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LI-FI – A REVOLUTION IN THE FIELD OF WIRELESS-COMMUNICATION

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Abstract: *In this current era where all the facilities that includes banking, shopping, online payments, games etc. can be accessed with internet, has lead to a drastic soar in wireless communication usage. The usable radio frequency spectrum is completely exploited and bandwidth re-use has begun to compensate with the increasing user demand. But, this re-use is shrinking the network and gap between user demands and network availability is increasing gradually. The visible light communication is the best solution for growing user demands. Li-Fi, is a innovative wireless communication system which uses VLC as a source of communication. The technology utilizes LEDs that help in the transmission of information much quicker than that of Wi-Fi. This technology is best for high density wireless data communication in restricted area and to overcome radio intervention problem. Li-Fi provides improved bandwidth, availability, efficiency and security and has already obtained very high speeds of about 10,000 times more than the conventional Wi-Fi in the lab. By using the low cost LED lamps and light producing units we can use visible light bandwidth. This paper attempts to review basic concept of visible light transmission, how it is different from Wi-Fi, its applications in various fields, future usage, challenges and latest advancements over Wi-Fi.*

Keywords: *LI-FI, WI-FI, LED, VLC, RF, Bandwidth*

1. INTRODUCTION

A current era in digital wireless communication is on the edge of revolution. Li-Fi (Light Fidelity) is the superior modification Wi-Fi. It is the latest and one of the greatest 21st century inventions. The thought behind this machinery is that the information required for communication can be transmitted by using LED light whose intensity varies more rapidly than the human eye can sense, that intensity is captured by using a detector. It is a form of VLC which is part of optical wireless communications and could be a substitution for RF ie Wi-Fi and cellular network communication. This new Li-Fi technology is till now calculated to be more than 10,000 times faster than many of Wi-Fi implementations [1], reaching up to the speeds of 250 gigabits per second.

HARALD HASS, who is known to be the father of Li-Fi from Edinburgh University at United Kingdom, says that at the centre of this technology there is a new generation of very sensitive ultra LEDs. He said, “My greatest vision is that light bulbs will become part of broadband communications equipment, so that the light emitting diode is not only able to provide light but also become a more necessary tool for visible light communication” [2]. As the transmission of the data takes place by using light emitting diodes (LED’s) the equipments are comparatively small. Now, days, it is called as the optimized version of WI-FI. The advantage is the wireless communication through visible light which decreases the cost and instead of Wi-Fi modems and routers.

Li-Fi would use transceiver fitted LED lamps that can serve dual purpose lighting a room as well as transmit and receive information in bits. As simple light bulbs are used, there be in principle many number of access points [3]. This technology uses a part of the electromagnetic spectrum other than RF.

Great thing about this technology is that we can encode data in the light by varying the rate at which the LED bulbs flicker on and off to give different strings and sequences of 1s and 0s. The intensity of LED can be modulated so rapidly that human eyes cannot notice, so the output appears almost constant [4]. More advance techniques could raise VLC data rates dramatically. Researchers at the University of Oxford and Edinburgh are focusing on analogous data communication by means of arrays of LEDs, where each LED transmits a dissimilar data stream than earlier. Some groups are using mixtures of red, green and blue

LED bulbs to alter the frequency of light, so that each frequency can encode a different data channel [5,6].

He envisions a future where data for computers, mobile phones, and tablets can be send out by using the light in a room instead of RF routers and security would be increased as- if you can't see the light, you can't access the data. The future applications of the this great technology can be predicted and extended to different platforms similar to educational fields, medicinal field, engineering and industrial areas and lots of other fields in wake of our future generations….!!

2. COMPARISON BETWEEN LI-FI AND WI-FI

Li-Fi is basically a visible light technology to achieve high speed wireless communication by using visible light to transfer data. It acquired this name due to its similarity to WI-FI which utilizes radio waves for transfer of data.

