IJCSE International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-7, Issue-2, Feb 2019 E-ISSN: 2347-2693

Survey on Improving Wireless Sensor Network (WSN) with Li-Fi and Wi-Fi for Smart City Applications

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DOI: https://doi.org/10.26438/ijcse/v7i2.477481 | Available online at: www.ijcseonline.org

Accepted: 22/Feb/2018, Published: 28/Feb/2019

Abstract **-** The need of seamless and ceaseless faster internet connection speed is on the rise. Since, most of us have access to Wireless Fidelity (Wi-Fi) to fulfill this need, which can become our only option. That's why, in 2011, a new revolutionary technology comes into light, which is known as, Light Fidelity (Li-Fi). But, testify existing Li-Fi system, a detailed study of its behavior with other IEEE standards such as, Low power Bluetooth (BLE), Wi-Fi, ZigBee etc. should done, which can fulfill by Wireless Sensor Network (WSN). This survey paper represents numerous work happened in field of Wireless Sensor Networks (WSNs) from various IEEE standard based protocols like, Wi-Fi and Li-Fi. So, here at first, brief introduction of various IEEE standards and Wireless Sensor Network (WSN) carried out. Then, in next section, a literature review of various research paper presented along with comparison between Li-Fi and Wi-Fi technologies and applications of Li-Fi in Wireless Sensor Network.

Keywords **–** *WSN, IoT, Wi-Fi, Li-Fi, Smart City*

I. INTRODUCTION

In current modern world, the search for faster and secure internet connection is limitless and the need for new technologies are at upmost higher level. Wireless Fidelity (Wi-Fi) is one of the valuable asset but still it has some limitations. Even some new challenges can occur if Wi-Fi is our only alternative. Challenges like, Security threats, Limited connection speed etc. are major disadvantages of Wi-Fi system. So, we require a new technological paradigm to tackle these challenges and Light Fidelity (Li-Fi) (IEEE 802.15.7) fits perfectly for it [1].

But, right now, we only have theoretical and practical knowledge about Wi-Fi module and Li-Fi modules and less information about how they will perform along with other IEEE standard protocols such as, low-powered Bluetooth, ZigBee etc.

Therefore, we require a Wi-Fi and Li-Fi based Wireless Sensors Networks (WSN) for performance measures. Also, at this point of time, Li-Fi can give us more benefits in real-world application, due to its usage of free bands of EM spectrum and ability to working in both underwater and underground environment, therefore, we need to have Li-Fi and Wi-Fi based smart city that can help in various areas such as, traffic regulation, vehicle and transportation etc.
So, a question may arise that why do we need Li- Fi since we already have a Wi-Fi? So answer to that question is that, as earlier mentioned, Li-Fi is much faster than existing Wi-Fi system. Also, Wi-Fi system have lack of security constraints such as, Wi-Fi jamming, hacking etc. But, Li-Fi is a relatively short-ranged network system, so it is more secure than Wi-Fi system [2]. And, Li-Fi systems have light as medium of communication which can made available. So, Li-Fi is also much suited for underground and underwater applications, where Wi-Fi's RF signal may not become useful.

In this paper, Section I contains the introduction of this paper. Section II is a literature review of various journal papers and other sources which represents existing research. Section III has applications of Li-Fi in Wireless Sensor Network (WSN). Section IV have summary and future scope of this survey about which paper has more suitable outcome for current topic and need of Li-Fi in existing technology system and future work for better further exploration of this project.

II. LITERATURE REVIEW

A. Li-Fi based techniques for WSN

Light Fidelity (Li-Fi) is a technology based upon IEEE 802.15.7 standard introduced such that the data transfer rate is over 1 Gbps, which is 100 times faster than the speed of Wi-Fi we are utilizing as of now. It utilizes light rays emitted form Light Emitting Diode (LED) by modulating information into visible light rays at transmitter and

demodulating it at receiver side. Li-Fi transmitter can transfer this information in 0s and 1s format, which shows by light on and light off respectively [1].

Mithileysh Sathiyanarayanan et.al [1], have proposed a basic base station and remote station model of Li-Fi system. Also, they have given introduction of Li- Fi system and presents various challenges and opportunities of Li-Fi system with IoT environment. Authors have mentioned challenges like, constant requirement of line-of-sight (LOS), wireless coverage up to 10 meters only, effects of weather conditions on Li-Fi system at outdoor environment etc. Authors have mentioned about various opportunities of Li-Fi system for example, underwater and underground communications, better medical facilities etc. Authors have presented various merits and demerits of Li-Fi system along with Li-Fi based smart home automation system.

