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Embedded System Design and Remote Monitoring of ECG using Cloud

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Abstract **– The need for a new healthcare system that is usable anytime and anyplace is growing due to paradigm shift from health supervision to health preservation, the increasing number of the elderly. Activities in this field include acquiring, man aging, and using biomedical information from personal to global level, to enhance quality and efficiency of medical care and the response to widespread public health emergencies. This technological advancement has led us to design a real time health monitoring and analysis system that is scalable and economic for people who require frequent monitoring of their health. This paper presents the development of a multipurpose remote monitoring system for ECG signals. A real-time patient monitoring system has been developed for patients at a disaster scene. This system can facilitate communication between providers at the disaster scene, medical professionals at local hospitals, and specialists available for consultation from distant facilities. This system is based on the concept of utilizing cloud computing for remote monitoring of ECG. Analog signal is acquired with the ADC unit of the PIC24 controller this information in terms of ECG is transferred through ZigBee network connected to the cloud and finally examination and storing are carried out. With this system, signals obtained from the patients can be monitored simultaneously by the experts. Cloud provides remote availability, reliability.**

Keywords **– ECG, Remote ECG Capturing, Telemedicine.**

I. INTRODUCTION

The electronics and computing technology has entered almost in all aspects of day-to-day life, and the medical field is not exception for that. The need for well-equipped hospitals and diagnostic centers is increasing day by day as the people are becoming more conscious about their health problems. Heart conditions are a common cause of death throughout the world and they are often not diagnosed early enough [3]. Coronary heart disorders are at the first place among the death causing diseases all over the world [5]. Time constraint is one of the important issues in patients suffering from heart diseases. Delay in getting treatment can be life threatening. Active processes for patients are, essential data collection require a great deal of efforts and time to collect and analyse the information. Health care peoples are trying to simplify the lives of the people suffering from chronic disorders like heart disease by using cost-effective and smart systems [11]. Electrocardiogram (ECG) signals are used to observe the electrical activity of the heart. It can detect abnormal heart rhythms, insufficient blood and oxygen supply to the heart and an excessive thickening of heart muscle [8]. In recent years the emergency medical system has made great progress. While the patient is shifted from his place to hospital, if patient's data could be sent to the cardiologist during this crucial period, by examining ECG signals, he may keep emergency systems on alert to save the life of the patient [6, 7]. He may instruct the attendant doctor in cardiac van to give necessary treatment, and if required then he may concern to other experts. Electrocardiogram and heart rate are vital physiological signals that have received increasing attention in recent years. Research indicates that each year more than millions of people around the world die of cardiovascular disease. Besides, every year, many people survive heart attacks and strokes and hence those people require continuous monitoring of their heart signals while they are not in the hospital. This leads to the need for a real time monitoring system for those who not under the care of the physician. This work deals with the easy monitoring of electrocardiogram signals for people who are leading a normal daily life and wireless transmission of the analysed ECG signals is sent to the doctor in case of abnormal beats and rhythms. Use of ZigBee leads to effective reduction in power consumption. Reliability of the system is another important issue. Use of cloud computing helps us in maintaining reliability of the system. The multiple network and data storage resources available in clouds help to maintain the reliability. Thus the proposed system has two advantages low power consumption due to use of ZigBee and reliability of the system by virtue of cloud computing. Cloud computing refers to the delivery of computing and storage capacity as a service to a heterogeneous community of end-recipients. Cloud computing entrusts services with a user's data, software and computation over a network. It has considerable overlap with software as a service. End users access cloud based applications through a web browser or a light weight desktop or mobile app while the business software and data are stored on servers at a remote location. Proponents claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance. Cloud computing relies on sharing of resources to achieve coherence and economies of scale similar to a utility (like the electricity grid) over a network (typically the Internet). At the

foundation of cloud computing is the broader concept of converged infrastructure and shared services. It shows that how the process works based on manual notes [1]. A staff member collects patient's data at bedside, writing it down to a paper spreadsheet then the notes are typed in a data entering terminals; the data is transmitted to a database server that organizes and makes it accessible through a database interface and at this point, medical staff can access this information through an interface application.