TABLE 2.1: LI-FI IN ALL ASPECTS IS WAY BETTER THAN WIFI

SrNo.	Comparison Basis	LIFI	WIFI
1.	Full Form	Light fidelity	Wireless fidelity
2.	Operation	Transmits data using bits with help of light from LED bulbs.	Transmits data with help of radio waves with help of WIFI router
3.	Security	Secured (cannot be hacked) as light is blocked by walls.	Not secured (can be hacked) as for RF signal dry walls are transparent
4.	Interference	Do not have any interference issue similar to radio waves.	Has interference issue from nearby access points (routers)
5.	Spectrum	The Spectrum range is 10000times than Wi-Fi	It has radio spectrum range.
6.	Frequency	The frequency band is 100 times of Tera HZ	The frequency band is 2.4GHz,4.9GHzand 5GHz
7.	Speed	Fast speed internet (greater than 1- 3.5Gbps)	Comparatively slow speed (54-250 Mbps)
8.	Where To Use	Anywhere, where light source is present.	Inside a building. typically Within a array of WLAN communications , habitually inside a structure.
9.	Cost	Cheap as LED lamps are used.	Quiet expensive.
10.	Data transmission rate	Very high rate of data transmission due to visible light spectrum.	Transmission rate is slow as compared to Li-Fi as RF is used to communicate.
11.	System components	Lamp drivers, LED bulbs and light detectors will form complete Li-Fi system.	Routers have to be to be installed, devices like laptops, PDAs, desktops are called as stations.

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2.1. Spectrum:

Wi-Fi works on radio frequency, which only formulate up a small part of the electromagnetic spectrum. With growing user demand for wireless internet, the available radio spectrum is getting exploited. Radio waves are harmful for human beings as they penetrate the body and may cause mutation. They can't be used in all environments, mostly in aircrafts, chemical factories and power plants as well as in hospitals.

In Li-Fi visible light spectrum is used to pass on information as there is much extra space existing in this spectrum and it has the potential to pass on higher bandwidths [2]. The communication of the information can be with the help of all kinds of light close to visible region [10]. This part of spectrum is not harmful to our body and is safe to use in different environments.

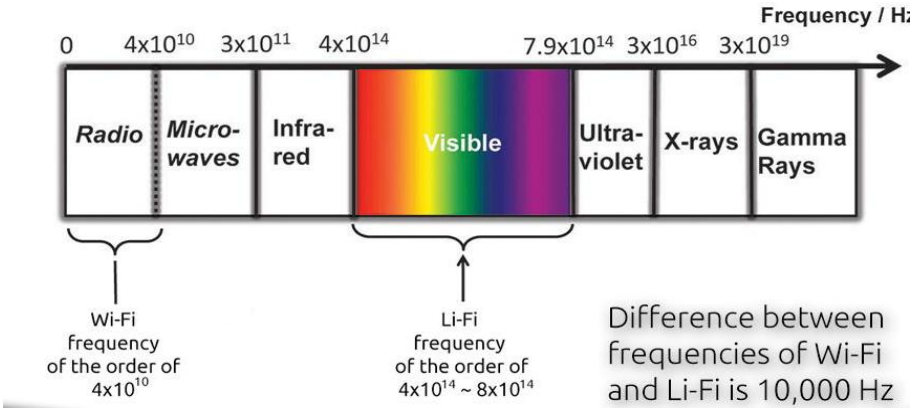

Fig 1: light spectrum for Wi-Fi and Li-Fi

2.2. LED:

This technology can offer us with a wireless Internet connectivity, as long as we have a LED light bulb. LED can be used to transfer binary coded information quickly by using visible part of spectrum. Total number of the world's light bulbs is projected at about 14 billion which can be used to obtain data transmission if we replace with LED's [11].

Fig 2: LED bulbs used for Li-Fi

Hence, Li-Fi is a rising way to create wireless connectivity links by means of the LED illumination networks. We can exchange light bulbs with LED's so that all street can be transformed into an Internet access points for all Electronics. Just Simply Light the LED lamp!

2.3. Speed

For Wi-Fi we have rate restrictions for information transfer. While, Li-Fi can offer enormously high speed of the internet and we can download massive files in just few seconds of time. Speed for Li-Fi is 10,000 folds more than Wi-Fi much larger than 1 Gbps can be achieved [1].

