Remote Health Monitoring System through IoT

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***Abstract*—Remote health caring of patients at home is increasing with the popularity of various nature of mobile devices that has developed to enable remotely caring. The cloud as well as IoT (Internet of Things) and the mobile technologies make it easier to monitor the patients health conditions by sharing the health information to health care teams such as doctors, nurses and specialists. However the guardians of the patients can be anxious about their patients when they are in work. By ensuring guidance awareness about the patients, it can bring more liability of the hospital management. We have demonstrated a health care system for hospital management to allow guardians along with doctors to remotely monitor health conditions of patients via internet. Remote monitoring and guidance awareness by sharing information in a authenticated manner are the main focus.**

***Index Terms*—Health Monitoring, IoT, e-Health Sensor, Arduino, Phidgets Sensors.**

I. INTRODUCTION

At present Internet has became a part of our daily life. Internet connected devices are becoming more available, it will be harder to imagine that the internet we use today to reach people, find information and assist us in our daily live with innovative services will not be extended toward creating value out of such increased availability of connected objects[1][2]. The Internet of Things (IoT) has given a wide set of predefined services and applications.

Internet of Things(IoT) is such when the internet and networks are mashed up. According to infrastructure, IoT is the combination of embedded electronics, sensors, software and connectivity and sometimes it is called internet of everything. Heterogeneity of interconnected objects are responsible for exchanging data those are interconnected between pcs, human to human, human to things, things to things[17]. The data can be accessed using the facility given from the magnitude of internet from any place, any time. So health data can be remotely accessed with the help of IoT. In this sense we have developed a prototype for collecting health data from patients as human to things and the health units accessed the data to supervise the patient's state any time remotely.

Almost people of all ages are using mobile devices such as smart phones and tablets for using various applications because of being advanced mobile technologies. As health is one of the biggest issues in the smart world so remote monitoring in everything is becoming popular. Availability of internet it is now becoming easier to use mobile technologies

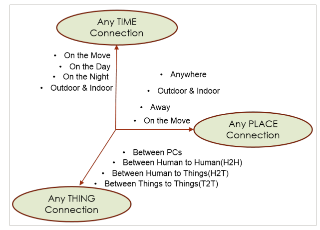

Fig. 1: Infrastructure of IoT[17]

for medical applications. A user can simply connect a health monitor via a mobile device to develop his or her own personal health[3]. There is currently strong need of advance in the field of health information[4].

Nowadays the need for the sharing of health data between health care teams and family members is increasing. It provides of safer and better health outcomes of the patients. Besides the professionals, guardians can get a complete overview of medical history of the patient. Sharing health information is also a key to lower health care costs[5].

When a patient is admitted into hospital the guardians are anxious about their patients and can't continue their works for their mental stress. On the other hand it is also possible to monitor health condition of the disabled patient remotely. Giving the information to the guardians will make the management units of hospital more responsible and liable about their works. Hospital managements are using huge machines to measure health data. We can easily measure 9 types of health data using e-Health Sensor Platform for Arduino and Raspberry Pi[6][15]. It can decrease the cost of health monitoring and also the space of room. We have tried to develop a system for the hospital management to share the information to the health units and guardians for remotely monitoring through internet. In order to do that, the information of health conditions of the patients is need to store into cloud (reliable domain). For the security issues a role based user authentication system is available in the system to access the information [7].

In our work, we have implemented a small prototype of our proposed system to improve the performance and functionalities of the health caring unit to take immediate decision and continuously update patients information which can be viewed

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remotely. Our main contribution is

- Workflow of the whole system: We have tried to demonstrate a work flow of processing the patients health information and environment condition, storing information in the live database. On the basis of this stored data the health monitoring unit can take decision about a patient as well as his guardian can get live information about his patient.

