Li-Fi Technological Development

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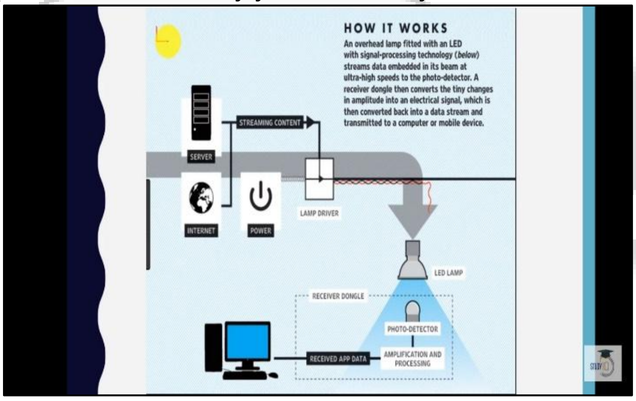
Abstract— Light-Fidelity (Li-Fi) is a new VLC (Visible light communication is much preferable than existing wireless technologies like Wi-Fi, Wi-Max, Bluetooth etc.) based technology that is proposed in late 2011 by prof. Harald Haas, uses illumination for internet data communication and will be implemented in a near future. The advantage of Li-Fi over present wireless systems is that the electromagnetic spectrum bandwidth used for visible light communication (VLC) of Li-Fi is 10,000 times greater than for electromagnetic spectrum bandwidth of radio frequencies for present wireless systems. As VLC is a relatively new concept in the field of data transmission, a lot of research is being done so that VLC can be used for various commercial purposes. It is found that not a lot research has been on the development of Li-Fi, so the possibilities are wide open. If this concept can be implemented successfully, it will surely bring a revolution in wireless data transmission. This paper presents an overview of VLC and the design of Li-Fi circuit and analysis of its performance over many years of Li-Fi systems.



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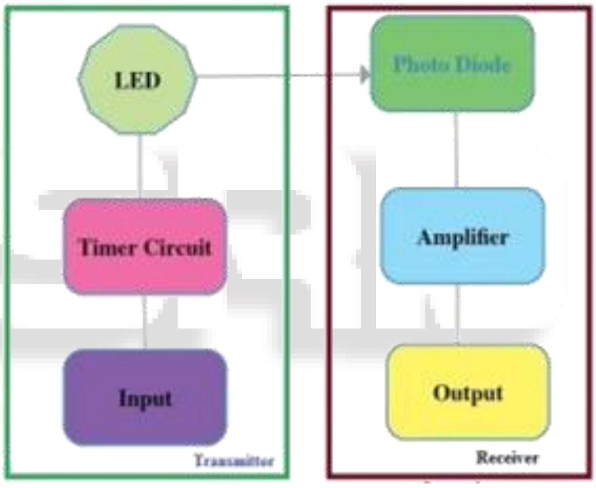
I. INTRODUCTION

LiFi is a wireless optical networking technology that uses light-emitting diodes (LEDs) for data transmission. LiFi is designed to use LED light bulbs similar to those currently in use in many energy-conscious homes and offices. However, LiFi bulbs are outfitted with a chip that modulates the light imperceptibly for optical data transmission. LiFi data is transmitted by the LED bulbs and received by photoreceptors. In technical terms, Li-Fi is a visible light communications system that is capable of transmitting data at high speeds over the visible light, ultraviolet, and infrared spectrums. In its present state, only LED lamps can be used for the transmission of visible light.

In terms of its end use, the technology is similar to Wi-Fi - the key technical difference being that Wi-Fi uses radio frequency to transmit data. Using light to transmit data allows Li-Fi to offer several advantages, most notably a wider bandwidth channel, the ability to safely function in areas otherwise susceptible to electromagnetic interference (e.g. aircraft cabins, hospitals, military), and offering higher transmission speeds. The technology is actively being developed by several organizations across the globe

The general term "visible light communication" (VLC), whose history dates back to the 1880s, includes any use of the visible light portion of the electromagnetic spectrum to transmit information. The D-Light project at Edinburgh's Institute for Digital Communications was funded from January 2010 to January 2012.[23] Haas promoted this technology in his 2011 TED Global talk and helped start a company to market it. Pure LiFi, formerly PureVLC, is an original equipment manufacturer (OEM) firm set up to commercialize Li-Fi products for integration with existing LED-lighting systems. Oledcomm, French company founded by Pr Suat Topsu from Paris-Saclay University.



