REVOLUTIONARY LIFI

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***Abstract*— Li-Fi stands for Light-Fidelity. Li-Fi technology, proposed by Dr. Harald Haas, provides transmission of data through illumination by sending data through an LED light bulb that varies in intensity faster than the human eye can follow. This paper focuses on developing a Li-Fi based system and clarify the difference between VLC & LiFi. Li-Fi provides better bandwidth, efficiency, availability and security than Wi-Fi and has already achieved blisteringly high speed in the lab. By leveraging the low-cost nature of LEDs and lighting units there are many opportunities to exploit this medium, from public internet access through street lamps to auto-piloted cars that communicate through their headlights. Haas envisions a future where data for laptops, smart phones, and tablets will be transmitted through the light in a room.**

***Index Terms*— Li-Fi, LED, VLC, photodiode, modulation, wireless communication.**

I INTRODUCTION

Due to ever increasing demand for Wireless data communication, the available radio spectrum below 10 GHz has become insufficient. Biggest room in this spectrum is occupied by ever increasing data sharing. As per CISCO by 2018, there'll be 16 Hexabytes of data to be send on Mobile Networks per month which is tantamount to 1.8 million years of HD movie. Another census said that by 2020 , there'll be estimated 1000 devices per person that will be share data by one or another way. The energy consumption by data sharing devices is more than the absolute global air traffic. The Base Stations powered by Diesel belched astronomical amount of carbon every day. Not just insufficiency of band but also with the increase in global warming it turns difficult to carry out the operation of wireless communication in traditional way in juxtaposition with implementing techniques to cut carbon emission. Beside Carbon emission, a press release of WHO dated 31 May 2011 said that Radio Frequency waves, currently in use for WC, are potentially carcinogenic to humans. So what we need is a greener technology that could be the substitute of the current wireless communication without much hindrance. But what that greener technology could be? Which greener 'force' could we facilitate to data-hungry applications of modern technology? Answer lies in 'Light'.

Alexander Graham Bell, famous for his invention of telephone, wasn't content with his invention which brought him fame. Alexander invented another telecommunication device called The Photophone which allowed the transmission of speech on a beam of light. "greatest invention[I have] ever made, greater than the telephone ", said Bell about the Photophone. Photophone can't be used in 21st century to deputize of RF Waves but it becomes the harbinger for the revolutionary Li-fi (Light Fidelity) Technology. In 2011, Dr. Harold Hass from the University of Edinburg,UK , suggested an idea called " Data through illumination ". Li-Fi is as continuation of trend to move to higher frequencies of EM Spectrum. Li-Fi is categorised under nm-wave communication. Li-Fi uses LEDs (Light Emitting Diodes) for high frequency transmission. It conserves electricity by transmitting data through light bulbs or other such light equipment. Incandescent bulbs are too slow to react but a LED, with a Li-Fi chip, can fickle rapidly. By varying the current through the LED at a very high speed,the out of the LED could be varied at high speeds. This is the principle of Li-Fi is itself very simple- if the LED is ON, the signal transmitted is digital 1 whereas if it is OFF, the signal transmitted is a digital 0. By varying the rate at which LED flicker, Data can be encoded & transmitted.

