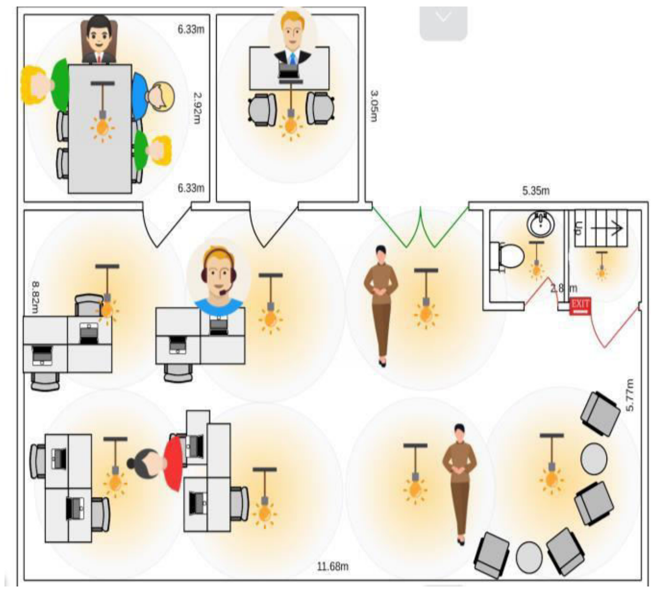

Fig 2. LiFi technology implemented in companies

Due to their strong radiation effects, radio waves should be avoided in a healthcare setting. LiFi technology is being utilized to address this concern to maintain a healthy atmosphere. Thus, visible light waves are used for medical applications like Magnetic resonance imaging (MRI) equipment [13]. Furthermore, LiFi technology can be used to communicate with LED lights in traffic signals, and messages can be sent to the cars to warn the driver about the speed that he or she should maintain to decrease the number of accidents and achieve a lower accident rate.

Fig 3. Represents applying LiFi APs in hospitals

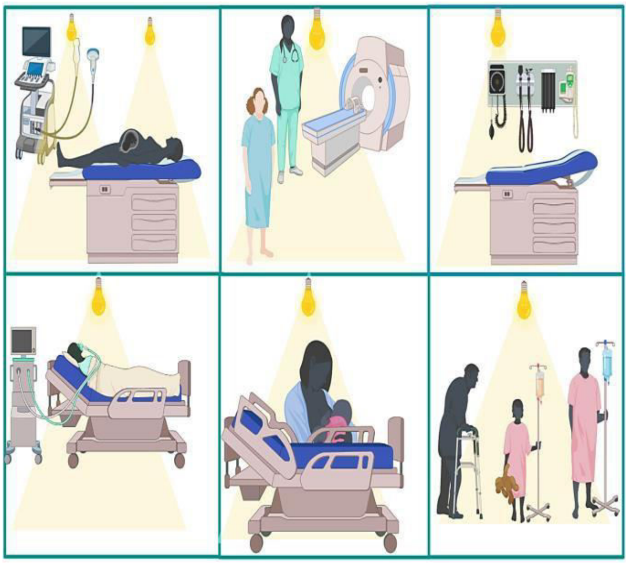

Fig 3. LiFi technology implemented in school companies and, Hospitals

3. LIMITATIONS AND ADVANTAGES OF LIFI TECHNOLOGY

There are limitations to any technology, and LiFi technology is no exception. It has been speculated that a LiFi device will not work well in direct sunlight. Further, any solid object, such as a wall, can readily block the signals' progress. On the other hand, there are solutions available. LiFi might be used with Wi-Fi to guarantee a trouble-free data transfer [18].

Researchers are working to prove LiFi im- so that it may serve as a viable "substitute" for Wi-Fi in the future. Smart architectural solutions can help overcome these constraints by directing light to follow the user wherever they go. More algorithms are being developed to analyze light and facilitate rapid data transmission. LiFi can be effectively implemented in various domains such as medicine, life sciences, and healthcare since it does not cause an electromagnetic reaction compared to Wi-Fi.