Kun Chen Hu et.al [3] shows us in their paper that how to create and deploy a Li-Fi based prototype based on Field Programmable Gate Arrays (FPGA). Here, they used two Spartan FPGAs for transmitter and receiver modules Here, transmitter module consists frame delimiter which, counts the frame size of data packets, emitter which emits data packets in byte frame of 0s and 1s and DSP Tx that performs encoding of data packets for security reasons. On the other side, receiver module consists DSP Rx which performs decoding of data packet, synchronizer which sync every data packet received so, corrupted data packets could get discarded. Along with this, authors explained real-time implementation of Li-Fi system and explained schematic overview of Li-Fi system.

V´ıctor Monz´on Baeza et.al [4] have presented deployment of Li-Fi based street light. Here, entire trans-receiver module is built upon street lamp as transmitter and mobile phone camera as receiver. Also, FPGAs used here under software defined radio (SDR) approach. Working of entire system explained by authors, where transmitter mechanism has Spartan FPGAs, which acts as Li-Fi modulator, LED driver circuit and white LEDs as transmission medium. Along with it, phototransistor is also available for modulating data packets into byte frames. Even, receiver side mechanism consists phone camera with demodulating FPGA along with light-resistance sensor (LDR). For better software configuration, Xlink suite IDE 14.7 is being used in this paper.

E.W Lam et.al [5] have explained light-based positioning for indoor environment. Here, they have introduced a new concept of ACTIVE ZONE. Here, Classification of various Visible Light Positioning (VLP) technologies and introduction of new concept of active zone and its physical implementation using baseline VLP model carried out. Even, signal analysis of this baseline VLP model carried out, which detects people available at particular place in a room with help of 3X5 VLP lighting arrays and optitrack cameras. Here, authors have categorized light-based positioning as per some classes such as, active vs passive, privacy preserving vs Non-privacy preserving, Mapped vs unmapped spaces etc.

B. Wi-Fi based techniques for WSN

Wireless Fidelity (Wi-Fi) is technology which supports radio spectrum as data carrier medium. It has frequency range from 2.0 GHz to 2.4 GHz. It is a IEEE 802.11n standard protocol. It has data transfer rate up to 150 Mbps and it ranges up to 1000m. It is a trademark of Wi-Fi alliance, which allows certification to Wi-Fi based products that successfully completes interoperable certification testing [6].

Pradip Kumar Sharma et.al [7] have introduced us to combination of various energy harvesting sensors (EH-sensors) and combinational Li-Fi and Wi-Fi based module. In this paper, they have shown an environmental friendly way of communication. Because, here EH sensors are sensors which are works over various non-conventional energy sources like, wind energy etc. In this paper, authors have classified various energy harvesting techniques for WSN such as, solar energy harvesting, RF-based energy harvesting, thermal-based energy harvesting and mechanical-based energy harvesting. Authors have also mentioned various modulation techniques such as, single-carrier modulation techniques like, pulse position modulation (PPM), on-off shift keying (OOFK) and pulse amplitude modulation (PAM), multi-carrier modulation techniques like, orthogonal frequency detection modulation (OFDM) and Li-Fi specific modulation techniques such as, color shift keying (CSK). Authors [7] have deployed a EH-sensor based Li-Fi WSN, which can elaborate transmission speed up to 25 Mbps.

Zhijun Li et.al [8] presents special software for physical layer cross communication named as, WeBee. Here, WeBee works on usage of a high-speed wireless radio to emulate the desired signals of a low- speed radio using QAM and channel coding emulation for better cross-platform technology (CTC). Here, ZigBee control signal transformed into Wi-Fi signals for better cross-platform communication. Authors of this research work explained how emulation of ZigBee signals to Wi-Fi signals happens. At first, emulation of ZigBee signals with Wi-Fi signals performed by modulation and transferred as Wi-Fi signals at transmitter side and at receiver side, these emulated Wi-Fi bits performs demodulation and ignore those Wi-Fi bits and intercept ZigBee bits.

