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Survey on Li-Fi technology

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Abstract
The speed of internet is a major issue and business, institutions, organizations, entrepreneurs is thrust for getting right information at the right time and right place. This requires fast internet connectivity, technology and large spectrum of channels. Present paper reflects the Future of Communication (LI-FI) which may affect all lives. It is a technology that may provide theoretically a speed of upto 10Gbps, cost effective and more robust and useful than Wi-Fi. Li-Fi is not expected to completely replace Wi-Fi, but the two technologies could be used complementarily to create more efficient, green and future-proof access networks. It is a wireless technology that makes use of visible light in place of radio waves to transmit data at terabits per second speeds—more than 100 times the speed of Wi-Fi. This technology has immense possibilities, from public internet access through street lamps to auto-piloted cars that communicate through their headlights.

Keywords: li-fi(light- fidelity), wi-fi(wireless- fidelity), LED(light emitting diode), VLC(visible light communication), wireless technology, LOS(line of sight), photo detector

1. Introduction

Fig 1: "Li Fi"- The Term Coined By Dr Harald Haas [1].

Whether you're using wireless internet in a coffee shop, stealing it from the guy next door, or competing for bandwidth at a conference, you've probably gotten frustrated at the slow speeds you face when more than one device is tapped into the network. As more and more people and their many devices access wireless internet, clogged airwaves are going to make it increasingly difficult to latch onto a reliable signal.

But radio waves are just one part of the spectrum that can carry our data. What if we could use other waves to surf the internet? One German physicist, DR. Harald Haas, has come up with a solution he calls "Data Through Illumination"—taking the fiber out of fiber optics by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. It's the same idea 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 [3].

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. The term Li-Fi was coined by Prof. Haas when he amazed people by streaming highdefinition video from a standard LED lamp, at TED Global in July 2011. Li-Fi is now part of the Visible Light Communications (VLC) PAN IEEE 802.15.7 standard.

2. Genesis of Li-Fi

Harald Haas gave a debut demonstration of what he called a Li-Fi prototype at the TED Global conference in Edinburgh on 12th July 2011. He used a table lamp with an LED bulb to transmit a video of blooming flowers that was then projected onto a screen behind him. During the event he periodically blocked the light from lamp to prove that the lamp was indeed the source of incoming data. At TED Global, Haas demonstrated a data rate of transmission of around 10Mbps -- comparable to a fairly good UK broadband connection. Two months later he achieved 123Mbps [1].

3. Design

Li-Fi architecture consists numbers of Led bulbs or lamps, many wireless devices such as PDA, Mobile Phones, and laptops. Important factors we should consider while designing Li-Fi as following:

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

As shown in figure 2 streaming content must have proper integration with server & internet network, so that it is easily possible to work efficiently [6].

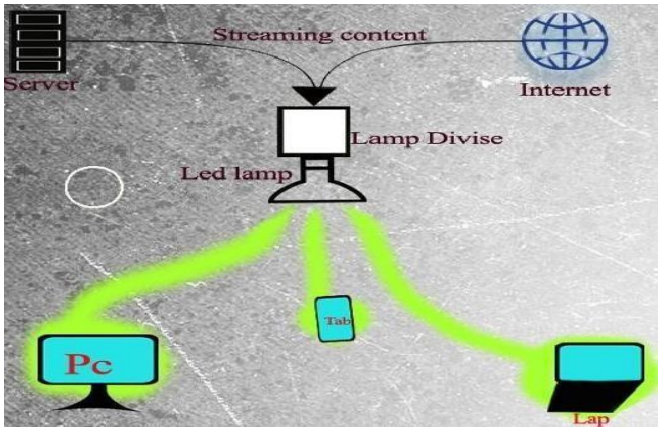

Fig 2: Architecture of Li-Fi [6].

4. Components

The main components of a simple system based on Li-Fi are:

- High brightness LED which acts as the communication source
- Silicon photodiode which serves as the receiving element

Data from the sender is converted into an intermediate data representation i.e. byte format and then converted into light signals which are 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. LEDs are employed as the light sources. The model transmits digital signal by means of direct modulation of the light. The emitted light is detected by an optical receiver.

4.1 Source Computer

Data Reading Module → Data Conversion Module → Transmitter Module

4.2 Destination Computer

Receiver Module → Data Interpretation Module → Data Display (GUI)

The different components serve the following functions

- **Data Conversion Module**
  Converts data into bytes so that it can be represented as a digital signal. It can also encrypt the data before conversion.
- **Transmitter Module**
  Generates the corresponding on-off pattern for the LEDs.
- **Receiver Module**
  Has a photo diode to detect the on and off states of the LEDs. It captures this sequence and generates the binary sequence of the received signal
- **Data Interpretation Module** – converts data into the original format. If encryption was done, it also performs decryption. [2]

5. Working of Li-Fi

Li-Fi 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 Li-Fi 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 at which the LED's flicker 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 10Gbps – meaning one can download a full high-definition film in just 30 seconds [6].

