Data Transfer System using Li-fi technology

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Abstract - Li-Fi stands for Light-Fidelity. Li-Fi is transmission of data using visible light by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. If the LED is on, the photo detector registers a binary one; otherwise it's a binary zero. This paper deals with the implementation of the most basic Li-Fi based system to transfer data from one computer to another. The main components of this communication system are high brightness LED which acts as a communication source and silicon photodiode serving as the receiving element. The data from the sender is converted into intermediate data representation, i.e. byte format and is then converted into light signals which are then emitted by the transmitter. The light signal is received by the photodiode at the receiver side. The reverse process takes place at the destination computer to retrieve the data back from the received light.

***Keywords* - Li-Fi, High-Brightness LED, Photodiode, Byte Format Wireless Communication.**

I. Introduction

Li-Fi stands for Light-Fidelity. Li-Fi is transmission of data using visible light by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. If the LED is on, the photo detector registers a binary one; otherwise it's a binary zero. The idea of Li-Fi was introduced by a German physicist, Harald Hass, which he also referred to as "data through illumination". The term Li-Fi was first used by Haas in his TED Global talk on Visible Light Communication. According to Hass, the light, which he referred to as D-Light, can be used to produce data rates higher than 10 megabits per second which is much faster than our average broadband connection.

This paper discusses the implementation of the most basic Li-Fi based system to transmit data from one device to another through visible light. The purpose is to demonstrate only the working of the simplest model of Li-Fi with no major consideration about the data transfer speed.

This model will demonstrate how the notion of 2-way communication via visible light works, in which off-the-shelf light emitting diodes (LEDs) are employed as the light sources. The model will transmit digital signal via direct modulation of the light. The emitted light will be detected by an optical receiver. In addition to the demonstration purpose, the model enables investigation into the features of the visible light and LEDs incorporated in the communication model.

II. Proposed system

This paper proposes a Li-Fi based system to transfer data from one device to another using visible light. The proposed system consists of Li-Fi transmitter and receiver circuits with LEDs, photo-detector, MAX232A IC and inverter, battery, connecting wires and USB or COMM port.

The sending device will select some data to the transmitter circuit of the sender's device. The LEDs in the transmitter circuit will transmit this data. The photo-detector of the receiver circuit will receive this data from the light detected and will send it to the receiving device which will interpret and obtain the final data that was sent by the sender.

The proposed Li-Fi system will consist of the following modules:

a) Graphical user interface
b) Data reading module
c) Data conversion module
d) Transmitter module
e) Receiver module
f) Data interpreter module

The different modules and the flow of data between these modules are shown in Fig. 1. The Data reading module reads data from the sender device and sends this data to the data conversion module.

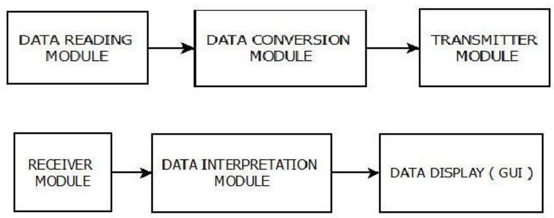

Figure 1: Block diagram for Li-Fi system

The data conversion module converts this data into suitable format, i.e. in the form of binary bits (byte format) so that it can be represented as a digital signal.

Before converting this data into binary form, the data conversion module can also apply some encryption algorithm to encrypt the sender's data. The data is then sent to the transmitter module which generates the corresponding on-off pattern of the LEDs. In this way, data is sent from the sender.

The Receiver module receives the data. The receiver module has a photo-diode to detect the on and off states of the LEDs. The receiver module captures this sequence and generates the binary sequence of the received signal. It then sends the binary sequence to the Data interpretation module which converts the data to the original format. If encryption was done at the sender, then Data interpretation module also performs decryption. It then sends the final result to the Data display module which displays the final received data to the receiver. In this way, the data is received by the receiver in a Li-Fi system.

III. Approach

A. IEEE Standard and Data Modulation Scheme

Li-Fi communication is modeled after communication protocols established by the IEEE 802 workgroup. The IEEE802.15.7 draft standard for VLC/Li-Fi defines the physical layer (PHY) and media access control (MAC) layer. The standard is able to deliver enough data rates to transmit audio, video and multimedia services. It takes count of the optical transmission mobility, its compatibility with artificial lighting present in infrastructures, the defiance which may be caused by interference generated by the ambient lighting. The MAC layer allows using the link with the other layers like the TCP/IP protocol [2].

