Framework for Data Communication in the Hospital using Li-Fi Technology

Hyung Jae Chang

Abstract— In the hospital, there are many medical equipment that are critical to monitor patients' status. For this reason, using Wi-Fi (Wireless Fidelity) is limited (or completely prohibited) especially in intensive care units due to possible interference between Wi-Fi radio frequence and medical equipment operation. To overcome such restrictions, this paper proposes application level framework for data communication using Li-Fi (Light Fidelity) Technology in the hospital. Li-Fi is based on LED light bulb through which data can be transmitted. By using LED lights as a transmission medium, the indoor wireless communication is achived in much faster rate than the one Wi-Fi can provide. As the flickering rate is faster than the human eye can realize, people still can use LED light as a light source for each room. Meanwhile, it doesn't interfere medical equipment operation since Li-Fi uses illumination for data communication.

Index Terms — Framework, Data Communication, Wi-Fi (Wireless Fidelity) and Li-Fi (Light Fidelity).

1 Introduction

IN the hospital, there are many critical care equipment operating to monitor patients' medical status. For doctors or nurses to monitor their patient's status, they have to use their own device, such as smart watch, cell phone or desktop computer, through data communication. If Wi-Fi (Wireless Fidelity) is used (for this data communication) at the same place with medical equipment, electromagnetic interference may occur and this could result in potentially hazardous events related to medical equipment operations [1]. According to van der R. Togt, in electromagnetic interference test with medical equipment, about 20% of the incidents was classified as hazardous or significant [1]. If this happens in intensive care room with critical care medical equipment, it may jeopardize some patients' lives from equipment malfunctioning. Due to this reason, the usage of Wi-Fi connection is limited (even prohibited completely) in the part of the hospital building; in this case, only wired communication channels are used.

To overcome such limitations using Wi-Fi in the hospital, we can use Li-Fi (Light Fidelity) instead. Li-Fi is a new technology that can transmit (exchange) data at high speed using visible light communication (VLC). The prototype of first wirless communication was proposed by Alexander Graham Bell back in 1880 for transmitting sound and human voice over a beam of optical light [2]. Since then, VLC did not get much attention for a while. However, with the advance of technology to make LED (Light Emitting Diodes) off-the-shelf product, it regained an interest from research community.

Li-Fi using LED was originally proposed by Professor Harald Hass at the University of Edinburgh. He, at TED (Technology, Entertainment, Design) conference in 2011, demonstrated the actually operating Li-Fi LED light bulb that transmits HD quality videos [3]. LED is suitable for data communication since it can be modulated faster than other light sources, such as incandescent bulbs and fluorescent lamps [4]. To utilize Li-Fi technology, we need two components: LED light souce and camera. To transmit data through light, the controller controls the flickering rate of the light souce, which is faster than the fuman eye can realize. Then the cemara captures and analyzes the transmitted light as a stream of data.

There are several benefits using Li-Fi technology. First of all, we already have lighting infrastrues built in when the building is constructed. This means all the old bulbs can be replaced to the Li-Fi capable bulbs with existing bulb sockets; of course, the wires to trasfer data in the backbone LAN must be added inside of the ceiling and/or wall. In this sense, using (or updating) Li-Fi technology is very cost-effective. In addition, as the flickering rate of the LED bulb for data communication is much faster than the duman eye can realize, we can use it as a regular light source and the functionality of Li-Fi bulb will be transparent to people in the hospital.

Secondly, current devices, such as cell phones, can be utilized to receive data from the light souces. To tramnit data through Li-Fi using LED, we need LED light source. To receive data through Li-Fi, camera lense is required. Current smartphone is fully suitable and ready to be used for this purpose. For example, Iphone has high resolution camera built in with external flash light. Indeed, Li-Fi capanility is found in IOS (Iphone Operating System) 9.1 firmware by Apple Inc. and this means Apple is considering Li-Fi as a future communication medium for future IOS [5].

Lastly, but most importantly, the data transfer rate through Li-Fi is much faster than that through Wi-Fi. [6] shows that the data transmission rate for Li-Fi is 100 times faster than that of Wi-Fi under a real world environment. Due to the benefits for Li-Fi described above, the technology is best suited in hospital building. To the best of author's knowlodege, there has been no papers published about Li-Fi application related to the hospital.