II. Literature Survey

The wireless systems for health monitoring have garnered lots of attention in the scientific community and the industry during the last years. Mainly motivated by increasing healthcare costs and propelled by recent technological advances in miniature bio-sensing devices, smart textiles, microelectronics, and wireless communications, the continuous advance of wearable sensor-based systems will potentially transform the future of healthcare by enabling proactive personal health management and ubiquitous monitoring of a patient's health condition. It attempts to comprehensively review the current research and development on wireless systems for health monitoring. A variety of system implementations are compared in an approach to identify the technological shortcomings of the current state-of-the-art in wearable solutions. New research published in the Lancet finds that India will bear 60% of the world's heart disease burden in the next two years. In 2 001 alone, some 7.1 million deaths were attributed to ischemic heart disease, 80% of which were in relatively poor countries. Medical and public health professionals expect that in developing countries, there will be a 137% and 120% increase in the disease for males and females, respectively, whereas these predictions lie in the 30% to 60% range for developed countries.

A. Research Prototypes

Some type of microcontroller board as a physiological data-collecting platform and that are usually based on wired transmission of bio-signals from the sensors to the processing board. The Media Laboratory of MIT, Cambridge, developed LiveNet, a flexible distributed mobile platform aiming at long term health monitoring applications with real-time data processing and streaming and context classification.

AMON or the advanced care and alert portable telemedical monitor was a project financed by the EUFP5 IST program. It resulted in the development of a wrist-worn device, which is capable of measuring blood pressure, skin temperature, blood oxygen saturation, and a one lead ECG. In addition to that it incorporated a two-axis accelerometer for correlating user activity with the measured vital signs. The researchers designed also the GSM-based secure cellular communication link, as well as the software package for the telemedicine center, where the physicians could analyze the received data from the wrist-worn device in greater detail [4].

Life Guard is a multi-parameter wearable physiological monitoring system for space and terrestrial applications, whose core element is a crew physiologic observation device (CPOD), which is capable of measuring two ECG leads, respiration rate via impedance plethysmography, heart rate, oxygen saturation, body temperature, blood pressure, and body movement. Data logger that can either send the data via Bluetooth to a base station or record them for 9 hours continuously on a memory card.

B. Wireless Communication Standards

Advances in wireless technology and supporting infrastructure provide unprecedented opportunity for ubiquitous real-time healthcare and fitness monitoring without constraining the activities of the user. Wirelessly connected miniaturized sensors and actuators placed in, on, and around the body form a body area network for continuous, automated, and unobtrusive monitoring of physiological signs to support medical, lifestyle and entertainment applications. BAN technology is in the early stage of development, and several research challenges have to be overcome for it to be widely accepted. Not the entire wireless network has peer-to-peer, some wireless networks are client/server. Personal Area Network (PAN) systems are intended for short range communication between devices typically controlled by a single person. Some examples include wireless headsets for mobile phones or wireless heart rate sensors communicating with a wrist watch [5]. Some of these technologies include standards such as ANT UWB, Bluetooth, ZigBee, and Wireless USB as shown in Table I. For wider area communications, Wireless Local Area Network (WLAN) is used.

Table I: Wireless Technologies

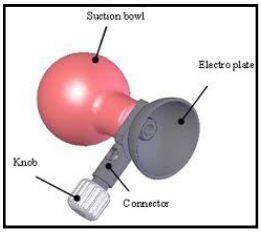
	Zigbee	802.11	Bluetooth	IR Wireless
Data rate	20-40 Kbits/s	11-54 Mbits/s	1 Mbits/s	20-40 Kbits
Range	10-100 m	50-100m	10m	>10m
Topology	Star	Point-Hub	Adhoc	Point to point
Operating Frequency	868Mhz	2.4GHz	2.4GHz	800-900nm
Power Consumption	Very low	High	Medium	Low
Application	Monitoring Sensor n/w	LAN broadband connectivity	Wireless between device	Remote control PC, PDA

