INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

LI-FI (LIGHT FIDELITY) TECHNOLOGY

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Abstract

Motivated by the looming radio frequency (RF) spectrum crisis, this paper aims at demonstrating that optical wireless communication (OWC) has now reached a state where it can demonstrate that it is a viable and matured solution to this fundamental problem.Whether you're using wireless internet in a coffee shop, stealing it from the guy next door, or competing for bandwidth at a conference, you have probably gotten frustrated at the slow speeds you face when more than one device is tapped into the network.As more and more people and their many devices access wireless internet, clogged airwaves are going to make it. One germen phycist.Harald Haas has come up with a solution he calls “data through illumination” –taking the fibber out of fiber optic by sending data through an LED light bulb that varies in intensity faster than the human eye can follow.Optical attocells are the next step in the progression towards ever smaller cells, a progression which is known to be the most significant contributor to the improvements in network spectral efficiencies in RF wireless networks.Haas says his invention, which he calls D-LIGHT, can produce data rates faster than 10 megabits per second, which is speedier than your average broadband connection.

Keywords: Li-Fi, optical wireless, LED (Light emitted diode), Wi-Fi, VLC, optical attocell.

1. 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.LiFi's early developmental models were capable of 150 megabits-per-second (Mbps). Some commercial kits enabling that speed have been released. In the lab, with stronger LEDs and different technology, researchers have enabled 10 gigabits-per-second (Gbps), which is faster than 802.11ad. “They can be switched on and off very quickly, which gives nice opportunities for transmitted data.”It is possible to encode data in the light by varying therate at which the LEDs flicker on and off to give

Vol.3 Issue.1, Pg.: 26-32
January 2015

different strings of 1s and 0s. 1 Most of us are familiar with Wi-Fi (Wireless Fidelity), which uses 2.4-5GHz RF to deliver wireless Internet access around our homes, schools, offices and in public places. We have become quite dependent upon this nearly ubiquitous service. But like most technologies, it has its limitations. While Wi-Fi can cover an entire house, its bandwidth is typically limited to 50-100 megabits per second (Mbps). This is a good match to the speed of most current Internet services, but insufficient for moving large data files like HDTV movies, music libraries and video games. The more we become dependent upon 'the cloud' or our own 'media servers' to store all of our files, including movies, music, pictures and games, the more we will want bandwidth and speed. Therefore RF-based technologies such as today's Wi-Fi are not the optimal way. In addition, Wi-Fi may not be the most efficient way to provide new desired capabilities such as precision indoor positioning and gesture recognition.The use of the visible light spectrum for high speeddata communication is enabled by the emergence of the light emitting diode (LED) which at the same time is at the heart of the next wave of energy-efficient illumination. Terms at the University of Oxford and theUniversity of Edinburgh are focusing on parallel datatransmission using array of LEDs, where each LED transmits a different data stream. Other groups are using mixtures of red, green and blue LEDs to alter the light frequency encoding a different data channel. In October 2011 a number of companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio basedwireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. The consortium believes it is possible to achieve more than 10 Gbps, theoretically allowing a high-definition film to be downloaded in 30 seconds.The vision is that a Li-Fi wireless network would complement existing heterogenous RF wireless networks, and would provide significant spectrum relief by allowing cellular and wireless-fidelity (Wi-Fi) systems to off-load a significant portion of wireless data traffic.

