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Li-Fi: Current Technology and Overcoming Disadvantages

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Abstract: ***Li-Fi (Light Fidelity) refers to 5G Visible Light Communication system using light-emitting diodes as a medium to high-speed communication in a similar way as Wi-Fi. In this digital age, internet and digital communication is second to none. The number of digital devices accessing a network is increasing exponentially which is leading to to congestion. This is also increasing conflict between frequencies of bandwidth of Wi-Fi in present days. Hence, to overcome these problems Li-Fi is introduced. However, Li-Fi presently has many disadvantages. This paper discusses the current advantages and disadvantages of using Li-Fi and ways to overcome some of the disadvantages.***

Keywords: Li-Fi, Laser, VLC, Digital Communication.

I. INTRODUCTION

The growth of data along with advanced computing technologies has resulted in an ever-increasing number of heterogeneous devices that need to be connected in a network, preferably wireless, a feat achieved by WiFi which uses radio waves for data transmission. However, the available radio spectrum below 10GHz has become inadequate. The spectrum above 10GHz seems the obvious solution following preliminary observations but as per Friis free space equation, the path loss is directly proportional to the frequency, alongside problems of shadowing and blockages. [1] A new concept that solves several drawbacks of traditional wireless technologies like WiFi was introduced by Professor Harold Hass from the University of Edinburgh, which involved usage of light waves instead of radio waves to transmit data. Termed "Data through illumination", the professor used fiber optics to send data through LED light bulbs. Light modulation may not be a new concept but using simple LED bulbs as WiFi access points certainly is and bound to stimulate speculation as to its applications what with the existing bandwidth being used up and simultaneous emergence of IoT. This idea was explained in a TED Global Talk on VLC in July 2011. A table lamp was used to transmit a video of a blooming flower which was projected on to a screen.[2].

Light waves have a 400THz-800THz range which is higher than gigahertz radio waves. LED bulbs can be modulated using OFDM(Orthogonal frequency division multiplexing), OOK(on-off keying), PWM(Pulse-width modulation), PPM(Pulse-position modulation) and SIM-OFDM(Sub-carrier index modulation)[3]. The bulbs are switched and off so fast that the human eye cannot perceive it due to persistence of vision of the eye. These two states of the LED are sufficient to represent a 0(OFF state) and a 1(ON state) which forms the basis of data communication for traditional computers.

VLC or Visible Light Communication is a subset of the optical wireless communication technologies that also employs visible light as the means of communication. The modulation scheme for VLC is color shift keying(CSK). The modulated signal has varying intensity which dictates a color change in the LED (the RGB values change instantaneously). It is a form of

frequency shifting where the signal jumps instantaneously from one color to another. However, due to limited temporal sensitivity in the human vision, the CFF(critical flicker fusion threshold) and CCF(critical color fusion threshold) cannot resolve temporal changes shorter than 0.01 second(persistence of vision). The LED transmissions are predefined to a time-constant color which tricks us into thinking that the light transmitted is continuous and there's no indication that an underlying data communication is also underway.

Specified in IEEE 802.15.7, CSK or color-shift keying is a protocol of IM used for wireless communication using VLC. By varying the red, green and blue light(RGB) of an LED, the intensity modulation is achieved with no fluctuation in the intensity of the luminary.[4] A LiFi system comprises of transmitter chip(example open-drain 8-bit current steering DAC-based LED driver using CMOS technology[5]), receiver chip(avalanche photo-detector-based receiver[1]). Li-Fi does not require expensive hardware to set-up so once the initial cost of rewiring is realized, it is an economical way to augment, if not totally replace existing WiFi routers. The market for LiFi is quite promising with Global Light Fidelity Technology market rocketing to 35.82 billion dollars by 2028 growing at a CAGR of 71.20% during 2018-2028.[6].

