I J C T A, 9(41), 2016, pp. 543-554 ISSN: 0974-5572

Detection and Alerting of Common Cardiac Conditions Using a Real-time Heartbeat Rate Monitoring System

Madhura Bhaumik*, Priyanka Verma*, Ravi Kant* and Pradeep Kumar, Lala Bhaskar**, Ashutosh Gupta****

ABSTRACT

With an extremely busy life and the intricacies associated with it, cardiac ailments are on the rise in every age group. Any cardiac disorder first reflects in an irregularity of the heartbeat rate, medically known as arrhythmia. So, for an early detection of these ailments, monitoring this very basic parameter i.e. the heartbeat rate of an individual is of utmost importance. Bradycardia and Tachycardia are the two major conditions of arrhythmia which are indications of various serious medical conditions like sustained arrhythmia, atrial fibrillation and hormonal tumors like pheochromocytoma. In this paper, the possibility of an early detection of these two types of arrhythmia and presenting it in a user-friendly format has been proposed. The proposed model employs the concept of photoplethysmography for detection. A sensor detects the heartbeat rate and communicates it wirelessly to a RaspberryPi module which uploads the recorded heartbeat on the worldwide web. The data can be accessed and downloaded on any basic computing system thus reaching the relatively lower strata of the society, with ease.

Keywords: Heartbeat Rate; Photoplethysmography; RaspberryPi; Arrhythmia; Bradycardia; Tachycardia;

1. INTRODUCTION

Heartbeat rate indicates the soundness of our heart and helps in identifying the condition of our cardiovascular system [1]. In a clinical environment, controlled conditions like blood volume measurement, heart voice measurement and electrocardiogram (ECG) affect the measurement of the heartbeat rate [2] but it can also be measured in home environment [3]. Real-time ECG monitoring is accurate [4], but the equipment is bulkier and inconvenient. In the proposed model, the heartbeat rate is detected by a photoplethysmographic sensor, which works on the principle that the power transmitted by the LEDs is matched with the photo sensor in such a way that the resistance will vary within the range of the photo sensor after attenuations through the index finger [5]. The concept of photoplethysmography (PPG) combined with an Arduino programming is used to detect arrhythmia to avoid redundant pulses [6]. Photoplethysmograph signals contain rich blood pulsating signals which are very similar to the electrical activity of the heart [7]. The data is transmitted using a Bluetooth module to Raspberry Pi (a credit card sized minicomputer) module [8] for the comparison and uploading of the data. Warning messages for arrhythmia allows a great opportunity for intervention of physicians [9]. Further this proposed method may be implemented on FPGA as other digital circuits implemented for high performance and efficiency in [10-13].

Today, as high blood pressure has become a major medical condition, patients are advised medications like beta blocker, calcium channel blockers etc. but as a side effect, these slow down the normal pace of the heart. This is medically known as bradycardia, a type of arrhythmia. The other type is tachycardia where the

* Department of Electronics & Communication Engineering Amity University Uttar Pradesh Noida, INDIA, *Emails: bhaumikmadhura@gmail.com; pri_ver_1995@yahoo.co.in; ravi.228865@gmail.com*

** Department of Electronics & Communication Engineering Amity University Uttar Pradesh Noida, INDIA, *Emails: pkumar4@amity.edu, lbhaskar1@amity.edu, agupta5@amity.edu*

heartbeat rate is higher than the normal pace. Continuous monitoring helps in keeping a check on these cardiac conditions. Also, patients resuscitated from a cardiac arrest, myocardial infarction or the ones who have just undergone a cardiac surgery need to be kept under continuous medical monitoring, especially towards the end of their convalescence period which is normally at their residence, away from expert medical attention; so this model can be of major use.

In this paper a model is proposed in which, the data is recorded using a sensor based on photoplethysmography. It is wirelessly transmitted to a RaspberryPi module. This module uploads the data on a website Thingspeak.com. The data can be viewed in graphical form and can be used to observe the trend of the heartbeat rate of an individual over a period of time. It can be further downloaded in a tabular form and the data can be used to identify the major types of cardiac conditions a person may be suffering from. The pre-defined range of heartbeat rates under the two conditions is set in the Raspberry Pi module. Whenever the heartbeat rates cross these limits, a warning message is sent to a pre-fed mobile number which show the possibilities of the conditions, so that the concerned medical personnel can take necessary action on urgent basis. The pattern also helps in identifying chronic ailments and taking required steps to prevent further deterioration in health conditions.

The organization of this paper is as follows: Section II describes the proposed model. Section III shows detectable cardiac conditions. Section IV describes the possible approaches to the proposed model. Further section V shows the results and last section concludes the work.

2. PROPOSED MODEL

The proposed model is comprises two modules. First module works as a transmitter and second module will act as a receiver. The first module senses and computes the heartbeat of an individual. The computed value of heartbeat is then transmitted wirelessly to the second module. The heartbeat is sensed using TCRT 1000 reflective optical sensor which works on the principle of polyplethysmography (PPG). For further computations, we use ATmega-328 microcontroller. It gets value from the sensor. The microcontroller is also connected to LCD (16x2) where it displays the obtained value. It is connected to a Bluetooth module which is set as transmitter and communicates with the second module.