Xinyu Zhang et.al [9] provide a framework that emulate performance of ZigBee and Wi-Fi networks, and analyzes the impact of key design parameters in new concept of Cooperative Busy Tone (CBT) using frequency flip and busy tone scheduler. CBT assigns a ZigBee node as

signaler as a proxy to send data packet concurrently with implicit carrier signal or busy tone. The key aspect of CBT is that, sending data packet over busy tone with balance without causing any interruption. Also, to measure performance of CBT, authors have developed an analysis framework where ZigBee and Wi-Fi technologies are available together, which analyzes network performance with and without CBT in that framework. As results, authors have concluded as, with CBT, Wi-Fi caused collision reduced by almost 42% to 90% with compare to non-CBT framework with 73.3% to 83.3% energy efficiency.

Li Li et.al [10] displayed application of Wi-Fi based wireless sensor network in Internet of Things and Smart Grid. Here, they have also listed out applications from other fields such as, Smart Agriculture and Intelligent environment protection. Along with it, authors explained status of smart grid in different countries like, US, China, and Japan. Also, authors have mentioned various benefits of Wi-Fi based WSN for example, higher bandwidth, non-line-of-sight transmission, cost-effectiveness and ease of expansion of WSN. User managing and automatic meter reading are being considered as application of WSN in smart grid environment. Also, sanitary-operation system which includes, garbage collection, water sewage cleaning etc. with Wi-Fi based WSN and GPS system considered as, application for intelligent environment protection.

Gerard Rudolph Mende et.al [11] did research on Wi-Fi based wireless sensor network for agricultural environment. This research investigates a remote node system where Wi-Fi nodes made of WSN802G module. Where these nodes send all data wirelessly to central server, which collects the data, store it and allows it whenever display needed. The major agricultural factors for this Wi-Fi based WSN are temperature, humidity, light, pressure and soil moisture and water level. Along with this, authors have explained hardware configuration of WSN802G with WSN and WSN802G specifications. Furthermore, authors even explained about data logging with the help of WSNApp application in .CSV format. In future work also, authors have mentioned to add nitrate in water to analyze its effect on agricultural environment.

C. WSN and various techniques for WSN

WSN is a wireless network with base stations and various wireless sensors nodes. Here, these networks use to monitor physical or environmental conditions like sound, pressure, temperature from end point nodes and transmits collected data through hub or gateway to a main location or base station WSN have different topologies such as, tree, bus, mesh and star. There is also various type of WSN are available for example, terrestrial WSN, underwater WSN, underground WSN and so on [12].

Intidhar Bedhief et.al [13] have shown us new way of enhance IoT heterogeneity by introducing new concepts like, Software Defined Network (SDN) and Docker. Representation of multiple IEEE standard working together on single platform via Docker and introduction of new SDN framework like, Ryu etc. described in that research paper. Here, authors have proposed two approaches to enhance IoT heterogeneity, first approach deals with SDN controller. SDN controller used for flow control management and mobility management. SDN controller divides geographical space into discrete smaller parts of areas. The second approach is to develop a software defined framework for IoT devices. Various IoT devices managed and controlled by this framework for achieving IoT heterogeneity using Dockers. Authors developed a testing environment with client-server model for verifying these two approaches. Various multiple servers used such as, TCP and UDP. As result, with both approaches, average data rate is somehow up to 10 Mbps to 20 Mbps.

R. Gunasagaran et al. [14] have presents a Multiprotocol trans-receiver system for better sensor-to-sensor communication in IoT environment, in which authors have also used Arduino board along with CEASTech software for providing IoT environment in indoor conditions. Also, authors have classified entire system with three parts: sensor nodes, front end multi-receiver architecture and back-end data analysis architecture. At first, sensor nodes consist various wireless sensor nodes such as, mesmic node, Wi-Fi node, ZigBee node and Bluetooth node. Then, front end multi-receiver architecture has Wi-Fi and ZigBee integrated Arduino based system connected with sensor nodes and PC with LabVIEW software for processing and MySQL database for database management. And at back node data analysis architecture, all the acquired data transferred to cloud system in case of future requirement of acquired data. In future works, authors mentioned about deployment of centralized server for central monitoring of system.

Amit Sharma et.al [15] have explained about Wireless Sensor Network (WSN) and wireless sensor nodes. All of these sensor nodes are best for harsh conditions and interoperability, which we can refer from this paper. Other than that, requirement of low power consumption for WSN sensors explained in that paper. Also, authors presented power requirement of wireless sensor node with some calculations. After that, authors explained about two IEEE standard for wireless sensor network which are IEEE 802.15.3 high-rate wireless personal area network (HR-WPAN) and IEEE 802.15.4 low-rate wireless personal area network (LR-WPAN). Also, software architecture of these wireless sensor nodes and wireless sensor nodes platforms such as, TelosB, MicaZ and Wi-Fire with their specifications explained by authors.