The MAC currently supports three multiple access topologies; peer-to-peer, star configuration and broadcast mode. The MAC also handles physical layer management issues such as addressing, collision avoidance and data acknowledgement protocols. The physical layer is divided into three types; PHY I, II & III, and these employ a combination of different modulation schemes [2].

There are 3 different data modulation schemes that can be used for Li-Fi systems:

a) On-off keying (OOK): The data is conveyed by turning the LED off and on (shown in Fig. 2). In its simplest form a digital '1' is represented by the light 'on' state and a digital '0' is represented by the light 'off' state. The beauty of this method is that it is really simple to generate and decode. The 802.15.7 standard uses Manchester Coding to ensure the period of positive pulses is the same as the negative ones but this also doubles the bandwidth required for OOK transmission. Alternatively, for higher bit rates run length limited (RLL) coding is used which is more spectrally efficient. Dimming is supported by adding an OOK extension which adjusts the aggregate output to the correct level [2].

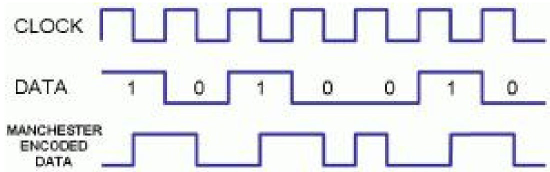

Figure 2: OOK modulation scheme using Manchester Coding [3]

b) Variable pulse position modulation (VPPM): Pulse position modulation (PPM) encodes the data using the position of the pulse within a set time period. The duration of the period containing the pulse must be long enough to allow different positions to be identified, e.g. a '0' is represented by a positive pulse at the beginning of the period followed by a negative pulse, and a '1' is represented by a negative pulse at the beginning of the period followed by a positive pulse. VPPM (shown in Fig. 3) is similar to PPM but it allows the pulse width to be controlled for light dimming support [2].

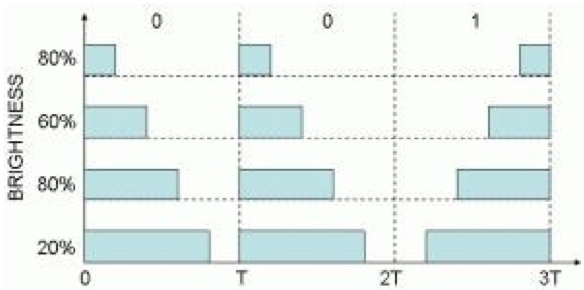

Figure 3: Variable Pulse Position Modulation to support dimming [4]

c) Colour shift keying (CSK): CSK (shown in Fig. 4) can be used if the illumination system uses RGB type LEDs. By combining the different colours of light, the output data can be carried by the colour itself and so the intensity of the output can be near constant. The x-y chromaticity diagram shows the colour space and associated wavelengths in blue text (units are nm). Mixing of the red, green & blue primary sources produces the different colours which are coded as information bits. The disadvantage of this system is the complexity of both the transmitter and the receiver [2].

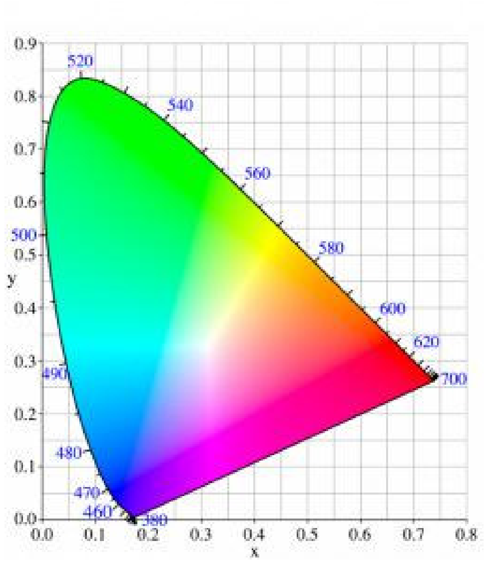

Figure 4: RGB LEDs that combines different wavelengths for CSK [5]

In Li-Fi system, which is based on visible light communication, data is modulated on the light source using modulation techniques like pulse position modulation or frequency shift keying. In the receiver end demodulation is performed using pulse position modulation technique to fetch the data back from the light source.

