Integrated Light Fidelity-Bluetooth Network for Hospitals

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Abstract

The scope of this project is to design a commercial LED system for hospitals that acts as a high bit rate transceiver and receiver for data transfer. This design includes the function of the LED LiFi/Bluetooth system, the power consumption of one of the LED's, and types of materials determined to be used based off of the design requirements.

I. INTRODUCTION

In hospitals around the country, RF signals are unable to be used in all areas because of certain health risks to patients. With the inclusion of LiFi into hospital light fixtures in the near future, there will be the availability of high speed data transfer in all areas of the hospital allowing for doctors to have faster access to patient information, a secure database that will store patients data that will only be accessible with a specific key, and won't cause the health problems that arise from RF and electromagnetic waves. Since LiFi is based in LEDs it does not cause as many health risks as the LEDs in hospitals already do, allowing for rooms to send information quickly without the concerns of additional health risks.

In the United States "It's estimated that more than 400,000 people are killed each year due to preventable medical errors… many of these errors are technology-related" [1]. Technological errors are a disaster for hospital in the country and two of the main problems for the technology are from inadequate alarm configuration and incorrect or missing data in EHRs and other health IT systems [1]. Through the use of LiFi technology, these problems can be eliminated, helping to save lives that should have been saved previously. With LiFi capability in lighting fixtures, immediate connection with machines hooked up to patients will be feasible to allow a specific warning for significant conditions that can be sent to a database that alerts nearby nurses or doctors to check in on the patient. There is also less of a chance for missing data from delay in transmission. LiFi can be implemented in all rooms, whenever there are updates to electronic health records, they would be immediately recorded and stored allowing for easy access by anyone who need the data and has proper access to it.

II. PROBLEM DEFINITION AND REQUIREMENTS

Hospitals pose as some of the most difficult locations to maintain a strong and consistent wireless connection throughout all of their facilities. There are many common technical and architectural parameters within hospitals that cause problems for creating an effective wireless network via WiFi and other means that utilize RF communication. Doctors and nurses need to be able to constantly send and receive various kinds of medical information and data from different parts of a hospital building. One of the main problems with current hospital floor plans and constructing its physical network architecture is that there are certain areas that are known to have a lot of foot traffic and high densities of device usage that routers and modems should be placed nearby. These locations include the

waiting room, nurse's stations, and cafeteria, among others [2]. However, it is much more difficult to create strong points of consistent wireless signals in areas with greatly fluctuating densities of people and devices. Also, with the rising number of devices and instruments being used, some of which experience interference issues with RF and WiFi, and the internet of things (IoT) in hospitals continually growing [2], the need for a more consistent network is in higher demand. Additionally, with highly sensitive information such as patient files, hospitals need to ensure that their servers and files are minimally susceptible to breaches in network security. The average cost of a breach in data for healthcare organization is $355 per lost or stolen record globally [3]. Nearly 90 percent of healthcare organizations experienced a breach in network security between 2014 and 2016, with an average cost of $2.2 million per hack [3]. With that said, wireless localized servers and networks can be established within the walls of hospitals by implementing LiFi-enabled LED light bulbs throughout these buildings. The light bulbs themselves must meet the following requirements:

- Bi-directional: must be able to send and receive data
- Be able to interconnect and form a localized server and LiFi network, to ensure consistent wireless connection, increase bandwidth and data speeds, and create an added level of security
- Encrypted data transmission and processing

III. COMPARATIVE ANALYSIS

There is a patent called "Machine-to-machine (m2m) communications using short message services (sms)" [4] which speaks of interconnection between machinery through the use of short message services. The proposed idea in this paper is similar but would also allow for equipment to not only communicate through short messages but be able to store and share results with the entirety of the facility, allowing doctors and nurses to get results faster. There is another patent called "System and method for communication with a mobile device via a positioning system including RF communication devices and modulated beacon light sources" [5] which includes some of the ideas this innovation includes such as an identifier for each 'node', as it is called in the patent. This project, however, proposes a more compact version, having modulation, transmitting, receiving, storage, and LED in one device. There is no patent that implements LiFi to allow for complete connectivity. There are however similar interconnection ideas such as the "Hospital video terminal and system with an intercommunicated internal network and external network" [6] patent, which attempts to connect an entire hospital. The proposed innovation is similar as all hospital equipment, hospital computers, patients, and hospital staff are being connected together through LiFi. Another example of a similar patent is "Digitalized information management system for nursing stations in hospitals and method for realizing same" [7] which covers a similar concept except it is specifically designed to connect hospital staff and information. As with the previous patent, the solution outlined in this report involves this connectivity mentioned, except it will be more encompassing and use a safer and faster way than Wifi. "Lighting Connectivity Module" [8] is another patent which is similar to our idea in that it provides a microcontroller, storage, and a way to send, process, and receive information. Ours is slightly different however as we are hoping to implement all of these components into the base of the light bulb. Also we are not adding an RF component. With our invention, we are hoping

