*IOSR Journal of Mobile Computing & Application (IOSR-JMCA)*
*e-ISSN: 2394-0050, P-ISSN: 2394-0042.Volume 3, Issue 3. (May. - Jun. 2016), PP 18-28*
*www.iosrjournals.org*

# Light Fidelity (Li-Fi): An Emerging Technology for The Future

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***Abstract:***Li-Fi is the term used to describe inexpensive and fast wireless communication system and is the future optical version of Wi-Fi. Light-Fidelity(Li-Fi) enable transmission of data through illumination by sending data using light emitting diode(LED) light bulb that varies in intensity faster than the human eye can follow. Li-Fi is part of visible light communication that applied to high speed wireless communication. It uses visible spectrum of light which is a part of electromagnetic spectrum, that could transfer thousands of streams of data simultaneously, in parallel at high speeds. Wi-Fi is excellent for general wireless application within a limited geographical area, while Li-Fi is most suited for high density wireless data coverage in a confined area and for mitigating radio interference problems. Li-Fi promote better bandwidth, efficiency and security than Wi-Fi. By taking advantage of low cost of LEDs and lightning elements, there are several window of opportunities to employ this medium, from public internet access through street lights to autonomous cars that can communicate through their headlights. It is envisaged that data for laptops, smartphones and tablets will be transmitted through light in a living space.

***Keywords:****Light Fidelity (Li-Fi), Wireless Fidelity (Wi-Fi), Visible Light Communication (VLC), Light Emitting Diode (LED), Electromagnetic.*

## I. Introduction

The information Age, also commonly called the Computer Age or the Digital Age is a period in human history characterized by the shift from traditional industry to an economy based on the information computerization. The onset of the Age is associated with the Digital Revolution. Today, the internet is far from obscure. It is the center of attention and has spawned industries to emerge as a global cultural phenomenon.


**Fig.1**. Internet

Taking a closer look at the boom of the Internet in fig.1 and the upcoming of the wireless technology in action in 1990s, Wi-Fi was invented with speeds of 1Mbps/2Mbps in designing standards such as IEEE 802.11b, 802.11a and 802.11g.**Wi-Fi** is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network based on the IEEE 802.11 standards. Wi-Fi uses the unlicensed 2.4GHz spectrum, which often crowded with other devices, may cause degradation in performance. Inter-operability issues can cause limited connection or lower output speeds. Wi-Fi networks have limited range. In the near future, the wireless technology is being replaced by a drift from Wi-Fi to Li-Fi technologies due to the disadvantages offered by Wi-Fi over the innumerable advantages proposed by Li-Fi. While Wi-Fi is predicated on the availability of a microwave signal, Li-Fi can hypothetically turn any lamp into a network connection operating at much higher frequencies. Li-Fi also offers more privacy than Wi-Fi. [1]

Li-Fi is a wireless optical networking technology that uses light-emitting diodes (LEDs) for data transmission. Li-Fi is designed to use LED light bulbs similar to those currently in use in many energy-conscious homes and offices. However, Li-Fi bulbs are outfitted with a chip that modulates the light imperceptibly for optical data transmission. Li-Fi data is transmitted by the LED bulbs and received by photoreceptors. Li-Fi's early developmental models were capable of 150 megabits-per-second (Mbps). Some commercial kits enabling that speed have been released. In the lab, with stronger LEDs and different

technology, researchers have enabled 10 gigabits-per-second (Gbps), which is faster than 802.11ad. [2]Li-Fi is newer wireless-communication systems which uses light as a carrier instead of traditional radio frequencies, as in Wi-Fi. Li-fi is an innovative idea in IT, one that aims at eventually replacing radio frequency wireless signals with those that come from light sources. This type of technology is still being developed, and may have the potential to introduce vastly improved wireless services. [3]

