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Latest advancement in Light Fidelity (Li-Fi) Technology

Anwesha Chakraborty[1]
Department of Computer Science
St. Xavier's College (Autonomous)
Kolkata, West Bengal – India

Trina Dutta[2]
Department of Computer Science
St. Xavier's College (Autonomous)
Kolkata, West Bengal – India

Sushmita Mondal[3]
Department of Computer Science
St. Xavier's College (Autonomous)
Kolkata, West Bengal – India

Dr. Asoke Nath[4]
Department of Computer Science
St. Xavier's College (Autonomous)
Kolkata, West Bengal – India

Abstract: ***In this modern day of technology, internet and digital communication has become a major factor. The number of devices accessing a network is increasing exponentially which is leading to complexity in network traffic and shortage of bandwidth. This increases the risk of conflict between frequencies of the bandwidth which is happening with Wi-Fi these days. To overcome these problems permanently, a new concept of super-fast wireless communication has been introduced, known as Light Fidelity or Li-Fi. In the present paper the authors have given a systematic study on latest development in Li-Fi technology.***

Keywords: Digital communication, Network traffic, Wi-Fi, Wireless communication, Li-Fi.

I. INTRODUCTION

Li-Fi stands for Light Fidelity. It is a high-speed wireless communication network similar to **Wi-Fi**. It provides bidirectional data transfer. It is a form of Optical Wireless Network (OWC). It was first introduced by German physicist **Harald Hass**. He coined the term 'Li-Fi' at his 2011 TED Global Talk. The idea he gave about this Li-Fi technology is called "Data through illumination". He and his team at University of Edinburgh first developed this technology.

In this era of modernisation transfer and sharing of data is very much important for various day-to-day activities. And that is why wireless communication was introduced because it provides faster data transmission. But current wireless networks are not fast enough for sharing of data while handling multiple devices since a fixed bandwidth is present. Moreover the current wireless networks use radio waves which are a small part of spectrum.

The solution to this problem is Li-Fi technology. Li-Fi works on the principle of Visible Light Communication (VLC).It uses the visible spectrum as well as ultraviolet and infrared radiations. It allows the data to be transferred by modulating the intensity of the light, which is then received by a photo-sensitive detector. The light signal is then demodulated into electronic form. The simple idea behind this technology is that when the LED is ON (digital 1) the data is transmitted and when it is OFF (digital 0) no data transmission takes place. The modulation of intensity of light is so fast it cannot be perceived by human eye and it appears constant to human. It is hundred times faster than Wi-Fi and it provides speed up to 224 gigabits per second. The data is transmitted through illumination of special LED bulbs and using a photo detector to detect the signal. These kinds of bulbs serve both purposes for transmitting data and also for providing lights. This kind of communication is very cheap and easy to maintain. It is already being used in various fields like military operations, underwater divers, aircrafts etc.

II. COMPARISON BETWEEN WI-FI AND LI-FI

Li-Fi or Light Fidelity is a completely new concept whereas Wi-Fi or Wireless Fidelity has been used for many years now.

Data transmission in Li-Fi takes place with the help light, LED bulbs to be precise. Data Transmission in Wi-Fi takes place with the help of radio waves.

The technology used in Li-Fi is the present IrDA compliant devices, whereas the technology used in Wi-Fi is WLAN 802.11 a/b/g/n/ac/ad standard compliant devices.

Li-Fi can be applied in airlines, explorations beneath the sea, hospitals, offices, schools, libraries for fast browsing and data communication. Wi-Fi can be used for internet browsing with the help of wifi hotspots.

Since in case of Li-Fi, light gets obstructed due to any physical object so greater security can be achieved, but in case of Wi-Fi different technologies need to be implemented for further security.

The data transfer speed of Li-Fi is about 1Gbps whereas Wi-Fi transmits with the speed of 150 Mbps with WLAN and up to 2Gbps with WiGig/Giga_IR technology.

Li-Fi can work in a environment where the density of data is high, Wi-Fi works in a low data density environment due to high network traffic issues.

Li-Fi can cover up a distance of up to 10 meters, whereas Wi-Fi has network coverage of 32 meters.

The major components to implement a Li-Fi system are: Lamp driver, LED bulb and photo detector. The major components that makes up a Wi-Fi system are: devices (laptop, desktop), router installation. [7]

III. HOW LI-FI DOES WORKS?

As the name suggests Li-Fi or Light Fidelity, it basically does data communication with the help of visible light, the process is also known as Visible Light Communication (VLC). A transmitter and a receiver are required. Let us consider any visible light source, this source of light can be switched ON and OFF very rapidly in order to transmit the data. The transition between these ON and OFF stages happens so fast that normal human eye cannot register or sense it. It is to be noted that even though the light is visible but not the data transmitted.