to implement a similar idea except in a much larger scale and specifically designed for use in hospitals. This includes many LED light bulbs virtually connected to be continuously sharing data. The patent only mentions the use of one LED bulb and how it will function connected to simply a computer and phone. We are hoping to connect all of the lights in a hospital with all of the machines and computers for fast processing of test results. This will allow for doctors and nurses to have the results of test instantly. The patent called "Method and apparatus for interworking between electronic devices" [9] has similar features to our innovation. The idea of moving towards a wireless connection between electronic devices is present in both the patent and our innovation. However, Samsung Electronics are continuing to move with frequency communications, whereas our innovation is implementing light fidelity communication. Additionally, there are using a docking station to vary the communication data depending on the connection state of the other electronic device. We are planning on using our LED bulb to include the processor, where it will determine what connections to make based on what is under the range of the light. The patent called "Mobile Terminal" [10] has a similar idea of what we are trying to achieve except we are hoping to perform similar functions within each LED light bulb installed in a hospital. The patent describes a mobile terminal with a processor, a LiFi receiving and transmitting module, a communication module, and a display screen. We are hoping to have similar components installed within each LED light bulb. We also are not planning on installing a display screen as it is not necessary for our implementation of LiFi. "Combined illumination and optical communication device"[11] is a patent that uses the source of light for data transmissions, similar to our innovation. This patent, however, focuses on the idea of using two sets of light sources as opposed to only one set. Their purpose is to have one set concentrate a beam of light to certain devices for data transfer and the other set to provide a fixed illumination of light in the area. The high speed modulation in our innovation will provide the secure and stable connection between the LED bulb and electronic device, so a concentrated beam of light will not be necessary. The patent called "Modularized Smart Home-Care Lighting Device" [12] is similar to our idea in that we are hoping to implement the components needed for our implementation into the base of a light bulb. Our implementation however and the components needed are different. The patent being discussed includes a "camera for panoramic surveillance and monitoring" [12]. Our implementation for hospitals does not include a camera. The base connection will include components related to the sending, receiving and processing of information using the modulation of light. The patent, "Modularized Smart Home-Care Lighting Device" [12] does not involve light modulation but rather just the use of cameras and detection components to detect whether or not a 'living organism' [12] is within view of the camera. The device described also includes a microprocessor which is also a component of our but theres is used to establish a connection to a computer or smartphone for access to the camera and to store data for establishing a personal health record.

IV. SOLUTION AND VALIDATION

The proposed solution for implementing LiFi networks within hospitals begins with the integration of a smart lighting system that utilizes LiFi-enabled LED light bulbs to replace the light bulbs of current modern lighting fixtures while creating an infrastructure that is accessed by doctors and nurses to alert them of potential dangers or events happening across the

hospital . The transceiver is capable of converting packages of data and altering the light wave frequencies emitted by the light bulb into signals that can be sent by the LED to another light bulb's transceiver or the photosensitive diode located on most devices, which can receive, process, and convert the light signals back into the data's original form. When a data package is converted into light signals, the signals themselves are encrypted to ensure security in data transfer between transceivers and that only the intended recipient(s) receive the data. The data package is sent through the hospital looking for its intended recipient and once they are found they are alerted of any problems with the patient.