Li-fi is a VLC (Visible Light Communication Technology) developed by a team of scientists including Dr Gordon Povey, Professor Harald Haas and Dr Mostafa Afgani at the University of Edinburgh. The term Li-Fi was coined by Professor Haas when he amazed people by streaming high definition video from a standard LED lamp, at TED Global in July 2011. Li-Fi is now part of the visible Light Communication (VLC) PAN IEEE 802.15.7 standard. Li-Fi is typically implemented using white LED light bulbs. These devices are normally used for illumination by applying a constant current through the LED. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. According to Dr Povey, unseen by the human eyes, these variations is used to carry high speed data. Li-Fi comprises a wide range of frequencies and wavelengths, from the infrared through visible and down to the ultraviolet spectrum. It includes sub-gigabit and gigabit-class communication speeds for short, medium and long ranges, and unidirectional and bidirectional data transfer using line-of-sight or diffuse links, reflections and much more. It is not limited to LED or laser technologies or to a particular receiving technique. Li-Fi is a framework for all of these providing new capabilities to current and future services, applications and end users. This brilliant idea was first showcased by Harald Haas from University of Edinburgh, UK, in his TED Global talk on VLC. He explained, very simple, if the LED is on, you transmit 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. [4][5] Dr. Harald Haas calls it "Data through Illumination" and he is able to stream high-definition video from a regular LED lamp.

**Fig.2.** Light Emitting Diode Bulbs

By flickering the light from a single LED, a change too quick for the human eye to detect, he can transmit far more data than a cellular tower, moreover it can be achieved in a way that's more efficient, secure and widespread.

## II. Brief History of Li-Fi

Li-Fi is a label for wireless-communication systems using light as a carrier instead of traditional radio frequencies. The term was first used in this context by Harald Haas in his TED Global talk on Visible Light Communication.

**Fig.3.** LiFi

Harald Haas, a professor at the University of Edinburgh who began his research in this field in 2004, 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 as seen in fig.3. During the event he periodically blocked the light from lamp to prove that the lamp was indeed the source of incoming data. He demonstrated a data rate of transmission of around 10Mbps. Two months later he achieved 123Mbps. In October 2011, a number of companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. The technology was demonstrated at the 2012 Consumer Electronics Show in Las Vegas using a pair of Casio smartphones to exchange data using light of varying intensity given off from the screens, detectable at a distance of up to ten meters [6] Li-Fi has the advantage of being able to be used in sensitive areas such as in aircraft without causing interference. Later in 2012, Pure VLC, a firm was set up to commercialize Li-Fi and to bring about Li-Fi products for firms installing LED-lighting systems. 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. Li-Fi is typically implemented using white LED light bulbs normally used for illumination by applying a constant current through the LED resulting in "Data through Illumination" producing data rates faster than 10 Mbps, which is speedier than our average broadband connection.

## III. Advantages of Li-Fi Over Wi-Fi

There are myriad advantages that Li-Fi has over Wi-Fi.

- While Wi-Fi is predicated on the availability of a microwave signal, Li-Fi can hypothetically turn any lamp into a network connection. Li-Fi operates at frequencies much higher than Wi-Fi.
- Li-Fi can be used in areas with a lot of Radio Frequency Noise or where Radio Frequency Noise is prohibited, such as hospitals and airplanes.
- In terms of security, Li-Fi offers more privacy and security than Wi-Fi because the signal is easily obscured by opaque materials and light does not penetrate through walls.
- Li-Fi can be used in places where it is difficult to lay optical fibres as in operation theatres.
- Li-Fi has high speeds, provides communications as high as 500 Mbps or 30 GB per minute, so it can easily be used in such places where Bluetooth, infrared, Wi-Fi and internet are banned. In this way, it will be the most helpful transferring medium.
- Li-Fi is a free band that does not need licence. Hence it is cheaper than Wi-Fi.
- Wi-Fi is great for general wireless coverage while Li-Fi is ideal for high density coverage in a confined region. It is believed that the technology can yield a speed more than 10 Gbps, allowing a HD film to be downloaded within 30 seconds.
- Theoretical speed up to 1 GB per second: Less time & energy consumption.
- No more monthly broadband bills.
- Lower electricity costs.
- Longevity of LED bulb: saves money.
- High instalment cost but very low maintenance cost.
- Li- Fi uses light rather than radio frequency signals, hence it is intolerant to disturbances.
- Li-fi could be used safely in aircraft without affecting airlines signals.
- It can be 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.
- 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.

