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A New Model of Wireless Communication for Environmental Sustainability using Light Fidelity

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Abstract**:** Environmental sustainability and protection are of high priority for the present conditions of world. One of the important responsibilities of environmental protection agencies is to set policies and regulations to protect the environment for humans and wildlife. For the last two decades, mobile phones and devices have been used exponentially by the people. Most of the wireless communications for the civilians use the radio and microwave spectrum with the frequency range of 3Hz to 300 GHz. The heavy use of radio wave and microwave communications affect the health of human life. In addition, the infrastructure developed for radio and microwave propagations affects the environment. Many species, such as butterflies and small birds have become victims of radio waves, and they are disappearing in the nature. The basic characteristics of the radio and microwave spectrum is that the emitted radiation is absorbed into the many objects during the signal propagations. This is harmful for many living beings. One of the best substitutes is to replace the radio waves with the visible light spectrum. The Light Fidelity (LiFi) uses the visible light spectrum as medium of transmission during communications. LiFi is useful for indoor communication and replaces WiFi, which uses the radio signals for communication. The replacement of WiFi with LiFi can provide environmental sustainability in terms of health of humans and wild species. However, the technology for LiFi is still underdeveloped to bring it to the commercial markets. In this paper, a prototype is developed for the LiFi using Raspberry Pi 4. The experiments were done to test on the prototype.

Keywords**:** Wireless Communication, radio spectrum, visible light communication, LiFi, environment sustainability.

1. Introduction

In the present conditions of society, the majority of the wireless communication medium uses electromagnetic radio spectrum. The radio frequency in the range from 100 MHz to 6 GHz is used for different generations of wireless communications such as 2G, 3G, 4G, and WiFi. The radio spectrum range is increased to 120 GHz for the 5G. However, the awareness on the environmental effects due to the radio wave propagations is significant as it directly affects human health and insect's biological systems. Since long time, it is studied by governmental agencies, policy makers, and researchers on the radio exposure to the living beings. In 2011, the radio frequency has been categorized as 'Group B' human Carcigeon by the International Agency for Research on Cancer (IARC). Some of the human concerns on the radiation exposure are chromosomal DNA damage, effects on children brain, and adult male reproductive system, such as low sperm count, sperm morphology, and DNA damage [1]. On the other side, the radio exposure on the insects leads to different issues such as insect's behavior, physiology, and morphology. But, insects play very important role in nature stability and environmental sustainability. A review on radio heating exposure and their effects on insects is given in [2]. Some researchers investigated environmental radio frequency effects on insects and their biological effects [2, 3]. The absorption of radio magnetic field on living beings can damage their health either directly or long-term basis. So it is important for environmental sustainability to replace or reduce the use of radio spectrum in devices, especially cell phones and smart phones. The recent investigations in wireless communications brought good news for the environment sustainability with the replacement of radio spectrum by visible light spectrum. In other words, the majority of radio wireless communication can use visible light spectrum for the communication without losing its purpose. Due to the physical characteristics of the radio signals such as signal penetrate objects, the radio wireless communication cannot be completely replaced. However, visible light can replace many subsystems such as indoor communication systems. There is a need for significant research for visible light-based wireless communication, such as Light Fidelity (LiFi), before they come to the commercial markets. In this paper, we investigate the consequences of radio based wireless communication, especially on the nature and environmental effects. In addition, it is proposed a prototype for the LiFi transceivers using Raspberry Pi.

The remaining paper is structured as follows. Section II presents literature review on the major elements of the paper. Section III describes the proposed model for implementing the LiFi. Section IV provides the discussions and analysis on the radio based wireless communication, and visible light-based wireless communications. Section V presents the implementation details and the results of the experiments. The paper is concluded in Section VI.

2. Related Work

In the worldwide, billions of mobile devices use wireless communication with the Radio-Frequency electromagnetic spectrum as communication medium. In many communication devices, the RF frequencies used between 100 MHz and 6GHz [4]. The base stations in telecommunication systems are major ones contributing to the damage of environment [4]. Many human beings, creatures, insects, and animals are affected by the RF and their body absorb this radiation [5]. The absorption is depending on the frequency used [6, 7]. There has been a study on the RF absorption on the insect bodies at different frequencies 27MHz [8, 9], 900–915MHz [9–11], and 2450MHz [12].

In order to reduce the use of radio electromagnetic filed, researchers started investigating for the replacements to the radio wireless communication. The optics is considered best alternative for this. The visible light spectrum is abundant and able to replace the radio wireless communication in many applications. The LiFi uses visible light spectrum as communication medium [13].