II LI-FI TECHNOLOGY

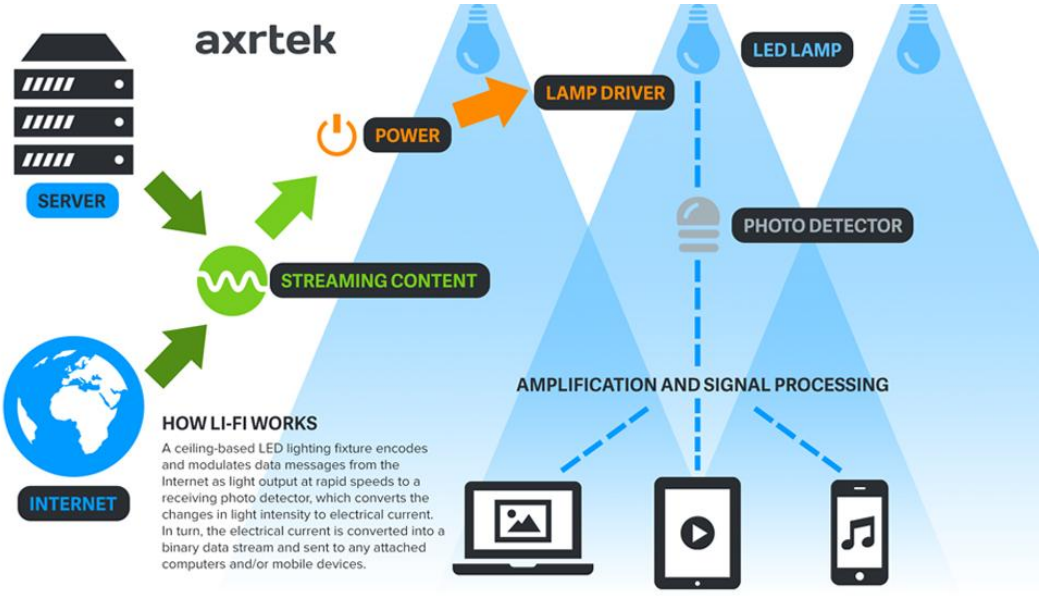
Li-Fi stands for 'Light Fidelity'. The technology uses a LED Bulb that flicker with an intensity faster than a human eye could follow. The light that zips data across the Internet's backbone used to stop a long way from the data's final destination but now it goes all the way to our homes. The LI-FI technology takes the last step and takes the light all the way to the computer or TV, projecting it

through the air over the last few meters and only converting it to an electronic signal at the end. Li-Fi takes the Visible Light Communication (VLC) further by using LEDs to realise fully networked wireless system. Li-Fi is considered as an optical version of WiFi.

In an era where human dependence on internet has elevated astronomical times from the period it was originally designed, and with that elevated is its usage and applications. It's impossible to think of a day in our lives, when we're not connected to the internet.

III WORKING PRINCIPLE OF LI-FI

Li-Fi is a Visible Light Communications (VLC) system for data transmission. A simple VLC system has two qualifying components: 1) at least one device with a photodiode able to receive light signals and 2) a light source equipped with a signal processing unit.



LiFi Technology(Image Credit : artex)

A VLC light source could comprise of a fluorescent or light emitting diode (LED) bulb. Since a robust Li-Fi system requires extremely high rates of light output, LED bulbs are most ideal for implementing Li-Fi. LED is a semiconductor light source, which implies that LED light bulbs can amplify light intensity and switch rapidly. Therefore, LED cells can modulate thousands of signals without the human eye ever noticing. In turn, the changes in light intensity from the LED light source are interpreted and converted as electrical current by the receiving photodiode device. Once the electronic signal is demodulated, it is converted into a continuous stream of binary data comprising of audio, video, web, and application information to be consumed by any Internet-enabled device.

LI-FI uses white LED bulbs at the downlink transmitter. Normally, a constant current is applied across the LEDs to use them. But by varying the current very fast, the optical output can be made to vary at very high speeds. This is property used in a LI-FI setup. If the LED is ON, we transmit a digital 1 and if it is OFF, we transmit a digital 0. We can easily transmit data by switching the LEDs ON and OFF very rapidly. Thus, we need some LEDs and a controller which can code data into those LEDs in order to set up the system. Now, by varying the rate at which the LEDs flicker, we can encode the desired data and thus transmit the data very easily. We may also make certain improvements to the system by using an array of LEDs for parallel data transmission and or using a mixture of red, green

and blue LEDs to alter the light's frequency, with each frequency encoding a different data channel. Theoretically, speeds of up to 10Gbps can be achieved using such a system.

IV LI-FI VS VLC

LEDs are used by VLC to transmit data wirelessly using IM. Photodiode uses the principle of direct detection to detect the signals at the receiver end. Albeit IEEE 802.15.7 was reserved for VLC but the standard was revised to include LiFi. VLC can be seen as point-to-point data communication technique which had replace cable wires while LiFi is a complete wireless networking system which include bidirectional multiuser communication: Point-to-Multipoint & Multipoint-to-Point. LiFi also includes multiple access points forming a wireless network of very small attocell with seamless handovers which further let the LiFi to enable full user mobility. LEDs being natural beam formers enables local containment of LiFi signals and because of the catholic fact that light signals can be blocked by the wall, CCI can be effectively managed & physical layer security can be enhanced.