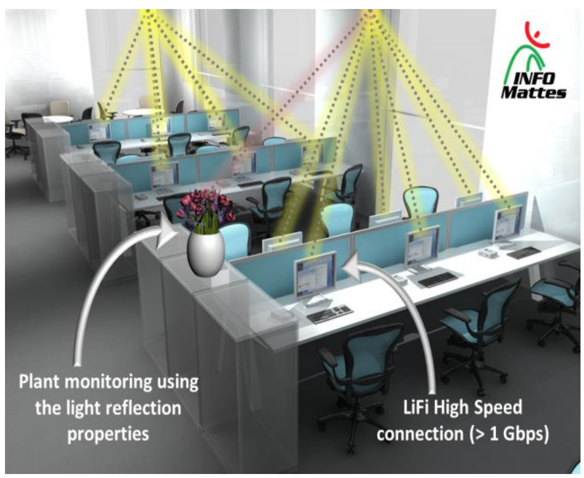

FIGURE 1: ENVIRONMENT OF LIFI

2. WORKING TECHNOLOGY OF LIFI

This brilliant idea was first showcased by Harald Haas from University of Edinburgh, UK, in his TED Global talk on VLC. He explained," Very simple, if the LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data." So what you require at all are some LEDs and a controller that code data into thoseLEDs. This can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military operations. Very interesting results have recently been reported from the use of millimeter wave (mmWave) communication in the 28 GHz region as well as from the use of infrared and visible light. The latter is particularly enticing as lighting is a commodity that has been integrated in virtually every inhabited environment and sophisticated infrastructures already exist. 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. In that sense, the concept of combining the functions of illumination and communication offers the potential for tremendous cost savings and carbon footprint reductions. First, the deployment of VLC access points (APs) becomes straightforward as the existing lighting infrastructure can be reused, and there exist off-the-shelf technologies such as power-line communication (PLC) and power- over-Ethernet (PoE) as viable backhaul solutions for retrofit installations, and new installations respectively. Second, because lighting is on most of the time in indoor environments even during day time, the energy used for communication would practically be zero as a result of the piggy-backing of data on illumination.

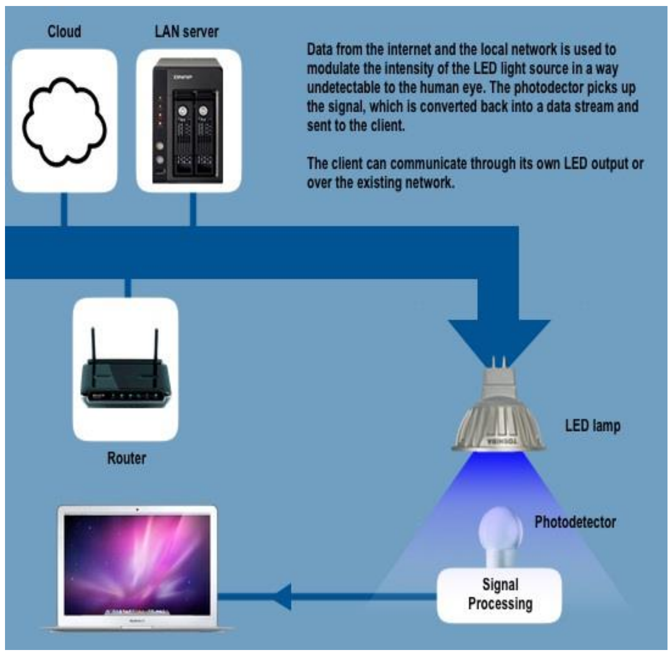

FIGURE 2: WORKING OF LIFI TECHNOLOGY

A flickering light can be incredibly annoying, but has turned out to have its upside, being precisely what makes it possible to use light for wireless data transmission. Light-emitting diodes (commonly referred to as LEDs and found in traffic and street lights, car brake lights, remote control units and countless other applications) can be switched on and off faster than the human eye can detect, causing the light source to appear to be on continuously, even though it is in fact 'flickering'. There are reasons to prefer LED as the light source in VLC while a lot of other illumination devices like fluorescent lamp, incandescent bulb etc. The vision is that a Li-Fi wireless network would complement existing heterogenous RF wireless networks, and would provide significant spectrum relief by allowing cellular and wireless-fidelity (Wi-Fi) systems to off-load a significant portion of wireless data traffic. The current paper summarizes some of the research conducted so far and looks at the different aspects of the communication system with a particular focus on wireless networking.

3. LI-FI ATTOCELL

In the past, wireless cellular communications has significantly benefited from reducing the inter-site distance of cellular base stations. By reducing the cell size, the network spectral efficiency has been increased by two orders of magnitude in the last 25 years. More recently, different cell layers composed of microcells, picocells and femto cells have been introduced. These networks are referred to as heterogeneous networks.23, 24 Femtocells are short range, low transmission power, low cost, plug-and-play base stations (BSs) that are targeted at indoor deployment in order to enhance coverage. They use either cable Internet or broadband digital subscriber line (DSL) to backhaul to the core network of the operator. The deployment of femtocells increases the frequency reuse, and hence throughput per unit area within the system since they usually share the same bandwidth with the macrocellular network. However, the uncoordinated and random deployment of small cells also causes additional inter- and intra-cell interference which imposes a limit on how dense these small RF can be deployed before interference starts offsetting all frequency reuse gains.

