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DATA COMMUNICATION USING VISIBLE LIGHT

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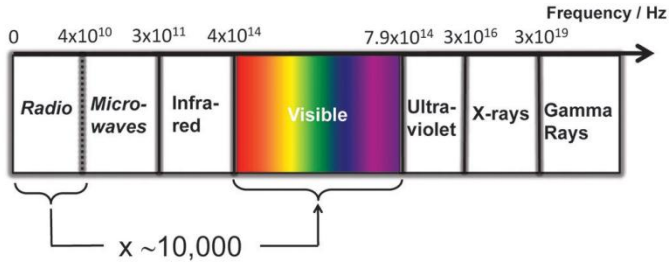
Abstract— Visible Light Communication (VLC) using a Light Fidelity system, as proposed by a German physicist—Harald Haas, provides transmission of data through illumination by sending data through an LED light source that varies in intensity that can be controlled and adjusted such that it appears as normal light to the naked human eye. Here the property of persistence of vision of the human eye is exploited for additional application of a free, sustainable and green source that can be used for wireless communication at very fast data rates. This paper focuses on developing a low cost Li-Fi based system and analyses its performance with respect to existing wireless technology. Wi-Fi is great for general wireless coverage within buildings, whereas Li-Fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues. Li-Fi based system provides better bandwidth, efficiency, availability and security than Wi-Fi and has already achieved higher data rates. By leveraging the low-cost nature of LEDs and lighting units there are many opportunities to exploit this medium, from public internet access through day-to-day light sources which have their primary purpose of only emitting light. This project envisions a future where data for communication devices will be transmitted through the visible spectrum thus de-clogging the currently overused RF spectrum. Keywords— VLC (Visible Light Communication), Li-Fi (Light Fidelity), Wi-Fi (Wireless Fidelity), LED (Light Emitting Diode), Wireless communication.

I. INTRODUCTION

Light Fidelity commonly known as Li-Fi is a 5G, visible light communication system that uses light from light-emitting diodes (LEDs) as a medium to deliver networked, mobile, high-speed communication in a similar manner as Wi-Fi. Li-Fi could lead to the Internet of Things, which is everything electronic being connected to the internet, with the LED lights on the electronics being used as Li-Fi internet access points. The Li-Fi market is projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018. [3]

Visible light communications (VLC) works by switching LED's on and off within nanoseconds, which is too quickly to be noticed by the human eye. Although Li-Fi sources would have to be kept on to transmit data, the bulbs could be dimmed to the point that they were not visible to humans and yet still functional. The light waves cannot penetrate walls which makes a much shorter range, though more secure from hacking, relative to Wi-Fi. Direct line of sight is not necessary for Li-Fi to transmit a signal; light reflected off the walls can achieve 70 Mbit/s. [2]

The Spectrum showing the different available bands of frequencies is given in Figure 1:



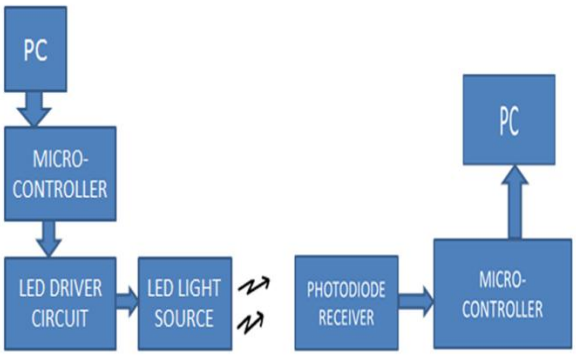
Li-Fi has the advantage of being useful in electromagnetic sensitive areas such as in aircraft cabins, hospitals and nuclear power plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilises radio waves, Li-Fi uses visible light. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Researchers have reached data rates of over 10 Gbit/s, which is more than 250 times faster than superfast broadband. Li-Fi is expected to be ten times cheaper than Wi-Fi. Short range, low reliability and high installation costs are the potential downsides. [4],[5]

II. DESIGN OF A LI-FI BASED SYSTEM

This brilliant idea was first brought to notice by Harald Haas from the University of Edinburgh, UK, in his TED Global talk on VLC. He explained that if the LED is ON, you transmit a digital 1, if it is OFF you transmit a 0. The LEDs can be switched on and off very quickly, which gives a nice avenue for transmitting data. The basic requirements are some LEDs and a controller that codes the 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. Extremely fast data rates and depleting bandwidths worldwide are just some factors that give this technology an upper hand.[6]

A Block diagram showing the basic elements of a Li-Fi System is shown in Figure 2:



III. IMPLEMENTATION

Using a standard white-light LED, researchers at the Heinrich Hertz Institute in Berlin, Germany, have reached data rates of over 500 megabytes per second[2]. Using a pair of Casio smart phones, the technology was demonstrated at the 2012 Consumer Electronics Show in Las Vegas to exchange data using light of varying intensity given off from their screens, detectable at a distance of up to ten meters [4].Researchers at the University of Strathclyde in Scotland have begun the task of bringing high-speed, ubiquitous, Li-Fi technology to market.[1]

A consortium called Li-Fi Consortium[17] was formed in October 2011 by a group of companies and industry groups to promote high-speed optical wireless systems and overcome the limited amount of radio based wireless spectrum. According to the Li-Fi Consortium, it is possible to achieve more than 10 Gbps of speed theoretically. The Li-Fi Consortium has several purposes:

- Promote optical wireless communications upto the multi-gigabit range in all their implementations;
- Inform potential implementers and investors of the companies and resources available to help them achieve their product or investment goals;
- Create whole solutions in anticipation of consumer needs and,
- Co-ordinate with standardization groups and other industry organizations to provide customers with a complete ensemble of technical and marketing support. [17]

A basic review of Li-Fi shows the current trends in the technology. Experiments carried out by researchers have shown remarkable advantages but to a certain extent there are certain disadvantages as well.

