International Journal of Electronic Devices and Networking

E-ISSN: 2708-4485
P-ISSN: 2708-4477
IJEDN 2021; 2(1): 27-29

www.electronicnetjournal.com
Received: 11-11-2020
Accepted: 15-12-2020

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Design of high-speed data transmission using LiFi

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Abstract
Light Fidelity is mode of data transmission wherein visible light spectrum is used to transmit data in a faster and more secure manner, resulting in theoretical speeds much higher than that of Wireless fidelity. Li-Fi is high speed and a bidirectional network using light. Li-Fi comprises of large number of light bulbs that form an efficient wireless network.
When some amount of electrical current is applied to a LED light bulb a stream of light is emitted from the bulb. The brightness of the light that is flowing through the LED can be modified at exceptionally high speeds. This allows us to send a signal by modulating the light at different rates. The signal can then be received by the receiver which interprets the changes in the intensity of light (the signal) as data.
The intensity modulation that is occurring cannot be seen by the naked eye, and thus communication is just as consistent as other radio systems, allowing the users to be connected where there is Li-Fi enabled light. Using this technique, data can be transmitted from a LED light bulb at high speeds.

Keywords: Li-Fi, modulating, intensity, high speeds, LEDs

1. Introduction
Light Fidelity is type of wireless data communication that uses visible light spectrum to transmit data, over the traditional radio waves used in Wi-Fi. The major advantages of using light as the transmission medium are the wider bandwidth and faster speeds. These advantages are obvious due to the speed at which the light travels. The data is transmitted by using light emitting diodes, by altering the current to it, too fast for the human eye to notice any flickering. The transmitted light is then picked up by a receiver and the end device also possess a LED which then transmit back some data, thus resulting in a full duplex connection. The major disadvantages are light's inability to penetrate walls, albeit it lowers the risk of being hacked and medium disturbances since visible light is everywhere around us. Some applications include high speed internet in offices with desks where this technology can be integrated onto the lights overhead, used to provide internet in hospitals and aviation where light will not render any disturbances onto equipment that rely on radio waves like medical instruments, radar etc. and communication between road vehicles via the headlamps and taillights, increasing road safety. Li-Fi is essential because it is predicted that over 20 billion devices will be connected to the internet by 2020 and with the boom of IOT, an energy neutral way of transmitting data is essential, ergo the light which will be used anyways for illumination, integrating internet to it will be brilliant way of reducing energy consumption, It also reduces infrastructure costs as both transmitter and receivers already exists i.e. LEDs for transmission and solar panels to receive the data, in addition to this devices can be charged at the same time.

2.1 Objectives
a. Security: One should present under the source of light, hence there's no way of unauthorized accessing.
b. Speed: Due to the bandwidth of visible light the data rate and speeds are very high. The speeds at which Wi-Fi.
c. Cost: Since LiFi uses existing infrastructure led, photodiode and other simple documents which requires no extra energy and investment.
d. The functioning of Li-Fi is similar to Wi-Fi and this requires no additional understanding. Thus using LI-Fi infrastructure won't be much different to that of Wi-Fi infrastructure resulting in ease of usage to be simple.

3. Materials and Methods

Light fidelity works on the core principles of light, its properties, and basic components such a LED which acts as a transmitter, the light itself acting as medium through which the data is transmitted and a device such as a photodiode which can detect the light and acts a receiver.

The particle nature is in charge of the light's ability to be integrated into application such as overhead lightings,

The wave nature on the other is reason for increased security as it cannot be penetrate through walls and thus increasing security and lowering risk of unauthorized access.

The bandwidth is responsible for the very high data rate.

The ability to modulate the LED is sole reason for the functioning of the concept of Li-Fi as it helps it transmitting the data

A. LEDs

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. It works on the principle of electroluminescence. The electrons present in the semiconductor recombine with electron holes and in doing so release energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.

B. Photodiode

- Light energy can be considered in terms of photons or in terms of packets of light. When a photon enters the depletion region and strikes an atom with sufficient amount of energy it releases the electron from the atomic structure thereby creating a free electron. The electron is negatively charged, while the hole is positively charged.
- The electrons and holes may either combine to form atoms or they may be pulled away from the depletion region. In this way the current through the diode will change and a photocurrent is produced.

C. Light's particle nature

Albert Einstein revived the theory of light being a particle back in the 19th century. Thus light is now proved as dual nature entity of being both a particle and wave, the theory then evolved from electromagnetics to quantum mechanics. Einstein said that the photons itself are particles while its flow is of wave nature. Light's energy is related to its oscillation frequency was the main point of his light quantum theory. Planck's constant times oscillation frequency is equal to energy of the photons and this energy is peak oscillation frequency and intensity is related to the quantity of photons. Light is a type of electromagnetic wave, and the properties exist due to the behavior of these small particles i.e. photons, which is not visible to our naked eyes.

D. Light's bandwidth

Light is electromagnetic radiation with extremely high frequencies. Frequencies of visible light lie roughly between 400 THz and 750 THz, corresponding to the wavelength range from 400 nm to 750 nm. (The difference of ultraviolet to the infrared are blurred due to responsivity of the human eye.) The oscillation cycles have durations of only a few femtoseconds which is implied by the fact of the enormously high oscillation frequencies.