C. Electrocardiography

Electrocardiography (ECG or EKG from German: *Elektrokardiogramm*) is a transthoracic (across the thorax or chest).The etymology of the word is derived from the Greek *electro*, because it is related to electrical activity, *kardio*, Greek for heart, and *graph*, a Greek root meaning "to write". The heartbeat is the definitive indicator for a wide range of physiological conditions. This necessitates the use of sticky pads, pastes or gel. While this method works for stationary patients, it suffers from several problems. First, the material used to construct the electrode or the paste could cause skin irritation and discomfort, especially if the subject is performing rigorous physical exercise and may be sweating. Another problem is that, during motion, the electrodes may become loose, breaking electrical contact and causing high noise spikes in the data. There are different types of electrodes. It is impossible to get rid of the lead cables during the ECG monitoring. ECG is derived from the biopotentials of the cardiac cell activities. At least two electrodes are required to be placed apart to measure the bio potential difference as the ECG. This differentiation depends on the material and shape of the electrodes. In Fig.1 (a) shows disposable electrodes. Disposable ECG Electrode is Ag or AgCl electrode, which consist of base lining material, conductive gel, and electrode buckle. The base lining material uses the nonwoven fabric, the breathable paper, cotton. Its DC offset voltage is ≤100mV and internal noise is ≤150μ.It having only one time use. In Fig.1 (b) shows limb electrodes. These are electrocardiographic electrode that is attached to an arm or a leg. Due to their physical property, electrodes can tightly hold the nodes on hands and legs. In fig.1(c) another type of electrode shown that is bubble electrode. It made up of metal and rubber; Due to its physical property bubble electrodes are connected with all leads of the body.

(a) Disposable electrodes

(b) Limb electrodes

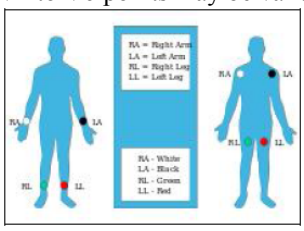


(c) Bubble electrodes

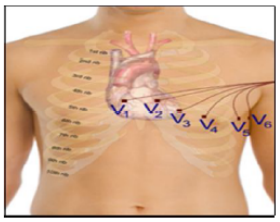
(d) Types of electrodes

Fig.1. Different types of electrode

Every ECG electrode placed on the body is attached by a wire to an ECG machine[2]. Fig.2 shows the placement of electrodes. The electricity that an electrode detects is transmitted via this wire to the machine, which translates the results into wavy lines that the machine then records on a piece of paper. For monitoring ECG signal, V1 to V6 points are available.V1 is the reference point voltage and V2 to V6 points may be variable.



(a) Placement on hands



(b) Placement on chest

Fig.2. Placement of electrodes

The electricity that an electrode detects is transmitted via this wire to the machine, which translates the results into wavy lines that the machine then records on a piece of paper. The ECG records in such great detail that the results can be used to diagnose a very broad range of heart conditions. Einthoven assigned the letters P, Q, R, S and T to the various deflections, and described the electrocardiographic features of a number of cardiovascular disorders ECG is interpretation of the electrical activity of the heart over a period of time.

Table II: Duration and Characteristics of Each Major Event in Cardiac Cycle

Event	Characteristic	Duration at 75 bpm
Atriial Ventricular Diastole	AV valve open, semilunar close	0.4 sec
Atrial systole ventricular diastole	AV valve open, semilunar close	0.1 sec
Atriial Ventricular systole	AV valve open, semilunar close, pulmonary artery	0.3 sec

This will usually be leading II (which shows the electrical signal from the atrium, the P-wave, well) and shows the rhythm for the whole time the ECG was recorded (usually 5–6 sec). Some this printing of lead II is continuous from start to finish of the process.

III. ECG MONITORING SYSTEM

With the rapid aging of population and more attention about our health, it's more and more important for the infirm to do the physical examination every day, according to the long time record, we can know the seriousness and infer the trend of disease, then take medical treatment in time. However, as we all know, it's very troublesome to have a physical examination in hospital, waiting for half a day is not only a waste of time, but also a challenge to weak or handicapped people. Fig.3 shows the remote monitoring system is a wireless network with the nodes of

the network installed in the patients' homes. These nodes are then connected to a central node located at a hospital through an Internet connection. The nodes of the proposed wireless sensor network are created by using a combination of ECG sensors, PIC24 microcontrollers, a low-power wireless Zigbee network protocol called the simplicity protocol.