## IV. Disadvantages And Limitations Of Li-Fi Technology

- One of the major demerits of this technology is that the artificial light cannot penetrate into walls and other opaque materials which radio waves can do. So a Li-Fi enabled end device (through its inbuilt photo-receiver) will never be as fast and handy as a Wi-Fi enabled device in the open air. Also, another shortcoming is that it only works in direct line of sight. Still, Li-Fi could emerge as a boon to the rapidly depleting bandwidth of radio waves. And it will certainly be the first choice for accessing internet in a confined room at cheaper cost.
- You cannot dim the light
- You need special LED

- 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.
- According to Harald, 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.

## V. Significance of Using Li-Fi

- Higher speeds than Wi-Fi.
- 10000 times the frequency spectrum of radio.
- More secure because data cannot be intercepted without a clear line of sight.
- Eliminates neighbouring network interference.
- Unimpeded by radio interference.
- Does not create interference in sensitive electronics, making it better for use in environments like hospitals and aircraft.

By using Li-Fi in all the lights in and around a building, the technology could enable greater area of coverage than a single Wi-Fi router. Drawbacks to the technology include the need for a clear line of sight, difficulties with mobility and the requirement that lights stay on for operation.

## VI. Application Areas of Li-Fi Technology

Li-fi technology can be integrated in so many areas of life: below are some areas of application;

### A. Medical Field

Integrated into medical devices and in hospitals as it can easily be used in such places where Bluetooth, infrared, Wi-Fi and internet are banned. 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 equipment's. 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 equipment's. This can even be beneficial for robotic surgeries and other automated procedures.

**Fig. 4** LiFi Medical application

### B. 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. Li-Fi can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military operations. [10]

**Fig.5** LiFi Underwater application

### C. Educational Sector

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. There are numerous advantage of Smart class but if it will used with Li-Fi technology, the more advantages will be added. A few teachers tell me to download lecture notes from their blog in my time. Half the time i wished, i already had the notes with me so that I could follow along as the lecture progressed. Imagine how interactive the classroom could be with real-time interconnectivity between 500 devices. [12]

**Fig.6** LiFi Educational application

### D. Aircraft

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 airplane. In aircraft, the overhead lights can be used for data transmission. It can also be used in petroleum or chemical plants where other transmission or frequencies could be hazardous. Airline Wi-Fi wants captive audience to pay for the "service" of dial up on the plane. And also they are very expensive. Passengers will soon be offered a "high-speed like “connection on some airlines. Li-Fi could easily introduce that sort of speed to each passengers reading light. It would be interruption free to and from other wireless signals on the board.

**Fig.7** LiFi Aircraft Application

**E. Public Li-fi Hotspot**

There are around 14 billion bulbs worldwide, they just need to be replaced with LED ones that transmit data as we reckon VLC at a factor of ten, cheaper than WI-FI. In streets for traffic control. Cars have LED based headlights, LED based backlights, and Cars can communicate with each other and prevent accidents in the way that they exchange such information. Traffic light can communicate to the cars and so on. By implementing this technology worldwide every street lamp would be a free access point. In traffic signals fig.10 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 numbers can be decreased. Also, LED car lights can alert drivers when other vehicles are too close. [10]

**Fig.8** LiFi Public Hotspot

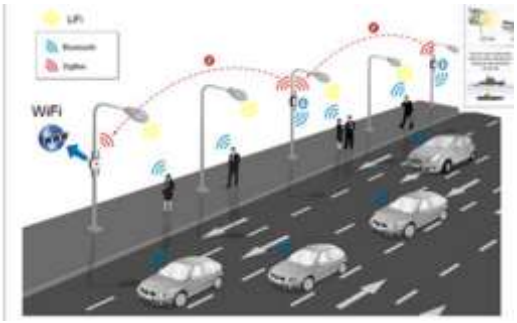


**Fig.9** LiFi Traffic

**F. Offices**

Imagine ourselves 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 our cell phone automatically receives these signals, it switches our navigation software to use this information to guide us to the nearest spot we are searching for. [6]

**Fig.10** LiFi Office

**G. Industries**

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 especially the atomic 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 tends to be hazardous.

