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IoT Based Health Monitoring System with LoRa Communication Technology

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***Abstract*— Supporting sensors integrated with IoT healthcare can effectively analyze and gather the patients' physical health data that has made the IoT healthcare ubiquitously acceptable. The continuous presence of the healthcare professionals and staff as well as the proper amenities in remote areas during emergency situations need to be addressed for developing a flexible IoT based health monitoring system. Development of IoT based health monitoring system allows a personalized treatment in certain circumstances that helps to reduce the healthcare cost and wastage with a continuous improving outcome. We present an IoT based health monitoring system using the MySignals development shield for Arduino Uno. Evaluating the performances and effectiveness of the sensors and wireless platform devices are also the aim of the project. MySignals enables multiple sensors such as temperature, ECG, oxygen saturation and pulse rate to gather the physical data. The aim is to transmit the gathered data from MySignals to a cloud or pc by implementing a wireless system with LoRa. The results show that MySignals is successfully interfaced with the ECG, temperature, oxygen saturation and pulse rate sensors. 36.5-37.5^{0}C body temperature, 60-100 bpm pulse rate, and 96-99% oxygen saturation have been experimented with confidence interval approximation of 95%, 99% and 99%, respectively. The communication with the hyper-terminal program using LoRa has been implemented and an IoT based health monitoring system is being developed in MySignals platform with the expected results getting from the sensors.**

Keywords*— IoT healthcare, biomedical sensors, MySignals, LoRa

I. Introduction

Continuous and long-term health monitoring system are essential in healthcare environment nowadays to make the involved process efficient and reliable; to provide peace of mind to the patients by ensuring complete medical care. Internet of Things (IoT) is a fast-growing worldwide network of interconnected variety of objects that supports many input-output devices, sensors and actuators based on standard communication protocol [1, 2]. A large number of applications are in the development process because of the IoT potentialities, of which quite a few numbers of IoT applications are being deployed or developed for our society. These autonomous quality IoT applications are helping to improve our daily lives [3]. In near future, IoT for healthcare will become a stable solution for the healthcare system. The IoT has a diversity of application domains in which IoT for healthcare is still in the top of the research because of its potentiality [4]. Besides, developing technologies of IoT such as (Radio frequency identification)RFID, cloud computing, wireless network technologies (BLE, Wi-Fi, ZigBee) and (Low power wireless area network) LPWAN technologies like LoRa and SigFox are promising in terms of the IoT application development in a large scale and they are contributing to improve the device connection to the internet as well as the efficiency of the IoT application operation.

Nowadays, one of the top challenges that every country is facing is healthcare. In developing countries, the feasible solution for reducing the expenditures of chronic diseases and disabilities is the healthcare monitoring system because heath organizations are transforming themselves into more efficient, coordinated and user-centered systems [5]. To address the health issues, the Internet of Things (IoT) offers a world of networked devices, cloud based applications and services, with diverse cooperation mechanisms based on the confluence of a right standardization, efficient wireless protocols, improved sensors, cheaper and low-power microprocessors and wireless technologies [6]. Besides, LPWAN technologies are taking the place to enable the new human-centric health and wireless monitoring applications [7].

TABLE I. COMPARISON AMONG COMMUNICATION TECHNOLOGIES [8]–[11]

Network Technologies	**Topology**	**Radio Frequency (MHz)**	**Data Rate**	**Range**
BLE	Adhoc	2.4 GHz	1 – 2 Mb/s	10 m
ZigBee	Mesh	868.3 MHz, 902-928 MHz, 2.4 GHz	0.02-0.25 Mb/s	100m
Wi-Fi	Star	2.4 GHz	11 Mb/s - 10 Gb/s	<1 km (MSC10, 1MHz)
SigFox	Star	862 – 928 MHz	100 - 600bps	10 km
LoRa	**Star**	**860 – 1020 MHz**	**290bps – 50Kbps**	**15 km**

TABLE I represents the characteristics of different network technologies for IoT. It is noticeable that, LoRa has a high communication range with lower data rate which is the best choice for IoT based healthcare system because of its specification that ensures the perfect interoperability between the IoT objects. In this paper, we will present an IoT based healthcare system with LoRa communication technology that is applied to different biomedical sensors with a MySignals development platform.

II. Related Work

LoRa is always different compare to other short-range sensor network technologies such as Bluetooth, ZigBee, Wi-Fi etc. and it provides a unique set of features including wide area connectivity for low power and low data rate devices. The existing IoT based healthcare issues including high cost communication links with 3G/4G, data privacy and ignorance of monitored health parameters is now a matter of concern. Many deployments and proposals about the solution of these issues have been made where it is shown that LoRa have the ability to solve all of these issues by integrating medical sensors, cloud and gateways. LoRa in mesh networking for large area monitoring application has been developed by Lee et.al [12]. They deployed 19 LoRa sensors in mesh networking devices to identify the Packet Delivery Ratio (PDR) by comparing with a star-topology networking device. The result shows that mesh networking devices achieved 88.49% where it is 58.7% for star-topology networking devices. A proposal has been made by Mdhaffar et. al [13] indicating that the usage of LoRa sensors in medical sector to monitoring patient can solve the aforementioned issues. Three steps are proposed including getting the patient physical metrics from medical sensors, transmit the data through LoRa sensors and gateway, and send the data to the cloud for further proceedings of medical records. Diabetes and arterial hypertension have been measured through this system, but it is not capable to get the continuous medical data that hinders the evaluation of ECG data.