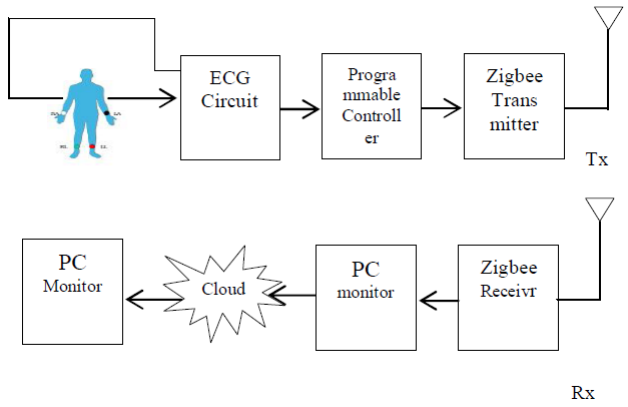


Fig.3. Wireless Health Monitoring System

ECG signals are first sampled by a small portable device which each patient carries. The captured signals are then wirelessly transmitted to an access point located within the patient's home. This connectivity is based on wireless data transmission at 2.4-GHz frequency. The access point is also a small box attached to the Internet through a home asynchronous digital subscriber line router. Afterwards, the data are sent to the hospital via the Internet in real time for analysis and/or storage. The benefits of this remote monitoring are wide ranging: the patients can continue their normal lives, they do not need a PC all of the time, their risk of infection is reduced, costs significantly decrease for the hospital, and clinicians can check data in a short time. Also with the advanced technique of Team viewer, Dr. can check and prescribed ECG signal from anywhere.

A. Hardware Design

The hardware block consists of ECG circuit, Signal processing unit and Zigbee modules.

1. Electrocardiogram Circuit

ECG signal is very weak low-frequency signal, amplitude 0.5-4 mV, frequency 0.05-100 Hz, in the testing process mixed with other biological signals, 50Hz frequency and the surrounding interference caused by electrical equipment [4]. Therefore, the acquisition method is component of extract the signal, signal amplification, signal filtering and signal processing.

2. Signal pre-processing

It is expected that any ECG recognition system will have to operate in a noisy hospital environment. The ECG signal is normally corrupted with different types of noises. Power line interface consist of 50 Hz pickup harmonics, which can be modelled as sinusoids and combination of sinusoids. Muscle contraction noise causes artificial milivolt-level potentials to be generated. The baseline electromyogram is usually in the microvolt range and therefore is usually insignificant. Electrode contact noise is transient interference caused by loss of contact between electrode and skin, which effectively disconnects the measurement system from the subject. Patient movement are transient baseline changes caused by variations in the electrode skin impedance with electrode motion. Digital and analog of filters can be used for noise cancellation. Adaptive filtering techniques are an effective method in cancelling the most interference polluting the ECG signal. An alternative noise cancellation method is band pass filtering. It can be having the combination of low pass filter and high pass filter.

Electrodes are connected to the hands and legs. Here three lead ECG circuit is designed. Different types of electrodes are used in this system. For connection of hands and legs; limb electrodes are used. Also instead of hands; electrodes can be connected to chest. Two types of electrodes are used in this system. For connection of hands and legs; limb electrodes are used.

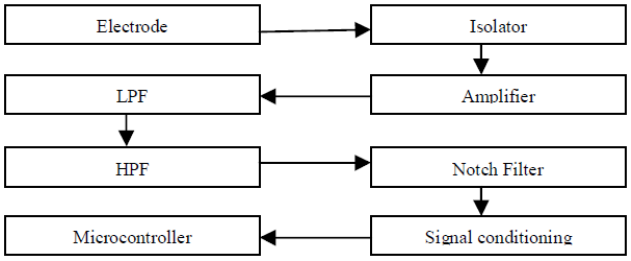


Fig.4. Block diagram of ECG system

Isolator having input from the electrodes. It isolates the signal and also uses a clamping circuit. Due to that signal can get protected because already it is in small values. The output of these sensors is in millivolts. It is amplified with the help of an instrumentation amplifier.

Instrumentation amplifier amplifies the output which comes from electrodes through isolator. AD620 IC used as a instrumentation amplifier. RA and LA(ECG sensors are connected at the inverting and non-inverting terminals of the instrumentation amplifier, while RL(Right Leg) ECG sensors is connected at the output of an operational amplifier. The output of the ECG sensor is amplified and it is filtered with a band pass filter.

Filter is made up of low pass filter and high pass filter. After the Instrumentation amplifier, a The filtered output is further amplified by non-inverting amplifier. Notch filter is designed to remove the noise of 50 Hz which may be get added into circuit.

