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RESEARCH ARTICLE

Light-Fidelity (Li-Fi): Transmission of Data through Light of Future Technology

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ABSTRACT: *Current era many people are using internet to accomplish their task through wired or wireless network. As no of users get increased in wireless speed decreases proportionally. Though Wi-Fi gives us speed up to 150mbps as per IEEE 802.11n, it is still insufficient to accommodate no of users. To remedy this limitation of Wireless Fdilityi, we are introducing concept of Li-Fi. As per germen phycist Harald Haas data through illumination taking the fibber out of fiber optic by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. It's the same idea band behind infrared remote controls but far more powerful. Haas says his invention, which he calls D-LIGHT, can produce data rates faster than 10 megabits per second, which is speedier than your average broadband connection.*

Light-Fidelity is a label for wireless-communication systems using light as a carrier instead of traditional radio Frequencies [1], as in Wi-Fi. Li-Fi has the advantage of being able to be used in sensitive areas such as in Aircraft and other transportation without causing interference. However, the light waves used cannot penetrate walls. It is typically implemented using white LED bulbs at the Downlink transmitter. This type of devices are normally used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This property of optical current is used in Li-Fi setup. The operational procedure is very simple-, if the LED bulb 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. Hence all that is required is some LEDs and a controller that code data into those LEDs. All one has to do is to vary the rate at which the LED's flicker [2] depending upon the data we want to encode. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frequency with each frequency encoding a different data Channel. Such advancements promise a theoretical speed of 10 Gbps – meaning one can download a full high-definition film in just 30 seconds.

Keywords*: Wi-Fi, Light-emitting diode (LED), Video LAN Client (VLC), Technology, Entertainment and Design (TED), Visible Light, Data utilization, server, lamp driver.*

1. INTRODUCTION

Li-Fi, as coined by Prof. Harald Haas during his TED Global talk,[1] is bidirectional, high speed and fully networked wireless communications similar to Wi-Fi. Li-Fi is a subset of optical wireless communications (OWC) and can be a complement to RF communication (Wi-Fi or Cellular network), or a replacement in contexts of data broadcasting. It is wireless and uses visible light communication or infra-red and near ultraviolet (instead of radio frequency waves) spectrum, part of Optical wireless communications technology, which carries much more information, and has been proposed as a solution to the RF-bandwidth limitations. A complete solution includes an industry led standardization process.

Light Fidelity is a new wireless communication technology which enables a wireless data transmission through LED light. Light Fidelity 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. Data can be received by electronic devices with photodiode [3] within area of light visibility. This means that everywhere where LEDs are used, lighting bulbs can bring not only The light but wireless Connection at the same time. With increasing demand for wireless data, lack of radio spectrum and issues with hazardous electromagnetic pollution, Light Fidelity appears as a new greener, healthier and cheaper alternative to WiFi. The term was first used in this context by Harald Haas in his TED [4] Global talk on Visible Light Communication. The technology was demonstrated at the 2012 Consumer Electronics Show in Las Vegas using a pair of Casio smart phones to exchange data using light of varying intensity given off from their screens, detectable at a distance of up to ten meters. In October 2011 a number of companies and industry groups formed the Light Fidelity Consortium, to promote high-speed optical Wireless systems and to overcome the limited amount of radio based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. The consortium believes it is possible to achieve more than 10 Gbps, theoretically allowing a high-definition film to be downloaded in 30 seconds. Li-Fi has the advantage of being able to be used in sensitive areas such as in aircraft without causing interference. However, the light waves used 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 Li-Fi makes possible to have a wireless Internet in specific environments (hospitals, Airplanes etc.) where Wi-Fi is not allowed due to interferences or security considerations. Light Fidelity is transmission of data through illumination by taking the fiber out of fiber optics by sending data through a LED light bulb that varies in intensity faster than the human eye can follow. Li-Fi is the term some have used to label the fast and cheap wireless Communication system, which is the optical version of WiFi. The term was first used in this context by Harald Haas in his TED Global talk on Visible Light Communication. "At the heart of this technology is a new generation of high brightness light-emitting diodes", says Harald Haas from the University of Edinburgh, UK,"Very simply, if the LED is on, you transmit a digital 1, if it's off you transmit a 0,"Haas says, "They Can be switched on and off very quickly, which gives nice opportunities for transmitted data. "It is