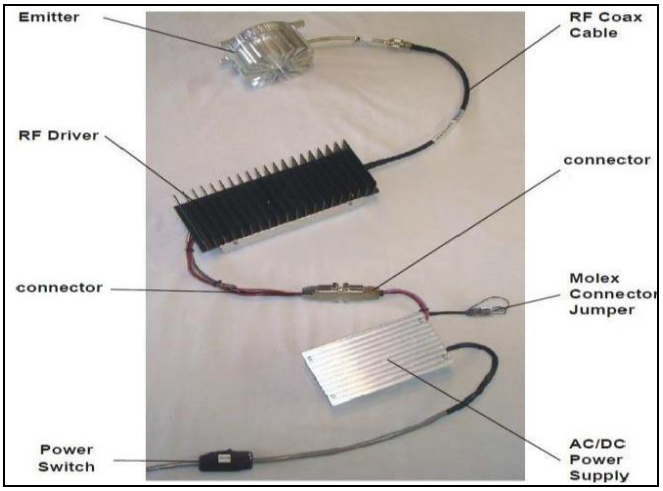

Fig 3: Implementation of LI-FI [6].

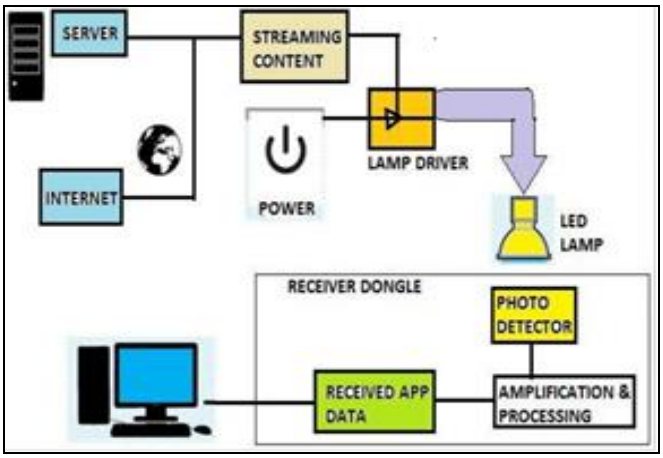

Fig 4: Data transmission using LED [6].

If the LED is on, you transmit 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." So what you require at all are some LEDs and a controller that code data into those LEDs. We have to just vary the rate at which the LED's flicker 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 you can download a full high-definition film in just 30 seconds. Simply awesome! But blazingly fast data rates and depleting bandwidths worldwide are not the only reasons that give this technology an upper hand. Since Li-Fi uses just the light, it can be used safely in aircrafts and hospitals that are prone to interference from radio waves. This can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military operations. Imagine only needing to hover under a street lamp to get public internet access, or downloading a movie from the lamp on your desk. There's a new technology on the block which could, quite literally as well as metaphorically, throw light on how to meet the ever-increasing demand for high-speed wireless connectivity. Radio waves are replaced by light waves in a new method of data transmission which is being called Li-Fi. Light-emitting diodes can be switched on and off faster than the human eye can detect, causing the light source to appear to be on continuously. A flickering light can be incredibly annoying, but has turned out to have its upside, being precisely what makes it possible to use light for wireless data transmission. Light-emitting diodes (commonly referred to as LEDs and found in traffic and street lights, car brake lights, remote control units and countless other applications) can be switched on and off faster than the human eye can detect, causing the light source to appear to be on continuously, even though it is in fact 'flickering'. This invisible on-off activity enables a kind of data transmission using binary codes: switching on an LED is a logical '1', switching it off is a logical '0'. Information can therefore been coded in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. This method of using rapid pulses of light to transmit information wirelessly is technically referred to as Visible Light Communication (VLC), though it's potential to compete with conventional Wi-Fi has inspired the popular characterization Li-Fi [6].

5.1 Visible light communication (VLC)

"A potential solution to the global wireless spectrum shortage" Li-Fi (Light Fidelity) is a fast and cheap optical version of Wi-Fi, the technology of which is based on Visible Light Communication (VLC).VLC is a data communication medium, which uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as optical carrier for data transmission and illumination. It uses fast pulses of light to transmit information wirelessly. The main components of this communication system are

- a high brightness white LED, Which acts as a communication source and
- A silicon photodiode which shows good response to visible wavelength region serving as the receiving element.

