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Li-Fi (Light-Fidelity) - A Future Wireless 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 remediate this limitation of Wireless Fidelity, we are introducing concept of Li-Fi. As per germen physicist Harald Haas data through illumination taking the fiber 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. He envisions a future where data for laptops, smartphones, and tablets is transmitted through the light in a room. And security would be a snap—if you can't see the light, you can't access the data.Li-Fi is a VLC, visible light communication, technology developed by a team of scientists including Dr Gordon Povey, Prof. Harald Haas and Dr Mostafa Afgani at the University of Edinburgh. Li-Fi is now part of the Visible Light Communications (VLC) PAN IEEE 802.15.7 standard. 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

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.

This 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.

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 eyes cannot notice, so the output appears constant.

More sophisticated techniques could dramatically increase VLC data rates. Teams at the University of Oxford and the University of Edinburgh are focusing on parallel data transmission using arrays of LEDs, where each LED transmits a different data stream. Other groups are using mixtures of red, green and blue LEDs to alter the light's frequency, with each frequency encoding a different data channel.

Li-Fi, as it has been dubbed, has already achieved blisteringly high speeds in the lab. Researchers at the Heinrich Hertz Institute in Berlin, Germany, have reached data rates of over 500 megabytes per second using a standard white-light LED. Haas has set up a spin-off firm to sell a consumer VLC transmitter that is due for launch next year. It is capable of transmitting data at 100 MB/s - faster than most UK broadband connections.

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. [4] Haas promoted this technology in his 2011 TED Global talk and helped start a company to market it.[5] PureLi-Fi, 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. [5] 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. [6] By August 2013, data rates of over 1.6 Gbit/s were demonstrated over a single color LED.[7] In September 2013, a press release said that Li-Fi, or VLC systems in general, do not require line-of-sight conditions.[8] In October 2013, it was reported Chinese manufacturers were working on Li-Fi development kits.[9]

In April 2014, the Russian company StinsComan 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. [6]

Architecture of Li-Fi System

Li-Fi which can be the future of data communication appears to be a fast and cheap optical version of Wi-Fi. Being a Visible Light Communication (VLC), Li-Fi uses visible light of electromagnetic spectrum between 400 THz and 800 THz as optical carrier for data transmission and illumination. It uses fast pulses of light to transmit information in wireless medium.

The main components of a basic Li-Fi system may contain the following:

- A high brightness white LED which acts as transmission source.
- A silicon photodiode with good response to visible light as the receiving element.

Switching the LEDs on and off can make them generate digital strings with different combination of 1s and 0s. To generate a new data stream, data can be encoded in the light by varying the flickering rate of the LED. In this way, the LEDs work as a sender by modulating the light with the data signal. The LED output appears constant to the human because they are made to flicker at a phenomenal speed (millions of times per second) and it's impossible for human eye to detect this frequency. Communication rate more than 100 Mbps can be achieved by using high speed LEDs with the help of various multiplexing techniques. And this VLC data rate can be further increased to as high as 10 Gbps via parallel data transmission using an array of LED lights with each LED transmitting a different data stream.

The Li-Fi transmitter system comprises of four primary subassemblies:

- Bulb
- RF Power Amplifier Circuit (PA)
- Printed Circuit Board (PCB)
- Enclosure

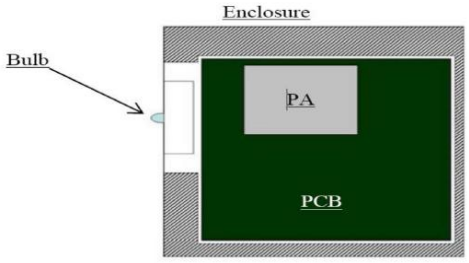

Figure 1: Block Diagram of Li-Fi sub-assemblies

The Printed circuit board (PCB) controls the electrical inputs and outputs of the lamp and houses the microcontroller used to manage different lamp functions. A Radio Frequency (RF) signal is generated by the Power Amplifier and is directed into the electric field of the bulb. As a result of the high concentration of energy in the electric field, the contents of the bulb will get vaporized into a plasma state at the bulb's centre. And this controlled plasma in turn will produce an intense source of light. All of these subassemblies are contained in an aluminium enclosure as shown in Fig. 1 above.