Block diagram for LiFi Technology

II. RESEARCH

Using off-the-shelf electronics, he can stream videos using an ordinary light bulb fitted with signal-processing technology of his own design. 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, 43, holds the chair of mobile communications at Edinburgh University's Institute for Digital Communications. His demo is scientifically ground breaking: it proves that large amounts of data, in multiple parallel streams, can be transferred using various forms of light (infrared, ultraviolet and visible). The technology, he says, has huge commercial potential. His device can be used with regular lighting and electronics -- albeit reconfigured -- and could transform the way we access everything from video to games, accelerating the speed of internet access by many hundreds of megabits. It could let us download movies from the lamps in our homes, read maps from streetlights and listen to music from illuminated billboards in the street.

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". Thereby flows the data.

The potential applications are enormous: divers working at depths could use light to communicate; air passengers could connect to the internet through the LEDs inside the aircraft. Haas sees the technology potentially disrupting industries from telecoms to advertising.

Engineering efforts are delivering Li-Fi technology that is unparalleled and research producing speed records. Our focus is on developing our technology as a fully-functional network offering in heterogeneous wireless networks – bidirectional multi-point, multi-access, with seamless handover – essential for indoor networking and cellular offload. We have an aggressive product roadmap that will let us deliver OEM products to engage with established industry partners", stated David Kirk, PureVLC Chairman.

Prof. Haas, working through the UOE within the Ultra-Parallel-Visible-Light-Communication project, has conducted research expanding the current capabilities of Li-Fi. He stated "We have completed ground-breaking research demonstrating speeds up to 1.67 Gbps on a single colour LED. By the end of this year, we believe we can achieve 2 Gbps on each of the R, G, B channels, with a target of demonstrating aggregate speeds up to 6 Gbps."

III. Growth

"Li-Fi is the most exciting communications technology in over a decade. Not only will it revolutionize telecommunications and networking, but is the most viable option for solving the RF spectrum-crunch that cellular carriers will face. PureVLC is taking the right approach by focusing on the full networking capabilities of Li-Fi, and not point features.", stated Mike Ramsay, co-founder and ex-CEO of TiVo, currently CEO of Invisioneer.

PureVLC today announced another breakthrough in the world of light fidelity (Li-Fi) by showing that it does not require a line-of-sight connection. In simple terms, Li-Fi is equivalent to Wi-Fi, but using light waves instead of radio signals.

At the beginning of August, PureVLC announced the world's first high-speed, bi-directional Li-Fi system as part of their revolutionary product strategy. This work complemented the world's fastest visible light communications (VLC) link developed by its strategic partner, the University of Edinburgh, as part of the Ultra-Parallel Visible-Light-Communications project under the guidance of Prof. Harald Haas, Chief Science Officer at PureVLC.

Long believed to be the Achilles Heal of Li-Fi technology, today, PureVLC has proven that Li-Fi does not require a line-of-sight connection between the transmitter and receiver. Indeed, engineers at PureVLC showed that Li-Fi can operate by using incident light (which includes reflections). The work was conducted in conjunction with the UK's leading jet engine manufacturer and demonstrated that Li-Fi can achieve the same high-speed performance from reflections. PureVLC is the first company to demonstrate high-speed Li-Fi from a reflection, streaming four videos in parallel.

This breakthrough opens a world of possibilities when considering the commercial applications of Li-Fi. By relying on incident light rather than just direct line-of-sight, Li-Fi can penetrate in diverse market segments, from aircraft cabins, to museums, everyday offices and more.

Mexican software development company Sisoft has succeeded in wirelessly transmitting internet data at 10Gbps using Visible Light Communications (VLC), a technology that can illuminate a large space, such as an office, while at the same time providing high-speed mobile internet connectivity to devices that come into range of the light spectrum.

Sisoft was able to transfer data at speeds of up to 10Gbps across a light spectrum emitted by LED lamps.

In April this year, E&T reported how Scottish researchers had achieved 1.1Gbps using the same VLC technology. Sisoft was able to transmit audio, video and Internet data across the spectrum of light emitted by LED lamps. Light fidelity, or Li-Fi, is being touted as an alternative to Wi-Fi as it has the potential to transmit data more cheaply and securely. Li-Fi uses light waves instead of radio waves. One advantage of Li-Fi over Wi-Fi is the difficulty in hacking the signal. Li-Fi is also put to good use installed in hospitals which use radiation apparatuses. The Li-Fi device works by transmitting data via LEDs that emit an intermittent flicker at a speed imperceptible to the human eye.

"Currently in Mexico the highest transfer rate is 200 megabytes per second. Just to get an idea, with Li-Fi you could quickly download an entire HD movie in just 45 seconds," said Arturo Campos Fentanes, CEO of Sisoft.