The second module comprises of Bluetooth module which is set as receiver, connected to Raspberry Pi. The Python scripts used in Pi contains 2 URLs of websites, where first one is used for data is being uploaded

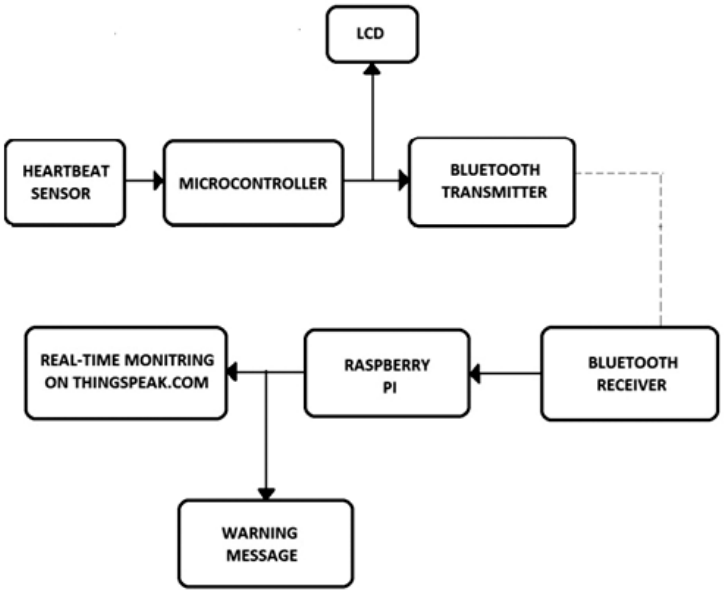

Figure 1: Block diagram of the proposed model

and another is online messaging service through which warning messages are generated.The USB port is used to connect a Wi-Fi dongle to the Raspberry Pi module. This dongle helps us to connect to the Personal Hotspot created by the Mobile Phone by giving a unique IP address to the RPi module. Each detected heartbeat is uploaded on Thingspeak.com account and is represented graphically. As soon as the heartbeat rate exceeds the certain defined limit, the RPi communicates with the online messaging service account and a warning message is sent to specified mobile number. The Heartbeat values sent by RPi are updated on this channel in every 30 seconds along with the time stamp. All the heartbeat values are represented graphically with respect to time. These values are stored and can be exported to the system in the form of tabular representation. Figure 1 shows the block diagram of the proposed model that is being used for the detection and uploading the data.

Figure 2 shows the work flow of the proposed model and how the control and synchronisation between the modules takes place. It describes the case where the heartbeat exceeds the range and includes how the warning message is sent to specified mobile number (the doctor in this case) when the value is exceeded. It further shows that the doctor can take necessary action based on the recorded data and pattern to help the patient convalesce easily.

The modification of the proposed model shows the different cardiac conditions that are depicted in the warning message when heartbeat range exceeds a certain range. The warning messages shows the possibilities of the conditions that are shown in Fig. 3

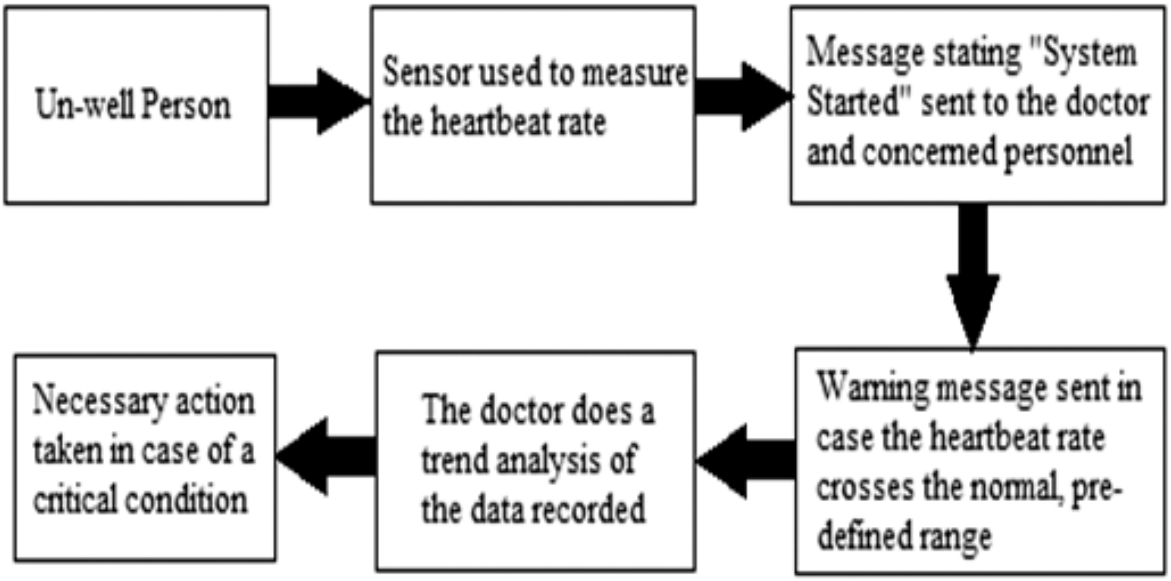

Figure 2: The flow of the working of the proposed model

3. DETECTABLE CARDIAC CONDITIONS

Arrhythmia is a cardiac condition where the heartbeat rate exceeds the normal range and can be an indication of other serious cardiac ailments. Figure 4 shows the various types of arrhythmia found in individuals, sinus bradycardia and tachycardia being the most common ones.

3.1. Sinus Bradycardia (less than 60 bpm)

The reduced heartbeat rate can be due to a congenital heart defect, heart tissue damage with age, hypertension, hypothyroidism, a complication in cardiac surgery, imbalance in electrolytes etc. Early detection of this condition can help in giving appropriate medication to the patient and helps in easy recovery.