Li-Fi Bulb sub-assembly

The bulb sub-assembly is the main part of the Li-Fi emitter. It consists of a sealed bulb embedded in a dielectric material which serves two purposes: one, it acts as a waveguide for the RF energy transmitted by the PA (Power Amplifier) and two, it acts as an electric field concentrator that focuses the energy into the bulb. The collected energy from the electric field rapidly heats the material in the bulb to a plasma state that emits light of high intensity of Visible light spectrum.

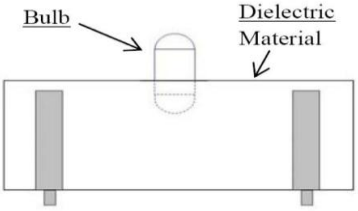

Figure 2: Bulb Sub Assembly

There are various inherent advantages of this approach which includeshigh brightness, excellent colour quality and high luminous efficacy of the emitter – in the range of 150 lumens per watt or greater. The structure is mechanically robust without typical degradation and failure mechanisms associated with tungsten electrodes and glass to metal seals, resulting in useful lamp life of 30,000+ hours. In addition, the unique combination of high temperature plasma and digitally controlled solid state electronics results in an economically produced family of lamps scalable in packages from 3,000 to over 100,000 lumens.

Important factors that should be considered while designing Li-Fi are as follows:

- Presence of Light
- Line of Sight (Los)
- For better performance use fluorescent light & LED

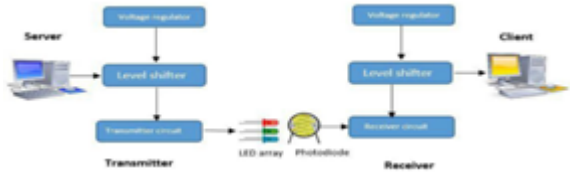

Figure 3: Construction of Li-Fi System

3. Working of Li-Fi

Basic Concept: Light Fidelity (Li-Fi) technology is a wireless communication system based on the use of visible light between the violet (800 THz) and red (400 THz). Unlike Wi-Fi which uses the radio part of the electromagnetic spectrum, Li-Fi uses the optical spectrum i.e. Visible light part of the electromagnetic spectrum. The principle of Li-Fi is based on sending data by amplitude modulation of the light source in a well-defined and standardized way. LEDs can be switched on and off faster than the human eyes can detect since the operating speed of LEDs is less than 1 microsecond. This invisible on-off activity enables data transmission using binary codes. If the LED is on, a digital '1' is transmitted and if the LED is off, a digital '0' is transmitted. Also these LEDs can be switched on and off very quickly which gives us a very nice opportunity fortransmitting data through LED lights, because there are no interfering light frequencies like thatof the radio frequencies in Wi-Fi. Li-Fi is thought to be 80% more efficient, which means it canreach speeds of up to 1Gbps and even beyond. Li-Fi differs from fibre optic because the Li-Fiprotocol layers are suitable for wireless communication over short distances (up to 10 meters).
This puts Li-Fi in a unique position of extremely fast wireless communication over shortdistances.

