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Review Article

HEALTHCARE MONITORING SYSTEMS USING LI-FI NETWORKS

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ABSTRACT

Constant monitoring of patient's health condition in hospital is either manual or wireless fidelity (Wi-Fi)-based system. Wi-Fi-based system becomes slow in speed due to exponentially increased scalability. In this scenario, light fidelity (Li-Fi) finds the places wherever Wi-Fi is applicable with additional features of high speed data network. Apart from the speed factor, Li-Fi is more suitable in hospital application for monitoring the patient's conditions without frequency interference with human body. This paper proposes an application of Li-Fi network in the hospital for monitoring the patient's conditions such as temperature, pressure, heartbeat, glucose level, and respiratory conditions using respective sensors. The collected data from the sensors is transmitted to the sink, and further these data are processed using microcontroller and sent to display unit in the form of graphs or charts. Based on the concept of visible light communication, a prototype model is built with the PIC microcontroller and basic sensors as peripherals and tested it's working. Thus, the application of Li-Fi as a health monitoring system demonstrated experimentally.

Keywords: Health-care monitoring, Light emitting diode light, Medical equipment, Patient condition, Visible light communications.

INTRODUCTION

Light fidelity (Li-Fi) is a revolutionary solution for the high speed data network, proposed by a German physicist Harold Haas. Li-Fi networks support the transmission of data through illumination of light emitting diode (LED) bulb, thereby it is also termed as visible light communications (VLC). In the epoch of internet, there is a continuous urge for faster, secure, and reliable wire-wireless connectivity in all fields, while wireless networks are more preferable in all domestic application in general and health-care application in particular. The reason for depending on wireless network in hospital is the cables which are running over the patient's body interconnecting the devices may cause contamination. Dependency on the wireless internet increases the burden on wireless fidelity (Wi-Fi) technology which, in turn, creates a huge demand for bandwidth and radio spectrum [1]. To reduce the load on Wi-Fi, an alternate mean of wireless internet is Li-Fi finds which find its applications in almost every field, even in vehicle technology [2]. Table 1 shows the comparison of Wi-Fi and Li-Fi based on various parameters.

For a long time, medical technology has lagged behind the rest. The scope for wireless communication in the medical field is set on the rise; there are many devices which work on Wi-Fi such as infusion pumps, defibrillators, lung ventilators, and anesthesia machine. When a doctor is supposed to use magnetic resonance imaging scanners along with infusion pumps, which work on Wi-Fi there results a frequency-overlapping problem. With more and more number of wireless medical devices coming up, utilizing the radio frequency (RF) spectrum increases which lead an electromagnetic interference (EMI) that results in potentially hazardous events related to medical equipment operations [3]. Apart from the interference with medical equipment, an EMI affects human body also in the form of diseases, immune dysfunction, electromagnetic hypersensitivity, etc., and in worst case, it may lead to cancer. Another limitation of Wi-Fi in hospital system is its security issue. Patient information must be private and secure but remain accessible to authorized persons. Hospitals are places where both EMI sensitivity and security of medical details are issues with the uses of Wi-Fi. To combat the above limitations of Wi-Fi in health monitoring system, Li-Fi is used, which is a novel technology for high-density wireless data coverage relieving radio interferences in confined areas [4].

VLC has definite scope in many areas such as smart stores, consumer electronics, defense and security, vehicle and transportation, aviation, hospital, underwater communication, and hazardous environment and it has spread across the regions of America, Europe, and Asia-pacific. The VLC market is expected to grow from USD 327.8 million in 2015 to USD 8,502.1 million by 2020, at a Compound Annual Growth Rate of 91.8% between 2015 and 2020. The global Li-Fi market is expected to exhibit growth at a robust pace between 2016 and 2023. Massive bandwidth owing to the growing RF spectrum crunch, together with a high degree of security and energy efficiency are expected to bolster the global Li-Fi market. Since the technology involves visible light wavelength and not radio waves, it is less likely to have a negative effect on human health. Experts often compare Li-Fi to free space optics as it also utilizes light to transfer data [5] but it cannot be used in the places where it is difficult to lay the optical fiber like hospitals. Parallel working with various EMI devices is feasible with Li-Fi and is also beneficial for robotic surgeries and automated procedures. During surgery, Li-Fi system along with various sensors is needed to get immediate guidance from experts in the therapy by sharing data, videos/live details about the patient for the best results [6].