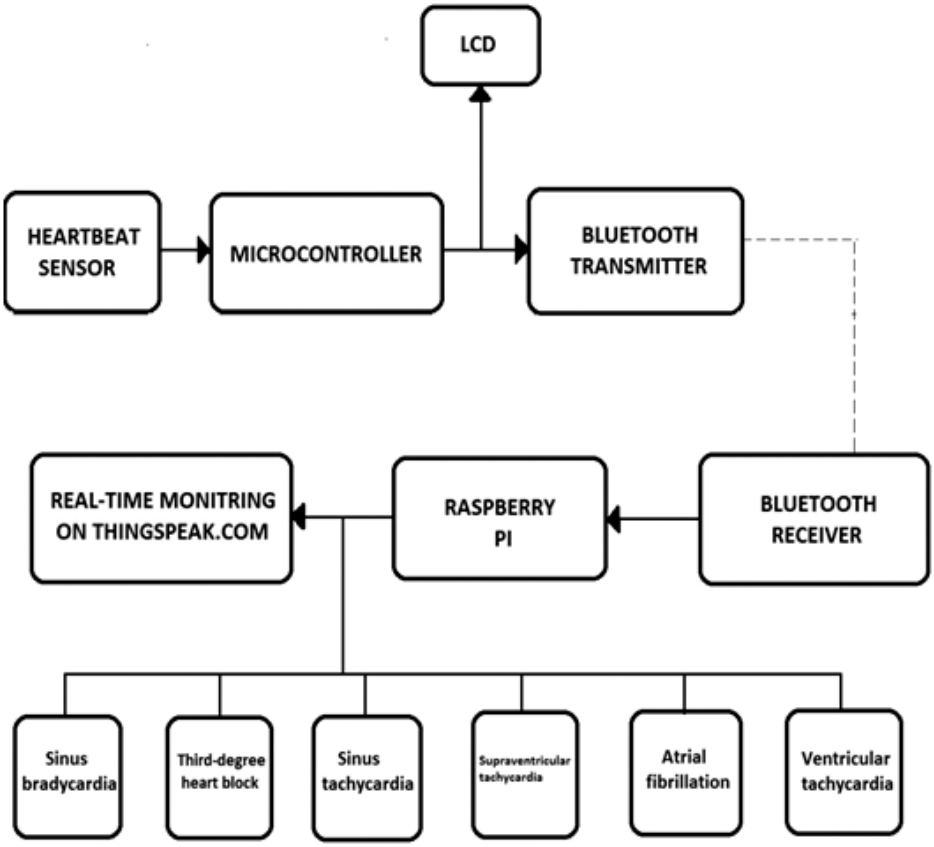

Figure 3: Block Diagram of the modified proposed model

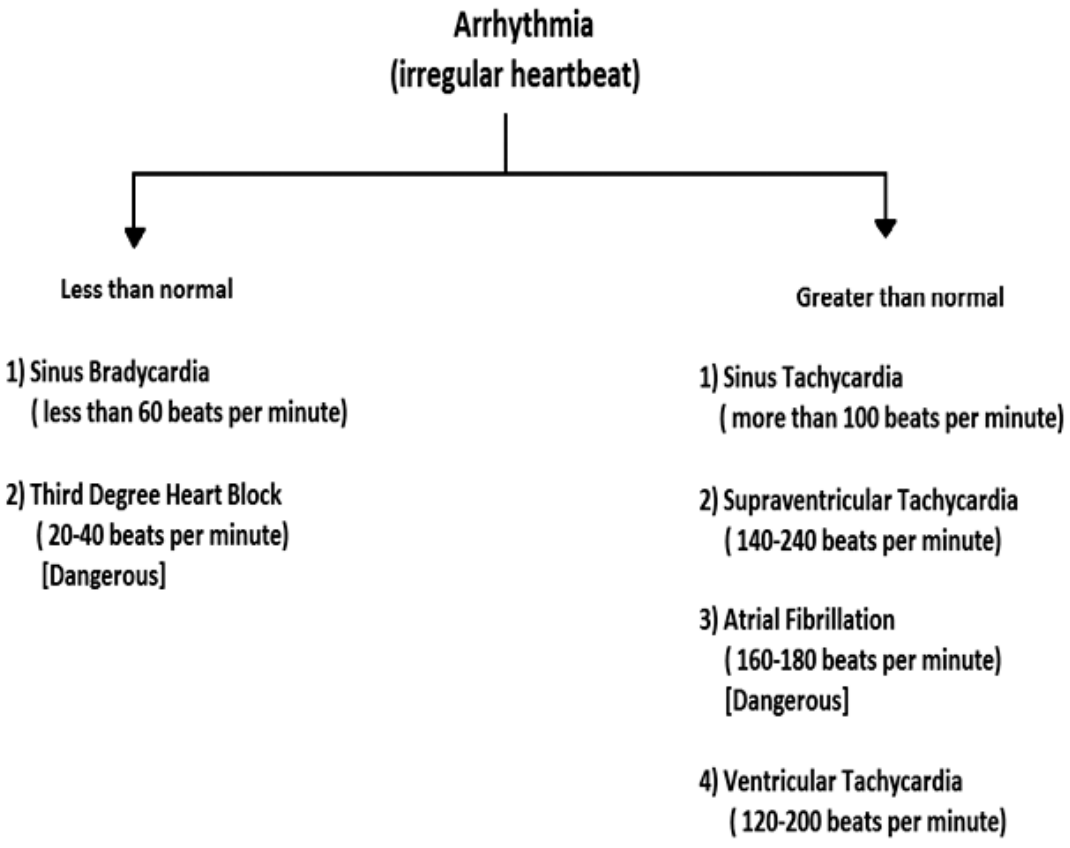

Figure 4: The types of arrhythmia found in individuals

3.2. Sinus Tachycardia (more than 100 bpm)

It is generally due to increased physical activities in a healthy adult. Increased catecholamines, adrenaline can also be a reason for sinus tachycardia. It is also a condition found in individuals during instances of high fever.

4. POSSIBLE APPROACHES TO THE PROPOSED MODEL

The modification in the proposed design is in the form of taking multiple individuals rather than only one. This is done by using multiple sensors, one for each person. However, only one Raspberry module will be used. The block diagram of this approach is shown in Fig. 5. This one module will handle computations from multiple sensors.

Considering a case where one Raspberry module is handling 4 sensors and receive data from them, we need ZigBee module for wireless data transfer between each sensor and Raspberry Pi module. Further we need 4 Thingspeak accounts for recording the heartbeat trend of all the four individuals. The messaging service will need four contact numbers for the different persons under medical monitoring.