Microcontroller gets amplified output voltage with removal of noise from the filter and signals conditioning. This amplified voltage is connected to ADC1.2 input of PIC24 micro controller. The on chip ADC of PIC24 micro controller will convert this analog voltage into 10-bit digital and l as stored in the on chip memory of PIC24 micro controller. Also these parameters are displayed on

the screen of local computer which is connected to the internet [10]. This data is placed on the internet. The PIC24FJ64GA004 family incorporates a range of serial communication peripherals to handle a range of application requirements. two independent UARTs with builtin IrDA encoder/decoders The peripheral pin select feature allows most digital peripherals to be mapped over a fixed set of digital I/O pins. 10-Bit A/D Converter module incorporates programmable acquisition time, allowing for channel to be selected and a conversion to be initiated without waiting for a sampling period, as well as faster sampling speeds. Devices in the PIC24FJ64GA004 family are available in 28-pin and 44-pin packages. The devices are differentiated from each other in two ways.

3. Zigbee module

Wireless module based on IEEE 802.15.4 is used for transmission and receiving the signal. ECG front end circuit is connected with wireless module as remote base station. Receiver module is interfaced with PC at Base station.

Fig.5. Zigbee Module

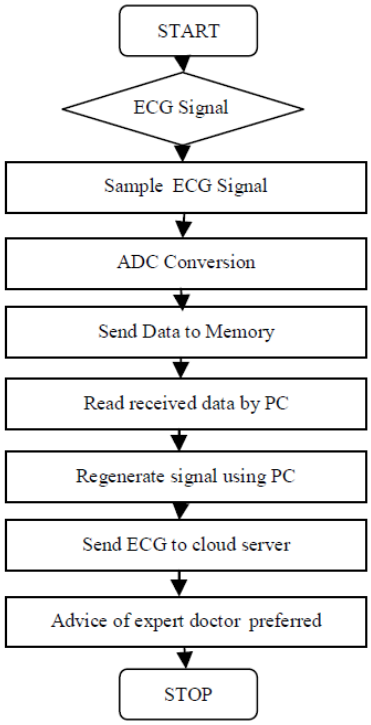


Fig.6. Execution of ECG monitoring system

ZigBee and ZigBee-PRO modules are engineered to meet ZigBee/IEEE 802.15.4 standards and also support the exclusive needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of critical data among devices as shown in Fig. 5.

B. Software Design

The system to platform uses embedded C Programming and Visual Basic and system software includes data collection and communication, while developing a remove running ECG server service program, which receiving patients' real-time

ECG signal and the signal analysis and processing, real-time monitoring patient. Fig.6 shows the execution of health monitoring system. Flow chart's wireless sensor network node placed at the side of the receiver is connected to a PC. Therefore, digital data received by receiver-transmitter is transmitted to one of any COM ports of the PC over controller. Drawing program loaded in the PC gets the received data array drawn on the screen by scaling it. At the receiver side programming is done in java. By using desktop sharing receiver sides PC can be handled by respected person from any other place. Also web page can also be designed through TOMCAT software. Due to that PC can also act as server. While the main focus of the application is remote control of computers, collaboration and presentation features are included. It is based on simple components deployed to commodity computing devices. In this case, it utilized commercially available wireless routers that allow the replacement of the operating software by Linux solution. The software provides a standard set of control interfaces easily configurable for different medical equipment; the data is transmitted over the wireless network cloud services". Exchange Service Application acts as a broker between locally attached devices and remote services; it has two main functionalities: (i) it works as an access point and (ii) it allows sensors to store data locally for pre-processing e.g. Content Service Application is a common interface used to show information to medical staff; it talks to the exchange service application to request pre-processed data. Utility Computing Provider is responsible to provides logical and physical infrastructure for storage, processing and content delivery services. The first results from our limited prototype implementation. Cloud computing relies on sharing of resources to achieve coherence and economies of scale similar to a utility (like the electricity grid) over a network (typically the Internet). With some improvements, especially in index and store collected data, we believe that prototype can be used in controlled environment to monitor non-critical patients.