V MODULATION TECHNIQUES FOR LI-FI

In principle, LI-FI also relies on EM radiation for Information transmission. Therefore typically used modulation techniques in RF communication can be applied to LIFi with necessary modifications. Moreover due to the use of visible light of wireless communication, LiFi also provides a number of unique & specific modulation format.

a) OOK : OOK(On-off Keying) is one of the well-known and simple form of amplitude-shift keying (ASK), and it provides a good trade-off between system performance and implementation complexity. It represents digital data as the presence of or absence of carrier wave. In the simplest form, the presence of the carrier for a specific duration represents a binary one, while its absence for the same duration represents a binary number. Some more sophisticated schemes vary these durations to convey additional information. It is very easy to generate and decode but is not very optical in terms of illumination control and data throughput.
OOK, by sequentially turning ON & OFF the LED, can inherently provide dimming support. OOK's, as defined in IEEE 802.15.7, dimming can be achieved by : 1) refining the ON/OFF levels(which helps in maintaining data rate. However reliable data communication will decrease at low dimming levels.) & 2) applying symbol compensation. As the maximum data rate is achieved with a 50% dimming level assuming equal number of 0s & 1s on average, increasing or decreasing the brightness of LED which would let data rate to decrease.

b) PWM :Pulse-Width Modulation is a technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. PWM transmits data by encoding the data into the duration of the pulses. More than one bit of data can be conveyed within each pulse.

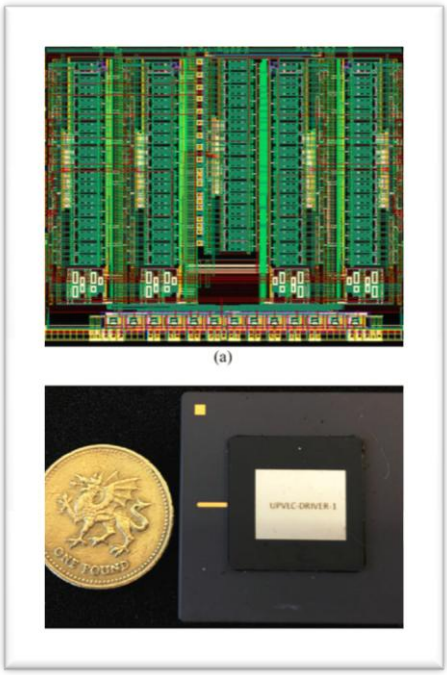
c) PPM : Pulse-Position Modulation (PPM) is more power-efficient than OOK but has a lower spectral efficiency. PPM is a form of signal modulation in which M message bits are encoded by transmitting a single pulse in one of possible required time-shifts. This is repeated every T seconds, such that the transmitted bit rate is bits per seconds.
A variant of PPM, termed variable pulse position modulation (VPPM), can provide dimming support brightness level. Therefore, VVPM can be viewed as a combination of PPM & PWM(Pulse Width Modulation). A novel SCM scheme, termed Optical Spatial Modulation relies on the principle which proves out to be both power and bandwidth-efficient for indoor optical wireless communication

d) LiFi Specific Modulation
Coloured LEDs are used in designing LiFi transmitters which are designed for wireless communication as well as for illumination.
CSK(Colour Shift Keying) is an intermodulation scheme based on IEEE 802.15.7 in which signals are encoded into colour intensities emitted by Red, Green

and Blue LEDs. The incoming bits are mapped on to the instantaneous chromaticities of the coloured LEDs while maintaining a constant average perceived colour. Advantages of CSK over IM : 1) since a constant luminous flux is guaranteed, there would be no flicker effect over all frequencies. 2) The constant luminous flux implies a nearly constant LED driving current, which reduces the possible inrush current at signal modulation, and thus improves LED reliability. CSK based Metameric Modulation (MM) was developed to achieve higher energy efficiency which can help in controlling the colour quality. But MM have a disadvantage of requiring an additional and independently controlled green LED.

VI LIFI TRANSMITTER CHIP

DAC (Digital-To-Analog Convertor) are used by conventional circuits, that can support OFDM/PAM, to generate high speed signals. Typical DAC structures requires an additional stage of current amplifier in order to drive a typical LED & can deliver only upto 30 mA. An open – drain 8-bit current steering DAC based driver using CMOS technology has been developed and it omits the ddditional current amplifier.