The changes in programming will be at the Raspberry Pi module. It will accept data from four sensors. It will identify the data which is received from four different sensors and then run instructions to send the data and upload it to respective website channel. Similarly, it will send instructions to online messaging service for warning message to respective pre-fed contact numbers

Figure 6 shows the flow chart of the first approach to the proposed model. As all the heartbeat sensors are initialized, the recorded heartbeat rate is displayed simultaneously on the 4 LCDs. 4 different accounts

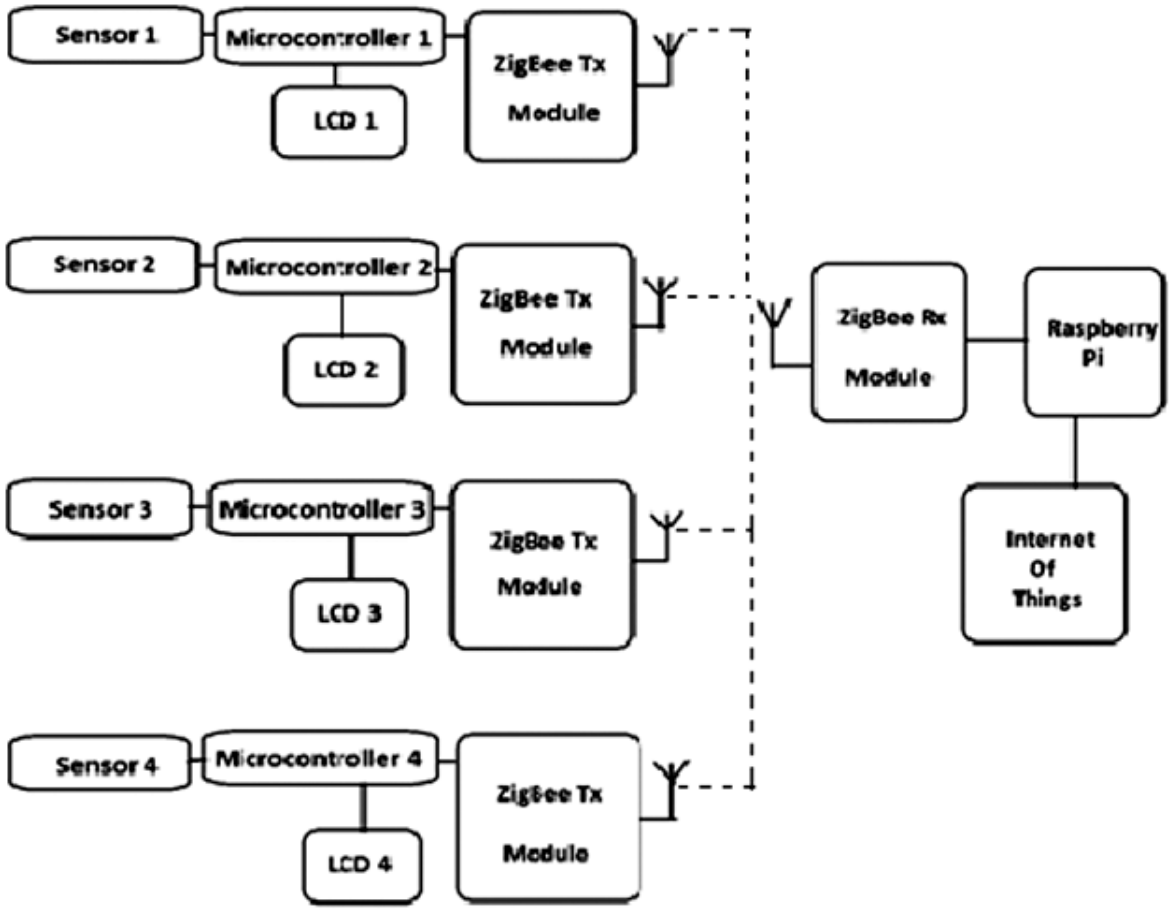

Figure 5: Block diagram of the first possibility

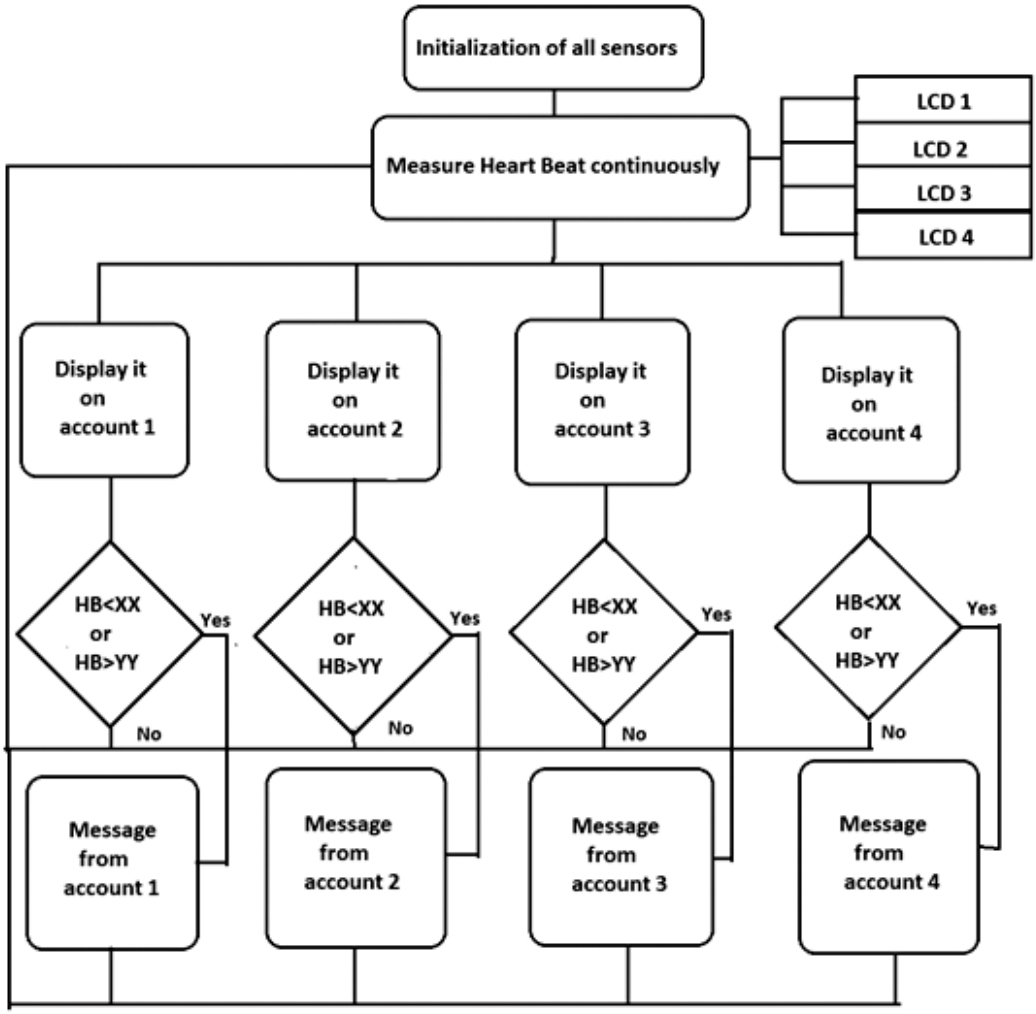

Figure 6: Flow Chart of the first possibility

for the 4 users are created and the condition for the heartbeat rate being in range is checked at each account as the recorded data is simultaneously uploaded and plotted against time. Since the cloud storage has practically an unlimited space, this can be done easily. The number fed in the 4 accounts can be of the same person as well as different ones.

Another possible approach is to use sensors which detect different parameters like blood pressure and temperature along with heartbeat detection sensor. These sensors will be controlled using different programming and 3 values will be sent to Raspberry Pi module as shown in Fig. 7. These values will be sent at programmed intervals. The computations for sending these values at certain intervals will be handled by the microcontroller.

For wireless transmission Bluetooth transmitter and receiver will be used. The Raspberry Pi module will send the values of different parameters to the pre-fed mobile number. Along with this, it will upload the value of these parameters on various fields of same channel.

As the initialization of the different sensors take place, an amount of delay is provided between them so that the data computation is not interfered. With the same amount of delay, the values of different body parameters are displayed on the LCD and it's further uploaded and plotted against time on ThinkSpeak.com, in different fields although being in the same account. The checking of the parameters being in range is done by different loops and the message is sent, with the initial delay, to the emergency number fed as shown in Fig. 8.