Additionally, because the data is being transmitted via light, transmission signals will not interfere with the performance of the various medical devices and instrumentation. This is a great advantage over WiFi and other RF frequencies under the 802.11 protocol. The light bulbs themselves will be connected to the internet via hardwire ethernet connection to a hospital's local routers. This is to ensure that the wireless access within the building remains as fast and consistent as possible. With the entire lighting grid of a hospital hardwired to the internet, the local network architecture within the hospital will become greatly optimized, with each light essentially acting in a mesh network with one another as wireless access points. This localized network architecture also creates an isolated digital ecosystem contained inside the hospital's premises that acts as the network's own added level of security, effectively reducing any possible network breach from the outside to just the hospital's network itself. Additionally, in the event of a natural disaster or any other unforeseen circumstance that would potentially take out the power or interrupt the signals transmitted via LiFi, this system implemented in hospitals will utilize short range Bluetooth transmission between LEDs and devices as a backup alternative. With these smart lights dispersed all across the halls and rooms of a hospital, the short range of Bluetooth should have no problem propagating a signal from location to location on the premises.

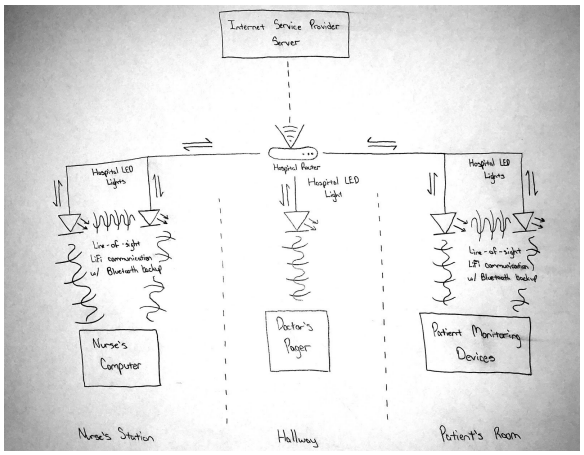

Figure 1: Hospital LiFi Network Diagram

With the proposed system patients who are in high risk of danger, will have an alert sent to doctor and nurses specific method of communication and to the central nurse to relay over the intercom. Each doctor and nurse will have a device that is connected to this central system and alerts them when necessary.

V. ENGINEERING ANALYSIS

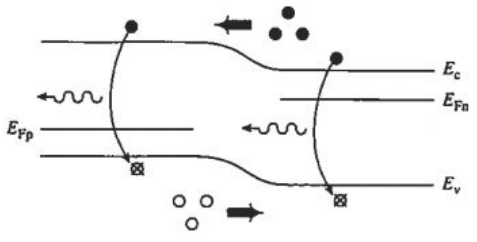

Figure 2. Production of light in an LED resulting from carrier injection in a

forward-biased pn junction diode and subsequent band-to-band recombination [13]

A light emitting diode (LED) is a semiconductor that produces light. When electrons enter the semiconductor, they bond with holes in the substrate and energy is released in the form of photons. With a higher intensity, a longer rise time will occur. Therefore, when lights are dimmed, the long rise time will allow for a longer lifetime for the bulb. However, with higher intensity, more power is needed.

$$P = VI \tag{1}$$

Power Equation

Where P is real power, V is voltage and I is current. With high power in mind, there is a need for high thermal conductivity and wide band gap. A wide band gap allows the LED to sustain higher voltages and run current through the device faster. High thermal conductivity means that it can conduct heat more efficiently. High thermal conductivity combined with a wide bandgap and high critical field are two important characteristics of a semiconductor when high power is a desirable feature.

Light intensity varies as the devices that connect with the LED light bulb move from one location to another. To determine the intensity of the light at multiple distances, the inverse square law formula can be used to calculate these intensities.

$$I \propto \frac{1}{d^2} \tag{2}$$

Inverse Square Law Formula

The strength of light, *I*, is inversely proportional to the square of the distance, d.

Another method of determining intensity is calculating how much power is transported through a unit area. This is known as the Poynting vector.

$$S = \frac{P}{A} = \sqrt{\frac{\varepsilon}{\mu}}\, E^2 \tag{3}$$

Poynting Vector

Where S is the poynting vector, P is the real power, A is the unit area, ε is the electric permittivity, μ is the magnetic permeability and E is electric field. A fundamental solution that is vital when it comes to transmitting bits of information is D'Alembert's solution. For any wave form, the real signals are described as pulses. These pulses can be represented by a superposition of multiple sinusoidal waves. The phase velocity and the frequency of the wave can be related with the following equation:

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{\sqrt{\varepsilon_r}} \tag{4}$$

Phase Velocity

Where v is the phase velocity and c is the speed of light. The relative permittivity, ϵ_r, depends on the frequency of the wave. Therefore, the phase velocity depends on the frequency. Thus, the signal, the pulse, disperses, broadening the pulse signal. This limits the maximum bit rate of a transmission channel, which is an important effect in data transmission.