D. *Comparison of Li-Fi and Wi-Fi technologies*

In [16] , a comparison has been carried out for two wireless technologies such as, Li-Fi and Wi-Fi on various parameters.

Table 1. Comparison of Li-Fi and Wi-Fi Technologies [16]

Sr .No	***Parameters***	***Light Fidelity (Li-Fi)***	***Wireless Fidelity (Wi-Fi)***
1.	Data Transfer Rate	Faster data transfer rate up to 1Gbps.	Moderate data transfer rate up to 25-150 Mbps.
2.	Data Carrier Medium	Visible Light	Radio spectrum
3.	EM spectrum range	Approximately 10,000 times broader than Radio frequency	Lesser than Visible light spectrum
4.	Operational Cost	Cheaper due to usage of visible light spectrum which is free band	Expansive compare to Li-Fi due to usage of Radio spectrum
5.	Operational Frequency	Hundreds of Tera Hz (THz)	2.0 to 2.4 GHz

Ashmita Shetty [16] have proposed basic principle of Li-Fi system and discussed about how Light Fidelity (Li-Fi) works in indoor conditions. Working of Li-Fi with transmitter-receiver module along with phototransistor being discussed in paper. Author even discussed about sources of data transmission with Li-Fi. Also, there is brief discussion about how Li-Fi is different from other IEEE standards such as, Wireless Fidelity (Wi-Fi) as, Wi-Fi cannot work underwater and underground where Li-Fi can. Even, various benefits of Li-Fi being discussed such as, underwater communication, medical emergencies, smarter and secure aircrafts etc.

III. APPLICATIONS OF Li-Fi IN WIRELESS SENSOR NETWORK

A. Underwater Communication: As we all know; Radio waves cannot penetrate through water after some distance. Therefore, underwater operating vehicles like, submarine may face difficulty while communicating with other inside sea or even communicating with outside world using radio waves. Therefore, Li-Fi could be useful at this situations, due to having light as prime source for communication, which can travel farther corners of sea. So, Li-Fi can work better in underwater environment [16].

B. Medical Emergencies: There are many places in a hospital where radio waves can become harmful for patients such as, operation room. Not even patients, radio waves can cause damage to equipment available in other rooms also. Therefore, Li-Fi can become very helpful in hospitals, because lights can cause less damage compare to radio waves. On economical level, this system costs very less compare to Wi-Fi based system, due to usage of normal LEDs as a communication module [16].

C. Smarter and secure aircrafts: Nowadays, airplanes have more facilities than previous years, such as, free internet access. To provide that, airlines uses Wi-Fi modules, which uses radio waves for providing internet services. But, may passengers may or may not access this services due to large amount of people in aircraft. Therefore, deploying Li-Fi modules on reading lights of every passenger will give every passenger a sufficient amount of internet access facility [16].

D. Free of cost frequency bandwidth: As we all know, Li-Fi uses light as communication medium and it is accessible at free of cost. Therefore, using Li-Fi is a cheaper option compare to other similar technologies and it has no requirement for licensing, which makes it accessible open for everyone too [16]

IV. SUMMARY AND FUTURE SCOPE

To summarize this review, we can say that, we get the basic introduction of Light-Fidelity (Li-Fi) and other IEEE standard and Wireless Sensor Network (WSN). Also, we get to know basic advantages of Li-Fi over Wi-Fi in brief. Also, we have seen various approaches of how Li-Fi and other IEEE standards can work together. but since, Li-Fi is not commercially available on a required scale, so real world implementation of Li-Fi system has less possibility to occur. Even though, improvement in WSN based on Li-Fi and other IEEE standard is very desirable in smart city where different fields such as, health-care, traffic regulation and etc. can take major benefits of Li-Fi and other IEEE standards to make future better.

So, the prime future scope for this research work could be a hardware implementation of Wireless Sensor Network (WSN) from Wi-Fi and Li-Fi. This WSN could have temperature and humidity sensor, PIR motion sensor and Gas leakage sensor as wireless sensor nodes for home automation system. A comparative analysis between these two WSNs on different parameters such as, data rates, energy-efficiency, cost-effectiveness can help for improvement in WSN. This comparative analysis helps to decide in which conditions Wi-Fi could be more beneficial and in which conditions Li-Fi could be more beneficial.

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