possible to encode data in the Light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. The LED intensity is modulated so rapidly that human eye cannot notice, so the output appears constant. More sophisticated techniques could dramatically increase VLC data rate. Terms at the University of Oxford and the University of Edinburgh are focusing on parallel data transmission using array of LEDs, where each LED transmits a different data stream. Fig2: Harald haas Other groups are using mixtures of red, green and blue LEDs to alter the light frequency encoding a different data channel. The Li-Fi Consortium is an international platform focusing on optical wireless Technologies. It was founded by four Technology based organizations in October 2011. The goal of Li-Fi Consortium is to foster the Development and distribution of optical wireless technologies such as communication, navigation, natural user interfaces and others This is accomplished by inviting technology experts, OEMs, end users and standardization groups to discuss needs, Challenges and eco-system approaches [6]. Li-Fi could free up bandwidth, especially as much of the infrastructure is Already in place. “There are around 14 billion light bulbs worldwide, they just need to be replaced with LED ones that transmit data," says Haas. "We reckon VLC is a factor of ten cheaper than Wi-Fi." Because it uses light rather than radio-frequency signals, VLC could be used safely in Aircraft, integrated into medical devices and hospitals where Wi-Fi is banned, or even underwater, where Wi-Fi doesn't Work at all. His technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum. Light is in fact very much part of our lives for millions and millions of years and does not have any major ill effect. Moreover there is 10,000 times more space available in this spectrum and just counting on the bulbs in use, it also multiplies to 10,000 times more availability as an infrastructure, globally.

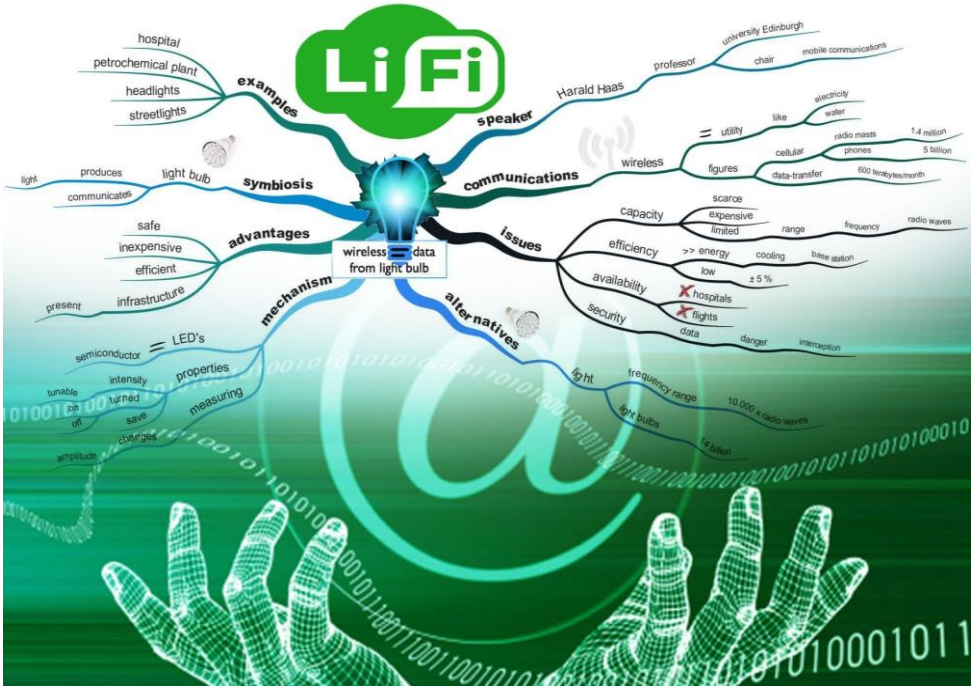

Fig.1 Li-Fi Technology, Source: sitetalkandunaico.wordpress.com

2. HISTORY

Professor Harald Haas, from the University of Edinburgh in the UK, is widely recognised as the original founder of Li-Fi. He coined the term Li-Fi and is Chair of Mobile Communications at the University of Edinburgh and co-founder of pure LiFi. The general term visible light communication (VLC), includes any use of the visible light portion of the electromagnetic spectrum to transmit information. The D-Light project at Edinburgh's Institute for Digital Communications was funded from January 2010 to January 2012.[15] Haas promoted this technology in his 2011 TED Global talk and helped start a company to market it.[16] PureLiFi, formerly pure VLC, is an original equipment manufacturer (OEM) firm set up to commercialize Li-Fi products for integration with existing LED-lighting systems.