2.4. Security

Radio waves can penetrate all the way through walls. This leads to numerous security concerns as they can be intercepted without difficulty. While information transfer for Li-Fi is very protected and safe (no one can hack it). As we use visible light no signal disperses through walls [12].Such visible light communication could be used securely in airplanes without disturbing airlines signals.

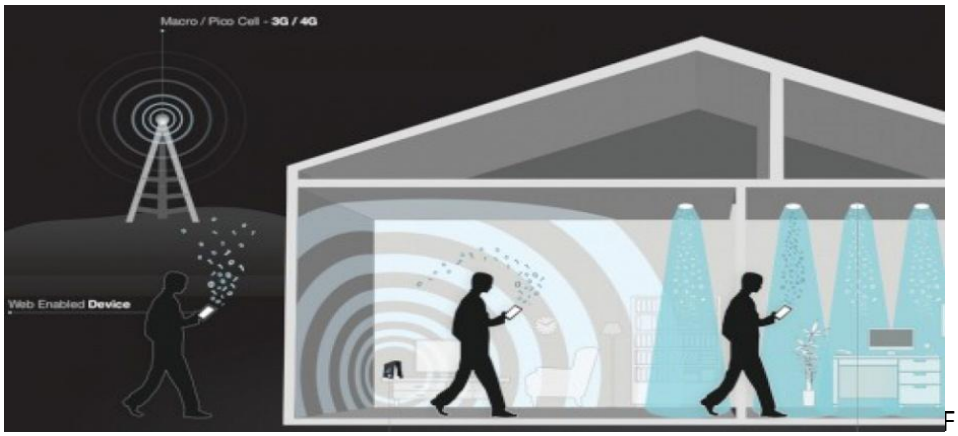

Fig 3: Data transfer by radio waves and visible light

3. WORKING OF LI-FI:

Light emitting diodes (LEDs) can be flickered 'ON and OFF' and the frequency being higher than the human eye can detect since the LED's operate at lesser than 1µs, thereby causing the light source to appear to be in continuous form. This invisible flickering activity enables the transmission of data using binary codes (0 & 1). Switching on an LED has the code binary '1' while switching it off is binary '0'. It is possible to encrypt data in light by controlling and varying the rate at which LED's flicker ON & OFF to give different strings/series of 1's and

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0's. A light sensitive device (photo detector/photo diodes) then receives the flickering binary signal and converts it back into original data [13].

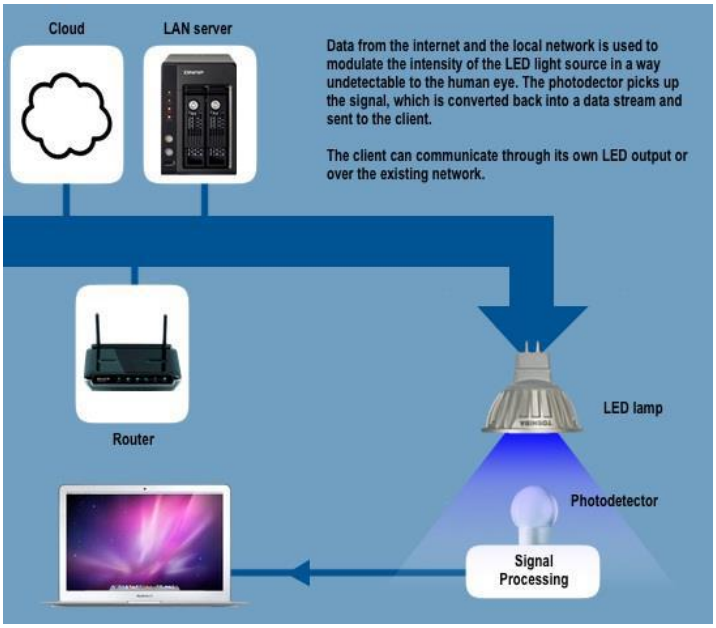

Fig 4: key components of Li-Fi system

This method of using rapid pulses of light for wireless information transfer is referred to as Visible Light Communication (VLC) in technical terms. The term Li-Fi has been in focus and is being advanced rapidly because of its potential to compete and possibly replace the conventional Wi-Fi technology. The VLC uses visible light between (400 - 800) THz / (375 - 780) nm as the optical carrier for transfer of data and for illumination [7, 14].