The LED can be switched on and off to generate digital strings of 1s and 0s. Data can be encoded in the light to generate a new data stream by varying the flickering rate of the LED. To be clearer, by modulating the LED light with the data signal, the LED illumination can be used as a communication source. As the flickering rate is so fast, the LED output appears constant to the human eye. A data rate of greater than 100 Mbps is possible by using high speed LEDs with appropriate multiplexing techniques. VLC data rate can be increased by parallel data transmission using LED arrays where each LED transmits a different data stream. There are reasons to prefer LED as the light source in VLC. While a lot of other illumination devices like fluorescent lamp, incandescent bulb etc. are available.

Fig 5: Visible light communication [6].

6. Multiple Accesses

A seamless all-optical wireless network would require ubiquitous coverage provided by the optical front-end elements. This necessitates the usage of a large amount of Li-Fi enabled lighting units. The most likely candidates for front-end devices in VLC are incoherent solid-state lighting LEDs due to their low cost. Due to the physical properties of these components, information can only be encoded in the intensity of the emitted light, while the actual phase and amplitude of the light wave cannot be modulated. This significantly differentiates VLC from RF communications. A networking solution cannot be realized without a suitable multiple access scheme that allows multiple users to share the communication resources without any mutual cross-talk.

Fig 6: Multiple Accesses [6].

Multiple access schemes used in RF communications can be adapted for OWC as long as the necessary

modifications related to the IM/DD nature of the modulation signals are performed. OFDM comes with a natural extension for multiple accesses – OFDMA. Single-carrier modulation schemes such as M-PAM, OOK and PWM require an additional multiple access technique such as frequency division multiple access (FDMA), time division multiple access (TDMA) and/or code division multiple access (CDMA). The results of an investigation regarding the performance of OFDMA versus TDMA and CDMA are presented in Fig. 3.18 FDMA has not been considered due to its close similarity to OFDMA, and the fact that OWC does not use super heterodyning. In addition, due to the limited modulation band width of the front-end elements, this scheme would not present a very efficient use of the LED modulation band width [6].

7. Comparison between Li-Fi and Wi-Fi

LI-FI as discussed, is a term used to describe visible light communication technology applied to high speed wireless communication. It acquired this name due to the similarity to WI-FI, only using light instead of radio. WI-FI is great for general wireless coverage within buildings and LI-FI is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary. Table 1 also contains the current wireless technologies that can be used for transferring data between devices today i.e. Wi-Fi, Bluetooth and IrDA. Only Wi-Fi currently offers very high data rates. The IEEE 802.11n in most implementations provides up to 150Mbit/s (in theory the standard can go to 600Mbit/s) although in practice you receive considerably less than this. Note that one out of three of these is an optical technology [3].

Table 1: Current vs. Future Wireless Technologies [3].

Techonology	speed	Data density
Wireless (current)		
Wi Fi- IEEE 802.11n	150Mbps	*
Bluetooth	3 Gbps	*
IrDA	4 Gbps	***
Wireless(future)		
WiGig	2 Gbps	**
Giga-IR	1 Gbps	***
Li-Fi	>1Gbps	****

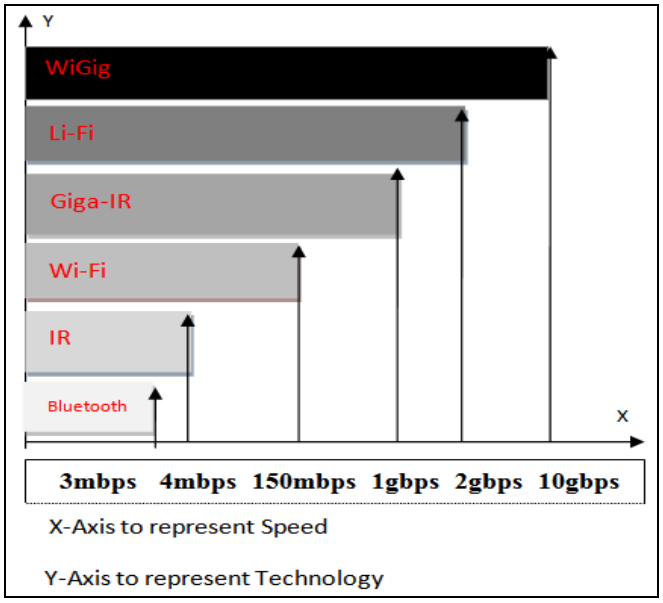

Fig 7: Current vs. Future Wireless Technologies [5].

