Remote Patient Monitoring and MANET: Applications and Challenges

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Abstract: *I*n the recent years, we have seen a rapid advancement in the field of mobile computing due to the rapid increase in the no. of inexpensive, widely available wireless devices. However, modern devices, applications and protocols solely focuses on cellular or wireless local area networks (WLANs), not taking into account the great potential offered by mobile ad hoc networking**.**. Apart from conventional SMS and voice calling, the mobile technology has found tremendous applications in various departments such as military services, healthcare services, etc. In this paper, we have discussed a prototype of a wireless patient monitoring system for the management of cardiac predicament and also compared its implication in ad hoc network environment. This is because it is not always practical to maintain wireless mobile communication in remote areas and hilly terrains and these places usually lack good doctors and proper health care facilities to treat various diseases. This problem has been addressed in this paper by the design and implementation of an Ad hoc sensor network based solution. The proposed technique is intended specifically for remote rural areas where the infrastructural facilities such as the internet, GSM/GPRS etc are not available. There are various health parameters like pulse rate, temperature etc. through which patients can be monitored**.** The work can be categorised into three stages of data acquisition, data processing and data communication stages. A data acquisition stage consists of sensors to monitor the temperature and pulse rate. The sensor outputs are converted to digital form and read by a basic atmega16 microcontroller which does some processing and is sent through the serial port to the data processing software. In data processing module critical values of the measured data can be set; exceeding which the processer will initiate the communication unit to send SMS to the predefined mobile numbers via GSM module. When any deviation from the normal behaviour is detected or the received parameters of the patient goes beyond the threshold limit, the processing unit automatically transmits therelevant data to the receiver's device as a SMS via a GSM module and at the same time the buzzer starts ringing.

Keywords-*Data Acquisition, Data Processing, Data Transmission, GSM, 3G, 4G, MANET, Physical Layer, Datalink Layer, MAC Layer*

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I. Introduction

Mobile communication system revolutionized the way people communicate, by joining communication and mobility together. Apart from conventional voice data transfer, many innovative applications with mobile phones were also implemented. Short Message Service (SMS) has found numerous applications recently including business transaction which was originally developed for sending status information by the service provider. Recently, very much research has been seen in the area development of systems for monitoring patients using advanced telecommunication technologies [1]. Remote monitoring systems have been advanced recently with the advent of Short Message Service (SMS) provided by the telecommunication service providers. Monitoring devices can now easily be interfaced to PCs and messages can be also be sent to programmed mobile numbers with the help of GSM gateway devices if a standard range of acceptable values are set as the threshold in the data processing unit [2]. The whole remote wireless monitoring system can be categorized into three main units as shown in the block diagram (Figure 1) that interacts with each other to provide real time monitoring, processing and reporting. They are the Data acquisition unit, the Data processing unit and the Data transmission unit.