Thus, a Li-Fi-based health-care monitoring hospital system secure patient's body from attack of many types of disease, as the resistance power of patients, is very low. Not only improving the patient's health conditions but also communications among the physicians and clinicians. Wireless technology with Li-Fi system enables clinicians to monitor patients remotely and give them timely health information, reminders, and support [7]. Li-Fi technology ameliorates medical field to the next level and has a plethora of merits when installed and used beneficially.

Organization of this paper is as follows. The basic architecture of Li-Fi based monitoring system is presented in LI-FI framework. A brief discussion about the proposed prototype model is presented in the section prototype model which is followed by the description of various sensors under the heading of "role of sensors". Extended application of Li-Fi technology related to the proposed paper is highlighted in the following section. Conclusion is derived towards the end of the paper and references are listed.

Table 1: Li-Fi/Wi-Fi comparison

Parameter	Li-Fi	Wi-Fi
Speed	H	H
Range	L	M
Data density	H	L
Security	H	M
Reliability	M	M
Power availability	H	L
Transmit/receive power	H	M
Ecological impact	L	M
Device-to-device connectivity	H	H
Obstacle interference	H	L
Bill of materials	H	M
Market maturity	L	H

H: High, M: Medium, L: Low, Li-Fi: Light fidelity, Wi-Fi: Wireless fidelity

LI-FI FRAMEWORK

The architecture of a Li-Fi-based health-care monitoring system (HMS) is depicted in Fig. 1. The proposed system is highly beneficial but it requires an initial infrastructure, i.e., a built-in lightning infrastructures in hospitals. All the existing bulbs are to be replaced by Li-Fi compatible bulbs and the wires to transfer data, in the backbone local area network must be added inside the ceiling and/or wall. Latest smartphones are compatible for this technology usage. i-phone has high-resolution camera built in with external flash light. Furthermore, a Li-Fi supportable operating system (OS) is found in i-phone OS 9.1 firmware by Apple Inc. Hence, an i-phone can be included in basic infrastructure for Li-Fi networks [8].

Li-Fi networks can be used as fully automated system. Normally doctors and nurses should periodically keep an eye on patient's health condition by taking measurements of blood pressure, heart rate, temperate, respiration rate, etc. In this proposed method, the measurements are made without any human intervention and various patient statistics are also recorded (real-time health monitoring system). Each patient is provided with a tag for their identification and to study their previous medications which can be useful if they are moved to another hospital or medicated by some other technicians [9]. Based on the proposed architecture, a prototype model is built to test the concept of Li-Fi in the medical field.

PROTOTYPE MODEL

The prototype model consisting of transmitter, receiver and various sensors is developed. The hardware setup of interfacing biomedical sensors with Li-Fi board is shown in Fig. 2 and the output in Fig. 3.

Transmitter section

The transmitter section contains one direct current (DC) power supply to supply 5 V DC. DC power supply consists of a step-down transformer for converting 230 V-5V, a bridge rectifier; a voltage regulator LM7805, and a filter capacitor of 1000 mF. Each of the sensors is connected to PIC 16F877A. The PIC16F877A is low power high-performance microcontroller with 8KB in-system flash memory. The special feature of this microcontroller is the presence of in-built universal asynchronous receiver/transmitter, which is used for serial transmission. The signal is transmitted through the Li-Fi transmitter, and the source of transmission is LED. The switching frequency of the LED must be high enough to avoid any flickering that might jeopardize the safety of the human eyes. The modulation scheme implemented in this system is the on-off keying (OOK) non-return-to-zero (NRZ) modulation scheme. OOK NRZ is a part of amplitude-shift keying modulation which represents the digital information through the presence and absence of the carrier wave.