LiFi incorporates direct modulation and relatively less expensive components such as photo detectors and LEDs. Moreover, LiFi is more secure since it cannot be interfered with, even across the walls, ensuring a secure data stream. However, it also means that people living in the same house but across different rooms will not be able to connect to the same network. Therefore, LiFi can transform any LED light into a high-speed data transmitter. The IoT devices can be compatible and in sync with LiFi for enhanced functioning. LiFi can conveniently accommodate multiple access points, as IoT connectivity requires, by using simple light bulbs as terminals. Researchers are focusing on LiFi as a viable solution for the rapid growth of IoT and Big data. They are working on developing more intelligent, faster, and more reliable data transmission methods. The efficacy of these technologies is entrenched in the efficiency of the network that supports them. Therefore, LiFi could be deemed an enhancement for IoT devices' workability and a means to leverage their optimum potential. Since LiFi does not result in electromagnetic interaction, it may be used in fields such as medicine, life sciences, and healthcare where Wi-Fi is permitted [19]. LiFi provides a more secure data stream, even over walls, since it is immune to interference.

This has the disadvantage of preventing members of the same household from sharing a single network even if they are located in different rooms of the same house. Moreover, direct modulation and inexpensive photodiodes and LEDs are two of life's defining features. That's why LiFi makes it possible to turn any LED light into a super-fast data transmitter. LiFi may be made interoperable with and synchronized with IoT devices to improve performance. With LiFi, numerous light bulbs may serve as terminals, making it easy to support the various access points needed for IoT connection [20]–[22]. Attempts to find a workable answer to the exponential expansion of the Internet of Things (IoT) and big data have led researchers to zero in on LiFi to create more efficient, speedy, and trustworthy means of data transfer. The effectiveness of these technologies is firmly embedded in the robustness of the infrastructure that supports them. Therefore, LiFi may be seen as a technique to enhance the usefulness of IoT devices and improve their usability [23]. Table 1. Illustrate all the advantages and dis advantages of LiFi technology.

4. CHALLENGES FACING IOT CONNECTIVITY

The IoT devices must be able to recognize information, process it, and link with other devices to work correctly. These needs frequently prove to be a barrier to the full-fledged, successful adoption of IoT technology since they cause various issues that make meeting these requirements difficult. Some of these challenges in the deployment of IoT is to provide dependable and bidirectional signaling, which is essential for IoT devices to provide a simple data channel; this problem must be solved by using a reliable, two-way communication channel that enables the data source to both send and receive data [21], [24].

Moreover, The IoT is intended to be a pervasive network that instantly determines if an IoT device is connected or disconnected. Ubiquitous detection is a technique for monitoring the condition of all connected devices, detecting network problems, and fixing gaps in real time. This widespread identification is a challenge to effective IoT deployment for obvious reasons [25]. Furthermore, ensuring IoT device communication is safe is another difficulty. Even though it was first advertised as a very secure network, the IoT's most prominent security problem is that it connects to the cloud. This makes it less suitable for storing and sending sensitive data [25]– [27]. Therefore, initiating data transport only after authorization by the primary IoT server is crucial. End-to-end encryption is necessary to verify the authorization. In addition, another challenge for IoT is its enormous power consumption. An efficient cellular system with long battery life and an intelligent detector built into the IoT device is necessary for effective, smooth, and real- time communication.

Moreover, the compatibility of devices is challenging for IoT [27]. This is because while the IoT expands in various directions and incorporates a wide range of technologies produced by multiple manufacturers, there is currently no universal standard. This results in several complications that need additional hardware and software implementation due to compatibility concerns. Because of this, gadgets of this kind will inevitably become rare in the future. Finally,

The IoT's connection seems to be its biggest challenge. Currently, the authentication, authorization, and connectivity of various nodes in a network are all handled through a centralized server-client model [28]. This model is responsible for providing connectivity. A model like this should be enough for the current state of IoT landscape, which only involves a small number of devices. However, centralized systems will only become a bottleneck for future networks that consist of hundreds of thousands, if not millions, of devices.