A researcher from the University of Southern Queensland has worked on Light Fidelity (LiFi) with Raspberry Pi. The method uses visible light communications (VLC). The LiFi's research area is part of VLC, which uses the visible light spectrum of electromagnetic waves. This range is 10,000 times larger than the radio frequency range. Data synchronization is faster than the processing speed of current consumer devices. Their work describes the construction and testing process of the LiFi prototype in detail. The prototype is low-cost and compact which uses affordable components, and delivers robust product [14].

The researchers presented a related work titled Data transmission using visible light communication authored by Anup Kiran et al. This work summarizes that the use of the radio frequency spectrum which will be exhausted due to its limited frequency and these resources will reach the point of overload. As LiFi is in the field of research that uses the visible light band, the paper describes about visible light communication using Universal Asynchronous Receiver/Transmitter (UART) [15].

Researchers demonstrated VLC or LiFi with the lab setup experiments. The setup of lab experiment demonstrates on creating a VLC link between two devices. Using this prototype, a data rate of 300 bps was attained. The achieved coverage is approximately two meters of distance. The proposed transceiver uses lasers both downstream and downstream while maintaining the same data rate. The prototype used can handle text communications, video and audio data [16].

A research on the suffering of the RF communications and the replacement of the RF communication is described in [19]. The role of optical communication for the replacement of RF also been presented. Visible Optical Communications (VLC) is the first choice in optical communications because it operates in the visible light spectrum, which is harmless and available abundant of bandwidth. The modulation methods are also reviewed and compared according to their characteristics. The paper presented the development and use of MultiBus Filter Bank (FBMC) method in VLC systems [17].

An article was published, which has presented a inclusive survey of VLC, focusing on the challenges in the indoor environment. The new technology VLC was compared with infrared (IR) and radio frequency based wireless communication systems. Discuss the advantages of LEDs over traditional lighting technology, and compare the various types of LEDs available. The mod scheme and dimming technique in VLC internals are discussed in detail. It also introduces ways to improve the performance of the VLC system, such as equalization, filtering, beamforming, and compensation [18].

Researchers proposed a model for utilizing the LiFi in the existing systems without losing the expensive public communication infrastructure and the extracting the high data rates in the communications [19]. Similarly, a three-level architecture was proposed, in which the best utilization of LiFi communication can be achieved for urban developments and reduce the radio spectrum utilization [20].

The researchers presented the importance of optical communications, especially Visible Light-based communications over the radio based wireless communication. They have described difficulties of RF communications in terms of interferences and low response time. It was mentioned that the visible light communications is the first choice in optical communications because it operates in the visible light spectrum. The paper also reviewed considerable developments in the field of semiconductors, especially the communication between LED and laser diodes in the lighting process. The methods of modulating the optical signal by these methods are also reviewed and compared according to their characteristics [17].

3. Methodology

The radio frequency for wireless communications causes damage to nature and the environment. The human's health and insect's biological systems are also affected by radio frequency exposure.

The usage of radio communication-based devices such as cell phones and smart phones is increased day by day. There is a need for the government agencies and public sectors to encourage the research on alternatives to radio based wireless communication. In the current systems, there are communication mediums other than radio frequency, such as infrared spectrum. However, the physical characteristics of infrared spectrum do not replace much area of radio-based communication systems. The researchers at University of Edinburgh explored the VLC based on visible light spectrum. The characteristics of visible light spectrum are feasible for the replacement of majority subsystems of existing radio-based communication systems. For example, the LiFi can replace the WiFi systems, especially for the indoor communication systems. However, there is a need to improve communication systems for the LiFi before they arrive to the commercial markets. In this section, a new prototype to design the transceiver of LiFi is presented.

The primary objective of this article presents the use of visible light spectrum for wireless communication, instead of radio or microwave spectrum. The following shows the circuit design for LiFi transmitters and receivers.

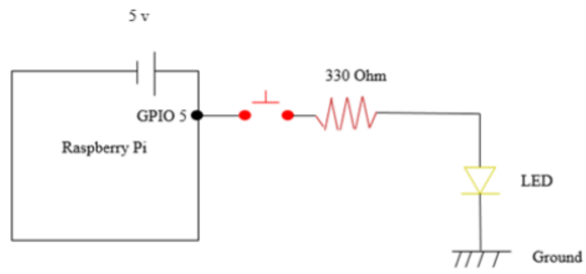

Figure 1. Transmitter Circuit

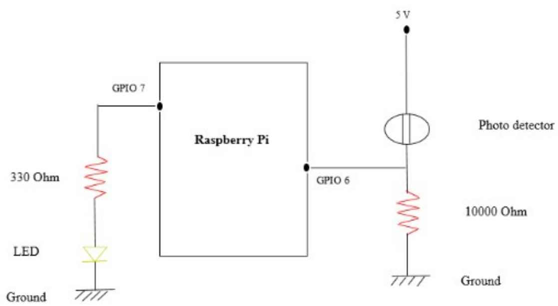

Figure 2. Receiver Circuit

The Raspberry pi is powered by a battery, see Figure 1. The GPIO in Raspberry Pi is the General Purpose Input Output pins in the processor. The GPIO pin of the Raspberry Pi is connected to one side of the tactile switch. The other side of the tactile switch line is connected to the resistor of 330 ohms. The resistor is used to limit current so that the LED doesn't burn and is connected to the switch. The negative pin of the LED is connected to the ground. To make sure that the circuit is working, a tactile switch is added so that when the button is pressed, the LED is turned on.