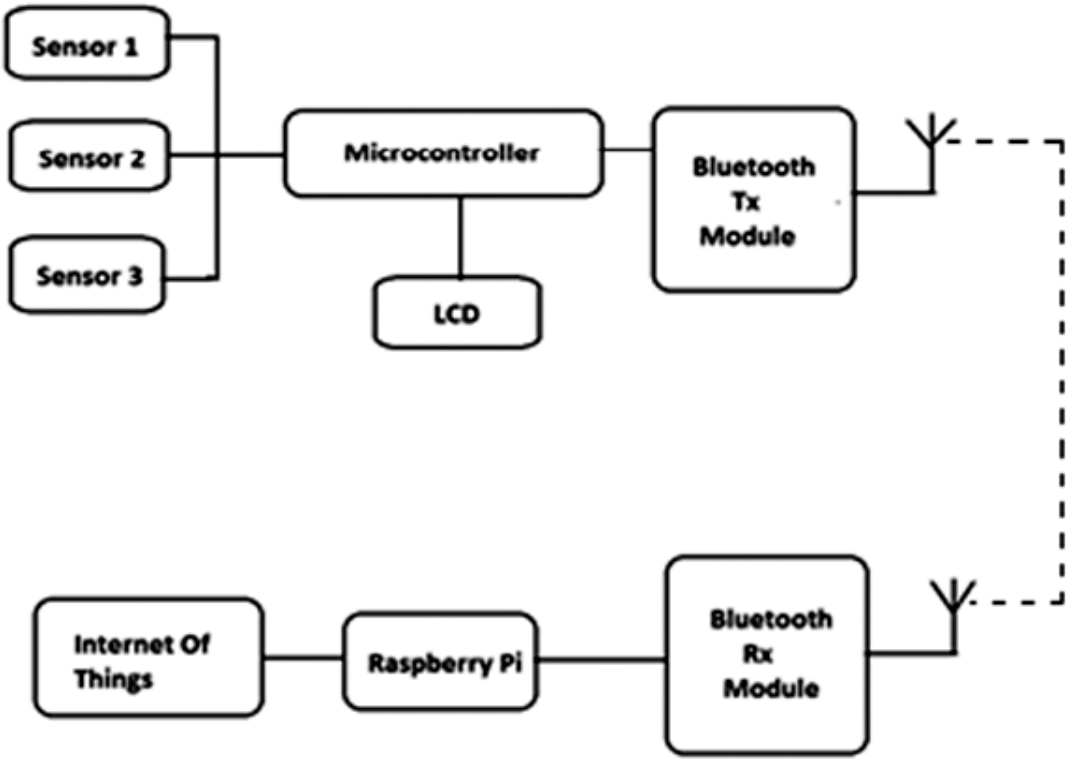

Figure 7: Block Diagram of the second possibility

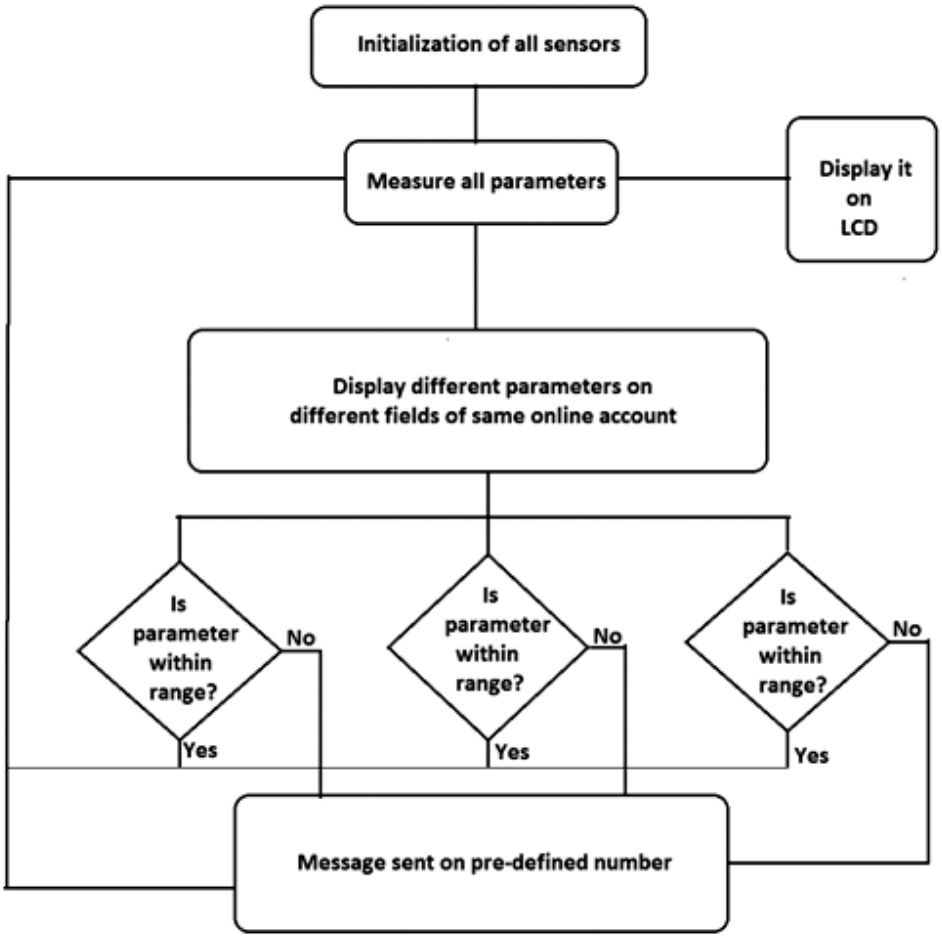

Figure 8: Flow Chart of the second possibility

The difference in approach to these two possibilities is that in first case, the same proposed model for multiple individuals can be used. The computations become complex at the Raspberry Pi module. The wireless transmission is done by using ZigBee module which creates a mesh network.

In the second approach, a similar model to detect various physiological parameters of an individual can be used. These parameters are transmitted using the same Bluetooth module but at different time intervals. The computations become complex at the microcontrollers reading these values.

Both the possibilities can be combined for the prototype to work for different individuals and have different sensors to show the physiological parameters.

5. RESULTS

The results shows the possibilities of the major cardiac conditions that can be detected by the proposed model. The setup of the proposed model is shown in Fig. 9. The detection is done based on the concept of photoplethysmography and the uploading of data is done through a RaspberryPi module.