**Fig.11** LiFi Industry Application

### H. Comparison between Wi-Fi and Li-Fi

Li-Fi is the name given to describe visible light communication technology applied to obtain high speed wireless communication. It derived this name by virtue of the similarity to Wi-Fi. Wi-Fi works well for general wireless coverage within buildings, and Li-Fi is ideal for high density wireless data coverage inside a confined area or room and for relieving radio interference issues. Table 1, shows a comparison of transfer speed of various wireless technologies. Table 2, shows a comparison of various technologies that are used for connecting to the end user. Wi-Fi currently offers high data rates. The IEEE 802.11.n in most implementations provides up to 150Mbit/s although practically, very less speed is received.

**Table 1:** Comparison of Speed of Various Wireless Technology [10]

| Technology | Speed |
|---|---|
| Wi-Fi – IEEE 802.11n | 150 Mbps |
| Bluetooth | 3 Mbps |
| IrDA | 4 Mbps |
| Li-Fi | >1 Gbps |

**Table 2:** Comparison of Technologies Used For Connecting To the End Users [11]

| Technology | Connection | Security | Reach | Impact | Cost | Bandwidth Expansion |
|---|---|---|---|---|---|---|
| Wi-Fi | Wireless- EMF | Good | Excellent | unknown | Good | Limited |
| Hardwired | Cables | Excellent | Fair | None | Good | Limited |
| Li-Fi | Wireless- Light | Excellent | Excellent | None | Low | Exceptional |

**Table 3:**Overall Comparison [11]

| 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

## VII. Design of Li-Fi Technology

In 2011, the "Fraunhofer Institute of Telecommunications" (Heinrich Hertz Institute) has improved a principle to achieve a flow rate of 800 Mb/s. To achieve this, they used conventional LED red, blue, green and white. With a flashing of the LED, the institute said that the system is able to cover an area of 10 m² with this flow of 800 Mb/s. The institute does not work alone on this subject since, Siemens Company and Orange Labs Company are also partners.

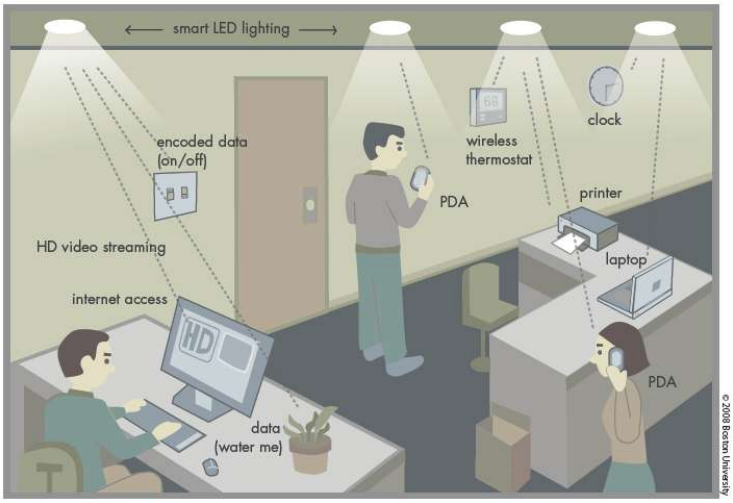


**Fig.12Li**-Fi Environment

A new step in the manufacture of this new type of network has been reached by recent research from the University of Strathclyde in Scotland. Professor Martin Dawson and his teams have miniaturized LEDs to a size of 1 mm ². Thus, these micro LEDs may flash even faster (on the order of 1,000 times faster) and can also be more easily integrated into everyday devices. The university has found a name for this network and called LED Light Fidelity (Li-Fi). [7]

Li-Fi architecture in fig.13consists 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