The receiver requires careful consideration choice of components than the transmission module. The receiver module contains two parts, see Figure 2. The first part is about detecting the light ray using the photo diode. The second part is the module that indicates whether the transmitted data is received or not. The first part is designed by connecting a 5V battery line to the photo diode which in turn is connected to the micro controller pin GPIO6. From the photo diode, the line is connected to the 10000-ohm resistor followed by the ground. The second part of the receiver module is connected to the GPIO 7 from one side of the resistor followed by LED. The negative side of the LED line is connected to the ground.

4. Discussion and Analysis

When The environment is affected by natural and artificial sources. The natural sources include Sun, Atmosphere, and Earth, whereas the artificial sources include the technologies that emits the electromagnetic fields into the environment. The following are the human made sources that affect the environment.

TV Transmitters and Radio Towers: The TV and Radio broadcast services, especially in the urban areas, pose significant effects on the environment. The mobile phone companies too implant the signal towers in the middle of the civilian places.

High Voltage Electric Lines: The electric lines propagate electric power in the frequency range from 50 Hz to 60 Hz. These lines span hundreds of kilometers.

Radar: The radar systems are used in many applications such as aircraft, GPS, and military surveillance systems.

Undersea Power Cables: Many countries are using undersea cables for different purposes such as transferring DC power and communication connections.

The VLC uses visible light as communication medium, whereas RF uses Electromagnetic radio waves. Hence replacement of EM radio waves by optical waves can reduce the EMF emissions into the environment. Some of the considerable differences of VLC and RF are shown in the Table 1.

Table 1. VLC vs RF

Parameters	VLC	RF
Frequency range	430 THz – 770 THz	3KHz – 300 GHz
Electromagnetic Interference	VLC is not affected by EM sources	Affected by EM sources
Power Consumption	Less power consumption system	High
Spectrum availability	Huge bandwidth	Lower compared to VLC
Deployment	Easier	Communication Infrastructure is required
Power Amplifier	Not required	Required
Communication Coverage	Short	Medium
Data Security	Secured communication in Indoors as the light does not penetrate into the walls	RF signals penetrate walls and can be less secured.

The VLC technology is used in LiFi, which uses the visible light spectrum for transmission of data. The VLC system has three components: Light-Emitting Diodes as transmitters, a silicon photodiode to detector the light and the air or fiber optics as communication channel. The source of VLC light could be a fluorescent bulb or an LED. A strong LiFi sys-

Table 2. Application Areas

Area	**Visible Light Communication**	**Radio Frequency based Communication**
Underwater Communication	Data rate is better than RF	Restricted data rate
Public Places	Already LEDs are deployed in streetlights, traffic lights, and headlights etc.	Needed a separate infrastructure
Aircrafts	The VLC technology can be used in Aircrafts during the fog and raining	Signal attenuation problem
Hospitals	Better option	Health issues and Signal Interference problem
Disaster management	VLC can be used to detect the cracks in aircraft engine and wings	Not flexible

tem needs high rates of light output. LED can provide efficient light output compared to fluorescent bulbs. The LED is manufactured from semiconductors, which provides efficient amplification and fast switching of light intensity. An LED is also a semiconductor, which implies that it can amplify the light intensity and switch rapidly. The LiFi system needs the LED to be dims up and down, which is not comfortable for household illumination. To provide a balance between VLC light source and household illumination, it is necessary to provide optical modulation techniques for extremely high-speed data transmissions, provided that the light fluctuations are unperceivable by the human eye. The receiver of LiFi system demodulated the signals and converted it into a continuous stream of bits that contains text, audio, video, and images [15]. Some of the applications of VLC are shown in Table 2.

The deployment of RF in public places, the EMF emissions affect the civilians, animals, and insects. In addition, the billions of mobile phones or cell phones cause the humans exposed to RF radiation. If the radio transmitters use high power signals, the problem increases for the people. Table 3 shows the risks associated with the RF and VLC.