So it forms a six step process (shown in Fig. 5):

a) Read data from Sender
b) Modulation
c) Transmit data using Light Source (LED)
d) CMOS/CCD
e) Demodulation
f) Received Data

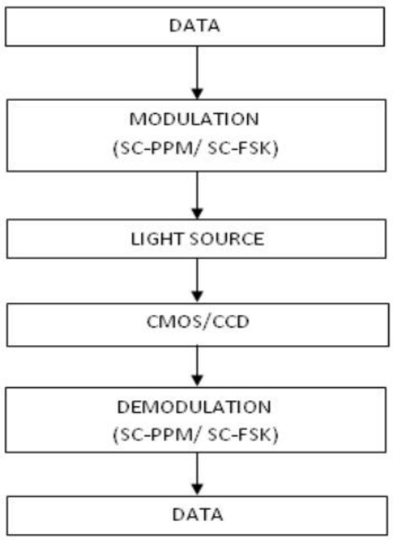

Figure 5: Six step process of data transmission using Li-Fi

B. Light Source

The most important requirement that a light source has to meet in order to serve communication purposes is the ability to be switched on and off repeatedly in very short intervals. By utilizing the advantage of fast switching characteristics of LED's compared with the conventional lightning, the LED illumination is used as a communication source. Since the illumination exists everywhere, it is expected that the LED illumination device will act as a lighting device and a communication transmitter simultaneously everywhere in a near future.

Typically, red, green, and blue LEDs emit a band of spectrum, depending on the material system. The white LED draws much attention for the illumination devices. Comparing the LED illumination with the conventional illumination such as fluorescent lamps and incandescent bulbs, the LED illumination has many advantages such as high efficiency, environment-friendly manufacturing, design flexibility, long lifetime, and better spectrum performance.

LEDs emit light when energy levels change in the semiconductor diode. This shift in energy generates photons, some of which are emitted as light. The specific wavelength of the light depends on the difference in energy levels as well as the type of semiconductor material used to form the LED chip. Solid-state design allows LEDs to withstand shock, vibration, frequent switching (electrical on and off shock) and environmental (mechanical shocks) extremes without compromising their famous long life typically 100,000 hours or more.

The basic LED consists of a semiconductor diode chip mounted in the reflector cup of a lead frame that is connected to electrical (wire bond) wires, and then encased in a solid epoxy lens. The architecture of LED is shown in Fig. 6.

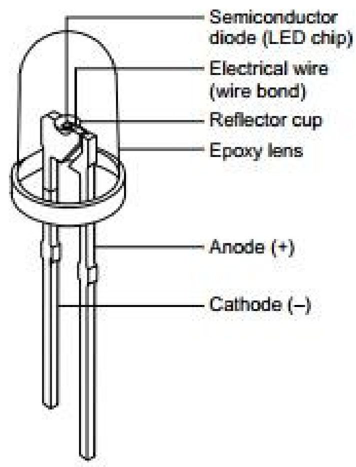

Figure 6: Architecture of LED

Operational procedure is very simple. If the LED is on, you transmit a digital 1. If it is off, you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data. Hence all that is required is some LEDS and a controller that code data into those LEDs.

IV. Design

For communication between two computers, a transceiver is connected to both the computers so that both of them are able to send and receive the data. The transceiver consists of transmitter circuit and the receiver circuit. The entire circuit is shown in Fig. 7.

A.Transmitter

The transmitter circuit consists of a PCB that controls the electrical inputs and outputs of the LED and houses the microcontroller used to manage different LED functions. The PCB consists of an opto-isolator and an open-collector hex inverter and some other components. The transmitter is powered by a 9V battery. The circuit uses an opto-isolator to couple a standard RS-232 signal from a computer to the driver section of the circuit. The resistor/diode configuration at the input to the opto-isolator converts the voltage variation of a RS-232 signal into a signal suitable for the LED in the opto-isolator.