While some sources emit quasi-monochromatic light, having a well-defined optical frequency, others have very large optical bandwidth of hundreds of terahertz.

E. Modulation

LED can be used to transmit data and information by modulating signals which control frequencies of LED. There are various techniques of modulation of LED to be used in Li-Fi. Modulation techniques are used so large amounts of data can be transmitted and the entire of potential of Li-Fi can be utilized. A modulation technique can be used where the intensity of light can be altered without removing the illumination of the light. The intensity of light is varied with respect to data that is transmitted. The intensity flashes are so quick that it seems constant and unaltered to our eyes. There are types by light can be modulated such as Single Carrier Modulation (SCM), Multiple Carrier Modulation (MCM).

F. Wave nature

De Broglie wave length: The momentum of photon of frequency v is given by

$$P = \frac{hv}{c} = \frac{h}{\lambda}$$

Since $c = v\lambda$

The wavelength of a photon in terms of its momentum is

$$\lambda = \frac{h}{p} \quad (1)$$

According to de Broglie, the above equation is applicable to material particles. Therefore, for a particle of mass m travelling with speed v, the wavelength is given by

$$\lambda = \frac{h}{mv} = \frac{h}{p} \quad (2)$$

This wavelength of the matter waves is known as de Broglie wavelength. This equation provides a relation with the wave character and the particle character through the Planck's constant.

3.1 Implementation

Proof of concept

To prove that light could transmit data, a set up was made to transmit audio signal via light, more complex types of data could be transmitted by using encoding methods to convert the data into digital signal which is transmitted via light.

Audio transmission

- A 9v battery is used to power the LED.
- A resistor is used so that the power doesn't reach the phone or burn out the LED.
- The LED is used so that we can change its intensity by which we can transmit the information.
- AUX cable is used to send information from phone to LED.

- The photo detector is used to receive the light signal from the transmitter.
- Another AUX cable is used to convert the received signal to sound output via speakers.

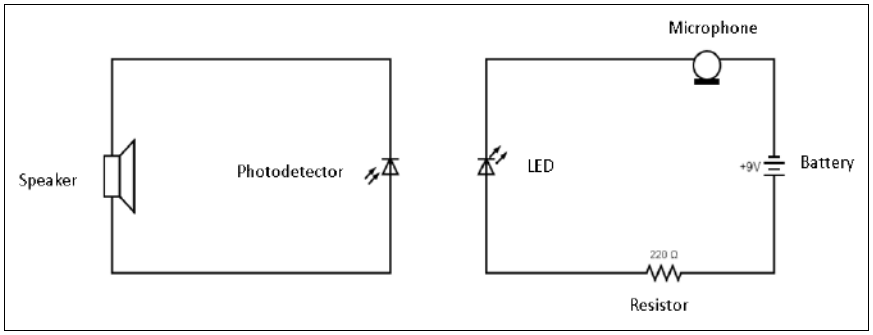

Fig 1: Circuit diagram of Li-Fi

4. Result

The system was set up with all the connections. The speaker was able to play the audio from the phone. The audio signal was transmitted through light, to prove it blocking the path of light resulted in the audio signal being lost and no sound was played in the speakers. Thus Audio data was successfully transmitted though light and the potential of Li-Fi was proved.

5. Discussions

5.1 Applications

With the boom of IoT, the number of devices connected to IoT is massive. Li-Fi reduces both energy consumption as well infrastructure costs, by utilising what already existing whilst providing faster speeds.

a. Hospitals
   Conventional Wi-Fi routers constantly interfere with Hospital equipment, Using LiFi will overcome this problem as light doesn't use EM waves like the equipment.
b. Workplaces
   Overhead lighting in office spaces can use LiFi for completely secure and superfast data speeds this enabling better internet.
c. Autonomous Driving
   Autonomous driving can use LiFi since all the cars will be able to communicate with each other through headlights and tail lamps, resulting in efficient traffic flow.

5.2 Disadvantages

a. Disturbances
   The visible light is everywhere, thus data may be vulnerable to disturbances via other light sources.
b. Coverage
   It can perform under ideal conditions such as a controlled indoor environment but outdoor and long distance and area coverage is not its strong suit.
c. Modulation
   Modulation of LED is a rather complex process that requires specialized techniques to utilize the entire potential of the light, which at the moment is computationally complex.

6. Conclusion

Thus the proposed project solved the issues faced with Wi-Fi. The Li-Fi is faster due to bandwidth of light, safer because it prevents unauthorized access and cheaper because it uses existing infrastructure such as LEDs. Overall the problems of Wi-Fi were fixed with use of Li-Fi and all the objectives were met. Although Wi-Fi can't be fully replaced by the proposed project it can serve as better alternative in certain applications.

6.1 Future scope

The project had a shortcoming, its inability to transmit video data due to its high bandwidth nature. This problem can be overcome by using an effective and optimized way of encoding the data. This enables in transmitting all types of data and function as well as a Wi-Fi.

The project can also be extended for various specialized applications such as high speed Internet in office spaces, in aviation field for internet inside an airplane, in under water communications and in other applications where Wi-Fi cannot be used due to its transmission through electromagnetic medium.

7. Acknowledgement

With profound respect, we express our deep sense of gratitude and sincere thanks to our guide Mrs. R. Kousalya (SVCE), for her valuable guidance and suggestions throughout this project.

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