Application of Li-Fi Networks in Patients Monitoring Systems

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Abstract- *As the internet users increase, load over the Wi-Fi also increases, which affects the speed of the network. In this scenario, 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 patents' conditions without frequency interference with human body. This paper proposes an application of Li-Fi network in hospital for monitoring the patients' conditions such as temperature, pressure, heartbeat, glucose level and respiratory conditions by 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 as patients' monitoring system is demonstrated experimentally.*

Keywords- Li-Fi, Patient Monitoring System, Visible Light Communications, PIC16F877A, UART, Keil C Compiler, LM35, LCD

I. INTRODUCTION

Li-Fi, called Light Fidelity, is a revolutionary solution for high speed data network, proposed by a German physicist Harold Haas. Li-Fi networks support the transmission of data through illumination of 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 over wireless network in hospital is the cables which are running over the patient's body interconnecting the devices may cause contamination. Dependency on wireless internet increases the burden on 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 finds its applications in almost every field, even in vehicle technology [2].

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 anaesthesia machine. When a doctor is supposed to use MRI 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 RF spectrum increases which leads an electromagnetic interference that results in potentially hazardous events related to medical equipment operations [3]. Apart from the interference with medical equipment, an electromagnetic interference affects human body also in the form of diseases, immune dysfunction, EM 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 patient's monitoring system, Li-Fi is used, which is a novel technology for high density wireless data coverage relieving radio interferences in confined areas [4].

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 negative effect on human health. Experts often compare Li-Fi to Free Space Optics (FSO) 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 fibre 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 patients' monitoring hospital system secure patients body from attack of many types of

disease, as the resistance power of patients are very low. Not only improving the patients' 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 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 section II. A brief discussion about the proposed prototype model is presented in section III which is followed by the description of various sensors in section IV. Software part is out of scope of this paper. However the challenges about the programming language is introduced in section V. Associated application of PMS is explained in section VI and concluded in section VII followed by the references.

II. LI-FI FRAMEWORK

The architecture of a Li-Fi based patients' monitoring system is depicted in in Fig. 1. The proposed system is highly beneficial but it require 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 LAN must be added inside the ceiling and/or wall. Latest smart phones are compatible for this technology usage. i-phone has high resolution camera built in with external flash light. Also a Li-Fi supportable OS is found in IOS (i-phone Operating System) 9.1 firmware by Apple Inc. Hence an i-phone can be included in basic infrastructure for Li-Fi networks [8].
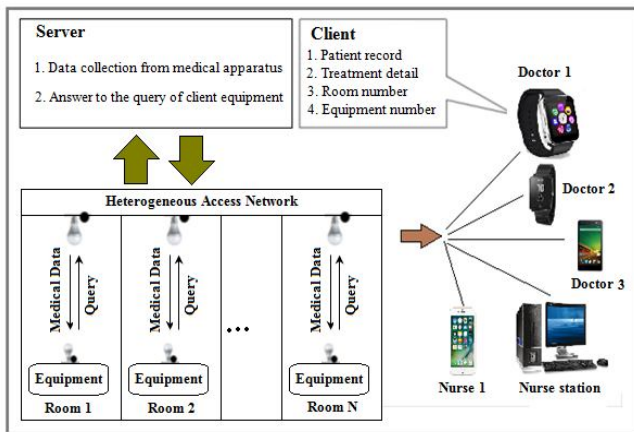

Fig. 1.The proposed system architecture of the health–monitoring system using VLC transmission

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 medical field.

III. PROTOTYPE MODEL

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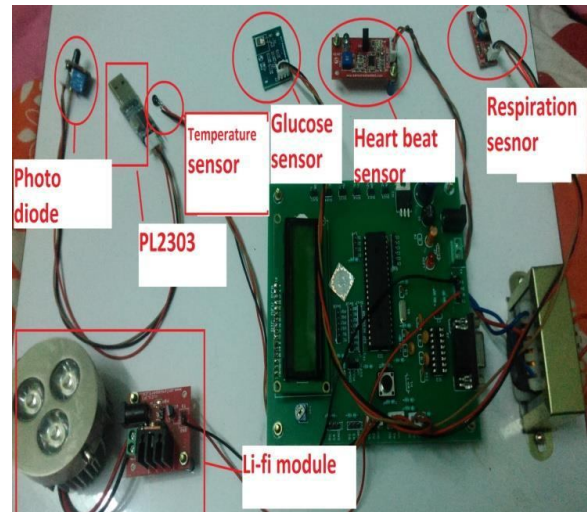

Fig. 2. A prototype model of the proposed system.