Table 2. LiFi Advantages and Disadvantages [7], [14]

Limitations of LiFi	Advantages of LiFi
The data can only be sent over very short distances due to high frequencies (400-800 THz)	Low Environmental impact
Due to the shorter distance between the transmitter and receiver, the signal-to-noise ratio (SNR) is high	LED lights are more efficient and use less energy than traditional lighting options.
Only devices with a LiFi receptor may utilize LiFi.	Many light sources will assist in the transmission of continual data.
Since any objects so easily hinder light, there must be no obstructions in the way of the transmission or reception of data.	No interference between devices since LiFi employs light frequency transmissions, which do not interfere with RF
Point-to-point communication is the only way to set up a network.	Up to 10 Gbps data transfer speeds are easily achievable
Small coverage area reaching around 10 meters in diameter	The visible part of the electromagnetic spectrum is a license-free zone where communication can occur without incurring costs.
Accessing the internet requires a continual source of light.	LiFi transmissions are secure since light cannot pass through
In order to increase the data transfer rate, arrays of LEDs are used, with some groups consisting of a combination of red, green, and blue LEDs to change the light's frequency, with each frequency encoding a data channel.	LiFi may be deployed and utilized everywhere, such as hospitals, offices, schools, and traveling such as airplanes and ships
Providing constant internet connectivity outside is challenging because of the increased likelihood of signal interference using LiFi (different light sources). As a result, Internet outages are inevitable when exposed to direct	LiFi can work underwater where the light can pass through salty sea water
Providing constant internet connectivity outside is challenging. Internet connectivity will be unstable because of the sun's	Not harmful to the human body
LiFi requires creating and installing a whole new infrastructure, which will take some	Less maintenance and implementation fees
Outdoor equipment setup requires adapting to various weather conditions	Every streetlight in the globe would be an accessible data connection point if this technology
The areas of security, privacy, architecture, and communications need to be improved.	Light has an extensive bandwidth, which improves capacity
Network coverage and reliability are the major issues to be considered while developing IoT	
Since light cannot pass through buildings or barriers, innovative ideas and solutions are required for remote access.	

5. OPPORTUNITIES AND CHALLENGES OF INTEGRATING IOT AND LIFI

Accuracy and security are two of the primary problems that must be overcome in the domain of indoor positioning [9]. There is an urgent requirement to construct a reliable system to deal with the issues discussed before; another issue is receiver sensitivity; the usual receiver has a sensitivity that falls in the range of -40 dBm to -45 dBm[34], [35]. Because of this, the number of photons that need to be gathered to reach a certain signal-to-noise ratio might be affected as a result (SNR). In contrast to fibre-optic communication, the light beam is highly concentrated on a relatively small detector [25]–[27]. The Internet of Things (IoT) is a system that consists of interconnected networks, gadgets, and computers that each have a specific identification; they can transmit information across different terminals without requiring human or computer intervention. At the level of the organization, the Internet of Things comprises a wide variety of work systems, servers, networks, databases, records, terminals, and communication gateways. This can incorporate security systems, cars, lights, and other electronic equipment used in commercial and residential environments, as well as alarm clocks, speaker systems, and vending machines. Table 2. Is illustrated by some recent studies that integrated IoT in LiFi.