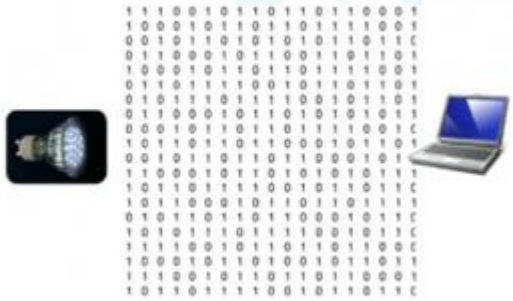

Figure 4: Li-Fi Transmission

How it Works: The working of Li-Fi is very simple. There is a light emitter on one end i.e. an LED transmitter, and a photo detector (light sensor) on the other. The data input to the LED transmitter is encodedin to the light (technically referred to as Visible Light Communication) by varying the flickeringrate at which the LEDs flicker 'on' and 'off' to generate different strings of 1s and 0s. The onoffactivity of the LED transmitter which seems to be invisible (The LED intensity is modulatedso rapidly that human eye cannot notice, so the light of the LED appears constant to humans), enables data transmission in light form in accordance with the incoming binary codes: switchingON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which theLEDs flicker on and off, information can be encoded in the light to different combinations of1s and 0s.In a typical setup, the transmitter (LED) is connected to the data network (Internet through themodem) and the receiver (photo detector/light sensor) on the receiving end receives the data aslight signal and decodes the information, which is then displayed on the device connected tothe receiver. The receiver (photo detector) registers a binary '1' when the transmitter (LED) isON and a binary '0' when the transmitter (LED) is OFF. Thus flashing the LED numerous timesor using an array of LEDs (perhaps of a few different colours) will eventually provide data ratesin the range of hundreds of Mbps. The Li-Fi working is explained in a block diagram (Fig.5).

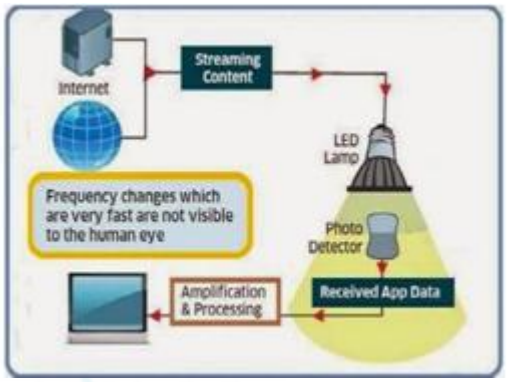

Figure 5: Block diagram of Li-Fi Sub System

Hence all that is required, is some or an array of LEDs and a controller that controls/encodes data into those LEDs. All one has to do is to vary the rate at which the LEDs flicker dependingupon the data input to LEDs. Further data rate enhancements can be made in this method, by using array of the LEDs for parallel data transmission, or using mixtures of red, green and blueLEDs to alter the light's frequency, with each frequency encoding a different data channel. Figure 6 shows working/deployment of a Li-Fi system connecting the devices in a room.

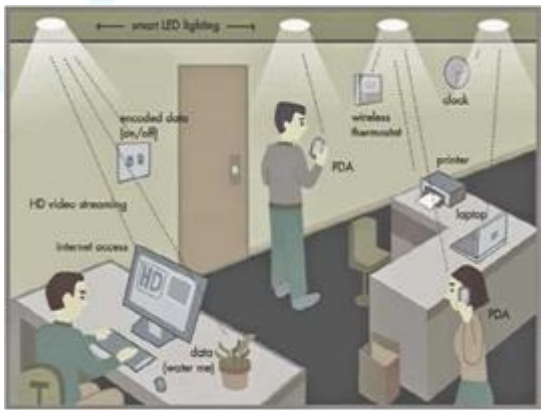

Figure 6: Li-Fi system connecting devices in a room

The frequency spectrum that is available to us in the atmosphere consists of many wave regions like X-rays, gamma rays, u-v region, infrared region, visible light rays, radio waves, etc. Anyone of the above waves can be used in the upcoming communication technologies but why theVisible Light part is chosen? The reason behind this is the easy availability and lesser harmfuleffects that occur due to these rays of light. VLC uses the visible light between 400 THz (780nm) and 800 THz (375 nm) as medium which are less dangerous for high-power applicationsand also humans can easily perceive it and protect themselves from the harmful effects whereas

The other wave regions have following disadvantages:-

- Radio waves are expensive (due to spectrum charges) and less secure (due to interference and possible interception etc.)
- Gamma rays are harmful because it could be dangerous dealing with it, by the human beings due to their proven adverse effects on human health.
- X-rays have health issues, similar to the Gamma Rays.
- Ultraviolet light can be considered for communication technology purposes at place without people, otherwise they can also be dangerous for the human body when exposed continuously.
- Infrared, due to high safety regulation, can only be used with low power.

Hence the Visible light portion (from red to blue) of the electromagnetic spectrum does not cause any harm to the people as visible rays are safe to use, provide larger bandwidth and alsohave a promising future in the communication field.

Comparison between Li-Fi and, Wi-Fi and Other Radio Communication Technologies

Both Wi-Fi and Li-Fi can provide wireless Internet access to users, and both the technologies transmit data over electromagnetic spectrum. Li-Fi is a visible light communication technologyuseful to obtain high speed wireless communication. The difference is: Wi-Fi technology usesradio waves for transmission, whereas Li-Fi utilizes light waves. Wi-Fi works well for generalwireless coverage within building/campus/compound, and Li-Fi is ideal for high densitywireless data coverage inside a confined area or room and is free from interference issues unlikethe Wi-Fi.

