Electrical Communications Systems Final Project: Free Space Optical Communications (LiFi)

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Abstract

This paper concerns the advantages and problems relating to Free Space Optical Communications, also known as LiFi. This LiFi works similarly to normal WiFi but using light to transmit signals instead of wireless connection. LiFi turns out to be very quick and useful both in standard residential areas and in more technologically busy places like Hospitals or Aircraft. However, there are drawbacks to this, such as inaccuracies in angle, distance, self-interference, and the inability to run without keeping a light on. Four major solutions were discussed and Assessed. It was determined that the best and most practical solution to make LiFi easier to access is a combination of Modulation Box and Infrared Light.

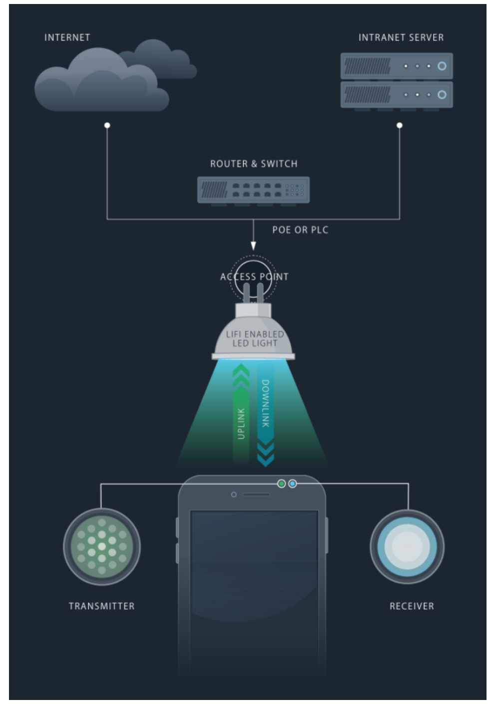

Fig. 1. A Diagram with the basic functions and pieces of a LiFi system

I. Introduction

LiFi, which stands for "Light Fidelity," is the proposed design to use a rapidly blinking light as a medium to transfer data. As long as the sender and receiver have line of sight the system can operate even in the heaviest of electromagnetic radiation due to bypassing all of the noise present in the area. The usage of light allows a variety of bandwidths as the chosen light has both a limited band of frequencies and the more light variety used the greater output of bandwidth increases with the increased availability of light bands, for example a pure white light system would have a lower bandwidth than an RGB system [1].

Figure 1 shows a diagram from PureLiFi [2] outlining the general design of a LiFi system and how it works. On the back end of the server, Internet and Intranet servers connect to the Router or Switch which themselves connect to the Access Point of the lighting fixture. The LED light bulb in the lighting fixture sends the signal to the Receiver in the intended device. The device can in turn send signals back to the lighting fixture using its own Transmitter [1] [2].

II. Advantages and Applications

One advantage LiFi has over normal WiFi is the speed. Normal LiFi speeds are somewhere from 10 to 20 Gbps, directly related to the rate at which standard LED light bulbs can be turned on and off. Some tests have even reached up to 224 Gbps. This greatly speeds past normal WiFI rates. On top of this, since the electromagnetic spectrum of light is larger and more powerful than the spectrum of normal WiFi, LiFi does not get as easily saturated as WiFI. This means that a LiFi transmission would need a lot more noise to become saturated or interrupted under standard conditions [3].

LiFi is convenient to use in a standard household. LiFi is simple to install in a building with existing light fixtures and setups, only needing to modify a single light and the device connecting to it. With the way LiFi is designed, either the bulb can operate at a level that would be hardly noticeable to the human eye or it can be done so fast that the switching power of the light would be imperceptible [3].

Unlike normal WiFi, which cannot operate in electromagnetically sensitive areas, LiFi does not interfere with running electrical equipment. This means that LiFi can run in places with lots of necessary equipment such as hospitals or aircraft [3]. LiFi in hospitals can allow for safer monitoring of patient data without the potential of interfering with any life-saving equipment [4]. In-flight LiFi allows the passengers and the plane itself to access Internet bandwidth without tampering with the plane's functionality [5].

An advantage which comes directly from the Light-based connection is light's inability to travel through walls. Someone trying to hack in to a local internet would have to be within the confines of whatever building the LiFi transmitter is located in. This could potentially prevent many cyberattacks from coming through and being viable.

III. Problems

Like any piece of technology there are trade offs. Current major issues plaguing the system are that due to it send data over beams of light the system is entirely line of sight, if something blocks the beam, lets say the user is using a handheld and shifts position, or if it were used outside a bird, leaf or other obstruction appears, all communication is cut off. Currently due to the demands of the system, the simplest solution is a receiver and a sender device. As such the design still requires either RF based communication or a physical wired connection. A two way system would require a device to have both a sending light bulb and some form of photo voltaic receiver [3].

Additionally, the devices would need to send and receive without interfering with each others data, as reflections or even shallow angles would allow the light of the receiver to interfere with the sender. While the system should be invisible to the human eye as the flickering of the system should be beyond recognition of the human eye but testing should be done to ensure even subconsciously humans are not effected by the device. Many buildings would need to be modified and upgraded to allow the usage so that would need to be considered in the design. Finally, in the current iteration of the device there can be a deviation of near negligible angles, +/- 1 degree can be sufficient to prevent proper data transfer, as lights are omnidirectional the receivers need to be improved to allow acceptable bandwidth without usage of the device essentially being a ceremony [3].