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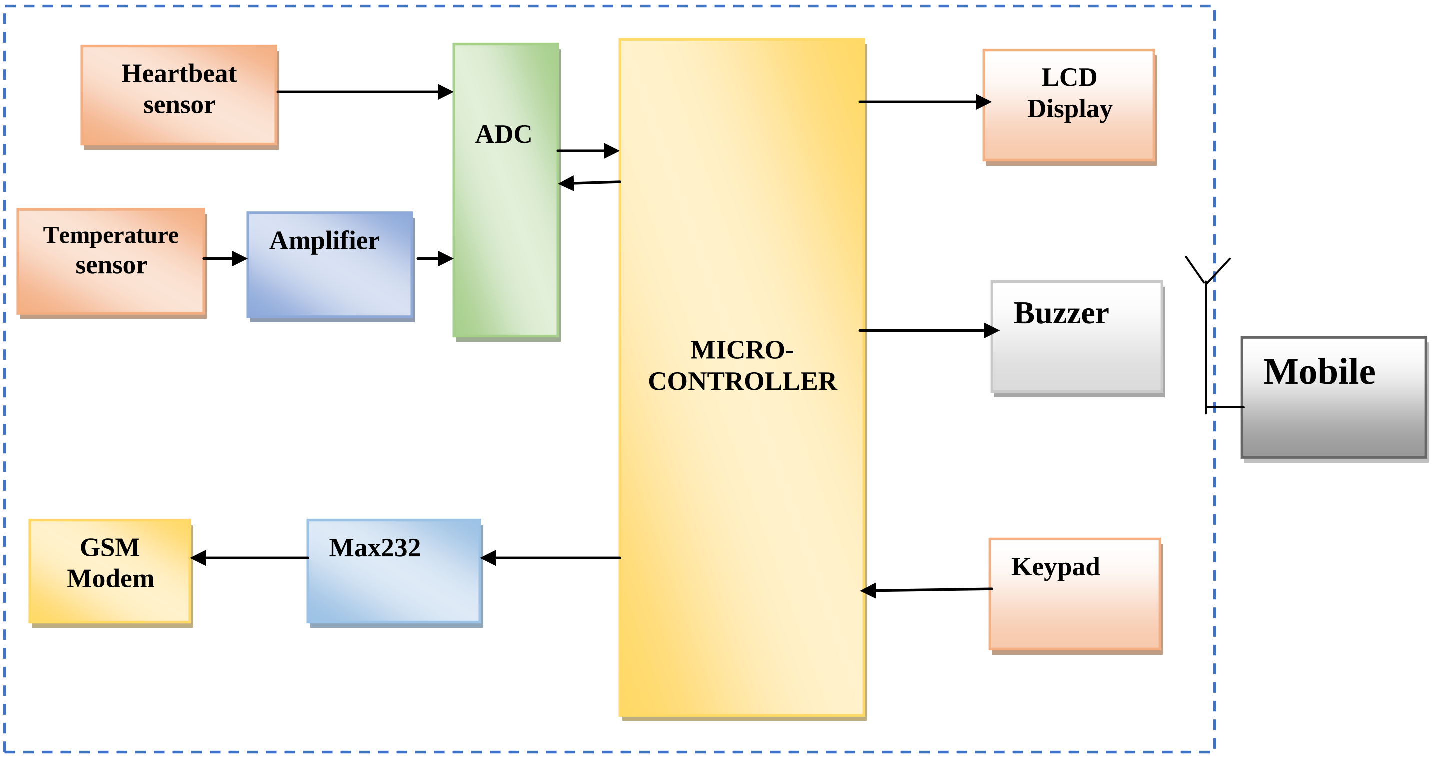

Figure 1. System block diagram

The Data acquisition unit mainly consists of biomedical sensors for measuring the body temperature the heart rate with interfacing to basic stamp microcontroller. This unit acquires the data and makes it available for the data processing unit; the complete circuit diagram for heart beat sensing device has been given in figure 2. The heart rate is measured by sensing the change in blood volume in a finger artery while the heart is pumping the blood. It consists of an infrared LED and a photo diode sensor. The infrared LED transmits an IR signal through the fingertip of the subject, a part of which is reflected by the blood cells. This reflected signal is detected by the photo diode sensor. The changing blood volume with heartbeat results in a train of pulses at the output of the photo diode, the magnitude of this signal is too small to be detected directly by a microcontroller. Hence, two Operational Amplifiers (Op-Amps) are used to design a two-stage high gain, active low pass filter to filter and amplify the signal to appropriate voltage level so that these pulses can be counted by the microcontroller. The signal conditioning circuit consists of two active low pass filters which are identical and have a cut-off frequency of about 2.5 Hz. This means the maximum measurable heart rate is about 150 beats per minute. The Op-Amp IC used in the circuit is LM324, a dual Op-Amp chip from Microchip. This IC operates through a single power supply and provides rail-to-rail output swing. The filtering provided by the Op-Amps is necessary to block any higher frequency noises which may be present in the signal. The gain is set to 101 of each filter stage, giving the total amplification of about 10000. A capacitor of 1 uF at the input of each stage is used in order to block the dc component in the signal. The two stage amplifier provides the sufficient gain for boosting the weak signal coming from the photo sensor unit and thus converts it into a pulse. An LED which is connected at the output blinks every time a heartbeat is detected.

The Data processing unit consists of a basic stamp microcontroller having sufficient memory to convert the digital signal coming from the Data acquisition unit through the sensors into a format appropriate for transmission via RS232 serial port communication to PC for analysing and displaying the data.

The Data transmission unit accepts the data from the Data processing unit for sending it to the hospital database via internet or LAN. When any anomaly is observed by the circuit or a critical condition is reached, the data is sent to the specified doctor’s cell phone number or any relative’s number as an SMS via the GSM modem or the SMS gateway [3-4].