Table 1: Comparison of speed of various wireless technologies

Technology	Speed
Li-Fi	~1 Gbps
Wi-Fi – IEEE 802.11n	~150 Mbps
IrDA	~4 Mbps
Bluetooth	~3 Mbps
NFC	~424 Kbps

Table 2: Comparison of Wi-Fi and Li-Fi

Parameter	Li-Fi	Wi-Fi
Spectrum	*Used* Visible Light	RF
Standard	IEEE 802.15.7	IEEE 802.11
Range	Based on Light Intensity (< 10m)	Based on Radio propagation & interference (< 300 m)
Data Transfer Rate	Very high (~1 Gbps)	Low (100 Mbps-1 Gbps)
Power consumption	Low	High
Cost	Low	High
Bandwidth	Unlimited	Limited

Shortcomings of Radio Waves Transmission: 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 radiospectrum.

b) ***Energy Efficiency:*** There are a large number of 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 Radio base stations is very low.

c) ***Availability:*** Availability of radio waves is a big concern. Further, Radio waves are not advisable to be used in aeroplanes and at places where radio interference may cause undesirable/catastrophic result.

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.

Advantages of Li-Fi: Li-Fi, which uses visible light to transmit signals wirelessly, is an emerging technology poised to compete with Wi-Fi. Also, Li-Fi removes the limitations that have been put on the user bythe Radio wave transmission such as Wi-Fi as explained above vide 4.1.

Advantages of Li-Fi technology include:

a) ***Efficiency:*** Energy consumption can be minimised with the use of LED illuminationwhich are already available in the home, offices and Mall etc. for lighting purpose. Hencethe transmission of data requiring negligible additional power, which makes it veryefficient in terms of costs as well as energy.

b) ***High speed:*** Combination of low interference, high bandwidths and high-intensity output, help Li-Fi provide high data rates i.e. 1 Gbps or even beyond.

c) ***Availability:*** Availability is not an issue as light sources are present everywhere.Wherever there is a light source, there can be Internet. Light bulbs are presenteverywhere – in homes, offices, shops, malls and even planes, which can be used as a medium for the data transmission.

d) ***Cheaper*:** Li-Fi not only requires fewer components for its working, but also uses only a negligible additional power for the data transmission.

e) ***Security:*** One main advantage of Li-Fi is security. Since light cannot pass through opaque structures, Li-Fi internet is available only to the users within a confined area and cannot be intercepted and misused, outside the area under operation.

Li-Fi technology has a great scope in future. The extensive growth in the use of LEDs for illumination indeed provides the opportunity to integrate the technology into a plethora of environments and applications.

4. Limitations of Li-Fi

Some of the major limitations of Li-Fi are:

- Internet cannot be accessed without a light source. This could limit the locations and situations in which Li-Fi could be used.
- It requires a near or perfect line-of-sight to transmit data
- Opaque obstacles on pathways can affect data transmission
- Natural light, sunlight, and normal electric light can affect the data transmission speed
- Light waves don't penetrate through walls and so Li-Fi has a much shorter range than Wi-Fi

- High initial installation cost, if used to set up a full-fledged data network.
- Yet to be developed for mass scale adoption.

5. Applications of Li-Fi

There are numerous applications of Li-Fi technology, from public Internet access throughexisting lighting (LED) to auto-piloted cars that communicate through their headlights (LEDbased). Applications of Li-Fi can extend in areas where the Wi-Fi technology lacks its presencelike aircrafts and hospitals (operation theatres), power plants and various other areas, whereelectromagnetic (Radio) interference is of great concern for safety and security of equipment and people. Since Li-Fi uses just the light, it can be used safely in such locations or areas.