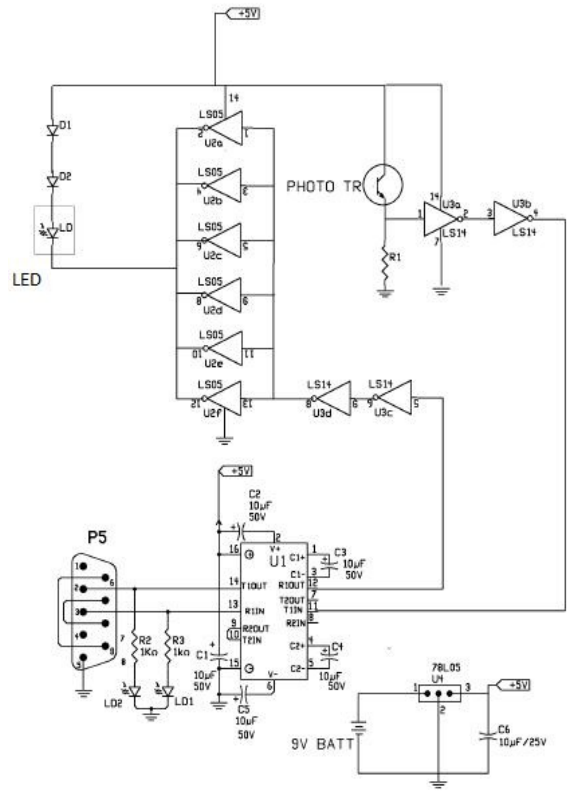

Figure 7: Li-Fi circuit diagram

B. Receiver

The receiving sensor is an NPN photo-transistor. Although the light wavelength is in the visible spectrum (~670nm) the photo-transistor's broad response band (550nm to 1050nm) is wide enough to sense the intense light beam. The signal from the photo-transistor is buffered via a pair of Schmitt trigger buffers to clean up and square the signal. The output of the second buffer is then directly converted to a RS-232 standard signal via an integrated circuit.

C. RS232 Standard

Communication as defined in the RS232 standard is an asynchronous serial communication method. The word serial means, that the information is sent one bit at a time. Asynchronous tells us that the information is not sent in predefined time slots. Data transfer can start at any given time and it is the task of the receiver to detect when a message starts and ends. The RS232 standard describes a communication method where information is sent bit by bit on a physical channel. The information must be broken up in data words. The length of a data word is variable. On PC's a length between 5 and 8 bits can be selected. This length is the net information length of each word. For proper transfer additional bits are added for synchronization and error checking purposes. It is important, that the transmitter and receiver use the same number of bits. Otherwise, the data word may be misinterpreted, or not recognized at all.

With RS232, the line voltage level can have two states. The on state is also known as mark, the off state as space. No other line states are possible. When the line is idle, it is kept in the mark state.

D. Software Details

The Data Reading module, Data interpretation module and the Data display (GUI) are implemented in software. The GUI is shown in Fig. 8 and Fig. 9.

The software performs the task of selection of data to be sent, reading the data to be sent and data conversion at the sender's side. First, the user selects the COMM port to which the Li-Fi circuit is connected and the other required settings for communication (Fig. 8). Then, the User interface appears which allows the user to communicate with the receiver and send text, image, audio and video files (Fig. 9). The data to be sent is selected by the user and the software reads this data. Then, this data is converted into byte format so that it can be sent to the transmitter circuit. Encryption can also be performed on this data. If encryption is performed, then the cipher text is produced by the software which is converted into binary form. Finally, this data is sent to the Transmitter circuit that transmits this data in the form of light.

At the receiver's side, the Receiver circuit captures the light signals, converts then into bit sequence and sends this byte of data to the software. The software then converts this byte data to the original format as sent by the sender (e.g., text format). If encryption was done by the sender, then the software decrypts the cipher text to get the plain text. This plain text is the received data. The received data is then displayed on the receiver's device as output.