In October 2011, companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum.[15] A number of companies offer uni-directional VLC products which is not the same as Li-Fi. VLC technology was exhibited in 2012 using Li-Fi.[16] By August 2013, data rates of over 1.6 Gbit/s were demonstrated over a single color LED.[17] In September 2013, a press release said that Li-Fi, or VLC systems in general, do not require line-of-sight conditions.[27] In October 2013, it was reported Chinese manufacturers were working on Li-Fi development kits.[18]

In April 2014, the Russian company Stins Coman announced the development of a Li-Fi wireless local network called Beam Caster. Their current module transfers data at 1.25 gigabytes per second but foresee boosting speeds up to 5 GB/second in the near future.[19]

3. WORKING PROCESS OF LI FI

Light Fidelity is typically implemented using white LED light bulbs at the downlink transmitter. These devices are normally used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This very property of optical current is used in Light Fidelity setup. The operational procedure is 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. Hence all that is required is some LEDs and a controller that code data into those LEDs. All one has to do is to vary the rate which the LED's flicker depending upon the data we want to encode. Further at enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frequency with each frequency encoding a different data channel. Such advancements promise a theoretical speed of 10 Gbps – meaning one can download a full high-definition film in just 30 seconds. To further get a grasp of Light Fidelity consider an IR remote.(fig 3.3). It

sends a single data stream of bits at the rate of 10,000-20,000 bps. Now replace the IR LED [7] with a Light Box containing a large LED array. This system, fig 3.4, is capable of sending thousands of such streams at very fast rate. Light is inherently safe and can be used in places where radio frequency communication is often deemed problematic, such as in aircraft cabins or hospitals. So visible light communication not only has the potential to solve the problem of lack of spectrum space, but can also enable novel application. The visible light spectrum is unused. It's not regulated, and can be used for communication at very high speeds. The University of Strath clyde in the UK has created a research center aimed at turning the constant flicker of LED lights into a way to transmit internet communications using visible light, as opposed to radio waves (Wi-Fi, cellular) or via cables. Dubbed, the Intelligent Lighting Centre (ILC)[8], the consortium is made up of researchers from several UK universities, and is backed with £4.6 million (US $7.28M) by the Engineering and Physical Sciences Research Council. Together the consortium aims to conduct research on a smaller LED than other groups around the world that are also investigating this technology. First, a bit on what they call Li-Fi from the university release (or you can go catch a TED talk on the topic):Underpinning Li-Fi is the use of light-emitting diodes (LEDs), a rapidly spreading lighting Technology which is expected to become dominant over the next 20 years. Imperceptibly, LEDs flicker on and off thousands of times a second: by altering the length of the flickers, it is possible to send digital information to specially-adapted PCs and other electronic devices – making Li-Fi the digital equivalent of Morse code. This would make the visible part of the electromagnetic spectrum available for internet communications, easing pressure on the increasingly crowded parts of the spectrum currently being used. Instead of researching Li-Fi LEDs around 1mm2 in size, the EPSRC-funded[9] team is developing tiny, micron-sized LEDs which are able to flicker on and off 1,000 times quicker than the larger LEDs. This would allow them to transfer more information, giving them greater capacity; think of comparable to the difference between DSL [10] and fiber connections.