The small cell concept, however, can easily be extended to VLC in order to overcome the high interference generated by the close reuse of radio frequency spectrum in heterogeneous networks. The optical AP is referred to as an attocell.25 Since it operates in the visible light spectrum, the optical attocell does not interfere with the macro cellular network. The optical attocell not only improves indoor coverage, but since it does not generate any additional interference, it is able to enhance the capacity of the RF wireless networks. Li-Fi attocells allow for extremely dense bandwidth reuse due to the inherent properties of light waves. The coverage of each single attocell is very limited, and walls prevent the system from suffering from co-channel interference between rooms. This precipitates in the need to deploy multiple access points to cover a given space. However, due to the requirement for illumination indoors, the infrastructure already exists, and this type of cell deployment results in the aforementioned very high, practically interference-free bandwidth reuse. A byproduct of this is also a reduction in bandwidth dilution over the area of each access point, which leads to an increase in the capacity available per user. The user data rate in attocell networks can be improved by up to three orders of magnitude.

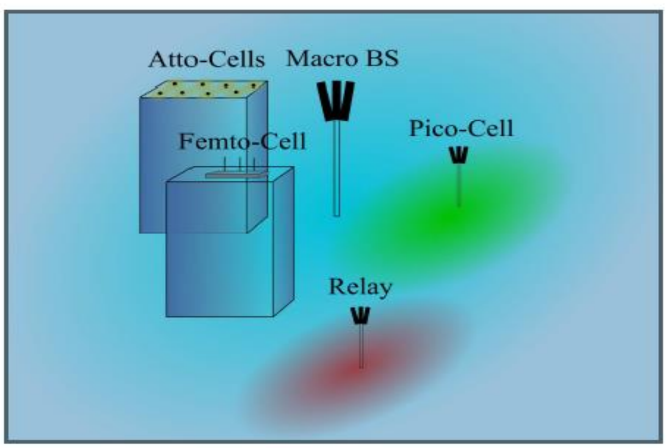

FIGURE 3: The attocell in the context of the heterogeneous network.

Moreover, Li-Fi attocells can be deployed as part of a heterogeneous VLC-RF network as illustrated in They do not cause any additional interference to RF macro- and picocells, and can, hence, be deployed within RF macro, pico and even femtocell environments. This allows the system to vertically hand-off users between the RF and Li-Fi sub-networks, which enables both free user mobility and high data throughput. Such network structure is capable of providing truly ubiquitous wireless network access.

4. COMPARISION BETWEEN LIFI AND WIFI

LI-FI is a term of one used to describe visible light communication technology applied to high speed wireless communication. It acquired this name due to the similarity to WI-FI, only using light instead of radio.WI-FI is great for general wireless coverage within buildings, and li-fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary.

Technology	Speed	Data density
Wireless (current)		
Wi-Fi – IEEE 802.11n	**150 Mbps**	*
Bluetooth	**3 Mbps**	*
IrDA	**4 Mbps**	***
Wireless (future)		
WiGig	**2 Gbps**	**
Giga-IR	**1 Gbps**	***
Li-Fi	**>1Gbps**	****

TABLE 1: Comparison between current and future wireless technology

The table also contains the current wireless technologies that can be used for transferring data between devices today, i.e. Wi-Fi, Bluetooth and IrDA. Only Wi-Fi currently offers very high data rates. The IEEE 802.11.n in most implementations provides up to 150Mbit/s (in theory the standard can go to 600Mbit/s) although in practice you receive considerably less than this.

5. CELLULAR NETWORK

The deployment of multiple Li-Fi attocells provides ubiquitous data coverage in a room in addition to providing nearly uniform illuminance. This means that a room contains many attocells forming a very dense cellular attocell network. A network of such density, however, requires methods for intra-room interference mitigation while there is no inter-room interference if the rooms are separated by concrete walls. The unique properties of optical radiation, however, offer specific opportunities for enhanced interference mitigation in optical attocell networks. Particularly important is the inability of light to penetrate solid objects, which allows interference to be managed in a more effective manner than in RF communication. the VLC interference mitigation caused by solid objects in a typical indoor environment leads to a tremendous increase in area spectral efficiency (ASE) over an RF femtocell network deployment in same LTE indoor office environment. The presented results highlight that the improvement with respect to ASE can reach a factor of up to 1000 in certain scenarios.