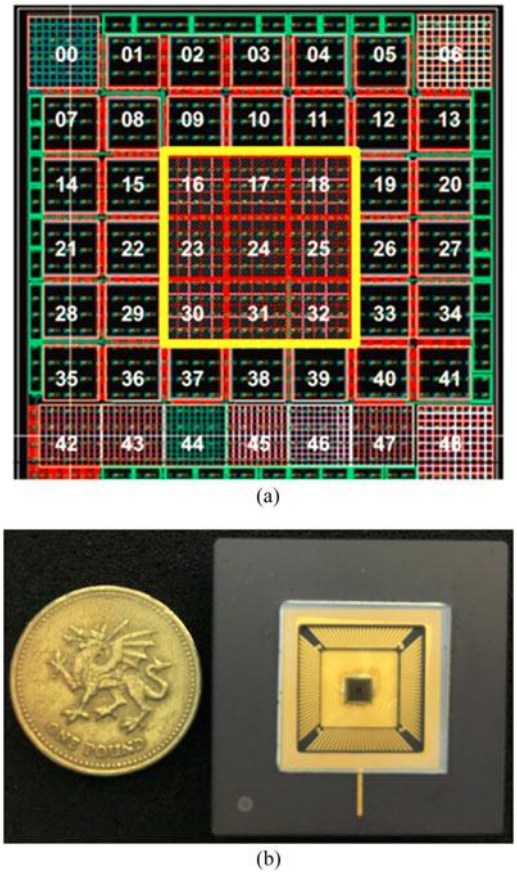
LiFi Transmitter Chip-developed with UPVLC Project. (a) Layout of LiFi driver chip in CMOS (b) Packaged LiFi driver Chip with a coin alongside to give the scale. (Image Credit : Pure LiFi)

The ASIC (Application Specific Integrated Circuit) could achieve 250 MS/s at a maximum full-scale current of 255 mA and exhibits a power efficiency of 72% . A differential optical drive is implemented by employing both current steering branches of the DAC to drive two different colour LEDs. This doubles the signal level and efficiency over a single ended approach. The chip has four separate driver channels. Each channel is capable of driving up to two LEDs allowing for CSK, lighting colour-temperature adjustment and a multiple input multiple output (MIMO) system.

VII RECIEVER CHIP

Being IM/DD based system, the average transmit power in LiFi systems is proportional to the transmit signal amplitude which made the electrical path loss tantamount to twice of the optical path loss. Therefore in order to achieve reasonable distances in an atto cell network, receiver devices

with sufficiently high sensitivity are required. Computer modelling suggest that an avalanche photodetector (APD)-based receiver with a typical input referred noise density of 10 pA/(Hz)$^{1/2}$ is necessary for reliable communication. A typical receiver chip composed of 49 APDs on 180 micrometre CMOS technology has been developed.



LiFi receiver chip – developed within UPVLC project. (a) Layout of LiFi receiver chip with 49 APD detectors on CMOS. (b) Packaged LiFi receiver with a coin alongside to give the scale.(Image Credit : PureLiFi)

The responsivity time of the nine APDs at the central core is 2.61 A/W at 450 nm. An APD gain of 10 dB is achieved at a reverse bias voltage of only 10 V. Each APD is connected to an integrated transimpedance amplifier based on a shunt-shunt feedback topology with fixed gain in order to obtain good performance. The APDs achieve a bandwidth of 90 MHz. The APDs outside the central core exhibit different colour sensitivities.

VIII APPLICATIONS OF LI-FI OVER WI-FI

a) VLC could be used safely in aircraft without affecting airlines signals.
b) 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.
c) 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.
d) 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.

e) Using this Technology worldwide every street lamp would be a free data access point.

IX 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. Li-Fi will also removes the limitations that have been put on the user by the Wi-Fi.

a) Capacity: Light has 10000 times wider bandwidth than radio waves .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.

X. CONCLUSION

LiFi is an emerging technology and so, there are a plethora of possibilities to be gouged upon in this field of technology. If this technology becomes justifiably marketed then every bulb can be used analogous to a Wi-Fi hotspot to transmit data wirelessly. By virtue of this a greener, cleaner, safer and a resplendent future can be expected. The concept of Li-Fi is attracting a lot of eye-balls because it offers a genuine and very efficient alternative to radio based wireless. It has a bright chance to replace the traditional 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 promises 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.

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