Li-Fi enjoys lots of applications from military, hospitals, homes, car to car communications, augmented reality commercial spaces to power plants and underwater explorations. In military, it is used to provide high-speed, non-detectable communications which cannot be identified through current direction-finding technology. BT defence along with pureLi-Fi started out experimenting with Li-Fi at Adastral Park Facilities a few miles from Ipswich. It helped to prove the security of the communications as light rays transmitting data are confined to a building.

Geo-fencing could be implemented effectively by applying different security levels to a group of lights or individual lights on a need basis. Another interesting possibility is that all war-time jamming is dependent on radio-waves so using Li-Fi gives an added advantage. Radio waves travel poorly through salt water so submarine communications are slow. The underwater VLC in blue/green spectral range(450-550nm) achieves data speeds of 100's of Mbps for short range.

Underwater ROV work on power supplying cables controlled by pilots from above the water level. If the cable is cut the work is terminated but if replaced with light from a suitable source, this difficulty can be overcome. Li-Fi enjoys preference in nuclear power plants as light waves have no effect on atomic excitation, unlike radio waves employed in existing wireless communication systems. Hospitals too could make use of Li-Fi as there is no harm rendered to living tissue on exposure to light photons.

II. ACHIEVEMENTS OF LI-FI

- Researchers at the University of Oxford have achieved a bidirectional speed of 224Gbps with Li-Fi, which is phenomenal compared to existing speeds offered by WiFi or other wireless technologies. The link operates over 3m range at 224Gbps and 112Gbps with a wide field of view(FOV) of 60 degree and 36 degree respectively. This demonstration shows room-scale coverage is practically possible with a wireless link with a FOV[10].
- Researchers from Fraunhofer Heinrich Hertz Institute in Berlin, Germany demonstrated _a bidirectional real-time visible light prototype using commercially available low-cost hardware, supporting adaptive data rates in accordance with the ambient lighting conditions. A 2m working distance from ceiling and table top was established and considering a working area of 60cm diameter, the system enables a data rate of 200Mbps per user, with narrow beam optics 100Mbps was offered over 20m and finally by reducing the distance, the peak data rate of 500 Mbps was reached[11].
- En Lighting is a low-data-rate device-to-device communication system demonstrated by Disney Research in Zurich. Enhanced with micro controllers and photo diodes, the system is implemented such that it is Linux programmable. It offers low-data-rate (maximum 600 bps) communication service in a room which may form the basis of other services like a location service[12].

- Researchers from the University of Edinburgh showcased the properties of off-the-shelf laser diodes. Compared with LED's or fast mu-LED's the laser diodes exhibit modulation speeds which are at least an order of magnitude higher. The output efficiency of laser diodes is high enough to support a coverage of 1m^2 at distance 2.88m and achievable data rate of 3.43Gbps for 1 single RGB triplet of LED's. [13]

- Researchers from universities and institutes are investigating the feasibility of a system which involves the co-existence of both WiFi as well as Li-Fi. As we shall see, the drawbacks of Li-Fi are varied and hence they may be an effective enhancement for existing WiFi systems, complementing the technology instead of attempting to outright replace it. More mobile users can be served using WiFi whilst the stationary ones are served by WiFi. Li-Fi and WiFi front ends have been used to demonstrate proof-of-concepts. Throughput for individual users can be tripled using both the technologies. It offers enhanced indoor coverage with the highest data rates which is imperative for the fifth generation of mobile networks(5G)[14].

- Nearly all communication infrastructure is destroyed during earthquakes irrespective of whether it be above or below the ground. The problem of gas leaks and inherent fire hazards form an indispensable part of earthquakes. In floods, the broadcast can happen through water itself. For this purpose, a network of LiFi ballons will be used, otherwise termed a LibNet. Each balloon with necessary LiFi equipment will cover a certain region via illumination. Uplink signatures from trapped lives, maybe received and downlink broadcast can be done. The sensing of uplink signatures can be done using concepts of machine learning[15]. All the balloons are connected to the internet via a fusion centre. Uplink and downlinks are routed to the Internet through the FC as a gateway. This is quite similar to a WSN(wireless sensor network) in a cooperative sensing environment. Various routing protocols have been devised to route the data effectively. The installation of the components is done using Philips LiFi equipment. LiFi is a high speed alternative to RF during emergencies. If correctly implemented, this concept can save millions of lives[16].