IV. Potential Solutions

Multiple potential solutions were proposed to address and fix one or more of the problems listed above.

A. Modulation Box

Currently, there are devices on the market called "powerline adapters" which (de)modulates data signals to be sent/received over the internal wiring of one's home[6]. For this to work, there needs to be a box for each side, that being one for each end of the connection. This could be one box for connecting one side to a modem which connects to the ISP and another which connects to a PC in a separate room. This technology could be adapted for use with Li-Fi as the technology of these powerline adapters can be inserted into the base of the Li-Fi bulbs as the way to connect Li-Fi to the network.

Fig. 2. A D-Link branded powerline adapter

Because powerline technology uses the AC power lines to transmit data, only one connection to the network would be needed for the entire home. This would most likely be a single modulation box which plugs into an outlet with an ethernet cable of capable speeds connected to both the main modem and the powerline box. Once this box is installed, connecting the Li-Fi bulbs to the network would be as simple as screwing the bulb into the socket. Once plugged in, these devices will sync up with the existing powerline infrastructure for the commencement of data transmission.

B. Smart Sockets

This idea is similar to the solution of the modulation boxes and bulbs but instead of the Li-Fi connected end being inside of the bulbs, the transceiver would be inside the socket of the bulb. The purpose of this is to allow for more connection opportunities and the use of traditional light bulbs in the Li-Fi system. This method, being that the sockets can have larger usable volumes than bulbs themselves, could add wireless fail safes into the Li-Fi system in case the powerline technology fails or is unusable due to existing infrastructure.

C. Node Separation

Similar to old routers or network switches the current Li-Fi system does not bother to sort information for the receivers. As such, the more people who use a system the more bandwidth is taken up by their requests and if a sufficient number of users are connected to the same node then the users could be swamped by too much data that is not theirs and spend a lot of time sorting through to receive the information they requested. Essentially the system operates like an Ethernet cable but made of light. Thus separating nodes would allow users to enjoy the full capabilities of the technology without any interference from one another, there would not even be a passive noise that a pair of routers would generate. Instead each user would be hardwired from their device to the close internet access point and able to communicate as fast as their provider would allow.

This is one of the simpler solutions to the problem as its using the tried and true pre-sort method to prevent end-users from being bogged down in each other's requests. The cost to implement such a method would increase based on expected number of access points. As opposed to the one node per room, due to the line of sight requirement, so the cost of implementation could easily be doubled or tripled before bringing in additional network switches to handle the increased connection requirement.

D. Infrared

Infrared light is light at a higher wavelength than visible light, and is invisible to the human eye. Therefore, it can flicker and transmit signals without being bothersome or irritating to the human eye. IR light fixtures are cheap and easy to install in existing device, and most modern buildings have extensive lighting fixtures which can support the IR bulbs.

Infrared lighting is not perfect, however. Infrared light has a longer wavelength than visible light, making the resulting bandwidth smaller as a result. Existing sensors which can pick up and transmit LiFi signals would need to be slightly modified to account for the differences between the IR lights and regular light bulbs.

This type of LiFi transmission has been tested by BMW. At the time of publication by LEDs Magazine [7], the company was using working IR LiFi in one of their testing warehouses. They gave it a 6 out of 9 in overall readiness. They stated that it functioned properly and with fast uplink and downlink rates, the modules were simply too large and would need to be made smaller in order to function. Figure 3 shows one of these modules [7].

V. Solution Assessments

The solution in which we have devised is using a combination of the modulation box and the infrared lights. To be exact, the bulb end of the connection would be regular visible light with a IR receiver built in but the light on the client device would be infra red. This combination would allow for the high-speed communication provided by Li-Fi in a manner

Fig. 3. The Infrared LiFi modules tested by BMW

comfortable to humans due to IR being outside the visible spectrum as well as an easy way to set up the Li-Fi network.

Despite this, there may be problems with this solution. First, because powerline technologies are already an existing technology, if there is existing powerline infrastructure which isn't compatible with the ones used by the Li-Fi's powerline infrastructure, this could cause data loss for both the existing and the new powerline connections. Also, powerline technologies are susceptible to noise from the lines itself, further reducing data rate. Second, due to the nature of Li-Fi, signals can be easily blocked, so there would need to be at least one Li-Fi source per room to get around walls and then the Li-Fi transceiver on the client device may be covered accidentally by the user's body. Another problem is that Li-Fi, being wireless, requires a broadcast of all data to every device connected to the Li-Fi network. Therefore, without encryption and special protocol, every packet gets received by every device and could allow for unwanted eavesdropping on the network or, with encryption, slow down network performance. This also means that bandwidth for each device gets slashed when another device gets added because every device would need to take turns with one another. The last big hurdle is the cost of use as the technology is new and pricey, especially since some existing infrastructure (the bulbs) would need to be replaced with special Li-Fi versions.

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VI. Appendices