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A Study on Li-Fi -Advanced Wireless Communication System

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ABSTRACT: This paper aims at demonstrating that Light Fidelity (Li-Fi) has now reached a state that is a viable and matured solution to wireless data transmission. Li-Fi technology will in future enable faster, more reliable internet connections, even when the demand for data usage has outgrown the available supply from existing technologies such as 4G, LTE and Wi-Fi. It will not replace these technologies, but will work seamlessly alongside them. Using light to deliver wireless internet will also allow connectivity in environments that do not currently readily support Wi-Fi, such as aircraft cabins, hospitals and hazardous environments. Light is already used for data transmission in fibre-optic cables and for point to point links, but Li-Fi is a special and novel combination of technologies that allow it to be universally adopted for mobile ultra high speed internet communication.

KEYWORDS: Principle of Li-Fi, Architecture of Li-Fi, Advantages of Li-Fi, Comparison of Li-Fi

I. INTRODUCTION

Now a day's Wi-Fi is the most used technology by everyone. The recent survey of CISCO says by 2016 the internet traffic will reach 1.3 zettabytes (1300 exabytes) which is 4 times more than 2011. This network demand on mobile data saturates the RF spectrum soon. It is estimated that by 2017, more than 11 exabytes of data traffic will have to be transferred through mobile networks every month.

RF Spectrum Crisis will be the popular term in 2020. It drives the technology service providers & Researchers to look for an alternative. Prof. Harald Haas, Edinburgh UK, addresses and answers the problem by introducing Li-Fi which is bidirectional, high speed and fully networked wireless communications, like Wi-Fi, using visible light spectrum. It is a 5G VLC system that uses light from light-emitting diode (LED) bulbs by switching them on and off within nanoseconds to transmit data

Li-Fi could lead to the Internet of Things, which is everything electronic being connected to the internet, with the LED lights on the electronics being used as internet access points. The Li-Fi market is projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018.

A. Principle of Li-Fi

Light modulation certainly isn't a new concept, but Has is looking to move things forward and enable connectivity through simple LED bulbs. With Li-Fi, you can connect to the internet simply by being within range of an LED beam, or you could conceivably transmit data using your car headlights.

Li-Fi Architecture is based on the concept of Illumination and transmission. It consists of 3 major components

i) LED Lamp

ii) Special Li-Fi Microchip

iii) Photo Detector

Heart of Li-Fi technology is high brightness LED's. Light emitting diodes can be switched on and off faster since operating speed of LED's is less than 1 µs, than the human eye can detect, causing the light source to be appear continuously. This invisible on- of activity enables a kind of data transmission using binary codes. Switching on and LED is a logical '1', switching it of is a logical '0'.It is possible to encode data in the light by varying the rate at which LED's flicker on and off to give different strings of 1s and 0s. Modulation is so fast that human eye doesn't

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notice. A light sensitive device (photo detector) receives the signal and converts it back into original data. This method of using rapid pulses of light to transmit information wirelessly is technically referred as Visible Light Communication (VLC) though its potential to compete with conventional Wi-Fi has inspired the popular characteristics Li-Fi. Refer Figure 2.1.

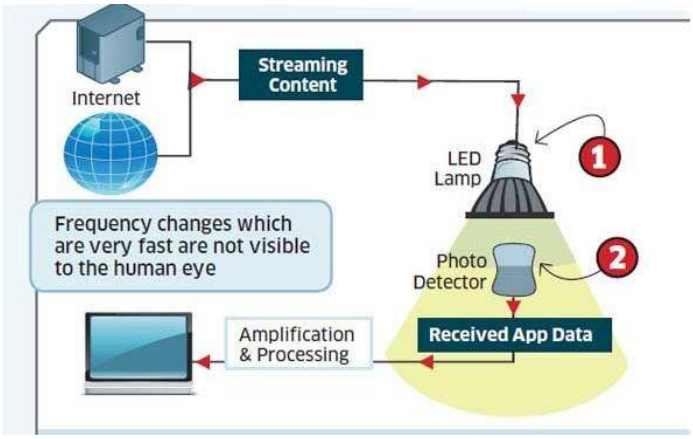

Figure i :- Li-Fi Principle

B. Li-Fi Suggested Architecture

The idea for novel architecture of Li-Fi technology is based on the Main LED Unit (MLU), Agent LED (AL) and Li-Fi cloud. The MLU is extended to the ALs where every AL has their own Li-Fi cloud to provide internet and other services connectivity through light. In this scenario the coverage area from a single node spread to the multiple nodes in the form of agent LEDs (AL). The main line is connected to the MLU and further it is extended to small nodes which are LED bulbs or lamps e.g. AL1, AL2, AL3 and AL4. The whole building is covered by these small nodes and provides wide coverage through light. The user can access the internet with little mobility inside the building as shown in figure 3.1 & 3.2. The number of ALs depends on the requirements and internal structure of the buildings