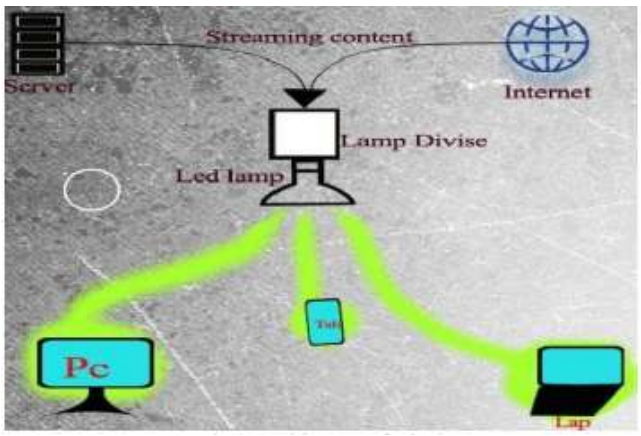


**Fig.13** LiFi Architecture

The lamp shines directly on to a hole cut into the oblong box on which it sits. Inside this box is a receiver that converts the light signal into a high-speed data stream, and a transmitter that projects the data on to a screen as a short video. If Haas puts his hand in front of the lamp, excluding the light, the video stops. Haas's discovery is based on a subset of optical technology called visible light communication (VLC), or Li-Fi, as it has been dubbed. VLC exploits a hack of human perception: light-emitting diodes can be switched on and off faster than the naked eye can detect, causing the light source to appear to be on continuously. Rapid on-off

keying enables data transmission using binary code: switching on an LED is a logical "1", switching it off is a logical "0" in fig.14. Thereby flows the data. [8]

**Fig.14**LED Switching

## VIII. How Li-Fi Works

Li-Fi works by turning LEDs on and off again fig.16, at a speed that is subtle enough to not be detectable by the human eye, but still slow enough for the receiver. Due to the vast amount of colours or wavelengths that are in the visible light spectrum, many numbers of Li-Fi channels are available. This means that plenty of data can be transferred simultaneously using multiple channels. [9]

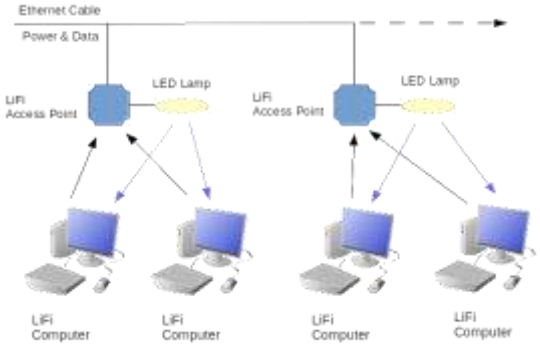


**Fig.15** LiFi Operation

Li-Fi Access Point System as shown infig.16works by using the existing lighting in a building and replacing the conventional lights, with Li-Fi AP (Access Point) LED lights. The lights can then be connected together with an Ethernet cable, which will connect them all to the main network and possibly power the lighting. The LED bulb will send signals to devices on the network and provide lighting for the room. Another part of the AP will receive signals from the Li-Fi clients, creating a bidirectional full-duplex connection. In other words Li-Fi allows for two way communication between two Li-Fi devices at the same time. Li-fi APs also allow for multiple devices to be connected to them as Wi-Fi APs also permit.

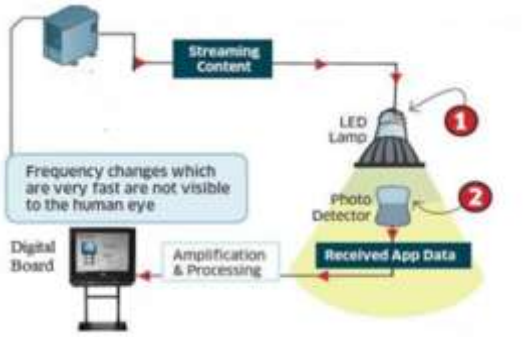


**Fig.16** LiFi Access Point System

When the system starts a constant current is applied to an LED light bulb then from the bulb a constant stream of photons are emitted, that light is called as visible light. But if the current is varied slowly the output intensity of the light dims up and down. For the communication as soon as, LED starts glowing, photo detector or light sensor on computer will detect light and get a binary 1 otherwise binary 0. The photo detector registers a binary one when the LED is on; and a binary zero if the LED is off. Flashing a LED certain times will build up a data to transmit. Flashing of light is detected by the photo detector or light sensor and it will receive a data and that data will display over the smart board with the help of the projector attached to the computer and smart board. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red.