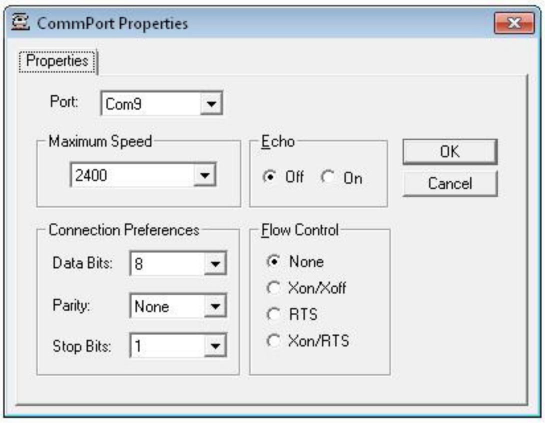

Figure 8: COMM port properties

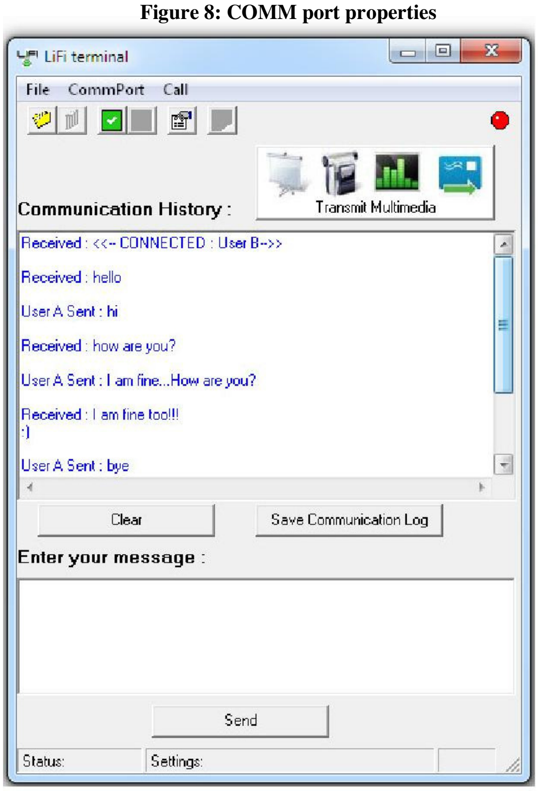

Figure 9: User interface

User can also save the communication history in a file by clicking on the "Save Communication Log" button. Fig.10 shows the "Save Communication Log" dialog box that will pop up. The user can save the file at any location with any name.

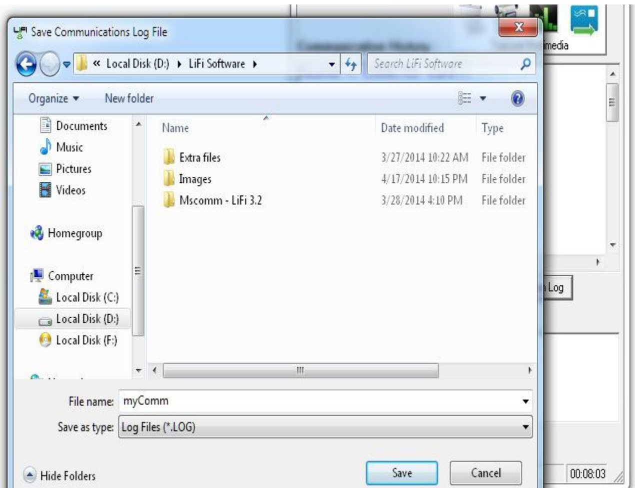

Figure 10: Screenshot of Save Communication Log File Dialog box

Also, a user can send any file such as a text file or an image file stored in his computer. The receiver will receive this file and will be prompted to save it on his system with any name. Finally, a file of that type will be saved at the receiver's side. Fig.11 and Fig.12 show the case when a sender has sent an image file 'hi.jpg' to the receiver.

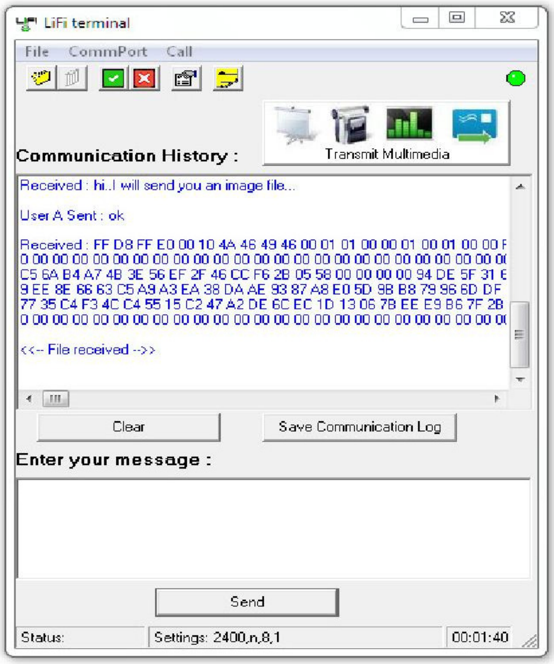

Figure 11: Screenshot of Receiver side Hexadecimal content of the image file received