Data rates of greater than 100 Mbps can be achieved by using high speed LED's with adequate multiplexing. Parallel data transmission using arrays of LEDs where each LED emits an independent data stream useful in increasing the VLC data rate. Though the lights have to be kept ON in order to transmit data, they can be dimmed to the point that they are invisible to human eye but can transmit data as per the requirement [2,8].

The key components of this system are:

1] A multipurpose LED (acting as light source as well as source of communication)

2] A silicon photodiode (Receiving element)

4. APPLICATIONS OF LI-FI

Applications of Li-Fi can broaden in areas where the Wi-Fi technology lacks its potential like medical technology, power plants, underwater applications and other diverse areas. All the

street lamps can be converted to Li-Fi lamps to transmit data and information [12]. Some of the future applications of Li-Fi are as follows:

4.1. Internet everywhere: street lamps, vehicular headlights can be modified by LEDs to access internet anyplace in public footpaths, roads, malls, etc. where light source is available.

4.2. Underwater ROV's: One of the applications of the Li-Fi is in under-water ROVs, those beloved toys of treasure seekers, function from huge cables that provide them power and permit them to collect signals from their pilots above. ROVs work great, except when their hop isn't extended adequate to investigate an area or when it gets jammed on something. If their wires are cut and substituted with light – say from some submerged, high-powered lamp – then they would be much freer to explore. They could use their headlamps to keep in touch with each other, analyzing data autonomously and referring their findings from time to time back to the surface. Li-Fi even works underwater where Wi-Fi completely fails, thereby giving open everlasting opportunities for military operations [12].

4.3. Health sector and medical applications: As Wi-Fi is harmful to be used in hospitals and at other several health care areas as it can penetrate through human body [18]. Wi-Fi is prohibited in operation theatres (OTs) because of its radiation effect. Wi-Fi signals intervenes with the tablets & personal computer (PCs) which interrupts the signals for monitoring gadgets. Li-Fi technology can be helpful for accessing internet and in medical equipment's. This can also be useful in robotic surgeries and other automatic procedures [12].

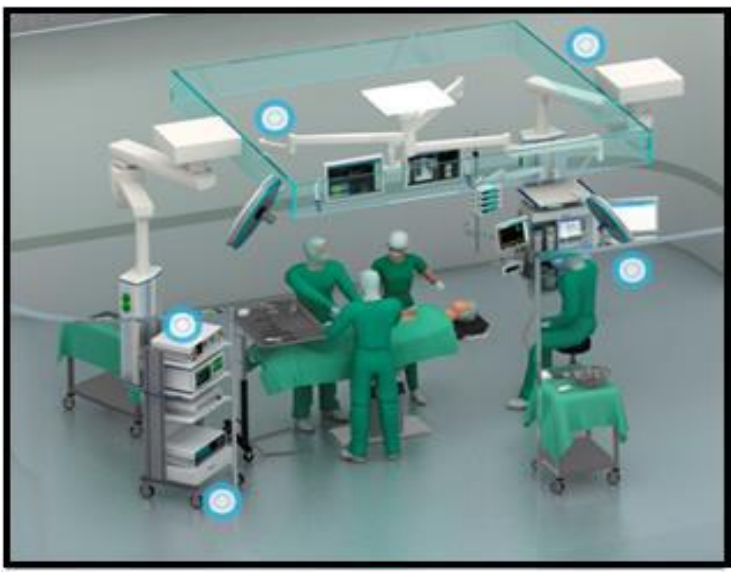

Fig5: Li-Fi inside an Operation Theatre

4.5 .Traffic control: Li-Fi can be used in traffic control wherein data can be exchanged among vehicles and traffic lights to improve road safety. It can also be used to revise traffic information at roughly every instant and it will be trouble-free for traffic police to pact with traffic and catch the one who disobeys the rules. In traffic signals, Li-Fi can be used which will communicate with the LED lights of the vehicles which can help in organization of the traffic in an improved way and the accidents can be avoided[12].