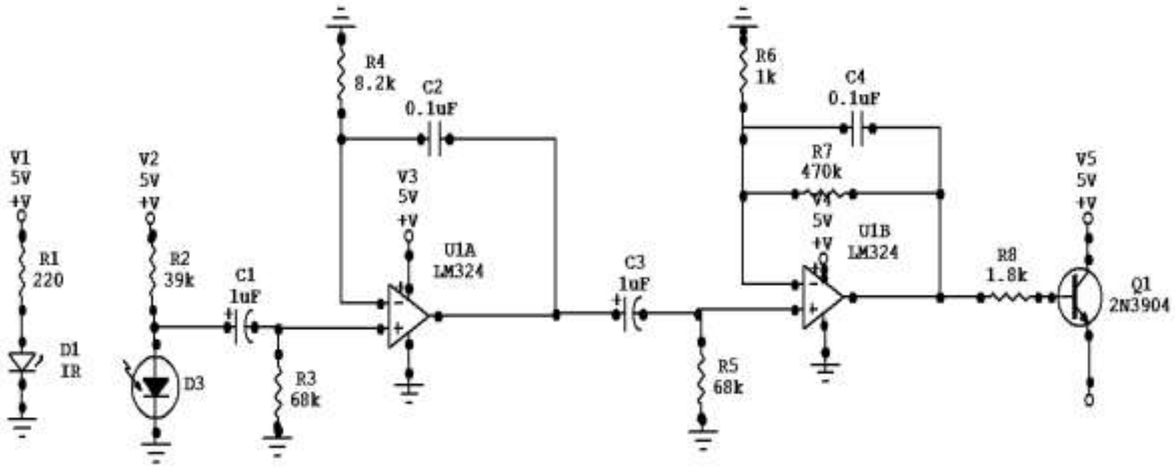

Figure 2.Heartbeat Sensor circuit Diagram

II. MOBILE ADHOC NETWORKS

Opposed to the infrastructure wireless networks, where each user directly communicates with an access point or base station, a mobile ad hoc network, or MANET, doesn't rely on a fixed infrastructure for its operation to be carried out (Figure 3).

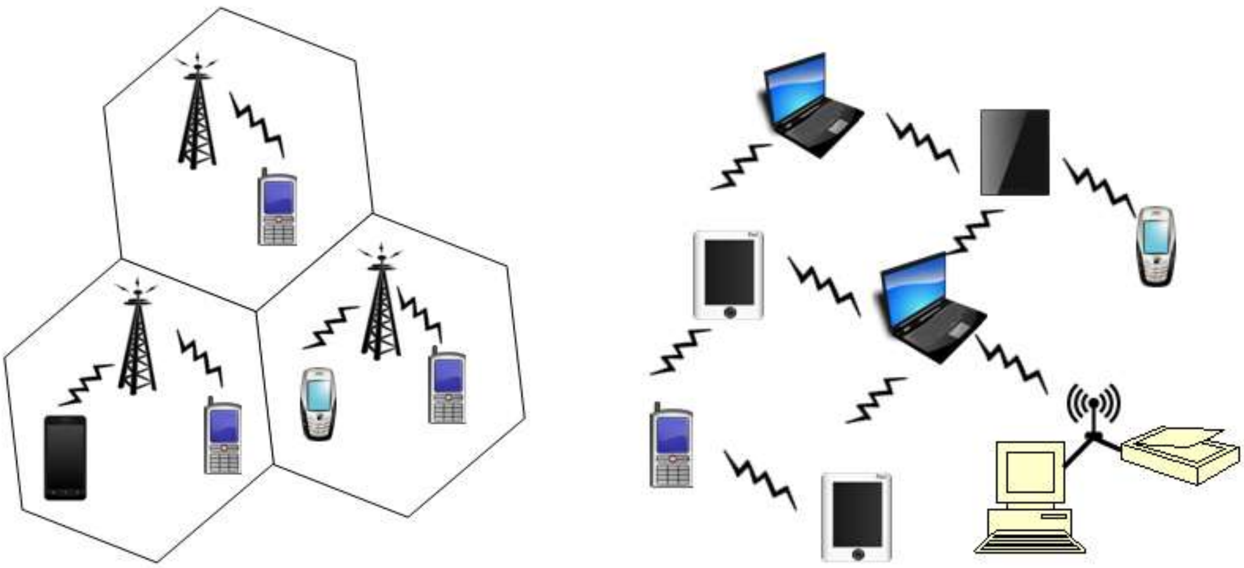

Figure 3. Cellular networks versus mobile Ad hoc networks.