- LiFi will enjoy benefits in the medical centers. There are many devices which rely on WiFi such as infusion pumps, lung ventilators, defibrillators and the like so when need arises of suing MRI alongside infusion pumps there is a frequency – overlapping problem. Too many devices using RF causes EMI that may lead to fatal consequences. EMI also interferes with living cells causing electromagnetic hypersensitivity, immune dysfunction, or even cancer in various forms. Light waves on the other hand offer no harm to living tissues; can be used parallel with existing WiFi networks whilst it is obvious that robotic surgeries and automated procedures. During surgery, LiFi system along with various sensors is needed to get immediate guidance from experts in the therapy by sharing data, videos/live details about the patient for the best results. Wireless technology with LiFi systems enables real-time updates on patient's health, reminders and support but since the nature of the data shared is highly sensitive without proper and full-proof security, such systems will only offer a golden opportunity for implementation of malicious intentions [17].

- NASA's Kennedy Space Center recently entered into a partnership with Light Visually Transceiving (LVX) System Corp. to collaborate in developing a potentially ground-breaking technology in electronic communications. Similar to high-speed communication known as Wi-Fi, visible light communication, or VLC, is a wireless method using light-emitting diodes (LEDs), referred to as Li-Fi. NASA and LVX are studying enhancements to lighting system capabilities in hopes of improving the technology and adding features such as Global Positioning Satellite Routing Systems architecture. While the Intentional Space Station already has a Wi-Fi system, Holbert says a Li-Fi network may be a possibility for a spacecraft making the first trip to the Red Planet[18].

III. Comparison of Li-fi and Wi-Fi Technologies

TABLE I Comparison between Li-Fi, WiFi and Ethernet[19]

Parameters	Li-Fi	Wi-Fi	Ethernet
IEEE Standards	802.15.17	802.11b	802.3
Frequency Band	100 X Tera HZ	2.4 GHZ	
Cots	Cheap	Expensive	Medium
Data Trans. Medium	Light	Radio Spectrum	UTP-STP- O.F.
Network Topology	Point-to-Point	Point-to-Point	Bus-Star
Speed	1-3.5Gbps	54-250Mbps	10-1000 Mbps
Range	10 Meters	20-100 meters	(100-185) meters
Security	High	Medium	High
Power Energy	Available	less available	Available
QoS			
Data rate		High(low-power models available for battery application)	High power over Ethernet
Wireless spectrum reliability		2.4GHZ 5GHZ	None
Reliability	High	High	Very high
Release Date	2011	1990	1980

- Frequency of operation will be 10 thousand times the frequency spectrum of radiowaves, which means a much higher bandwidth will be afforded to transmit larger chunks of data.
- Maximum speed of 224Gbps to 2Gbps
- WiFi signals leave contained areas like buildings so it's freely available to potential intruders who might intercept the signal. Light cannot pass through opaque objects so although that offers greater security, we get limited range of 32 metres.
- It is more energy efficient as the main proponent is LED bulbs which are cheap and can undergo bulk manufacture. According to a study by a professor at Fudan University, one micro-chipped LED bulb can generate as much as 150 megabits per second. A standard 1 watt LED could offer net connectivity to as many as 4 working computers.
- Availability and eco-friendliness are key to its importance. Visible light has no harmful effects on live cells hence apt for hospitals. Light also has no effect on excitation of sub-atomic particles hence useful for work in nuclear power plants.
- Light can pass through salt water effectively unlike radio waves hence it is possible to use this technology for underwater explorations, in ships or submarines.