Harald Haas has explained, "Very simple, if the LED is on, you transmit a digital 1; if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data."**[1]**In this case LED is chosen since it consumes comparatively less power than other visible light sources. But other sources like Solar Cells, LASER can be used as well. Harald Haas said in EDINBURGH UNIVERSITY "… a solar cell has become a receiver for high speed wireless signals encoded in light, while maintaining its primary function as an energy harvesting device…" In this way the energies from solar cells on roof of hut or translucent solar cells used as window glass can also be used as receivers in Li-fi implementation for wireless communication.

In order to implement Li-Fi following structures can be considered:

1. **TRANSMITTER:** An LED is used as the transmitter or sender of signal here. The flickering in the LED is basically the signal that is to be sent. The rapid ON (transmits 1) and OFF (transmits 0) of the LED is used to encode a string of data signal. Now this technique can be improved by using multiple LEDs or LEDs of different colours like red, green, blue for more complex data communications. Theoretically, the speed of data communication through Li-Fi can be up to 10Gbps.
2. **RECEIVER:** Since Li-Fi uses visible light to transmit data, it is important to convert them into digital signals with the help of modulation. It includes silicon photo diode which shows good response to visible wavelength, optical

concentrator and filter and an amplifier. The optical concentrator is used to compensate for high spatial attenuation due to the beam divergence from the LEDs to illuminate large area **[2].**Some of the modulation techniques are given below:

- **OFDM:** Orthogonal frequency-division multiplexing
- **OOK:** On-off keying
- **PWM:** Pulse-width modulation
- **PPM:** Pulse-position modulation
- **SIM-OFDM:** Sub-carrier Index Modulation**[3]**

How can we implement a 3rd gen Li-Fi instrument?

The following steps will discuss about the implementation of the Modular Li-Fi: [4]

I. The transmitter sensor module and the transmitter control module are required to measure and process the real time process-variables like temperature, pressure. The exchange of information (real time variable process) is exchanged between these two modules via hardware signals. This information as collected from the optical transmitter sensor module is then sent to the nearby optical access point via optical signal. Then the information will be updated to the OAP or DCS.

The transmitter control module then converts the real time process variable value into encoded switching signals. This signal controls the LED driver to transmit signals to the OAPs.

II. The light sensitivity sensor module than registers the flickering of the LED and then converts this optical signal into an electrical signal. The electrical signal then is sent to the sensor processing and amplification module.

III. The next step requires filtration, amplification, analysis and processing of the output sent by the sensor processing module. Further the output from this step is sent to Ethernet media conversion module.

IV. The Ethernet media conversion module is used to facilitate the amplified electrical media conversion into a fibre-optic compatible optical signal, or light signal. Then this optical signal is sent to the control room/local substation via redundant fibre-optic cable.

V. The optical signal received from a field optical access point is then converted into the corresponding Ethernet compatible electrical signal.

VI. The DCS receives the electrical signal from the field instrument for processing and sends the field process-variable information to the display module. The display module presents the process-variable information to the engineering workstation (EWS) or operator workstation (OWS) for further action.

VII. The appropriate control action signal is generated by DCS from the process variable information to control the process and then is sent to the ICS communication cabinet via Ethernet cable.