- Integration of the technologies: We have developed a prototype for health monitoring unit with the help of IoT related technologies e-Health sensor V2 for measuring patients health information which interfaced with Arduino, Phidgets sensor shield for measuring environment condition, data storage, and a web application has been developed using PHP programming language for remotely view patients condition. Maximize the collection of health data at a time via Arduino and send it to the server is the most challenging issue and we have found a solution; that's we are able to send maximum 273 of health data at a time form Arduino to server.

The remaining part of the paper is created as: Section II provides System description, Section III provides details of implementation, and finally results and discussion, concluding remarks are presented in Section IV and Section V, respectively.

II. System Description

Basically a hospital management consists of some groups of experts such as doctors, nurses, higher authorities etc. In a busy day the full units have to be very careful about the health condition about their patients. But it is much tough to take the appropriate action when the patient are many in number. And also the cost for the medical purpose is high for the huge machines like ECG machine. Each machine can measure each type of data only. It takes also huge space. The management units store the health data in written. But they can easily use cloud for unlimited storage with low cost. They can consult with specialist anytime from anywhere they want. Hospital management can't provide patient's health information to their guardians all-time. They provide only visiting hours to the guardians. Using this system they can easily monitor more patients and give proper treatments to the patients. The guardians can also get the health information instantly.

A. Phidgets Interface kit

Phidgets Interface kit receives analog input which can measure the continuous quantities like as temperature, humidity, position, pressure, etc. This kit allows extensive variety of sensors which can be connected directly with this kit using cable included with the sensor[16].

1) Accelerometer : The Phidget Accelerometer is a accelerometer that measures 3 gravitational(29.4m/s2) change per axis having three axis(x,y,z). This sensor can measures both dynamic acceleration named vibration and static acceleration named gravity or tilt[16]. The data are taken from this sensor are as decided below

x-axis	y-axis	z-axis	Patients condition
×	-	-	Sitting
×	×	+	Lying
×	×	-	Fall down

TABLE I: Combination of axis for determining patient's physical state(× means don't care).

2) Touch Sensor: A binary result such as Touch Detected or No Touch Detected is the output of the Phidgets touch sensor. Touch is detected when patient is regularly using the sensors or patient is in touch of sensors[16].

3) Light Sensor: Precision light sensor measures human perceptible light level in lux; its measurement range is from 1 lux to 1000 lux of the living environment of the patient. Firing activities are measured by this sensor[16]. Here firing level of 0 to 30 is considered as darkness, more than 30 to 100 is considered as dim light and more than 100 is considered the daylight.

4) Humidity and Temperature Sensor: Humidity sensor measures relative humidity from 10% to 95% with a typical error of 2%RH at 55% RH on the contrary temperature sensor measures ambient temperature in the range of -30^{o}C to +80^{o}C with a typical error of 0.75^{o}C in the 0^{o}C to 80^{o}C range. The temperature sensor component is rated at -40^{o}C to +100^{o}C[16].

B. E-Health Sensor Shield kit

The e-Health Sensor Shield approves Arduino and Raspberry Pi users for causation of biometric and medical applications which is used for measuring health condition through using different sensors. All this information can be used to monitor in real time the condition of a patient or to get sensorial data in order to be subsequently analyzed for medical diagnosis. All this biometric information which is gathered by this kit; can be sent through wireless using any of the 6 connectivity options available Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4 and Zigbee[6] depending on the application. This E-Health Sensor Shield kit also ables to make interface with Arduino and RasperBerry board for making communication with personal computer[6].

1) E-Health ECG Sensor: The electrocardiogram is such a diagnostic tool that regularly measures the electrical and muscular functions of the heart. Normally an ECG machine uses 12 electrodes, but this sensor only 3 electrodes for generating patients ECG signal because, this 3 electrode create a triangle around the heart and can receive the information form heart position V1 to V5[6]. Besides this ECG sensor is self-configurable. A user can measure a patients ECG data at any interval he likes. But minimum data interval is one microsecond when this sensor is programmed to make interface with Arduino UNO. But, as comparing with normal sinus rhythm rate[18] this ECG sensor is programmed to get data after each 8 millisecond interval. The Arduino can receive maximum of

273 data of 8 millisecond interval each at a time as it's buffer size is fixed. When the buffer size of Arduino is full then it push the data stream to PC through COM port.