Table 2: Comparison between LI-FI & WI-FI [2]

Parameter	LI-FI	WI-FI
Speed	High	High
Spectrum	10,000 times broader than that of Wi-Fi	Narrow spectrum
Data density	High	Low
Security	High security due to non-penetration of light through walls	Less secure due to transparency
Reliability	Medium	Medium
Bandwidth	High due to broad spectrum	Low
Transmit/receive power	High	Medium
Ecological Impact	Low	Medium
Device-to-device connectivity	High	High
Obstacle interference	High	Low
Bill of materials	High	Medium
Market maturity	Low	High
Latency	In the order of microseconds	In the order of milliseconds

8. Issues with Wi-Fi using Radio Waves

There are four issues with the current wi-fi scenario, which are

8.1 Capacity

- We transmit wireless data is by using electromagnetic waves -- inparticular, radio waves.
- Radio waves are scarce, expensive and we only have a certain range of it.
- Due to this limitation one can't forever hope to cope with the demand of wireless data transmissions and the number of bytes and data which are transmitted every month [4].

8.2 Efficiency

- There are 1.4 million cellular radio masts deployed worldwide.
- Most of the energy consumed, is not used to transmit the radio waves, but is used to cool the base stations.
- The efficiency of such a base station is only at about five percent [4].

8.3 Availability

- Availability of radio waves or RW signals causes another concern
- We have to switch off our mobile devices in aero planes
- It is not advisable to use mobiles at places like petrochemical plants and petrol pumps.[4]

8.4 Security

- The radio waves penetrate through walls.
- They can be intercepted, and somebody can make use of one‘s network [4].

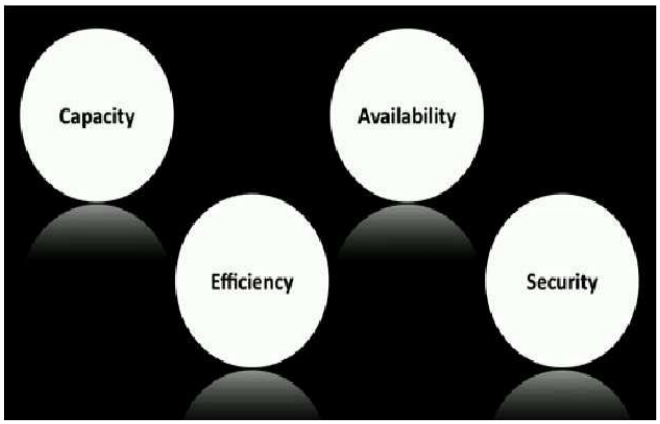

Fig 8: Four aspects of WI-FI [4]

9. Applications of Li-Fi

There are numerous applications of this technology, from public internet access through street lamps to auto-piloted cars that communicate through their headlights. Applications of Li-Fi can extend in areas where the Wi-Fi technology lacks its presence like medical technology, power plants and various other areas. Since Li-Fi uses just the light, it can be used safely in aircrafts and hospitals where Wi-Fi is banned because they are prone to interfere with the radio waves. Some of the future applications of Li-Fi are as follows: [4].

9.1 Enhanced & Exclusive Shopping Experience

Imagine yourself walking into a mall where GPS signals are unavailable but the mall is equipped with ceiling bulbs that create their own constellation of navigation beacons. As the camera of your cellphone automatically receives these signals, it switches your navigation software to use this information to guide you to the ATM machine you‘re looking for. You conclude your ATM transaction and notice the GigaSpot sign for instant digital movie downloads. You pick out that new Tom Cruise movie using your phone‘s payment facility, and then download within a few seconds the high-definition movie into the GigaLink flash drive plugged into the USB port of your smartphone. As you walk away, your phone notifies you that the leather jacket Tom featured in the movie is on sale nearby. You walk over towards the show window and your image comes up on the screen, wearing that coveted jacket. You turn and pose while the image matches your orientation and body gestures for a digital fitting. When you walk into the store, the clerk hands you the actual jacket in exactly your size [4].

9.2 You Might Just Live Longer

For a long time, medical technology has lagged behind the rest of the wireless world. Operating rooms do not allow Wi-Fi over radiation concerns, and there is also that whole lack of dedicated spectrum. While Wi-Fi is in place in many hospitals, interference from cell phones and computers can block signals from monitoring equipment. Li-Fi solves both problems: lights are not only allowed in operating rooms, but tend to be the most glaring (pun intended) fixtures in the room. And, as Haas mentions in his TED Talk, Li-Fi has 10,000 times the spectrum of Wi-Fi, so maybe we can delegate red light to priority medical data [4].