Long coverage area is one of the main characteristics of LoRa sensors. Many applications have been tested within a large geographical and indoor areas. The performance of LoRa sensors in the indoor areas are measured by Petjjrvi et. al [14]where the target was to check the hypothesis of health monitoring applications. The sensor nodes are operated with various physical layer settings of LoRa sensors. The results of the experiment show that the sending data amount may differ up to 200-fold which indicates the efficiency of selecting LoRa sensors in terms of indoor health monitoring. For the large area coverage area, an aforementioned developed framework indicates that the data transmission works perfectly using LoRa sensors with a low power consumption although the security issues are not mentioned [12].

TABLE II COST ESTIMATION COMPARISON AMONG LPWAN TECHNOLOGIES [15]

	Spectrum cost	**Deployment cost**	**End-device cost**
NB-IoT	>500 M€ / MHz	>15000€ / Base Station	>20€
Sigfox	Free	>4000€ / Base Station	<2€
LoRa	Free	>1000€ / Base Station	3-5€

TABLE II represents the comparison among the LPWAN technologies in terms of cost estimation with spectrum cost, deployment cost and end-device cost, respectively.

III. Development Methodology

One of the core components in this project is the MySignals which is an e-health monitoring development platform working in conjunction with the Arduino Uno. MySignals can connect and measure upto fifteen sensors. Biomedical sensors like ECG sensor, body temperature sensor, and oxygen saturation and pulse rate sensor are used with the MySignals platform (Fig. 2).

Fig. 2. Biomedical Sensors

To transmit the measured health data wirelessly to the cloud, LoRa communication technology is used, which is a new, private and spread-spectrum modulation technique that allows sending data at extremely low data-rates to extremely long ranges that is shown in Fig. 3.

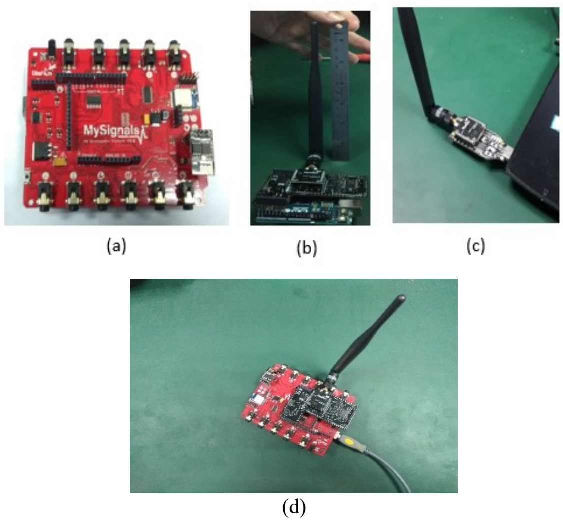

Fig. 3. (a)MySignals board (b) Arduino interfaced with multiprotocol shield and LoRa (c) LoRa gateway consisting of LoRa module and Waspmote gateway (d) Connected MySignals with LoRa and Arduino

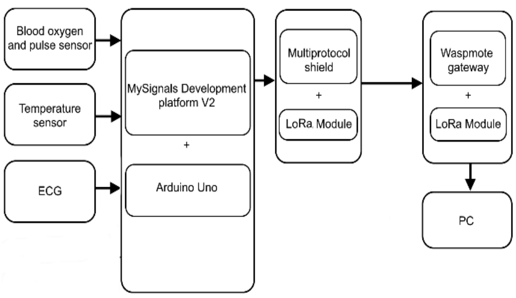

Fig. 4. Block diagram representing the overall system

Fig. 4 represents the overall block diagram where the development process of the health monitoring is given. Biomedical sensors are connected to the MySignals and Arduino Uno to collect the health data. The collected data then transfer via LoRa module and Waspmote gateway to the personal computer. One hyper-terminal named RealTerm is used to connect with the Lora modules and to send and receive packet data with a specific baud rate due to confirming the data is transferring successfully.

IV. Results and Discussion

The analysis is aimed at evaluating the performance and effectiveness of the sensors and the wireless platform to ensure the suitability of the devices in an IoT based health monitoring system. The ECG results obtained from sensor show a normal heart rhythm of the test subject. The body temperature is shown 35^0c which is a normal data rate for human body. The blood oxygen saturation and pulse rate sensor are a simple and non-invasive device to check for percentage of oxygen in the patient's blood stream and pulse rate. The normal percentages for blood oxygen are around 96% to 99%, any lower than 90% could be an indication of disease. The results shown was 35° Celsius where normal body temperature would 37° Celsius shown in Fig. 5.