MANET find their great use in military communication in an inaccessible remote terrain, healthcare, fire prediction in a forest terrain, weather forecasting, etc. [5]-[6].Here, the network is an autonomous transitory association of the mobile nodes that communicates with each other using wireless links. Nodes that lie within each other's sending range can communicate directly and hence are responsible for dynamically discovering each other. For enabling communication between the nodes that are not directly within each other's sending range, intermediate nodes are there to act as routers that relay packets to their destination which are generated by other nodes. These nodes are often energy constrained i.e., these are battery-powered devices having a great diversity in their capabilities. Moreover, these devices are free to join or leave the network and they may also move randomly which may possibly result in rapid and unpredictable topology changes. In order to provide the necessary network functionality in the absence of fixed infrastructure or central administration in this energy-constrained, dynamic, distributed multi-hop environment, nodes need to organize themselves dynamically. These technology aided health services have also resulted improvement in the care quality of patients in the remote areas and of course with an added advantage of great reduction in costs [7]. Many design challenges may be imposed to the network protocols due to the specific characteristics and complexities, which are summarized in Table 1. In addition, these networks faces the traditional problems inherent to wireless communications such as physical security, time varying channels, lower reliability than the wired media, limited interference, etc. Despite the many design constraints, the mobile ad hoc networks also offer numerous advantages. First of all, in situations where a fixed infrastructure is not available, not trusted, too expensive or unreliable, this type of network is highly suited for use. Ad hoc networks can be rapidly deployed with minimum user intervention because of their self-creating, self-organizing and self-administering capabilities,the overall system representation is shown in Figure 4.

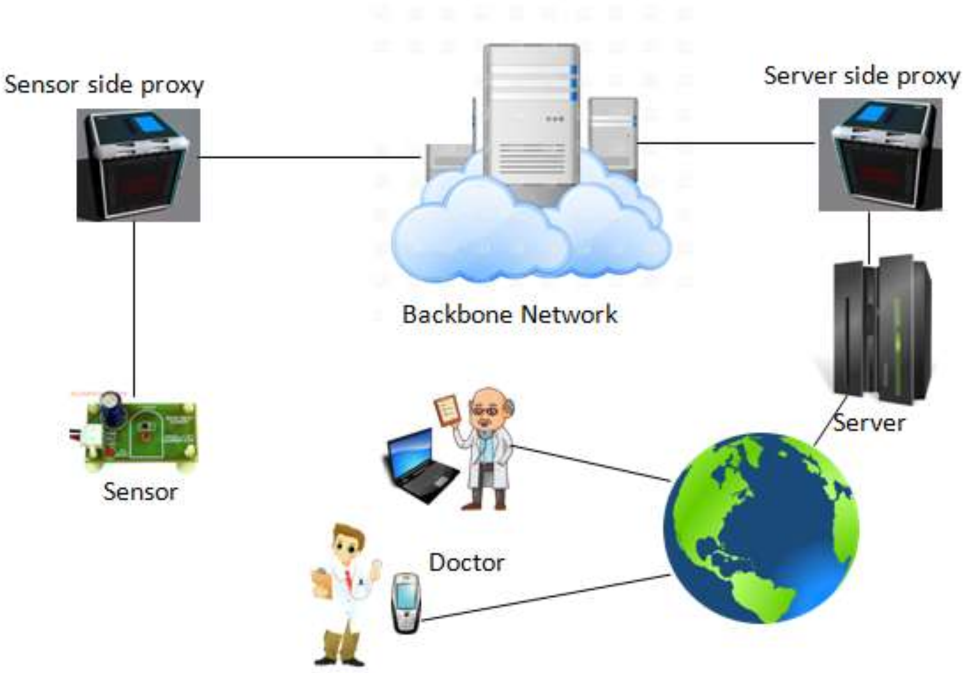

Figure 4. Ad Hoc Sensor Network based Remote Patient Monitoring System

Table 1.Characteristics and complexities of mobile ad hoc networks

Autonomous and infrastructure less
Multi-hop routing
Dynamic network topology
Device heterogeneity
Energy constrained operation
Bandwidth constrained variable capacity link
Limited physical security
Network scalability
Self-creation, self-organization and self-administration

The algorithm used for routing purposes is the Bellman Ford Algorithm [8]. The Bellman-Ford algorithm computes single-source shortest path in a weighted graph. The metric used here for the cost is the distance between the nodes. We assume the average radius of the village is about 2-3 kilometres. The range of every mica2 Mote is on an average 50 meters. This means that a maximum of 60-70 hops would be required to transmit the packets across the ad hoc network nodes. For the current example system, the number of hopes (via the intermediate routing nodes) is FOUR (as shown in fig. 5.). The updated routing table for the above networks with respect to node c is shown in Table 2.