4.5.1. Inter Vehicle Communication: vehicles headlights and their headlights are gradually being substituted with LED's. This offers the hope of vehicle-to-vehicle communication through Li-Fi, and thus allowing development of the anti-collision systems and swap over of the information at time of driving between vehicles. Traffic lights now already use LED lights, so that there is also the vision presented of city wide traffic organization systems [7].

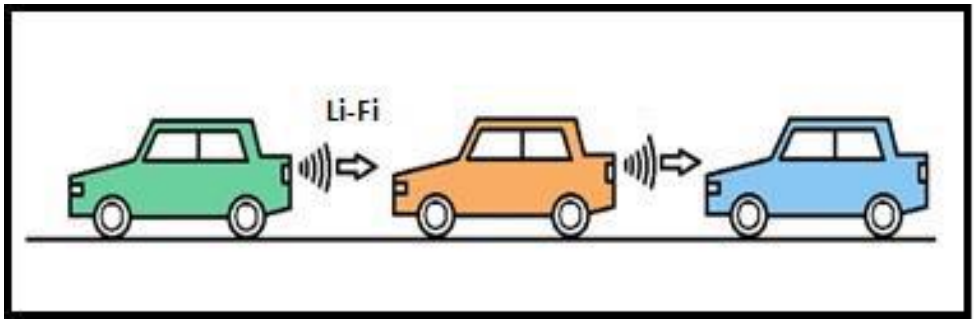

Fig 6: inter vehicle communication

4.6. Cheaper Internet in Aircrafts: The travelers which travel in airplanes presently get access to slow internet at a very high charge. Also Wi-Fi may disrupt with the navigation system of the aircraft. In airplanes we can use Li-Fi for data & information transmission. Li-Fi without difficulty can offer high speed internet with the help of every light source for instance overhead reading bulb, etc inside the airplane [11]. It will allow connectivity at almost all time without leading to electromagnetic interference (interventions) (EMI) with sensitive radio systems on the flight deck. The reduction in cabling necessity also will lead to lighter aircrafts.

4.7. Education systems: Li-Fi is the most recent technology that can give access to high speed internet. So, it can substitute Wi-Fi at learning institutions and at companies so that all people will be able to make use of Li-Fi with the equivalent speed proposed in a particular region [6].

4.8. Applications in sensitive areas: Power plants require quick, inter-connected data and information systems so that demand, grid integrity as well as core temperature (in case of nuclear power plants) can be monitored. The reserves from accurate monitoring at a sole power plant can sum up to hundreds and thousands of dollars.

4.8.1. Chemical Industry: As we are familiar with radio frequencies being damaging in chemical or petrochemical sectors but Li-Fi is communication system based on the visible light which is used in all industries. So Li-Fi is secure alternate for data transmission [11].

4.9 GPS practice: Satellite map-reading has been one of the most significant hi-tech advances of the last 5 decades. No matter how fine the method gets, it doesn't work preciously where we spend the most of our time i.e. indoors. Gears have been invented that smartly use Wi-Fi triangulation & "hybrid" GPS (say, GPS synchronizes combined with censored data from a accelerometer, pedometer, and compass), but these are erroneous and usually untrustworthy. A company called Byte Light is attempting to change this with a mechanism that uses LED to offer devices with exact location data [13]. Byte Light's indoor position system works by scheming the pulses of LEDs to make them work in definite pattern. This pattern is not noticeable to the naked eye but can be picked by the specialized camera [13]. By means of the information collected from LED modulation, the machine works with an application to execute client-side computation to outline where it is within the arrangement. Wi-Fi is not used so, networking is not a problem, and the calculations are done on the device, so everything come about speedily.

4.10. Smart Lighting: With the arrival of VLC, smart lighting will be available which in turn will be used for lighting as well as data transmission. Diverse types of management can also be done with the help of this concept. In all energy, expenditure and wiring included will also be reduced as lights are already ON for lighting, so no extra energy is necessary for data communication. Its use can also be seen in Projection Display Systems (PDS). Lamp Technology using Li-Fi has been produced for projection display applications [19]. An optics situate is used to change light in an output which is capably acknowledged by the projector. It presents flexibility in the nature of output. It accepts the system integrator to translate between outputs. This flexibility aids in the use of the single lamp for a lot of projector categories.