Table 3. Human Health Issues

Area	**VLC**	**RF**
Health Risks	Low	High
Human Organs affected	Eye	Brain, Skin, Respiratory systems, and Heart
Newborn babies	VLC applications are used for health monitoring of babies	High Risks for newborn babies
Adult Reproductive System	Low risks	High Risks, Adult Male reproductive systems, such as low sperm count, sperm motility and morphology
Human cells	VLC can be used to detect the cracks in aircraft engine and wings	Chromosomal DNA damage
Ray penetration	No	RF can penetrate into objects

5. Prototype Implementation

In this section, it is presented the implementation of LiFi module for the LiFi Communication. Two circuit boards

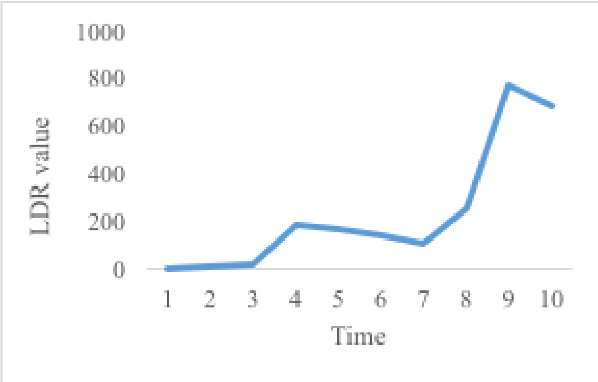

Figure 3. LDR Scenario 1

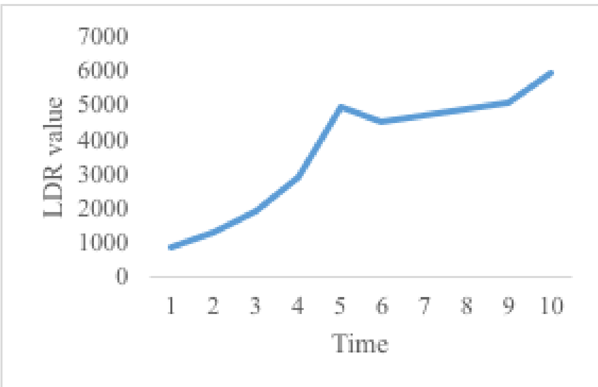

Figure 4. LDR Scenario 2

are developed, one for transmitter and another for receiver. Each circuit used a separate Raspberry Pi 4 processor. In the transmission circuit, it is tested the communication circuit using Python programming to control LED using Raspberry Pi GPIO pins. It uses some basic equipment including Raspberry Pi, LED, 330 Ohm resistor, wires and Breadboard. The LED indicator is connected to the GPIO pin without resistance, the LED will pull a lot of current, which may lead to damage raspberry Pi processor or burn LED. The receiver circuit uses LDR sensor to detect the light emitted from the transmitter circuit. After connecting the hardware components correctly, it was programmed using Raspberry Pi processor coding to turn the LED lamp on and off at varying intervals. It was tested the LDR readings while the LED is being blinked in transmitter circuit. The Figure 3, Figure 4, and Figure 5 show the LDR values at different scenarios. These scenarios indicate the various external light interference to the experimental bed. However, the readings were taken with different intervals between ON and OFF of LED in the transmitter.

The graph in Figure 6 shows the average LDR value for all the experiment.

6. Conclusions

In this paper, it has been investigated and analyzed the seriousness of high usage of radio signals. The high usage of RF based cell phones or smart phones causes damage to the environment. A new paradigm of wireless communication is

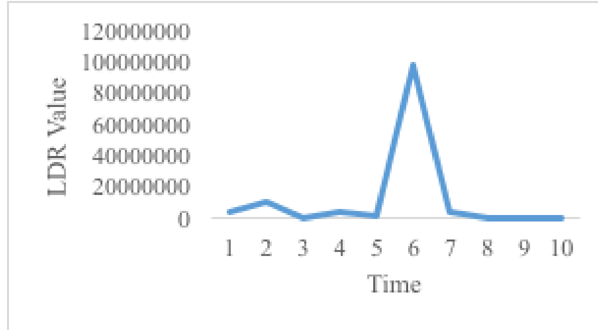

Figure 5. LDR Scenario 3

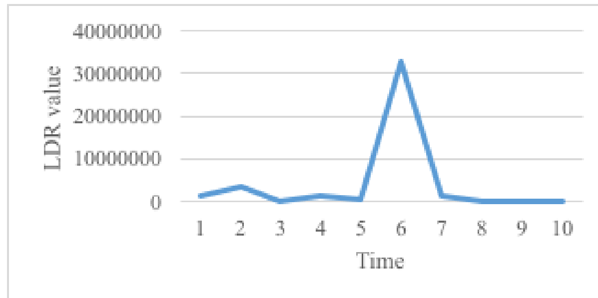

Figure 6. LDR Scenario 4

explored with the use of the visible light spectrum. In this paper, it is proposed a prototype of wireless communication using visible light. This prototype uses the Raspberry Pi in both the transmitter and receiver. The LRD experiments were done and presented the results. It is encouraged to expand the research in developing new models for wireless communication using visible light spectrum, which supports environmental sustainability.

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