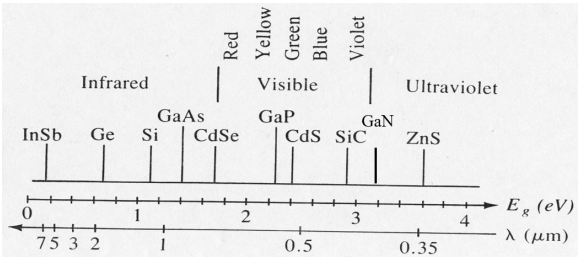

Figure 3. Semiconductor material vs Wavelength size [8]

VI. CONCLUSION

In this paper, the idea is to establish a working LiFi-enable LED system that can be

integrated in hospitals. LEDs used for LiFi technology are the future and can be implemented in any area of work, educational institute, government, or the public. However, in order to generate a network for it, it is important to develop infrastructures and working systems in specific areas, such as hospitals. This system can improve the security of patients information, upgrade the speed of data transmission, and reduce the death tolls due to technical errors. Unlike WiFi, LiFi will have less health concerns, such as radio frequency radiation with WiFi and radio frequency, as well as light already provided in hospitals. With semiconductor technology continuing to improve, data bit transfer will continue to increase in 20 years. With high-speed data rates, more LiFi LED systems can be inserted in many other areas to improve how fast information is transferred and the safety of information being transferred.

For future work, a need for standardization is required and an adaption of LiFi technology needs to be integrated into companies that are using WiFi as a basis for data transfer.

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VIII. REFERENCES

[1] R. J. Szczzerba, "Forbes," 11 February 2015. [Online]. Available: https://www.forbes.com/sites/robertszczerba/2015/02/11/beware-of-these-10-deadly-tech-hazards-in-hospitals/#69901271464a. [Accessed 19 April 2019].

[2] B. Cooper, "Common Problems with Managing a Hospital WiFi Network," SecurEdge Networks, 25 October 2018. [Online]. Available: https://www.securedgenetworks.com/blog/common-problems-with-managing-a-hospital-wifi-network. [Accessed 21 April 2019].

[3] C. Badrick, "3 Reasons Wifi Fails In Hospitals," Turn-Key Technologies, 10 November 2016. [Online]. Available: http://www.turn-keytechnologies.com/blog/network-solutions/3-reasons-wifi-fails-in-hospitals. [Accessed 21 April 2019].

[4] J. Chou, "Machine-to-machine (M2M) communications using short message services (SMS)". United States Patent US9344835B2, 14 July 2011.

[5] D. R. E. G. P. M. Klitenik, "System and method for communication with a mobile device via a positioning system including RF communication devices and modulated beacon light sources". United States Patent US9692510B2, 2014.

[6] 王干兵, "Hospital video terminal and system with intercommunicated internal network and external network". China Patent CN202524503U, 7 November 2012.

[7] 徐继平柏贺, "Digitalized information management system for nursing stations in hospitals and method for realizing same". China Patent CN102592063A, 2012.

[8] LIFI Labs, Inc. (2019). LIGHTING CONNECTiVITY MODULE. US 10,375,804 B2.

[9]Samsung Electronics Co., Ltd., Gyeonggi-do (KR) (2019). Method And Apparatus For Interworking Between Electronic Devices. US 10,172,175 B2.

[10] BOE TECHNOLOGY GROUP CO., LTD., Beijing (CN); K-TRONICS (SUZHOU) TECHNOLOGY CO., LTD., Suzhou, Jiangsu (CN) (2018). MOBILE TERMINAL. US 2018/0116011 Al.
[11] ORANGE, Paris (FR) (2019). Combined illumination and optical communication device. US 10,180,239 B2.
[12] Kaipo Chen, T. (2018). MODULARIZED SMART HOME-CARE LIGHTING DEVICE. US 9,874,334 B2.
[13]R. F. Pierret, Semiconductor Device Fundamentals, Addison-Wesley Publishing Company, Inc., 1996.