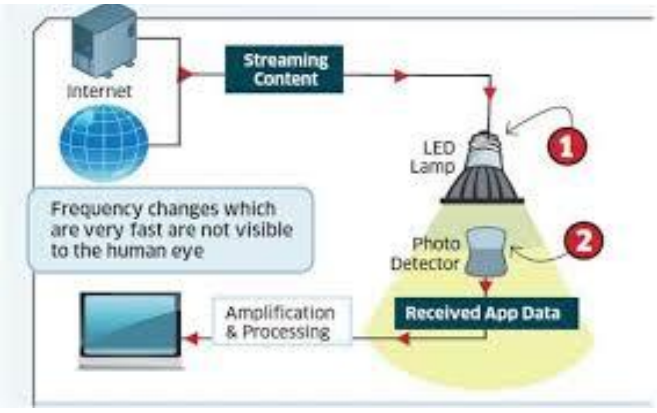

Fig.2 Li-Fi Technology, source: newtecharticles.com

4. ADVANTAGES OF LI-FI OVER WI-FI

- Light Fidelity uses light rather than radio frequency signals so are intolerant to disturbances.
- VLC could be used safely in aircraft without affecting airlines signals.
- Integrated into medical devices and in hospitals as this technology doesn't deal with radio waves, so it can easily be used in all such places where Bluetooth, infrared, Wi-Fi and internet are broadly in use.
- Under water in sea Wi-Fi does not work at all but light can be used and hence undersea explorations are good to go now with much ease.
- There are billions of bulbs worldwide which just need to be replaced with LED's to transmit data.
- Security is a side benefit of using light for data transfer as it does not penetrate through walls.
- On highways for traffic control applications like where Cars can have LED based headlights, LED based backlights, and they can communicate with each other and prevent accidents. Using this Technology worldwide every street lamp would be a free data access point.
- The issues of the shortage of radio frequency bandwidth may be sorted out by Li-Fi.•

5. LiFi vs WiFi

Difference between LiFi and WiFi technologies. Following table mentions feature comparison between both.

Feature	LiFi	WiFi
Full form	Light Fidelity	Wireless Fidelity
Operation	LiFi transmits data using light with the help of LED bulbs.	WiFi transmits data using radio waves with the help of WiFi router.
Interference	Do not have any interference issues similar to radio frequency waves.	Will have interference issues from nearby access points(routers)
Technology	Present IrDA compliant devices	WLAN 802.11a/b/g/n/ac/ad standard compliant devices
Applications	Used in airlines, undersea explorations, operation theaters in the hospitals, office and home premises for data transfer and internet browsing	Used for internet browsing with the help of wifi kiosks or wifi hotspots
Merits(advantages)	Interference is less, can pass through salty sea water, works in densy region	Interference is more, can not pass through sea water, works in less densy region

Privacy	In LiFi, light is blocked by the walls and hence will provide more secure data transfer	In WiFi, RF signal can not be blocked by the walls and hence need to employ techniques to achieve secure data transfer.
Data transfer speed	About 1 Gbps	WLAN-11n offers 150Mbps, About 1-2 Gbps can be achieved using WiGig/Giga-IR
Frequency of operation	10 thousand times frequency spectrum of the radio	2.4GHz, 4.9GHz and 5GHz
Data density	Works in high dense environment	Works in less dense environment due to interference related issues
Coverage distance	About 10 meters	About 32 meters (WLAN 802.11b/11g), vary based on transmit power and antenna type
System components	Lamp driver, LED bulb(lamp) and photo detector will make up complete LiFi system.	requires routers to be installed, subscriber devices(laptops,PDAs,desktops) are referred as stations

6. Problems in Wi-Fi

The following are the basic issues with radio waves:

a) Capacity: Wireless data is transmitted through radio waves which are limited and expensive. It has a limited bandwidth. With the rapidly growing world and development of technologies like 3G, 4G and so on we are running out of spectrum.

b) Efficiency: There are 1.4 million cellular radio base stations that consume massive amount of energy. Most of the energy is used for cooling down the base station instead of transmission. Therefore efficiency of such base stations is only 5%.

c) Availability: Availability of radio waves is a big concern. It is not advisable to use mobile phones in aero planes and at places like petrochemical plants and petrol pumps.

d) Security: Radio waves can penetrate through walls. They can be intercepted. If someone has knowledge and bad intentions, they may misuse it. This causes a major security concern for Wi-Fi.

7. APPLICATIONS OF LI-FI

The LI-FI system finds a variety of uses in many fields from access to internet by the general public using street lamps to auto-pilot cars which communicate through their headlights. Moreover, in areas such as medicine and aircrafts where WI-FI cannot be used, LI-FI is an alternative which can provide faster data access rates. Some of the applications are discussed below:

Education systems:

Li-Fi is the latest technology that can provide fastest speed internet access. So, it can replace Wi-Fi at educational institutions and at companies so that all the people can make use of Li-Fi with the same speed intended in a particular area.