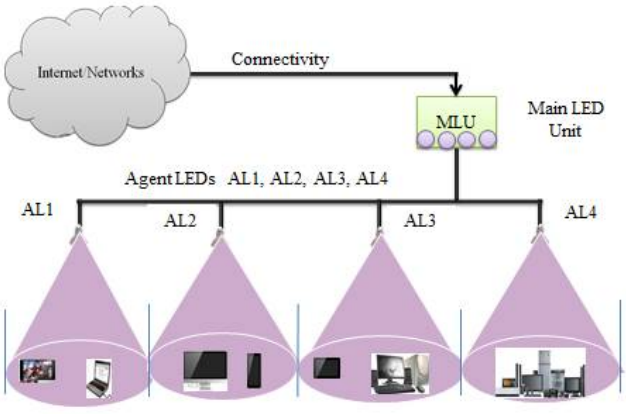

Figure 3.1. Li-Fi Suggested Architecture

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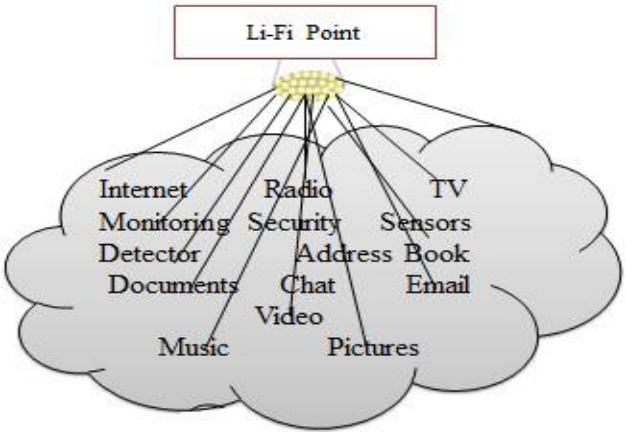

Figure B-(i):- Li-Fi Cloud

C. Tuning Factors for Maximum throughput

i) Dimension of LED

ii) Internal Structure Design

iii) Data Rate vs Size of LED

iv) Data Rate vs Number of LED

v) Data Rate vs ON-OFF Switch Rate

a) Dimension of LED

Placement and positioning of LED plays a vital role

In **Fixed Position**, the LED lamp or bulb is fixed inside the room or building or any other place. The position is adjusted in such a way that it can cover the maximum area with high intensity of light. The LED lamp or bulb can be fixed on walls and ceiling of the room or building. The user can access the services and applications of Li-Fi technology in a fixed area where the LED lamp light can reach.

In **Movable Position**, the LED lamp is adjusted in such a position that it can move with some specific angle and user can access the services of Li-Fi with low mobility. This type LED can be used widely because the lamp is moved around a fixed position. The LED lamp or bulb is mounted on the walls and ceiling of the room and the direction

b) Internal Structure Design (ISD)

The ISD dimension is measured with different parameters such as the diameter and position of the LED lamp. The ISD depends on the number, size and structure of the LEDs placed in the lamp. The lamps may be in flat, circular (round tip) and movable shape. The LEDs are of different types; round tip and chip LEDs are very common. Both types are used in the lamp for different purposes in Li-Fi technology. The round tip and circular shape LEDs are used to focus light on a fixed spot, it means that the data is transmitted through light towards a fixed point. The chip LED disperses the light in a wide area with high intensity.

c) Data Rate vs Size of LED

The variations in data rate (R) with the size of LEDs (S_{led}) are very critical in the Li-Fi technology. Different data rates can be achieved with different sizes of LEDs. The size of normal LED bulb can be reduced to micro-LED which handles millions of alterations in light intensity. A micro LED light bulb to transmit 1.3 Gbps and the data rate of more than 10 Gbps is possible. The tiny micro LED bulbs allow the stream of light to be beamed in parallel and

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transmitting huge amount of data in terms of Gbps. The microchip LED bulb can generate data rates up to 150 Mbps with single bulb which provide fast internet connectivity and services. Here it can be concluded that data rate (R) is inversely proportional to the size of LED (S_{led}). The LEDs are of different sizes e.g. 5mm, 3mm, 1.8mm, 1mm, 1 m and 1nm LED. The maximum data rate can be achieved with 1 m and 1nm LED which is considered to be a pixel in size.

$$R \alpha 1/S_{led}$$

d) Data Rate vs Number of LED

The data rate can be increased with the increasing number of LEDs. The number of LEDs (N_{led}) can be according to the available space inside the lamp. The number of LEDs can be adjusted so that it can achieve the maximum bit rate (bps).

$$R \alpha N_{led}$$

e) Data Rate vs ON-OFF (Oled) Switching of LED

The ON-OFF switching of LED light bulb can create binary data of 1s and 0s e.g. 1 for ON and 0 for OFF. The micro-LED handles millions of alterations in light intensity per second and faster the ON-OFF switching, transmitting large amount of data at high speed. The ON-OFF switching of LED bulb is at a very high speed so that the human eye cannot detect the alterations. Micro-LED is capable to transmit data 1000 times faster than normal LED with faster ON-OFF switching, transmitting large amount of data at high speed

$$R \alpha O_{led}$$

f) Li-Fi Home Wi-Fi LAN

In simple terms, Li-Fi can be thought of as a light-based Wi-Fi. That is, it uses light instead of radio waves to transmit information. And instead of Wi-Fi modems, Li-Fi would use transceiver-fitted LED lamps that can light a room as well as transmit and receive information. Since simple light bulbs are used, there can technically be any number of access points.