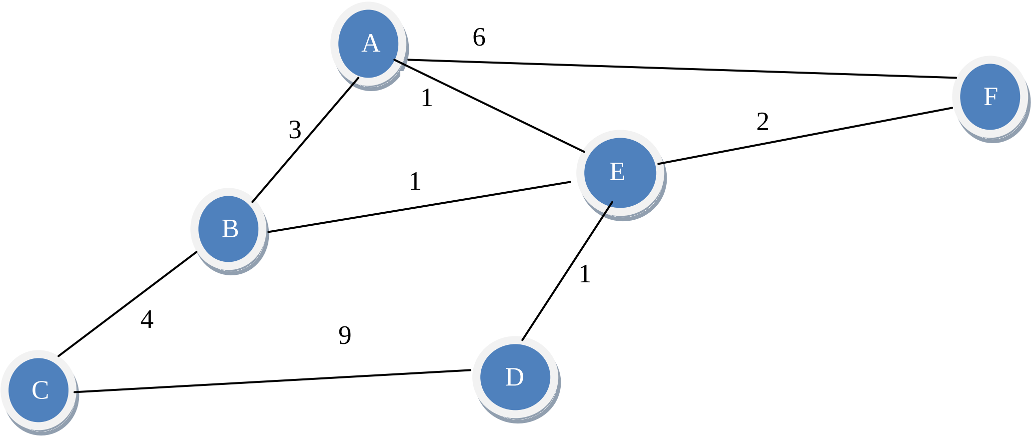

Figure 5. A Sample Network

Table 2. Routing table for the Sample System

DEST ID	NEXT HOP	COST (Distance between nodes)
A	B	6
B	B	4
C	C	0
D	B	6
E	B	5
F	B	7

Here, node C is the first node that receives the patients' data and node F is the terminating node of the Ad Hoc network. The routing algorithm is implemented in NesC programming language. The TinyOS platform is used to execute the program on sensor motes [8].

III. TECHNOLOGICAL CHALLENGES

As already stated, the specific characteristics of MANETs impose many challenges to network protocol designs on all layers of the protocol stack5 [9-11]. The physical layer must deal with rapid changes in link characteristics. The media access control (MAC) layer needs to allow fair channel access, minimize packet collisions and deal with hidden and exposed terminals. At the network layer, nodes need to cooperate to calculate paths. The transport layer must be capable of handling packet loss and delay characteristics that are very different from wired networks. Applications should be able to handle possible disconnections and reconnections. Furthermore, all network protocol developments need to integrate smoothly with traditional networks and take into account possible security problems.