9.3 Airlines (Data on the go!)

Nothing says captive audience like having to pay for the "service" of dial-up speed Wi-Fi on the plane. And don‘t get me started on the pricing. The best I‘ve heard so far is that passengers will "soon" be offered a "high-speed like" connection on some airlines. United is planning on speeds as high as 9.8 Mbps per plane. Uh, I have twice that capacity in my living room. And at the same price as checking a bag, I expect it. Li-Fi could easily introduce that sort of speed to each seat's reading light. I‘ll be the guy WoWing next to you [4].

9.4 Smarter Power Plants

Wi-Fi and many other radiation types are bad for sensitive areas. Like those surrounding power plants. But power plants need fast, inter-connected data systems to monitor things like demand, grid integrity and (in nuclear plants) core temperature. The savings from proper monitoring at a single power plant can add up to hundreds of thousands of dollars. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations. Not only would this save money related to currently implemented solutions, but the draw on a power plant‘s own reserves could be lessened if they haven‘t yet converted to LED lighting [4].

9.5 Undersea Awesomeness

Underwater ROVs, those favourite toys of treasure seekers and James Cameron, operate from large cables that supply their power and allow them to receive signals from their pilots above. ROVs work great, except when the tether isn‘t long enough to explore an area, or when it gets stuck on something. If their wires were cut and 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 referring findings periodically back to the surface, all the while obtaining their next batch of orders [4].

9.6 It Could Keep You Informed and Save Lives

Say there‘s an earthquake in New Delhi,or a hurricane. Take your pick — it‘s a wacky city. The average Delhiite may not know what the protocols are for those kinds of disasters. Until they pass under a street light, that is. Remember, with Li-Fi, if there‘s light, you‘re online.

Metro stations and tunnels, common dead zones for most emergency communications, pose no obstruction. Plus, in times less stressing cities could opt to provide cheap high-speed Web access to every street corner [4].

9.7 Advantages of Li-Fi

Li-Fi technology is based on LEDs or other light source for the transfer of data. The transfer of the data can be with the help of all kinds of light, no matter the part of the spectrum that they belong. That is, the light can belong to the invisible, ultraviolet or the visible part of the spectrum. Also, the speed of the communication is more than sufficient for downloading movies, games, music and all in very less time. Also, Li-Fi removes the limitations that have been put on the user by the Wi-Fi [2].

- **Capacity:** Light has 10000 times wider bandwidth than radio waves [2]. Also, light sources are already installed. So, Li-Fi has got better capacity and also the equipments are already available.
- **Efficiency:** Data transmission using Li-Fi is very cheap. LED lights consume less energy and are highly efficient.
- **Availability:** Availability is not an issue as light sources are present everywhere. There are billions of light bulbs worldwide; they just need to be replaced with LEDs for proper transmission of data.
- **Security:** Light waves do not penetrate through walls. So, they can‘t be intercepted and misused. With the advent of Li-Fi, now it is not mandatory to be in a region that is Wi-Fi enabled to have access to the internet. One can simply stand under any form of light and surf the internet as the connection is made if light is present.

9.8 Disadvantage of Li-Fi

- Light can't pass through objects.
- A major challenge facing Li-Fi is how the receiving device will transmit back to transmitter.
- High installation cost of the VLC systems.
- Interferences from external light sources like sun, light, normal bulbs, opaque materials.

9.9 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 [5].
- Reliability and network coverage 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.
- 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.
- We still need Wi-Fi we still need radio frequency cellular systems. You can’t have a light bulb that provides data to a high-speed moving object or to provide data in a remote area where there are trees and walls and obstacles behind [5].

10. Conclusion

There are an excess of possibilities to be squeezed upon in this field of technology. If this technology becomes admissibly promoted then every bulb can be used analogous to a Wi-Fi hotspot to transmit data wirelessly. By virtue of this we can ameliorate to a greener, cleaner, safer and an impressive future.

The concept of Li-Fi is attracting a lot of eye-balls because it offers an unassuming and very efficient alternative to radio based wireless. It has a bright chance to replace the customary Wi-Fi because as an ever increasing population is using wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. This concept assurances to solve issues such as the shortage of radio-frequency bandwidth and boot out the disadvantages of Wi-Fi. Li-Fi is the upcoming and on growing technology acting as competent for various other developing and already invented technologies. Hence the future applications of the Li-Fi can be predicted and extended to different platforms and various walks of human life. There are no dead ends to technology and science. Now both light and radio waves can be used simultaneously to transfer data and signals.

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