2) E-Health Body Temperature Sensor: Body temperature sensor measures the temperature level of a patient. When a person get sick his body temperature do not remain constant as natural. The reason is that various diseases are accompanied by when characteristic changes in body temperature. Similarly, body temperature allows to monitor of the motion of certain diseases, and a physician can easily evaluate the efficiency of a treatment[6].

C. Arduino UNO

Arduino UNO is a microcontroller which is based on ATmega328. To support as a microcontroller it contains everything it needed. Such that it has 6 analog inputs, 14 digital input/output pins, a 16 MHz ceramic resonator, single USB connection, a power jack and a reset button. Simply the microcontroller can be connected to a computer with a USB cable or an AC-to-DC adapter or battery to get started[15].

D. System Architecture

We have proposed health monitoring system includes patients, health monitoring unit, cloud for data storage and guardians with the help of some hardware units, various sensors and devices with internet connection. The system functionality is divided into three modules. 1) Sensing 2) Main module and 3) Interaction. Sensing module is for sense the state of the patient. Main module is for collecting data via sensing module and for data storing into the cloud. And lastly is the user interact with the system via interaction module.

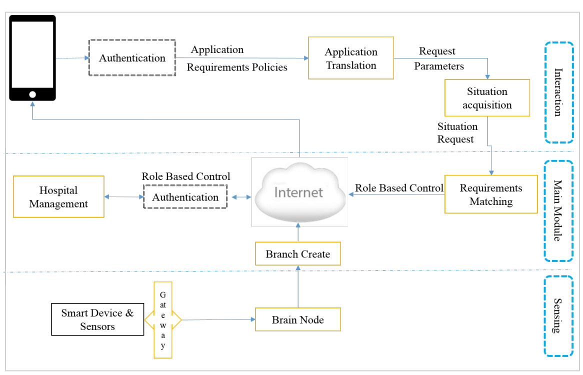

Fig. 2: System Architecture

1) Sensing module: sensing module consists of some sub-modules called sensors and brain node. Sensors are for perceiving health data from the patient. And this perceived data are transmit form sensors to brain node through gateway. All collected data are stored into temporary memory of sensing module called brain node. After some time limit brain node transmits a set of data to main module.

2) Main module: Branch creation, request matching and data base which is live in internet are the sub module in the main module. The data base is for permanent storage of data. Data in branch node is distributed into some different branch. This branch are stored in database through internet. Request taken from the user are matched with the storage having some role based authentication process. On the other hand hospital management ensure the patients entry. They also need to follow role based authentication process.

3) Interaction module: Application translation, situation acquisition are the su-module in interaction module. Here the situation parameter is date, time, location etc. and application requirements are patients information. The authenticated user interact with the system by requirement matching and application gives access permission to interact with the system.

E. System Flowchart

There are three modules in our system as we have described before. At the starting of the main module, the monitoring system collect the data via brain node. If previously a patient id is given then the system create branch and store the data to the cloud, if not then system waits randomly for input of the patient's ID for which respect data will be stored in cloud. In the meanwhile if stop command is given then the system will go to the end and stop storing data to the database.

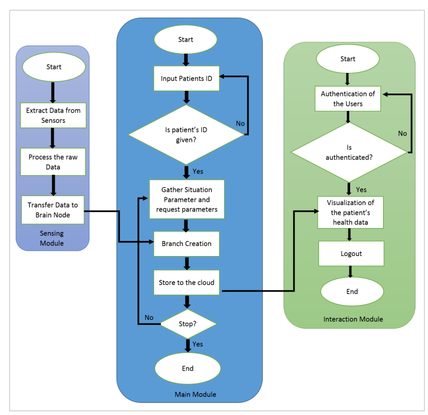

Fig. 3: Flowchart of complete system

In the interaction module only an authenticated user will be able to see the information of his patient. This module directly access the data from cloud. If he ends his session he again need to verify to interact with the system again.