IV. RESULTS

Experiments were performed on the developed ECG system. Fig.7 shows Generated ECG signal is filtered to

remove noise from signals. Data is transmitted in form of packets in zigbee module with inbuilt ADC. The data is stored on data servers and is made accessible universally. Here three electrodes are placed on body; one is on left hand and second is on right hand. Third is acts as ground which is connected to leg. Also same nodes can be used for observing the chest signals. Three nodes are used. Two nodes are connected to V1 and Between any nodes from V2 to V6. Third node is connected to legs as ground. As shown in fig.7 ECG signal of the abnormal person. four Bazett-corrected time intervals (QTonset-c, QTpeak-c, QTc, and Tduration-c, in milliseconds) and the absolute height of the T wave (Tamplitude, in millivolts).

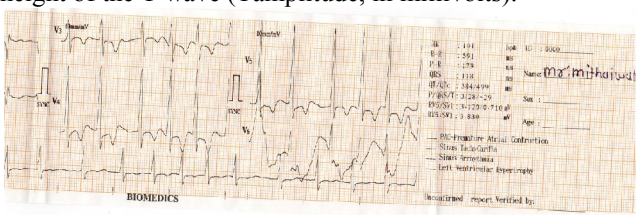


Fig.7. ECG graph of Abnormal Person

If sleep apnoea could be diagnosed using only the ECG, it could be possible to diagnose sleep apnoea automatically and inexpensively from ECG recordings acquired in the patient's home. For software design java language is used which shows the result output window. It consists of ECG signal wave. Also result window can be monitored by doctor from any place.

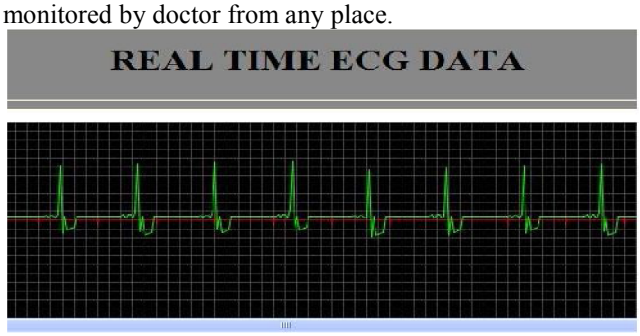


Fig.8. ECG graph on the client system

This solution provided by cloud computing. Simulation result of ECG pulse rate using Net bean software which uses java language as complier.Also web page can be designed by this language. So for implementation of cloud computing concept, space can be buy and put the data file onto the cloud. Whatever, space is available that can be registered for used. By using URL data can be observed. So web page is connected to that link. Fig.6 shows flowchart of software implementation. Here ECG circuit is connected through serial cable to controller. After interfacing data is collected and that coding is in java language. That data is store in temp folder in .dat extension. By using these readings graph is mounted. There are option to save that ECG data including all the detail information. This result is also store on cloud. So it can be accessed from anywhere.

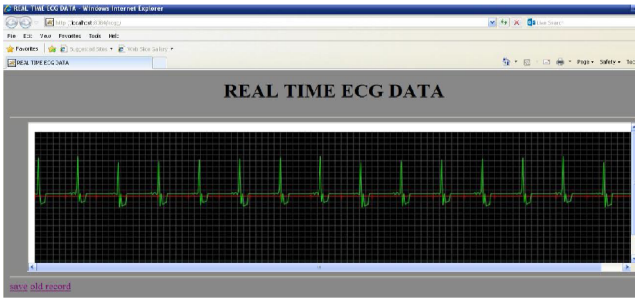


Fig.9. ECG graph on cloud server

Fig.9 shows the client screen which can be observed by doctor through cloud server. This data is on the cloud, it is save data. If doctor comparing this data with original ECG graph paper then it shows same node potentials and amplitude as on the paper with respect to this output window.

V. CONCLUSIONS

The objective was to find out energy efficient, secure and reliable solutions for wireless biomedical applications. By this aim, an ECG acquisition and wireless transmission system was designed using ZigBee technology along with cloud computing. With use of ZigBee malicious users cannot access the data; the power requirements are very low. Cloud computing provides reliability and availability. The ECG signal can be observed by experts from any place in the world through cloud computing facilities. As discussed earlier Time constraint is one of the important issues in patients suffering from heart diseases. Delay in getting treatment can be life threatening. On time treatment from experts can save the life of patients away from experts. The system will help to save the life of the cardiovascular patients

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