IV. Limitations of Led Li-Fi

Presently LiFi is mainly based on LED technology. However, Li-Fi based on LED has multiple disadvantages:

- The inherent principle of both VLC and FSO is a concept called LOS or line of sight. For such mechanisms to operate there must be an unhindered pathway through suitable media between the sender and the receiver. Light can be obstructed by any opaque material so holding a piece of paper in front of our data transmitting LED will stop the process (easily occluded). Light bulbs must be positioned overhead. Our synonymous association of wireless and portability is questioned as we are restricted to using this technology in a well-lit room instead of on the roof or in the garden.
- A lot of devices are necessary for set-up with a host of LED bulbs with data transmission capabilities, a receiver for each device, then Li-Fi routers and the same set of items to be multiplied by the number of locations we want to use connectivity.
- Light from other sources can interfere like bright sunlight. The receiver will still be able to distinguish between LED light and sunlight however the high intensity of sunlight will reduce the intensity of LED light, reducing the connection speed.

- Temporary problems include rewiring the house, fitting the light apparatuses and the need for adapters, at least one per room. Li-Fi-X or Li-Flame try to ease this hurdle as they are comparatively easier to set-up but still adapters need to be carried around if we want to move to a separate location.
- What about when there is no light? There's debate to use infrared light instead in such situations, however the idea is still in its infancy due to reduced data speed and ill-effects on the health of living tissues.
- Many LED's use phosphor coating to convert blue to white light which limits the speed at which data can be sent.
- LiFi can mostly be used in point to point communication since a high frequency (400-800 THz) is being used here which results in short distance coverage. [7]
- There are numerous hurdles in the integration of Li-Fi with existing light resources. Li-Fi transmitters use solid-state LEDs integrated/embedded with controllers that receive data and modulate the light output of LED according to bits of data. The lighting devices are generally phosphor based or RGB lighting and both has their own set of strengths and weaknesses. Phosphor based light sources are cheaper in cost as compared to RGB based devices, but they provide less bandwidth than RGB sources due to their low switching speed.[8] Hence, integration of Li-Fi with existing light resources is not easy.
- Since internet usage is inevitable 24x7, whatever light source is used needs to be switched on even during the day wasting a considerable amount of energy. [9]

V. Overcoming Disadvantages of Conventional Li-Fi Using Laser Based Li-Fi

- Lasers with their high energy and optical efficiency can be modulated 10 times the rate of LED's. Lasers do not use phosphors; they mix light of different wavelengths to get white light. Each wavelength is a separate data channel that can be modulated.
- Emitted light power of lasers is high, proportional to current above the threshold whereas for LED power is low, linearly proportional to drive current. Due to these reasons, laser Li-Fi can operate in sunlight.
- Speed improvement of over 100Gbps compared to LED Li-Fi.
- Lasers are more expensive, lesser expected lifetime, more difficult to manufacture and use than LED, yet the advantages offered by its usage offsets most of the drawbacks.
- The rods and cone cells of the eye can be destroyed due to the high intensity of laser light so they must have wavelengths strictly less than 1400nm to be deemed eye-safe. This can be achieved by usage of optical filters.