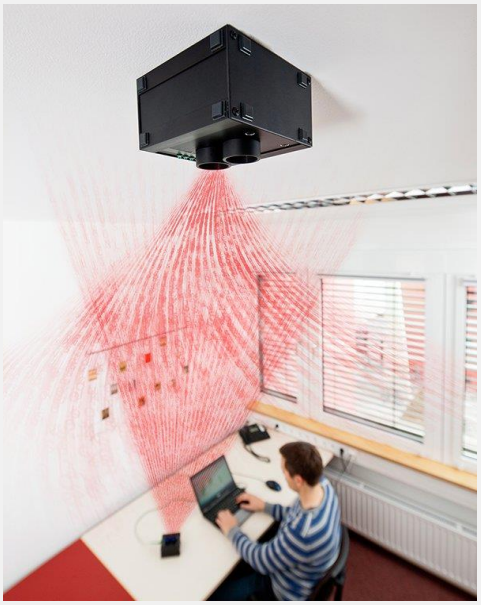

Fig3: Li-Fi used in Education.

Medical Applications:

Operation theatres (OTs) do not allow Wi-Fi due to radiation concerns. Usage of Wi-Fi at hospitals interferes with the mobile and pc which blocks the signals for monitoring equipments. So, it may be hazardous to the patient's health. To overcome this and to make OT tech savvy Li-Fi can be used to accessing internet and to control medical equipments. This can even be beneficial for robotic surgeries and other automated procedures.

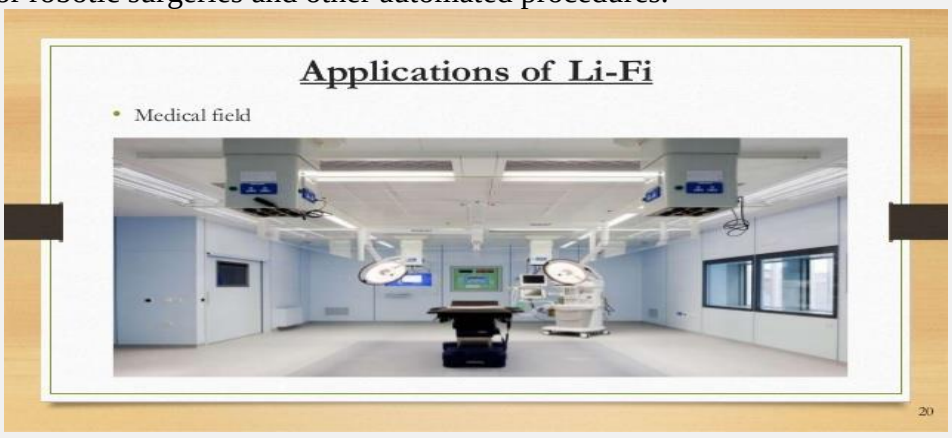

Fig4: Li-Fi used in medical

Cheaper Internet in Aircrafts:

The passengers travelling in aircrafts get access to low speed internet at a very high rate. Also Wi-Fi is not used because it may interfere with the navigational systems of the pilots. In aircrafts Li-Fi can be used for data transmission. Li-Fi can easily provide high speed internet via every light source such as overhead reading bulb, etc. present inside the air plane.

Fig5: Li-Fi used in aircraft.

Disaster management:

Li-Fi can be used as a powerful means of communication in times of disaster such as earthquake or hurricanes. The average people may not know the protocols during such disasters. Subway stations and tunnels, common dead zones for most emergency communications, pose no obstruction for Li-Fi [1].Also, for normal periods, Li-Fi bulbs could provide cheap high-speed Web access to every street corner.

Applications in sensitive areas

Power plants need fast, inter-connected data systems so that demand, grid integrity and core temperature (in case of nuclear power plants) can be monitored. Wi-Fi and many other radiation types are bad for sensitive areas surrounding the power plants. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations. This can save money as compared to the currently implemented solutions. Also, the pressure on a power plant‘s own reserves could be lessened. Li-Fi can also be used in petroleum or chemical plants where other transmission or frequencies could be hazardous.