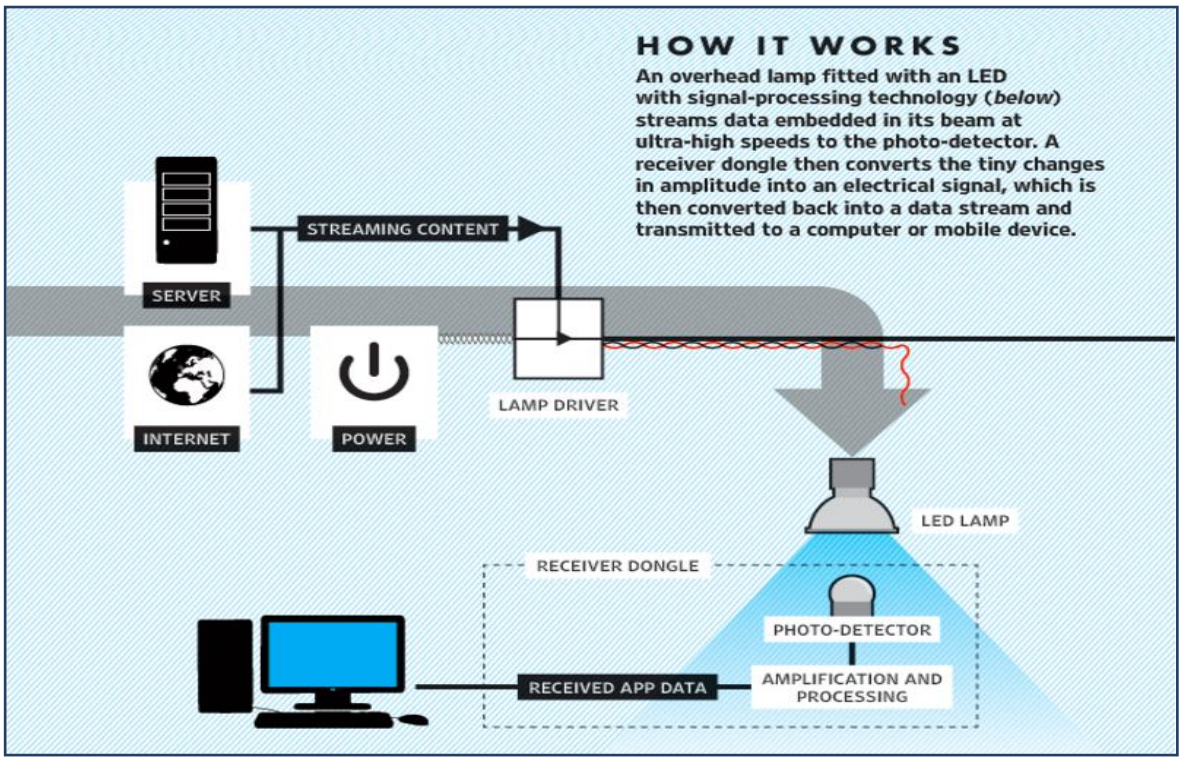
VIII. The ICS communication cabinet contains multiple control network switches to facilitate the media conversion from Ethernet to fibre-optic compatible. The fibre-optic cable carrying the corresponding control signal in the form of an optical beam, or light beam, is sent to the field optical access point followed by fibre-optic/Ethernet media conversion.

IX. The received control signal from the DCS converts the optical signal media into an Ethernet compatible corresponding electrical signal.

X. The OAP receives the control signal from the DCS via Ethernet cable. This electrical signal is further encoded in a certain frequency of the switching signal. This switching signal is further sent to the high speed LED light driver.

XI. The high speed LED light driver regulates the intensity modulation of the LED lights, which is not observed by human eye, and is received as encoded switching signal. The optical access point emits the control signal in the form of an optical signal, which is further received by the control device, such as a valve.

XII. The received optical signal carries action information of the final control element and is further converted into an electrical or pneumatic or hydraulic signal to control the process.



IV. Red Life Applications of Li-Fi

Here are some applications of Li-Fi technology in real world-

- RETAIL – It will help customers to easily get more information about the products and finding their way in the store
- TRAFFIC LIGHTS & HEADLIGHTS – Li-Fi does not only provide internet access to pedestrians but also will help in improving real time traffic updates with the traffic lights and Li-Fi enriched vehicle headlights
- UNDERWATER–Li-Fi technology can easily reach and work under water unlike Wi-Fi providing internet connectivity to ocean environment
- WEARABLES – Li-Fi inventor Harald Haas remains optimistic about the prospect of connecting smart clothes and jewelry with LED Li-Fi lights
- MUSEUM –Light illuminating objects can provide media rich information about the objects illuminated
- PETROCHEMICAL PLANTS – Li-Fi won't pose any problem unlike cellular network causing any spark or electrical explosions
- AIRCRAFT CARRIERS - Airline passengers can access high-speed internet using Li-Fi without causing any hazard to the signals received by the airplane

One example of recent project of Li-Fi technology implementation:

A French firm has won the contract to supply internet-over-lighting technology on the Paris Metro. The ambitious project – which will allow over two million daily commuters to use lights as a form of Wi-Fi, dubbed 'Li-Fi' – now looks firmly on track. Already La Defense station has been successfully equipped with the tech.