A. *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 content and data communication all in very less time. Also, Li-Fi removes the limitations that have been put on the user by Wi-Fi.

a) **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.

b) **Efficiency**: Data transmission using Li-Fi is very cheap. LED lights consume less energy and are highly efficient.

c) **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.

d) **Security**: Light waves do not penetrate through walls. So, they can't be intercepted and misused.

B. *Disadvantages of Li-Fi*

A major demerit of this technology is that the light transmitting data cannot penetrate into walls and other opaque materials which radio waves can do. So a Li-Fi enabled end device through its inbuilt photo-transceiver 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 is the best possible solution to the rapidly depleting bandwidth of radio waves. It will certainly be the first choice for accessing the internet in a confined room at a cheaper rate.[3]

IV. COMPARISON OF LI-FI WITH WI-FI

A justified overview of certain variable parameters can be visualized from the given table. All viable parameters play a crucial role in adjudging the capabilities of Li-Fi over the counterpart Li-Fi. Though Wi-Fi offers a variety of avenues

for high speed data transfer, the advancements in Li-Fi technology can surely give a upheaval to the existing forms of communication.

TABLE 1 – TABLE SHOWING GENERAL COMPARISON BETWEEN LI-FI AND WI-FI

PARAMETER	LI-FI	WI-FI
Speed	***	***
Range	*	**
Data Density	***	*
Security	***	**
Reliability	**	**
Power Available	***	*
Transmit/Receive Power	***	**
Ecological Impact	*	**
Device-to-device connectivity	***	***
Obstacle Interference	***	*
Bill of	***	**
Market Maturity	*	***

*low **medium ***high

It is thus visible that Li-Fi is well more considerable than the currently augmented Wi-Fi Technology. Providing a generally more secure and efficient means of reliable communication of data and providing a wider spectrum of improvement of technology in the future. Li-Fi based systems thus promise a wider range of benefits.

TABLE 2 – TABLE SHOWING COMPARISON BETWEEN CURRENT AND FUTURE WIRELESS SERVICES

WIRELESS SCENARIO (CURRENT)		
Technology	**Speed**	**Data Density**
Wi-Fi – IEEE 802.11n	150Mbps	*
Bluetooth	3Mbps	*
IrDA	4Mbps	***
WIRELESS SCENARIO (FUTURE)		
Technology	**Speed**	**Data Density**
WiGig	2Gbps	**
GigaIR	1Gbps	***
Li-Fi	>1.5Gbps	****

The current technologies in use mainly rely on the congested usage of the RF spectrum. This is an important drawback due to which the data density of the current technologies is at a minimally low quality. A simple Wi-Fi connection promises a speed of around 72Mbps in a commercial utility area. The viable usage of current technologies have led to the congestion of the Radio Frequency spectrum and thus the future technologies mainly rely on the de-clogging of this overused spectrum in order to provide a solution to the ever growing problem of faster communication methods. Certain other future technologies promise a great increase in the density of data and secure and reliable communication.

It is thus evident that with the current development of Li-Fi based systems, the future scenario ensures much faster mechanisms for the transfer and sharing of data.[4]

Devices connected wirelessly using Li-Fi based system are shown in Figure 3:

V. APPLICATION OF LI-FI BASED SYSTEMS

There is a wide necessity for data transfer and by the end of the day every field involves the use of technologies. One such technology is Li-Fi which can have its application of systems extended in areas where the Wi-Fi technology lacks its presence.

Some of the future applications of Li-Fi based systems are as follows:

a) **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.[5]

b) **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 computer devices which blocks the signals for monitoring equipment's. So, it may be hazardous to the patient's health. To overcome this, a Li-Fi based system can be used to accessing the internet and to control medical equipment's. This can even be beneficial for robotic surgeries and other automated procedures.[5]

c) **Use of Internet in Aircrafts:** Wi-Fi is not used in aircrafts 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.[5]

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d) **Underwater applications:** ROVs (Remotely Operated Vehicles) operate underwater 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.[8] 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.[13]

e) **Disaster management:** Li-Fi systems can be used as a powerful means of communication in times of disaster such as earthquake or hurricanes when conventional wired means of communication are down. Crowded areas are known for most emergency communications, but pose no obstruction for Li-Fi. Also, for normal periods, Li-Fi bulbs could provide cheap high-speed Web access to every street corner.[12]

f) **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 based systems could offer safe, abundant connectivity for all areas of these sensitive locations.[4] 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 based systems can also be used in petroleum or chemical plants where other transmission or frequencies could be hazardous.[5]

g) **Traffic management:** In traffic signals, Li-Fi based systems 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.[7] Also, LED car lights can alert drivers when other vehicles are too close. Thus it can be used as a secondary purpose.

h) **Replacement for other technologies:** Li-Fi does not work using the current radio spectrum that relies on radio waves. So, it can be easily used in the places where Bluetooth, infrared, Wi-Fi, etc. are banned.[12]

i) **Secure communication:** These systems are a reliable method of safe and secure communication. As light cannot penetrate through walls, there is an assurance that no other device is using a personal connection. A gratified application in which a persons information is kept private.[16]

A Li-Fi Sensor attached to a smartphone enabling connectivity is shown below in Figure 4:

VI. CONCLUSION

Li-Fi based systems which can transfer data using visible light are upcoming and growing technologies acting as competent for various other developing and already invented technologies. Since visible light is the major source for transmission in this technology, it is very advantageous and implementable in various fields and environments where Wi-Fi and other technologies fail and cannot be used to to certain drawbacks. Hence the future applications of Li-Fi based systems is very vibrant and can serve as a new platform for research and development in this ever growing and speedy world of wireless communication.

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