Sisoft worked with researchers from the Autonomous Technological Institute of Mexico (ITAM) in adapting the VLC system to be able to achieve five times the original transfer speeds of 2Gbps, to 10Gbps.

Campos Fentanes explained that the first experiments were conducted with audio, in which a cable was connected from the 3.5mm audio jack of a smartphone to a protoboard tablet, transforming the audio signals to optical waves. A special emitter transmitted data across the spectrum of light generated by an LED lamp, which in turn was captured by a receptor located in a speaker that reproduced the sound.

For wireless internet transmission, the mechanics are similar. The electronic apparatus developed by Sisoft sits above the router and the light emitted by the LED lamp acts as an antenna. The apparatus has an in-built receptor for the "optical audio" signal.

There has been significant progress towards the realisation of optical receivers fully integrated with the standard digital CMOS technology. Recent trends towards integrated CMOS high-speed optical receivers have specially employed avalanche photodiodes (APDs). However, the maximum achievable gain of an APD is limited due to low sensitivity and the gain-dependent excess noise. This necessitates the use of intricate high gain trans impedance amplifiers (TIAs), limiting amplifiers and adaptive equalization.

These challenges can be tackled by operating the APD in Geiger-mode as a single photon avalanche diode (SPAD). Due to the high electric field, avalanche multiplication leads to a large internal gain, creating a density modulated pulse train and the additional noise source can then be avoided.

The high sensitivity and time resolution of SPADs have highlighted the potential of employing SPADs as photon counting receivers for Li-Fi systems. They can be used with the long term aim of power efficient, high sensitivity receivers and are particularly attractive because they are able to closely approach quantum-limited sensitivity in the detection of weak optical signals in long distance communications, such as in the gas extraction industry, or in downhole monitoring communication systems.

Despite advances, the maximum achieved data rate by a SPAD receiver is still limited to a few MHz. Currently at the Li-Fi Centre at the University of Edinburgh, we are conducting research on these state-of-the-art receivers and trying to provide solutions to possible challenges by investigating alternative approaches.

In order to respond to the increasing demand of capacity and bandwidth caused by the high number of wireless applications and users, LiFi technology was introduced. It uses the visible light spectrum instead of the radio spectrum to transmit data wirelessly through the illumination of LED lamps. The main advantage of this technology is to provide wireless communications with high data rates. Other advantages include efficiency, availability, security and safety. Also, this technology uses free unlicensed spectrum, and it is cost-effective. Additionally, unlike RF systems, no multipath fading and the transmitter and receiver circuits are not complex. However, LiFi has several issues, which include high path loss, sensitivity to blockages and Non-line-of-sight (NLOS) situations. Probably, the biggest issue of LiFi is the uplink communication which is difficult to implement due to practical and cost reasons. Several future applications of this technology include places where RF is restricted such as hospitals and airplanes. Also, it can be used for traffic management, underwater communication, and outdoor access to the Internet. Moreover, it can be combined with WiFi technology either in hybrid technique or aggregated technique. It is found that later technique gives better results. Another possible application is the optical at to cells. It is found that the hexagonal cells model is the best for deterministic deployments of optical APs, whereas the hard-core point process (HCPP) model is the best for random deployments. Furthermore, LiFi can be used for multiuser access with high data rate by using non-orthogonal multiple access (NOMA) technique. Due to the great features of LiFi, more applications and everyday life devices will adopt this technology in the future. However, Because of its limitations, it may not totally replace RF technology, but they will work collaboratively to achieve a better performance.

IV. Advantages of Li-Fi

Ultra-fast data communication – no limit for data rate
No interference like traditional radio waves
Cost effective solutions – much cheaper than other wireless technologies
High security data transmission – light can't penetrate through wall, wooden doors and metallic blocks
Multiple device support – many devices without any limit and no network overloading
Highly energy efficient solutions – energy spending for wireless data communication can be significantly reduced using Li-Fi implementation
Scalable network for enterprise and home applications
Highly reliable network – chances of device malfunctioning, interference from other sources are lesser compared to conventional network using radio waves
Simple implementation – no need for expensive spectrum, equipment and antenna system
Limitations of Li-Fi:
Device must be compatible – Li-Fi enabled devices are required to configure network
Any distraction could stop connection (requires line of sight communication)
Integration and coordination of device manufacturers is required for standardization

V. Future Applications of Li-Fi

- Smart home application for various appliances
- Wireless solutions for enterprise and offices
- Smart city applications
- Smart transport
- Hospitals and healthcare
- Security applications
- Most important data communication option for future 5G and IoT networks

VI. Conclusion

From this paper we have displayed the yearly growth of LiFi where it plays and important role by giving the ultra-fast data transfer rate and highly secure environment for communication.

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