Paris-based Oledcomm, a spin-off of the University of Versailles, won the contract from RAPT to initially supply Li-Fi installations in 66 stations across Paris, involving over 250,000 LED luminaries. **[5]**

V. LIMITATIONS AND CHALLENGING WITH LI-FI

1. The services of Li-Fi can be availed only in presence of direct light source since visible light acts as a data carrier here.
2. There shouldn't be any obstruction between the sender and the receiver. Any kind of physical barrier might hinder the range of the signal.
3. Light coming from other sources other than the intended light source will disrupt the signal. This is one of the major drawbacks. Even sun rays coming from outside will affect the communication.
4. Entirely different infrastructure and mechanism is required in order to implement this mode of communication.
5. Li-Fi can mostly be used in point to point communication since a high frequency (400-800 THz) is being used here which results in short distance coverage.
6. Since a constant line of sight and light source needs to be maintained between the sender and the receiver, Li-Fi enabled devices can be installed only in limited type of places.
7. Since internet usage is inevitable 24x7, whatever light source is used needs to be switched on even during the day wasting a considerable amount of energy.[6]

VI. RESULTS

After some market research, it has been revealed that Li-Fi technology will hit a market value of 8500 Million USD within 2020. Although, for now, there are very few products and prototypes of Li-Fi model that is being launched in the market, but due to its advantages, Li-Fi is predicted to get very famous and useful in the near future.

Many big organizations like Microsoft, NASA, and European Space Agency (ESA) have started working or experimenting with infrastructures operating with Li-Fi. Even Apple is also experimenting with Li-Fi for their future devices.

Although, we are using the term 'near future' there many challenges and constraints that we need to solve and overcome, in order to enjoy the services that Li-Fi technology has to offer. [11]

VII. FUTURE SCOPE

Li-Fi technology is still unknown to many people and is beyond imagination for many people. It has not been implemented totally. Once it is put into practical use it can solve many problems of networking and can overcome many limitations of current wireless communication systems. There are various fields where we cannot use RF (radio frequency) communication since they are harmful. For example, in hospitals radio waves are dangerous to the patients and can also affect readings of machines like MRI machines etc. If we use Li-Fi we can solve the problem since it will not affect anything. Also in some military operations, RF communication is not allowed and to resolve such problem Li-Fi could be used to transmit data. Normal Wi-Fi technology cannot provide privacy of data or hide the data but using Li-Fi can provide total privacy of data which various companies can use to hide their important details. Water absorbs signal so RF communication underwater is not possible and moreover the waves could affect the marine life. Li-Fi wouldn't create such problems and can provide efficient solution for short-range transmission. In traffic system Li-Fi could be used through the street lamps and it would serve as Li-Fi hotspot too.[10]

In various ways the Li-Fi could be used to provide a better communicative world. Data can be transmitted easily and very fast. Heavy data can also be transmitted. This technology can prove a turning event to this high-tech world.

VIII. CONCLUSION

It is pretty clear from the advancement in researches on Li-Fi technology that it will be accessible to the common citizens in near future. It will be beneficial to most of the research works, underwater/underground research and communication, medical science and even in military sectors for its aid in secured communication. A great change in daily life on every aspect will happen if Li-Fi technology replaces Wi-Fi and other broad band networks. Though this technology has many advantages but data hand off over different access points and data upload on a very high speed is the biggest challenge to this technology.

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AUTHOR(S) PROFILE

Anwesha Chakraborty, is currently pursuing M.Sc. in Computer Science (2017-2019) from St. Xavier's College (Autonomous) Kolkata. She has received her B.Sc. degree in Computer Science in 2017 from the same college. Her final year project on B.Sc. was based upon Virtual Classroom, a web based project. She has also done a review paper on Java, defining it with the help of Finite state automation.

Trina Dutta, is currently pursuing M.Sc. in Computer Science (2017-2019) from St. Xavier's College (Autonomous) Kolkata. She has received her B.Sc. degree in Computer Science in 2017 from the same college. Her final year project on B.Sc. was based upon Virtual Classroom, a web based project.

Sushmita Mondal, is currently pursuing M.Sc. in Computer Science (2017-2019) from St. Xavier's College (Autonomous) Kolkata. She has received her B.Sc. degree in Computer Science in 2017 from the same college. Her final year project on B.Sc. was based upon Virtual Classroom, a web based project.

Dr. Asoke Nath, is working as lecturer in the Department of Computer Science, St. Xavier's College (Autonomous), Kolkata. He is engaged in research work in the field of Cryptography and Network Security, Steganography, Green Computing, Big data analytics, Li-Fi Technology, Mathematical modelling of Social Area Networks, MOOCs etc. He has published more than 224 research articles in different Journals and conference proceedings.