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IV. FLOW CHART FOR CODING

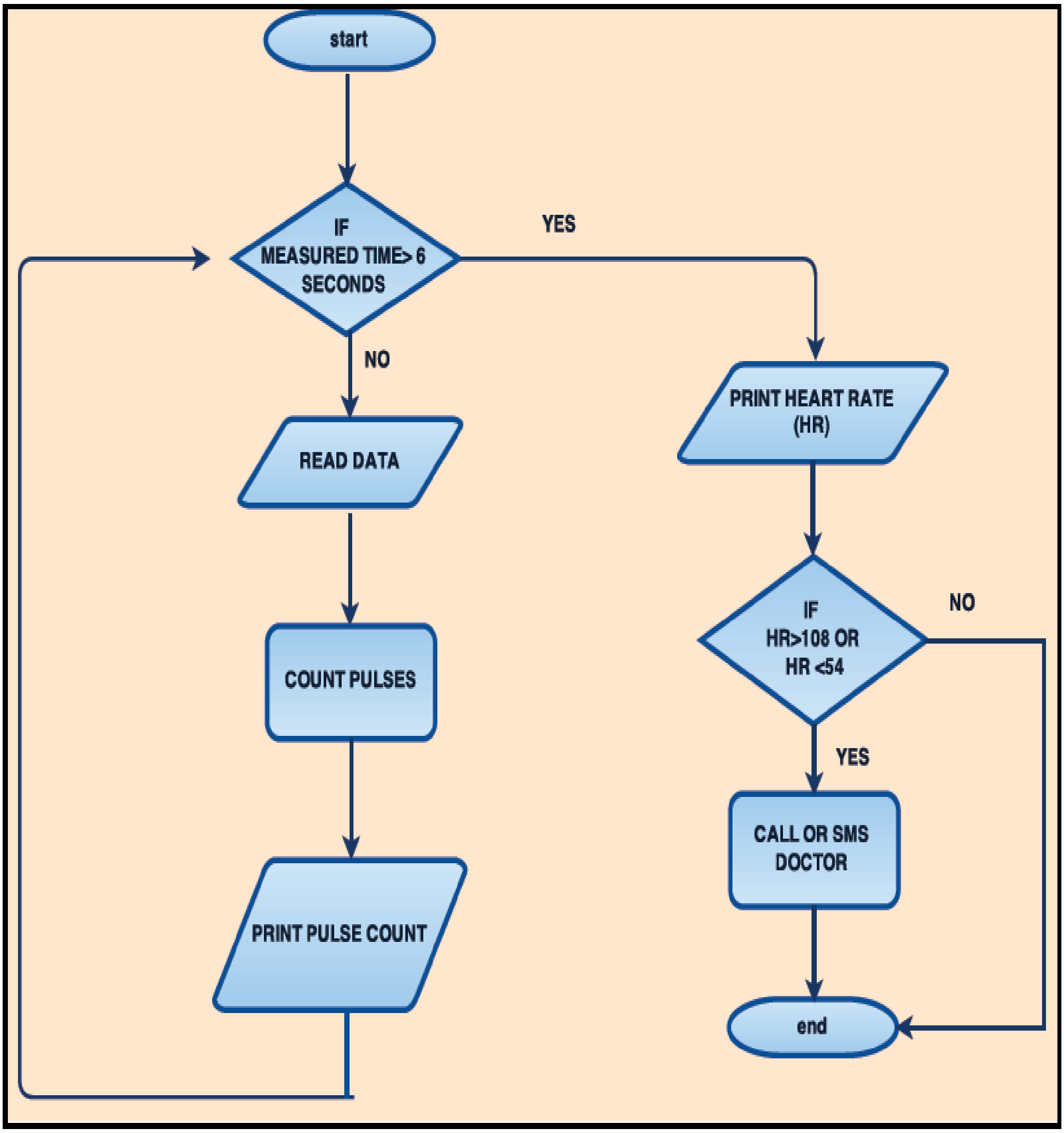

Figure 6. Flow chart for heart beat counting and it's monitoring

When the circuit is turned on, it first checks through the timer whether the measuring time has reached the mark of six seconds or not. If not, then it continues to read data and count the pulses and after six seconds, when the condition becomes true, it calculates and prints the heart rate on the LCD. Then it checks whether the heart rate is abnormal (i.e. HR>108 or HR<54). If not, then it again starts the whole process, but if yes then a call will be sent to the doctor along with the sms showing the critical condition of the patient so that the doctor may take further actions. (Refer figure 4.1).

V. RESULT

The device is continuously monitoring the heart rate and sending the messages/sms or calling to the desired number whenever there is any abnormality found, heart rate(in beats per second) was observed experimentally (figure 7-8) that is when heart rate goes beyond the decided limits (70 bpm – 90 bpm). The imlementaion result can be seen in figure 9.1-figure 9.3.

