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Serial Data Transmission using Visible Light Communication

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Abstract— Li-Fi is a label for wireless-communication system using light as a carrier instead of radio frequencies as in Wi-Fi [1]. The light waves cannot penetrate walls hence Li-Fi (Light-Fidelity) can be used in sensitive areas such as in Aircraft [13, 15]. It can be implemented using white-LED light bulbs at the downlink transmitter. In these types of devices a constant current is applied for the purpose of illumination. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. Due to this characteristic of optical current it is used in Li-Fi setup. The operational procedure is very simple- if the LED is on, then transmit a 1, if it's off then transmit a 0. The LEDs can be switched on and off very quickly, and hence it gives nice opportunities for transmitting data. All that is required is some LEDs and a controller that code data into those LEDs. All one has to do is to increase the rate at which the LED's flicker [2] depending upon the data needs to be encode. Further enhancements can be made in this method, like we can use an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs. It can alter the light's frequency with this approach each frequency encodes a different data Channel [5]. Such advancements promise a theoretical speed of 10 Gbps – meaning you can download a full high-definition film in just 30 seconds.

Keywords- *Photodiode; ATMega16; LiFi; LM324; Gbps*

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I. INTRODUCTION

Li-Fi is a new wireless communication technology which enables a wireless data transmission using LED light. Li-Fi is based on a unique ability of solid state lighting systems to create a binary code of 1s and 0s with a LED flickering that is invisible for human eyes [11]. Data can be received by electronic devices with the help of photodiode [3] within area of light visibility. This means that wherever LEDs are used, these bulbs can bring not only the light but able to provide wireless connection at the same time to transmit data. With increasing demand for wireless data transmission but due to lack of radio spectrum and various issues with hazardous electromagnetic waves comes out from it, Li-Fi appears as a new cheaper, greener, and healthier alternative to traditional Wi-Fi. The term was demonstrated in this context by Harald Haas in his TED [4] Global talk on Visible Light Communication. This was demonstrated at the 2012 Consumer Electronics Show in Las Vegas to exchange data with the help of light waves of varying intensity given off from their screens, at a distance of up to ten meters, between a pair of Casio smart phones. In October 2011, the Li-Fi Consortium was formed by a number of companies and industry groups, to overcome the limited amount of radio based wireless spectrum and to promote high-speed optical wireless communication systems available by exploiting entirely different part of the electromagnetic spectrum [19]. The consortium believes it is possible to achieve more than 10 Gbps, theoretically allowing a full high-definition film to be downloaded in just 30 seconds. Li-Fi has the advantage over Wi-Fi since it can be used in sensitive areas such as in aircraft without causing interference. However, the light waves used in Li-Fi cannot penetrate walls [5].Later in 2012, Pure VLC, a firm set up to commercialize Li-Fi, will bring out Li-Fi products for firms installing LED-lighting systems. Moreover the usage of Li-Fi is possible in several different environments such as in Hospitals, Airplanes, and Underwater etc. where Wi-Fi is not allowed due to security reasons and its hazardous radio waves.

Justification and objective of carrying out the research work.

II. ARCHITECTURE OF LI-FI SYSTEM

Li-Fi which can be the future of data transmission appears to be a cheap and fast optical version of Wi-Fi. Being a Visible Light Communication (VLC), Li-Fi uses visible light of electromagnetic spectrum between 400 THz and 800 THz as optical carrier for data transmission and illumination [8]. It uses fast pulses of LED light to transmit information in wireless medium. The main components of a basic Li-Fi system may contain the following:

a) A high brightness white LED which acts as transmission source.

b) A silicon photodiode with good response to visible light as the receiving element.

Switching the LEDs on and off can make them generate different strings of digital data which is combination of 1s and 0s [7]. To generate a new data stream, data can be encoded in the light by varying the flickering rate of the LED. In this way, the LEDs modulate the light with the data signal and works as a sender. It is impossible for human eye to detect the frequency of LED lights because they are made to flicker at a phenomenal speed (millions of times per second) [15]. With the help of various multiplexing technique more than 100 Mbps communication rate can be achieved by using high speed LEDs. And this VLC data rate can be further increased to as high as 10 Gbps via parallel data transmission using an array of LED lights with each LED transmitting a different data stream.