III. Implementation

A. Implementation of sensing module

A patients health condition is measured in the sensing module. This module is the key element of the system. Smart sensors are connected with human body for sensing and generating the raw data. The e-Health sensor internally uses some filtering mechanism to remove the noise and digitize the measurement[6] and send output via Arduino digital I/O port. Arduino itself receives the data via I/O port as a brain node.

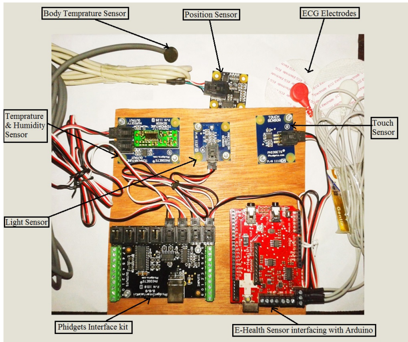

Fig. 4: Implementation of Sensing Module

B. Patient's activity with the system

For testing the functionality of the proposed system, the developed prototype is applied upon patients. As in Fig.4 the ECG sensors need to set up any position of the body which will make a triangle with its electrode on all direction of heart to measure the electrical and muscular functions of heart through the heart position V1 to V5. And the body temperature sensor need to keep in touch with patient's skin to determine the temperature level, besides the accelerometer need to attach with patient to determine whether patient is sitting or laying or fall down. Also there is a touch sensor is used to detect whether the patient is using the module or not. The environment sensors are just need to keep inside the room to represent environment condition to understand in which environment patient is staying as environment plays an important role for patients.

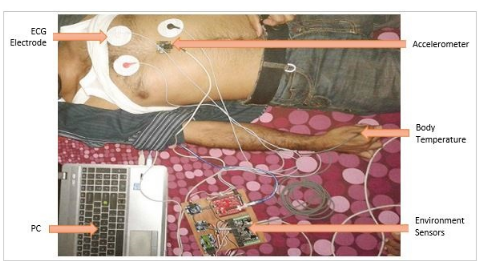

Fig. 5: Patient's activity with the system

C. Display in Desktop Interface

A Windows based desktop application is developed to collect the health data from the smart sensors via COM connection and represent the health data for visualization for locally monitoring. This desktop based application is developed using Microsoft Visual Studio 2012. This application creates the branch of health data and send the data for storing in database through the TCP/IP protocol over internet.

D. Data Storage

A UNIX based server receives sample data through TCP/IP packets at the gateway encapsulation. A web application is developed which is running at the server to receive that TCP/IP packets and store them in the relevant MySQL database. There are 4 tables in the database; user authentication, patients health data, patient's room environment and authentication. The TCP/IP packets which transmits are added to the table patient's health and room environment. This web application is developed with web programming language PHP and data transmission are written in C#.

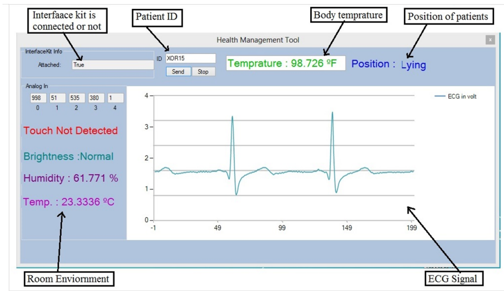

Fig. 6: Implementation in desktop interface

E. Display in Web Interface

A patient's sample health data can be accessed from the database hosted in the server. A person must be authenticated as which role he is accessing the data. The web interface is divided into two section, one for the health management unit and another for patients guardian to get update about patient through role based access control[7]. The sample data in the web application is represented as time series as the data is measuring in specific time interval. The web interface is developed using Java Scripts HTML5 and PHP.