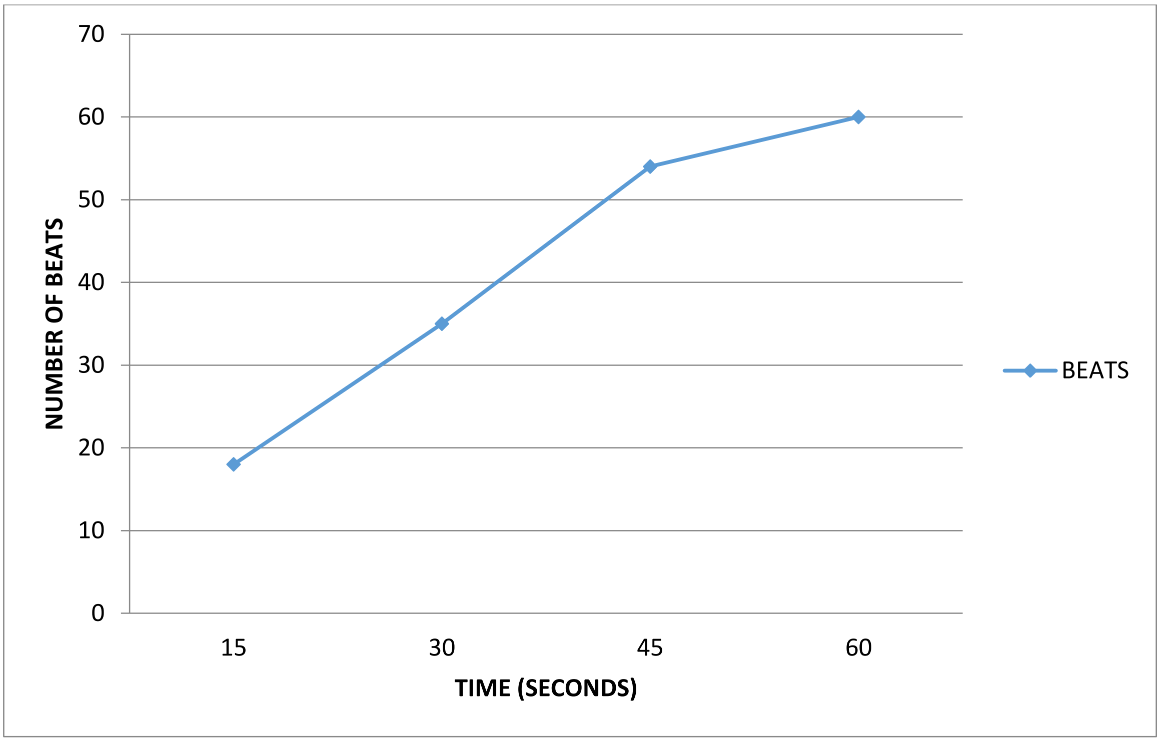

Figure 7. Measured heart beat at an interval of 15 seconds.

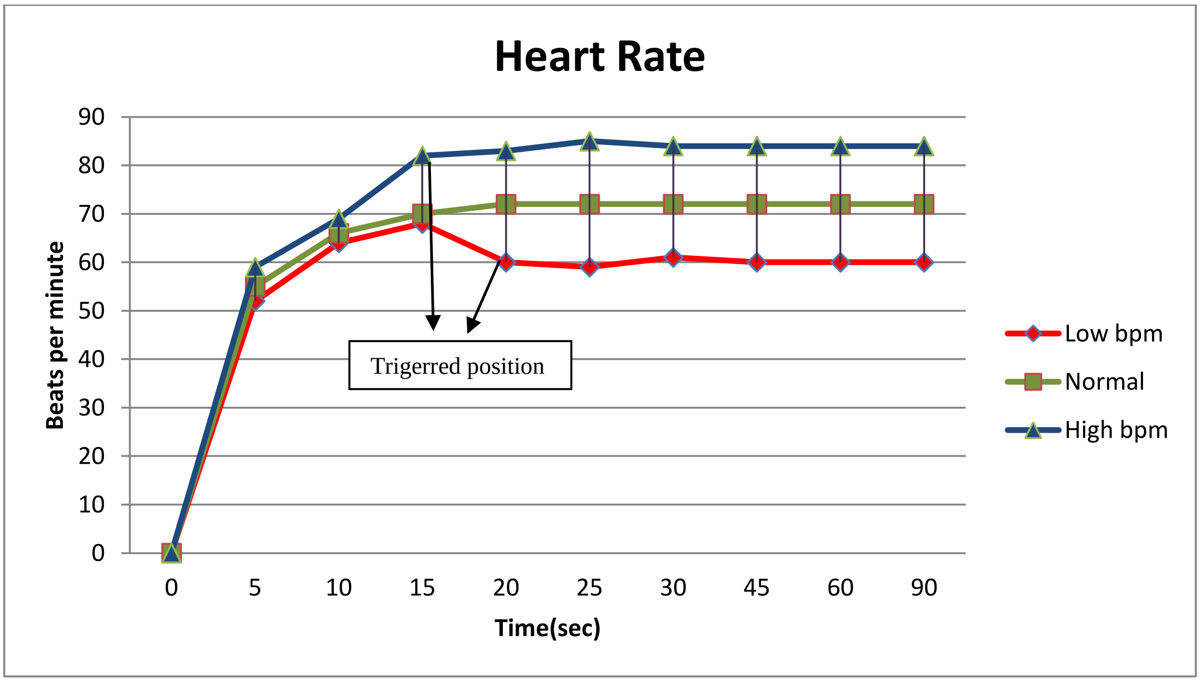

Figure 8. Heart beat measured in different cases (e.g. normal/critical).