Receiver section

A photodiode is used as a receiver in this section which works as a light to electricity converter. The resulting electric signal would be weak and noisy, hence, it passes through signal processing and amplifications units. An envelope detector and a low pass filter are further used to demodulate the signal from the carrier wave and to remove high-frequency noise respectively. Finally, a voltage comparator is used to transform the signal into digital format, before passing it to the microcontroller for further processing. The transmitter and the receiver section should be placed in line of sight position [10].

The received information can be depicted in the form of a graph to analyze the patient's health by connecting the receiver end to the computer. The health report of the patient can be mailed to the concerned person automatically without any human intervention through the internet.

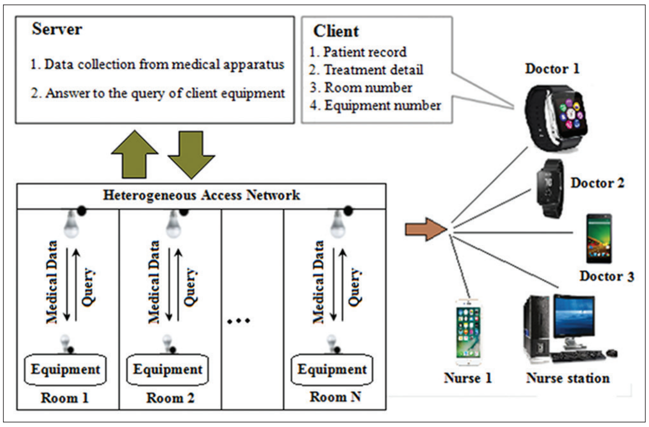

Fig. 1: The proposed system architecture of the health monitoring system using visible light communications transmission

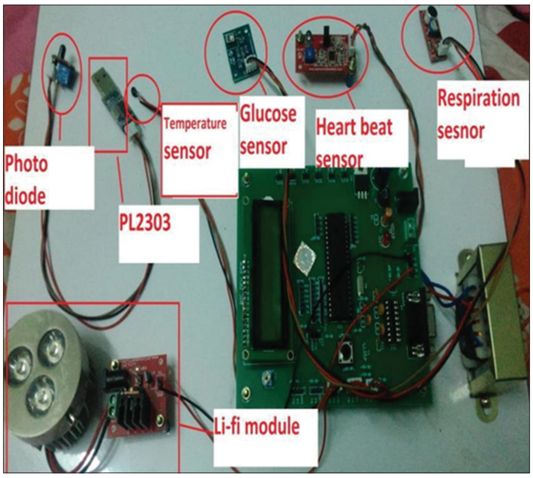

Fig. 2: A prototype model of the proposed system

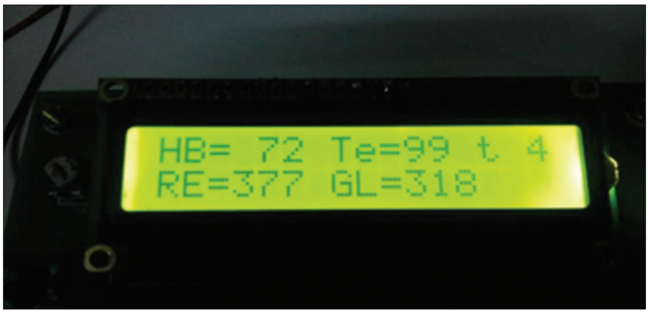

Fig. 3: Liquid crystal display output

ROLE OF SENSORS

The performance of the proposed system is highly dependent on the various sensors used in the system. A brief introduction of the sensors used is presented in this section.