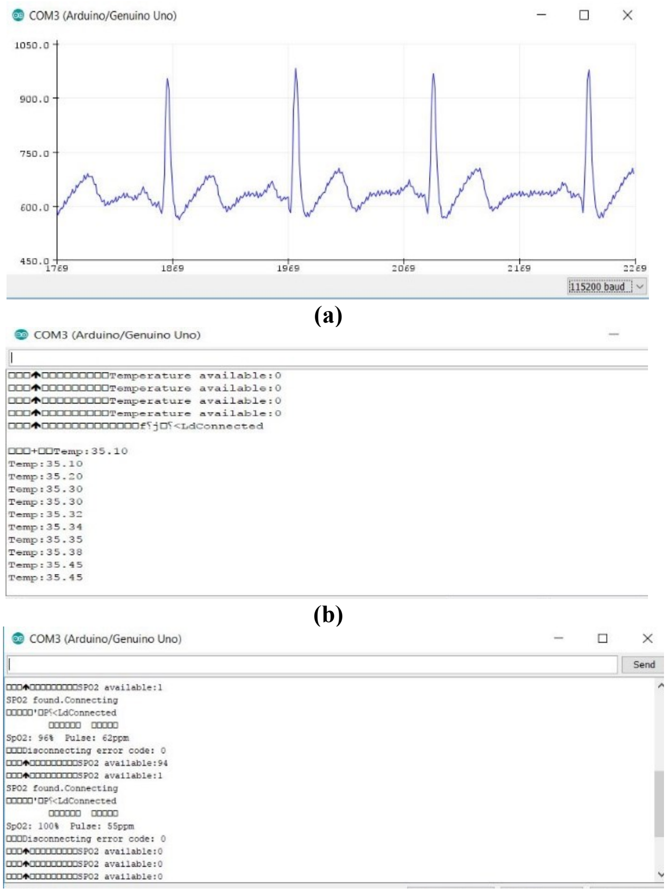

Fig. 5. (a) Serial Plotter ECG Reading (b) Temperature & (c) SpO_2 Readings from Serial Monitor

Fig. 6 represents the results displayed on Realterm which is a terminal program to read the serial data coming from the COM port shows two different messages repeating which are the Arduino interfaced with the multiprotocol shield and LoRa module.

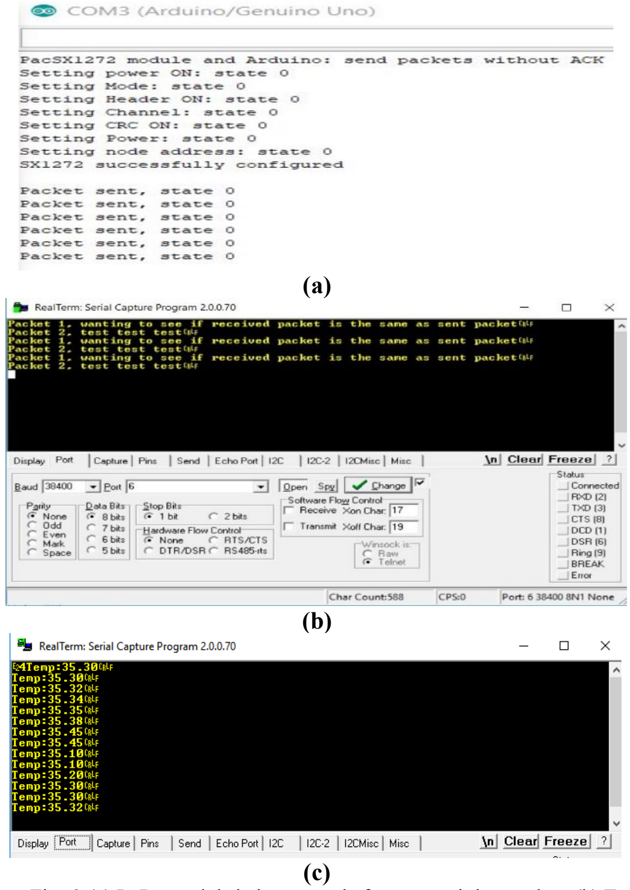

Fig. 6. (a) LoRa module being set up before transmitting packets (b) Test packets received using Realterm (c) Sensor data receiving using LoRa.

TABLE III. RANGE VS TRANSMISSION TIME

Channel Number	Central Frequency	Range (m)	Transmission time for a 100-byte packet sent (approximate)	Power consumption (mA·ms/1000)
CH_01_900	905.24 MHz	1	700	28
CH_01_900	905.24 MHz	3	1000	40

The LoRa transmission and receiving range in terms of distance has been analyzed and shown in TABLE III. It is noticeable that the transmission and receiving time is high due to the increased distance. It also increases the energy consumption rate due to the range and slower data rate. With a minimum range, the data rate is faster and shows lesser energy consumption.

V. Conclusion

This paper presented an overall healthcare system that is performed by biomedical sensors, MySignals and LoRa communication. MySignals is successfully interfaced with ECG, temperature, pulse rate and oxygen saturation sensors to produce vital signs for medical applications later. The LoRa module has been installed and configured to enable communications with a terminal program. The overall performances of the system are effective in terms of collecting human body data that is a suitable solution for IoT based healthcare.

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