## IX. Implementation Of Li-Fi Technology

Li-Fi is typically implemented using white LED light bulbs at the downlink transmitter as shown in fig.17. 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 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. [5][11][12]

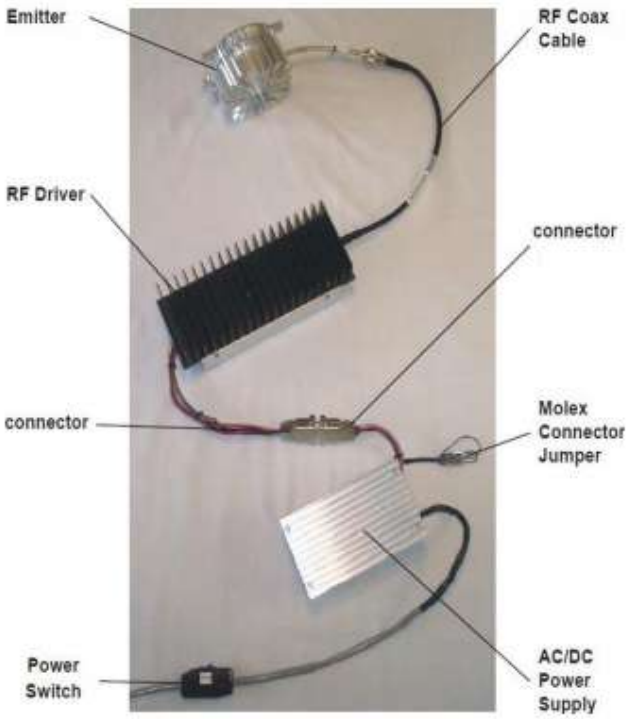


**Fig.17**Implementation diagram for Li-Fi

The more LEDs in your lamp, the more data it can process. To further get an clear idea of what is said above let us consider a IR remote which sends data stream at rate of 10000-20000 bps. Now replace the IR LED with a light box containing a large LED array which is capable of sending thousands of such streams at very fast rate. LEDs are found in traffic and street lights, car brake lights, remote control units and countless other applications. So visible light communication not only solves the problem related to lack of spectrum space but also enable novel application because this spectrum is unused and not regulated thus can be used for communication at very high speeds. This method of using rapid pulses of light to transmit information wirelessly, technically referred to as visible light communication (VLC) has a potential to compete with Wi-Fi and hence inspired the characterization of Li-Fi.

## X. Conclusion

The possibilities are numerous and can be explored further. If this technology can be put into practical use, every bulb can be used 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, since with this enhanced technology, a growing number of people and their many devices access wireless internet, on one way, transmit data at higher rates and on the other it is very cheap as compared with Wi-Fi. Li-Fi on the other hand is certainly not useless, but it has certain inherent limits for the technology. Li-Fi may not be able to replace conventional radios altogether, but it could turbo charge the development of wireless television and make it easier to throw a wireless signal across an entire house. At present, finding the ideal position for a wireless router is something of a divine art. If the signal could be passed via VLC from Point A to Point B inside a home, small local routers at both points could create local fields with less chance of overlapping and interfering with each other. Large scale areas that are saturated with radio signals or that doesn't permit them for security reasons could use Li-Fi as an alternate high-speed wireless network solution. The issues of shortage of radio frequency can be tackled easily with only limitation being that it works in direct line of sight of light. There are no dead ends to technology and science. Now both light and radio waves can be used simultaneously to transfer data and signals. The concept of Li-Fi is now attracting a great deal of interest, because if offers a genuine and efficient alternative to radio based wireless systems.

## XI. Recommendation For Further Studies

For further study, we recommend that a lot of research can be conducted in this field. Already, a lot of scientists are involved in extensive research in this field. This technology, pioneered by Harald Haas, can become one of the major technologies in the near future. If this technology can be used efficiently, we might soon have something of the kind of Wi-Fi hotspots wherever a light bulb is available.

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