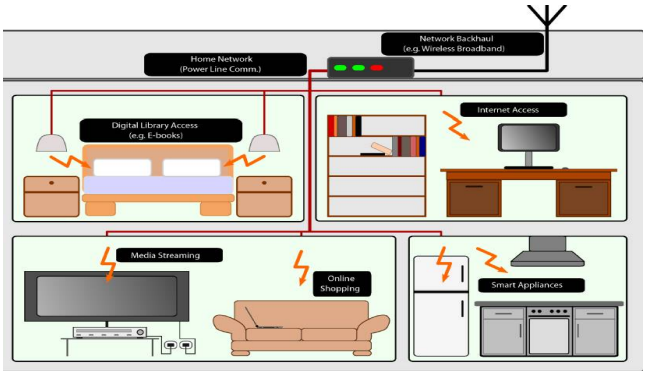

Figure ii :-Li-Fi Home Wi-Fi

II. ADVANTAGES OF LI-FI

Using of Li-Fi provides many advantages as below

- Operates on Visible Light Spectrum having 10,000 times more spectrum bandwidth than current RF spectrum
- Visible Light Spectrum is a free spectrum, there is no license process enabled for that by TROI. That means free of license cost

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- Visible Light Spectrum uses the Atto Cell, which not only improves the indoor coverage, but since it does not generate additional interference, it is able to enhance the capacity of RF wireless networks
- **Atto cell** helps and being the bridge between RF and VLC Li-Fi Sub networks
- High Installment cost but low maintenance cost
- Uses the LED bulbs which is Cheaper than Wi-Fi
  - Theoretical speed of 1.3 Gbps by using the different color LEDs we can achieve the more speed of 10 Gbps
  - Less time & energy Consumption
  - Lower electricity Charges
  - Longevity of LED bulb saves money
  - More Expose of VLC spectrum **won't cause any health problems**
  - **Secured access** because of light penetration restriction through wall
  - LiFi – can be used as **remote signal under water Ocean** where RF will not work
  - Can be used **Petrochemical plants** where the RF usage is not secured
  - Can be used in **Hospitals** where RF signals cannot be used
  - Can be used in **Auto Driven Cars** to avoid the traffic / accident collisions
  - Can be used in Streets to control the traffic signals also to form the Li-Fi Wi-Fi Network
  - Can be used in **Air Cabins** where RF signals are restricted

III. LI-FI COMPARISON OVER WI-FI

Table :- Li-Fi vs Wi-Fi

Parameter	Li-Fi	Wi-Fi
Speed	***	***
Range	*	**
Data density	***	*
Security	***	**
Reliability	**	**
Power available	***	*
Transmit/receive power	***	**
Ecological impact	*	**
Device-to-device connectivity	***	***
Obstacle interference	***	*
Bill of materials	***	**
Market maturity	*	***

* low ** medium *** high

All these above comparision reveal Li-Fi better than Wi-Fi

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IV. LIMITATIONS OF LI-FI

- The main problem is that light can't pass through objects, so if the receiver is inadvertently blocked in any way, then the signal will immediately cut out. ―If the light signal is blocked, or when you need to use your device to send information ― you can seamlessly switch back over to radio waves, Harald says.
- Reliability and network coverage are the major issues to be considered by the companies while providing VLC services. Filtering of Interference from external light sources like sun light, normal bulbs; and opaque materials in the path of transmission work in progress
- High installation cost of the VLC systems can be complemented by large-scale implementation of VLC though Adopting VLC technology will reduce further operating costs like electricity charges, maintenance charges etc.
- Li-Fi uses light-emitting diodes (LEDs) which are rapidly gaining in popularity for standard light bulbs and other domestic and commercial purposes. They are expected to be ubiquitous in 20 years. VLC is not in competition with Wi-Fi, Prof. Haas says, it is a complimentary technology that should eventually help free up much needed space within the radio wave spectrum.

V. CONCLUSION

In future, data for laptops, smart phones & tablets can be transmitted through light in room by using Li-Fi. Researchers are developing micron sized LED which are able to flicker on & off around 100 times quicker than larger LED. They offers faster data transfers and take up less space so we could save space or and more LED's to further boost the channel of communication. Also 100 micron sized LED can fit into area required by 1sq. mm large single LED. A 1 sq.mm sized array of micron sized LED's could therefore communicate 100×100 (i.e. a million) times as much information as a single 1mm LED. We can be sure that the future for Li-Fi is bright. Li-Fi consortium believes it is possible to achieve more than 10Gbps, theoretically allowing a high definition film to be downloaded in 30 seconds. The realization of a bidirectional connection also seems to have been addressed successfully to an extent that the first commercial bidirectional point-to-point Li-Fi systems are available.

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