Some of the future applications of Li-Fi could be as follows:

a) ***Education systems:*** Li-Fi is the latest technology that can provide fastest speed forInternet access. So, it can augment/replace Wi-Fi at educational institutions and atcompanies so that the people there can make use of Li-Fi with the high speed.
b) ***Medical Applications:*** Operation theatres (OTs) do not allow Wi-Fi due to radiationconcerns. Usage of Wi-Fi at hospitals interferes / blocks the signals for monitoring equipments. So, it may have hazardous effect to the patient's health, due to improperworking of medical apparatus. To overcome this and to make OT tech savvy Li-Fi canbe used to access internet and also to control medical equipments. This will be beneficialfor conducting robotic surgeries and other automated procedures.
c) ***Cheaper Internet in Aircrafts:*** The passengers travelling in aircrafts get access to lowspeed Internet that too at a very high price. Also Wi-Fi is not used because it may interferewith the navigational systems of the pilots. In aircrafts Li-Fi can be used for datatransmission. Li-Fi can easily provide high speed Internet via every light source such asoverhead reading bulb, etc. present inside the airplane.
d) ***Underwater applications:*** Underwater ROVs (Remotely Operated Vehicles) operatefrom large cables that supply their power and allow them to receive signals from theirpilots above. But the tether used in ROVs is not long enough to allow them to explorelarger areas. If their wires were replaced with light — say from a submerged, highpoweredlamp — then they would be much freer to explore. They could also use theirheadlamps to communicate with each other, processing data autonomously and sendingtheir findings periodically back to the surface. Li-Fi can even work underwater whereWi-Fi fails completely, thereby throwing open endless opportunities for militaryunderwater operations.
e) ***Disaster management:*** Li-Fi can be used as a powerful means of communication in timesof disaster such as earthquake or hurricanes. The average people may not know theprotocols during such disasters. Subway stations and tunnels, common dead zones formost emergency communications, pose no obstruction for Li-Fi.
f) ***Applications in sensitive areas:*** Power plants need fast, inter-connected data systems sothat demand, grid integrity and core temperatures (in case of nuclear power plants) can bemonitored. The Radio communication interference is considered to be bad for suchsensitive areas surrounding these power plants. Li-Fi can offer safe, abundantconnectivity for all areas of these sensitive locations. Also, the pressure on a power plant‘s own reserves (power consumption for Radio communications deployments) will belessened.
g) ***Traffic management:*** In traffic signals Li-Fi can be used to communicate with passingvehicles (through the LED lights of the cars etc) which can help in managing the trafficin a better manner resulting into smooth flow of traffic and reduction in accidentnumbers. Also, LED car lights can alert drivers when other vehicles are too close.
h) ***Mobile Connectivity:*** Mobiles, laptops, tablets, and other smart phones can easilyconnect with each other. The short-range network of Li-Fi can yield exceptionally highdata rates and higher security.
i) ***Replacement for other technologies:*** Li-Fi doesn‘t work using radio waves. So, it can beeasily used in the places where Bluetooth, infrared, Wi-Fi, etc. are banned.

6. Future Scope

As light is everywhere and free to use, there is a great scope for the use and evolution of LiFi technology. If this technology becomes mature, each Li-Fi bulb can be used to transmit wireless data. As the Li-Fi technology becomes popular, it will lead to a cleaner, greener, safercommunications and have a bright future and environment. The concept of Li-Fi is derivingmany people as it is free (require no license) and faster means of data transfer. If it evolvesfaster, people will use this technology more and more.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 [10] 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.

Currently, LBS (location Based Service) or Broadcast solution are commercially available. The next step could be a Li-Fi WLAN for B2B market with high added value on specific business cases and could grow towards mass market. In the long term, the Li-Fi could become an alternative solution to radio for wireless high data rate room connectivity and new adapted service, such as augmented or virtual reality.

7. Conclusion

Although there’s still a long way to go to make this technology a commercial success, it promises a great potential in the field of wireless internet. A significant number of researchers and companies are currently working on this concept, which promises to solve the problem of lack

of radio spectrum, space and low internet connection speed. By deployment of thistechnology, we can migrate to greener, cleaner, safer communication networks. The veryconcept of Li-Fi promises to solve issues such as, shortage of radio-frequency bandwidth and eliminates the disadvantages of Radio communication technologies. Li-Fi is the upcoming and growing technology acting as catalyst for various other developing and new inventions/ technologies. Therefore, there is certainty of development of future applications of the Li-Fi which can be extended to different platforms and various walks of human life.

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