VI. CONCLUSION & FUTURE WORK

The remote wireless health monitoring system was able to successfully monitor the change in the patient's health status and transmit vital signs. We have also thrown some lights on the basics of mobile ad-hoc networking (MANET), technical challenges in its implications and its tremendous applicability in coming days.
The rapid evolution in the field of mobile computing is driving a new alternative way for mobile communication, in which mobile devices form a self-creating, self-organizing and self-administering wireless network, called a *mobile ad hoc network*. Its intrinsic flexibility, lack of infrastructure, ease of deployment, auto-configuration, low cost and potential application makes it an essential part of future pervasive computing environments. As a consequence, the seamless integration of mobile ad hoc networks with other wireless networks and fixed infrastructures will be an essential part of the evolution towards future fourth generation communication networks. From a technological point of view, the realization of this vision still requires a large number of challenges to be solved related to devices, protocols, applications and services. The concise discussion in this paper shows that, the system works in an Ad Hoc network environment where the patient is located in a far off inaccessible location.
As an extension, a better range of routing nodes can be used in conjunction with an improved routing algorithm to extend the coverage area of the Ad Hoc Network.

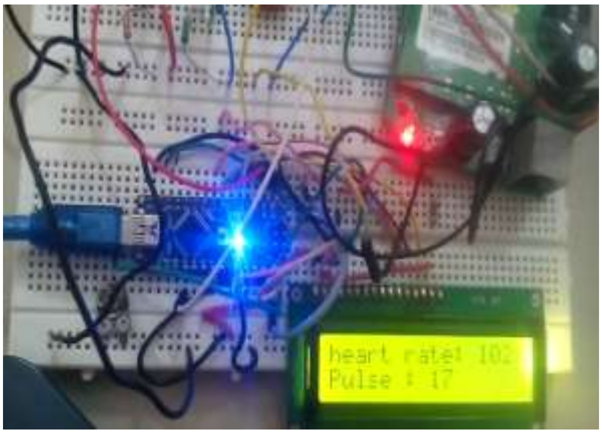

Figure9.1. Acquiring the data (in bpm)

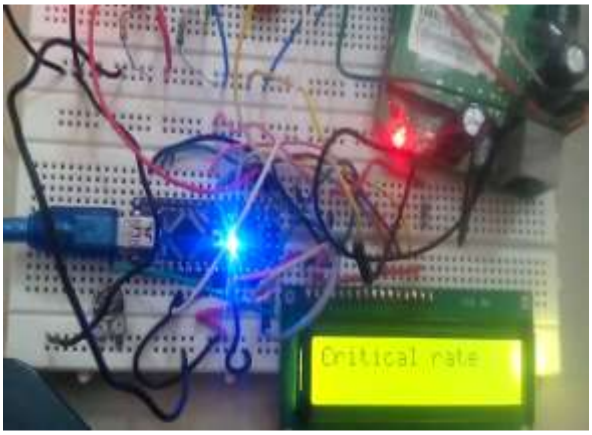

Figure9.2. Data Processing by microcontroller

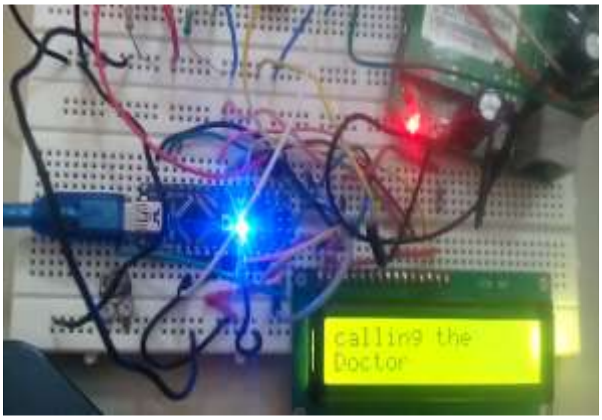

Figure 9.3. Calling to the doctor when heart rategoes beyond the critical limit.

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