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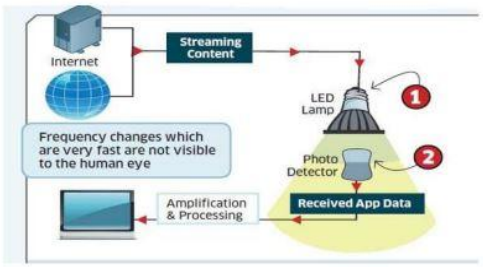

Figure 1: Block Diagram of Li-Fi Sub-assemblies.

The Printed Circuit Board (PCB) controls the various electrical inputs and outputs of the lamp and the microcontroller is used to handle different lamp functions. A Power Amplifier generates the Radio Frequency (RF) signal and is given to the electric field of the bulb. As a result due to high concentration of energy in the electric field, the contents of the bulb will get vaporized into a plasma state at the center of the LED bulb. And this controlled plasma inside the bulb, in turn will produce an intense source of light. All of these subassemblies are contained in an aluminium enclosure as shown in Figure. 2 below.

Important factors that should be considered while designing Li-Fi are as follows:

- Presence of Light
- Line of Sight (Los)
- For better performance use fluorescent light & LED

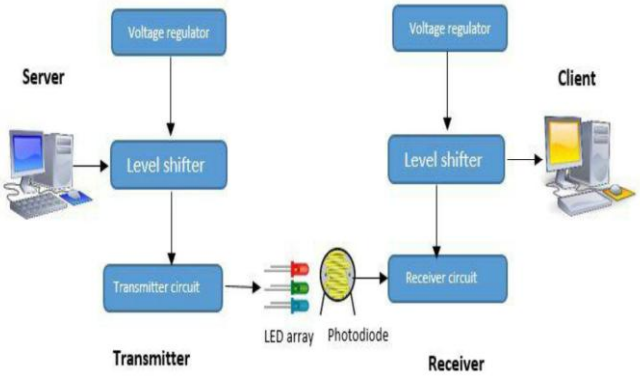

Figure 2: Construction of Li-Fi System

III. WORKING OF LI-FI

A. *Basic Concept*

Light Fidelity (Li-Fi) is a wireless data communication system based on the use of visible light waves between the violet (800 THz) and red (400 THz). Unlike traditional Wi-Fi which uses the radio part of the electromagnetic spectrum whereas Li-Fi uses the visible light part of the electromagnetic spectrum i.e. optical spectrum. The concept of Li-Fi is based on sending data by amplitude modulation of the light source in a more standardized and well-defined way. Since the operating speed of LEDs is less than 1 microsecond LEDs, it can be switched on and off faster than the human eyes can detect [3]. The data transmission is done using binary codes which uses invisible on-off activity of LED light waves. A digital '1' is transmitted if the LED is on and a digital '0' is transmitted if the LED is off. Also these LEDs can be switched on and off very quickly and hence it gives us a very nice opportunity for transmitting data through LED lights, because there are no interfering light frequencies as it happens in the case of radio frequencies in Wi-Fi. Li-Fi is thought to be 80% faster and more efficient which means it can reach speeds of up to 1Gbps and even beyond. The working principle of Li-Fi is different than fiber optic because the Li-Fi protocol layers are suitable for wireless communication over short distances (up to 10 meters). Due to this reason Li-Fi is unique and provides extremely fast wireless communication over short distances.