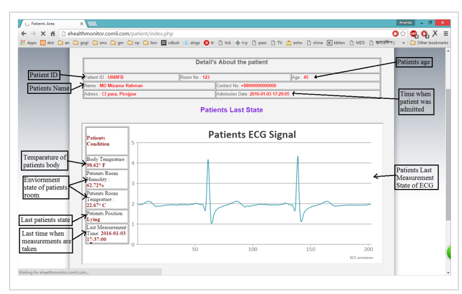

Fig. 7: Display in web interface from a patient's panel.

IV. Results and Discussion

The target of the proposed system is to determine the acceptance, validity and usability. So system has been tested with real patients in medical environment in Khulna University Medical Center, Khulna, Bangladesh. The experimental result are shown below with picture that is taken during experiment. The acceptance, validity and usability test are evaluated by some questionnaires. Also data transfer and response time of the system are analyzed.

A. Data Transfer and Response Time of complete System

As we have used different types of sensor and storing them in remote database so response time of the sensor plays a vital role here. Response time of the system largely depends on 3 major times. They are
1) Times needed to getting data from sensors and sending to main module, rt_s_m(t)
2) Times to send data from main module to Internet, rt_m_i(t)
3) Times needed to visualize data from web Storage, rt_i_w(t)
Now, if response time is R(t), then the equation is
R(t) = rt_s_m(t)+ rt_m_i(t)+ rt_i_w(t)

rt_m_i(t) and *rt_i_w(t)* depends on the bandwidth of the internet connection. We have measured total 10 times and the result is shown below with the help of Fig. 8.

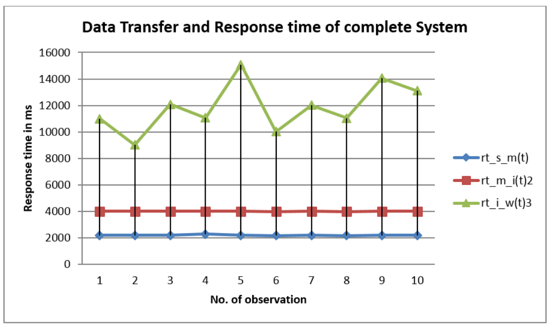

Fig. 8: Response time of proposed system

From above figure, the value of *rt_i_w(t)* is fluctuating between 9 to 16 second, and *rt_m_i(t)*, *rt_m_i(t)* are respectively on an average of 4 and 2 second.

B. Usability Analysis

As described earlier we have two kinds of user of our system. And they are the health units and the guardians of patients. We have prepared some questionnaires for both of the users for the acceptance of the system. The questionnaires are given below by the TABLE II and TABLE IV are for the health units and guardians of the patients. We have made the rating of the answers as Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. Here Strongly Agree, Agree are decided to count as the positive response.

1) Usability Analysis with Health Units: Here TABLE II representing the eight consecutive questions that we have frequently asked to the health unit who are the doctors, the internship doctors and nurses from Khulna University medical center and Khulna Medical college hospital.

TABLE III represents upon how many person of health unit we have described, applied and shown our system. And their usage of internet connected device availability is 85.74%. And Fig.9 represents the result that we have got from those health units with respect to the questions from TABLE II. In the graph shown in Fig.9 we can see the percentage of answer of the question that is asked to the Health units for usability study. It is worth mentioning that average 83.75% of the total users would like to use the proposed system and give positive response.

#	Question
Q1.	Proposed system is acceptable.
Q2.	Response time is satisfactory.
Q3.	Observation power increased.
Q4.	Helpful to take immediate action.
Q5.	System is easily adaptable.
Q6.	Caring level satisfactory.
Q7.	System can harm patients.
Q8.	Consider using the system in necessary purpose.

TABLE II: Questionnaires to health unit for usability analysis.

Information	Total	Doctor	Internship	Nurses
Number of Users	7	3	2	2
Personal computer/smart phone and internet connection	85.74%	100%	100%	50%

TABLE III: Information of usability test upon health unit for the questionnaires listed in TABLE II.