The rest of paper is organized as follows: Section 2 presents the rationale why Li-Fi could be a suitable replacement option for Wi-Fi in the Hospital building and Section 3 shows the overall framework architecture when we use Li-Fi in the Hospital building. Finally, Section 3 will concludes this paper with possible future works.

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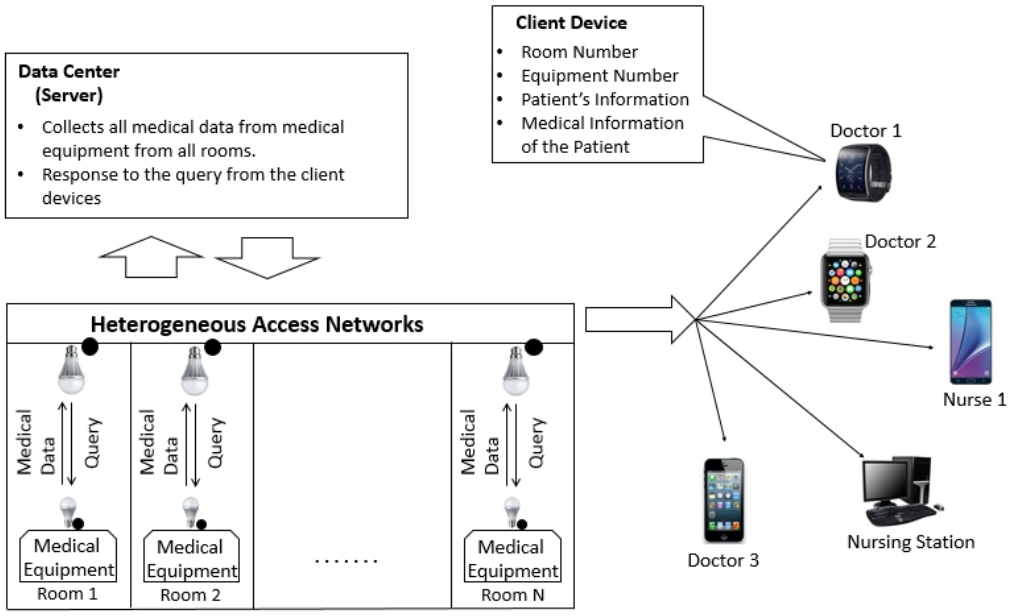

Fig. 1. Architecture of the framework for using Li-Fi in the hospital building with data flow.

2 Why Li-Fi Technology in the Hospital?

Since 2011 when Dr. Hass demonstrated, in TED conference, working Li-Fi LED bulbs to transmit HD quality video streams, researchers have proposed may applications using Li-Fi technology from digital urban infrastrcuture to underwater applications and disaster management [7][8]. However, the scope of this paper is limited to the application of Li-Fi in the hospital building.

Then, why is it good to use Li-Fi technology in the hospital building? There may be several benefits of using Li-Fi instead of using Wi-Fi. **Free of Potential Hazard**: First of all, as described in Section 1, there are potential hazards to use Wi-Fi in the hospital due to possible electromagnetic interference with medical equipment (especially critical care medical equipment in intense care facilities) and this may result a life-threatening medical incident from medice device malfunctioning. However, Li-Fi is free of such incidents as it uses light source for date communication.

Cost Effective: Secondly, all the hospital buildings already have lighting infrastructures. It means, we have all electrical wireling built-in above the ceiling and in the walls. Thus, if all the regular light bulbs are replaced with Li-Fi ready LED light bulbs and some wires from the buls for access networks are installed, there will be no more extra cost needed to realize Li-Fi data communication in the hostipal building.

Fast Speed: Lastly, the speed of Li-Fi is roughly 100 times faster than Wi-Fi; Li-Fi was tested in real world situation by the company called Velmenni that the data can be transferred at 1 Gbps. In the lab test under an ideal environment, 224 Gbps was achieved by the researchers at the University of Oxford [6].