The Internet of Things carries with it an extraordinary amount of promise for organizations, particularly in terms of simplifying and improving operational procedures; the enormous demand for data transfers and the extraordinarily high, seamless, and dependable Wi-Fi capacity that is required for those transmissions are putting a strain on the existing technological infrastructure, which is becoming challenged as a result, in the not too distant future, the number of mobile devices in use around the globe will have reached billions. These portable gadgets will produce an incredible one thousand terabytes of data monthly. However, A new way of information transport has been developed by researchers that are one hundred times quicker than the standard Wi-Fi protocol, which is LiFi. However, the main practical difference between LiFi and Wi-Fi is that Wi-Fi relies on radio frequency to transport data, whereas LiFi uses visible light spectrum, such as LED lamps; this wireless communication technique takes advantage of the visible light spectrum (as well as the ultraviolet and infrared spectrums, if necessary). This will assist in achieving high- speed data transfer between devices, terminals, and servers and can satisfy the vast demand for devices. The development of such a light-based technology was motivated by the observation that light travels more quickly than radio waves and, as a result, makes it possible to exchange information at a rate up to 250 times faster than high-speed broadband. This technique uses LED light knobs to facilitate communication and provide lighting at much-reduced costs. The Internet of Things (IoT) is an organized mix of supplementary computer devices, exceptional industrial devices, and the capacity to share information beyond the requirement of human-embedded technology. The Internet of Things uses various computing devices to transmit and exchange data using embedded technologies. According to research conducted by Transparency Market, the market for IoT-enabled Li-Fi technology is expected to grow with a robust and consistent CAGR during the

LiFi's capabilities of LiFi that make it an essential technology in forming IoT, where LiFi can enhance availability. In most parts of the world, the international market is still in its early stages, but it has the potential to grow steadily over the next few years. One of the best things about LiFi is that it can be used in many places where Wi-Fi does not work, or electromagnetic interference can be dangerous [41]. Airplanes are a perfect example. LiFi, which does not use radio waves and only uses the LED lights already inside the plane, could change the way passengers and cabin crew connect while in the air.

LiFi can potentially assist the growth of the Internet of Things as the need for data and connection continues to rise (IoT). Furthermore, LiFi could be less expensive and use less energy than other kinds of wireless communication [36] because LED bulbs are already energy efficient. Furthermore, It can also help solve one of the challenges of the IoT with LiFi; IoT devices do not always need routers, modems, and wave amplifiers. Also, IoT devices that use LiFi can use the LED lights in the area to connect. If you have a light, it will be much simpler to guarantee that all devices connect quickly, effectively, and without problems. [27][42][43].

Table 2. Literature review for the studies relater to LiFi -IoT Integration

Ref	Proposed Method Or Design	Year	Objective	Network Types	Strength	Limitation
[29]	designed a system idea that is both adaptable and reliable for multiple use cases of LiFi and	2020	To underline the need of harmonising the primary features and functional blocks, as well as employing proven technology, in order to lower total costs.	LIFi	To propose such a flexible system idea for LiFi by introducing a common set of basic technologies and combining them in various ways to create customised solutions.	They considered Lifi only not Hybrid LiFi Wi-Fi
[30]	The ELIoT project addresses present the current state of the art of LiFi systems and provide additional features that will be required for future applications involving the internet of things	2020	To improve reliability while simultaneously boosting throughput	Hybrid Networks	Providing interworking with other systems such as radio and wired infrastructure, achieving mobility both horizontally (to LiFi access points) and vertically (to other technologies such as WiFi and 5G), developing cost-effective and easy-to-install in-building backbone infrastructure networks, and demonstrating end-to-end link security	They didn't consider the complexity of the system
[31]	This study presents a method that is both energy efficient and capable of providing quality service for access point selection in hybrid WiFi and LiFi Internet of Things networks.	2021	Provisioning of QoS while simultaneously enhancing energy efficiency	LiFi only Or WiFi only	A distributed client-side AP selection technique with cubic complexity is provided where multihoming is not permitted.	They considered Lifi only or Wi-Fi only not Hybrid LiFi-Wifi
[24]	provides unique green communication methods that can be utilised for the coexistence of LiFi users and light communication (LC) enabled IoT devices under a common LiFi access point.	2021	Reduce the complexity and increase the energy efficiency at	LiFi-IoT	provides a complete study of the many variants of DCO- OFDMH that have been proposed and those that already exist in the coexistence schemes in terms of key performance criteria including system complexity.	Efficiency in the use of energy is not taken into account.
[32]	an energy-efficient NOMA approach for bidirectional LiFi-IoT connection	2021	To improve the energy efficiency (EE) of the bidirectional LiFi-IoT system	LiFi-IoT	Extensive analytical and simulation findings are presented here to evaluate the performance of various multiple access approaches in a typical bidirectional LiFi-IoT system. The collected findings prove that NOMA using OPA with adaptive channels and QoS-based user pairing is optimal for use in energy-efficient bidirectional LiFi-IoT systems.	They considered LiFi only not hybrid network
[33]	New algorithm was proposed based on the access point selection model, considering the strategic behavior of the objects and users	2021	increase the efficiency of IoT network	Hybrid network	The proposed method can significantly improve the effectiveness of Internet of Things networks and more evenly distributes network load among access points that utilise a variety of technologies.	They didn't consider calculation overhead, network fairness, etc.