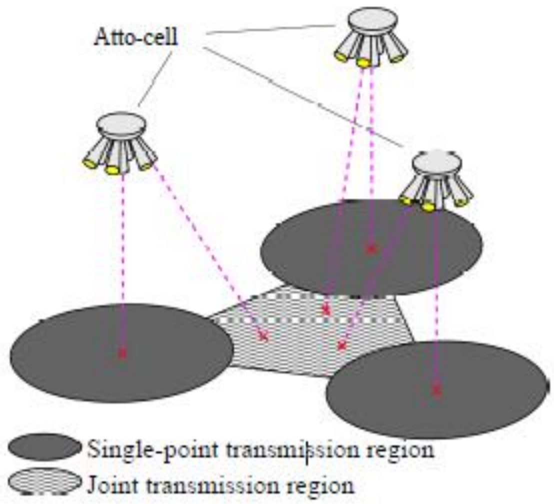

FIGURE 4: Illustration of signal contributions to cell-center regions and to conflicting regions.

Essential techniques for increasing wireless system capacity such as beamforming are relatively straightforward to use in VLC as the beamforming characteristic is an inherent, device specific property related to the field of view (FOV), and no computationally complex algorithms and multiple transmitting elements are required. The application of multiple simple narrow-emission-pattern transmitters at each attocellular AP results in significant co-channel interference reduction. The technique allows the cellular coverage area to be broken down further into areas of low interference and areas that are subject to higher interference – typically at the cell edges.

6. APPLICATION OF LI-FI

For a long time, medical technology has lagged behind the rest of the wireless world. Operating rooms do not allow Wi-Fi over radiation concerns, and there is also that whole lack of dedicated spectrum. While Wi-Fi is in place in many hospitals, interference from cell phones and computers can block signals from monitoring equipment. Li-Fi solves both problems: lights are not only allowed in operating rooms, but tend to be the most glaring (pun intended) fixtures in the room. And, as Haas mentions in his TED Talk, Li-Fi has 10,000 times the spectrum of Wi-Fi, so maybe we can, I dunno, delegate red light to priority medical data. Code Red!

Airline Wi-Fi. Ugh. Nothing says captive audience like having to pay for the "service" of dial-up speed Wi-Fi on the plane. And don't get me started on the pricing. The best I've heard so far is that passengers will "soon" be offered a "high-speed like" connection on some airlines. United is planning on speeds as high as 9.8 Mbps per plane. Uh, I have twice that capacity in my living room. And at the same price as checking a bag, I expect it. Li-Fi could easily introduce that sort of speed to each seat's reading light. I'll be the guy WoWing next to you. Its better than listening to you tell me about your wildly successful son, ma'am.

Wi-Fi and many other radiation types are bad for sensitive areas. Like those surrounding power plants. But power plants need fast, inter-connected data systems to monitor things like demand, grid integrity and (in nuclear plants) core temperature. The savings from proper monitoring at a single power plant can add up to hundreds of thousands of dollars. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations. Not only would this save money related to currently implemented solutions, but the draw on a power plant's own reserves could be lessened if they haven't yet converted to LED lighting.

Say there's an earthquake in New York. Or a hurricane. Take your pick — it's a wacky city. The average New Yorker may not know what the protocols are for those kinds of disasters. Until they pass under a street light, that is. Remember, with Li-Fi, if there's light, you're online. Subway stations and tunnels, common dead zones for most emergency communications, pose no obstruction. Plus, in times less stressing cities could opt to provide cheap high-speed Web access to every street corner.

7. CONCLUSION

The concept of Li-Fi is currently attracting a great deal of interest, not least because it may offer a genuine and very efficient alternative to radio-based wireless. As a growing number of people and their many devices access wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. The unique physical properties of light promise to deliver very densely-packed high-speed network connections resulting in orders of magnitude improved user data rates. Based on these very promising results, it seems that Li-Fi is rapidly emerging as a powerful wireless networking solution to the looming RF spectrum crisis, and an enabling technology for the future Internet-of-Everything. This may solve issues such as the shortage of radio-frequency bandwidth and also allow internet where traditional radio based wireless isn't allowed such as aircraft or hospitals.

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