VI. Over Coming Disadvantages of Integrating Li-Wi With Existing Light Source

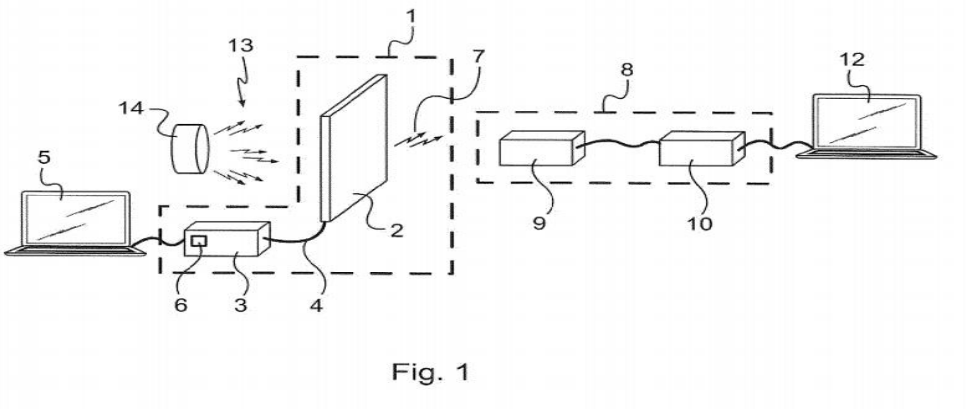

Fig. 1

Fig.1 LiFi System Working and Utilization

VII. EP3139524A1

The EP3139524A1 is a new patent on Li-Fi where inventors introduce a new modulating element. The latter when attached to the existing light source has the capability to modulate the existing light output based on the data that needs to be transmitted. The modulator selectively alters the reflection or transmission of light in response to the data to be transmitted and thereby converting the normal fixtures into LiFi transmitter. The need for changing light fixtures is hence reduced.

Another similar product is WO2017042093A1.

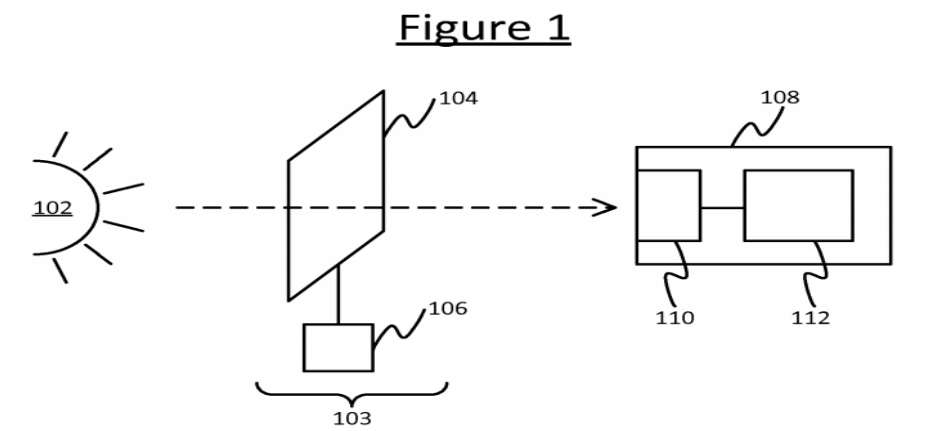

Fig.2 LiFi Controller

Another possibility is to use an add-on controller is used as a stand-alone component, which can be attached to the preexisting light source. The controller can work as back-end modulator and direct the light source to emit a light of particular intensity/power by modifying the power input. The controller contains

- A data signal receiver that is configured to receive data from the external data source,
- A VLC protocol engine configured for interpreting the received data according to VLC protocol, and
- A VLC transceiver for converting the received data into one or more LIBM (Light Intensity Baseband Modulation) modulated signals.

The control unit then activates and deactivates its power output port to supply output voltage responsive to the one or more LIBM-modulated signals and controls the light source output[20].

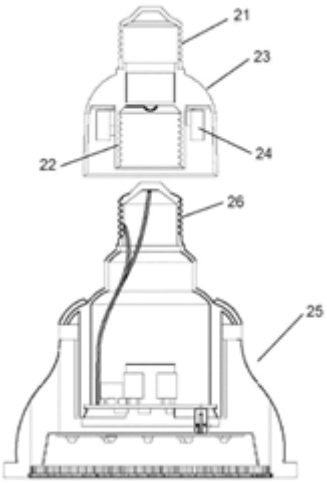

Fig 3: LiFi Emitter

VIII. Conclusion and Future Scope

Li-Fi(Light Fidelity) is already available to common users albeit at a very small scale. It is mostly used indoors for point to point communication and is generally used in smart homes to connect smart devices. In the near future, it will be available at a larger scale to meet the demands of connectivity(reliability as well as performance). If the disadvantages of Li-Fi are overcame, it will broadly replace Wi-Fi as the most popular means of internet connectivity since it is much more capable in terms of performance. A great change day to day life will take place if Li-Fi manages to replace Wi-Fi and other means of internet connectivity in the near future.

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