5. CONCLUSION

LiFi utilizes LED lamps for wireless communications, where a visible light band is used as a replacement for the radio spectrum. There are various advantages and usages for this technology ranging from being a very high data rate technology with an energy efficient system based on the lighting available everywhere anda simple circuit with naturally a security feature. This technology and its capabilities are also prone to different challenges and limitations, especially when integrated with other technologies like IoT. We presented a comprehensive review discussing various LiFi and IoT integration aspects, including LiFi ad- vantages in different environments, including those related to workspace, Offices, and schools, followed by other classes of challenges for IoT integration and connectivity. We lastly presented a summary of LiFi opportunities and challenges of both technologies when coupled together. This review will present researchers with a starting point and future pathways where LiFi is considered not only a unique technology but also a technology that can be integrated with other technologies. This technology is still in its early ages, and more real applications will emerge in the future.

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BIOGRAPHIES OF THE AUTHORS

Rozin Badeel Abdal (Sm) received her Bachelor degree in Computer Science and Information Technology in 2012 from Nawroz University in Dahuk, Iraq. Then, she received her M.Sc. degree in Distributed Computing and Networks in 2018 from University Putra Malaysia, Malaysia. She is currently pursuing a PhD in Computer Science at the University Putra Malaysia, Malaysia. Her main research interests are focused on cloud computing, Optical Wireless Communication (OWC), hybrid optical wireless and RF communications, and LiFi and Systems Simulation networking and Modelling.

Shamala K. Subramaniam received the B.S. degree in computer science and the M.S. and PhD degrees from Universiti Putra Malaysia, in 1996, 1999, and 2002, respectively. She is currently a Professor with the Department Communication Technology and Network, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia. Her research interests include computer networks, simulation and modelling, and scheduling and real-time systems.

Zurina Mohd Hanapi received the B.Sc. degree in computer and electronic system from the University of Strathclyde, Glasgow, U.K., in 1999, the M.Sc. degree in computer and communication system engineering from Universiti Putra Malaysia (UPM), Malaysia, in 2004, and the Ph.D. degree from Universiti Kebangsaan Malaysia, in 2011. She is currently an Associate Professor with the Department of Communication Technology and Network, Faculty of Computer Science and Information Technology, UPM, where she has been a Lecturer, since 2004. She has authored over 70 articles in the cited journals and conferences in the area of security and wireless sensor networks. Her current research interests are on security, routing, wireless sensor networks, wireless networks, distributed computing, and cyber-physical systems. She is a member of the Malaysian Security Committee Research.

Abdullah Muhammed received the bachelor’s degree from University Putra Malaysia, Malaysia, in 1998, the master’s degree from Universiti Malaya in 2004, and the Ph.D. degree from the University of Nottingham, U.K., in 2014, all in computer science. He is currently a Senior Lecturer with the Department of Communication Technology and Network, Faculty of Computer Science and Information Technology, University Putra Malaysia. His research interests include grid/cloud computing, and heuristic and optimization.