4.11. Smart Class: Li-Fi also finds application in the innovative smart class technology which is rapidly turning vital for progressive educational institutes. With the help of this technology, teachers can give details on diverse topics, zoom in to demonstrate the major particulars and freeze and explain for right importance. Using attractive animations, sounds and colors, the teachers can get the complete attention of each child in the lecture hall. Every child acquires image input on what, how, when and where everything occurs and the notions are nicely understood. Currently the smart classes use Wi-Fi in which every single computer is linked to the server with the help of wired LAN technology. The physical transmission means for wired LAN includes cables, which can be either fiber optics or twisted pair [3]. But wired LANs have a lot of drawbacks because it requires drilling of holes in walls, running cables in roof space, fitting hole, etc. Therefore, the gear is costly to install, time consuming and need safeguarding by expert technicians and flexible materials. Executing smart classes with the help of Li-Fi can work out these troubles.

5. ADVANTAGES AND CHALLENGES OF USING LI-FI:

5.1. Advantages of Li-Fi:-

1. Li-Fi can attain 1000 folds the info density of Wi-Fi, as visible light can be curbed in the light but in case of RF it is prevented due to interference.
2. A very widespread spectrum of operation over the visible range of EM is present.
3. A very high speed secure of information access can be possible from Li-Fi
4. Li-Fi is a harmless alternative as compared to radio waves (RF), because in these waves the electromagnetic interference takes place in environments such as in mines and petrochemical sectors [20].
5. Integrated into medical appliances and in hospitals as this tech doesn't deal with RF, so it can easily be used in all such places where Bluetooth, IR, Wi-Fi and internet are broadly in use
6. Using this technology globally every street lamp would be a open data access point.
7. It can be used to revise traffic information at almost every moment and it will be simple for traffic police to deal with traffic and arrest the one who breaks the rule [19].
8. Dynamic dark i.e. glow Modulation of lamp output to improve video contrast.

9. LED lights eat less energy and very competent. As it uses less energy it is economical and easy to use.

5.2. Challenges of using Li-Fi:-

1. It can only transmit when in the line of vision.
2. Although this technology sounds like a substitute to Wi-Fi but this high speed information transferring technology also has some restrictions that is the lack of ability of light to go by obstacles. It cannot go by the walls and can be blocked. If the light signal is blocked, we can seamlessly change back over to radio waves (Wi-Fi) [2].
3. As Li-Fi technology uses light as communication means, so if the receiver is somehow blocked in a way then the signal will directly be cut out.
4. Information transfer obstruction from exterior light sources for instance sunlight, normal bulbs, and dense materials can cause loss of consistency and network.
5. We still need Wi-Fi and we still require RF cellular systems. You can't have a light bulb that provides info to a speedy moving object or to make accessible data in a remote area where there are trees, walls and obstacles.
6. This tech requires constant supply of illumination which means that the LED have to be kept on throughout the day and albeit the cost of using LED is lower, the requirement by Li-Fi will raise the expenditure [16].

6. CONCLUSION:

Now days, Li-Fi is getting worldwide attention due to its futuristic technology where every bulb can be converted into a whole new Wi-Fi hotspot. As also the light being easily and freely available everywhere further advancements have a vast scope in this field. As compared to conventional Wi-Fi, Li-Fi is better in almost all respects whether in speed of transfer, accessibility, security, efficiency and applications. It also resolves the issues of limitations of radiofrequency bandwidth. The unique properties of light being modulated and used here result in improved data transfer rates even in densely packed connections. Even though Li-Fi has some disadvantages, but it shows impressive developments in the world of wireless technology. It contributes in almost all sectors and certainly going to be boon for our world. Thus with Li-Fi technology, 14 billion bulbs can be replaced by 14 billion multipurpose LED's on a worldwide level in a near future which would not only provide

illumination but will also provide Wi-Fi hotspots that too in cleaner, greener and brighter ways.

Fig 7: illumination of led bulb

Fig 8: Data transfer by led light

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