Traffic management:

In traffic signals Li-Fi can be used which will communicate with the LED lights of the cars which can help in managing the traffic in a better manner and the accident number scan be decreased [1]. Also, LED car lights can alert drivers when other vehicles are too close.

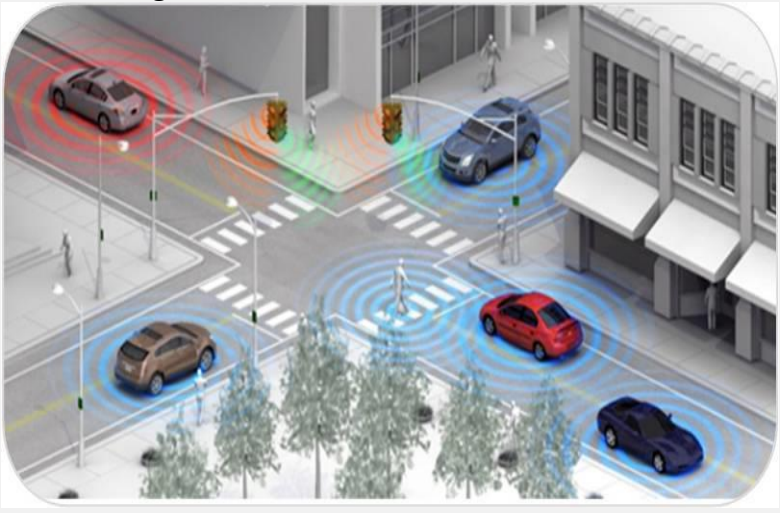

Fig5: Li-Fi used in a Traffic management.

Underwater applications: Underwater ROVs (Remotely Operated Vehicles) operate from large cables that supply their power and allow them to receive signals from their pilots above. But the tether used in ROVs is not long enough to allow them to explore larger areas. If their wires were replaced with light — say from a submerged, high powered lamp — then they would be much freer to explore. They could also use their headlamps to communicate with each other, processing data autonomously and sending their findings periodically back to the surface [11]. LI-FI can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military operations.

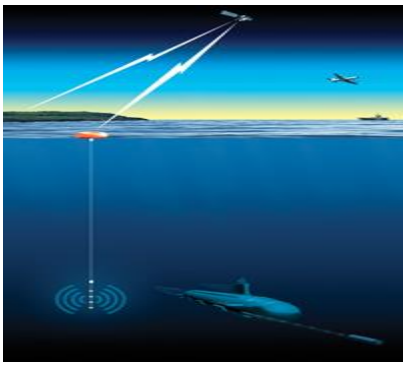

Fig5: Li-Fi used in a underwater applications

8. LIMITATIONS OF LI-FI

- This research report categorizes the global VLC technology market; based on component, applications, and geography. 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.
- The 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.
- Network coverage and reliability and are the major issues to be considered by the companies while providing VLC services. Interference 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 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.

9. CONCLUSION

There are a plethora of possibilities to be gouged upon in this field of technology. If this technology becomes justifiably marketed then every bulb can be used analogous to a Wi-Fi hotspot to transmit data wirelessly. The possibilities are numerous and can be explored further. 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. The concept of Li-Fi is currently attracting a great deal of interest, not least because it may offer a genuine and very efficient alternative to radio-based wireless. As a growing number of people and their many devices access wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. This may solve issues such as the shortage of radio-frequency bandwidth and also allow internet where traditional radio based wireless isn't allowed such as aircraft or hospitals. One of the shortcomings however is that it only work in direct line of sight.

10. FUTURE SCOPE

The area of Li-Fi is very broad in the manner of Hospitals, Academics, Airlines and more. Can be used in the places where it is difficult to lay the optical fiber like hospitals. In operation theatre LiFi can be used for modern medical instruments. In traffic signals LiFi can be used which will communicate with the LED lights of the cars and accident numbers can be decreased. Thousand and millions of street lamps can be transferred to LiFi lamps to transfer data. In aircraft LiFi can be used for data transmission. It can be used in petroleum or chemical plants [13] where other transmission or frequencies could be Hazardous. Such advancements promise a theoretical speed of 100 Gbps - meaning one can download a full high definition film in just 3 seconds

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