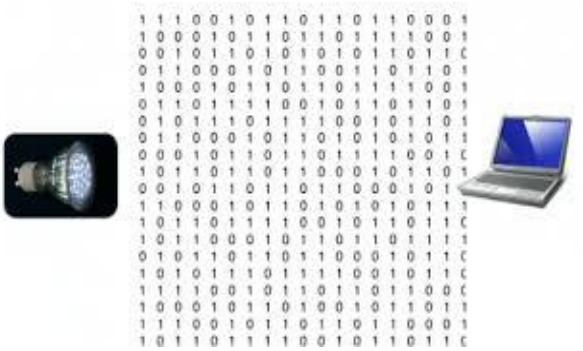

Fig 3: Li-Fi Transmission

B. *How it Works*

The working of Li-Fi is very simple as it uses already available light waves for data transmission. Light emitter is used at one side i.e. an LED transmitter, and a photo detector (light sensor) is used at another side. The data provided as an input to the LED transmitter is encoded into the light (technically termed as Visible Light Communication) to produce different combinations of 1s and 0s at which the LEDs flicker 'on' and 'off' by varying the flickering [16]. The on off process of the LED transmitter is invisible (The LED intensity is changes so rapidly to human eyes that cannot notice it.) The light of the LED is constant to humans as enables data transmission in light waves in accordance with the incoming binary codes: switching ON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which the LEDs flicker on and off, information can be encoded in the light to different combinations of 1s and 0s. In a typical setup, the transmitter (LED) which encodes the input is connected to the data network (Internet through the modem) and the receiver (photo detector/ light sensor) on the receiving end receives light signal i.e data and decodes the information, which is then produces output on the device connected to the receiver. The receiver (photo detector) registers a binary '1' when the transmitter (LED) is ON and a binary '0' when the transmitter (LED) is OFF. Thus using an array of LEDs of a few different colors and flashing the LED numerous times will definitely provide data rates in the range of hundreds of Mbps. The Li-Fi working is explained in a block diagram (Figure.4) and (Figure.5).

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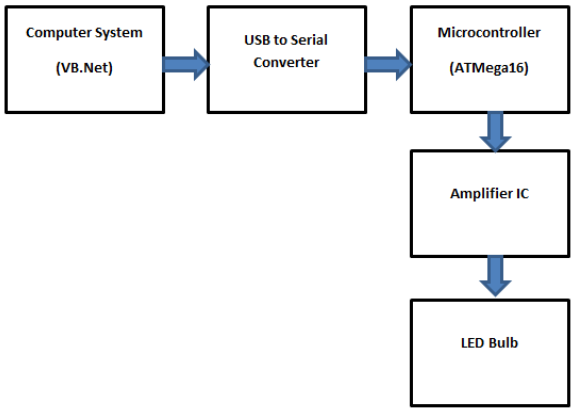

Figure 4: Transmitter Section

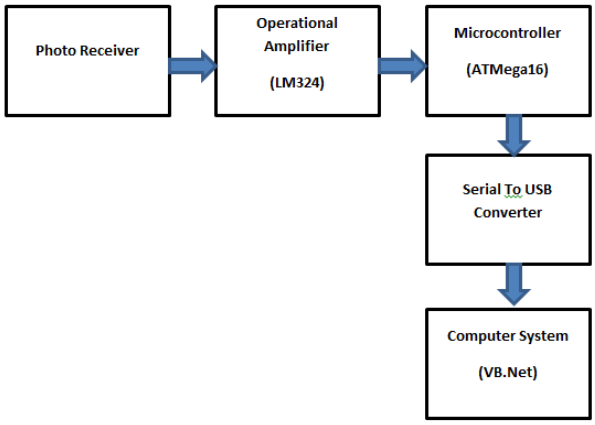

Figure 5: Receiver Section

It is clear from the above block diagram that the transmitter end consisting of computer software for data transmission via microcontroller using USB to serial communication system, which will be decoded into digital data by the microcontroller and again encode into digital bits transmission through LED bulb. At the receiver end a photodiode is attached with the system for digital light detection, further it will be amplified by the operational amplifier for sending to the microcontroller via serial transmission. The microcontroller attached at the receiver end will decoded into original format and display in on the LCD screen and parallel it will transmit its data to the other computer system via usb to serial medium.

IV. Comparision Between Li-Fi, Wi-Fi and other Radio Technologies

Both Wi-Fi and Li-Fi technologies use electromagnetic spectrum to transmit data and can provide wireless internet access to users [13]. Li-Fi is a visible light communication technology which is useful to obtain high speed wireless communication. The difference is: Li-Fi uses light waves and it is free from interference issues whereas Wi-Fi uses radio waves for data transmission. Wi-Fi works well within building/campus/compound, and Li-Fi is ideal for coverage inside a confined area or room [20].

Table I shows a comparison of transfer speed of various wireless technologies. Table II shows a comparison of Li-Fi with Wi-Fi.