Temperature sensor

LM35 can be used to measure body temperature. It is an integrated circuit temperature sensor which converts temperature radiated by human body into voltage waveform. Fig. 4 shows LM35 DT temperature sensor with its pin detail. The output is voltage waveform which is linearly proportional to the temperature in Celsius.

Electrocardiogram (ECG) sensor

ECG sensor is shown in Fig. 5. ECG electrode is attached to a patient's body during electrocardiogram procedure. Each heartbeat produces an electrical pulse. ECG details are of much help in diagnosing heart conditions. Off late wireless body sensor network for recording high-quality electroencephalogram/ECG utilizing non-contact electrodes are introduced. Future work will focus on miniaturizing and better packaging the electrode as well as reducing the power consumption of the digital and wireless transmitter components [11].

Respiration sensor

The respiration sensor has a small mike, which will amplify weak signals of human breath. Oxygen enters the lungs and then is passed on into the blood. The main way oxygen is carried in our blood is by haemoglobin. The difference in temperature of our breath changes the thermistor's resistance which is used in the sensor. The temperature will be low during inhalation and high during exhalation; this produces current accordingly measuring the lung capacity.

Glucose sensor

Blood glucose sensor is an instrument used for monitoring glucose level in blood. The test is performed by piercing the skin to draw blood which is then placed on a disposable test strip that the meter reads and uses it to calculate blood glucose level. The meter then displays the level in mg/dl.

Here, this sensor works on near infrared spectroscopy concept. The NIR signals are absorbed at slow rate in a weak manner by the glucose in our body. When the finger is pressed on the sensor button, it identifies the depth of the infra-red penetration through the tissues (usually 1-100 mm) and based on the penetration depth of the infrared waves the glucose from the human body can be measured.

EXTENDED APPLICATION

Apart from the routine normal monitoring of patients two very important services are emergency alert mediclaim and robotics surgery.

Emergency alert

Health-care professionals cannot be always readily available near the patient 24×7. In traditional methods, doctors have to be informed in person in case of any abnormality, under worst cases even first aid providence will not be possible. It is very time sensitive for a responsible personnel to react to the emergency calls. Therefore extra efficient high-speed timely alarm should be given to alert medical technicians through an effective HMS. This is made feasible via the proposed system. Patient is fitted with biomedical sensors, which captures the continuous physiological changes in real time and convert them into e-data, then compares it with predefined values or range of values if any discrepancies are noticed, notification will be communicated to the doctors or emergency medical technician staff (nurses and technicians) on their handheld devices. A screenshot of such, generating alert messages is shown in Fig. 6. This framework is independent of the device hardware, specially designed android application or compatible software can be developed and installed through which information could be transferred. The broadcasted information or data contains the room number, equipment id and patient id; these will be available to the client devices of the responsible personnel who is supposed to have the correct application and right authority for access [4,12].