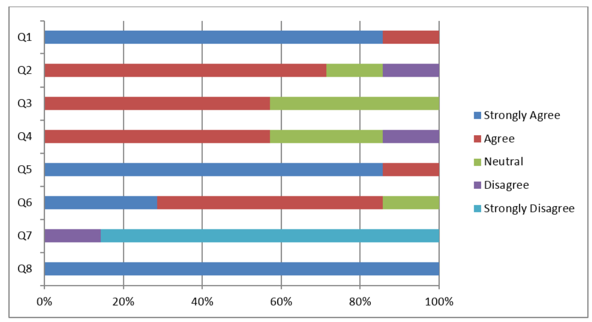

Fig. 9: Usability study based on the questionnaires listed in TABLE II

2) Usability Analysis with Patient's Guardian: In TABLE IV, there are three consecutive questions that we have frequently asked to guardian who have patient in hospital or someone from their keen is ever in hospital.

#	Question
Q1.	Proposed system is acceptable.
Q2.	Anxiousness minimization.
Q3.	Helpful to take immediate action.

TABLE IV: Questionnaires to patients guardian for usability analysis.

Here TABLE V represents upon how many person of patien's guardian we have described, applied and shown our system, and their usage of internet connected device. And Fig.10 represents the result that we have got from those guardians with respect to the questions from TABLE IV.

In the graph shown in Fig.10 we can see the percentage of answer of the question that is asked to the Patients guardian for usability study. It is worth mentioning that average 86.66% of the total users would like to use the proposed system and give positive response.

Implementing and analyzing the results we can say that our system would be effective for critical patients and health units

Information	Total	Male	Female
Number of Guardian of a patients	10	6	4
Personal computer/smart phone and internet connection at Guardian residence	60%	66.67%	75%
Number of patients	10	5	5

TABLE V: Information of usability test upon patient's guardian for the questionnaires listed in TABLE IV.

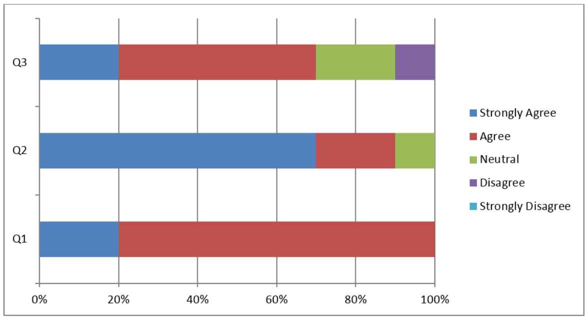

Fig. 10: Usability study based on the questionnaires listed in TABLE IV.

also to improve observation power. Based on the usability analysis and response time, our system is quite satisfactory. Most of the user gives positive response to our system. The guardian of the patients also takes our system positively according to our analysis.

V. Conclusion

With the development of technology it can be expected that the availability of internet is everywhere. Besides, low cost sensors are very easy make interface with any devices to serve information globally. And this sensors have also less power consuming and able to perform the work like big health measurement machineries. We have tried to make such system that can be used for remote monitoring of patient's health condition and taking necessary steps. The goal of this system is to automatically gather data from patients and store the gathered data into cloud for permanent use that can help health professionals to remotely health monitoring. The hospital management can be able to monitor more patients at a time. The system will also help guardians of the patients to know the health information. This system is also portable. So it can be expect that it will help the health units and guardian of the patients for good caring and minimizing risk taking required immediate action.

In future new health sensors can be added and analyzing the data to provide a satisfactory result based on the measured data to provide live opinion about patients state. There may be a phone call or SMS service can be included to inform guardians and health units about patient's critical condition.

This system needs a appropriate bandwidth since communication through internet depends on the bandwidth of the internet connection. Moreover the sensors are need to be placed properly with body, due to misrepresent of the sensor, wrong result will come.