TABLE I: Comparison of speed of various wireless technologies

Technology	Speed
Li-Fi	~1 Gbps
Wi-Fi-IEEE 802.11n	~150Mbps
IrDA	~4Mbps
Bluetooth	~3 Mbps
NFC	~424 Kbps

TABLE II: Comparison of Li-Fi and Wi-Fi

Parameter	Li-Fi	Wi-Fi
Spectrum Used	Visible Light	RF
Standard	IEEE 802.15.7	IEEE 802.11
Range	Based on Light Intensity (< 10m)	Based on Radio propagation & interference (< 300 m)
Data Transfer Rate	Very high (~1 Gbps)	Low (100 Mbps-1 Gbps)
Power Consumption	Low	High
Cost	Low	High
Bandwidth	Unlimited	Limited

https://www.ijsr.net/archive/v4i12/NOV151778.pdf

V. Components Used

A. Hardware components required for the development-
The major components are given below.

- ATMega16 Microcontroller
- Photodiode Transreceiver Module
- ELCD-16x2 Display
- Motor Driver L293D
- DC Battery
- LM324 Opam
- Voltage Regulator
- USB to TTL Converter
- LED Bulb
- PCB

B. Software components
- AVR Studio
- PCB Artist
- Win AVR

C. Language used
- Embedded C

VI. Advantages

Li-Fi uses visible light for wireless data transmission, it's an emerging technology balanced to compete with traditional Wi-Fi. Also, Li-Fi removes the shortcomings that have been put on the user by the radio wave transmission such as Wi-Fi as explained above.

Advantages of Li-Fi technology include

a) *Efficiency*: Power consumption can be minimized with the use of LED light bulbs which are already available in the home, offices and Mall etc. for lighting purpose. And using

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this light waves for data transmission makes it very efficient in terms of costs as well as energy.

b) *High speed:* Li-Fi provides high data rates i.e. 1 Gbps or more because of low interference, high bandwidths and high-intensity output.

c) *Availability: L*ight source is available everywhere such as in homes, offices, shops, malls and even planes, which can be used as a medium for wireless data transmission.

d) *Cheaper*: Li-Fi requires fewer components for its working, and requires negligible power for the data transmission.

e) *Security:* Li-Fi data transmission is security. Since light cannot penetrate through walls, Li-Fi internet is available only to the users within a confined area and cannot be misused and intercepted, outside the area under operation.

f) Li-Fi technology has a brilliant scope in future. The extensive growth in the use of LED light for illumination gives the opportunity to integrate the technology into a plethora of applications and environments.

VII. Future Scope

As light is everywhere and free to use, there is a great scope for the use & evolution of LiFi technology. If this technology becomes mature, each Li-Fi bulb can be used to transmit wireless data. As the Li-Fi technology becomes popular, it will have a bright future and lead us to a cleaner, greener, safer communications. The concept of Li-Fi is attracting many people as it is free (require no license), safe and faster means of data transfer. People will use this technology more and more, if it progresses faster.

VIII. Conclusion

The possibilities are numerous and can be further explored. If this technology can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to transmit wireless data and we will proceed toward the cleaner, greener, safer and brighter future. In comparison to traditional radio-based wireless communication system the concept of Li-Fi is new and currently attracting a great deal of interest because it may offer very efficient and genuine. With a growing demand of wireless internet connection, the airwaves are becoming increasingly clogged, making it more difficult to get a reliable, high-speed data signal. Li-Fi technology may solve problems such as the shortage of radio-frequency bandwidth and it can also allow internet where radio based wireless communication system isn't allowed such as in aircraft or in hospitals. One of the limitations however is that it only work in direct line of sight**.**

Abbreviations

- Li-Fi: Light Fidelity
- TED: Technology, Entertainment & Design
- VLC: Visible Light Communication
- LED: Light Emitting Diodes
- PA: Power Amplifier
- PCB: Printed Circuit Board
- RF: Radio Frequency
- M2M VLC: Mobile-to-Mobile Visual Light Communication
- PHY: Physical Layer
- MAC: Media Access Control
- CSK: Colour Shift Keying
- OOK: On-Off Keying
- Gbps: Gigabit per Second
- IrDA: Infrared Data Association
- NFC: Near Field Communication

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