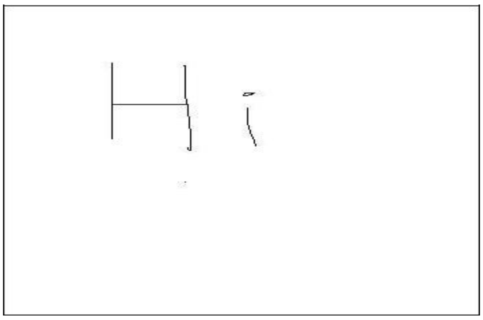

Figure 12: Image File saved at the Receiver side

V. Discussion

The Li-Fi system proposed in this paper is capable of transmitting data such as text, image, audio and video between two devices at the speed of a few kbps. The main requirement is line of sight between the sender and the receiver and hence it can be used to transmit data within a room.

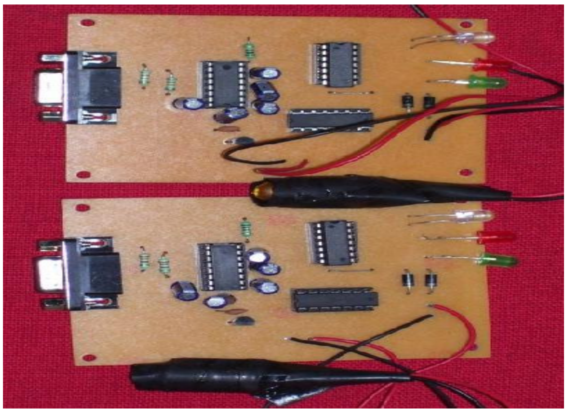

Figure 12: Li-Fi circuits

Li-Fi technology is based on (Visible Light Communication) VLC technology. VLC is one of the advanced optical wireless communication technologies in which light in the visible region (375nm-780nm) is used as a medium for data transmission. It is more secure and achieves high data rates as compared to

conventional wireless technologies like Wi-Fi, Bluetooth, Wi-max, etc. which use radio waves for communication [8]. Initially researchers were able to achieve network speed of about 100Kbps. With continuous developments, VLC systems can now achieve about 800Mbps data rate for short range communications. Many companies and research institutes are conducting research to develop and commercialize Gigabit networks for long range communications.

Reliability and network coverage are the major issues to be considered by the companies while providing VLC services. Interferences from external light sources like sun light, normal bulbs, and opaque materials in the path of transmission will cause interruption in the communication. High installation costs of the VLC systems can be complemented by large-scale implementation of VLC. Adopting VLC technology will reduce further operating costs like electricity charges, maintenance charges, etc. [8].

Li-Fi technology is still in the introductory phase. Indoor networking and location based services are the only applications that are quite penetrated in the market. Li-Fi may be implemented as a complementary technology to the existing wireless networks. It is expected to penetrate M2M communication, smart cities, power over Ethernet (PoE), wireless sensor networks, ubiquitous networks, augmented reality etc.

Li-Fi relies heavily on these special LED light bulbs for data transmission. The market availability of these Li-Fi compliant LED bulbs is extremely important. In addition, the usability of these LED bulbs with current home electric wiring is another catalyst. The manufacturing and retail costs of LED are major factor for Internet Service Providers and customers wishing to switch from Wi-Fi to Li-Fi respectively.

Personal computers and home entertainment devices in portable forms are an integral part in current households. Li-Fi technology can perform a critical role in providing super -fast home broadband speed that will allow higher bandwidth data communication on different platforms at the same time.

VI. Conclusion

The concept of Li-Fi is attracting a great deal of interest because it may offer a genuine and very efficient alternative to radio-based wireless technology. If this technology is put into practical use, every bulb can be used like a Wi-Fi hotspot to transmit wireless data and the world will proceed towards a cleaner, greener, safer and brighter future. In future one can use micro LEDs for data transmission which flickers at a much higher rate than ordinary LEDs and in turn provides higher speed. A cluster of LEDs can be used for parallel data transmission. LEDs of different colors such as red, green and blue can be used to enhance the transmission rate.

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