3 Application of Li-Fi in the Hospital

In this section, the overall framework architecture is presented for how Li-Fi technology can be applied to hospital environment.

3.1 Architecture

The overall framework is shown in fig. 1. As shown in the figure, the framework consists of 4 parts as follows;

1. Each room has Li-Fi ready medical equipment and Li-Fi ready LED light blub(s) on the ceiling. Both equipment and ceiling must have bulb and camera as the data communication must be done in bidirection (bulb as a transmitter and camera as a receiver). This is because medical equipment may receive a query from either data center or client devices regarding the patient's live medical status and transmit inquired data. In fig. 1, Li-Fi ready LED bulb and camera are presented as a bulb image and solid black dot, respectively.
2. Heterogeneous Access Network is used as a backbone of the hospital LAN. This is used as a data bus where the data traverses among client devices, data center and medical equipment.
3. Data center is used as a server to store all the patients' medical information and to provide the information to interest groups, such as doctors, nurses and even medical equipment. Secrutiy can be a concern for data center and it is not discussed in this paper as the topic is out of the scope of this paper.
4. Various types of client devices are used to view patients' medical information with proper authentication and authorization check. At the application level in the device, the access control is managed for which each

doctor only can see the information of the patients who are assigned to each doctor.

In each patient room (including intensive care unit), there may be several medical equipment. The equipment is Li-Fi ready (LED light souce with camera) to communicate with Li-Fi LED bulb and cemare installed on the ceiling. There may be one or more bulbs installed in each room depending on the size of the room and the number of equipment. Once the medical data is transferred from medical equipment to camera on the ceiling, the information is first sent to data center through heterogenous access network.

When any of the client device queries on specific patient's information using its own hardware platform (smart phone, smart watch, tablet or desktop computer), data center will send appropriate data to the requesting device based on the query. Theh device may request patient's live medical history. For this, the medical equipment will reply for the query with the live medical information. When the data is exchanged, each information block for each query includes specific information with which room and which equipment it comes from and for which patient.

3.2 Broadcasting Feature of the Network

In hospitals, emergency situation occurs very frequently and this may threaten patient's life. It is very time-sensitive for a responsible personel to react to the emergency calls. The proposed framework architecture can make this possible. As Li-Fi ready light bubs communicate with the medical equipment in real-time, the bulb plays a role as a sensor that detect abnormal condition of the patients. As soon as the buld receives emergency signal from the medical equipment, it broadcasts it to all connected clients devices in the same network to notify such situation to doctors and nurses. As the broadcasted message contains room number, equipment id and patient id, theh client devices of responsible personels will be alarmed

The proposed architecture is independent of the hardware (client devices), but driven by an application installed in the device as shown in Fig. 1. Therefore, if any person has correct application installed in their device with an authority to receive medical information and connected to the same Li-Fi network as LiFi ready bulbs and Data Center, then one can receive emergency call initiated and broadcasted from any of the rooms. Since we have a Data Center in the architecture, we can utilize it to log all the broadcast incidents for future reference.

3 Conclusion

In hospital buildings especially in intensive care units, Wi-Fi usage must be limited (or completely prohibited) due to the interference by radio frequency. If the operation of the medical equipment is interfered, it may malfunction and can jeopardize patients' lives. Thus, in this paper, we propose the framework for using Li-Fi technology in the hospital building instead of Wi-Fi. Li-Fi is a new technology that can transmit (exchange) data at high speed using visible light communication. The working prototype was demonstrated in TED (Technology, Entertainment, Design) conference in 2011 and this implies practicality of the Li-Fi for the real world application.

By using Li-Fi in a hostipal building, we can avoid potential hazards/malfunctionings on the medical equipment due to the interference from the radio frequency that is resulted by Wi-Fi communication. In addition, it is cost effective as we can use current infrastructure by adding few Li-Fi ready components. More importantly, it is faster than Wi-Fi. In addition, the proposed framework architecture provides broadcasting feaster through the network in case of emergency situation when it must be notified to the responsible personnel as soon as possible.

The following topics will be candidates for future extension of this study; efficient locality of the light souces, light source coverage problem and other applications of Li-Fi technology. The research might significantly improve the real world data communication paradigm.

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