Figure 10 shows the warning message for the possibility of sinus bradycardia, which shows that the heartbeat recorded is less than 60 beats per minute and an action needs to be taken to avoid further deterioration in the health condition.

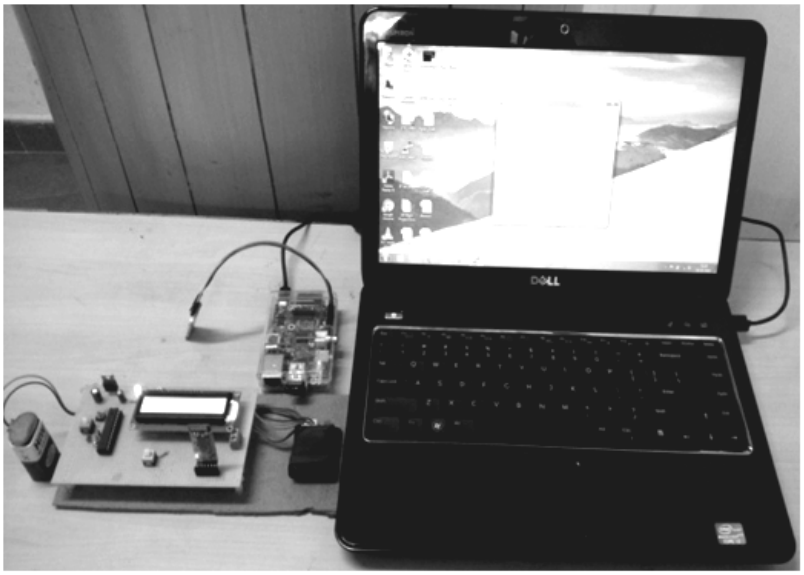

Figure 9: The setup of the proposed model

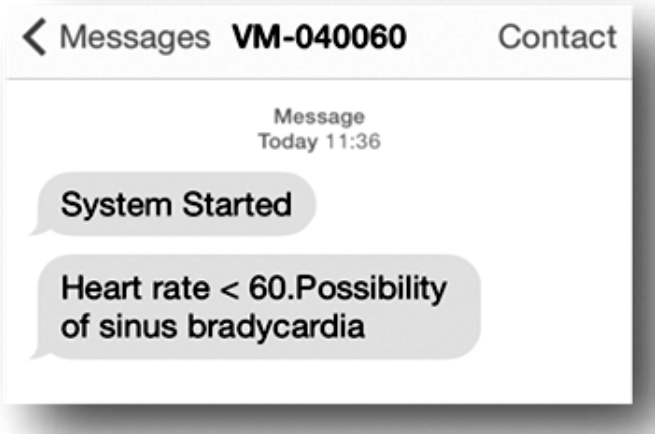

Figure 10: Warning message for the possibility of sinus bradycardia using the proposed model

The graph plotted between heartbeat and time, on a particular date shows the pattern of the condition of sinus bradycardia, in Fig. 11.

Figure 12 shows the tabular form of the data recorded for the possibility of sinus bradycardia where "created_at" defines the date and time of the creation of chaneel on ThinkSpeak.com, "entry_id" depicts the number of recordings and "field1" shows the data recorded in the particular field created.

Figure 13 shows the warning message for the possibility of sinus tachycardia, which shows that the heartbeat recorded is more than 100 beats per minute and an action, needs to be taken to avoid further deterioration in the health condition.