Transmitter Section

The transmitter section contains one DC power supply to supply 5V DC. DC power supply consists of a step down transformer for converting 230V to 5V, a bridge rectifier; a voltage regulator LM7805, and a filter capacitor of 1000mF. 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 UART, 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 (ASK) modulation which represents the digital information through the presence and absence of the carrier wave.

Receiver Section

A photo diode 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 graph to analyze the patients' 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.
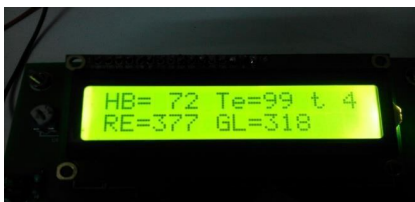

Fig. 3. LCD Output.

IV. WORKING OF THE SENSORS

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. Figure 2 shows LM35 DT temperature sensor with its pin detail. The output is voltage waveform which is linearly proportional to the temperature in Celsius.

ECG sensor

ECG sensor is shown in Fig. 3. ECG electrode is attached to a patient's body during electrocardiogram procedure. Each heart beat produces electrical pulse. ECG details are of much help in diagnosing heart conditions. Off

late wireless body sensor network for recording high quality EEG/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].
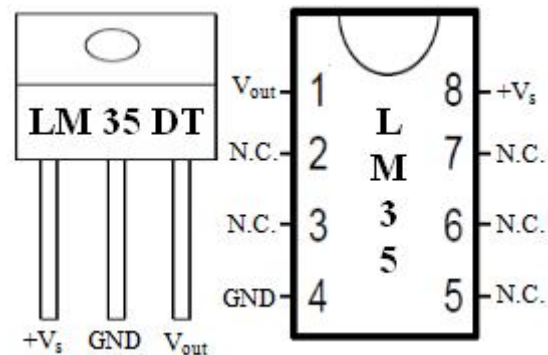

Fig. 4. Temperature sensor LM 35 DT and its pin detail.

Fig. 5. ECG sensor.

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 breathe 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 to 100 mm) and

based on the penetration depth of the infrared waves the glucose from the human body can be measured

V. PROGRAMMING CHALLENGES

Coordination of a diverse array of sensors, active tags, handheld computers, and fixed terminals in this proposed frame work requires a cohesive communication and programming model to underlie the system's operation. Existing software for sensor nodes is in a very low-level and does not provide higher-level services such as discovery, naming, security and data delivery within a common framework [9].

VI. EXTENDED APPLICATION

Apart from the routine check up and normal monitoring the patients, two very important services are associated with patient's monitoring system: Emergency alert Mediclaim and robotics surgery.

Emergency alert

Health care professionals cannot be always readily available near the patient 24x7. 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 patient monitoring system (PMS).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 & technicians) on their hand held devices. A screenshot of such, generating alert messages is shown in Fig. 5. 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]

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 minimised errors. As data transfer rates are high in prescribed framework (224 GBPS), Secured transactions are also feasible .Automated billing system for supermarkets have been proposed with Li-Fi already .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 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. Healthcare 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 law suits; 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].
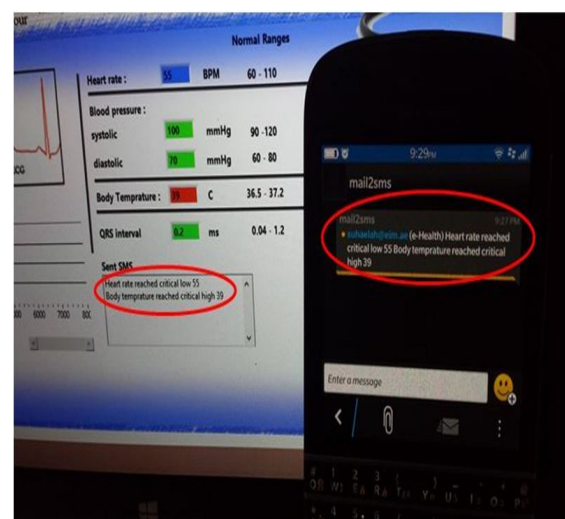

Fig. 6. Generating alert messages

Automated and robotic surgeries

Robotic surgeries and other computerized automated treatments play a vital role in minimizing patient trauma and provide better medical outcomes. From gynaecology to cardiothoracic N number of surges is carried out. University of Nebraska medical centre 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 towards robot through Li-Fi technology [17] as such surgical robots can also be implemented. VLC will not cause electromagnetic interferences; time consumption will be less and provide high data security. Automated surgery is a technologically challenging area; 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.

VII. CONCLUSION

In this paper, we have demonstrated the application of VLC in patient's monitoring system 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 heart beats, blood pressure, temperature and various other parameters. Using this technology in medical field makes diagnosis faster and allows to access internet along with the radio waves based devices. The proposed system is fully automated and it could be milestone in medical filed if successfully implemented.

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