References

[1] Vlacheas, P., Giaffreda, R., Stavroulaki, V., Kelaidonis, D., Foteinos, V., Poulios, G., & Moessner, K. (2013), *Enabling smart cities through a cognitive management framework for the internet of things*, Communications Magazine, IEEE, 51(6), 102-111.

[2] Sasidharan, S., Somov, A., Biswas, A. R., & Giaffreda, R. (2014, March), *Cognitive management framework for Internet of Things:A prototype implementation*, InInternet of Things (WF-IoT), 2014 IEEE World Forum on(pp. 538-543). IEEE.

[3] Thilakanathan, D., Chen, S., Nepal, S., Calvo, R., & Alem, L. (2014), *A platform for secure monitoring and sharing of generic health data in the Cloud*, Future Generation Computer Systems, 35, 102-113.

[4] Giniat, E. J. (2011), *Cloud computing: innovating the business of health care*, Healthcare financial management: journal of the Healthcare Financial Management Association, 65(5), 130-131.

[5] Jassas, M. S., Qasem, A. A., & Mahmoud, Q. H. (2015, May), *A smart system connecting e-health sensors and the cloud,* In Electrical and Computer Engineering (CCECE), 2015 IEEE 28th Canadian Conference on (pp. 712-716). IEEE.

[6] E-health Sensor Module. Available: [Online] https://www.cooking-hacks.com/documentation/tutorials/ehealth-biometric-sensor-platform-arduino-raspberry-pi-medical, *last accessed: 10th July, 2015*

[7] Ferraiolo, D. F., & Kuhn, D. R. (2009), *Role-based access controls*, arXiv preprint arXiv: 0903.2171.

[8] Feldman, L., Patel, D., Ortmann, L., Robinson, K., & Popovic, T. (2012), *Educating for the future: another important benefit of data sharing*, The Lancet, 379(9829), 1877-1878.

[9] Hung, N. T., Keong, N. W., & Zhu, H. (2012, June), *Cloud-enabled data sharing model, In Intelligence and Security Informatics (ISI)*, 2012 IEEE International Conference on (pp. 1-6). IEEE.

[10] Chen, D., & Zhao, H. (2012, March), *Data security and privacy protection issues in cloud computing*, In Computer Science and Electronics Engineering (ICCSEE), 2012 International Conference on (Vol. 1, pp. 647-651). IEEE.

[11] Gradl, S., Kugler, P., Lohmuller, C., & Eskofier, B. (2012, August), *Real-time ECG monitoring and arrhythmia detection using Android-based mobile devices*, In Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE (pp. 2452-2455). IEEE.

[12] Xia, H., Asif, I., & Zhao, X. (2013), *Cloud-ECG for real time ECG monitoring and analysis*, Computer methods and programs in biomedicine, 110(3), 253-259.

[13] Mell, P., & Grance, T. (2009), *The NIST definition of cloud computing*, National Institute of Standards and Technology, 53(6), 50.

[14] Haghighat, M., Zonouz, S., & Abdel-Mottaleb, M. (2015), *CloudID: Trustworthy cloud-based and cross-enterprise biometric identification*, Expert Systems with Applications, 42(21), 7905-7916.

[15] Arduino. Available: [Online] https://www.arduino.cc, *last accessed: 10th July, 2015*

[16] Phidgets Inc. Available: [Online] http://www.phidgets.com, *last accessed: 20th October, 2015*

[17] Cisco Systems Inc. Available: [Online] http://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html, *last accessed: 12th April, 2016*

[18] PhysioNet(MIT-BIH Normal Sinus Rhythm Database). Available: [Online] https://physionet.org/cgi-bin/atm/ATM, *last accessed: 10th January, 2016*

[19] Hossain, M. Shamim, and Ghulam Muhammad, (2016), *Cloud-assisted industrial internet of things (iiot)–enabled framework for health monitoring,* Computer Networks.

[20] Hossain, M. S. (2015), *Cloud-Supported Cyber–Physical Localization Framework for Patients Monitoring*.