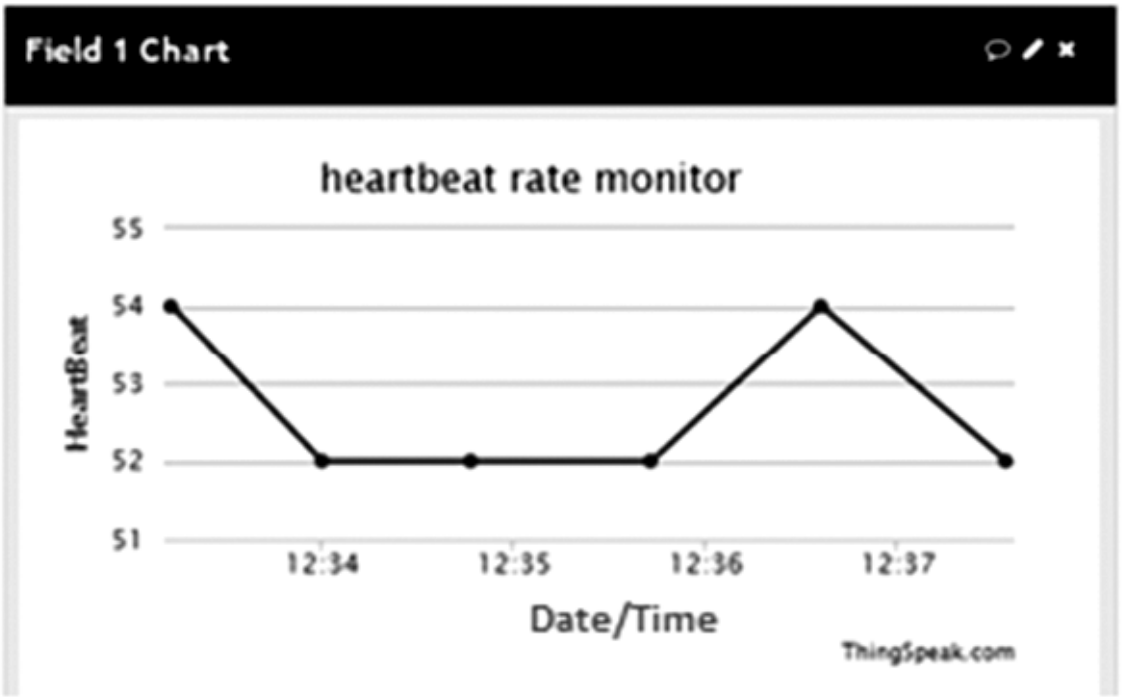

Figure 11: Graph plotted shows the possibility of sinus bradycardia with respect to time using the proposed model

created_at	entry_id	field1
2016-05-10 07:03:13	1	54
2016-05-10 07:04:00	2	52
2016-05-10 07:04:47	3	52
2016-05-10 07:05:43	4	52
2016-05-10 07:06:36	5	54
2016-05-10 07:07:34	6	52

Figure 12: Data depicting sinus bradycardia using the proposed model

The graph plotted between heartbeat and time, on a particular date shows the pattern of the condition of sinus tachycardia, in Fig. 14.

Figure 15 shows the tabular form of the data recorded for the possibility of sinus tachycardia where "created_at" defines the date and time of the creation of chaneel on ThinkSpeak.com, "entry_id" depicts the number of recordings and "field1" shows the data recorded in the particular field created.

The above results were obtained by recording heartbeat rate of an old person in case of Bradycardia and the heartbeat rate of a person just after exercise in case of Tachycardia. In this way these two conditions were detected and the results were obtained.

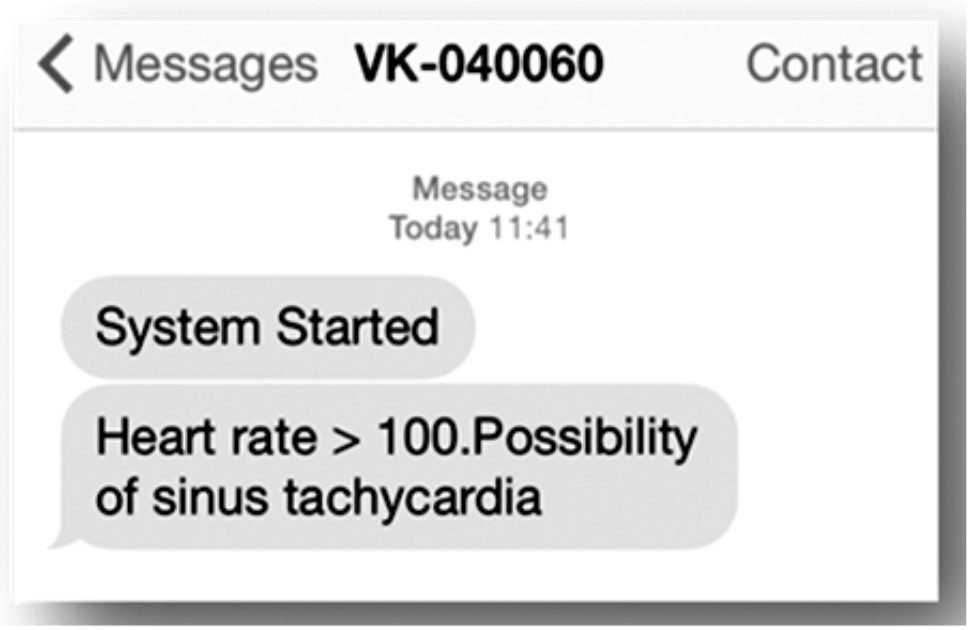

Figure 13: Warning message for the possibility of sinus tachycardia using the proposed model