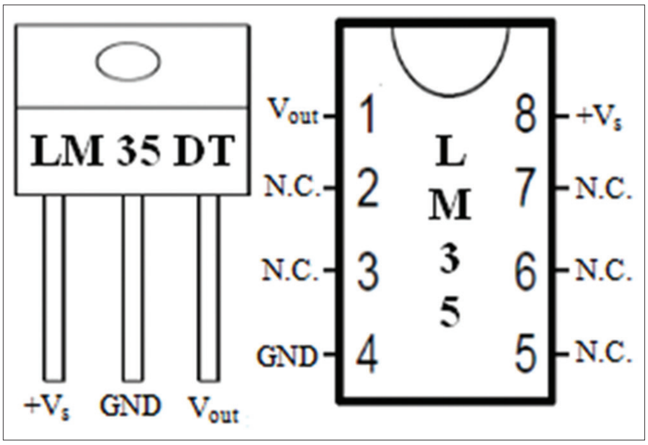

Fig. 4: Temperature sensor LM 35 DT and its pin detail

Fig. 5: Electrocardiogram sensor

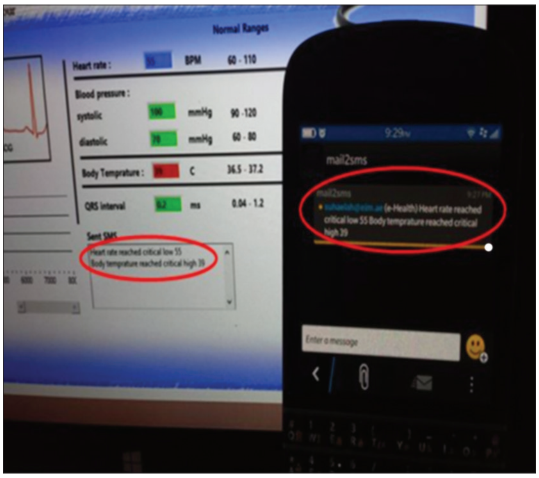

Fig. 6: Generating alert messages

Mediclaim

Health-care providers submit and claim with health insurance (the medical expenses). Before providing services and billing a patient, the hospital staffs should cross check with software in the patient's insurance company, whether the treatments and services offered are eligible for insurance. Medical billing procedures are subjected to continuous changes. Employing a staff for billing can turn out to be expensive and keeping up with these changing scenarios will be difficult, time-consuming and may lead to errors [11,12]. With the help of Li-Fi technology, the billing process can be speeded up to great extent with minimized errors. As data transfer rates are high in prescribed framework (224 GBPS), secured transactions are also feasible. Automated billing system for supermarkets has been proposed with Li-Fi already [13,14]. Every product has a Li-Fi module with a unique ID. The ID's are stored in the server database and the trolley section, then payment proceedings are made through the mobile banking system. At the gate section, cross verification is done, which generates an alarm in case of any unbilled products [15].

The same can be implemented in medical stores, hospital medical billing, insurance, etc., to improve efficiency and to reduce time consumption. Creating the database and fitting everything with Li-Fi module is yes indeed a tedious process, but once the initial setup is launched successfully, then everything can be carried out with much ease and in a jiffy. Life insurance companies can collect the data from the database to settle the medical claims. Health-care providers such as hospitals, insurance agencies, and the government are becoming interested in investing in this area. Cost saving is one of the main factors here since medical errors by doctors bring in lawsuits; patient and hospital management turn out to be very expensive. The amount of time doctors and nurses spend on billing and staffing concerns can be eliminated. This freed-up time can be used to take care of patients [9].

Automated and robotic surgeries

Robotic surgeries and other computerized automated treatments play a key role in minimizing patient trauma and provide better medical outcomes. From gynecology to cardiothoracic N number of surges is carried out. University of Nebraska medical center has led a multi-campus effort to provide collaborative research on mini-robotics among surgeons, engineers, and computer scientist [16]. Besides appropriate manufacturing, adequate control strategies are required to ensure maximal effectiveness and safety. Li-Fi is a good solution to this necessity. Li-Fi-based voice controlled robots have already been introduced in industries; robots are used to avoid any accidents that occurred because of workers mistakes. The voice controlled robot is one of them. By using this robot, we can control the movements of the robot. The instructions of this operator are transmitted toward robot through Li-Fi technology [17] as such surgical robots can also be implemented. VLC will not cause EMIs; time consumption will be less and provide high data security. Automated surgery is a technologically challenging area and it needs fine adaptation to the changing environment of the operating room [18]. Research has to be carried out further to make this system completely feasible.

CONCLUSION

Li-Fi is emerging as more suitable networks in next generation healthcare services in the hospital. In this paper, the application of VLC is demonstrated in HMS using one prototype model. It is shown that Li-Fi network is successfully can be used as a high-speed, secure and safe to human body data communication to provide real-time monitoring of heartbeats, blood pressure, temperature, and various other parameters. Using this technology in medical field makes diagnosis faster and allows to access the internet along with the radio waves based devices. The proposed system is fully automated and it could be a milestone in medical field if successfully implemented.

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