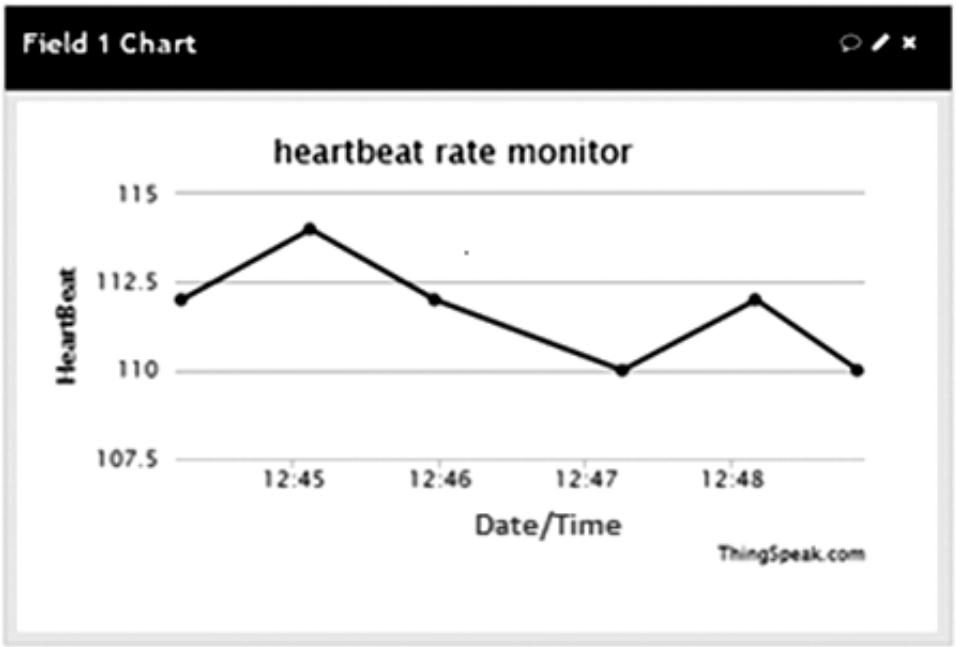

Figure 14: Graph plotted shows the possibility of sinus tachycardia against time using the proposed model

created_at	entry_id	field1
2016-05-10 07:14:14	1	112
2016-05-10 07:15:07	2	114
2016-05-10 07:15:58	3	112
2016-05-10 07:17:15	4	110
2016-05-10 07:18:10	5	112
2016-05-10 07:18:52	6	110

Figure 15: Tabular form of the data depicting sinus tachycardia using the proposed model

6. CONCLUSION

On the basis of obtained results for cardiac conditions like Bradycardia and Tachycardia, the proposed model can also be used to identify the various conditions of arrhythmia by the trend analysis of the data recorded. The real time monitoring of these conditions is possible by uploading the data on the website. In addition to this, the facility of an alert message system makes it possible to get immediate medical attention for the person under monitoring. This allows the concerned medical personnel to take immediate actions in case of a critical condition.

The two approaches discussed will prove beneficial when monitoring cardiac conditions for multiple individuals. This will further make the proposed model more cost effective since only small modifications are required to apply it when monitoring multiple individuals. The proposed model is suitable for detection and monitoring of cardiac conditions at an earlier stage so that we can stay alert and take actions to prevent any serious medical conditions in future.

REFERENCES

[1] R.G. Landaeta, O. Casas, and R.P. Areny, "Heart rate detection from plantar bioimpedance measurements", 28th IEEE EMBS Annual International Conference, USA 2006, pp. 5113-5116.

[2] H. Shim, J.H. Lee, S.O. Hwang, H.R. Yoon, and Y.R. Yoon, "Development of heart rate monitoring for mobile telemedicine using smartphone", 13th International Conference on Biomedical Engineering ICBME 2008), Singapore, 2008, pp. 1116-1119.

[3] P. F. Binkley, "Predicting the potential of wearable technology", IEEE Eng. Med. Biol. Mag., Vol. 22, 2003, pp. 23-27.

[4] Stefan Gradl, Patrick Kugler, Clemens Lohmuller and BjoernEskofier, "Real-Time ECG Monitoring and Arrhythmia Detection using Android-Based Mobile Devices", Annual International Conference of the IEEE Engineering in Medicine and Biology Society, San Diego, ISSN No. 1094-687X, August 2012, pp. 2452-2455

[5] M.M.A. Hashem, Rushdi Shams, Md. Abdul Kader and Md. Abu Sayed, "Design and Development of a Heart Rate Measuring Device Using Fingertip", ICCCE 2010, Kuala Lumpur, Malaysia

[6] AndriusSolosenko, VaidotasMarozas, "Automatic Premature Ventricular Contraction Detection in Photoplethysmographic Sensors", IEEE Biomedical Circuits and Systems Conference Proceedings, Lausanne, ISSN No. 2163-4025, October 2014, pp. 49-52

[7] Luisa F. Polania, Lalit K. Mestha, David T. Huang and Jean Phillipe Couderc, "Method for Classifying Cardiac Arrhythmias using Photoplethysmography", 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Milan, ISSN No. 1094-687X, August 2015, pp. 6574-6577

[8] A. Swapna, Mr. Md. Ammeenuddin, "Implementation of Sensor Data Monitoring and Transmitting using Raspberry Pi with reference to healthcare industry", International Journal & Magazine of Engineering, Technology, Management and Research, Vol. No. 2, Issue No. 7, ISSN No. 2348-4845, July 2015, pp. 1849-1853

[9] El Mimouni El Hassan and Karim Mohammed, "Design and Implementation of an Embedded System for Ambulatory Cardiac Monitoring", International Conference on Broadband and Wireless Computing, Communications and Applications, Barcelona, October 2011, pp. 437-440.

[10] Agarwal, C.; Gupta, A., "Modeling, simulation based DC motor speed control by implementing PID controller on FPGA," in Confluence 2013: The Next Generation Information Technology Summit (4th International Conference) , vol., no., pp. 467-471, 26-27 Sept. 2013.

[11] Gupta, Ashutosh and Murgai, Shruti and Gulati, Anmol and Kumar, Pradeep, "Design and implementation of low power clock gated 64-bit ALU on ultra scale FPGA", AIP Conference Proceedings, 1715, 020001 (2016), DOI:http://dx.doi.org/10.1063/1.4942683.

[12] Gupta, Ashutosh and Murgai, Shruti and Gulati, Anmol and Kumar, Pradeep, "Power efficient, clock gated multiplexer based full adder cell using 28 nm technology", AIP Conference Proceedings, 1715, 020003 (2016), DOI:http://dx.doi.org/10.1063/1.4942685.

[13] Gulati, Anmol and Gupta, Ashutosh and Murgai, Shruti and Bhaskar, Lala, "Design and implementation of power efficient 10-bit dual port SRAM on 28 nm technology", AIP Conference Proceedings, 1715, 020002 (2016), DOI:http://dx.doi.org/10.1063/1.4942684.